

Mr. Morton. delivered directly into his precipitation-tanks. With regard to the use of snifting-valves on large pumps, the statement in the Paper (p. 235) was perhaps too universal, and he was quite willing to say, "were often fitted." In sewage-pumps the snifting-valve was very useful, but there was no necessity to use it to such an extent as to seriously reduce the displacement efficiency of the pumps. The pumps described in his Paper could run quite well without snifting-valves. The question as to the efficiencies when the snifting-valves were open was fully answered at the foot of p. 235. The trials carried out with the engines had been made scrupulously under working-conditions, with ordinary fuel, and without special preparation.

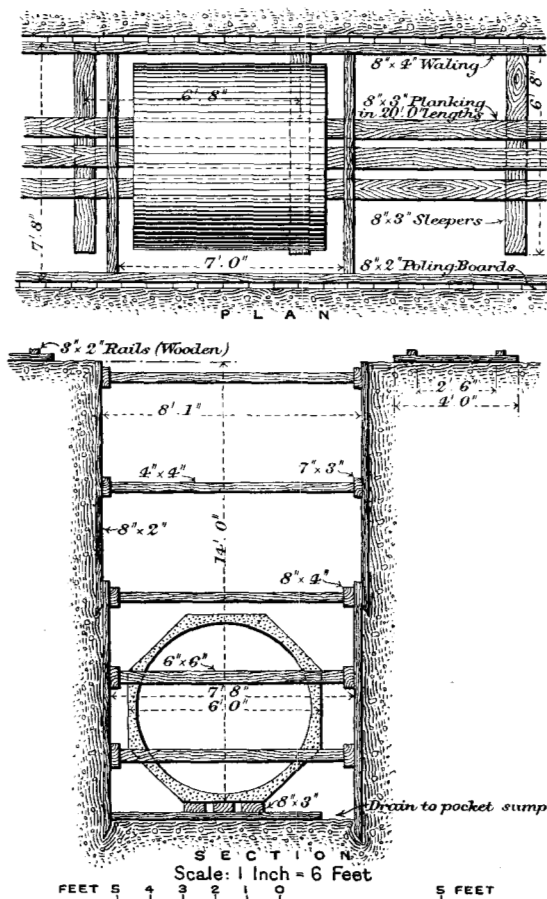
The President. The PRESIDENT thought he might be able to clear up one point by pointing out that Mr. Parsons, in advocating the use of the centrifugal pump, was not referring to the ordinary form of that machine. Mr. Parsons was using a special kind of centrifugal pump which was able to chop into small pieces any stuff that would otherwise be stopped by screening. It was also a pump that had very great resistance to wear. He did not know whether Mr. Parsons was right or wrong, but wished to say that experience with the older type of centrifugal pump was not conclusive in connection with pumps of the more modern type such as Mr. Parsons's argument was based upon.

Correspondence.

Mr. Anderson. Mr. J. T. NOBLE ANDERSON wished to acknowledge the assistance which he had derived from privately-communicated drawings and specifications of the works carried out in Glasgow when obtaining the sanction of the Dunedin (N.Z.) Drainage and Sewerage Board to the scheme drawn up by him in 1902 and since carried out. Following on the lines of Glasgow, he adopted the circular form for all sewers more than 3 feet in diameter, and arranged the gradients to give a minimum velocity, when the sewers were full, of about 180 feet per minute. Beyond such general features, and the fact that the sewers were designed to carry storm-water to the extent of only $\frac{1}{4}$ inch of rainfall in 24 hours, the resemblance ceased. The higher cost of labour in Dunedin (1s. an hour and upwards), the restrictions in quality of the materials, especially such manufactured products as stoneware pipes and bricks, and the scattered population over a precipi-

tous and broken district, rendered it necessary there to adopt every Mr. Anderson. possible economy in construction. The chief saving effected in the main intercepting sewer was the use of reinforced-concrete pipes of all sizes from 15 inches up to 6 feet in diameter. Sizes less than

Figs. 1.



3 feet were supplied by contractors, but it was found cheaper to design the larger sizes specially and construct them by day-labour. *Figs. 1* showed how these large pipes were laid in the soft ground, which much resembled the Glasgow mud. More than 3 miles of this main intercepting sewer was deeper than 20 feet below the surface,

Mr. Anderson, and was 10 to 20 feet below low-water level in the harbour, which it skirted. The other important saving in the construction of this sewer had been effected by using Australian hardwood—chiefly *Eucalyptus globulus* (blue gum) from Tasmania—in place of concrete, as a foundation for the reinforced pipes. This was justified by the fact that when protected from air, as this would be, buried 20 feet deep in harbour mud, such timber, judging from geological evidence, was practically everlasting. The pipes were octagonal in section on the outside, but cylindrical internally, a section which had facilitated their construction, in accordance with Parisian precedent, in vertical moulds. The length of the sections was 6 feet, and the timbering of the trenches often required very heavy walings, since the struts had to be at least 7 feet apart between centres. Great convenience and considerable economy had resulted from the use of screw-jack ends to all the struts; and he attributed largely to this the entire immunity from accidents which the whole of this work enjoyed. Upwards of a thousand of these screw-jack ends were used. Perhaps, also, this immunity was due in some measure to the fact that all the work was carried out by day-labour. Obviously, work carried out as this was, with reinforced-concrete pipes made in a yard, matured, and then laid in the trenches, was cheaper when constructed with open trenches, alongside or astride of which a steam-crane in one part, and a gantry where the ground was very soft, effected the lifting and laying. In several places, however, it was found necessary to resort to tunnelling. Compressed air was provided, but, except for grouting leaks with cement grout, it was seldom needed. On completion and careful inspection the works were found to be quite free from leakage, and no signs of any settlement or departure from true gradients were detected. In the rising main timber was substituted for cast iron. This was the most troublesome of all the innovations, but ultimately was sufficiently successful to warrant its duplication. One great advantage, as compared with Glasgow, was that, discharging as it did into the open ocean, the sewage required no treatment: it only needed to be allowed sufficient quiescence between pumping to liquefy the bulk of its solid contents. It was discharged into the ocean within a few cable-lengths of where the great southern current passed at a velocity seldom less than $\frac{3}{4}$ knot per hour. At Dunedin Diesel engines driving centrifugal pumps were used. Though the small quantity which was pumped there in three 20-inch Gwynne centrifugals—one pump raising 2 million gallons in 2 hours per day—as compared with the total capacity of the plant, should make it expensive, yet,

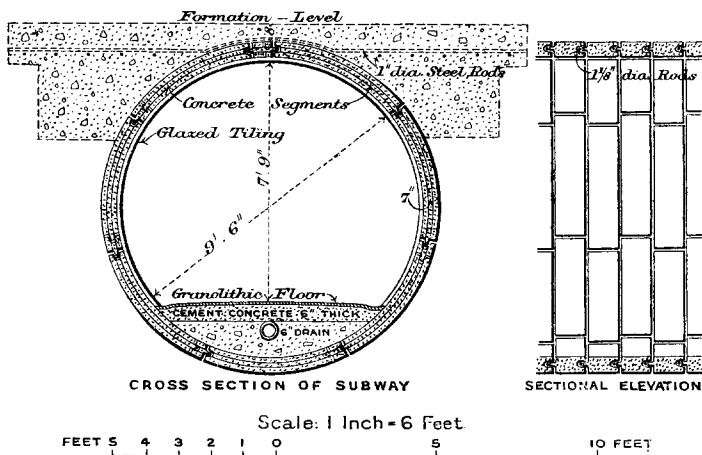
owing to the fact that Diesel engines worked very economically on Mr. Anderson. a low load-factor, the cost was surprisingly low. The extreme ease of starting this type of engine rendered it peculiarly suitable where, as in a mountainous district like Dunedin, floods came down with practically no warning. Within 2 minutes from the time the compressed air was turned on to the engines from the compressors, he had found the pumps discharging at their maximum rate of 57 million gallons per day (say 106 cubic feet per second). The performance of these engines was tested by a Froude dynamometer, in addition to the usual gauges and indicators. The engines, each normally of 120 B.H.P., often in times of flood worked up to 150 B.H.P. All the main sewer and 70 per cent. of the other works were carried out by day-labour, which was always the cheaper.

Mr. JOHN BARR asked whether the screening-arrangements at Mr. Barr. Kinning Park were any more efficient than those at Partick, and in what essential points they differed. The frames and seatings for the pump-valves were of gun-metal at Partick, while at Kinning Park they were of steel. Were the latter quite as good? and why were the valves at Partick of cast iron instead of steel as at Kinning Park? Were those at Partick heavier? At Partick the boiler-efficiency was given as 70 per cent.: what was it at Kinning Park? Glasgow water was said to cause pitting of wrought-iron or steel pipes, and he would like to know whether Mr. Morton considered that it would be advantageous to add some lime to the water, as was done at Birmingham. Further, did he consider that a lower proportion of carbon in the steel boiler-flues which failed at Partick would have given a more reliable material? What was the percentage of carbon in that case? Figures for the corresponding quantity of heavy solid material taken from the pumps at Kinning Park would be interesting, and also the reason for its being more or less than at Partick. Was there any valid objection to having feed-pumps on the main engines, and would not this tend to better economy? Again, underfeed stokers at Partick, as at Kinning Park, might have given better economy. The necessity for admitting air to pump-chambers was due to the large volume of liquid pumped, and to the necessity of using flap-valves of large area for sewage-pumping. Finally, what means were employed to determine the quantity of sewage flowing in the outfall-sewer above and below the station at Kinning Park?

Mr. G. F. CARTER, referring to the tunnel under the Broomie- Mr. Carter. law (p. 198), remarked that the drawback undoubtedly was that, although care was taken to have reinforced segments, there was no cohesion in the structure, owing to the continuous horizontal

Mr. Carter. joints. The same contractors, Messrs. Robert McAlpine and Sons, were now constructing for him at Croydon a reinforced-concrete tunnel 9 feet 6 inches in internal diameter, in which the weakness of the Glasgow section was entirely overcome (*Figs. 2*). This tunnel for foot-passengers, which was approached by slopes, commenced at Station Road, Croydon, passed under Norwood Junction station, which had eight lines of railway, and terminated in Clifford Road. The segments were of concrete composed of cement, sand, and granite siftings up to $\frac{3}{8}$ -inch gauge in the proportions $1:1\frac{1}{2}:3$, making a 3-to-1 concrete. The mixture was run into a cast-iron mould on a shaking-table, from which the segment was removed after 3 days and laid out to mature. The tunnel, which

Figs. 2.



was in London clay, had been formed by driving about 1 foot at a time and inserting a complete ring of segments, the method allowing of joints being broken horizontally. At each foot a steel ring of rod $1\frac{1}{2}$ inch in diameter was inserted in two halves, and the two joints were made by pinning together the overlapping ends. The joints and spaces behind the segments were afterwards filled under pressure with Portland-cement grout. The tunnel was lined with white glazed tiles and lighted by electricity. Under the railway-lines reinforced-concrete saddles were formed, as indicated in the Figure, before the tunnel was driven. There were great possibilities in this form of construction in numerous ways, e.g., as a framework to be lined afterwards, or as a finished tunnel for tube railways, subways, etc.

Mr. J. EASTON CORNISH remarked that it was a great advantage Mr. Cornish. to be able to follow such an important work in its inception, its construction, and its mechanical equipment; each of them treated in these three able Papers by those intimate with the subject. The principal object of Mr. Easton's Paper appeared to be to show the respective advantages of carrying out works of this description with and without a contractor. The many difficulties had been successfully overcome in a manner which reflected the greatest credit on Mr. Easton and his staff. Whatever opinion might be held with regard to other works, his Paper went far to show that the Glasgow authorities had chosen the best way of carrying out their own drainage-works. It might appear rather disappointing to some people that after such a wealth of detail Mr. Easton should not arrive at some more definite conclusions than the two paradoxical ones given at the end of his Paper, which only tended to show that the question was a very difficult one, and that each case must be decided on its merits, the solution depending largely on financial considerations. Still, the Paper gave much valuable information, which might help those who had to advise on such matters.

The detailed description in Mr. Morton's Paper of the fine sets of three-throw pumping engines at the Partick and Kinning Park pumping-stations was particularly interesting. He was surprised to hear on such good authority that there were still people who could not properly see the merits of a three-throw pump; he remembered well the disfavour with which this class of pump was looked upon by many waterworks-engineers in its early days—more than 50 years ago. In those days men took things to heart more than they did now; up to the death of Brunel, the "battle of the gauges" still raged among railway men; and the waterworks man who proposed at that time to use three-throw pumps ran some risk of being treated by his confrères as hardly worthy of being spoken to in the street. Amid much that was admirable in the engines described, there were some few details which it would be well not to imitate. Mr. Morton stated that there were three bed-plates to each engine; they were, in fact, separated by the fly-wheels, and the necessary stiffness was ensured by an elaborate and costly system of bracing, both above and below, much of which might have been rendered unnecessary. About the time when these engines were made, several sets of waterworks-engines of the same type were designed, in which the bed-plates were firmly bolted together to form one piece. No difficulty was found in carrying the light fly-wheels which this class of engine required at each end of the

Mr. Cornish. crank-shaft outside the bed-plates, with a light plumber-block carried on a special girder. In these engines much height was saved by the lower ends of the connecting-rods being carried within the pump-plungers, which were made in trunk form. These formed the guides, and no better guide could be found than a 30-inch or 36-inch plunger; not only was height saved, but the connecting-rods had the advantage of being considerably longer in proportion to the stroke than was the case in the Glasgow engines. Some of the engines in question had been working constantly for the last 7 years, with only a few days' stoppage, and hardly any repairs. Mr. Morton's statement that the delicate $\frac{5}{8}$ -inch thick gun-metal plungers were liable to come in contact in the pump-chambers with 1 to 4 tons of granite grit in the course of 30 days' work gave one an uncomfortable feeling. The steam-consumption of the engines driving centrifugal pumps was stated to be about double that of the engines driving reciprocating pumps; also, the centrifugals had impellers of the open-vane type. Modern practice had proved that this form of impeller gave a much lower duty than could be obtained from the shrouded impeller. The centrifugal pump had profited in recent years by many improvements, chiefly due to better comprehension of the great advantage of guiding the water, by properly curved blades, both into and out of the impeller. It was true that the pump was now sometimes called by other names, e.g., "turbo-motor pump," etc., but it was still that old friend the centrifugal pump, without much alteration. It gave, however, a much better duty, and when combined with an oil-engine of the best type, it could be depended on to give a result much nearer to that of reciprocating engines and pumps than had been obtained in the Glasgow drainage-pumps. This subject was now receiving close attention, especially in countries where the engineer had constantly before his eyes the high price of coal.

Mr. Hazen. Mr. ALLEN HAZEN, of New York, observed that Mr. Easton's preference for constructing city sewers in tunnel, even where the depth was not very great, seemed to be fully justified by the results. Certainly the advantage of avoiding interruption of traffic and interference with business was an important matter in many places. He was interested in the low average age of the men on Mr. Easton's staff. In America, England was usually regarded as a place where the average age of engineers in active work was higher than in newer countries; but here was an important piece of work, the practical details of which had been in the hands of very young men. The description of the Kinning Park pumping-station illustrated how rapidly expenses might accumulate on a deep and difficult site.

The vertical, triple-expansion, fly-wheel pumps adopted at both Mr. Hazen. pumping-stations were economical in working, but necessitated a larger outlay for their purchase and installation than would usually be made for corresponding service in America. Centrifugal pumps had been generally used for sewage and also for water, with moderate lifts, and had shown, on test, duties about two-thirds as high as those found in this case, but with a great saving in the cost of equipment and usually also in space. Mr. Morton's remarks as to the amount of rainfall provided for in the main-drainage works of London, and in the Glasgow works, were especially appreciated by Mr. Hazen. This allowance had been frequently quoted, and usually in the easily and commonly misunderstood way in which it was mentioned by Messrs. McDonald and Taylor. He believed that in America heavy showers were more frequent than in London or Glasgow, and that the quantity of sewage to be discharged by storm-overflow, other things being equal, would be much larger than the quantities found in these cases. The Tables of analyses and other data showed that the works were operated as nearly all sewage-disposal works were operated years ago, namely, for the removal of the suspended matters and other ingredients which tended to render unsightly and disagreeable the water into which the effluent was discharged. In America, especially in recent years, there had been a strong movement for sewage-purification, which was satisfied with nothing less than the elimination of the bacteria from the sewage. He believed that in many cases the removal of these bacteria was entirely unnecessary and useless, and was interested to see that no attention had been paid to this phase of the matter by the Authors.

Mr. JOHN W. HILL, of Cincinnati, considered that the Papers Mr. Hill. contained information of profound interest to those engaged on the sanitation of the larger cities of the world. The difficulties of construction, as described by Mr. Easton, had called for care and skill to avoid serious injury to property, doubtless due, in a measure, to the restricted areas upon which the pumping-stations had been constructed, and the congested streets in which the sewers had been laid. The driving of tunnels for sewer work on a large scale was seldom resorted to except for deep sewers, and had doubtless been adopted on account of the exigencies of the situation. Streets containing water- and gas-mains, electric conduits, old sewers, and tramway-tracks, and fringed with important buildings, presented great difficulties if work on new sewers was to be done in open cutting, and no doubt tunnelling was the least expensive and most rapid means of progress with the work. With the growth of cities

Mr. Hill. and the massing of population on comparatively small areas, the difficulties surrounding the collection and disposal of sewage became greater, and Glasgow, which was favoured in this respect, as compared with large inland cities, was to be congratulated upon a method of sewage-disposal which could doubtless be considered final. It would only be necessary in the future to enlarge the capacity of the pumping-stations, and to carry away more sludge from the outfall-works for deposition in deep water. The use of steam-driven plunger pumps for lifting the sewage from the low-level to the high-level sewers was contrary to the general practice in the United States, where low-lift turbine or centrifugal pumps, driven by compound or triple-expansion piston engines, steam-turbines, or electric-motors, were employed. There was no doubt of the higher efficiency of plunger pumps, but the gritty character of the liquid to be handled, and the consequent wear and tear of pump-valves, plungers, stuffing-boxes, and packing, had to be considered. It was believed in the States that the highest net economy in first cost and working was probably to be obtained from centrifugal or turbine pumps, even with screened sewage. The plunger pump, however, had the mechanical advantage of being adaptable, by varying its speed, to the exact flow of sewage from hour to hour within its rated capacity, without serious loss of efficiency. The centrifugal pump, as was well known, must for best efficiency be run at a nearly uniform speed where the head (as in this instance) was constant. It would be interesting to know, in view of the large volumes of sewage to be handled against a moderate head, if any consideration had been given to the use of gas-engines instead of steam-engines as the motive power for the low-lift pumps. The rapid development of the gas-engine using natural gas, artificial gas, or producer-gas, suggested that it was the cheapest artificial power available; and large experience with gas-engines had fully demonstrated their efficiency and reliability. It would seem, therefore, that the conditions of a large permanent equipment such as the Glasgow main-drainage works required should have suggested the gas-engine as the most economical source of power now and in the future. One of the largest motor-car manufacturers in America was now constructing a 6,000-HP. gas-engine to furnish the motive power for his works, as the result of nearly 20 years' previous experience with gas-engines, not only motor-vehicles of his own manufacture, but also engines of large capacity for supplying the motive power for his works. Doubtless other conditions than superior mechanical efficiency had led to the adoption of steam-driven plunger pumps for the low lift of sewage from the low intercepting to the

high intercepting sewers, and a review of these conditions by Mr. Hill. Mr. Morton would be of advantage to other engineers who might be called upon to determine the type of pump best suited for a service of this kind. The simple screening of the flotsam from the sewage, and the precipitation by lime and acid of a part of the suspended matter, which was subsequently removed as sludge from the sedimentation-tank, simplified the problem of sewage-disposal very much, as compared with cities like Birmingham. In London, situated on a tidal river, the cost of disposal per million gallons of sewage dealt with should be correspondingly low. Apparently the Glasgow works had been planned for the pumping of the full flow-capacity of the sewers, or with no provision for the overflow, from the sewers direct to the river, of part of an excessive discharge due to rainfall. In planning works of this description for American cities, provision was usually made only to accommodate the early street-washings, the subsequent discharge being usually diverted, over a weir or in some other manner, direct to the stream or body of water into which the effluent was discharged. In sewage-disposal works planned for an American city the allowance per head of the population to be served was rarely less than 100 U.S. gallons (about 14 cubic feet) per day. This quantity largely exceeded the sewage-flow of many European cities with which Mr. Hill was familiar; it at once imposed much larger capital charges for the construction of disposal-works and, of course, much larger working-costs in the constant treatment of the sewage. Most of the large American cities were alive to the importance of broad and comprehensive improvement of their methods of collecting and disposing of sewage and of a part of the street-wash from rainfall; but the relatively high cost of construction and the high working-cost of modern disposal-works had caused many of them to proceed slowly in the matter of improvement on these lines. Nearly all, if not all, of the larger cities of America, in addition to some lake, large river, or the sea, into which sewage-effluents were discharged, were compelled to deal with numerous small watercourses which traversed the city. These might not attain to the dignity of rivers, but they were at times heavily charged with storm-water, which must find an outlet into the neighbouring river, lake, or ocean. In carrying out main-drainage schemes for such cities, therefore, not the least of the problems to be solved was the regulation of these smaller watercourses, which during floods might spread over several hundred acres of valuable land within the city limits, rendering it valueless and inaccessible for the time being. The method which had

Mr. Hill, generally been adopted was to confine the section of such streams to a channel of least width and of the proper form to discharge flood-waters at the highest velocity consistent with the permissible bottom slope, and to regulate the height of the banks so as to avoid overflow during the period of maximum-flood flow. Sometimes this might require the rip-rapping of banks and the construction of hard permanent floors, and sometimes it might call for occasional dredging of such channels. At all events, any considerable rise of the floor-level must be prevented, either by the natural scouring effect of floods or by artificial removal of deposited matter. When large sewers took the place of open watercourses, the removal of stranded matter from the invert usually accompanied flood-discharges, and where it did not do so such matter should be removed periodically by scraping and hoisting it through the man-holes. In large cities land adjacent to these open watercourses became too valuable to permit of maintaining them in their original condition, and sewers, culverts, or improved open channels must be substituted. The carrying-out of work without contractors would be impracticable in most instances in the United States, and in some cases it would be barred by law. Most of these States, if not all, had laws which required all public work to be constructed by contract after a public letting. The contractor made the price, and this price governed, irrespective of the real value of the work; and in preparing estimates engineers must have regard to the prices which would probably be bid, in order that the prices bid, taken in the aggregate, might not exceed the estimate. It was immaterial that the corporation might be able to purchase materials and perform the work at a lower cost than that offered by the contractor: the law said it should not be done. Frequently an engineer realized that the cost was in excess of the real value of the work performed, and that he could save his principals considerable money if it were not for the law. The political conditions, too, in most American cities would render it impossible to organize a satisfactory working-force, kept together from year to year during the progress of a large undertaking, except where the work was being conducted by a special commission.

Mr. Marsh. Mr. C. F. MARSH thought Mr. Easton's Paper was particularly interesting and useful, on account of the unit prices given in the third Appendix; such prices were always welcomed by engineers. Mr. Easton was very much in favour of work carried out by administration, and, from the figures he gave, it was evident that a considerable saving had been effected by adopting this method at Glasgow. The general experience of the relative cost of work

executed by administration and work carried out through contractors was, however, very different from that described by Mr. Easton, and it would undoubtedly be found in most cases that the employment of a contractor was advisable, if economy in the cost of construction were desired. There were, of course, many cases in which it was better that the work should be carried out by administration, e.g., in the construction of the pumping-station foundations at Kinning Park, where the work had been of such a nature as to require special precautions, and where the methods of carrying out the excavations had had to be varied as circumstances dictated. When the work was of the ordinary kind, and such as was generally entrusted to a contractor, there was every reason to avoid carrying it out by administration. The latter course would almost certainly prove the more expensive, and while doubtless the work could be done quite as efficiently as, or even more efficiently than, by employing a contractor, there was always a great temptation to vary small and really unessential details in a manner which the engineer would hesitate to do where he had to face the certainty of a contractor's claim for extras. When work was being done by administration the proper apportionment of the establishment charges was very likely to be forgotten, and, if it were, the unit prices would not be comparable with those of a contractor, who had to cover, in the rates he entered against the various items, the expenses of his central and works offices, stationery, postage, and travelling, as well as interest on capital, and depreciation of plant. These and many other items were liable to be debited to the general working-expenses of the company, board, or authority carrying out work by administration, instead of being included in the unit prices for works. Referring to the tunnel under the Broomielaw, on the Island Barn reservoir-works of the Metropolitan Water Board the Chief Engineer had allowed Messrs. McAlpine to line a tunnel in the London clay, $7\frac{1}{4}$ feet in external diameter, with the reinforced-concrete segments, on their giving an undertaking that they would be responsible in the event of any failure, and would make good the work in such manner as he should deem fit, at their own cost, if a failure should take place. These segments remained the sole lining of the tunnel for more than a year, although it was deemed advisable to add two rings of brindle bricks to the lining of segments, in the place of three rings of brindle bricks shown in the original design. No signs of failure, however, could be found in the segments when these rings were added, just before the completion of the reservoir-works.

Mr. Marsh.

Mr. Robinson. Mr. H. St. G. ROBINSON pointed out that the difficulties encountered in the construction of a portion of the sewers, owing to the existence of old coal-workings, were somewhat similar to those met with during the construction of a section of the Paris Metropolitan Subway, in a district underlaid by old gypsum-workings. A detailed account of this work has recently been given¹ by Mr. L. Suquet, one of the engineers. An interesting feature of the sewerage systems of many large continental towns was the provision of "strangers' galleries," consisting of large, well-lighted chambers, which, placed at important junctions, provided the public with easy means of inspecting in comfort the sewerage system provided at great expense for their benefit. The absence of such arrangements at Glasgow, and even in London, suggested that some municipal engineers took the erroneous view that the extent of the British ratepayers' interest in large municipal undertakings was limited to bearing the cost. With regard to the increasing use of cast iron in the construction of large sewers, tube railways, and similar underground structures in towns where electric tramways and railways abounded, in view of the frequent extensive injury to large water- and gas-mains caused by electrolysis, it would be interesting to know if any consideration was given to the possibility of electrolytic corrosion in these larger structures. In Messrs. McDonald and Taylor's Paper passing reference was made to contemplated use of reinforced concrete for the construction of the precipitation-tanks at the Shieldhall works. As considerable attention was now being given to this subject, a somewhat fuller explanation of the matter would be of interest and might save other authorities, faced with a similar problem, from traversing the same ground. Mr. Robinson had found that in the construction of tanks and reservoirs considerable economy could be effected by the adoption of reinforced concrete, particularly when the structure was to be founded on soft and yielding ground. There could now be little doubt that, correctly designed, reinforced concrete was structurally much superior to plain concrete for tanks situated above the ground, as the troublesome contraction and shrinkage cracks so often found in mass-concrete structures could generally be avoided. Reinforced concrete had advanced in popularity since the carrying out of the Shieldhall tanks about 6 years ago, but even now its application to municipal works carried out on loans was somewhat limited—a condition of affairs which was directly traceable to the innate conservatism of the Local Government Board. It was to be hoped

¹ *Le Génie Civil*, vol. lviii (1911), p. 509.

that the results of the investigations on the subject now being Mr. Robinson. carried out by The Institution would go far to allay the suspicion with which reinforced concrete was regarded in several quarters.

Mr. H. STOWELL regretted that, in a description of such highly Mr. Stowell. successful precipitation-plants as the results showed the three Glasgow works to be, more detailed particulars were not given of the sludge-production, including percentages of moisture. From figures given in Messrs. McDonald and Taylor's Paper, however, it was possible to compare the sludge produced from the three

Works.	Sewage Sus- pended Solids.	Lime added.	Total Sus- pended Solids.	Vari- ation from R.C.'s Figures. Sus- pended Solids.	Dry Material in Sludge.	Actual Weight of Wet Sludge.	Moisture calcu- lated from Two Previous Columns.	Weight of Wet Sludge if reduced to 90 per Cent. Moisture	Vari- ation from R.C.'s Figures. Wet Sludge.
	Grains per Gallon.	Grains per Gallon.	Grains per Gallon.	Per Cent.	Tons per Million Gallons.	Tons per Million Gallons.	Per Cent.	Tons per Million Gallons.	Per Cent.
Dalmarnock	38·04 ¹	6·4	44·44	+58	2·83	37 ³	92·3	28·5	+58
Dalmuir	23·29 ¹	4·0	27·29	Practi- cally iden- tical	1·73	24 ³	92·8 ⁴	17·3	Practi- cally iden- tical.
Shieldhall	19·81 ¹	7·54	27·35		1·74	29 ³	94	17·4	
Royal Com- mission figures	24·5 ²	3·5 ²	28·0 ²	18·0 ⁵	..

¹ Average from Table IV, *ante*, p. 187.

² Royal Commission on Sewage Disposal, Fifth Report, p. 37. Reduced to grains per gallon.

³ From Table II, *ante*, p. 185. The Shieldhall wet sludge is stated to be 28 tons (p. 182).

⁴ Stated to be 93 per cent., *ante*, p. 179.

⁵ Revised on basis of total elimination of suspended solids.

Glasgow sewages with that estimated to be produced by continuous precipitation from the average sewage on which the Royal Commission based their figures. When the respective sludges were compared on a similar basis of suspended solids, added precipitant, and percentage of moisture, the actual results at Glasgow were a singular confirmation of the Royal Commission's estimate, and the apparently large difference between the quantity of wet sludge at Dalmarnock, namely, 37 tons per million gallons, and the Royal Commission figure of 16 tons was accounted for by the excess of suspended solids and higher percentage of moisture. The Royal

Mr. Stowell Commission's estimate was based on a 90-per-cent.-moisture sludge from an average sewage containing 35 parts per 100,000, plus 5 additional parts from the precipitant, less 4·5 parts of suspended solids discharged in the effluent; and if these figures were revised on the basis of total elimination of suspended solids, as at Glasgow, and the Glasgow figures were reduced to a 90-per-cent.-moisture basis, the Table on p. 281 showed how closely they compared, and might be of interest as a record. Briefly, this Table showed that at Dalmarnock, with a sewage containing suspended solids plus precipitant 58 per cent. in excess of the Royal Commission's figures, there was 58 per cent. more wet sludge (90 per cent. moisture). At the other two works, with almost identical solids, the wet sludge results were almost identical.

In Fig. 4, Plate 5, the storm-overflow at St. Andrew's Road appeared to be defective in one important point. The vanes would tend to deflect over the sill all floating faecal matter, paper, corks, and other detritus. This was matter which caused a very unsightly nuisance when discharged. Some arrangement of horizontal upward screening or of scum-boards should be provided, whereby all such matters would be passed forward along the main sewer.

Mr. Tait. Mr. W. A. TAIT observed with satisfaction that the rate of progress in sewer-tunnelling in Glasgow had greatly increased since the first adoption of compressed air about 20 years ago. In the discussion on Mr. Greathead's Paper on the City and South London Railway he described¹ the methods then in use in Glasgow. The progress was about $4\frac{1}{2}$ feet daily at each face in the neighbourhood of the Central railway-station. Recently the daily progress seemed to have been about 10 to 15 feet at each face, in King Street. The high rate was due not entirely to the ground in King Street being so much better from the contractor's point of view, but largely to the improved methods adopted and the better plant now available. Little or no timber was now used except in the temporary poling of the face, and practically no timber was built in. The shields used recently for the small sewer were 8 feet in internal diameter, and had a cutting edge projecting 2 feet. The shields were fitted with eight rams, which were actuated by hydraulic power, water being obtained from the Corporation power-mains at a pressure of about 1,000 lbs. per square inch, which was intensified at the shaft to about 3,000 lbs. per square inch before the water was delivered to the rams. It was also

¹ Minutes of Proceedings Inst. C.E., vol. cxxiii, p. 119.

found to be convenient to use the Corporation electric current with Mr Tait. 55-B.H.P. motors to drive the air-compressors, which were capable of supplying about 800 cubic feet of air per minute at the required pressure. An independent motor and compressor was used for the purpose of grouting under pressure—an operation which for years had been erroneously called “bogeeing.” Some of the silt encountered in different parts of Glasgow was extremely fine; when wet, it became as mobile as jelly, and it was frequently rather troublesome to deal with by ordinary methods of excavation. With great respect to Mr. Easton’s preference for tunnels, it must not be overlooked that excavation by open cut, however slow and expensive, helped to lower the water-level in the ground in a way that a tunnel driven under compressed air never did. Such a lowering of the water-level must be in the interests of the community, and the non-lowering was accentuated when grouting under pressure was performed. Mr. Easton also stated that contractors had been asked to tender on the basis of receiving extra payment for the use of compressed air. Mr. Tait understood that several of the present-day contractors preferred to fill up one price only, and to employ, or dispense with, compressed air as seemed to be most desirable in the circumstances of the moment. Probably the fact that power was so readily available from the Corporation mains had something to do with this. He would be glad if Mr. Easton in replying would clear up a point near the foot of p. 198 by stating whether a shield was used with the concrete segments when working near the Broomielaw; also whether compressed air was employed, what was the rate of progress, and when the centres were struck. Neither Mr. Easton nor Mr. Morton offered any justification for the choice of the site of the pumping-station at Kinning Park. It did not seem that the Corporation or their advisers had taken account of the information as to the strata in the neighbourhood which became available after the driving of the Glasgow Subway tunnels shown in Fig. 7, Plate 6. Having had the pleasure of accompanying the Engineer to Kinning Park at a very interesting stage of the works there, he was quite satisfied that the operation of taking out the excavation and putting in the foundations was carefully and thoroughly done. He took the liberty, however, of expressing the opinion that the money spent at this place was quite out of proportion to what had been gained in saving the granary and the tramway-depot. Indeed, it was not easy to understand why, when the Corporation were so frequently before Parliament, the opportunity was not taken to change to some other site, where the strata had

Mr. Tait. been reasonably proved. The Paper did not state, though it would be interesting to know, whether the work eventually carried out by the Main-Drainage staff at Kinning Park was ever offered to contractors in the ordinary way.

Mr. Williams. Mr. G. B. WILLIAMS remarked that, apart from their magnitude and the constructional difficulties, the works did not differ greatly from those of other large drainage-schemes. The most instructive parts of the Papers were, in his opinion, the descriptions of the outfall-works, and it was interesting to learn that a comparatively moderate degree of chemical purification had sufficed to transform the Clyde from a filthy channel into a comparatively wholesome river. Mr. Easton appeared to be satisfied with the method of carrying out the works by direct administration in the particular conditions obtaining in this instance; but a system whose chief advantage was that the work was carried out under a number of inexperienced youths, who disregarded everything except getting the work done quickly, would appear not to be an ideal arrangement. While the relative advantages of tunnelling and open cutting obviously depended upon numerous factors, e.g., the nature of the ground, the width of the street, the amount of traffic, and the position and character of the adjoining buildings, the general experience of engineers would probably be in agreement with Mr. Easton's view that tunnelling was preferable to open cut in the streets of large towns in sewer-trenches more than 20 feet deep. The successful completion of the Kinning Park pumping-station under the difficulties described by Mr. Easton, reflected great credit on all concerned.

He had had cause recently to investigate the comparative cost of electric and steam pumping for waterworks. Pumping by electricity seemed to have a remarkable attraction for the lay mind, and he had had considerable difficulty in persuading some of the municipalities in Bengal, who wished to tack a municipal electric-lighting scheme on to a waterworks scheme, that by combining with their lighting scheme an unnecessarily costly method of pumping they could not transform what would otherwise be a financial failure into a financial success. This description of a large and costly modern sewerage scheme suggested a striking contrast with the conditions under which Indian towns had to be drained. In Bengal, Calcutta alone was at present drained on European lines, with a system of underground sewers and pumping-stations. A sewage-scheme for Dacca was in course of preparation, but whether sufficient funds would be available to carry the work to completion remained to be seen. At Gaya (which until the recent partition was in the Bengal

Province) work was now being commenced on a scheme which was Mr. Williams. a combination, on somewhat novel lines, of a sewerage system with an open surface-water drainage-system ; and for some of the suburban municipalities near Calcutta he had projected systems of main sewers, to be developed as funds permitted. The objects to be aimed at in draining Indian towns were : to get rid of the sewage and liquid wastes, which in the undrained towns stagnated and soaked into the ground around the houses ; and to reduce malaria by lowering the subsoil-water and draining the small pools of water which provided breeding-places for mosquitoes during the rains. The relative importance of these objects depended on local circumstances. The typical town of 5,000 to 50,000 inhabitants in Lower Bengal was a huddled mass of mud huts and dilapidated plastered brick houses, interspersed with numerous tanks or ponds, and surrounded by an outer ring of detached huts situated in the midst of jungle, swamps, and partly cultivated lands. The ground everywhere was almost absolutely flat, and in the cases of towns near the large rivers, any slope there might be was generally away from the river-bank. The main thoroughfares in the town were narrow lanes, with roughly-constructed masonry drains on either side, laid to no particular gradients and running under verandas, steps, and booths which had been allowed to encroach on each side of the public road. Into these drains the inhabitants flung daily large quantities of refuse of the most inconvenient and obnoxious description, whilst effluent from cesspools and latrines soaked out at intervals from holes in the plinths and walls of the buildings ; and in the rains the whole ground was sodden and waterlogged. Funds for sanitary engineering works in Bengal were provided from four sources : (a) Government grants ; (b) Government loans ; (c) municipal funds ; and (d) private donations. Government grants did not usually exceed one-third of the total cost of a drainage-scheme, although, in some exceptional cases, one-half or even more might be contributed. The municipality was generally on the point of bankruptcy and had the greatest difficulty in meeting the very moderate demands of the expenditure on conservancy, scavenging, lighting, and road-repairs. It was to the credit of the wealthier Bengali landowners that donations for sanitary works were fairly often forthcoming. Municipal drainage-schemes in Bengal might be divided into four classes. The simplest type was the anti-malarial drainage of a scattered municipality, which consisted of digging a number of earthen drains discharging into main channels. The latter were sometimes provided with masonry inverts, and sometimes had only masonry bed-blocks at intervals, as guides to cleaning out the

Mr. Williams, drains to the correct gradients when they filled. The next more elaborate form of drainage was a system of open masonry drains discharging sewage and storm-water, the final outfalls being into neighbouring rice-fields, swamps, or a river. The third type of drainage system was an elaboration of the second, adopted in the larger towns, in which the open drains discharged into one or two main sewers and an attempt was made to deal with latrine effluent. The fourth type was the complete sewerage system for storm-water and sewage, of which, as already mentioned, Calcutta was at present the only example in the province of Bengal. Darjeeling had just introduced a system of underground sewers, septic tanks, and aerobic filters for night-soil and latrine effluent only, but the conditions there were so peculiar that they could not be compared with anything existing elsewhere, except at other Indian hill-stations. The first two classes of scheme did not offer much scope for originality of design, although they involved much laborious detail in arranging sufficient gradients to give something approaching a self-cleansing velocity for the drains. The third class was in the experimental stage at present. He was endeavouring to solve its difficulties by introducing partial purification of the more obnoxious liquids before they were mixed with the surface water and sewerage in the main sewers. In the fourth class the difficulty was to decide how much of the storm-water could be economically admitted to the sewers, and to devise practical means of separating the surplus and disposing of it. The solution appeared to him to lie in a system of slow-flow open surface-water drains, from which all sewage was excluded as far as possible, with masonry open-surface branch drains connected with the sewers through catch-pits, and with the main surface-water drains through overflows. The problems of Indian municipal drainage were so peculiar, and so unlike anything of which the ordinary English engineer had experience, that he had taken this opportunity of giving a rough outline of them.

Mr. Easton. Mr. EASTON, in reply, stated that at Kinning Park the use of steel piling specially designed with a metal-to-wood joint had been seriously contemplated, but the adoption of timber piling had been fortunate. Neither shields, air-pressure, nor centres had been used in the Broomielaw tunnel of concrete segments. The result of breaking out in 1903 a length of iron-tunnel sewer 12 years old, in wet strata, with underground electric cables above, had dispelled any fears of corrosion. He considered screens on an overflow sill a counsel of perfection; if there was work for them, they entailed close attention during overflowing. At St. Andrew's Road the

overflow discharge had to travel $\frac{3}{4}$ mile at a velocity of about 10 feet per second. He disagreed with Mr. Tait on the lowering of the subsoil-water: it encouraged claims for alleged damage to property, and was not permanent if the sewers were watertight. His experience was that, except where it was possible to determine with practical certainty, when pricing, whether air-pressure would be necessary or not, one price covering either alternative would work out unfairly to one of the parties to the contract. He had no responsibility for the choice of the site of Kinning Park pumping-station, and for long had held very strongly the opinion expressed by Mr. Tait. The actual costs had, however, justified the site. The question of work with and without contractors had produced the desired criticism. As, however, views had been credited to him which were directly contrary to those he held or had expressed, a fuller statement was necessary. The importance of Mr. Marsh's point regarding unit prices had been realized throughout, and the division of all charges incurred into "Costs of Construction" and "Other Charges" had been scrupulously made on work without contractors, by the Police Treasurer (now City Chamberlain). The former included all charges which would not have been incurred under the latter had there been a contractor, and *inter alia* the items detailed by Mr. Marsh, with the exception, for financial reasons relating to the sinking-fund, of interest on capital. The book value, reduced by charges to "Costs of Construction," of the unsold plant, much of which was now in use in the Sewage Department, was at 31st December, 1911, £218 7s. 5d., or scrap value. Schedule or unit prices covered all "Costs of Construction." The rules and general atmosphere essential to the efficiency of the regular and permanent work of a corporation were unsuitable to the entirely different work of contractors. Two examples must suffice:—(1) The skilled contractors' foreman, engaged and tolerated until his own picked men had got a grip, had sooner or later become possessed by the policy known as "ca' canny." This policy had been killed at the outset, but Mr. Easton had doubts whether the free hand which he had had in dealing with it could usually be counted on. (2) Standing orders not dissimilar to the laws referred to by Mr. Hill, and many rules and regulations—often unfairly designated "red tape"—were insuperable obstacles. Authority to suspend, even temporarily, any of these would, as a matter of public policy, be a worse evil. Chronic forgetfulness—the remaining alternative—although successful at Glasgow, was rather dangerous. He considered that it was not possible for a corporation to execute contractors' work at as low unit or schedule

Mr. Easton. prices as a contractor, although he noted with interest the experience of Sir Maurice Fitzmaurice. With one exception, where in his opinion the strata were held in too bad repute (see p. 264), the estimates priced by him—miscalled “tenders”—had amounted to about the mean of the tenders received. These estimates safely covered all risks. The policy of giving much of the most risky work to the staff consequently amounted to one of saving the cost of insurance by taking the heavier risks. Fortunately, the luck had been with Glasgow every time, and her courage had been fully justified by success. Failure, however, which might often result from caution, was throughout such work a very real possibility, and public bodies must remember that when it occurred courage would receive a very different name. For obvious reasons tenders had not been received, nor an estimate given, for the work at Kinning Park. He had to give an estimate 6 months after the work started, and the amount estimated for the work below ground-level turned out to be fully 50 per cent. above the completed cost; but, looking to the risks and the good luck experienced, he would be unwilling to say that such cover was unreasonable. He was puzzled by Mr. Williams’s interpretation of his statements; no youth had been given responsible work until he had been proved.

Mr. Morton. Mr. MORTON, in reply, explained that the selection of lifting screens at Kinning Park in preference to fixed inclined screens, as at Partick, depended chiefly on the fact that the former were better suited to the design of the deep foundations. The steel valve-seating faces resisted the action of hard grit better than the hardest gun-metal, which was used at Partick, and the grease in sewage seemed to be sufficient to prevent decay by rust. Steel valve-flaps had been adopted with the steel valve-frames at Kinning Park, to reduce the risk of fracture, though the trouble from this cause with the cast-iron valves at Partick had been trifling. The difference in weight of the valves in the two materials, as made, was negligible. In mentioning the failure of one of the boiler-flues at Partick, the lesson which he had meant to point was that in quantities of good steel there might be some which possessed the dangerous defect of obscure or “potential” brittleness, although, according to the test-sheets, it was the same as the rest. The material in question was the usual low-carbon soft steel, suitable for welding and flanging. The most economical method of driving feed-pumps was from the main engine, if the steam-consumption only were concerned. But where there were several main engines it was convenient to have a separate feeding-system. He was familiar with the details of the waterworks pumping-engines referred to

by Mr. Cornish, but the conditions could not be compared with Mr. Morton. those at Kinning Park or Partick, where the pumps had to be set low in the deep foundation-works, with good delivery-pipe arrangements, and engine-floors at suitable levels. Accessibility for cleansing, repairs, and renewals was also very important. Too often reciprocating pumps below engine-floors were so closely hemmed in by walls that proper access was impossible; and there were cases in which it would seem that pumps could only be removed either by lifting the engines or by excavating through the side walls. Mr. Cornish referred to "an elaborate and costly system of bracing." As far as Partick was concerned, in the absence of the framing with bracing which was used, there would have been heavy transverse brick walls; the account would simply have been transferred from one contract to another, and the pumps would not have been nearly as accessible. At Kinning Park the engines were supported on plain cast-iron beams, which had been obtained at a very low rate per ton, compared with machinery rates. As a matter of fact, the bed-plate and shaft arrangements, for which Mr. Cornish claimed so much economy, were not less costly than those employed by Mr. Morton for engines of equal power and length of stroke. The engines referred to by Mr. Cornish had three-throw double-web marine cranks, and six bearings, with fly-wheels near the outer ends of the shafts. In some larger examples of engines of this type there were eight bearings, whereas in the Kinning Park engines there were only four bearings, one double-web middle crank, and two single side cranks. Designers of engines with these long expensive marine shafts seemed to forget that the power was not to be transmitted through the shaft-ends, and that the function of the crank-shaft was simply to regulate the strokes and transmit minor differences; also they seemed to forget that the proper position of a fly-wheel was in the plane of its duty, and that the value of a fly-wheel of given weight varied as the square of the angular velocity of the radius of gyration; hence the efficiency of large light wheels compared with smaller wheels of equal weight, in assisting the engine to run at a low rate of revolution. These considerations accounted for the details of the Kinning Park and Partick engines—a simple short crank-shaft, three separate bed-plates to permit the use of large fly-wheels, and six beams to support the separate bed-plates. This method of arranging the crank-shaft, fly-wheels, bed-plates, and supporting beams, was one which had been adopted as standard for years by a well-known contracting firm responsible for the design and erection of a large number of important and economical pumping-engines in various

Mr. Morton. parts of the world. Having already given in the Discussion his opinion in regard to the relative advantages of reciprocating pumping-engines and centrifugal pumps for sewage, he need only reaffirm that improvements and refinements which had increased the efficiency of the centrifugal pump in dealing with pure water were not well adapted for use in a pump which had to deal with heavy industrial sewage. Mr. Hill mentioned one advantage of the reciprocating pump, namely, that its speed could be readily adjusted to suit the wide variation in the quantity of sewage pumped. In a waterworks, the pump could generally be run at its most suitable speed, and then stopped until required again; the sewage-pump must work continuously, and take the sewage as it came. In selecting machinery for any particular duty, the considerations which guided the engineer were probably complex. It had been part of the duty of Mr. Morton's firm for many years to make such selections, and, naturally, the question as between steam-engines and gas-engines had frequently arisen. For plant of moderate power or capacity, under suitable conditions, he had not the slightest objection to using gas or oil with a high-class engine—such as the Diesel engine, for example, in its most improved form for oil. Just, however, as electrical engineers often did not seem to know how economical a modern steam-driven pump might be made, so gas-engineers were not always too well acquainted with the capabilities of the best class of steam-engines, which they sought to supersede. Remarkably good results had been obtained in recent years with small waterworks plant having gas- and oil-engines, usually driving three-throw pumps by means of gearing, and there was no doubt that for such small plants gas- or oil-driven pumping-engines easily excelled steam-driven pumps of correspondingly small size. In the larger sizes there was no such obvious advantage, and granting the use of reciprocating pumps to run at moderate speeds, in preference to centrifugal pumps for sewage, the introduction of wheel gearing between the engine-shaft and the pump-shaft was rather an objection, and a means of lowering still farther the mechanical efficiency of the transmission, which, with a gas-engine, was, of course, lower in any case, owing to its cycle. For intermittent pumping, as in storm-water relief works, or emptying graving-docks, for example, a combination of oil-engines and centrifugal pumps made an ideal plant, likely to be largely used in the future. The supply of oil-fuel was not yet, however, staple in this country, and small coal was likely to be cheap for years to come. For continuous duty, pumping-engines like those at Partick and Kinning Park were well able to hold their own against gas-driven

engines with producers. With regard to capital cost, stations of Mr. Morton. magnitude with deep foundation-works, and the highest class of mechanical equipment, could not properly be compared with smaller works, which, broadly speaking, were on the surface. They must be compared with similar large works, such as the stations of the London main drainage, for example. The western pumping-station at Pimlico cost about twice as much as Partick station or Kinning Park station; nevertheless, if only the fourth engine, for which a large portion of the necessary preparation had been made in each station, were added, the capacity of each would exceed that of the Pimlico station. The lift of the pumps in the London station was only half that at Partick, and four-tenths of that at Kinning Park, and the machinery in the Glasgow stations was naturally more efficient, because more modern.

26 March, 1912.

W. CAWTHORNE UNWIN, B.Sc., LL.D., F.R.S., President,
in the Chair.

The discussion upon the Papers by Messrs. McDonald and Taylor, Easton, and Morton on the "Main Drainage of Glasgow" was continued and concluded.
