Discussion.

Sir Benjamin Baker.

Sir BENJAMIN BAKER, President, said that many Papers on water-works and on sewerage works had been brought before the Institution, but that was the first occasion on which a Paper had been read dealing with the complete sanitary works of a city of the great importance of Buenos Ayres. The Author had had a unique opportunity, and had worthily taken advantage of it. It would be evident to those members who had read or even glanced through the Paper that the abstract which they had just heard read was in reality little more than a table of its contents. He had much pleasure in asking the members to accord a very hearty vote of thanks to the Author for the valuable contribution which he had made to the Proceedings of the Institution.

Hon. R. C. Parsons.

The Hon. R. C. PARSONS observed that since the preparation of the Paper the figures given in it as to the consumption of water per head in Buenos Ayres had been reduced from 58 gallons to 54 gallons, and he could not help thinking that this consumption would be further reduced, as the regulations became more perfect. Again, the population, which was given as 600,000, had now reached 680,451. That was the population of the total municipal area of Buenos Ayres, which extended beyond the area shown in Fig. 1, Plate 1, and was the federation of a number of townships together with Buenos Ayres, under the Mayor of the city. The death rates given in Appendixes IV and V were calculated upon the population of 618,685. With regard to the districts shown in Fig. 1, Plate 1, the population was now 570,000 instead of 560,000, and of that number about 375,000 inhabited houses supplied with water, and about 300,000 those connected with the sewers. He was able to give from the recent returns some additional figures with reference to Appendix V. During the year 1895, up to October, the portion of the population using the sewers amounted to 53 per cent. instead of 40 per cent. Small-pox had increased; there appeared to have been an epidemic of this disease raging in Buenos Ayres during the year, not nearly as severe, however, as that in 1890, but the mortality had been 0·45 per 1,000 instead of only 0·0053 in 1895. Diphtheria, which was always a measure of the improvement of the sanitary condition of the town, had been reduced from 0·75 to 0·63, in addition to the reduction which had already been made by the use of the sewers. Typhoid fever had remained the same, viz., 0·36 per thousand. Hon. R. C. Parsons.

Mr. R. J. NEILD had, with some interruptions, resided in the city of Buenos Ayres for twenty years, his first visit having been in 1866, thirty years ago. He might, therefore, possibly be able to say something about the local circumstances, which would throw not an uninteresting light on those great and important works. When he first went to Buenos Ayres, the population was about 170,000, and, according to the last census, it now amounted to 700,000. Not only had that almost unheard-of increase taken place, but during the whole of the time there had been a succession of changes in the political constitution, and the social and commercial conditions of the people, which was almost without precedent in any country in the world, with the exception perhaps of the United States. The result of the constant change in that cosmopolitan country had been that, on more than one occasion, money which was intended to be devoted to the purposes of the works had been diverted from it through political changes, wars, epidemics and the like, and a delay had occurred which must have been as unsatisfactory to the subscribers of the loans for carrying out the works as to the engineers who were charged with the spending of the money. The extension of the town had been of a character that it was very difficult to explain. When he first knew it, four years before the epidemic of 1871, which had been the cause of the works being first conceived, the townships of Belgrano and Flores, now included in the capital of the Republic, were distant villages rarely visited, and certainly were not used for residence, by any number of the population. So great had been the progress of building that those outlying townships were now merged with the capital, and many rows of fashionable villa residences connected them with Buenos Ayres itself. The ideas of the people had also undergone many changes, but no changes had occurred up to the present time such as to teach the people the habit of paying the imposts which the maintenance of such costly works necessitated. Works of that sort were often compared with similar works in England; but in Buenos Ayres the population was composed of almost more foreigners than natives, every kind of nationality, speaking every kind of language and having all kinds of customs, and there was great difficulty in collecting the taxes and carrying on extensive works with regularity. He considered that the Argentine Republic was an example to the whole of South America for the wonderfully liberal views which it held, and the manner in which, with many trips and falls, the Mr. Neild.

Mr. Neild. people had adhered to their purpose, and carried their improvements into operation. He trusted the few words he had uttered would enable the members to see that in forming a judgment of the works, they must not be guided entirely by the criterion formed from experience in England. The cost of the works, also, had been to a great extent in gold, for material imported from England. The wages had been paid in the equivalent of gold, and during the time the currency of the country had so depreciated that the dollar, which at the beginning of the works was worth 4*s.* 2*d.*, was now only worth 1*s.* 3*d.*; so that the raising of the necessary taxes to pay the interest on that money was very arduous.

Mr. Hawkshaw. Mr. J. C. HAWKSHAW had paid several visits to Buenos Ayres during the last ten years, and would point out how the Port works, which had been designed by and executed under the direction of his firm, had affected the drainage. A large area of the foreshore, about 900 acres in extent, had been reclaimed by the construction of a sea-wall, 3½ miles in length, extending along the frontage of the city. Within this area a chain of docks had been built, closed by gates at each end, so that a constant level could be maintained in the water within them. This precaution was necessary, because the level of the water in the River Plate, which was here some 30 miles wide, was liable to great fluctuations during gales. Since some of the docks had been open for traffic, the level of the water in the river had fallen on one occasion to 8 feet below zero (low-water spring-tides), leaving only 13 feet of water on the sill of the locks. The storm-water culverts discharged on to the foreshore along the old river margin, the storm-waters flowing behind the docks in an open channel, and discharging at the northern end through a temporary outlet in the sea-wall into the River Plate. The permanent intercepting culvert which was required to replace the open channel, had not yet been begun. It might be inferred from the Author's remark (p. 31) that this delay in constructing the intercepting culvert was caused by the Port works. Such, however, was by no means the case, but the contrary. The intercepting drain could have been begun five or six years ago, soon after the first dock was constructed, and could have been extended as the docks proceeded; and expenditure on the Port works for temporary expedients would have thereby been saved. The Port works reclamation could not be completed, and much of the land could not be made available for building until the intercepting sewer was made. Those, however, who knew the surrounding conditions would be best able to realize the

Mr. Hawkshaw.

difficulties to be encountered in carrying out the works described in the Paper. The streets and side-paths were somewhat narrow; and although the rainfall of the year was not very great, there were heavy downpours at times. He had seen one of the principal streets, with a stream of water flowing down it the full width of the roadway, and even over the pavements.

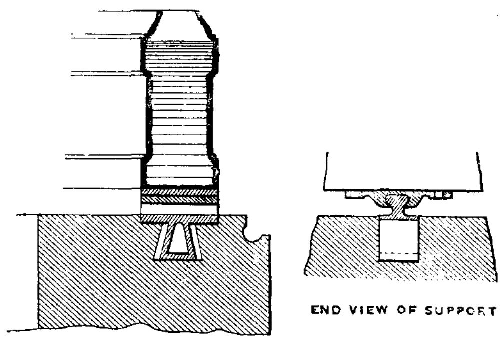
Mr. Binnie.

Mr. ALEX. R. BINNIE observed that the members had not often the privilege or opportunity of receiving a Paper giving an account of a work undertaken and completely carried out. In a country like England which had been civilized for certainly 300 years, the works partook more or less of additions to previous work; but in the Paper there was described what was most valuable, especially to the younger members of the Institution, a large work, well designed by a master of their profession, and carried out with perfect success. The striking fact about the Paper was that the whole of the works had to be constructed in a country which produced no stone, and where sand had to be brought from a considerable distance. When the difficulties and limitations which such natural obstacles would always impose were considered, it would be seen at once that new circumstances arose calling for great skill. The Paper dealt with works in a sub-tropical climate, where two conditions had to be met—the average daily discharge of the sewage, dealing at the same time with the possibility, at intermittent intervals, of a truly tropical rainfall. He was glad to see that in those works—not for the first time perhaps—a systematic attempt had been made to deal with the possible arising of bad smells from drains and sewers, which of necessity must be made of much larger capacity than that of the average flow of the sewage. In a tropical country, that must always prove one of the great difficulties with water-carried sewage. Perfect ventilation, which had been applied with so much success to house-drainage, had been applied by Mr. Bateman to the public sewers, and on exactly the same lines. It was now held as an axiom of house-drainage that all internal drains should be free from pressure, and have a free communication with the atmosphere. In the works described the public sewers were placed under exactly the same treatment. Shafts were carried up for ventilating the sewers without the necessity of resorting to the crude methods which were often adopted of ventilating at the level of the street. From what he had seen in England and in India he believed that was the proper solution of the difficulty. If sufficient ventilation was afforded a great step would be made in the treatment of town sewage. In reading the account of the reservoir constructed

Mr. Binnie. in the peculiar manner described, with all the elaborate precautions taken to prevent rupture of the structure owing to unequal expansion and contraction, due to changes of temperature, he thought that those precautions were useful in another way in preserving the whole structure when they, in common with the whole system, were subject to the severest trial to which any works could be subjected, viz., shocks of earthquake. Their having passed through such an ordeal with success was in itself good proof that the works were well designed and executed.

Mr. Davey. Mr. HENRY DAVEY thought some particulars of the cost of working would be interesting. The filters were stated to work at a percolation rate of 6 inches per hour, and the water contained a very large amount of suspended matter. He imagined that the

Figs. 52.

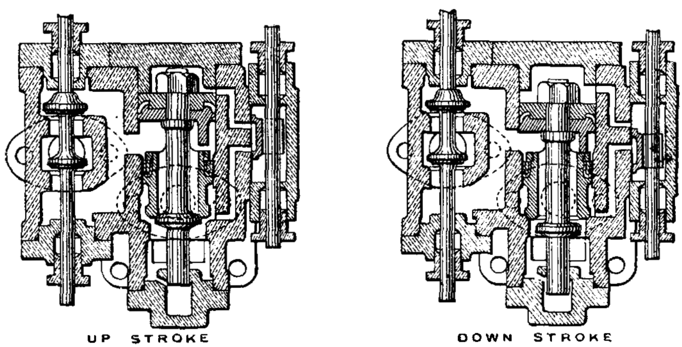


Scale, $\frac{1}{4}'' = 1$ foot.

filters required very frequent cleaning; particulars of the mode, the frequency, and the cost of cleansing the filters, would form an interesting addition to the Paper. As to the method employed to counteract the effects of expansion and contraction in the large reservoir, he had some time ago to support an annular tank, of 22 feet outside diameter, on the top of a tower, where it was exposed to the sun's rays and to wind-pressure. The problem was how best to support the tank to admit of free expansion and still resist wind-pressure. This had been solved in the manner shown in *Figs. 52.* The points of support were constructed like the slide-rest of a lathe, and were arranged radially, so that the tank was free to move, at any point in its circumference, towards or from the centre. The material used, phosphor-bronze, was non-corrosive, so that the tank was not of very great weight, and the question of rust did not enter into the problem. In a plane surface, fixed at one point, any point displaced by expansion moved radially from the fixed point, so that a cylindrical joint, or knuckle-joint, instead of a ball-and-socket joint, might be employed. The knuckle-joint was very easily and inexpensively constructed as compared with the ball-and-socket joint, and gave a better bearing surface, and steel facings could then be introduced. If instead of a ball-and-socket joint there had been a knuckle-joint, the axis of which was placed at right angles to a radius drawn from the fixed point to the point of support, it would have answered the same purpose. Although, as the Author had said, it answered its purpose admirably, he thought the ball-and-socket joint an expensive one. Mr. Davey.

Mr. VON LENGERKE regretted that the Author had not given more Mr. Lengerke.

Figs. 53.

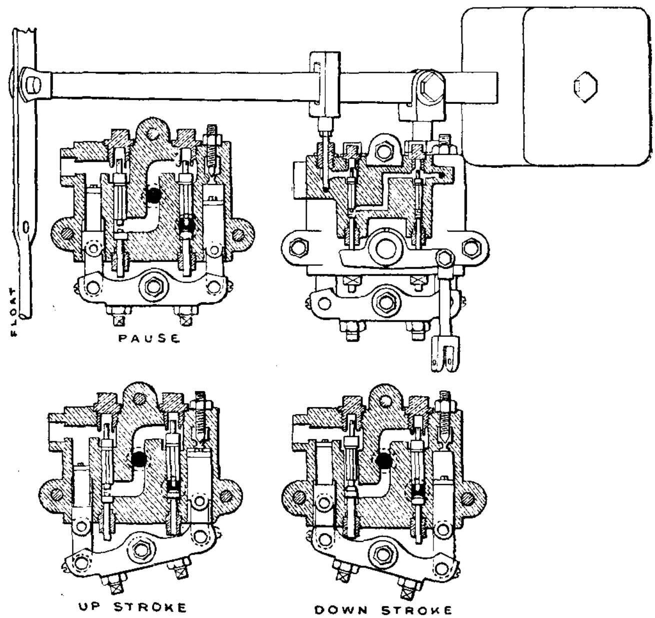


Scale, 1 inch = 1 foot.

information as to the details of the valve-gear of the hydraulic sewage-pumps. A sewage-pump had not only to comply with the conditions laid down by the Author at p. 43, but it also had to work noiselessly, otherwise it was a great source of trouble. He had been resident engineer at the Esher Sewerage Works under Mr. Baldwin Latham, which had been the first extensive application of hydraulic power to sewage-pumping carried out in this country. There had been at first some difficulty in getting the machinery to work automatically and noiselessly, and also without serious leakage, but those difficulties had been eventually overcome. The valves originally supplied to the Esher pumps were shown in *Figs. 53.* They were of a well-known type, and had been used for similar purposes in coal-mines and other places, but they certainly did not work well at Esher. The automatic valve to enable the

Mr. Lengerke. machine to remain at rest until it was required to come into action was a double-beat valve actuated by a float. It had given much trouble, and could not be maintained watertight for many days together. He had concluded that the double-beat valve could not perform the very important work imposed upon it of controlling the sewage-pump. The main valves were in the centre of the valve-box; the exhaust-valve was annular, and the pressure-valve rose against it, both being actuated by the piston

Figs. 54.

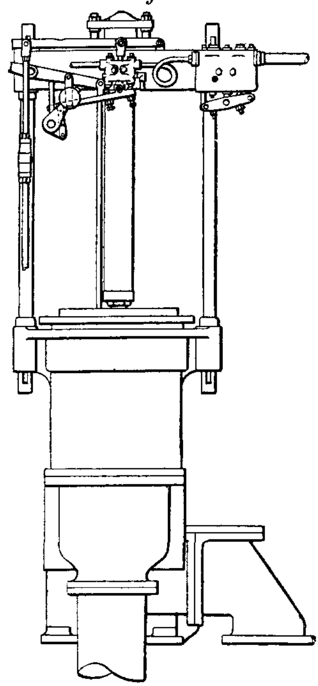


Scale, 1 inch = 1 foot.

at the top. The little slide-valve on the right-hand side was actuated by tappets, and allowed exhaust or pressure on the upper surface of the piston to move the valves either one way or the other. In action one of these valves lifted the other; consequently no sooner had the engine pumped to one end of the stroke than it was immediately started in the reverse direction. That arrangement was supposed to have the advantage of producing a uniform flow in the hydraulic main, but it assumed that the pumping stroke was uniform. On the Esher pumps, owing possibly to the very large flap-valves, the pump started its stroke at a very high speed, in fact it went off with what might be described as a kick and a jump. There was a loud report as the suction-valve closed, followed by another from the delivery-valve, and the working was very noisy and unsatisfactory. The leakage had also been a source of trouble, and was largely attributable to the little slide-valve. After considerable trouble had been taken in endeavouring to get the valves to comply with the specified conditions, Mr. Baldwin Latham had decided that the valves shown in *Figs. 54* should be substituted. The valves to admit the water were perfectly simple check-valves, closed by pressure, and instead of the piston above there were two plungers, one having twice the area of the other. The larger plunger was controlled by tappet-valves, taking the place of the slide-valve, and when the water was exhausted from it thevalve-gear took the position shown in the lower left-hand *Fig.*; when pressure was applied to the large plunger it moved into the reverse position. By these valves the difficulty of leakage had been overcome, but there was still the question of silent working, and that had been attained by throttling the supply of water to the large plunger, so that as the little engine made its strokes it travelled gently from side to side. The lifting plugs were shaped so that there was an interval between the closing of one valve and the opening of the other, to produce a pause at each end of the stroke, enabling the clacks to close silently and without slip. As to automatic action, instead of the float-valve being on the main supply-pipe of the engine, where it must be of considerable size, it had been placed on the little supply passing to the subsidiary piston or subsidiary engine. The float-valve had thus been rendered very simple, was easily replaced, and had the effect of always stopping the engine at the end of the stroke. When pumps for Margate, *Fig. 55*, had been designed somewhat later, the float-valve had been dispensed with. Automatic action was secured by causing the float to throw out of action the tappet-lever, which

Mr. Lengerke.

Fig. 55.



Scale, $\frac{3}{8}$ inch = 1 foot.

Mr. Lengerke. acted on the two tappet-valves. The valve-gear he had described had been designed by Mr. Baldwin Latham, Mr. Arthur Rigg, and himself; and it overcame the difficulties of automatically working sewage-pumps by hydraulic power.

Mr. Davey. Mr. DAVEY remarked that the valve shown in *Fig. 53* was his.

The President. The PRESIDENT: That was the one that had failed?

Mr. Davey. Mr. DAVEY said it was according to Mr. Lengerke's statement. It ought also to have been said that the one claimed as a success by Mr. Lengerke was an invention of Mr. Baldwin Latham and Mr. Lengerke. In the first place the valve shown in *Fig. 53* was in use in, perhaps, over 1,000 hydraulic engines, and was working perfectly satisfactorily. Engines had been constructed for the last fourteen or fifteen years with that valve, and it was preferable to the small valve *Figs. 54* which had to be kept down with springs that broke about five or six times a week. The valve would not drop of itself; it was not much heavier than a penny piece. The Esher valves had springs behind them for purposes of experiment, and he believed they had been retained, for if they had not, their efficiency would be impaired by the smallest amount of dirt. With regard to the automatic action of the valve, the double-beat throttle-valve was not intended to stop the pump. It was not his intention that it should stop the pump suddenly, and start it suddenly; but that when sewage was coming at a lower rate, the pump should work at a lower rate, and the method described by Mr. Lengerke of throwing out of gear the tappet-rod actuating the subsidiary valve was obviously applicable in the one case as well as in the other, so that if Mr. Lengerke's intention was not to use his own valve but to use his (Mr. Davey's) with such alterations as would satisfy him, he might have applied that to the original valve as well as to have swept the thing away and apply it to something altogether new. The tappet-rod was the same; in fact, there were many mechanical solutions of the problem.

Mr. Latham. Mr. BALDWIN LATHAM was glad to find that the Author had adopted the hydraulic system for dealing with this low-lying district of Buenos Ayres. He had no hesitation in saying that in future it would be universally adopted by all engineers who gave careful study to the question. He would like to know something as to the efficiency of the hydraulic machinery. No information was given in the Paper as to the relation between the power employed and the work performed—a point upon which every engineer desired to have most explicit information. He had studied this question, nearly ten years ago, of introducing the hydraulic system for pumping sewage, believing both from a sanitary and Mr. Latham. economical point of view that it was the proper system to be used. In work he had carried out he had taken care as far as possible to determine the efficiency. At Margate there had been very great difficulty in arriving at it, because the Corporation insisted on placing the station from which the power was generated attached to the waterworks at Tivoli. As those waterworks were always in use for supplying water to the town, it was very difficult to discriminate as to the amount of fuel used for pumping the water-supply and that used for hydraulic transmission of power. There were times, but they were rare, when there was such an abundance of water at Margate that the waterworks at the Dane had kept the town supplied, and it had been possible, perhaps for a month together, to work that machinery and to determine with accuracy the cost of pumping. There were four hydraulic stations at Margate, three of which were used for the purpose of dealing with the sewage proper of the town, and a fourth which came into operation at a time when a heavy storm occurred coincident with a very high tide. Under those conditions Margate used formerly to be flooded, and, as in all the low-level districts the separate system had been adopted, a station had been constructed on the surface-water system of drainage containing two of these hydraulic pumps, and so soon as the surface-water rose to a certain level it overflowed into a chamber, raised a float, and started one or both machines to work, as the case might be. It was curious that although these engines had been erected seven or eight years, they had not more than half-a-dozen times in that period been actually brought to work, showing how rare the occasions were when there were heavy rains coincident with high tide. It was, however, a matter of chance, and might have been the reverse. In the three other cases, the average lift at the three stations was 33 feet, and taking labour, fuel, oil, repairs, renewals, and everything into consideration, it cost $\frac{3}{8}d.$ per 1,000 gallons to pump the sewage by this method of transmission of power—by no means an extravagant sum having regard to the cost of pumping sewage in many districts, even around London, where steam-power was used direct and the actual efficiency was a little more than 50 per cent. As to what had been said with regard to Esher, he could only add that Mr. Davey had for many months the opportunity of making his machines as perfect as possible, and that ultimately his firm had left the machines in an imperfect state, when he (Mr. Baldwin Latham) was called upon to advise what means could be adopted to effect a remedy. That remedy had been accomplished in the

Mr. Latham. way that Mr. Lengerke had described. At Margate, one of the original machines had been erected under Mr. Davey's auspices, and was found to behave itself in exactly the same way as those at Esher; it had therefore been superseded by the arrangement of valves which had been described by Mr. Lengerke.

Mr. Davey. Mr. DAVEY said that the engine referred to by Mr. Latham had not that particular valve; it had valves of another kind.

Mr. Latham. Mr. BALDWIN LATHAM said whatever its kind, it was neither automatic nor noiseless. The result was that he had been called upon to deal with the matter. With reference to the scheme delineated by the Author, he thought that the proper system had been adopted, in dealing with the pumping of sewage by the use of high-pressure water, one advantage of which was, that it could afterwards be used for other purposes. For instance, at Margate, where there was a pressure of 700 lbs. per square inch, it was still economical to lead the waste water from the hydraulic engine to a considerable distance from the machinery, and to discharge into flushing-tanks, making use of the water afterwards for the purpose of flushing the sewers. At Esher it had cost about 6*d.* per 1,000 gallons to pump high-pressure water which was after use in the hydraulic engines delivered at an altitude of nearly 70 feet above the hydraulic lifting-machinery, where it was delivered at the head of all the sewers, and was applied to the purposes of flushing; whereas if that water had to be bought from the water company for flushing purposes, it would have cost 1*s.* 3*d.* per 1,000 gallons. In the case of Friern Barnet, the cost of transmission vanished; the value of the water saved by not having to purchase water for flushing, more than paid the whole cost of the transmission of power. The result would be the same in a work of that magnitude. So great was the pressure—800 lbs. per square inch—that water could be conveyed from the hydraulic engines, stored in the automatic flushing-tanks, and used for the purpose of flushing the various branch sewers. In cases where excessive rainfalls had to be dealt with, it was contrary to his practice to carry out a combined system of sewerage, admitting all the rainfall and the sewage to the same sewers. It was mentioned in the Paper that at times the rainfall was as much as 4 inches per hour, and that 9 inches a day was not uncommon. That resembled the tropical falls of Bombay and other Indian cities, and in those cases he had always held it to be absolutely necessary that the rain water should be kept distinct from the sewers. In the case of Buenos Ayres it seemed of paramount importance that that should be observed. The outfall sewer was carried 12 miles down the river ostensibly for the purpose of preventing the sewage from being brought back to the source of water-supply. The water-supply as shown in Fig. 1, Plate 1, was an intake near point G, which did not appear to be more than 2 miles or 3 miles above the city. The effect, therefore, of combining rainfall and sewage was that whenever there was a very heavy rain a large portion of the mixed sewage and rain would be discharged immediately opposite the city, and therefore there would be a liability, as it appeared, of the dilute sewage, which was as much a danger as any other sewage, being carried back to the intake. If it was necessary to carry the sewage 12 miles below the city, in order to protect the intake for the waterworks, it would appear essential that a complete system of sewerage should have been adopted, so that no sewage should ever have been allowed to enter the river at a point nearer than 12 miles from the city. Mr. Latham.

Mr. E. B. ELLINGTON had been largely responsible for the designs of the hydraulic machinery described by the Author. The sewage-pumps were worked by slide-valves; and the tappet which controlled them worked a small valve as shown in *Figs. 54* of the Esher sewage-pump. The main slide-valves were controlled by hydraulic plungers worked by the small valves. The floats were connected to separate small slide-valves controlled by hydraulic plunger plug-valves, which started and stopped the pumps. Ordinary screw-down stop-valves were also fixed to the service-pipes. The easy working of the pumps to prevent noise or shock had been attained in precisely the same way as had been indicated by Mr. Lengerke; there was a small controlling-valve which was adjusted by hand in the passage leading from the small valve to the main valve. The speed of the main valve could be controlled so that any amount of pause could be given at the end of the stroke. These pumps had been first introduced by himself in connection with hydraulic-power works in London, and were erected at Millbank pumping-station in 1887, where the quiet working of valves controlled in that way could be seen. He believed it was the successful working of these pumps in London which had induced the Author to adopt this particular system. These pumps were in use at the other pumping-stations of the London Hydraulic Power Company, in fact, all the water that came from the river and the docks was pumped by them automatically. The pumping continued day and night, and there was no noise, shock, or trouble in any way. The details to make them suitable for sewage were somewhat varied, but essentially they were the same in principle. The pumps working in London had to deliver Mr. Ellington.

Mr. Ellington. at 70 feet to 80 feet head, and gave an efficiency of about 75 per cent. The efficiency of the pumps at Buenos Ayres was a good deal less than that, owing to the very low head at which they had to work—in some cases only about 10 feet or 12 feet, and the distance from the pumping-station was considerable, sometimes more than 3 miles. At the time the experiments were made there were no houses connected with the sewers in that district. The machinery which had just been erected had to be tried by admitting water into the sewers, so that he had no particulars as to what they would do under actual sewage discharge. The average efficiency of the Buenos Ayres pumps was about 40 per cent. of the indicated power of the engines at the central station. Considering all the special circumstances, 40 per cent. was quite as high an efficiency as could be expected, and would compare favourably with other installations.

Prof. Robinson. Professor HENRY ROBINSON asked whether the Author could give any information with regard to the filtration contemplated at the early stages of this work. The filtration of water of the River Plate had been experimented upon in 1878 by Mr. George Higgin,[1] who had come to the conclusion that the ordinary method of sand filtration would not succeed in clarifying it. In describing the water as delivered, the Author had said, "The results of numerous experiments, however, showed that in order to provide an adequate supply of drinking-water to the city, at a reasonable expense, fine-sand filters were the most satisfactory; and although after passing through such a medium, the water remains slightly turbid, it is not found to be injurious to health." That could scarcely be considered a very high standard for an ideal water, and although he did not wish to suggest it was not an excellent water, Mr. Higgin, in the Paper he referred to, had said that the finely comminuted clay which gave that water its distinct yellow colour was incapable of being removed by ordinary filter paper in the laboratory; and after his experiment he said that a perfect filter was made at last by using engine-cinders, first washed so as to free them from the fire-powder, and then pulverised. Referring to that Paper, in the light of what Mr. Bateman had afterwards decided, he could not help feeling that what he had settled as the right system to adopt must be taken as the best under the circumstances. The result of Mr. Higgin's experiment was conclusive, and the opinion he had expressed in his communication was that a filter made on that basis would not be more expensive than an ordinary

[1] Minutes of Proceedings Inst. C.E., vol. lvii. p. 272.

sand-filter. It would be interesting to know whether the Author had any information upon that point. With reference to drainage, the Author had referred to the flush of the cisterns in houses as being 2 gallons. It would be well to bear in mind that at the present time the matter was under the consideration of the Local Government Board with a view to deciding whether that flush was sufficient. He had been engaged upon the subject during the past year, and the view that he had taken was that a 2-gallon flush was insufficient in England, and it would be more so in Buenos Ayres. If the Local Government Board came to the conclusion that a 2-gallon flush was insufficient, the Author would most likely advise the authorities in Buenos Ayres to take some measures to prevent the 2-gallon flush being employed as the ascertained flush of the future. At a recent inquiry held at Southend, he had advised the Corporation to obtain from the Water Company a larger flush than 2 gallons, and a 2½-gallon flush had been agreed to. With reference to that inquiry, information had been obtained from fifty-three towns as to the flush employed, and he was surprised to find that in thirty-four a larger flush was used than 2 gallons; in twenty-one towns a 3-gallon flush was used, and in four towns a 2½-gallon flush, so that out of fifty-three towns more than half had the larger flush. Prof. Robinson.

Mr. ARTHUR RIGG had designed and made one of the Margate pumps, *Fig. 55.* The sewage-wells were 9 feet in diameter, and contained two pumps, 20 inches in diameter with a stroke of 3 feet, worked by hydraulic engines, like those at Buenos Ayres. He wished to contrast the pumps used at Buenos Ayres and Margate respectively as to the conditions under which they were working, and to show that while the former might be very good for some purposes, it would not do for the purposes which he had considered to be essential for Margate. It was a great mistake to treat sewage as if it was water. It was a great deal heavier than water, and it required more power to work it. The Buenos Ayres pump, shown in Figs. 49, 50 and 51, had wells 13 feet in diameter, and was perfectly flat at the bottom. That appeared to be a bad arrangement, because the sewage would naturally lie all over the bottom, and not run into a little hole where it could be taken out. In the Margate pumps the two suction-pipes were placed in the centre of the well, which was bow-shaped underneath, so that all the sewage was drawn out. There was no double float at Margate, as there was in Mr. Ellington's arrangement, because directly the sewage was sufficient to work the float it started the pump, and the well was emptied. As far as he Mr. Rigg.

Mr. Rigg. could understand from the plans, there must be a large amount of sewage remaining in the well, until it arrived at a point when it reached the upper float. The pump shown in Fig. 51 was not able to suck to a great height. The pump plunger having a 3-foot stroke, the capacity of the clearance space in the pump amounted to about 128 per cent., which was very high indeed. With a 4-foot stroke it was 71 per cent., which was more than sufficient. His own pump, *Fig. 55*, had 53 per cent. clearance. The point was very important, because in these deep wells the object was to keep the pump as far above the sewage as possible. A pump with a large clearance would not suck to great heights; the consequence was that the one pump would suck well whilst the other would not. The same remark might be applied to the waterworks pumps, a section of which was shown in Fig. 23, Plate 2. The waterworks pumps in that particular case had the same evil—they would not suck very high; and they had also, as shown by Fig. 19, a section vessel on one side which was wrongly arranged. The large flap-valves on the sewage-pumps were very noisy, and there was a very elaborate system of buffer-springs upon the rods to prevent any accident happening. He could quite believe, as Mr. Ellington said, that the pump, as a rule, worked quietly, but something might go wrong, and then the buffer would be very useful. The pump at Margate was specially arranged to give ease of access for repairs. The Margate well had a large area for the attendants to stand upon, and the pumps were placed one on each side; the area was covered with a platform so that the men could move about with ease. If there was anything wrong with one of the sewage-pump valves it could be drawn out. They were not large single valves, but four small valves for suction and four for delivery. A necessary feature of a sewage-pump was that the delivery should always be downwards and never upwards, because in the latter case the sewage settled in the pump and everything went wrong. If it was made to flow down the pump it emptied itself every time. As far as he knew there was not more than the average amount of trouble with those valves. There was also in his pump a discharge-valve below which could be opened from above to empty the well. He had seen sewage-pumps in which the lid of the suction-valve had to be raised to let the sewage out. The valves of the hydraulic engine were the same, as to their general principle, as he had used for many years with his hydraulic rotative engine for altering the stroke; and, for that particular arrangement also, they worked extremely well. The Buenos Ayres hydraulic engines, shown in Fig. 51, appeared to be made partly of iron, probably cast-iron. He thought it was the greatest mistake to use anything but gun-metal in hydraulic engines. Iron would rust and give trouble, and the use of gun-metal for the hydraulic engines would not have entailed much additional expense. He thought the engineers who carried out the work must have had great difficulties to contend with; he could not understand the statement, however, of the Author, on p. 39, that exceptionally high tides occurred at frequent intervals. Mr. Rigg.

Mr. W. R. Smith observed that engineers appeared to have implicit faith in the efficiency of a water-seal trap when combined with so-called inlet and outlet ventilating-pipes on the sewers and drains to prevent the escape of sewage gas into houses. It was stated by the Author that the closets were all "flush-out," which of course indicated that the only defence against the escape of sewage-gas into the houses was a water-seal of about 1 inch head. In addition to that there was a water-seal trap immediately outside the house, also ventilated, but these were two separate water-seals and might be considered separately. The water-seal might be considered efficient in normal states of the atmosphere. The water constituting the seal was always in contact with sewage-gas on one side of it however, and consequently became putrid, even in England, in three or four hours and required to be renewed frequently to be innocuous. In a tropical climate the water would become a source of nuisance in a much shorter time. But the conditions in abnormal states of the atmosphere must also be taken into account, for in Buenos Ayres there were occasional pamperos with velocities reaching 100 miles per hour. Under such circumstances the wind could not be regarded as blowing in at the so-called "inlet" ventilator at a high velocity and out at the so-called "outlet" at an equally high velocity. He should rather look upon the atmosphere as a deep ocean in a state of agitation, the greatest agitation taking place next to the earth. Considering that vast volume of air about four, five or six thousand feet deep, and contrasting it with the height of an ordinary dwelling-house, it was difficult to see how that high wind, that violent agitation of the atmosphere, could discriminate between the so-called "outlet" and "inlet" pipes. There was a non-agitated volume in the house at the bottom of the ocean, and a great volume of violently agitated air seeking by every possible aperture to get into the non-agitated portion, and that was the problem to be dealt with. It was impossible, so far as he could see, to count upon one aperture being an inlet ventilator and another an outlet. Considering that all there was to resist the combined action of the two currents Mr. Smith.

Mr. Smith. of air entering by the so-called inlet and outlet vents at that high velocity was a water-seal of, say, $\frac{1}{2}$ oz. pressure on the square inch, and that the pressure increased as the square of the velocity, the 1-inch water-seal was quite unreliable. The wind velocity corresponding to a head of 1 inch of water was 30 miles or 32 miles an hour, while the head equivalent to a wind velocity of 100 miles an hour was about 15 inches or a pressure of 7 ozs. per square inch. Two currents due to the higher velocity combined could not possibly be resisted by a water-seal of only 1 inch head. The water-seal appeared to be the principle upon which the flush-out closet had been universally substituted for the older forms of water-closets. The original water-closet, so far as he was aware, was that invented by Bramah, and, notwithstanding the so-called improvements of over a century, the Bramah closet to most engineers would present itself as the only perfect closet, and it was a matter of astonishment that County Councils allowed any other. The Bramah closet had a flap-valve closing from below the basin. The valve itself was a perfectly efficient gas-trap, and above that there were 8 inches head of water. Below it again there was the same 1-inch water-seal of the ordinary gulley trap. Successive improvements of water-closets had been made in the form of the pan-closet, which became a nuisance because it had such a large area to become coated with sewage refuse, then had followed the Shanks plunger with a similar defect, and now these attempts at simplification had been discarded, and "flush-out" closets were used entirely depending upon 1 inch of water-seal. The most important water-seal of all for the sewage system was the constant immersion of the main sewage outfall. At Aberdeen the main sewage outfall was uncovered at every half-tide. For six hours every tide the outfall was exposed to all gales blowing towards the sewage pipe, the highest gales generating a very great pressure, and causing a terrible escape of sewage-gas into the houses in the neighbourhood. He had known many cases of illness and premature death which could be traced to that cause in Aberdeen. The most important of all water-seals was therefore to have the main sewage outfall immersed at all states of the tide. He could not gather from the Paper whether that was the principle adopted at Buenos Ayres.

Mr. Crimp. Mr. W. Santo Crimp remarked, with regard to the principle upon which the City of Buenos Ayres had been drained, that the Author had stated that a system of sewers had been constructed capable of carrying off $\frac{1}{4}$ inch of rain in twenty-four hours, the amount to be carried off by the intercepting-sewer. That meant that the sewers would practically carry off about $\frac{1}{100}$ inch per hour. In England the average rate of rainfall was about $\frac{6}{100}$ inch per hour. It would seem, therefore, unless the conditions relating to rainfall were in Buenos Ayres very different to those in England, that the intercepting-sewers were by no means too large. He presumed that the channels shown in the regulating-chamber indicated the means by which the excess volume of rain-water escaped into the storm-water conduit and so into the river. It would be interesting to know the relation which the dry weather sewage-flow bore to the storm-water when the overflows were first brought into operation. The question as to the proper method to be adopted in draining a city of that kind had been raised by Mr. Baldwin Latham. It was an extremely important point, and, having for many years been connected with the London main-drainage system, he had come to the conclusion that for a city closely built over, the combined system was the proper one to adopt. In the case of the separate system, the street-washings, which were necessarily foul, due to the lightest of the rainfalls, would be carried into the river. On the other hand, in the combined system, all these foul street washings, due to light falls of rain, were carried to the outfall works, and in the case of Buenos Ayres they would be discharged into the river many miles below the town. He thought, therefore, that upon the question of principle, the system adopted for the drainage of that city had been the right one. Mr. Crimp.

Mr. T. Hennell observed that the water for the supply of Buenos Ayres had to be passed through a complicated system of settling-ponds and then through another system of filter-beds, and after that, according to the Author, there were difficulties owing to alluvial deposits in the service-reservoir and the main pipes. It appeared at the same time that a large quantity of subsoil water was finding its way through the neighbourhood of the intake into the river, which gave rise to considerable difficulties in constructing the tunnels. He would ask why that naturally filtered water had not been utilized to supply the town? One tunnel, from G to H, Fig. 1, Plate 1, was 1 mile long, and so much water was met with that the contractor was overpowered, and a great deal of difficulty had arisen in getting rid of it. There was another tunnel, 3 miles long, from H to C, and there the difficulty from the water had been so great that the tunnel had to be raised, even at the cost of providing, and working for ever afterwards, a separate pumping-station. This tunnel was raised 22 feet to bring it out of that water. It appeared, without explanation, Mr. Hennell.

Mr. Hennell. that the quantity of water must have been so great as to be very useful for the supply of the town, and that if a tunnel had been made, perhaps not 3 or 4 miles only, but possibly 5 or 6 miles long, parallel with the river, going up the valley away from the town, to intercept the subsoil water, a supply might have been obtained sufficient even for the requirements of the whole area. If so, this supply could have been delivered without any intermediate process direct from the tunnel to the service-reservoir.

Mr. Hawksley. Mr. C. HAWKSLEY wished to express his opinion that a 2-gallon flush was amply sufficient for all purposes when properly applied. The reason why it was sometimes said to be insufficient could generally be traced to one or more of three causes: first, to the water not being brought down with sufficient rapidity from the flushing-cistern into the basin of the water-closet; secondly, to the imperfect construction of the basin of the closet itself; and thirdly, to the very imperfect way in which the drains leading from the water-closet to the public sewer were frequently constructed. When these three points were properly attended to, it was found that a 2-gallon flush was sufficient for all reasonable purposes. He therefore ventured to think Mr. Bateman had exercised a wise discretion in not making the flush larger.

Mr. Parsons. Mr. PARSONS, in reply, with reference to the cost of working of the hydraulic system in Buenos Ayres, thought it would be interesting to ascertain the sequence with which the pumps would work when in use, some would probably work in unison and some alone, and sometimes possibly the whole system might work at the same time. It had hitherto not been possible to make these experiments, in consequence of the small number of houses which were as yet connected with the sewers. He was told that the houses were now being rapidly connected, and he hoped to obtain the results of some satisfactory experiments which he would have pleasure in laying before the Institution. With regard to the cleansing of the filters, they worked consecutively for about three weeks, when a thin coating of very fine alluvial deposit accumulated on the surface. A layer of sand, between $\frac{1}{2}$ inch and 1 inch thick, was then scraped off, washed and replaced on the surface of the filter, after which it would work as well as before. The peculiar arrangement of module shown in Fig. 11 was especially invented for the purpose of regulating the depth of water on the filters and worked exceedingly well. By this means a very much greater head was obtained on the surface of the filter when it became dirty and the water was then forced through it. When it was clean, a smaller depth was

Mr. Parsons.

required, as the water passed through quite easily. The reservoir described in the Paper was very much larger than any reservoir which had yet been made, and he doubted whether the knuckle-joint would meet that case satisfactorily. It would meet the case with regard to the expansion of the floor, no doubt, but there was another question to be considered, viz., the danger of a creeping of the material. It was not clear that the expansion and contraction in those various complicated members would always be equal to one another, and there was a danger of the expansion or contraction from one day to the next accumulating, and, if it did accumulate, the displacement would become very considerable, and not necessarily in the direction of the knuckle-joint. If this did occur, possibly these columns, upon each of which there was a weight of about 450 tons, would become strained beyond their limits of elasticity. For that reason he thought it advisable, although the ball-and-socket joint was slightly more expensive than the knuckle-joint, to adopt it. A question had been asked with reference to the hydraulic valve. In adopting the slide-valve he always had in view the opinion of his late master, Dr. Wm. Anderson, namely, that the best and most enduring valve was the slide-valve. With regard to the silent working of the pump, every pump was thoroughly tested before it left the works of the manufacturers, and the slide-valve fitted, with a "V" groove in the edge, so that the hydraulic pressure did not come suddenly on the plunger. They worked noiselessly, and he could not see why Mr. Baldwin Latham had not adopted a similar valve instead of the complicated one shown in *Figs. 54*. The question of the admission of the rainfall to the sewers was a very important one, and the gradients of the city and the narrowness of the streets were such that it was found less expensive to adopt this system than to provide a separate one. That had been arranged many years ago, and the separate system which had since been carried out might possibly throw further light on the subject, but that was a question which he could hardly discuss, seeing that it was adopted long before he became connected with these works. With regard to the sewage becoming mixed with the water-supply, as explained in the Paper, exhaustive experiments had been made, and it was found that at the time of heavy rainfall the stream was always down the river. The amount of water flowing into the River Plate was so great as to quite overcome all tidal action. There was therefore no possible danger of sewage being carried up to the inlet of the water-supply. In the experiments of Mr. G. Higgin it had been found that there were several *media* which could be used for filtering the water, Mr. Parsons. viz., cinders, as Prof. Robinson had mentioned, and also animal charcoal, all of which rendered it perfectly clear. The Chamberland filter, which was of porcelain, would also make the water perfectly clear, but all these methods were expensive, and in the supply of 20,000,000 gallons per day to a town the cost of filtration was a matter of very great importance, and the slight alluvial deposit left in the water was not considered to be injurious to health. It was entirely a question of expense. The water could be cleared absolutely if it was necessary, but up to the present time he had not thought it advisable to recommend the adoption of any of those processes which would entirely clear the water. Attention had been drawn by Mr. Rigg to the height of the suction of the sewage-pump, who also mentioned several points with reference to clearance in the pumps. There was a plunger in the pumps and an absolutely perfect contact of the sewage with the plunger. The question of clearance affecting the efficiency did not enter into the matter. The waterworks pumps also no doubt had a lift on the suction, and it was found that they worked perfectly. As to the high tides occurring at frequent intervals, the wind was the main factor. When it blew from the south there was always a high tide. The diurnal tides in Buenos Ayres were almost invisible; their height depended upon whether the wind was blowing from the south or the north. When it was blowing from the south, tides were high, and when it was blowing from the north, they were proportionately low. The same thing took place in the Baltic, where it was found in St. Petersburg that the tides depended almost entirely upon the wind. With regard to the traps in houses being unsealed, that was a point which had been very carefully considered, and throughout the town the ventilation was so good that wherever a water-closet was connected with the sewers there was a ventilator. The consequence was that the ventilation was such that the seal of the traps was practically never disturbed by the action of the wind. With reference to the ratio of sewage to water at the time of overflow into the intercepting sewer, it was about 3 of sewage to 4 of rain, and when those proportions were reached the overflow began. A question had been raised by Mr. Hennell as to why the town of Buenos Ayres was not supplied with water from the subsoil. The subsoil undoubtedly carried a very large quantity of water, but the water-bearing strata were not very far below the surface. The system adopted for the disposal of the sewage of houses not connected with the sewers was by means of cesspools, as explained in the Paper, and the contents of the cesspools invariably communicated with the subsoil water; if, therefore, the water was taken from the subsoil, there was always a danger of its being contaminated with sewage. With regard to the proper quantity of flush which Mr. Hawksley and Professor Robinson had alluded to, he thought the amount necessary depended entirely upon the construction of the sewers. If badly constructed, the amount of flush necessary to keep them clean was large; if, on the other hand, they were properly constructed with adequate gradients, then a small quantity only was necessary. In Buenos Ayres he believed a 2-gallon flush was amply sufficient to keep the sewer in proper working order. Mr. Parsons.

Correspondence.

Mr. A. FAIRLIE BRUCE had found, with regard to the subterranean flow of water towards the rivers of the Argentine Republic, that in the province of Santa Fé the same conditions prevailed, there being a general rise in the level at which water stood in the wells as they receded from the Paraná. A considerable supply of clear water had been obtained in several cases by sinking wells in the foreshore at the foot of the Barranca. Its greater hardness was, no doubt, due to the fact that the tosca, through which it had passed, contained a considerable quantity of lime nodules, from which lime was made in some places. As the water which leaked into the tunnel from the Buenos Ayres intake was of perfectly good quality there did not appear to have been any reason for excluding it, the leaks would tend to take up in time if they had not already done so. At Rosario,[1] where, in addition to repairing the existing works, he had carried out an extension of the waterworks, for the Rosario Waterworks Company, the general conditions were similar to those in Buenos Ayres, save that deep water occurred close to the foot of the Barranca; and that the quantity of solid matter in suspension in the water of the Paraná was perhaps somewhat less than in that of the River Plate. There were four settling-ponds, lined with concrete and with no cross walls. The water was pumped into them, and allowed to settle for about forty-eight hours, when it was drawn off by decanting pipes to about 2 feet from the bottom. They required to be washed out about once a month in summer, when the river was high and heavily charged with silt, and about every three months in winter. They worked perfectly satisfactorily, the cost of that which he Mr. Bruce.

[1] Minutes of Proceedings Inst. C.E., vol. cviii. p. 334.