Discussion.

The President. The PRESIDENT, in moving a vote of thanks to the Author, remarked that the Author and he had worked together for many years; he knew how carefully the Author did his work, and the same care was exhibited in the Paper. At the end of the Paper the Author mentioned that about £1,000,000 worth of the work described in the Paper was carried out by the London County Council's Works Department some years ago, but, with due modesty, the Author had not stated that he was the head of that Department at the time. It was 20 years since a Paper was read on the subject of London main drainage at the Institution, and as about £5,000,000 of money had been spent during that period, it was well to bring the subject before the Institution again. Many people were not quite sure why certain things had been done or why certain other things had not been done. He was quite sure of one thing, however—that it was well the London County Council had got all the work which was vitally necessary done at a time when money was cheap, as the work had cost only two-thirds of what it would cost if carried out to-day; what it would have cost if put off for some years more it was impossible to estimate. He had great pleasure in according the thanks of The Institution to the Author.

The AUTHOR exhibited a series of lantern-slides illustrating the subject of the Paper.

Mr. Binnie. Mr. W. J. E. BINNIE said his father had desired him to express to the Author his regret that he was unable to be present that evening. Sir Alexander Binnie had read the Paper with great interest, and thanked the Author for his reference to the work which he had done while he was Chief Engineer of the London County Council. Mr. Binnie desired to make one or two remarks on the subject of the Paper, the first being the question of population. In the Report which was presented to the Council in 1899 that matter was entered into very fully by Sir Alexander Binnie. At that date the population had been increasing at the rate of about 400,000 in 10 years, and Sir Alexander Binnie anticipated that the growth would go on, not on the north side of the Thames, where at that time there was a density of population of about 106 persons per acre, but in the Administrative County area on the south side of the Thames, until the density of population reached about 100

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persons per acre, which would bring the population on the south side of the river up to about 4,000,000 persons. From the Census Returns for 1901 and 1911, it would be found that the actual population within the Administrative County area, instead of having increased, had decreased slightly. It was 4,536,000 in 1901 and only 4,521,000 in 1911. The diagram in the Paper (*Fig. 8*) showed that that was accounted for by the decrease in the population on the north side of the river. He did not make those remarks by way of criticism, as the allowance for rainfall could not be considered as very generous, and it provided a larger capacity in the sewers for disposal of storm-water if the anticipated population were never reached at all. Turning to the rate of flow, it would be seen that $\frac{1}{5}$ inch per diem was allowed as the rate of flow from the whole area. As the commencement of the sewer was approached, the area to be dealt with became smaller and the period of concentration became less, but the Author did not state whether the same ratio was kept up throughout, or whether a greater rate of flow was allowed for as the commencement of the sewer was approached. London was fortunate in being able to get storm overflows into the river, but in some of the outside areas the case was quite different. In the Appendix various outlying districts were mentioned as being now included in the London area, and amongst them was Acton, which was included in 1908. Acton originally discharged its storm-water into the branches of the London County Council sewers which ran west through Hammersmith. In the time of the Metropolitan Board of Works there were houses actually draining into the streams, which were then converted into sewers. After considerable litigation it was decided that Acton had a prescriptive right to continue that drainage, but that no more houses could be connected with those sewers, and therefore Acton had to establish sewage-works in its own district in order to deal with the flow of sewage, while the storm-water was allowed to pass separately into the London County Council sewers. As time went on, Acton grew until the sewage-works became entirely surrounded by a dense population. The Bedford Park estate was immediately to the south of the sewage-works, and factories such as new motor-works had sprung up all round the sewage-works to the north, so that there was no possibility of extending the sewage-works. Acton, therefore, had to come to an arrangement with the London County Council in order to get rid of the difficulty in which they were placed. It was obvious that the County Council would be benefited by excluding the storm-water, because the rate of flow entering their

Mr. Binnie. sewers during heavy rain would be extremely high. The Bill, which became law in 1908, made an arrangement whereby Acton had to dispose of the storm-water in the best way possible, while London undertook to take the sewage from the district and dispose of it at Barking. When the question of the flow which the London County Council would allow Acton to discharge into its system was considered, an endeavour was made to get as much as possible, but the County Council would only allow an average of 50 gallons per head per day, though at times of maximum flow Acton was allowed to send in as much as 100 gallons per head per day. The flow at Acton was between 34 and 35 gallons per head per day, and the arrangement practically meant that Acton was allowed to discharge three times the dry-weather flow as a maximum into the London system. In the Act of 1908 Chiswick (through whose district the storm overflow sewer to the river passed) intervened, and Acton was obliged to construct storm-water beds in its own area, in order to pass the storm-water (fixed at 125 gallons per head per day) through them before it was discharged into the river. The storm overflow sewer passed under the channel between Chiswick Eyot and the north bank of the river, discharging into the Thames on the south side of the Eyot. In order to render the arrangement effective, all sewage and storm-water was discharged at the sewage-works without any previous overflow. When it reached the sewage-works it passed into a chamber with a very long weir, about 180 feet in length. At a certain level two orifices were fixed, so that when the sewage- and storm-water reached the level of the crest of the weir each of those orifices discharged 50 gallons per head per day. In that way the flow was regulated automatically, the length of the weir being so great that the variation in head could only be extremely small. There was another weir about 380 feet in length regulating the discharge into the Thames. Until it reached the crest of that weir the water had to pass through the storm-water beds; but when it reached the crest of the weir it overflowed and passed through a storm-water sewer 6 feet in diameter which ran to the river. In the days when that scheme was carried out Acton had a great deal of permeable surface area. One part of the district was a high-level part, with London clay coming to the surface, bounded roughly on the south by the Uxbridge Road; the southern area was very open gravel, and consequently the rain falling on the surface of the streets used to go through the gravel to a very large extent, and there was not much trouble with regard to storm-water sewers. Within the last few years, however, the Council had tarred all the macadam roads, and the

consequence was that the rate of flow in storm times had been increased by about 50 per cent., due to the fact that the surfaces had been rendered impermeable. It was now necessary to construct a large sewer from the north, and the question arose what allowance should be made for the discharge of rainfall under the altered conditions. They had been guided by the experience of the past as to the maximum discharge from the areas in the sewers carried out in 1908; but in the new system it had been decided to use the methods set out in Mr. Lloyd-Davies's Paper,[1] in which there was a curve showing the intensity of rainfall over different periods. As the length of time taken for the storm-water to reach any point on the sewer from the boundary of the district drained increased and the interval of time through which the rainfall took place became longer, the rate of flow for which provision had to be made decreased, namely, for a storm of 15 minutes' duration the rainfall might be at the rate of 1·24 inch per hour for that 15 minutes; but for a rainfall lasting 4 hours, the average rate would be only 0·21 inch per hour. Sir Alexander Binnie was asked by the Manchester Corporation to advise them as to the size of their new storm-water sewers at Manchester, and the late Mr. T. de Courcy Meade, the City Engineer, supplied him with a diagram showing the allowances which he considered should be made for the intensity of rainfall over different periods. On comparing Mr. Meade's conclusions with the diagram in Mr. Lloyd-Davies's Paper, there was found to be so little difference that it was thought Mr. Meade must have adopted the diagram from the Institution "Proceedings." Mr. Binnie wrote, shortly before Mr. Meade's death, to ask whether that was so, and the reply was that, at the time he drew up the diagram, Mr. Meade had not seen Mr. Lloyd-Davies's Paper and that the Manchester diagram had been prepared from local gaugings. Seeing that the observations at Manchester and at Birmingham had led to exactly the same conclusions, it was thought it would be safe to adopt the same diagram at Acton, and it was assumed that in the future, when the district was fully developed, the roads would all be made impermeable. Mr. Lloyd-Davies, in the Paper already referred to, did not appear to take into consideration the actual capacity of the sewers in determining the period of concentration at any given point—a factor which was allowed for at Manchester and Acton. In the Paper[2] by Messrs. Worth and Santo Crimp, an example

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[1] Minutes of Proceedings Inst. C.E., vol. clxiv, *Pap.* 4, p. 48.
[2] *Ibid.*, vol. cxxix.

Mr. Binnie. was given of a flow from a fully built-over area on the north side of the Thames, which had a population of 114 persons per acre. The sewer there had a free discharge and its carrying-capacity was known: it was observed to run just full on five occasions between 1889 and 1897, which meant that the maximum quantity of rain running off the area was equal to 0·4 inch of rain per hour from that district. This was considerably lower than the calculated maximum rate of flow worked out on the basis of the Birmingham observations, and therefore it would appear that his firm were on the safe side in assuming that the Birmingham and Manchester observations were applicable to Acton. He would like to ask the Author whether any further information had been obtained in the London area which would be of assistance to those who had to design sewers for districts within a certain radius. There were also one or two minor points in connection with the design of the sewers on which he wished to speak. He noticed that in the 11-foot 6-inch sewer there was a brick lining which occupied about one-third of the circumference; while, in the smaller sewers, the lining occupied about one-half. In dealing with a concrete sewer he had come to the conclusion that if it were lined on the bottom for about one-fourth of the circumference it would be really safeguarded against erosion, and that erosion above the level to which the brick lining rose was likely to be very slight. Another point was the difficulty of pumping sewage. There was no pump so convenient for dealing with storm-water as the large centrifugal pump; such pumps would pass anything through. At Acton it had been necessary to put down two large pumps for pumping $13\frac{1}{2}$ million gallons a day each, and one small pump for 2 million gallons a day. The large pumps never gave trouble, but in the small pump trouble was caused by rags, hair, and fibrous matter getting in. A very good arrangement had been suggested which was devised in Cairo in connection with the drainage there. It was a kind of circular box which revolved on a spindle and was worked by the pump. The sewage flowing towards the pump had to pass through the box by means of holes and was screened; it then passed up to the pump and the pump delivered it back to the box and so cleaned away the screenings. The box revolved so that alternately the sewage was sucked through and driven out.

Mr. Willis. Mr. EDWARD WILLIS observed that the Paper was interesting to a large numbers of engineers concerned with districts on the fringe of the London area. He had had experience as the assistant engineer at Willesden, just north of Acton, and lately as Chief Engineer to Chiswick, just south of Acton. In the latter case all

the storm-water from the Acton area still came through his small district through storm-water sewers, but at Willesden, where the whole of the designs for sewers had been carried out by his former chief, Mr. O. Claude Robson, M. Inst. C.E., the district was in the peculiar position of having a large portion of its area drained into the Metropolitan system under the old Board-of-Works scheme. There was, however, a large area, north of a line passing across Willesden, which drained entirely into the river Brent. The whole scheme of drainage there had been designed and carried out from its inception by Mr. Robson, who had consistently represented to the Council, in view of the properties growing up all round the sewage-farm, the desirability of draining the whole of the area into the London County Council system, or into a Brent Valley outfall. It was only about 7 years ago that his scheme was carried into effect, and Mr. Willis had the privilege of being engaged on the drawings before he was appointed to Chiswick. One of the sewers referred to by the Author had been largely necessitated by the introduction of Willesden sewage into the area. It had often been mooted before the war that the London County Council would extend its tentacles, and the point many engineers would have to consider was how far they could adapt their existing works for dealing with the storm-waters, because, whatever happened, there was very little doubt that the recommendation of 50 gallons maximum flow would never be exceeded by the engineers of the London County Council. The difficulty some engineers had had, and that his own Council had had when he advised them to drain into the system, was this maximum quantity of sewage, and that the County Council made it a *sine qua non* that a portion of the expenditure of the past must be allocated to the district coming in. At Chiswick, after going into the matter very carefully, it had been just that extra expenditure already charged on the system which had prevented Chiswick from being linked up in the same way as the urban district of Acton. That was a point that the outer districts would have to consider. Whilst it was equitable from the point of view of the present population and rateable value of the County, yet it enhanced the cost to the outer districts which might come in. Mr. Willis.

Mr. Francis Wood thought the Author must have found serious difficulty in making up his mind not as to what he should put into the Paper but as to what he should leave out; and what had been left out was perhaps of much greater importance, from an instructive and scientific point of view, than what had been put in, although that of course was very valuable. The drainage of Mr. Wood.

Mr. Wood. London was an important problem, having regard to the area and population, but there were a number of factors which rendered it perhaps more difficult than the case of any city in the provinces. In the first place, there were extraordinary rainfalls. He noticed that the sewers were capable of taking ½ inch of rainfall, but that did not give any idea of the rainfall actually dealt with by the main outfall sewers. If 40 per cent. of the rainfall entered the sewer during a fall it would provide for 1¼ inch of rain. It would have been interesting if the Author could have given some idea as to what area was covered by intense local falls, in relation to the total area, and whether there was any relation between the intensity of a fall and the area covered by it. It was quite possible that the sewers, although only capable of dealing with ½ inch of rainfall generally, actually dealt with a much larger quantity when heavy rainfalls were confined to small areas. In Fulham, in 1894, there was a population of 100,000, and in 1904, 150,000, or an increase of 50 per cent. in 10 years. He presumed that the design of the original sewers did not make provision for such a rate of increase of population, and consequently the sewers were naturally not capable of dealing with the flow satisfactorily. He took it that that increase of population was not peculiar to one district. Since national registration had been in force more than 10,000 people had come to live in Fulham and rather less than 10,000 had left it; and it was quite conceivable that in some cases people might enter a district without others leaving, so that there would be a sudden increase of population in one area with a possible decrease of the population in another. Another point he wished to raise was the inadequacy of the original design of the sewer. That was exemplified by the fact that the rainfall provided for on the north side of the Thames was ¼ inch, on the south side it was $\frac{1}{10}$ inch, whereas the sewers in the new scheme provided for ½ inch. In that connection the influence of the infiltration of subsoil-water had to be taken into account. If the quantity mentioned in the Paper (3 to 6 gallons per head of population) were distributed over the whole area of London, it would have no material bearing on the size of the sewers. He thought, however, that was not the case. The subsoil water going into the sewers was confined to the areas where the sewers were below subsoil water-level. There was a sewer passing through the district of Fulham which was at all times of the day half full of water, and that flow represented about twice the ordinary dry-weather flow of Fulham. It seemed to him that the quantity of water passing through the sewers, and which represented the infiltration of subsoil water from that district, was

about 40 or 50 gallons per head per day, and if such was the case elsewhere it would materially affect the capacity of the sewer to deal with the ordinary drainage. It would have been of great interest if the Author had given some idea as to how the sewers affected the subsidiary drainage-areas such as Fulham and other districts. A portion of the intercepting sewers constructed some years ago passed through the Fulham district, but it did not have the slightest effect on the sewers in that area, probably because the area cut off was not equal to the area that had been increased below the intercepted area. Similarly the Lots Road Pumping-Station was not effective because the sewers delivering to the pumps were not capable of supplying to the capacity of the pumps. It was mentioned in the Paper that the London County Council were proposing to disconnect cellars and basement areas from the main drainage system in order to get over the difficulty of flooding, but that proposal did not seem satisfactory in view of the fact that the sewers in flooded districts were not capable of dealing with the normal flow, the infiltration of subsoil-water, and the rainfall. The proposed step might hide the fact that cellars or basements were flooded, but the fact would remain that the sewers were being surcharged, and that affected very materially the drains discharging into those sewers. Times of storm, when the drainage was going into main sewers constructed on the basis of self-cleansing velocities, and dependent on the rainfall to give those self-cleansing velocities, were just the times when the drains had no velocity at all, and in consequence all the drains in the areas deposited material which has to be cleared away at very considerable expense by the Local Authorities at a later period. It seemed to him desirable that London, with its wealth and standing in the world, should have the best drainage system that could be devised. Mr. Wood.

Mr. William Fairley remarked that the original sewers put down by Sir Joseph Bazalgette were designed to take twice the dry-weather flow with $\frac{1}{4}$ inch rainfall, while in the new system the capacity was $1\frac{1}{2}$ times the dry-weather flow and $\frac{1}{3}$ inch of rainfall. When those were compared and worked out for a drainage-area with 80 to 100 persons per acre, the capacities of the two systems were practically the same. The advantage was on the suburban sewers only, where a much smaller rainfall was allowed for at the beginning, and $\frac{1}{3}$ inch of rainfall was a very large increase on the allowance originally made. He had recently to make inquiry into the maximum flow in sewers, and he was not quite sure that twice the dry-weather flow with $\frac{1}{4}$ inch of rainfall was applicable to the whole of the main sewers of London. Sir Joseph Bazalgette Mr. Fairley.

Mr. Fairley. in his Paper[1] differentiated between drainage and intercepting sewers, particularly when he was dealing with the trunk sewer which travelled along the north part of London. Speaking of the High-Level Sewer, which was 7 miles long and drained 10 square miles, he said: "It has been constructed of such dimensions as to be capable of carrying off the largest and most sudden falls of rain." That did not seem compatible with the allowance of $\frac{1}{4}$ inch rainfall. On the south side of the river, where $\frac{1}{4}$ inch of rainfall for certain sewers seemed to be out of the question, on account of the small number of overflows, Sir Joseph Bazalgette said of the High-Level Sewer and its Southern Branch: "Both lines are constructed of sufficient capacity to carry off all the flood-waters, so that they may be entirely intercepted from the low and thickly-inhabited district which is tide-locked and subjected to floods." In reading over Sir Joseph's Paper it was clear that he made a difference between main drainage sewers and what he called intercepting sewers. No doubt the Low-Level Sewer along the Thames Embankment to Abbey Mills was designed for $\frac{1}{4}$ inch rainfall; but whether all the other main sewers were designed for that Mr. Fairley doubted, and as the Author had access to information which ordinary people could not obtain, he might clear up that point. Comparing the $1\frac{1}{2}$ times the dry-weather flow with Sir Joseph Bazalgette's twice the dry-weather flow, he thought the new figure was rather on the low side. There was no doubt that the sewer-gaugings taken from 1850 to 1860 clearly proved that the flow during the 8 hours of maximum flow often accounted for 7 per cent. of the total flow. From *Fig. 10* (p. 38) it was evident that, although the diagram was an accurate record of the flow at Barking, it was yet influenced by the pumping-station at Abbey Mills and also by the long length of outfall sewers, and did not show the actual rate of flow. He had compared a great many diagrams from all parts of the country, and that was the conclusion he had come to. The top of the curve was clearly flattened down and the minimum flow was raised, which was generally the case when there was a pumping-station or a long length of outfall sewer. With regard to the question whether a larger capacity for rainfall might not have been given; when Sir Joseph Bazalgette's scheme was submitted, the engineering referees advised that a rainfall of $\frac{2}{5}$ inch should be carried off in the sewers during the 8 hours of maximum flow: $\frac{2}{5}$ inch in 8 hours was equivalent to $\frac{1}{20}$ inch in an hour, or $1\frac{1}{5}$ inch per day. He was afraid that London

[1] Minutes of Proceedings Inst. C.E., vol. xxiv, p. 280.

could hardly be compared with other cities in connection with sewerage schemes, because in Sir Joseph Bazalgette's time there were 1,300 miles of sewers in London and probably at the present moment there were over 2,000 miles, the storage-capacity of which must be enormous, and so conveniently placed as to act as balancing reservoirs. The Author, in dealing with the pumping-plant, came to conclusions with many of which he heartily concurred, especially where he spoke of the adaptability and convenience of centrifugal pumps for storm-water. There was no question that where a station had only to pump 100 or 200 hours in a year moderate efficiency and low capital expenditure were all that was required, but the Author incidentally mentioned that, while he thought gas-engines were the best for pumping storm-water, he had not the same opinion with regard to electrically-driven pumps. The electrically-driven pump for storm-water, especially where current could be obtained cheaply, was an ideal machine where it could be used conveniently; but when it came to pumps which had to bear the whole burden of the day, so to speak, pumping throughout the year, the Author condemned reciprocating pumps and suggested that centrifugal pumps, from which he expected an efficiency of 68 per cent., should be used in their place. He took that to mean overall efficiency, and not pump efficiency only, and he doubted whether the Author would be able to get such an efficiency continuously. His own experience was that 68 per cent. could not be obtained in continuous daily work, because centrifugal pumps were just as liable to wear as any other type of pump. For everyday work he believed the reciprocating pump with outside packed plungers was the best from every point of view. If, however, the sewage was not very carefully screened there would be trouble with any type of pump used, even centrifugal. The screens used by the London County Council did not appear to be of altogether a good type. He had had similar screens in other places taken out owing to trouble. He had had no trouble with mechanically-cleaned screens properly fixed. A good deal of the Author's trouble appeared to have arisen from the screening of the sewage. He was sorry to read what the Author said about the large Worthington pumps at Abbey Mills. The London County Council put in those pumps at the same time as Mr. Fairley was putting in a similar Worthington pump for the Richmond Main Sewerage Board. The pump at Mortlake was rather smaller, delivering about 20,000,000 gallons. The pumps at Abbey Mills were to be taken out and replaced by centrifugal pumps, but the Worthington pump put down at Mortlake 20 years ago had given absolute satisfaction, and had not cost £20 in repairs. The plungers had never been

Mr. Fairley.

Mr. Fairley. touched, and a few days ago he was told by the manager that he actually charged the pump by the pump itself, because the other apparatus was out of work. That could not be done without very tight plungers. In his own case the pumps were vertical, not horizontal, and possibly that had a good deal to do with the difference in results, although he knew of many very large horizontal pumps of the same type which had been running for many years in Holland and elsewhere without any trouble. He preferred a vertical pump to a horizontal pump for dealing with sewage. He noticed in Tables IV and V that, although the sewage dealt with at Barking and Crossness had increased between 1905 and 1914 by nearly 15 per cent., the annual quantity of sludge taken away during that period remained practically the same, so that it would appear that a fixed quantity only was taken away by the ships. Although the sewage had increased, a smaller quantity per million gallons had been taken out in 1913–14 than in 1905. He recently noted that the first real start for a proper scheme for the drainage of London was the result of a competition which was put out by the then Authority, and the person who was first in that competition was Mr. J. R. McClean, who was the President of The Institution at the time when Sir Joseph Bazalgette's Paper was read.

Mr. Cooper. Mr. C. H. COOPER thought Mr. Fairley had furnished the answer to his own remarks as to the pumps at Abbey Mills. Anyone who wished to court trouble had only to put in a horizontal reciprocating pump for lifting sewage. The grit carried by the sewage was bound to settle and lead to excessive cost in repairs. Centrifugal pumps might not maintain their high efficiency, but they were very convenient and required little repair. He wished to emphasize a point with regard to pumping storm-water. He thought he was right in saying that in such a place as the Isle of Dogs pumps might not be required for the best part of a year, and in such a case it was necessary to have motive power that could be called on at very short notice to deal with storm-water. With an ample supply of electricity from a large Company the difficulty was met, but the *sine qua non* was to have reserve power to cope with the quantity of water, which in some cases was eight or nine times the maximum dry-weather flow. With regard to the sludge-ships, the Author said: "Certainly by no other means could a less costly method of handling a ton of liquid sludge, with such complete immunity from prejudicial results, be attained." What was sludge? What value did the Chinaman place on the contents of his cesspool? He did not have to pay a man to empty it; the man that emptied it paid him. The war had brought out one

salient fact in connection with the economy of the nation, namely, that for years many of its resources had been wasted. At present sludge was required by agriculturists to augment their supply of manure, so that they might produce the food so much needed. The supply of manure from horses had practically failed. At Wimbledon for many years it had not cost a penny to get rid of sludge, as contractors removed it free or paid for it to retail to farmers. He did not know what authority the Author had for saying that the sludge went out to sea with immunity. It was well known that the deposition of sewage at sea had injured fishing-grounds, whilst the sewage that reached shell-fish led to deaths from typhoid. There was not the slightest doubt that wherever human excrement was brought into contact with the food-supply, as it was by sludge at sea, the nation reaped a just reward in the illness caused thereby. It was the first principle of sanitation to keep excrement away from the food-supply. On the question of sludge, Dr. Rideal had written a very interesting Paper recently in which he mentioned that all the explosives needed for the war could be obtained by two classes of individuals—the managers of gas-works and the managers of sewage-works. He could not argue with Dr. Rideal on that point, because he knew nothing about it, but he did know what was happening with regard to the destructive distillation of sludge at Wimbledon, where oils, ammoniacal liquor and carbon were obtained, whilst the gas produced supplied more heat than was required to work the plant. There was no doubt that sending sludge to sea deprived agriculturists of manure; whilst the authorities that had adopted this method had failed to initiate research into the utilization of products which might be obtained from sludge. With regard to the main sewers, he well remembered the old scheme of Sir Joseph Bazalgette for taking sewage from Kingston to Crossness on the south side. At the present time there were no less than six sewage-works between the metropolitan area and Kingston, which was far too many; but it should be remembered that there were two salient facts governing the drainage of a town now, which did not exist in Sir Joseph Bazalgette's time. One was that sewage could be treated on a very small area, practically in the settling-tanks, so that large areas for sewage-farms were not needed; and the other was that, instead of streets being, so to speak, sewers for carrying off the excrement of animals, the introduction of the motor had practically removed, and before many years would entirely remove, all excrement from streets, so that storm-water might be carried directly to the rivers and streams. He spoke rather feelingly on that point, because the storm-water from the foul-water sewers of

Mr. Cooper.

Mr. Cooper. a portion of Streatham drained to the Graveney, a tributary of the Wandle. Formerly that brook ran perfectly clear, but within recent years that portion of Streatham had been built over and the population had increased since the war began; the consequence was that storm overflows had had to be provided so that the water that fell in storms merely flushed the foul-water sewers into the brook, which was neither more nor less than a rank sewer whenever heavy rain occurred. If the London County Council had made the owners of estates in Streatham put in a duplicate set of sewers this nuisance would have been obviated.

Mr. Ward. Mr. HENRY WARD considered the Paper an ideal one to be read at the Institution, as it was a description of work actually completed. He doubted if a work of such magnitude as the main drainage system of London had ever been carried out with fewer mistakes. He had been a member of the Main-Drainage Committee of the London County Council for 25 years, and during that time a very large number of complaints had been received, the great bulk of them quite trivial, but some serious; yet when he looked back and thought of the genius of Sir Joseph Bazalgette, who designed the system originally, a system which, if redesigned to-day could hardly be improved upon, he felt that it spoke volumes for Sir Joseph Bazalgette and for the Metropolitan Board of Works, under whom he carried out the scheme. Also, speaking as an old contractor's engineer, he could say there was no work he had seen in any part of the world of superior quality. Whenever the sewers built by the Metropolitan Board of Works under Sir Joseph Bazalgette were cut into, they were certain to be found thoroughly sound and good. He did not think there was such a thing as infiltration in the sewers built by Sir Joseph Bazalgette. In those sewers, built of the soundest bricks that could be bought and with workmanship that could not be surpassed, the joints of the brick-work were laid with such nicety that infiltration was impossible. He had been down many of the main sewers, but had never seen a case of anything which could be called infiltration. Such infiltration as there might be was probably due to the very old local sewers which existed in some cases as long as 70 or even 100 years ago. With regard to the engines, those which Sir Joseph Bazalgette designed were working to-day almost as well as they worked 60 years ago. It was true that the Council had kept them in repair and had placed an extra cylinder or two cylinders in them to make them double- or triple-expansion, but that had been a comparatively easy task and the engines remained as they were at first—the best means possible of lifting sewage. There were two

main points open to discussion. One of the problems—and it would always remain a difficult problem—was how to purify sewage. On the whole, London was so conveniently situated in having such a magnificent tidal river into which to discharge its effluent that it could afford to discharge the effluent in a much less pure condition than other towns less conveniently placed. The County Council had been equally fortunate in its engineers. At first it had Sir Alexander Binnie, who, with Sir Benjamin Baker, made that excellent Report on which all the later works had been founded. After Sir Alexander Binnie had come Sir Maurice Fitzmaurice, and he had been followed by the Author. One of the difficult problems in connection with the effluent was how to deal with storm-water, and that had been Sir Maurice Fitzmaurice's special work. He had carried out a large part of the work started by Sir Alexander Binnie, and had helped very materially indeed in dealing with storm-water. It was strange to hear the number of complaints received about storm-water. They had all the character of those referred to by Mr. Wood, who had suggested that many of the sewers were too small to carry off the storm-water. That was hardly so. The difficulty was at the other end of the sewer—how to empty the sewer when the level of the river was higher than the outlets; and it was because of the difficulty in discharging the sewer that nearly all the outcry was raised about flooding. Unfortunately Fulham and Battersea, and one or two other districts, had a great deal of land lying below high-water mark; buildings had been put on those low-lying lands, and, worse still, basements in many cases had been built below the buildings, and it could be imagined what a task it was to drain such houses and basements. He thought it would be impossible to obtain a really satisfactory system in London without filling in the basements of all the very low-lying houses; and in future he thought legislation should prevent the construction of buildings on land below high-water mark. He agreed that land in the London area was so valuable that it was hardly practicable to say it should not be built upon at all, but much might be done in bringing up the level of that low land to high-water mark, or something near it, before building operations were begun. Another matter about which there was much to be said was the question of bacteria-beds. The Council had been urged for many years past to purify the sewage by making a large installation of bacteria-beds. If London were an inland town there was no doubt whatever that that system would have been adopted long ago, but with such a splendid river into which to discharge he saw no immediate necessity for bacteria-beds being

Mr. Ward.

Mr. Ward. laid down. Hereafter, if the population increased greatly, and the quantity of sewage increased accordingly, the Council might be compelled to adopt something of that sort; but for the moment it would not be right to put the ratepayers to the very large expense which would be involved by having bacteria-beds for any considerable portion of the sewage. Then came the question of the storm-water. At the time of high water some of the houses built on land 7 feet below high-water mark could only be drained by pumping. The quantity of water that descended on London at storm times was so great that it was almost impossible to deal with it by any reasonable engine-power, and all that it was possible to do was to help it over the worst period. A time would come when that would be forced home still more on those local authorities who possessed a great deal of low-lying land within their areas, and they would join with the London County Council in trying to obtain some measure from Parliament by which all building on low-lying land would be stopped. He recognized that it might be possible to raise the level of the land somewhat; but he felt sure The Institution would agree that it would not be right to be called upon to drain a basement house originally built on land 6 or 7 feet below high-water mark. On the south side the outfall sewer was very large, 11 feet 6 inches in diameter, which perhaps had been large enough in Sir Joseph Bazalgette's time; but unfortunately all the water from the high land south of the Thames had to go through that sewer, and that involved further pumping. In the new system a great improvement had been made by keeping one sewer on top of the other, so that the water from the high-level district could go to the Thames through the upper one without pumping, while the lower one simply served as a duplicate of the original one. That was a very great help. Unfortunately, for many years it had been impossible to get inside the original sewer, as it was always about half full; but, now it had been duplicated, the sewers could be used alternately and cleaned out as necessary. He would also draw attention to the excellence of the design. The marsh level there was about 6 feet below high-water mark; it would be essential in any case to build the upper sewer at the height shown, and it was also essential to carry the other down to the depth shown, to obtain a foundation. The Council had duplicated the sewer by forming a hole in the block of concrete, and so had obtained an extra sewer made at what was comparatively little additional cost.

Mr. Alford. Mr. J. S. ALFORD remarked that about 4 or 5 years ago a drawing of a centrifugal pump which the London County Council were

Mr. Alford.

going to employ for their sewage-works was published in the technical papers: he would like to know whether that pump was one of those described in the Paper, and, if so, whether it had given any trouble by clogging, as his experience of centrifugal pumps was that the same pump would clog in one town and would not clog in another. The only explanation he could give for that was that there was a difference in the nature of the sewage; he did not think it was accounted for by difference of screening-plant, because the material which clogged the pumps would come through any reasonably fine screen. Some years ago those who put down centrifugal pumps for pumping sewage were accustomed to employ the open impeller, and in those days there was rapid deterioration but very little clogging. Now it was more usual to put down the closed type of impeller, and there was more clogging but less deterioration. The Author had very properly remarked that pumps suitable for waterworks were not suitable for sewage-works, and that remark was especially applicable to centrifugal pumps. There was very little on record as to the deterioration of centrifugal pumps. When an engineer went to buy a standard type of centrifugal pump for pumping sewage he found the original capacity and efficiency the subjects of much discussion, and a great deal of ink was spilt about the precise values, but nobody seemed to worry as to what happened afterwards. Many engineers had centrifugal pumps pumping sewage, and he was sure they could say a great deal about the wear of centrifugal pumps if they liked to do so. He knew of a centrifugal pump which after working about half its time for 3 or 4 years had lost 40 per cent. of its original capacity. A great deal depended on the sump from which the pump drew. If the pump-sump was fed by an overflow from another pumping-station or from a sewer, there was not so much wear. In an ordinary pumping-station if the pump drew from the middle water or top water there would be some clogging possibly, but less wear; if it drew from the bottom water there would be more wear and more clogging. Therefore any results that were given should be accompanied by a statement as to where the suction was placed in the sump. An engineer having under his charge sewage-pumping plant did not trouble so much about the original efficiency of the pump; what he wanted was pumping-capacity at the time the rain came. A type of pump which deteriorated rapidly did not serve the purpose. There was an advantage in centrifugal pumps which was not mentioned by the Author—a very important advantage especially in lands which were below the level of high-water—namely, that as the sewage rose in the sump the pump's

Mr. Alford. capacity increased; in other words, as the emergency became greater the output became greater. That seemed such a valuable characteristic of centrifugal pumps that it almost outweighed any other advantage that could be mentioned. He had found pumps clog both with open and with closed impellers, but more with the closed, and he would suggest to pump-makers that it might be worth while to consider a return to the open impeller, combined with renewable cheeks on the casing, whereby the pump could be restored to its original capacity and efficiency at a minimum cost, and to face the deterioration for the time that the engineer agreed to allow it to go on. But unfortunately, seeing that guide-passages could not be used with sewage-pumps, the open impeller brought with it the difficulty that the excess power which had to be provided to meet the demand on the pump when it was pumping at a lower head than the normal was greater, and consequently when the pump was pumping under normal conditions it must be working at a lower point on the load-curve, and therefore at a lower efficiency. There was one point favourable to the employment of centrifugal pumps generally; they were machines of low capital cost. The present was a period of dear money, and for some time to come Local Authorities and others who employed pumping-plant would not be able to raise loans at the same rate as previously: pressure would therefore be put upon engineers to reduce capital expenditure at the cost of higher working-expenses. Local Authorities had not hitherto financed their business by short-term loans, and therefore the opportunity of centrifugal-pump makers was rather more in evidence now than perhaps it had been for some time past.

Mr. Watson. Mr. JOHN D. WATSON wished to associate himself with those who had spoken so highly of the London main drainage. It was a marvellous work. It had struck him in reading the Paper that everything which had been done during the past 50 years had contributed in one way or another to the good results which were shown to-day; nothing of a material kind had had to be undone, a conclusive evidence of the value of comprehensive planning. In undertaking a work of such magnitude it was essential to see, pretty well, the end from the beginning, and it appeared to him that everything that had been done by Sir Joseph Bazalgette, including the various extensions and improvements upon the original scheme, by Sir Alexander Binnie, by the President and by the Author, had all contributed to the proper and efficient disposal of the filthy liquid which debouched into the Thames from the great city of London. One of the most wonderful things about the whole matter was that the huge volume of sewage which flowed down to Barking

and Crossness was got rid of without marked nuisance in the river. Mr. Watson.
He had thought over that more than once, but he had not realized until he read the Paper that the volume of effluent daily was 280 million gallons, while the fresh water coming down the river at Teddington in time of drought was no more than 400 million gallons, and in time of flood it appeared to be no more than 2,000 million gallons. The Author mentioned that at spring-tides sewage was diluted with 15,000 million gallons, and at neap-tides with 13,000 million gallons of sea-water. Sometimes one was inclined to think that insufficient attention and credence was given to statements that had been reiterated from various parts of the world, particularly from the other side of the Atlantic, that sewage treatment by dilution was the right system where possible. Some 20 years ago he had experience of the River Dee, from above Balmoral down to the sea, and he was responsible for certain sewage-works which sent imperfectly treated sewage into the river. Naturally the water-supply had to be considered. Professor Percy F. Frankland, now of Birmingham University, was asked to look into the question, and to the astonishment of all it was found that the water at Invercannie, the intake of the Aberdeen water-supply, was purer than the water between Balmoral and Ballater, about 20 miles above Invercannie. Everyone was well acquainted with the fact that purification did go on in a swift-flowing river, but the Thames could hardly be regarded as swift-flowing. The volume of sewage which was discharged into the Thames and various other great rivers, as compared with the available river-water, was both instructive and interesting. At Glasgow, at the works highest up the river (Dalmarnock), the dilution was 1 in 50, and there they had recently had to introduce bacteria-beds to supplement the chemical-precipitation works. At Chicago there was a dilution of 1 in 60; at Dresden 1 in 300; at Vienna 1 in 460; at Cologne 1 in 1,230; and at Llanrwst, on the Conway, 1 in 2,000. He mentioned the last place, as recently the High Courts had granted an injunction against Llanrwst for allowing their sewage, notwithstanding the fact that it was diluted to the extent of 1 in 2,000, to flow into the Conway without purification. But mere ratios meant very little. The Royal Commission on Sewage-Disposal, after going into the question, had produced some very useful figures, and he thought they had come to a very sound judgment when they said that when dilution was between 1 in 100 and 1 in 300 a sewage effluent, after being dealt with by chemical precipitation, might be discharged into a river, provided the suspended solids did not exceed 6 parts in 100,000; that when the dilution was between 1 in 300 and 1 in 500 it might

Mr. Watson. be discharged without any chemical precipitation, and in that case they were quite prepared to allow the suspended solids to rise to 15 parts in 100,000; and that when the dilution was 1 in 500 the sewage might be discharged without treatment of any kind, provided the screens and the pits were efficient. Just before the war he was called in with Dr. Soper, of New York, and Mr. Arthur J. Martin, M. Inst. C.E., as a Board of Experts to advise as to the efficiency of dilution *per se* in disposing of the Chicago sewage. In comparing Chicago with Glasgow, or with London, it should be remembered that in Chicago the water-supply was equal to at least 200 gallons per head per day, so that the strength of the sewage was entirely dissimilar. The Board found that for 30 miles down the artificial channel which had been constructed for the purpose of leading the water plus sewage away from Lake Michigan to the Mississippi there was a great collection of sludge, which was putrefying and giving off foul gas, and was reducing the oxygen in the water as it passed towards the Mississippi. They were all more or less surprised to find that examination of the river for 100 miles showed a continuing evidence of sewage pollution; they found dead fish, with fungoid growths on the banks of the river, and on the surface of the water indication of pollution. Altogether it was astonishing to find that, although there was such enormous dilution as there was after the Illinois had been joined by the Kankakee, the James and other rivers, and although the water was excellent fresh water, there was still evidence of visible pollution for 100 miles down the river. The Author said the filth of London was carried right away without apparently injuring any part of the stream below. Some years ago, when Mr. Watson was called in to advise Southend-on-Sea, he thought it was very hard that a great city like London should get off scot-free without doing anything more than pass the sewage through screens and tanks, and that Southend should be called upon to put down a plant which corresponded with the kind of plant that would be put down for an inland town. With regard to the Author's remarks in connection with the detritus-pit, a detritus-pit was an essential feature in a sewage scheme, and he would like to know what volume of sewage actually passed through it and how much grit was arrested. One pit appeared to be quite inadequate. Recently an excellent example of a detritus-pit had been built at Leeds by Mr. George A. Hart, M. Inst. C.E., who had succeeded in constructing it on something like scientific principles. Ordinarily, with one or two pits only, the constant variation in velocity was bound to affect very materially the nature of the work done. If sewage were passed through a pit at a velocity of something like 12 inches per

second all the grit would probably be deposited, and there might not be much organic matter deposited; but, when the velocity was reduced to 3 inches per second, rags and organic matter of all kinds, mingled with grit, coal-dust and inorganic deposits, were obtained. Where this was dredged up, taken away and buried at once, it formed about the cheapest part of sewage-disposal work. Where it was necessary to distinguish between inorganic and organic matter a higher velocity was required and more pits were essential. If six times the dry-weather flow had to be dealt with, there should be at least six pits to do the work properly. He had adopted that principle on recent occasions, and he thought it was likely to give greater satisfaction than had been experienced in some well-known cases. He wished the Author to give analyses of the sewages at Crossness and at Barking, and say how he had obtained the density of the sludge, especially why he should imply that it contained uniformly 92 per cent. water: it was most difficult to measure density accurately. It was possible to reduce the water percentage enormously; that had been done by Dr. Imhoff, of Essen, and before him by Dr. Travis, of London, and it had been done at Birmingham, where the sludge was reduced, after having been stored in sludge-deposit tanks, to an average of 80 per cent. water. The difference in conveying to sea sludge of which 80 per cent. was water, as compared with sludge containing 90 or 95 per cent. of water, was very great. He did not say that it was a wise thing to do in London, because it was impossible to have many tanks without exposing a certain amount of the most objectionable feature of sewage, but it was a subject well worth careful consideration. Mr. Watson.

Mr. CUTHBERT BROWN observed, with reference to the inclusion of outside districts, that he would like to say a word about the Lea Valley. About 7 years ago the Districts of Leyton, Walthamstow, Edmonton, Southgate and Enfield, decided to connect their sewage systems with the London County Council system at Abbey Mills, at an estimated cost of £220,000, which meant to Edmonton a rate of 5*d.* in the £ against the present rate of 2½*d.* However, before signing the agreement it was decided by the Local Authorities concerned to ask the London County Council to corroborate the estimate, and it was found that the cost would be much exceeded, and would be nearer £350,000 than £220,000. That meant that the rate upon Edmonton would work out at 9*d.* in the £ instead of 5*d.*, which was more than the district could bear. The rates at the present time were 10*s.* in the £, and the addition would have meant a rate of 10*s.* 6½*d.* in the £. Edmonton was the poorest district in England, taking into consideration the population as against the Mr. Brown.

Mr. Brown. rateable value, which was considerably under £3 per head. It was proposed at that time that the sewer should be large enough to provide for the five districts, and in going into the matter since he had come to the conclusion it would be much better if the scheme could be drawn up to include not only Leyton, Walthamstow, Edmonton, Southgate and Enfield, but also Friern Barnet, East Barnet, Finchley, and a part of Hornsey, which would mean a larger sewer but would distribute the cost over a larger area with a greater population, and would help the whole of the districts concerned. If the scheme were carried out for the five districts and the other districts were left out, he understood it would not be possible to get the sewage of Friern Barnet and Finchley to the west, and therefore when London had extended, those districts would be isolated and would neither be able to drain to the east nor to the west into the London system. With regard to the bench-marks on the old southern outfall mentioned in the Paper as having subsided, he had been much interested in that statement, as he happened to have been connected at one time with a seaside colliery town the whole of which sank 4 feet within 6 years. Coal had been worked out beneath it and no pillars had been left. Walking down the village street it was not possible to tell whether any subsidence had taken place or not, but one morning the quay-wall turned over at spring-tide and there was at once 4 feet of water in the roads and in the houses. With regard to the easements of sewers, when an engineer in the provinces laid out a main sewer or a sewage system one of the chief difficulties he had to contend against was the easement of the sewers. If a sewer was laid through purely agricultural land it generally ended in an arbitration case. Some eminent architect was called in to lay out as many houses and streets on the land as possible, and usually that was made the basis of the cost, and easement had to be paid accordingly. Some years ago he was connected with a large reservoir in the north of England where the land was bought from the lord of the manor, who owned the fell land, and the work was about to be proceeded with when they were told they must pay also a very stiff price for the coal beneath the surface, which could not be worked. The London County Council appeared to be very much favoured, as they were able to run a sewer straight across London, from north to south or east to west, under the whole of the houses and public buildings, without having to pay any compensation at all; and if that was so, London was highly favoured compared with country towns.

The AUTHOR, in reply, remarked that he had been fortunate in succeeding to a heritage which had left very little to be improved upon. Many things had been said in the discussion which would prove in the future very helpful to those who were concerned with the construction and working of the London main drainage system. Mr. Binnie had voiced an aspect of criticism of the system which had been developed by other speakers, namely, that the provision for ½ inch of rain for the outfall sewers was not very liberal. But he would remind the members that when ½ inch of rain was spoken of it only meant the capacity of that part of the intercepting sewers, namely, the combined capacity of the outfall parts of all those sewers for delivering the rainfall at the two outfalls, and that was an entirely different thing from what the system could deal with at the time of low water, when all the old main valley sewers were open and a very heavy storm could be discharged into the Thames. Mr. Binnie had stated that Acton desired to send as much storm-water into London as possible. The distance from Acton right through London to Barking, was about 18 miles in a direct line. Obviously, if the whole of the drainage of London had been designed on that system of storm-water sewers or interceptors to carry storm-water it would be colossal and impracticable. He was not going to say that everything had been done that ought to have been done, because a great deal could be done still. One speaker had alluded to the balancing action of the present system of sewers, and that was a very important factor, the proper effect of which had not yet been fully gauged. It was only the advent of the war shortly after the completion of the system that had delayed a scheme for gauging more definitely the rate of flow over certain areas. It was an important question complicated by many factors. He had been interested to hear Mr. Binnie's estimate that the advent of the tar-macadam road had increased the flow by 40 per cent., but he had not sufficient data to speak definitely himself as to the degree of importance to be attached to that change. Further information as to the areas covered by intense local falls was required. London was so large that a fall local only in its intensity covered in many instances a larger area than that of many a provincial town. Mr. Wood in his remarks appeared to have assumed that the capacity of the sewers was the same as that stated to be the capacity of the outfall sewers. The expression "outfall sewers" must be construed as representing the outfalls as defined in the Paper on p. 6, that was to say, the eastern-most portion of the intercepting sewers. The capacity of the inter- The Author.

The Author. cepting and the main sewers generally in a district were capable of dealing with a much larger downpour than ½ inch of rain. In a large area like London, the growth of which had not been uniform over the area but spasmodic as to districts, it was only natural that the provision in different areas varied, and some were better provided than others. With regard to variations of population within an area, speaking generally, the covering-in of a district with roads and roof-areas was in London a larger factor in determining the amount of sewer-capacity to be provided than that arising from variations in the population occupying that area, due to the excessive discharge of storm-water that might flow off the covered-in area. These considerations obviously accentuated the necessity for control of the level of drains and house-connections to buildings so situated on low-lying land that their complete drainage at times of high water could only be effected by artificial power. The district of Fulham was an example, although by no means the worst in London, of such a low-lying area. Mr. Wood's remarks as to infiltration had been in part answered by Mr. Ward, but the Author was glad that attention had been called to the necessity of making the sewers watertight. The sewers had had the general effect of lowering the subsoil-water drainage-level in London to a level approximately corresponding with the underside of their construction, but in some cases this drainage-level was higher. It was always a difficult matter to construct tight sewers in waterlogged ground, and some people had been disposed to grumble at the precautions taken and the orders issued to ensure this result. Perhaps at some time in the past the necessity had not been so well realized as it was at present. Mr. Fairley's remarks as to the capacity of the trunk sewer in the north part of London were in part replied to above, where it was stated that ½ inch was given as the capacity of the "outfalls" only; the capacity of the trunk sewer in question, not including the sewage-flow, was about 1·8 inch of rain per day reaching sewers on the whole area drained, so that in considering the discharging-capacity of the system and drawing any conclusions from the diagram recording the flow at Barking (*Fig. 9*, p. 36) it must be remembered that the latter was influenced by the magnitude of the area from which the flow was drawn, such flow being 3 or 4 hours later than the flow in any average town's sewers, and that the capacity of the outfall sewers given at the foot of p. 37 referred only to the easternmost ends of the system of intercepting sewers and not to the general capacity of the intercepting and main sewers over any specified area. With regard to the motive power for storm-water plant, the Author

thought that if Mr. Fairley would consider the exceptional load-factor for the work in question, which was of the order of 0·01, he would agree that however economical and convenient electrical power might be for such a duty, the question really was, where could a supply of energy best be found at a moment's notice to turn on to the work desired? The energy available and readily stored in the large gasholder was undoubtedly, in the Author's opinion, that which should be utilized. The Author did not wish to be taken as having condemned the use of reciprocating pumps and advocating entirely the use of centrifugal pumps. On the contrary, he would dissent from such a proposition, and partly from this point of view had included the results of the excellent performance of the reciprocating plant over a term of years. The choice of type in any particular instance must depend on full consideration of every phase of the proposed installation, but the fact had been that in the last decade the centrifugal had proved to be the most suitable type for the needs of the London County Council during that time. Mr. Fairley had called attention to the quantity of sludge taken away remaining practically constant over a term of years, although the flow of sewage had augmented. Mr. Watson had also asked how the density of the sludge had been obtained, and why it was stated that 92 per cent. of it was water. The density of the sludge was, of course, a very important point in considering the quantity of impurities that were taken away. The 92 per cent. mentioned in the Paper must be taken as a general average only; the figure had varied between 86 and 98 per cent.; but every 1,000 tons of cargo was sampled and examined by the chemical staff at the outfalls. There was a tendency for the amount of water to increase, and ready methods of reducing this would be welcomed; but the controlling factor in its disposal in present circumstances was the number of ships available, and had not the war intervened, in all probability another vessel would now be running. The Author must adhere strongly to his views as to the soundness of existing methods for sludge-disposal, in spite of Mr. C. H. Cooper's remarks to the contrary. The paragraph quoted by Mr. Cooper must be read with its context. There were about 50,000 tons of sludge to be dealt with weekly. Hitherto, in spite of many endeavours, no one had succeeded in putting forward any proposition that would deal with even a fraction of this huge quantity of London sludge which, week in and week out, was carried away and effectually disposed of. In 25 years' experience no evidence had been produced that any harm to the food-supply or to the community resulted from its emission in the open water to which it was carried, and in the Author's opinion

The Author.

The Author. it would be as correct to say that the huge organic processes going on in the assimilation and disposal of the sludge when mixed with the large expanse of sea-water in which it was placed were beneficial, as to say the discharge was injurious to the food-supply which was derived from the adjacent waters. The drawing published in the technical papers to which Mr. Alford had referred was that of the centrifugal pumps at the Abbey Mills pumping-station alluded on p. 30. As to open versus shrouded impellers, there were many of both types at the Council's stations. Experience showed that with the open type wear was considerable, and loss of efficiency was also considerable. With a shrouded type, even when the pumps were running on side-rings in bad conditions, the loss of efficiency was small. All pumps were cleaned from time to time, and varying quantities of rags were removed. The quantity in the case of the larger pumps used at the storm-water stations was rarely of any consequence. Mr. Watson's remarks as to dilution were interesting, but it must not be forgotten that the examples given by him were examples of tideless rivers. The experience cited of pollution in the artificial channel from Lake Michigan to the Mississippi corroborated the views expressed by many, and set out in the Report of the Royal Commission, that it was the suspended solids in a stream, and not the impurities in solution, which were the main polluting agency. Of their action there was now abundant evidence, as also of the good results attendant upon their elimination. There was much scope for investigation in the future as to what degree of dilution in a tidal river like the Thames should be assured in order that the disposal of an effluent might be effected without resort to the expense of further treatment. The analysis of the sewage of London for the year 1916 was given in the following Table:—

AVERAGE OF DAILY EXAMINATIONS.

Parts per 100,000.

	Suspended Solids.	Solids in Solution.	Chlorine.	Ammoniacal Nitrogen.	Oxygen absorbed in 4 Hours at 80° F.	
					Crude.	Clear.
Barking . .	41·6	83·4	13·5	3·28	10·48	4·23
Crossness . .	44·6	97·7	18·9	2·89	10·26	4·22

With regard to Mr. Watson's remarks as to detritus-pits, the Author concurred that their extended use was desirable. London

was poorly furnished in this respect, but any figures giving the results obtained from the use of the pit mentioned in the Paper would be misleading, owing to its being only in partial use and only applicable to one sewer in which the flow was not readily ascertainable. The question raised by Mr. Cuthbert Brown as to the drainage of the extensive area north of London was an exceedingly complex one and beyond the scope of the Paper. Many proposals had been made, dating back as far as 50 years, for dealing with the problem, and whether the drainage would ultimately be received into the London system, or be taken by a separate outfall to the Thames, or continue to be treated separately by the various authorities as at present, was a matter for further investigation. The Author welcomed Mr. Brown's reference to the legislation under which the London sewers had been constructed. Generally speaking, it had been possible to carry out the works on the lines dictated by engineering considerations, to the public benefit and without damage to the interests of any class of the community. Supplementing the information given in the Paper, the Author would observe as a matter of history that when the pumping-station at Pimlico was built, it was the intention to pump part of the low-level sewage on to land near the Pimlico station and treat it there, and the lifts were arranged accordingly. It was a matter for congratulation that this proposal did not mature. Somewhat akin to it was a decision of the Metropolitan Board of Works to purchase a large area of land in the neighbourhood of the Abbey Mills pumping-station, for the purpose of building a large deep reservoir to receive storm-water from the low-level sewer, to be pumped by degrees with the station's plant after the period of greatest flow was over. Land was actually bought, but this proposal also never matured. The Author.

Correspondence.

Mr. KENNETH ALLEN, of New York, had visited the Barking works some 4 years ago, and had been shown the cast-iron gates which admitted the sewage to the thirteen precipitation channels. These gates were of unusual size, but, in spite of their 25 years of service, it was stated that they had remained almost perfectly tight, and had never required repairs of any kind. That seemed typical of the thoroughness with which the Main Drainage Mr. Allen.