Mr. BAZALGETTE said, that he had no further information to add to his Paper on the Main Drainage of London. With respect to the Drainage of Paris, it appeared from the Paper on that subject, that there were about 217 miles of sewers of all kinds in Paris, or about one-sixth of the length of sewers in London. A large number of the streets in Paris had a sewer on each side of the street, so that it might be fairly assumed, that the length of streets drained by sewers in Paris was only one-tenth of the whole length drained in London. Then again, the sewers of Paris carried off the liquid refuse only, and not the solid: thus the system was very complicated. There was a large number of cesspools requiring to be cleansed by manual labour; and those acquainted with Paris must be aware, that many of the streets were drained on the surface, in a most offensive and objectionable manner. The cost of constructing sewers in that city, ought to have been much cheaper than in London, because a smaller city could always be drained at a cheaper rate than a larger city. The sewage of the smaller one had not to be carried so far: it did not accumulate in such large masses, and the sewers could therefore be constructed *pro rata* of smaller dimensions, and at a smaller cost. The greater width of many of the streets, and the smaller amount of traffic, was another reason why the sewage of Paris should have been proportionately more economical than that of London; but that was not so, as the cost of constructing the sewers for a given length of street had been much in excess of the average cost of constructing the sewers of London. It had been stated, that the cost of maintenance was £30,000 per annum; whether that sum included the cost of cleansing the cesspools did not appear; but at the same rate, the cost of maintaining the London sewers would be £180,000 per annum. He was not, however, surprised at this great difference, when he learnt that the smallest size of sewer now used in Paris was 5 feet 6 inches by 3 feet. He had never been favourable to the system of extremely small sewers, at one time advocated and adopted, but, he considered, that the Parisians had gone to the opposite extreme. The perfection of Engineering was to have the capacity of a work exactly adapted to the duty it had to perform. By constructing sewers of such great size, with so small a fall, they were prevented carrying off the deposit which they were intended to remove. Those considerations would account for what, at first sight, must appear an anomaly. In Paris, the minimum fall of the sewers was 1 in 1000, or about 5 feet to a mile, and yet the sewers collected deposit. In fact, it would appear that instead of constructing the sewers so as to carry off the deposit, great ingenuity had been expended in inventing appliances to cleanse them by artificial means. Surely the necessity for those appliances

indicated that there must be some radical defect in the construction of the sewers; or how was it to be accounted for, that sewers with a fall of 5 feet to a mile, collected deposit, and had to be cleansed at great cost, while the Northern Outfall Sewer of London, which had only a fall of 2 feet to the mile, required no artificial cleansing? That sewer had now been in operation more than a year and a half, and the invert was quite clear of deposit. In designing sewers, the object to be attained was, to get such a velocity of flow through them as would be sufficient to keep them clean. The section of the sewer carried through the Boulevard de Sebastopol showed, that at least two-thirds of its area was utilized only to accommodate two water-pipes. It was an enormous cost to pay for such an arrangement, which when effected appeared to him most inconvenient. The pipes were placed on costly brackets almost at the top of the sewer, at a point where there was difficulty in getting at the joints to repair leakage, or form connections. For these and other reasons, which would occur to Drainage Engineers, he thought the works of drainage in Paris did not afford an example either of economy, or efficiency.

Mr. G. R. BURNELL said, at first sight it might appear that the sewerage of Paris was designed as much for the relieving of the houses as for the relieving of the streets; but in that city, on the contrary, not any of the house-sewage was admitted into the drains. The fact was, that the French people regarded the sewers as performing a different function to that which the English Engineers considered necessary. The Paris sewers were constructed to carry off the road sweepings, and the storm and surface waters, and therefore were of greater sectional area than the London sewers. As regarded the drainage of London, he believed, that almost all the matter which was deposited in the River Thames came from the sea, and not from the land, and therefore, when the drainage-works were executed, it would be found, that all the matters which were deposited from the sewers would find their way back again to London, as much as they did at present. It was to be regretted, that the Author of that Paper had not stated the difference between the estimated amount of the contract, and the actual cost of the works. The estimated amount of the contract was about £2,130,000, whereas, the actual cost of the works executed had been about £4,100,000, and yet the works of the low-level sewers were still incomplete. Those facts required a little explanation. As regarded the execution of the works, he would notice, that the specimen of Portland cement, which had been exhibited, had considerably swollen since it first set. If the cement which had been used for the works was in a similar condition, it would not argue well for their duration. The test which had been imposed upon the cement was not of the same character

as the exigencies of the works required. It was a test only of pure cement, and not a test of cement mixed with sand. In such a case it would have been better to have employed the test used by the French Engineers, namely, that of mixing one part of sand and one of cement, and then applying to it a pressure of 144 lbs. on the square inch. The results given in the Paper ought not to be taken as affording an indication of the extent to which the sewers might be affected, after some time had elapsed. In conclusion, he submitted a specimen of M. Coignet's béton, which had been alluded to in the account of the Drainage of Paris.

Mr. ROBERT RAWLINSON said, that reference had been made in the Paper on the Main Drainage of London, to certain formulæ which, it was stated, were applicable to the construction of sewers. In his opinion, however, no formulæ existed, which Engineers could use, for the apportionment of the cross sectional dimensions of sewers. To talk of a formulæ for main sewers, devised and drawn up from any one set of experiments, would only tend to mislead young Engineers. There were no two places which required precisely the same treatment. In the case of the Metropolitan Drainage, the whole water supply had been taken on the two sides of the Thames, and the intercepting sewers were made on the south side for four times the present volume, and on the north side for three times that volume, while flood-water outlets were made to deliver surface water out of the sewers down into the natural channel of the river. That was a method which might be studied with advantage, and in some form be applied in other districts. The proper mode of proceeding was:—before attempting to fix the dimensions of main sewers, to take the area to be operated upon as it existed; to consider what nature had previously done with that area: then to consider the special duties which the sewers had to perform, and apportion them to the water supply and to the probable increase of the population; and if the dimensions adopted were calculated for passing off three times, or four times that volume, the Engineer would not be far astray in his calculation. The rainfall, as rainfall, had very little to do with the question. There might be a rainfall, as in England, varying from 17 inches per annum, on the eastern coast, to 150 inches per annum, in some of the hill districts of Cumberland; and in town districts, it might range from 20 inches to 50 inches; while in parts of India, the rainfall, during the monsoons, was from 150 inches per annum, to 300 inches per annum. He discarded altogether, in his calculations, the question of these excessive rainfalls, as the discharge of such large volumes of rainwater must continue to be over the surface, or by large overflows from the sewers, to natural streams, or valley lines. Sewers large enough for men to enter, merely to cleanse them, were not necessary, and he believed it to be possible

so to deal with different districts by constructing small or egg-shaped sewers as to make them work without great difficulties. Where sewers had been made of sufficient capacity for men to enter them, and with flat inverts, it had been found in practice that such sewers required to be regularly cleansed, because the excessive dimensions and flat inverts retained all solids, until removed by hand-labour at great cost. As regarded the metropolitan main sewerage, the most difficult task would be, to revise, renovate, and reconstruct the 1,300 miles of old sewers which already existed; many miles of which were in ruins and choked with filth to such an extent that no ordinary application of water could remove it, and which, at great labour and expense, had now to be removed by shovels. When main sewers were well graded, and made of proper cross sectional form, and properly constructed, they were self-cleansing. In a city, or town that was sewered on proper principles, it was absolutely impossible for rats to exist, because they could not find either food, or lodging. The periodical battues upon rats was the strongest evidence of the inefficiency of the Parisian system. It had been stated that the modern system of sewerage in Paris was not intended to take away the house-sewage. The Parisians committed the fatal mistake, about the year 1820, of insisting, by ordinance, on cesspool construction. It was recorded that the whole sub-soil of Paris was on the point of becoming putrid with cesspit matter, and that the ordinance was passed in consequence. By it, all cesspits, as matters of private construction, were abolished, and the construction of cesspools upon a gigantic scale was undertaken, or dictated by the municipality, and all persons thereafter building hotels, or houses were obliged to construct "hermetically-sealed cesspools" after a municipal or royal pattern, which had been devised by the Government Engineers of France. Into those cesspools effete matter from water-closets, grease and washings from the sinks, and other such refuse was to be discharged. He considered Paris, when he visited it twelve years or fourteen years ago, to be, on the surface, perhaps, the cleanest city in the world. Nothing could be more beautiful than the order and cleanliness of its paved streets; but the stench, even in the best houses, was almost insupportable. The possibility of hermetically-sealed cesspools was therefore a fallacy. However much cesspools, or sewers were trapped, the foul gases would escape. No main sewer, or house-drain could be over-ventilated, but a great many were under-ventilated. After the first attempt to sewer the metropolis (from 1820 to 1840), and after the first sewers had been made, which only took the overflowings of putrid cesspits and cesspools (for then it was illegal to drain direct into the sewers), the first effects of this system was a considerable addition to epidemics and especially of

typhus fever. The sewers were unventilated, the foul gases fermented through the houses, and the inmates of the houses breathing those gases were afflicted with typhoid, or typhus fever, in some form or other. Thus it was that the ventilating of the metropolitan sewers was brought about; but even now, although they were pretty liberally ventilated, it was done in a clumsy and obnoxious manner. A shaft, carried from the crown of the sewer direct to the street, and opened by a grating upon the surface above, admitted into the atmosphere whatever gases were generated in the sewer below. The present system of ventilation was the source of two mischiefs: the gases were passed unmodified into the atmosphere, and the grates allowed stones and mud to fall through and form a barrier to the passage of the sewage below. It would be a simple thing to form a side chamber upon these vertical shafts, and to put an intermediate connection between the shaft and side chamber, placing the grating over such side chamber. The road grit would grind down into it, no doubt, but it would not obstruct the sewage. A wire tray, or basket filled with wood, or with bone charcoal, might be placed in the passage to the side chamber. The power of charcoal, in disinfecting or burning sewer gases, was in some degree as efficacious as the heat of a furnace. If that were done in the first place, the blocking of the invert by the grinding in of the mud would not take place, and, to a certain extent, the foul gases passing from below would be disinfected. But the true way to ventilate a system of sewerage for a great city like London, or Paris, was to break the system up into sections, to lay the plans out in such a manner as to be absolutely masters of the position, and ventilate effectually as arranged on plan. For instance, all the low-lying districts of London should be so ventilated, that there could be no possibility of sewage gases ascending to the higher parts of the city. If London were thus dealt with, the whole of the gases from the lower districts would be prevented rising to the higher parts of Hampstead, Highgate, &c. Where the sewers had a steep gradient, they ought not to be allowed to come down an even incline. All steep gradients in sewers, under any circumstances, ought to be broken at intervals by steps, for two reasons: in the first place, it was very destructive to sewers, if the gradient was greater than was required for the proper discharging power of the sewer, the wearing upon the sewer invert being greater than it ought to be subjected to. If the gradient were broken, the rapid flow of sewage would be checked; and the lower end of the sewer could be protected by a hanging flap, not covering the whole area, but leaving at the bottom of the sewer, space sufficient to discharge the ordinary flow of sewage; and above, ample means might be provided for ventilation, by running off the whole of the gases up to that point, and discharging

them there, that they should not be injurious. It was not necessary to discharge the gas at the particular point where it was brought to the surface. It was possible for the Engineer to make gas sewers, or conducts, to lead the gases safely to any point at which he wished to discharge them so as to do a minimum amount of injury, and if he could not sufficiently get rid of them by the use of charcoal as a disinfectant, they might be burnt through a furnace, or discharged through an elevated shaft.

The intercepting sewers in the metropolis had been devised, at present, to carry the whole of the sewage to outfalls at Barking on the north, and at Crossness on the south, and enormous reservoirs had been constructed at those points to receive the sewage and enable it, at certain states of the tide, to be discharged at the ebb of the flood. In his opinion that was a mistake. The flow of sewage was constant, and in the metropolis it was so enormous, that if tanks were used they must be large and costly works, in which the matter would collect, and although, if it was discharged daily, the matter itself would not perhaps putrefy, in bulk, yet the sediment that was left in those tanks, and the filth which become entangled and hung about the walls, would set up putridity, and the tanks would become foul abominations. If the money expended upon those tanks had been expended in continuing the outfalls to any given point below, equivalent to the same purpose of preventing the sewage coming back again by the incoming tide, it would have been much better spent.

With regard to the Parisian sewers, it had been stated that those sewers were made to take away surface water only, and not sewage; he was sorry to say, that that principle had been adopted by the French government in other cities and places: in Lyons, and Marseilles, for instance, the same system was carried out. Large sewers were constructed with subways, for the passage of carts, and railway trucks which received the refuse emptied out by hand-labour; that refuse, if the sewers had been constructed upon proper principles, would have been carried out by the action of the water flowing regularly through them. To show how perfectly this was done in sewers properly constructed, he would instance Birmingham, where the outlet sewers were egg shaped, or circular. Birmingham was, perhaps, about as difficult a town as any Engineer would wish to deal with, for there was not a mile of paved surface, the whole of the roads and streets being macadamized, and very few of the channels being paved. That part of England, too, was subject to violent summer floods; the tributary gradients of Birmingham were very steep; and grit was washed down into the sewers, until at the outlet tanks, in the lower part of the system, there were no less than 25,000 tons of gritty matter per annum, which had to be removed. This heavy matter had been regularly

washed through the sewers, showing that when sewers, made upon the egg-shape principle, were graduated to anything like their work, they would carry off anything that might pass into them, from the streets and drains.

Admiral BELCHER, in reference to what had fallen from Mr. Rawlinson, suggested that a large portion, if not the whole, of the noxious gases evolved from the sewers, might be burnt, by connecting the sewers with the street lamps and large factory chimneys.

Mr. W. HAYWOOD said, the subject of large sewers and small sewers, which was earnestly discussed before that Institution many years ago, had been again alluded to, but it had really nothing to do with the matter, although many persons thought it had. Rightly, or wrongly, there were, at the period when the intercepting sewers were first designed, a thousand miles of sewers in the metropolis, mostly of large size, and every house was draining into them, the whole of the water-closets in the metropolis were being discharged into the sewers, and the sewers all discharged into the Thames. The problem which had to be solved was, therefore, how to get rid of the nuisance incidental to that state of things, in the quickest and cheapest way, and there were four points to be determined, before a scheme for that object could be framed. The first was the outfall, and that was originally fixed by the late Mr. Frank Forster and himself, and had never been altered (he alluded to that on the northern side), although successive Engineers had considered the matter. The next was the prospective population over the extensive metropolitan area. After much consideration, this was fixed at 30,000 per square mile, and that number had, also, been subsequently adopted. Then came the question of the water supply which was to be given to this prospective population, and it was taken at 5 cubic feet per head per day. It had been frequently stated by professional men, that a larger consumption per head might be expected, but he thought the time would come when the water supply must be economised, and when 5 cubic feet would certainly be the maximum consumption of the metropolis. The point which was most difficult to determine was the amount of rainfall to be carried off. He believed that he fixed upon the exact amount which was decided on by Mr. Forster, viz., a quarter of an inch per twenty-four hours; and that was afterwards adopted by Mr. Bazalgette and himself. The soundness of these conclusions had been subsequently confirmed by men of the highest reputation, and were the basis of works that, no doubt, would perfectly effect that which was anticipated from them.

There was one point which he thought was deserving of discussion, and that was, whether the water-closet system was a right

one. This was one of the most important questions that had to be considered, inasmuch as upon the continuation, or not, of that system, it depended whether the most valuable manurial products of the whole country should be rendered valueless, or almost so, as they at present were, in the metropolis. He most sincerely hoped that this subject, in its relation to small towns yet undrained, would be well and carefully considered, because the necessities of London were not the necessities of smaller towns. In small towns it would be well to consider, whether it was desirable to adopt the water-closet system, and, as the consequence, to discharge its sewage into a river, or to adopt some other less wasteful system. If the town possessed ample garden-ground, ample room for ventilation, and for the construction of closets and other accommodation of that character, so as to cause no nuisance or offence, it might be possible to adopt some other system, and, if possible, it should be adopted.

With regard to the rainfall to be carried off by the intercepting sewers, which had been fixed by Mr. Forster and himself at a quarter of an inch, there was no allowance made for evaporation, or absorption; it assumed a uniform fall of rain in twenty-four hours, the total in that time amounting to a quarter of an inch, with a uniform discharge into the sewers during that period of the same quantity. But as rain seldom, or ever fell with regularity, and it never happened that the quantity which fell was delivered in its entirety into the sewers, a margin was actually allowed for a much larger rainfall. Those sewers which were to take the entire drainage of districts, as well as to act as intercepting sewers, were of course intended to carry off all the rain which might find its way into them, and were regulated, as to size, by a different formula; but, as he had before observed, under any conditions, the quantity of rain which fell was never entirely delivered into the sewers, not even on occasions of the greatest storms. This question had an important bearing upon the size of sewers generally, and though the main and intercepting sewers of the metropolis had been determined on as to size, yet it was important in regard to districts of, or adjacent to, the metropolis not yet built over, or drained; for with the rapid extension of London there would, before many years had passed, be some districts which would require main sewers. Now the observations of Mr. Bidder and Mr. Hawksley, in 1857, upon the Savoy Street sewer, showed that of a rainfall of 2·90 inches in twenty-six hours, only 64½ per cent. of the fall was delivered into the sewers, all the rest being either absorbed, or evaporated. In the Ratcliff Highway sewer they found, on the same occasion (which was an unusual rainfall, it having rained without ceasing, he believed, for twenty-six hours), that 52 per cent. of the total quantity only was discharged into the sewers. It so happened

that, without any co-operation with the gentlemen named, he was at the same time engaged in gauging the flow of the London Bridge sewer, which drained an area of 2,250 acres, partly urban, and partly suburban; it was necessary that this should be known, as the character of the surface much affected the quantity delivered into sewers in times of storm. Now, with the same rainfall, or rather a fall of 2·75 inches instead of 2·90 inches, being the amount recorded by Mr. Glaisher on the occasion alluded to, he found, that in the London Bridge sewer, 53 per cent. of the total quantity only ran off. On one occasion, in April, 1858, he had gaugings taken of the same sewer, when 0·24 of an inch of rain fell, in an hour and a half: he then found that 74 per cent. of the total quantity was run off, leaving 26 per cent. absorbed or evaporated. Of a rainstorm of 0·54 of an inch in five hours, in June, 1858, there was delivered into the Irongate sewer, which drained an area entirely paved and built over, as much as 94½ per cent. of the total rainfall, and that, of all the storm-gaugings he had made, was the greatest per centage of rainfall he ever knew to be discharged by a sewer. In August, 1858, with a rainfall of 0·48 inch in one hour and two-thirds of an hour, he found only 78 per cent. of the total quantity discharged into the Irongate sewer. There were, of course, many circumstances which would affect the quantity of water which would be discharged into sewers from rainfalls: no two cases would be alike. Storm-gaugings had been, he believed, but little taken by any one; in fact, it was a difficult matter to get them taken at any time, as they required men to be in readiness at any moment to make the observations, and competent assistants to see that the men did their duty. He had paid much attention to these points for many years: he had had the requisite staff in readiness, and he believed his observations were as accurate as it was possible to make them. It had been stated, that one-half of the whole daily discharge of the sewers of the metropolis took place in six hours, and that the hours of minimum discharge, at the west end, differed much as to time, from that of the east end of London, that being attributable to the difference in social habits. Now he believed there was no material difference whatever in the periods of greatest discharge of the sewers; and that, taking the outlets of all the main sewers of the metropolis, the maximum discharge took place nearly at the same time; certainly, upon the averages of some hours, it was so. In 1850, no gaugings existed that he was aware of, except those taken by Mr. Hawkins in 1844, which related only to some of the sewers in Westminster, and were not of a character to be then serviceable. Mr. Frank Forster and himself had no gaugings of the sewers to aid them, as they did not, in fact, exist. They found it indeed stated in one

of the Reports of the Board of Health, published about 1847, or 1848, upon the evidence of Mr. Phillips, that half the daily sewage was discharged in six hours, but the Blue Book referred to was remarkable for assertions and statements, and for the absence of that detail by which the correctness of the statements could be checked, and Mr. Frank Forster and himself applied for but could not obtain, either from Mr. Phillips, or Mr. Roe, or from anybody else, information which would aid them in this investigation, and he believed that, at that time, there were no reliable gaugings in existence. They therefore took some general observations, collated the opinions of the various officers and others consulted, and arrived at the conclusion, that in deciding upon the sizes of the sewers, the safest course was to take double the then existing water-supply. That, added to the quarter of an inch rainfall, was the quantity then provided for. In 1853, when he and Mr. Bazalgette were engaged together in perfecting the scheme for sewage interception for the north side of the Thames, the information on this subject was much more extensive than in 1851, but still no complete gaugings existed. He therefore, in that year, commenced an extensive series of gaugings of the discharges of sewers which drained 11 square miles, including some of the most densely-populated districts of the metropolis, as well as suburban districts. These gaugings were carried on, night and day, for months, and he deduced from them the fact, that the average discharge of the sewers in eight hours, was 49 per cent. of the whole daily discharge. Within one year, or two years afterwards, Messrs. Galton, Simpson, and Blackwell gauged all the sewers of the metropolis, and they ascertained, that almost exactly the same proportion was discharged during the eight hours, as he had proved to be the case in those sewers which he had gauged in 1853. The details of his own gaugings were published by him at the time, while those of the gentlemen he had named were embodied and published in their Report,[1] in which they also drew attention to the fact, that he (Mr. Haywood) was the first who had ever taken a complete series of gaugings, and that their gaugings were entirely corroborative of his results; and it might be taken as a positive fact that, as nearly as possible, one-half of the daily sewage of the metropolis was discharged between 9 A.M. and 5 P.M., or in eight hours, and that the social habits of those who lived at the west end of London, therefore, did not affect that point at all. That circumstance, however, did not vitiate the present scheme. Although that provided for half the sewage in six hours, it only gave a little

[1] *Vide* "Report upon the Main-Drainage of the Metropolis, by Messrs. Douglas Galton, James Simpson, and Thomas Blackwell."—Parliamentary Paper, August 3rd, 1857, No. 233, Sess. 2.

more room for any additional rainfall, and that was all; but as the Members of this Institution should have the facts, as nearly as possible, he ventured to lay these before them, and to give the references by which the correctness of his statements might be verified.

With regard to the ventilation of the sewers, the mode at present in use throughout the metropolis, and the country generally, was not designed by Mr. Roe, but by Mr. Richard Kelsey, in the year 1840, and the first gullies which were trapped were those in the City of London. He had no credit to claim in the matter; he merely referred to it to correct an error as to fact. He believed the London sewers were kept in fair condition at the present time. The sewers of Paris were ventilated entirely by the gullies; they had no central openings as in the metropolis, and he mentioned this, because he did not think that point was alluded to in the Paper on the Drainage of Paris. The temperature of the sewers was a point which bore upon that of their ventilation. He had ascertained that the mean temperature for the year, in the sewers of Paris, was 63° Fahr., while that of the sewers of London was about 55°; in the hottest months he never found the mean to exceed 62° Fahr. Notwithstanding that a large quantity of fœcal matter went into the Paris sewers at the present time, indeed far more than was usually thought to be the case, they were undoubtedly much less offensive than the sewers in London. This was a subject which, perhaps, could be more usefully discussed by medical men, or chemists than by Engineers; but he might mention that, having made observations with regard to the sewage of many countries of Europe, he found that the effluvium of the sewers was greatest amongst the northern nations. In England the effluvium was, he thought, worse than in any: he alluded in all cases to the internal atmospheres.

Some remarks had been made about the large size of the Parisian sewers. The Engineers of the Ponts et Chaussées, who had charge of the sewers of Paris, never recognised, in the slightest degree, the pipe system. They proceeded upon the assumption that it would be necessary, at some time or other, to have their sewers inspected, and for men to work in them; and having settled that point, they next determined to make the sewers large enough to enable men to work in them with some degree of comfort; and if the first point were conceded, he was not sure they were not right in the second. In an economical point of view, the difference between men working in sewers where they could not stand upright, and where they had good head-room, was very great indeed. In a sewer 4 feet, or 3 feet 6 inches high, a man could not do as much work in a day as he could in two hours, in a sewer 6 feet high. He was therefore inclined to think that

the Parisian Engineers, if they were right in the first assumption, were undoubtedly right in making the sewers of their actual size. He had often regretted, that the funds at his disposal would not allow him to make some of the sewers in the City of London of larger dimensions, mainly on account of the facilities of inspection, and of working in them.

Allusion had been made to the mode of cleansing the sewers of Paris. It was to be recollected, that throughout Paris, the largest portion of the street-sweepings went into the sewers; the contents of the gutters were always disposed of in that way. The detritus of the roads was not so heavy as that in London, owing to the difference in the material employed for the road surfaces; still it was a heavy material, and a large amount went into the sewers, and it was principally in the removal of that detritus, that the sewer-men were employed. It was to be remarked also that it was done at a great cost. He had ascertained, that about three men were required to every two miles of sewers, these men being entirely engaged in helping to keep that length of sewer clean; and the total cost for wages, superintendence, lighting, clothes, &c., he believed, was about £100 per mile per annum, while in London the whole cost of cleansing the sewers, including the expense of water for flushing, and the labour bestowed upon their interior, and also of keeping the gullies and ventilating-shafts in condition, which in the City, owing to the enormous traffic, was a work of considerable labour, and a heavy item of expense, was about £40 per mile per annum. But though the sewers in the City were kept clean, they were undoubtedly not in such a state in that respect as the sewers of Paris. It was impossible, without making a personal inspection, to conceive the extreme cleanliness of the sewers of Paris, not only of their inverts but of their entire internal surface.

Mr. F. J. BRAMWELL said, there was one point of great importance in connection with this system which had not yet been alluded to,—that was the pumping engines. Without the aid of those engines it would seem that two of the most important and densely-populated areas of the whole district could not have been drained as they had been, with the hope of delivering the sewage water at such a distance from London as that it should not return by the river so as to be a nuisance; and therefore the pumping operations must be regarded as a vital point of the system. He believed it was this which distinguished the sewage of London from that of every other large city in this, or in foreign countries. Twenty years ago, it would have been considered a most serious thing to attempt the application of steam power to the getting rid of so large an amount of water. The duty of these engines was stated to be, at Crossness, 20,000 cubic feet of water per minute,

and at Abbey Mills 16,000 cubic feet per minute, which was equal to a river 40 feet wide, 3 feet deep, and running at a velocity of 3 miles an hour—an enormous stream to raise and keep in motion by artificial means. He was glad that the gentlemen who advised upon these engines had recommended, that the rotative engine should be used instead of the Cornish. He thought, at the present day there was far less difficulty in coming to a proper decision on this point than was the case at the time this question was decided. No doubt, Cornish engines had been put up in London for lower lifts than these, and the results had been most disastrous; he was afraid to say how much duty was got out of them, but he believed it was not more than one-third of that which was guaranteed in these engines. He was surprised at the duty stated of 80,000,000 lbs., amounting to about $2\frac{1}{4}$ lbs. of coal per theoretical H.P. per hour, the theoretical H.P. in this case being, as he understood, calculated on the amount of water delivered, so that for the gross indicated H.P. the consumption of coal was only about 2 lbs. of coal per hour. The undertaking on the part of the contractors to fulfil this duty showed the great confidence they had in the design of the engines. There was, however, one matter which he should be glad to have explained—that was, as to the different relations between the work to be done, and the size of the engines at Deptford and at Crossness. At Deptford the lift was not quite 20 feet, at Crossness it might be as much as 36 feet. The cylinders of the two engines were of equal size, and the length of their stroke was equal. The pump strokes were half the length of those of the cylinder; but in the Deptford engine, where there was a low lift, the area of the pump-plungers was 49 circular feet, or 3 to 1 as compared with the 16 circular feet of the piston; while in the Crossness engine, with a high lift, the areas of the four plungers were 81 feet compared with the 16 feet; that was five times as great with a lift of nearly double. The result of this large area of pump-plunger, combined with high lift, was to put on the Crossness engine a load that required an average pressure of 30 lbs. per square inch all through the stroke of the piston to meet it; but to realise that average pressure all through the stroke of the piston, was imposing on the engines a very high load. The Paper stated that the plungers were made in sets to be disconnected and worked in ratios of 1, 2, and 3, but he did not gather that it followed, that when united to raise the greatest amount of sewage they were wanted to raise, they would be always pumping at the lowest lift, or that they might not have to use the greatest amount of pumping capacity combined with the greatest lift. It appeared from the Paper, and in the absence of the explanation that no doubt could be given, that at Deptford the engines were

not sufficiently loaded, while at Crossness the load might often be a heavy one. He noticed in the Paper the statement that the foundation of the boiler-house was used as a tank for cooling the injection-water. It seemed that there was in this case little additional cost to make those tanks; for some chamber must have been made in taking the foundations deep enough to support the building above, and it was therefore comparatively a matter of indifference on the score of expense, whether afterwards the space was used to store injection-water or not; but if this had not been so, it appeared to him, looking at the extensive use of surface condensers, either totally immersed, or of evaporative condensers (which also worked well), it was not expedient to go to a large outlay for cooling injection-water, when those well-known means were at hand as a substitute, and were also valuable as giving pure feed-water. The valves at Crossness and at Deptford were stated to be leather valves. He thought it would be found, that the leather would not answer, but that india-rubber facing would be better, as it was sufficiently elastic to reject the particles of gravel; and that circumstance might make all the difference between the proper, and the improper working of these engines. It appeared to him that the plunger-pump adopted, arranged so that half the work was done by the suction and half by the lift, was the best that could be devised for equalising the strains upon the engine. He should have been tempted, if he had had the advising upon the designs of the engine, to have adopted an excess of metal in the beams, so as to act directly in equalising the irregular strain due to working steam expansively. The beams, however, were of the ordinary size, and the means of equalizing the effect of expansion were put into the fly-wheels. But if that were done, viz., the putting extra matter into the fly-wheel to equalize expansion, he should have been tempted to have adopted the blast-engine plan of putting the fly-wheel at the cylinder end. These were the only observations that occurred to him with respect to the engines, and he had no doubt the Author would give a satisfactory explanation as to the apparent discrepancy of the load, to which he had referred.

It had been stated that in Paris, as a rule, the sewers were used, not for the carrying away of solid refuse matters from the houses, but only for liquid sewage. It had also been urged, that the legitimate purpose of sewers was to take the matters from the houses, and that they should have nothing to do with surface waters. Again, it had been said, that in inland country towns, such a system might be correct; while in London there were sewers not only taking the refuse of the houses, but also a great part of the storm-waters. All these three plans had their advocates, and no positive decision had been come to, as to which was the best. If the first

of matter. But, besides this, even if there was a uniform flow, in many districts and towns, the ground was too flat to admit of gradients suitable to such a theory; at all events, without pumping to a much larger extent than many small places could afford.

With regard to the great work of the metropolitan drainage which had been brought before the Institution, and which, so far, had been most successfully carried out, he knew something of it from having been a Member of the last Royal Commission, which had to consider the scheme, before it went into the hands of the Metropolitan Board of Works. In common with the other gentlemen who were members of that Commission, he indorsed the proposed plan which had been elaborated by previous Commissioners, and which was, so far as they could then tell, the best system for the drainage of the metropolis that could be devised. Looking to the future, however, he had, on one point, some misgiving in which he hoped he was mistaken, but it was a matter which was worth consideration. It affected nothing that had been done, but merely raised a question, as to whether something more was not required to be added to it. The system embraced many miles of underground drainage. These sewers could not be, as he had endeavoured to point out, so apportioned as to size, and so graduated as to inclination, as at all seasons to fit the flow of sewage and of rain water. It was possible in this metropolis, to have occasionally, summers of unusual drought, and to be for months without rain, and the question was whether on such occasions, unless the sewers were flushed, serious epidemics might not result from this new system of sewers. He was not now broaching a new opinion, for the last act which he performed when a member of the Commission of 1854 was to write to Mr. Jebb, who was then the Chairman of the Commission, to explain the mischief which might result unless ample powers of flushing the sewers were provided. He believed, wet summers would be healthy, but he feared dry summers would be sickly, unless the sewers were capable of being thoroughly flushed. The suggestion he made at that time was, that means should be provided for forcing water into reservoirs at the upper extremities of the large intercepting sewers, to be used in dry summers, for flushing the sewers, about once a week, but the oftener the better.

Having said thus much on this branch of the subject, he had to add a few words with regard to the past history of the scheme. It had occupied the attention of a great number of gentlemen, for a long period of time, and the history of it should be correctly given. He would go as little as possible into the question of individual claims, because that would most likely lead to a tiresome discussion. He thought justice should be done to Mr. Frank Forster, to Mr. M'Clean (President Inst. C.E.), and to others who had

view were correct, then the surface water ought not to be considered at all, and only the sewage from the houses should be dealt with; if the second system were right, sewers for houses must be abandoned. Now, it only required to put these two theories together, and it would result in the entire abolition of sewers. The difficulty in which they were left seemed to be this, and he stated it thus early, in order that those who were competent, might explain the real office which sewers were required to fulfil.

Mr. HAWKSHAW, Past-President, said that, as regarded the size of sewers, and their being sufficiently large for a man to enter them, no doubt it was a disagreeable duty to be obliged to send men into sewers, but at present there was no means of obviating that necessity. It had been stated, that the plan of sewage was so regular and so uniform, that all Engineers had to do, was properly to apportion the size and the gradient of the sewers to the quantity of sewage to be discharged, and that the sewage would then run on in a perpetual stream, and that the sewers would in consequence never require any artificial cleansing. These views appeared to him, in many cases, to be inapplicable; in the case of towns in flat districts, how were gradients everywhere to be obtained precisely fitted to this assumed regular and uniform flow? The assumption that the flow through a sewer was uniform was fallacious; he would say that he knew of nothing, in his experience, that was less uniform. The fact was, that the flow along sewers must be irregular. Dealing only with that portion of sewage which came from the houses, cesspits, and water-closets, even that could not be so regular as seemed to be required to carry out the theory he referred to, but when rainfall was admitted into the sewers, the whole assumption of uniform flow immediately vanished. In England there were sometimes months of dry weather, and months of rainy weather, and it was impossible therefore to devise sewers of such areas and gradients as would, at all times, be exactly proportioned to the amount of fluid which would pass down them. He was a Member of the last Royal Commission of Sewers, and he remembered, that a portion of a district in London had previously been given over to certain gentlemen, who held the views upon which he was commenting, and who were authorised to drain it after their own fashion. Those gentlemen were allowed to carry out their plan of back drainage and front drainage, &c., and he believed they did so with great skill, and as ably as it was possible to carry out the system for which they contended; but the result was, that five years, or six years afterwards, the drains were obstructed and stopped; and, if he recollected rightly, the end of it was, that the whole had to be dug out. The occasion of its failure was obvious—there was no such uniform flow of sewage as the system required. It was impossible to accurately apportion sewers both to a dry, and to a wet state

devoted much time to the subject. But, without going into the question as it regarded other individuals, he would suggest that the Report which was laid before the Metropolitan Commission of Sewers on the 15th of March, 1850, and which was signed by Sir John Burgoyne, Captain Vetch, Mr. Rendel, Captain Harness, and Mr. Robert Stephenson, together with a Report, written by Mr. Frank Forster on the 1st August, 1850, and one by the same gentleman on the 30th January, 1851, should be printed in the Proceedings.[1] Those three reports would sufficiently show what had been done, previous to the drainage of London being intrusted to the Metropolitan Board of Works.

Mr. EDWIN CHADWICK, C. B., said that, in his view, most of the early historical matter might have been omitted from Mr. Bazalgette's Paper, as of no engineering consequence, whilst much of recent history (immediately preceding the appointment of the Consolidated Metropolitan Sewers Commission, of which Mr. Hawkshaw had been a prominent member) ought to have been included, as of importance for engineering science and for the benefit of young Engineers. Mr. Chadwick's examinations had led him to propound as an administrative principle, that the proper chief attributes of local administrative bodies, were works—works of water supply, of house drainage, for the removal of waste and foul water, of subsoil drainage, for the relief of surcharged sites, of garden and uncovered areas, for the formation of roads, for their maintenance and cleansing, and that all these works should be comprised under one local administrative body, and that body a competent and really responsible one. And, further, that the area of the administrative jurisdiction should be defined by the Engineer, and its foundation being drainage works, that to be efficient and economical it should comprise the whole of the natural drainage area, from the line of watershed at the hill top, to the valley bottom, or the outfall at the river. Thus, for example, the drainage area, and administrative jurisdiction proper for the metropolis would comprise the hill tops of Hampstead and Highgate, down to the Thames, and the area up to any river divisions east and west, which might comprehend reasonably connected portions of the covered and uncovered suburban connected areas. As a matter of history, it should have been recorded, that the principle thus stated, had been partially applied in the case of the metropolis, by the consolidation of seven conflicting and capricious jurisdictions into one;—with the exception of the jurisdiction of the corporation of the City of London, of one square mile of covered area, which in despite of engineering as well as of administrative principle, was allowed to remain independent and obstructive in the

[1] These three Reports will be found in the Appendix to this Volume, p. 513.

midst of some twenty square miles of metropolitan covered area. The southern part of the metropolis, as divided by the Thames, might, in strict engineering principle, have been dealt with separately, and have been placed under a separate administrative authority; but he had proposed that the south side should be included in the same jurisdiction, on economic grounds,—to save the unnecessary expense of separate establishments, of separate water supplies, and on other grounds on which uniformity was conducive to economical administration. The historical statement should have stated the fact, on engineering as well as on administrative principles, that by means of this consolidation, a general survey of the whole area had been obtained, which had served as the foundation of the Main Drainage Works in question. As the public paid for Royal Engineers, who had in peace little to do, he thought they might as well be employed in doing such a work, and it would be acknowledged that they had done it well. There was another point to be noted, in connection with this survey, as new in town drainage works on such a scale. His own investigations in sanitary matters, had led him to the conclusion, that all such works, to deserve to be called systematic and complete, must comprehend the means of the constant removal of all refuse, from the house or from the water-closet to the farthest outfall; that the main trunk lines must be adjusted to amended and self-cleansing branch sewers, and that the amended self-cleansing branch sewers must be adjusted to amended self-cleansing house drains,—which, as being self-cleansing without storm or rain water, or the need of flushing, were as a system, a new invention. The general survey of the whole of the drainage area had been accomplished on a scale to include the drainage of every house, or yard, or stable. As connected with the foundation laid for complete town drainage work by a survey, there was another point, which should be mentioned for the completion of the historical matter. Of the several old drainage jurisdictions, it might be supposed that by a sort of subdivision of labour, they had the most complete knowledge and records of the existing works. But their knowledge was most imperfect, and except of large and recently-constructed works, there was really nothing deserving the name of record. To provide for any systematic amended drainage, it was necessary to ascertain what sewers there were, and what was their condition. Besides the great surface survey, therefore, a general subterranean survey of all the existing sewers that could be found was undertaken, and completed, as should be done in all cases of old cities. In some fifteen hundred miles of streets, there was on this subterranean survey found to be some thousand miles of sewers of deposit,—sewers which detained, to be cleansed at an expense of upwards of twenty thousand pounds per annum, what a

good system of sewers, mostly tubular, removed constantly before it could enter into noxious stages of decomposition. Judging from the smells in the streets and the price paid for cleansing, this length of sewers and their contents had been little disturbed by any new outfalls; or were, he apprehended, likely to be. The proceedings taken on another topic should be noticed, as of great sanitary as well as of engineering and economical importance. Finding the vast extent of noxious evaporation from the old brick house drains, as well as from such sewers of deposit, which were really only extended cesspools, he could not but ask—whether this was a normal condition of things and a final result of all engineering art; and he called for the rules on which such constructions were regulated, when he found that the hydraulic formulæ in use even among Engineers of the greatest eminence, who had had the direction of the largest expenditure in such works of town-drainage, in which it appeared they followed the empirical practice of architects, were widely contradictory and erroneous as to the requirements of pipes for the discharge of water. The old formulæ were founded on experiments mostly on a small scale, and applicable only to very different circumstances, and when applied to common drainage works, they presented differences of more than one-third even in the discharge through six-inch pipes; and observations preparatory to actual experiments were made, which showed that the differences between the fact and the common practice, as well as the common formulæ, increased in a still greater ratio with the larger discharges of water. The only way out of the difficulty in obtaining sanitary as well as economical results was to promote new trial works, which was done. In respect to town drainage, the practice of architects, and of some engineers who followed them, was to enlarge the area of any main pipe in the proportion of the sectional area of each junction into it: whereas it was found by the trial works that the addition of eight junctions, each of 3 inches diameter, into a main line of pipe of only 4 inches diameter, so increased the velocity of the stream, that there was no increase of its sectional area required. It was a practice in town drainage, and defended, too, by professional men, to make junctions of streams at right angles, and it was now the common practice to form the junctions of land-drains at right angles and with projecting pieces, so as positively to impede the flow. On a large scale it was found that when equal quantities of water were running direct at a rate of 90 seconds, with a turn at right angles, the discharge was only effected in 140 seconds, whilst with a turn or junction with a gentle curve the discharge was effected in 100 seconds. He would cite one illustration of a trial work in a sewer of the class of the vast extent of sewers of deposit to which he had adverted. In this sewer which had a flat segmental bottom 3 feet

wide, a sectional area of 15 feet, and an average fall of 1 in 118, the deposit from the 1,200 houses regularly accumulated at the rate of 6,000 cubic feet per month. But a pipe of 15 inches diameter placed along the bottom of this sewer, with a somewhat less inclination (1 in 153) kept it perfectly clear of deposit. The average flow, without rainfall, was about fifty-one gallons per house, per diem; the absolute sewerage, apart from rainwater, from all the 1,200 houses would have passed through a 5-inch pipe (of the relative size of the smaller one placed along the bottom of the brick sewer) within the 15-inch tubular pipe, or not one-third the area of the minimum-sized drain which had, up to the time of the investigation and upon the advice of professors of architecture, been declared and enacted in the Metropolitan Building Act to be necessary for a single house; namely, one of not less than 9 inches in diameter.

Since he had promoted the use of pipe sewers, he was told that upwards of twelve thousand miles of them had been manufactured and sold at Lambeth alone. They were often made inexactly, and laid ignorantly, and badly jointed, so as to let out the fluid, and like the old sewers detain the matter which it was the object to discharge; but on the whole they were a success. It would not be disputed that it would yet be important to have the results of the working of the various sizes of the channels, competently and impartially examined for the future guidance of young Engineers in this important branch of engineering science.

One important test of a complete system of town drainage was the condition of the sewage at the outfall. He had been in sewers and examined the chief outfall sewers of the metropolis, and other large cities, when it struck him, as remarkable, that neither in the branches nor in the mains could he discover a bit of paper, nor any fæces in form. He had asked officers and men engaged in them and their observation was similar. How was this, it might naturally be asked? The answer was that the sewage was either the overflow of cess-pits, or that the matter was detained in the old brick drains of deposit, or in the sewers of deposit, until it was disintegrated by decomposition, when the matter was discharged in this disintegrated state, or by occasional storms. When the new system of tubular house drains and pipe sewers in a town was completed, they were surprised to see 'coprolites' discharged in form, and masses of paper which might be read. At Salisbury, where the new pipe sewerage discharged, fresh upon all water meadows beneath the town, the fertility of which was vastly increased thereby, the farmers, in grateful acknowledgment of the value derived therefrom, were wont to call the pieces of paper which bestrewed their fields 'bank notes.' On the old system, the drainage of that city was pronounced to be impracticable, but on

the new system well adjusted main-pipe sewers would be found to be self-cleansing with such falls as 1 in 1,000, and notwithstanding all that had been said, it would on proper examination appear, that the construction of sewers of deposit, or of a size for men to enter and cleanse them, must be classed as things of the past, and the bad. One method of testing the action of a complete system of town drainage works, was to go to the water-closets of the upper part of a town, and discharge from thence substances such as might be recognised, pieces of turnip were very convenient, and time their arrival at the outfall. If these pieces were detained, or were comparatively slow in their arrival, the work was bungled somewhere and incomplete. When the new works of a town were completed, not only for the discharge of the sewage of a town, but for its proper application to agricultural production, it might be immediately taken up by engine-power, and be distributed over distant fields. It was proved that, as a rule, the sewage of the largest city, of the metropolis itself, might be thus deposited on the day of its production; in small towns, within less than half a day. He might mention, as an illustration of the rapidity of its application, that on one occasion he took some French commissioners to see the works at Watford. A drove of bullocks preceded them to the slaughter-house. The visitors paid their respects to the Earl of Essex, and then went to see the outfall of the town sewerage, which was reddened with the blood from the slaughter of those same bullocks; which blood was being taken up by the engine, and might have been distributed over the fields, possibly whilst it was warm. Now, it was to be observed, that the waste refuse of towns, which a complete system of exterior, as well as the new interior works, enabled to be so quickly deposited on the land, was, with proper preparation of the land, and the proper adaptation of the quantities of manure to its absorptive power—deposited not in mechanical or chemical suspension, but in immediate chemical combination with the soil. At the outset of his investigations, Mr. Chadwick had had some correspondence on this topic with Professor Liebig, who decidedly discountenanced any application of the refuse of towns, in a liquefied form, to the land; and alleged that it would in that form be washed out by every shower of rain. He proposed a patent solid manure on that hypothesis. The patent solid manure, like the precipitants and solidified manures, on which money had been spent, had failed. The professor could not but recognize the proofs afforded by empirical trial works, as well as by carefully conducted chemical experiments, of the absorptive power of soils; and that manures distributed in the liquefied form were retained in the soil in fast combination, until they were taken out by vegetation. Hence they might be distributed over fallows, as well as by repeated dressings over land with growing

crops. The experience of Rugby had shown that it might, by proper agricultural management, be in constant distribution every day in the year. This was a point of engineering importance, as it showed that large storage reservoirs of sewage, so objectionable in a sanitary point of view, were unnecessary. The best storage reservoir, the most perfect deodoriser, and the cheapest, was the soil itself. As dependent on the due observation of trial works on the sizes of pipes, to effect the self-cleansing and quick discharge of sewage from houses as well as from streets, it had been proved that the sewage was obtainable by good works in an entirely new condition; that was fresh, instead of putrid. Along the streets, and at the outfalls of well-conducted sewerage works, there were now no foul smells, that was to say, no smell of decomposition, for decomposition would not take place within the short time of the discharge. It had been ascertained that with fresh sewage in ordinary weather, active decomposition began only in about four days; but with proper and complete works external as well as internal, all fæcal matter should be on the land within one day. Now, all decomposition was waste of manure.

In respect to stable manure, it was proved that when it was applied fresh it was one-third more powerful than when it was old, and so it was with all town manures. The effect of the new conditions, brought about by improved works in discharging sewage fresh instead of putrid, was shown in rivers; the old putrid sewage killed fish; the fresh sewage fed them. At Carlisle, which was pipe-drained, it was alleged that the fish had increased in quantity and had been greatly improved in quality. At Ely, which was pipe-drained, the best fish was found at the sewer outfall. At Salisbury, which was also pipe-drained, enormous trout had been caught at the sewer mouth; but although the Engineer might, pending the formation of new works, throw the fresh sewage into the river with impunity, the matter discharged from the London sewers was calculated to be about a year old, and in a state of putrefaction. But fresh sewage was too valuable to be thrown into the river to feed fish, and should be on the fields to feed men. A poetical French writer, Victor Hugo, had said upon this subject: "These heaps of ordure in the corners of the streets—these cart-loads of manure which go jolting along the streets at night—those horrible tubs of liquid—the pestilential flood concealed beneath the pavement—do you know what it all is? It is the meadow in flower—the green herb—the wild thyme and clover—it is the abundance of game—it is the flocks of sheep and herds of cattle—it is the contented lowing of oxen in the evening—it is the scented hay and golden corn—it is the bread upon our table—it is the rich blood in our veins—it is health—it is enjoyment—it is life: so it is ordained by that mysterious creation, which is transforma-

tion on earth and transfiguration in heaven. Give all this to the great crucible, and receive back abundance. The nutrition of plants is the food of man." This poetical description was more properly applied to fresh sewage than to putrid. Of the matter retained in the cesspools of Paris, as well as of London, the poet might be asked if he knew what it was. It was dysentery, diarrhœa, ravaging typhus, measles, miasmatic disease—the consequence of insanitary architecture, mal-administration, and bad engineering. Connected with the new system of town drainage works and the application of the sewage from them to production, there were important points to be observed, as respects interior arrangements not to occasion the unnecessary dilution of the sewage with pure water. Schemes for the separation of the rain water from town sewage has been objected to; but Mr. Chadwick differed from those who would exclude from the sewers roof-water from houses. He was for admitting such water, and also for admitting the water from paved surfaces, such as streets, mews, courts, alleys, and paved squares; for he had found reason to believe that such water —the surface washings of towns—commonly contained more manure (except at the end of heavy storms) than was delivered from within the houses. One load of stable dung was taken up daily from the surface cleansing of every quarter of a mile of such traffic as Regent Street. Then there was the soot on roofs, and the dung of birds and animals, all of which was frequently stronger manure than the sewage of houses delivered in dry weather. But the subsoil water proper—that surplus water which was obtained through permeable tile drains, from surfaces of gardens, open, unpaved squares, common and meadow land—ought not to be mixed up with common sewage, but ought to be sent to the river, or otherwise utilized. He had proposed that the subsoil water of the fields, and all the uncovered suburban areas, up to the hilltops of Hampstead and Highgate, should be utilized, amongst other things, for fountains at the lower levels, or for keeping fresh any ornamental waters which it might be expedient to continue; and so with the surface water of parks and open commons, a great deal of which water was eligible even for domestic use. Near the metropolis, and such cities, the subsoil drainage for public roads, byeways, and footpaths would yield far more water than was commonly supposed. It was a serious error to waste such water in the common sewers. It perplexed the application of the sewage, by the enormous and extremely variable extent of the dilution. And so with respect to the waste of water from the interior of houses in the water-closets as carelessly constructed, acted sometimes with half a gallon and sometimes with two gallons or more of water. By the information he had obtained by gauging the old sewers on the days of water supply, as compared with the run on other days

in dry weather on the intermittent system, it was proved that full three-fifths of all the pipe-water delivered in the metropolis was delivered in waste. These various conditions were often overlooked by chemists, who spoke of sewage as of a positive quantity, some asserting that sewage was absolutely of no value by the extent of dilution, never considering the dilution as waste, and brought about by a bad system. On the principle he had advocated, of cutting off all house sewage or drainage from brooks or natural streams, it was with such limitations, or extensions, that the axiom might be put forward, of "the rainfall to the river, the sewage to the land." In respect to outfalls, which were properly not the first but the last portion of works to be considered in such a system as the metropolitan works, he was of opinion that it was a mistake to send all the sewage of a city in one direction. He proposed to pump some of it back, as from Westminster, in the direction of the western market gardens and other cultivated lands. If it paid to carry up solid manure for such high lands as Hampstead and Highgate, it would pay for pumping up liquid manure for distribution; but the public mind on the subject of the application of sewage was not sufficiently advanced for him to press that principle. He had therefore yielded to the proposal of having intercepting sewers of the right sizes, the plans of which were on much the same lines, as far as he recollected, as those on the plan now before them, only they were much less costly, whether properly so might be determined by impartial observation. But it was a great misconception to suppose, that the sanitary condition of the metropolis was largely or most affected by the discharge even of putrid sewage into the river. It had been proved during the cholera, that the population who lived in houses immediately opening upon the river, and, indeed, living on the river itself, were less affected by miasmatic diseases than those living in the interior of the city. Dr. Macwilliam, the medical inspector of the Board of Customs, had proved, in respect to the Custom House officers living on board ships in the river during an epidemic period, that they had lost only two, and those two from diseases which there was reason to believe they had contracted whilst on shore. It was proved in respect to house drainage works and the removal of cesspools, that the type of health had improved house by house as the works were carried on, whilst he apprehended it would be seen with respect to these main drainage outfalls as now constructed, without due adaptation, as he considered, to interior works, would have very little effect in the reduction of the mass of preventible diseases in the metropolis. On the whole, he would advance, as axioms, that all smells of decomposing matter in towns, and all smells from sewers or house drains, denoted ignorant engineering, waste of money, of manure, and, moreover, of life. The

general effect of complete drainage works in the towns which he had named, where all cesspools had been abolished—though they were not always done in the most complete manner—had been to reduce the rate of sickness and death fully one-third. When corporation surveyors and others talked of "a judicious return to cesspools," they should begin by reintroducing them in their own dressing-rooms, or within their own suburban houses. In his view, in an assembly of Engineers, such a remark was, as a matter of art, like talking of giving up railways, and returning to the judicious use of broad-wheeled wagons, or of wheelbarrows.

Mr. PHIPPS said that, whilst expressing his high appreciation of the excellence of the works described, he thought that where so large a portion of the present plan depended upon the pumping power of the steam-engine, the name of his friend, Mr. Thomas Wicksteed (M. Inst. C.E.), might be appropriately mentioned. He was the first to propose steam pumping, for the permanent drainage of large towns, where the surface was too low to admit of drainage by gravitation. As early as 1841 Mr. Wicksteed proposed to drain the City of Berlin by means of steam power.

In the years 1845-46 and 1849, he proposed plans for the drainage of the metropolis, by means of a deep underground sewer, commencing in the earlier project, at the Ranelagh Sewer, Chelsea, in the other two, at Northumberland Street, Strand, and all terminating at Barking-creek, whence the sewage was to be deodorized and pumped into reservoirs to the level of high water; the nitrogenous matter and salts being precipitated by means of lime, which it was expected, from the opinions of trustworthy chemists, would yield a valuable manure. The sewage-water, now rendered limpid, was then (as at present) to be discharged into the Thames at, or about the time of high water. The plans for the above schemes were duly deposited for application for Parliamentary powers, but owing to the state of the money market at that period of depression, the necessary sum to comply with standing orders, could not be obtained. The estimate for the first of the above plans was £1,500,000, which, however, included the drainage of the south side of the river, by an outfall at the Greenwich Marshes. The last plan (of 1849) was for the north side only, and was estimated to cost £600,000. The sewer in that case was to be circular; at the lower end at Barking up to the London Bridge sewer, it was to have been 10 feet in diameter with a fall of 2 feet 3 inches per mile, and thence westwards 8 feet in diameter with a fall of 2 feet $9\frac{3}{4}$ inches per mile, being calculated, when full, to deliver 20 million cubic feet every 24 hours. At Barking, the whole was to be raised by pumping to a height of 58 feet 6 inches. Subsequently, in 1855, the sewage of the town of Leicester, under Mr. Wicksteed's plan, was lifted by steam pumping, for

the purpose of being deodorized and clarified, which it continued to be up to the present time; by a recent statement, the quantity of sewage was 21 million gallons per week, raised 24 feet high.

With regard to Mr. Wicksteed's plans of 1845-9, he thought there was quite sufficient resemblance to the present plan, to justify the conclusion that much valuable information was derived from the facts and figures accompanying them, and it was worthy of notice, how long before Mr. Frank Forster's well-known float experiments, Mr. Wicksteed had fixed upon Barking, as the best point for the outfall.

Mr. BATEMAN said he should be sorry that the dogmas advanced by Mr. Chadwick should pass without contradiction. The merest tyro in hydraulics would know that high velocities in drains meant great inclinations, and when Mr. Chadwick talked about eight 3-inch pipes forcing their full contents into one 4-inch pipe, and of velocities so high that a man must run to see that emerge at the outfall which he had deposited at some inner point, the fall must have been immense. Such a thing might possibly happen in mountainous districts, where one part of a town was hundreds of feet above the other; there, such magical performances might be attained, but what was to be done with many parts of London, such as Southwark, which was on a dead level? There, other measures must be adopted; with lower falls, there must be larger sewers, and larger sectional areas, for such a quantity of water could not be carried off in small pipes with a small fall. No Engineer would venture to enunciate these elementary truths in the Institution, if it were not for the positive manner in which Mr. Chadwick had spoken. He merely mentioned this for the purpose of telling that gentleman that his enthusiasm and his love of the subject had carried him away, for he had stated what everybody at all acquainted with the subject knew to be diametrically opposed to the facts of the case. He thought that Mr. Chadwick's dogmas were mischievous and dangerous, and with the best possible feeling towards him, he would say that he believed he could collect evidence for the administration of public affairs, and report on what other people had done better than he could carry out systems of drainage.

Mr. G. W. HEMANS remarked, that it was impossible to have heard these two Papers upon the drainage of London and of Paris, without perceiving at once, the great superiority and the more complete results, which had been derived in the drainage of London. He had visited the works in Paris, which were magnificent and executed in costly style, as also, in some respects with the highest engineering skill: at the same time he confessed his astonishment at the comparatively small results which had been obtained from that undertaking; and those who

had not visited Paris, having heard these Papers, must regard with astonishment the fact that, after all the outlay that had been incurred, the solid sewage matters of Paris were not removed by the drains, but were carted away, while the deposit in the sewers was so great, as to require an outlay of £30,000 a year to keep them clean. The results of the London drainage were infinitely superior when compared with those of the Paris system. He could not forbear alluding to the opinion that, under this great Main Drainage system, the effects of a season of long drought might be more injurious than under the previous state of things. He thought Mr. Bazalgette was the proper person to reply to that point, but in his belief, it would be found, that the main drains of London were entirely free from dependence upon the rainfall for the flushing. If the present supply of water per head of the population were delivered into London, that supply would be quite sufficient to make all the sewers of London self-cleansing, and to prevent any dangerous results to the public health. He said this with all deference, but he believed and hoped, that there was no sufficient foundation for the alarming opinion expressed on this subject. He thought there was reason for congratulation, on the results of this great system of sewerage of London, and one of the points in which it was most successful was, that the whole of the sewage, north and south, was concentrated at two distinct points, so that it could be handed over to other parties, for the purposes of utilisation. The redistribution and utilisation of the sewage formed a natural consequence of the main drainage.

Mr. JOHN GRANT having superintended the construction of the southern portion of this important system of drainage, begged to offer a few remarks. With respect to the anticipation, that under certain circumstances, the sewers might become so charged with deposit, that an epidemic might result in consequence, he could state that such a contingency had in this scheme been carefully guarded against. They had the means at twenty, or more places on the Thames of letting in fresh water, and so thoroughly could these sewers be flushed, that it was impossible that either soft deposit, or hard material, could lodge in them. A stream could be sent through the sewers from Putney to Crossness sufficient to carry with it anything that could get into the sewer; a similar arrangement was made for the north side. In the low-level sewers water from the Thames and certain of its tributaries, was thus used. In the case of the high-level sewers, the water could be accumulated behind dams at numerous points, and be used for flushing if necessary. The Falcon, the Effra, and the Ravensbourne streams on the south side, and other rivers on the north, could in this way be let into the high-level sewers, for cleansing

purposes. The reservoir for condensing the feed-water was constructed under the boiler-house, because the ground upon which the Crossness works were built had to be excavated for foundations to a depth of 25 feet below the surface. If that space had not been used as a reservoir, the excavation must have been filled in with concrete, or other material. The plan adopted was the most economical as a foundation, and was made to subserve the important purpose of holding the water required for the engines and boilers.

With regard to the discrepancy between the steam power at Crossness and at Deptford, he would remark that at the latter place there was an almost uniform lift, varying only from 18 feet to 22 feet; whereas at Crossness, which was the lower end, there was a lift varying from 10 feet to 31 feet 6 inches. Moreover, the minimum quantity of water to be dealt with at Crossness was, in comparison with the maximum, as 1 to 14; the minimum being 1,330 cubic feet per minute, and the maximum 19,000 cubic feet; but there never, by any possibility, could be the extreme lift with the maximum quantity of water to which Mr. Bramwell had referred. To bring 19,000 cubic feet of sewage per minute it must rise to a level of 11 feet 6 inches above the invert, which reduced the lift. These extreme variations in the lift, and in the quantities to be lifted, accounted for the peculiarity in the arrangements of the pumps at Crossness. At Deptford they were simply single plungers, 7 feet diameter, working in a 9-feet barrel. At Crossness the pumps had 12-feet barrels, and in each pump there were four plungers 4 feet 6 inches diameter; two plungers having a stroke of 4 feet 6 inches, and two having a stroke of 2 feet 3 inches. When they had a minimum quantity of water to deal with, they had simply to disengage the two pairs of outer plungers of one pump, and to work with one-third the power of one engine. When they had the maximum quantity to lift, the whole of the plungers of the four engines, 32 in number, were worked, and were capable of lifting the 19,000 cubic feet per minute to the level of high water, and at this rate the reservoir could be filled in four hours. An additional reason for the apparent discrepancy of pumping power at Crossness, and at Deptford was also furnished by the fact, that at Deptford there was no reservoir; moreover, to the west of Greenwich, the sewers rose with more rapid inclinations and were of smaller capacity, and in time of flood it was necessary to keep pumping into the outfall sewer, and thence into the reservoir at Crossness. If the water was allowed to rise at Greenwich to a level of about 14 feet above the invert, it began to affect some of the lower basements of the warehouses and dwellings in Bermondsey, Rotherhithe, and the lower parts of Southwark. On the other hand, they had at Crossness a reservoir capable of

holding double the present discharge from the sewers during each tide, and they had in addition an equal capacity in the sewer itself from Greenwich to the reservoir. In other words, they could store in that sewer 4¼ millions of cubic feet in addition to the 4 millions of cubic feet that could be stored in the reservoir at Crossness. There was storage-room, therefore, for a quantity of sewage equivalent to four times the amount they would get in one tide.

There was another point of interest to which he would refer in connection with the reservoir at Crossness; namely, the character of the invert which they were compelled to adopt on account of the unfavourable nature of the ground. As he had stated, the foundations of the walls and piers were 25 feet below the surface. Had they been taken to a less depth than that they would not have been safe. To get over the difficulty in the least expensive way, longitudinal arches were carried from north to south in the line of the piers, and between them, were built convex arches, and upon these again were placed the inverted arches, the object of the latter being to facilitate the process of flushing away the deposit which might accumulate from time to time. In speaking of the reservoirs and sewers, reference had been made to the subject of ventilation; that was a matter requiring great consideration and opening a wide field for discussion. He wished, however, to say, that this feature had been by no means neglected. In the course of the last few years, in fact before these works were commenced, they had tried almost every scheme of ventilation that had been suggested. They had ventilated the sewers by means of the steam jet, and into chimneys. At Deptford the sewers and at Crossness the reservoir were ventilated through the furnaces, and in other cases the foul air was carried up iron pipes and discharged at a height which did not affect the attics. They had ventilated into the streets, and one of the latest modes adopted, throughout the whole of the southern main sewers, consisted simply of a ventilating shaft carried into the street through a catch-pit for mud and stones which might fall through the grating. Between the air-shaft and the catch-pit, there was a semicircular opening 2 feet 6 inches in diameter, into which a vessel containing charcoal could at any time be fitted.

All he had to say further was, that from the experience hitherto obtained, these sewers would not be "sewers of deposit," and the ventilation of them would be by no means so necessary as it had hitherto been, or as it was at the present time, in the stagnant sewers of London. The sewage would be carried off in an ever-flowing stream by day and night, and there would be no festering mass to create the foul smells, which were so dangerous to health. These were, however, the different means of ventilation which had

been provided, though they might not be absolutely required. Many gentlemen now present, who had watched the progress of these works, might have come to the conclusion that they were costly in their character and execution. When commenced, the brickwork was £14 per rod, and it had risen to £20; the work on the south side being done in gault clay bricks and Portland cement. He considered this thorough mode of executing the work was the most economical. There would have been the same amount of excavation and filling in, and the same amount of pumping, whether they had put in cheap brickwork, or the more expensive work which had been adopted, and those who had to do with works in which pumping formed so large a proportion of the whole cost knew that to execute repairs in such works would be so costly, that inferior work was not for a moment to be contemplated. He had always been an advocate of economy in drainage works, and for many years before this was commenced he had the opportunity of carrying out an extensive system of tubular drainage and brick sewers of different sizes. His reason for making inexpensive branch sewers had been, that for one brick sewer of large size it was practicable to make eight times the length of smaller sewers of sufficient size to serve any purpose for which branch sewers were required. He had carried out the whole of the southern sewers, and he thought one of the most satisfactory features of Mr. Bazalgette's scheme was, that it had been executed in an efficient, though perhaps costly manner. Taken in connection with the branch drainage, yet to be carried out, it must, he thought, be regarded as the best solution that had yet been proposed of an extremely difficult question.

With respect to the earlier features of the scheme, he would take this opportunity of stating that in 1850, when Mr. Frank Forster and Mr. Robert Stephenson entered upon this subject, and before it came under the notice of Mr. Haywood, those gentlemen had well considered the questions of outfalls, rainfall, the proportion of the latter it would be desirable to attempt to carry away by the sewers, the water-supply both present and prospective; in fact, all the main points of this large question. At the same time he did not consider that this detracted from the merit due to Mr. Bazalgette in the prosecution of this scheme. As far as the south side was concerned, with which he (Mr. Grant) was more familiar, Mr. Bazalgette had added the high-level sewer, which carried off by gravitation the water from the Crystal Palace down to Crossness, where the sewage had only to be pumped once. That was an important feature which entitled Mr. Bazalgette to the highest credit.

Mr. JOHN AIRD, Jun., would take this opportunity of indorsing the remarks of Mr. Grant, with regard to the works on the south

side of the Thames. Of those works, he could say with confidence, that they had been carried out in the highest style of construction, and no expense had been spared, as far as it could be usefully applied.

In reference to the system of subways constructed in Paris, Mr. Bazalgette had designated it as a costly addition to the sewer-works, and one which had not been justified by the practical results obtained from it, the principal object being only to carry gas-pipes and water-pipes. Yet the same plan had been adopted in the new street in Southwark, and was also proposed in the Thames embankment, in both cases, as a separate chamber over the sewer, the expense of which would, he believed, far exceed the Paris plan. At the same time he was strongly of opinion that the system of subways was one which could never be admissible, or be carried out with any good practical results. It would doubtless be remembered, that at the time the question of subways was under the consideration of a Parliamentary Committee, M. Belgrand, the principal engineer in charge of the sewers of Paris, came to London to give evidence before that Committee, and he stated, that subways were found to be most objectionable, and that they had been abandoned in Paris, in consequence of the accidents, and other inconveniences which they had occasioned. With regard to the prices paid for the works in Paris, he only wished contractors in this country could obtain the same figures as were mentioned. They so far exceeded all previous ideas, that he thought there must have been some error in putting those figures forward.

With respect to the sewers on the southern side, with which he had been principally and intimately connected, he had much pleasure in saying, as a young man, addressing other members of the profession younger than himself, that he had derived great experience and advantages from the part he had taken in the execution of those works, and which he believed would be most useful to him in after-life.

In executing the works on the south side of the Thames, the sinking of the cylinders was always adopted previous to the commencement of the works, even before the way in which the work itself was to be done was determined. These cylinders were sunk at spots quite away from the line of the works, and to a depth considerably below that to which the work was to be extended. By this means, the precise nature of the ground, and the amount of pumping-power that was required to master the water, were at once ascertained, and then, after thoroughly draining the ground, the works were commenced. In the prosecution of these works, the value of such a system was greater than he could well express; it enabled the Engineer to know exactly what difficulties had to be

contended with, and when the work was proceeded with, it could be executed with certainty.

There was another point of importance for which he must give Mr. Grant credit. A drain-pipe, and in some cases two drain-pipes, were carried underneath the whole of the work, and securely bedded in concrete, and this was found to be of the greatest value in getting in the foundations, which were thus done in a perfectly dry condition. With regard to the cement-testing, when the walls were commenced he certainly thought the testing was somewhat too rigorous, and that the strictness with which it was conducted was trouble thrown away; but eventually, experience showed that was not the case, as at times, when the works required to be pushed, such cement was used as was at hand, and that was done sometimes, he admitted, without the knowledge of the Engineer; but afterwards it could be always seen, from the work itself, which cement had been tested and which had not.

With respect to the cost of construction, he could state that, with few exceptions, they were executed within the contract price. One of these exceptions occurred in a portion of the work on the premises of the Deptford Gasworks, where it was intended to put up a gasholder. To facilitate this, the work of the sewer underneath, for a length of 130 feet, was commenced. Unfortunately, the contractor was not able to carry it out; his firm then undertook the work and completed it. The estimated cost was about £2,000, whereas it actually cost upwards of £16,000. While speaking of estimates, he would like to mention, that his firm had had the honour of carrying out four contracts under the Metropolitan Board, and on the whole he might say there had been a saving rather than an addition to the contract amounts.

Mr. VIGNOLES said that he would follow up the remarks that had been made as to the alleged prices paid for the Paris works. He had had much experience of works on the Continent, and he ventured to say that in no part of the world was drainage work done so well and so cheaply as in England. The annoyances and the vexations which contractors had to put up with, under the system of engineering in France, were such, that he was not surprised at any amount of cost; and no greater proof of this statement could be afforded, than the fact that it required £30,000 a year to clean out the Paris sewers.

Mr. BIDDER, Past-President, said that, indirectly, he had taken part in this subject, at an early stage, on account of his intimacy with the late Mr. Robert Stephenson, and finally, in connection with Mr. Hawksley and Mr. Bazalgette, by producing the Report which had the effect of settling the course of legislation on the question.

Before, however, making any remarks upon the Paper, he thought

it would be most ungracious, if he omitted the present opportunity of congratulating the Author on the completion of the scheme. Mr. Bazalgette had achieved a great work; he had made a reputation which was now world-wide, and which would be lasting; and he was sure, from what he knew of him, that he would be the last man to deny a due share of merit to anybody concerned in the early inception of the scheme. The question of the Metropolitan Drainage, and the purification of the River Thames, had gone through a great variety of difficulties, moral, political, and physical, and had it not been for the determined and resolute interference of Mr. Robert Stephenson, in putting an end to many of the schemes which overloaded this great question, he much doubted whether the Institution would have been able, at the present time, to congratulate Mr. Bazalgette on the completion of the works.

The one great question, which everybody thought himself competent to deal with, was the drainage of the Metropolis, the purification of the River Thames, and the Utilisation of Sewage. The discussion of the subject had gathered round it numerous inventors who adopted this, as a means of earning notoriety, and at various periods the newspapers enunciated schemes which violated all common sense and outraged all mechanical science. Water was to flow along a pipe 70 miles long; it was to flow through a pipe without any power, from London to Southampton. Because persons were in the habit of saying of every place that they went down to it from London, it was therefore thought that the water would go down there too. Then commission after commission was appointed. Mr. Hawkshaw attended one commission, which resigned, because the commissioners were called upon to carry into effect a particular proposition, which, as was to be expected from men of their standing, they would not do. The question then got into a state in which nothing could be done with it; it was referred from one to another, and at last it got into the hands of Mr. Hawksley, Mr. Bazalgette, and himself, to make a final report upon it. Personally, he claimed no credit, for he initiated no scheme; but if he took any merit at all, it was, that, with the other gentlemen, he had carried out the resolution that they began with, that they would not be tempted to consider any scheme of their own, but confine themselves to that which had been initiated by Mr. Frank Forster, and perfected by Mr. Haywood and Mr. Bazalgette, after more intimate knowledge of the facts on the subject; and which came to their consideration with all the latest information. All that they had had to do was so to fortify the scheme, so as to justify the Legislature, in giving it their sanction, and in empowering the Metropolitan Board of Works to carry it into effect. The first thing he recollected in connection with it, was the fact of Mr. Stephenson, Mr. Forster,

and some other gentlemen, having to consider a great number of plans, which had been invited by advertisement from everybody in the country. Incidentally he must protest against this method of draining the intellect of the country, because it occupied time to no useful end, and cost great sums of money. The result was, tha beyond the present scheme, the only one sanctioned was that which was propounded by the President of the Institution, Mr. M'Clean, and which, in fact, carried out, to some extent, the principle adopted in the Metropolis Sewage and Essex Reclamation Bill of this Session.

Before going into the main question, he would observe with regard to the works, that the only criticism he had heard was, that they had been executed in a style superior to the requirements of the case; but he considered that Mr. Bazalgette was quite right in what he had done. He did not know that he would have been right, if he had been acting for a body of shareholders. If he had had to meet such a body on the first occasion without a dividend, they would have looked out for a victim, and the first victim would have been the Engineer, who would have been denounced if he had put a bit of carving, or a useless piece of stone anywhere on the works; but Mr. Bazalgette had been carrying out a great public work. There might be some little complaint about the rates, but the desire of the public had been satisfied by the universal approbation which the works had excited. He believed, therefore, that Mr. Bazalgette was quite justified in completing the works in the style he had, and he only wished that he could get some public money to deal with in the same way.

He thought there could be but one opinion, that the drainage of London had been most successfully accomplished; but the question of the purification of the Thames had yet to stand the test of experience, and there were some points connected with that subject which he should like to bring under the consideration of the members. He had been professionally connected with works on the River Thames ever since the year 1825. He was then occupied upon the London Docks, and he remembered perfectly well, as no doubt some others did, a bathing-machine being established on the west side of the Blackfriars Bridge. He remembered the London Docks themselves being choked with fish; the water for the supply of the ships was taken in from the river, just opposite the docks. The water, for the supply of the East Indiamen at Blackwall, was taken in by a pumping-engine on the old wharf, which pump was worked at low water, and another great thing was, that in those days, the whitebait was caught opposite Blackwall. But what was the state of things at the present day? The bathing-machine was a matter of mere history; the London Docks, instead of being choked with fish, were full of offensive water, in which only the very lowest form of animal life could exist;

the whitebait had receded to Gravesend, and the sea-water, which then scarcely reached above Blackwall, had at present been detected as high up the river as Chelsea. All this, indicated two things, that the sewage of London had driven the whitebait lower down the river, and that, from the river having less fresh water, owing to the greater drainage of land, and the removal of old London Bridge, the salt water had been allowed to permeate farther up. Besides this, there had been a large and growing population on the banks of the river, all the way from London up to Oxford; at Kingston, Richmond, and other places, all of which had been seeking to pour their sewage into the Thames. The only part of the work which had not been tested, was, whether pouring the whole of the sewage into the river at Crossness would relieve the river from the presence of the sewage within the Metropolitan District. Of course this would have no effect upon the sea-water, which, he believed, with the completion of the Thames Embankment, would find its way still higher up the river. During last summer, some sewage from the north side was thrown into the river at low water, and there was a complaint at Woolwich. Whether that complaint was entirely due to the sewage, or not, Mr. Bazalgette would probably be able to state; but the sewage was now to be poured in on the ebb-tide, and into a volume of water enormously in excess of the sewage, and the apprehension was, that the salt water would still be found as high up the river as Chelsea, and that the sewage would, in some form or proportion, also find its way in the same direction; but how far it would be offensive, was entirely a matter of experience. It must not, however, be forgotten, that in bringing the whole of the drainage to Crossness, or to any other point on the side of the river, it had been brought where it could be dealt with. At present it was thrown into the river in such a way as to be obnoxious, and difficult to manage. He did not say it was impossible to do anything with it, but it could not be dealt with so conveniently as it could be when it was all carried to one place, as it now was to Crossness. Mr. Hemans had propounded a plan for taking the sewage down to the sea. He would express no opinion upon this scheme, because it was a commercial question, but he only hoped it would be successful, because if it should be a commercial success, then the inhabitants of London would be relieved from all anxiety about it. There was, however, one point in Mr. Hemans's bill, though not a mechanical point, which he thought ought to be adverted to, and that was, that the company had a concession of the northern sewage of London for fifty years. He thought that period, or even one of thirty years, was too long, and that there ought to have been a narrower limitation. He would explain, in what way this had to do with the drainage of London. The whole of the scheme proceeded at present on the idea that

the drainage of London and the suburbs was to be entirely by sewers, and provision had been made not only for the present, but for the anticipated population. But the time might come when some other arrangement might be made, and the sewage be otherwise dealt with, and in the event of the present scheme not answering, the promoters of it ought not to stand in the way of any other appropriation of sewage which science or experience might suggest.

He now came to the great question, as to how the rivers were to be dealt with in future, and to be protected from the pollution which must occur, if the drainage were poured unrestrictedly into them. The laws of this country were all that could be desired with regard to the protection of rivers, the only difficulty, was to put those laws into operation. No better law was wanted, for the present law would protect and recognize any man's rights, so that the water which he enjoyed should be preserved to him, if he could satisfy the Court of Chancery, and that was the difficulty, as to the injury which he might sustain. What was wanted for the purity and protection of rivers was, that a body like that which was now regulating the salmon fishery, should be appointed to deal with the impurities which might be put into rivers. He knew one river in Devonshire, a beautiful stream, which all at once became turbid, and on inquiring into the cause, he found that it was from the refuse of a mine being thrown into it, by which the river was polluted, the fish killed, and the enjoyment of the adjoining property interfered with for miles. He was told, that that very mine had never paid a shilling, and was being worked at a loss, but even if it were worked with a profit, he did say, that the proprietors on the river ought to be protected, and that the machinery for doing so should be cheap and effective.

Mr. HEMANS said, that it was not to be supposed that any company would spend £2,000,000 of money in bringing a project into operation, without having a guarantee, that the very foundation of the whole concern should be secured to them for a certain term of years. It was, in fact, impossible to carry out the operations without the concession.

Mr. JAMES LEMON would offer a few remarks upon the objects and the construction of the Paris drainage; through the medium of a professional friend, he had obtained the following information, from one of the French municipal Engineers. The house-washings and the rain-water were drained into the collecting, or other public sewers, and each house had a particular branch, which was in communication with the public sewer. The rain-water from the houses was drained by an iron pipe, the mouth of which was trapped, to prevent smell. A ventilating tube was carried up, either in the thickness of the wall, or outside of it, from the branch sewer to the top of the roof of the house. The waterclosets of the houses did

not empty themselves into the sewers, but the urinals placed along the Boulevards were, in most cases, drained directly into the sewers. There had been a project to connect the drainage of the water-closets of all the houses with the sewers, but at present it was only carried out in a few isolated cases. These statements confirmed the account given by the Author.

Then, as to the form of the French sewers, it was curious that a nation, which has produced some of the most eminent authors on hydraulics, should have lost sight of one of the first principles, that of obtaining the maximum hydraulic mean depth of flow in the sewers in dry seasons: for which purpose the egg-shape was one of the best forms.

Now, what was the case in the French system? According to the diagrams exhibited by Mr. Hederstedt, many of the sewers had flat bottoms, or nearly so. For example, the drainage space of the sewer under the Boulevard Sebastopol was 4 feet wide, and only 2 feet 1 inch deep, which he would instance, as one of the causes of the silting up of the sewers.

Another of the causes of deposit, was the want of properly-constructed gullies. In Paris, the streets were often cleansed twice in the day, and the sand from the surface was washed directly into the sewers, by a vertical channel, constructed in the side of the subways with an opening on the surface of the street under the kerb, but if the gullies were constructed on the metropolitan system, this flow of sand into the sewers would be prevented.

There could be no doubt, that the proposed improvements in the water supply of Paris, would produce a reform in the present defective state of the watercloset arrangements; if that were the case, how was the increased consumption of water to be disposed of? The present cesspools would not contain the sewage, without connection with the sewers, as they were constructed of masonry, in the best manner, and no liquid matter could percolate through the walls.

As an instance, he would take the number of houses draining into one cesspool, at 12, the number of persons at 10 to each house, the water consumed, and the urine, at 2 gallons per head per diem; hence $12 \times 10 \times 2 = 240$ gallons per day $= 1{,}680$ gallons per week, for which there would be required a cesspool about 28 feet in area by 10 feet deep, which would also require emptying once a week; or if the population were taken at 1,700,000, and the estimate made of 2 gallons per head per diem as before, cesspool accommodation would be required equal to $1{,}700{,}000 \times 2 = 3{,}400{,}000$ gallons per day $= 95{,}200{,}000$ gallons per month; a quantity which would require a cubic capacity of 15,232,000 feet, which was about $2\frac{1}{2}$ times the contents of the northern reservoirs at Barking. Taking the cesspools at the same depth as those reservoirs, 24 acres of the city of Paris would be occupied by cesspools, which would

require emptying every month, involving a large annual outlay, besides the annoyance of the carts, &c., passing through the streets. These data showed, that a system of cesspools with good water supply, without connection with the sewers, would be exceedingly unwise. Moreover, in the foregoing calculations, the drainage from the waterclosets only had been included, whereas in practice, it would be found that a large quantity of the house-washings would also be thrown down the closets. Supposing that the whole of the drainage of every kind was admitted into the sewers, which must ultimately be the case, then it would be found that the main sewers would be inadequate to carry off the sewage, without overflowing the floor of the subway. For example, the collector under the Boulevard Sebastopol had a drainage space of about 8 feet area, and it would be required to take the sewage of 400,000 persons.

But, if the total quantity of sewage were estimated at the London rate of water supply, viz., 5 cubic feet per head per diem, discharged in 12 hours, then, by the formulæ of Mr. Beardmore, there would be rather different results, showing that here would be required an area about double that provided, without considering the rainfall. In the Paris system, the acquisition of a good water supply would involve the deepening of the invert, or some other reconstruction of the égout collector. He would refer to the great size of the sewers and subways in the Parisian system: if a comparison were made of the sewer and subway under the Boulevard Sebastopol, with that lately constructed in London, in the new streets, it would be found that the area of sewer was nearly the same, whereas the area of subway was nearly three times that of the London section. The cost of the Paris subway and sewer, at the London rate of prices, would be about £7 per foot run; that of the London sewer and subway had cost about £2. 10*s*. per foot run. It was true, that the French subway was designed to take the storm-waters, but overflow sewers might have been constructed at much less cost, and with better sanitary results.

Mr. BAZALGETTE, in reply, said, that in the first place he was glad to be enabled to express his thanks for the support which he had received from the late Mr. Robert Stephenson, especially at a period when he had met with much opposition, in carrying out the arduous works, which formed the subject of the Paper, in addition to the support which he had also received from Mr. Bidder and Mr. Hawksley. On bringing the subject before the Institution, he found, that there were now a great number of persons who claimed to be the "pioneers" of his design, and it was a source of regret to him, that he had not been aware before, of the existence of many of the schemes which had been referred to, for it would have saved him many anxious days and sleepless nights, in working out for himself, that which it was now alleged, had all been done and

prepared before. All he could say was, that if there were any gentlemen who had previously designed, or worked out his scheme of drainage, and who would produce their drawings and designs, and show them to be similar to those he had presented to the Institution and had executed, he should be most happy to acknowledge the fact. It was, at any rate, satisfactory to him to find, that they approved of what had been done, and it would also have been very satisfactory to him, supposing the works had failed, to have found so many gentlemen ready to come forward, and say—"Well, never mind, we designed the same thing, and are ready to share the opprobrium with you."

But, there were one or two points, raised in the course of the discussion, to which he must briefly allude, and the first was a leading principle, viz., of separating the sewage and the rainfall. It had been said, exclude all rainfall from the sewerage system. He could imagine, that in a village, or in a small town the sewage of which had previously been drained into cesspools, but which had had sewers provided for the rainfall, it might be advantageous to construct a system of sewers for the house-drainage alone, and to allow the rainfall to pass off through the old sewers; but, if this principle were attempted to be applied to the metropolis, it could not be carried out. It would involve what he had alluded to in his Paper, a double system of drainage; it involved going into every house in the metropolis, and telling the owner, that his house must be redrained, and that he must go to the cost of it. At the present time, one house-drain took the sewage from within the house, and the rainfall from the roof and the area, and before these could be separated, it would be necessary to construct a double set of house-drains and sewers. He had investigated the subject very carefully, because it was one of the theories which he had to contend against for some considerable time, and he found, that besides the revolution, which such wholesale interference with house property would cause in London, the scheme would be altogether impracticable. The advantage of a large volume of rain-water which now cleansed the sewers would be lost; the fall in the sewers would have to be increased to compensate for this, thus leading to an increase in the lifts and pumping power, and the whole undertaking would involve an outlay of no less than £10,000,000 or £12,000,000 of money.

It had been alleged, that the reservoirs would collect deposit and become a nuisance, and that the money would have been better expended in carrying the sewers lower down the river. He only wished that those who took this objection would, as he had done that day, walk into the reservoirs, just after the sewage had been in them; had they done so they would have found that there was not the slightest deposit collected in them, and if there had been, nothing would have been more easy than to have removed it

by allowing the tide at high water to run into a culvert, prepared for the purpose, and then by opening a pen-stock, to wash the deposit completely away. The reservoirs, which contained the sewage till the time of high water, and then discharged it into the Thames, were equal, in effect, to the construction of twelve miles of sewers, because the tide, from high water to low water, carried the sewage twelve miles lower down the river, whereas not even six miles of sewers could have been constructed for the cost of one of the reservoirs. The minimum fall of the sewers was two feet per mile, but the fall in the river was only about three inches per mile, at that point, and to have extended the sewers would either have involved having sewers tide-locked, which was most objectionable, or else a resort to a large increase of pumping. He conceived, therefore, for these reasons, that no other plan would have been so economical, or have answered so well, as the reservoirs which had been constructed.

He would now refer to the allegation, that it was a great mistake to conduct the sewage to one point, and that it ought to have been distributed over a number of points. If this proposal were carefully considered, it would be seen, that it would involve taking the sewage from the low districts, on the margin of the river Thames, up to the high districts, such as Hampstead, Highgate, Kentish Town, or other similar neighbourhoods, and for what purpose? Why, only enormously to increase the expense of pumping. If the sewage were conveyed to those high districts, what was to be done with it? If distributed as liquid manure there, it must be done amongst the houses, and in the streets of those thickly-inhabited neighbourhoods; but this was clearly impossible. If made to flow down to some low district, as had been done, and concentrated at a point where it could be conveyed with very little lifting, or by gravitation, over agricultural land, and at the same time at a point where it would cease to be a nuisance to the metropolis, he thought that was the cheapest and best arrangement, which could be entered into.

Mr. Chadwick's recollections of the sewers of London must be of rather ancient date. He had stated, that there were a thousand miles of sewers, of decomposing deposit, and he talked as if pipe sewers were the only means of getting rid of that deposit. It was well known that Mr. Chadwick was fond of the subject, and it was to be wished he would only go and spend a day in the sewers, for he would very soon change his present views of the state of the so-called sewers of deposit. Now that they had ceased to be tide-locked, there was no reason why there should be any sewers of deposit, for the flow in the sewers would carry off the deposit, if their inverts were only properly constructed, and the fall sufficient. The cause of the deposit in the sewers was, that in former times, as the sewage of London fell from the high districts into the low

districts, they could not discharge from the low level into the river except at low water, and therefore for eighteen hours of the twenty-four, they were tide-locked, and became filled with the deposit which Mr. Chadwick had so well described, and no doubt, decomposition was then going on; but, from the moment the new system came into operation, there was a constant discharge produced in the formerly tide-locked sewers, and they ceased to be sewers of deposit. This had been accomplished by means of the intercepting sewers and pumping stations, and he believed that Mr. Chadwick's picture was overdrawn, and that the notion that the sewers of London were now in the state he had described, was entirely erroneous. During the time the sewers were tide-locked, the cost of cleansing was very heavy, probably about £30,000 a year, and the reason was, that the labour of cleansing was exceedingly great. Men could not get into the South London sewers, except for an hour at low water, and they had not been there long, before they were driven out again, by the sewage rising upon them. He could not tell what the present cost of cleansing sewers would be, because there had not yet been sufficient experience, but he was able to say, that with a fall of two feet per mile, in one of the large sewers, it had required no cleansing throughout the year. He had now had experience of that sewer for more than two years, and he had found that the flow kept it perfectly clean, and therefore he thought he was warranted in coming to the conclusion, that wherever sewers of any size had been constructed with a proper section and fall, and a constant flow, they would require no cleansing.

From his experience of the velocity of the flow in sewers, and their power of discharge under various conditions, he was somewhat surprised to hear Mr. Chadwick come forward and tell the Institution, that the whole of the theories of the Engineers, and the experiments of eminent Engineers of olden time, were fallacious; that a Trial Works Committee had been appointed when he was a Commissioner of Sewers, and that that committee had instituted experiments, which entirely upset the calculations and theories of Engineers of ancient date. He happened to know something of this Trial Works Committee, for he had examined their minutes and reports, and Mr. Chadwick would excuse him if he mentioned some facts respecting it. Mr. Chadwick had stated, that one experiment showed how, in a main pipe-sewer with seven branches, or eight branches, each contributing additional sewage to that which was already in the main; the velocity of flow was so increased, that the additional quantity did not increase the volume in the main; after that extraordinary result it was certainly surprising that Mr. Chadwick did not put in a few more junctions, and at last arrive at the conclusion, that the increased velocity had so reduced the volume that there was no want of an

outlet. But he was not astonished at the results of the Trial Works Committee, for he found that the experiments were mainly conducted by persons never before heard of, as Engineers. He had looked into the results discovered through that Committee, and in the margin of the book kept by it, he had seen the observations of Mr. Cowie, a very distinguished member of that Committee, and an able mathematician; he had seen, in his writing the word "impossible" affixed to the record of some of the experiments. He did say that it was absurd to tell the Institution that such experiments were to be relied upon, as upsetting the careful and well-tried experiments and inductions which had been successively worked out upon a large scale, and verified, by Engineers of standing and repute. He had imagined that this was one of the bubbles of the day which had long since burst, and he was surprised to hear the Trial Works Committee now upheld at that Institution.

He came next to the observation, that the addition of the intercepting sewers to the sewers of London was likely, in times of dry weather, to lead to some pestilence, or disease from the stagnation of the sewage. How was it that, with the 1,300 miles of sewers at present existing in London, some of which were formerly tide-locked, and all constructed for carrying off the largest rainfalls, while the amount of sewage in them and consequently the flow was very small in dry weather, the addition of eighty miles which would relieve all stagnation and carry off the sewage as fast as it was poured in—how was it that these relieving sewers could produce the disease and the evil results as foretold? In the old sewers, constructed to carry off both extraordinary rainfalls and a comparatively small amount of sewage, the scouring power in dry weather was but small, but the intercepting sewers were half filled with the maximum flow of sewage in the period of dry weather, and, as was well known to the Institution, a circular sewer, half-filled, had the same scouring power as a circular sewer quite filled; he contended therefore that those sewers during the maximum flow in dry weather had as good a scouring power as they would have during a storm. He thought that argument was unanswerable, and therefore not only was theory strongly in his favour to prove that the sewers would not collect deposit, but experience on this point had already shown that the intercepting sewers produced a constant flow in the formerly tide-locked sewers, and thus relieved the metropolitan district from that stagnation of the sewage which had previously existed, and which had actually produced the diseases now apprehended.

With respect to the comparative pumping power at Deptford and Crossness, it must be borne in mind, that at Crossness, the maximum lift and maximum flow could never occur together, and during the period of maximum flow, if the engine did not take the whole

of it, the main outfall sewer would act as a reservoir for the time being, until the lift was reduced, and the engines were capable of taking it; whereas at Deptford, the whole of Bermondsey, Rotherhithe, Lambeth, and that low district, was entirely dependent on the pumping engines to relieve them from inundation, and therefore it was necessary to have a larger margin of power at Deptford.

It had been thought that the cost of the subway in the Thames embankment was greater than that of the Paris subways. But the plan showed that that subway formed in fact nothing more than a relieving arch to the abutment of the embankment. Engineers were in the habit, when constructing long piers, of putting an arch in the centre to save brickwork, and the subway was a work much of that character, and was constructed at little or no additional cost.

Respecting the purification of the river Thames, there must be apparent to every one a striking contrast between the old and the new system of discharge into it. Under the old system the sewage was only discharged at London during the time of low water, when there was but little water to dilute it; it was then carried up the river to Richmond, and came back and got mixed with the next day's supply of sewage, and so the evil went on, from day to day; but compared with the present state of things, when the sewage at Barking and at Crossness was discharged at high water, 14 miles below London, and was carried with an immense volume of water to a still greater distance from London, there was no doubt, that the new system was a vast improvement on the old.

As to the complaints made at Woolwich last year, he would say, that at that period the sewage of the south side of the Thames was being discharged into the Thames at low water, and had been until that very day. It was, therefore, until now, subject to the objections, which applied to the tide-locked sewers under the old system; that was to say, the outfall sewer was tide-locked, and accumulated deposit; the sewage discharged at low water flowed back to London, and no doubt was objectionable to Woolwich for the time being, but he did not believe that a nuisance was ever caused at Woolwich, or at any other locality, by the discharge of the northern sewage at high tide at Barking.

With regard to granting the sewage to a company for the period of fifty years, it had been thought objectionable, because some other scheme might be discovered which would be more useful and beneficial, therefore the Board of Works should not have granted the concession for so long a period. But experiments had been tried with regard to the utilisation of sewage, for the last ten years, or fifteen years. There had been precipitation by lime, by perchloride of iron, and by almost every other means

which could be thought of; one after another had failed, and doubtless years might elapse before there would be a better solution of this problem. But there had been some successful results of the application of sewage in a liquid form; there were some eight or nine towns where it had been so applied, and surely it would be unreasonable to expect any body of men to expend £2,000,000 of money, with the prospect of the whole expenditure being sacrificed after some short period. Besides this, it should be borne in mind, that the arrangements made, had in view the benefit of the ratepayers of the metropolis, and yet they were not called upon to expend one penny in this great utilisation scheme. They had spent their money only in purifying London, and the public money had not been speculated with, but the Company had undertaken to share with the ratepayers, in liberal proportions, the profits of the scheme.

Mr. M'CLEAN, President, said that he would ask the Members to join with him in congratulating Mr. Bazalgette on the successful manner in which he had carried out the works, and on the excellence of the workmanship, and the perfectness of the scheme.

March 21, 28, and April 4, 1865.

JOHN ROBINSON M'CLEAN, President,
in the Chair.

The discussion upon Papers No. 1,126, on "The Drainage of Paris," and No. 1,229, on "The Main Drainage of London," was continued throughout these evenings, to the exclusion of any other subject.

At the Meeting of March 28th, His Royal Highness Albert Edward, PRINCE OF WALES, was elected by acclamation an Honorary Member.

At the Meeting of April 4th, the following candidates were balloted for and duly elected:—FREDERICK ASHMEAD, WILLIAM HENRY CODDINGTON, OSBORNE CADWALLADER EDWARDS, HENRY OSBURN, DEVONSHER JACKSON SCOTT, WILLIAM BURTON WADE, and MATTHEW WOODIFIELD, as Members; WILLIAM PODMORE BAYLISS, Major ANDREW CLARKE, R.E., WILLIAM NAYLOR, JOHN CHARLES RAYMOND OKES, THOMAS OLIVER, Captain WILLIAM COLES PHILLPOTTS, R.E., ALFRED ROBSON, GEORGE HENRY SMITH, and JAMES YOUNG, as Associates.