

Discussion.

Mr. E. MONSON inquired what was the gradient of the main sewer at Abingdon? It was singular that a sewer should be constructed requiring flushing twice a week. He thought it would prove difficult to collect sewage without any surface water. He should like to know whether the sewers were fully ventilated; whether the openings were offensive; how many persons it was intended to make provision for to an acre of land; what was the cost per acre of preparing the land, and what it included; how the carriers were made; what distance the drains were apart, and how deep? These questions were of great importance. In the inquiry now going on concerning the Thames Valley, it had been stated that the land could be prepared, 9 feet deep, at £11 per acre. Such statements ought not to be made; it was only by getting at the facts in connection with works already constructed that satisfactory information could be obtained. To prepare a filtration area 9 feet deep would cost, not £11, but about £200 per acre. The cost of digging would be £146. The soil was sandy, and it would be necessary to go down with poling boards, and perhaps close pole it; and then there would be the cost of the roads and of the carriers. It would be impossible to make carriers by simply ploughing a sandy soil, and permanent carriers would be necessary. Altogether, he believed the cost would be £208 per acre. The Abingdon sewage was delivered on a free soil, and he presumed it would have to be prepared in a similar way to that in the Thames Valley.

Mr. BALDWIN LATHAM said Mr. Monson was entirely in error with reference to the cost of preparing land for the Lower Thames Valley sewage. The estimate of engineers exceeded £46 an acre all round. It would have been better if his views had been expressed at the inquiry, where he could have been cross-examined, instead of making an *ex parte* statement before the members of the Institution. In Mr. Gower's Paper it was stated that the population of Abingdon was six thousand; that at present it had no waterworks; that the inhabitants drew their water-supply from local wells, and that it was estimated, when the population should increase to ten thousand, the volume of sewage would be 25 gallons per head per day—250,000 gallons in twenty-four hours. He wished to ask how it was that there was a much larger volume of sewage than that at the present time. He had not given the volume per head per day, but it was easy to ascertain that it was over 30 gallons. Reference

Mr. Latham.

had been made to the importance of the sewers being watertight, of which there could be no doubt, especially in a district depending for its water-supply upon local wells. The tank sewer was calculated to hold 100,000 gallons, and at present it held that quantity at the time when the pumping was discontinued. The Author further stated that seven or eight hours' pumping per day was necessary in order to lift the sewage. The amount lifted was 400 gallons per minute; and eight hours' pumping would therefore lift 192,000 gallons in twenty-four hours, which was more than 30 gallons per head, with the present population. There was another way of looking at the question. It was stated that the tank sewer held 100,000 gallons, and was pumped out in eight hours: that was when the maximum flow was taking place from the town, and in that time half the volume of sewage would come down; so that if 100,000 gallons during that period were pumped out, together with 90,000 gallons due to the maximum period of flow, that came to as nearly as possible the same figure, showing that the present volume of sewage pumped was more than 30 gallons per head per day. That clearly showed, in his opinion, that the sewers could not be of the water-tight character described by the Author, or there were some exceptional circumstances in Abingdon to account for such an extraordinary volume of sewage. It was well known that, in a town of that description, where the people depended for their water-supply on local wells, the volume of sewage would not exceed 10 gallons per head per day. Of course he was referring to the dry-weather period. In wet weather, the Author stated that it was necessary to work two engines, and he had therefore confined himself to the dry-weather period. No data had been given as to the acreage of the land that had been selected, or as to the volume of the sewage it was intended to purify. It was stated, however, that the ordinary level of the Thames in the district was 162 feet above Ordnance datum; that storm water overflows had been fixed in the sewer at 6 inches higher than that; that the level of the lowest part of the land was 165 feet above Ordnance datum, and the highest 168 feet; and that in flood the river rose to 167 feet above Ordnance datum; so that in flood time the area selected for the treatment of the sewage, with the exception of the upper portion of it, would be under water. There would only be the margin between 168 feet, the level of the highest portion to be used for sewage purposes, and 167 feet, the height of the river at flood times, for the purpose of dealing with the sewage. That, too, occurred in a district in which pumping was resorted to. He

considered that where it was necessary to resort to pumping, for *Mr. Latham.* the sake of a few extra feet, it was better to select a site that would be out of the reach of floods. At Abingdon, however, although pumping was resorted to, the area would still be liable to flood.

The Paper by Mr. Chatterton was a valuable contribution with reference to the cost of works executed in tunnel under difficult circumstances, and it would be well if similar records could be made of other works of that class. The engineers had had to contend with great difficulties, on account of the failure of the contractors; and those who had experience of Town Councils knew how difficult it was to manage some of the members in such a case. At Torquay, the engineers had been able to get out of their difficulty without serious outlay or burden upon the town; and great credit was due to them for the advice they had offered to their clients, and to their clients for adopting that advice. He could not pass over what appeared to him to be an invidious remark in the Paper, contrasting the system used at Torquay, of pumping the low-level sewage, into the high-level intercepting sewer with the method adopted, when a system of tank sewers was in operation. The case of Torquay was exceptional, and the point of discharge was exceptional; but he contended that a system like that at Torquay might be prejudicial to an ordinary seaside town, because a continuous flow of sewage into the sea might prejudicially affect a town, for as the tide flowed at one period of the day in a direction in front of a town, and at another period from it, with a continuous discharge at one period of tidal flow the sewage would be brought back to the town, which was not a desirable state of things. In a tank sewer so constructed that the discharge should take place on the ebb tide, the sewage would be entirely got rid of; to say nothing of the diminution of the cost by reason of not having to pump the low-level sewage. It was stated in the Paper that a tank sewer at one period drove the foul air back into the town. It might be all very well theoretically to say so; but if twice every day the sewers were tide-locked when the subsidence in the sewers took place, a sure mode was provided by which a large volume of fresh air was immediately drawn into them; so that, virtually, the rise and fall of the sewage in a tide-locked sewer acted like a pair of bellows, making the ventilation perfect. Fresh air was drawn in at one period of the day, to be expelled when mixed with a small quantity of foul air from the sewage at another period. The test whether a continuous discharge or a tank sewer was the best mode to be adopted might be found in the

Mr. Latham. results upon public health. Could it be said that in any town that had adopted a tank sewer, that system had been detrimental to health? After all, the test of sanitary works was the influence they exercised on public health. In the report of the Registrar General on the Health Resorts, published in June 1879, it was shown that in Llandudno, where he had adopted a tank sewer, during the previous three months there had not been a single death from any zymotic disease. In that respect Torquay could not compare with it. In Worthing also, where Mr. Rawlinson had adopted a tank sewer, the zymotic death-rate was much lower in the same period than at Torquay. He thought, therefore, that it ought not to be laid down as a general rule that the system of continuous discharge was better than a system in which tank sewers became a requisite part of the system of sewerage.

Mr. J Mr. R. H. HILL contended that Torquay was the resort of invalids, especially those suffering from diseases of the chest; so that there might be a higher death-rate there without the place being unhealthy. He believed there was at one time a panic in the town with regard to the sewage, which on that account was carried as far as Hope's Nose. Many persons thought that it would have been sufficient to take it as far as the Shag Rock; but in deference to public opinion, or public panic, it was thought desirable to go to the expense of taking it to Hope's Nose. He was sure Torquay was a healthy place, although the death-rate, from the cause he had mentioned, might be higher than in some other localities.

Mr. Latham. Mr. LATHAM said he had referred to the zymotic death-rate.

Mr. Rawlinson. Mr. R. RAWLINSON, C.B., desired to make a few remarks with reference to towns having steep gradients, and towns having flat gradients, and the difference in the death-rate of such towns. It would appear from the Registrar General's returns that some towns having steep gradients had a high death-rate; and that some towns with flat gradients had, almost as a rule, a low death-rate. Portsmouth, with its barracks, constantly appeared in the Registrar General's returns as having one of the lowest death-rates. Hull also with its flat site and unventilated sewers frequently stood very low. Liverpool had been notoriously high. It had been his duty for many years to investigate the question. Until recently engineers, in constructing sewers in towns, had not had their attention drawn to the necessity of dividing them into zones, breaking the steep gradients at various contour lines, and stopping the gas at such points, and not permitting it to rise to the upper gradients. Some years ago he held an inquiry at

Leeds, where there had been a large death-rate in the higher and better districts. Returns were produced showing the money expended year by year upon the sewers. The death-rate returns for the same years were also produced, and he pointed out that in proportion as money had been expended in sewerage Leeds the death-rate had been raised, especially in the higher class of houses in the suburbs. There was not a single ventilator on the sewers. The main outlet was a sewer about 6 feet or 7 feet high, and 4 feet or 5 feet wide, running parallel with the river for more than a mile, and having its mouth wide open for the air to blow into it; and, as the house drains were unfortunately connected directly with the sewers, there was nothing to cut off the flow of sewer gas into the houses that had been drained. Hence the high death-rate of the town. He had in his possession a report with regard to the sewers in Whitehall, Downing Street, Great George Street and Victoria Street. He had felt obliged to make complaints of the closets connected with the new buildings in Whitehall, occupied by the Board of Health, and he declared that there was no new public building in Great Britain in a worse sanitary condition. It appeared from the return to which he had alluded, that the sewers were flat-bottomed, flushing was never thought of, and that there was a deposit 15 to 18 inches deep in these sewers. The drains coming from the buildings had flap valves where they entered the sewer, these drains went direct into the buildings without any break, or other means of ventilation, to prevent the inflow of gas. The closet in the corridor leading to his office was occasionally so bad that he could not use it. Sometimes the wind entering from the drain would, he believed, have blown out a lighted candle, and the stench was horrible. Every drain had been tried upon that length of sewer all round Whitehall, and there was not a single instance where the inflow was not direct into the building. That matter ought to be attended to, and nothing was easier than to sever every building from the sewer as perfectly as if it were a mile away. That was what every one inhabiting a dwelling house ought to look to. His own house was in Chelsea, a flat district. It was drained by a pipe sewer down the back. It had never been flushed, and it had, and always would have, deposit. His house drains were close to the sewer, but they were cut off effectually from it, so that any gas passing the drain must rise outside. It could not by any possibility get inside the house. If such things were properly attended to the rates of mortality would be very different. He had reported upon Brighton some time ago, and recommended main sewer ventilation, Mr. Rawlinson.

Mr. Rawlinson and had a few experimental ventilators put down in the flat part of the town. There was then much difference of opinion in the Council, some of the members were determined that they would not have the ventilators, and would choke them up. Since that time Brighton had been obliged to come to the Local Government Board to borrow money for its main sewers, and he had persistently stipulated that no loan should be granted unless the Council gave an undertaking that they would ventilate the sewers. Remonstrances had been sent in, and requests to be relieved from the stipulation, the ventilators being complained of as "nasty, stinking things," the fact being that one or two had been put in improper places, and the whole of the sewers were not fully and properly ventilated. He wished to urge that the health of a district depended, in the first place, upon the proper arrangement of the sewers; in the second place, upon their proper ventilation; and in the third place, on the effectual cutting off of house drains from all direct communication with the sewers.

Sir Joseph
Bazalgette.

Sir JOSEPH BAZALGETTE, C.B., said that the subject under consideration had been frequently discussed by the members with great advantage, and it was one admitting of many different phases and possessing a growing interest in the country. He agreed with Mr. Baldwin Latham that it was undesirable in such discussions to refer to any official inquiry going on elsewhere. The two Papers advocated two almost opposite and distinct principles, each of which had, probably, been properly adapted to the circumstances of the place in question; for he thought that no rules could be laid down for general application, different cases requiring totally different treatment. At Abingdon there were three sets of sewers, one to take the rain-water, another to take the sewage, and a third to carry off the subsoil water; and the sewage, when removed, was used to irrigate land, the effluent water being turned into the river. In the other case there was one sewer of large capacity discharging the functions of the three sewers at Abingdon, carrying away the rainfall, the sewage, and the subsoil water. It might be cheaper, and in many cases it was necessary, to separate the surface water, the subsoil water, and the sewage. Where there was a large rural district, and a small town area, it was impossible to deal with the rain-water, and where the sewage was pumped or treated upon land, it became of the utmost importance to reduce the quantity. But in dealing with a large town where the whole of the sewage could be removed by gravity, or mainly by gravity, the one expense of forming a tunnel outfall saved the great inconvenience of breaking up all the streets in a town, and forming

new connecting drains with every house, and also the expense of constructing sewers through all the streets. Such an outfall sewer would intercept the sewage from the existing sewers at and near to their outfall, and when constructed, its operation was exceedingly simple; no annual expenditure was involved, and the work once done was done for ever. He was surprised to hear Mr. Baldwin Latham say there was an advantage in having what he termed a tank sewer, which was tide-locked, and which could discharge only a few hours at a time. He held it to be a great advantage to have a continuous discharge wherever it could be obtained. If a tank sewer acted as a bellows, it no doubt received pure air when the outlet was free; but when it was closed the sewage rose in it, and the air was pumped out of the sewer into the atmosphere. He quite agreed with what had been said with reference to the danger of having steep sewers rising to a considerable elevation, without precautions being taken to secure their proper ventilation. Such sewers naturally acted as shafts carrying the sewer gases to the higher points. At Torquay and at other places great difficulties and dangers had arisen from want of attention to that point, and he quite agreed with Mr. Rawlinson as to the importance of paying attention to it. The difficulty, however, was one that could be readily overcome, and there were great advantages in having sewers with good falls and steep gradients. He did not agree with what had been said as to the desirability of constructing sewers with insufficient falls to keep them self-cleansing, and having to resort to flushing for the purpose. Flushing by means of flushing-gates, or by storing up the sewage, was, in his opinion, exceedingly unsatisfactory in its results. Water so backed up caused a deposit behind it, and when it was let go, it simply caused a flush for a short distance, raising a bank before it. Thirty years ago one of his predecessors, Mr. John Roe, had constructed a number of flushing gates in the King's Scholars pond sewer, to see the effect of the operation. Every now and then, as Sir Joseph Bazalgette walked along, he came to a hillock of mud, then it was tolerably clear for a short distance, and then there was another hillock, which he had to scramble over, then another hole, and again a hillock. He believed that system of flushing was not successful. At Torquay the different modes of disposing of the sewage had been discussed. Town Councils were generally desirous of adopting any mode that offered a profit, but after considerable investigation of the subject, the authorities at Torquay came to the conclusion, guided to a large extent by the advice of Sir John Hawkshaw, that it was better

Sir Joseph
Bazalgette.

Sir Joseph
Bazalgette.

to face at once the expense of carrying the outfall to a distance and effectually getting rid of the sewage, than to be dabbling with it with a view of making a profit from it. He believed that the works there carried out had given great satisfaction, and that the authorities had never regretted the course they had adopted. There was a good deal of difficulty experienced in conducting the works. The first set of contractors failed, and the works were then re-advertised. The tenders sent in were 50 per cent. beyond Sir Joseph Bazalgette's estimate. Having confidence in his assistant engineers, he advised the Board to undertake the work themselves. It was a serious responsibility, but he was justified in the course he took, and he now stated with pleasure that the successful result of carrying out the work within his estimate was mainly due to the zeal shown by his assistants. The work was one of some difficulty owing to the hardness of the rock through which they had to tunnel for 3 or 4 miles. At one time it was so hard that it damped the ardour of those concerned in the work, and they were disposed to cut it short, but at that time the Ingersoll drill was introduced, which enabled them to double the rate of progress without increasing the cost. He recommended the drill to any engineer having to tunnel through hard rock. It was simple in its mode of operation, and it had the great advantage of supplying air to the men who were engaged in the tunnel. It was a modification of the tool that was employed in the Mont Cenis tunnel. He had seen that drill at work, and he was much struck with the fact that when walking along the tunnel, he felt oppressed for want of fresh air, but when he got into the head of the workings, where many men were employed, the air was pure and fresh, and all were working with freedom. At Torquay the pumping area had been reduced to so small an extent that it was worked by a water-engine, and required no supervision and no regular attendance. Where that could be done either with a gas-engine or a water-engine in the drainage of towns, it was an economical mode of disposing of the sewage.

With reference to Abingdon, he should like to know something more of the way in which the sewage was disposed of, and what was the population contributing to the land that was drained. It was stated in Mr. Gower's Paper that a considerable portion of the town was provided with cesspools. He should also be glad to know something more as to the cost of preparing the land. Such facts, if accurately recorded, would, he thought, prevent a great deal of misunderstanding on the subject. If the leakage in the sewers to which Mr. Baldwin Latham had referred was really

going on, the condition of Abingdon ought to be carefully looked to, because it was obvious that if the subsoil water got into the sewers, the sewage would at times percolate towards the wells; and anything more dangerous than that could hardly be imagined. No doubt Mr. Gower would be able to give some information on the subject, which, he hoped, would clear away the difficulty. Sir Joseph
Bazalgette.

Mr. W. SHELFORD feared that the branch of engineering under Mr. Shelford. discussion had of late years made but little progress. Neither of the Papers appeared to help forward the only true and permanent solution of the sewage problem—the profitable application of sewage to land. In 1871 he had been requested by one of the companies working a precipitation process to go to Torquay and report upon the subject. He did so; and so far from opposing the scheme which Sir Joseph Bazalgette and Mr. Little had laid before the Local Board, he stated publicly that in his opinion the sewage of the town was far too dilute to be treated profitably by any precipitation process, and he strongly urged his clients to have nothing to do with it. At that time he was struck by what he had heard of the offensive condition of the bay, owing to the discharge of the sewage by the existing outfall, and it occurred to him then, as it had often since, that the subject had not received sufficient consideration and required elucidation. Mr. Chatterton in his Paper said: “The tidal scour at the point of outfall is so strong that the rocks on the foreshore do not exhibit any trace of sewage.” From this he gathered that Mr. Chatterton was imbued with the ordinarily received notion that sewage discharged in a tidal stream would be removed if the scour were considerable. He was not sure that that was the cause of the improvement that had occurred at Torquay. He thought engineers designing outfall sewers had hitherto paid too little regard to the matter in suspension in the water into which sewers were discharged. His opinion, which he believed was supported by that of some of the highest authorities, was that sewage consisted of organic and mineral matter; that the organic matter, being for the most part flocculent, became entangled with a certain quantity of mineral matter; and that the net result was that the mineral matter was sensibly, although imperfectly, precipitated by reason of the greater bulk attained by the entanglement. Now that was nothing more nor less than what occurred in the ordinary precipitation process. It was a misnomer to call the precipitation process a chemical process; it was a mechanical process; the chemical agents were introduced merely for the purpose of producing an aggregation of particles, and those particles when brought together went to the bottom from the

Mr. Shelford. mechanical action of gravity by reason of their greater bulk. This might be illustrated by a piece of China clay, which, if put in a lump into the water, went to the bottom immediately, but if it were finely comminuted it took a long time to settle. He thought it might generally be said that sewage matter in suspension consisted of organic matter and mineral matter in the proportions of 2 to 1; consequently if the detritus or mineral matter in the sewage was entangled with a small portion of the organic matter, and was more or less precipitated, it followed that a large quantity of organic matter was left to float in the waters into which the sewers discharged. If those waters were free from matters in suspension and were clear, the organic matter would flow away and in all probability be dissipated, even although the waters were moving at a low velocity. But if the waters were charged with detritus or matter in suspension, then that process of imperfect precipitation, which occurred with the mineral matter, would take place when the organic matter of the sewage came in contact with the mineral matter in the waters. He put that forward as a suggestion, for it seemed to him that in that way, rather than in the mere difference in velocity, the benefit which had been derived from the alteration of the outfall at Torquay might be explained. His contention was that though sewage might be discharged with impunity into clear water, it could not be discharged into water already loaded with suspended matter without causing a tendency to deposit. It was a point worthy of the consideration of engineers since it had a wide application.

Mr. Bazalgette. Mr. NORMAN BAZALGETTE called attention to the statements in Mr. Gower's Paper that "the Corporation of Abingdon, being under notice from the Conservators of the Thames to desist from discharging sewage into the river, called upon Mr. Bailey Denton, M. Inst. C.E., in the autumn of 1874, to advise them as to the best means of sewerage the town of Abingdon," and that "samples of the effluent water . . . were stated to be less contaminated than the water from some of the wells in use in the town;" and asked Mr. Gower how, in view of those statements, he could explain a paragraph that had recently appeared in the papers, to the effect that proceedings had been taken by the Thames Conservators against the Town Council, for allowing an impure effluent to pass from their sewage farm into the river Thames. It had been stated that the execution of the works at Torquay had involved a rate of about 7*d.* in the pound on the present rateable value. He wished to ask Mr. Gower what was the rate involved by the works at Abingdon. It would be the height of absurdity to suggest that

Abingdon should adopt a seaboard system of sewerage. At the same time, it was open for Torquay to adopt a system of intermittent downward filtration, and he should be glad to have some information that would enable him to form an opinion as to the comparative economy of towns situated on the sea coast availing themselves of their natural outfall, or disposing of their sewage upon land. Mr. Baldwin Latham had referred to what he called an invidious remark by Mr. Chatterton, to the effect that the flow of sewage was continuous, so that sewer-gas was not generated to anything like the same extent as in the tank sewers, and he referred to the zymotic death-rates of Torquay and Llandudno to disprove this view. He was not prepared to state what the zymotic death-rate at Torquay was, but it formed a large proportion of the total death-rate of a place, and the total death-rate was no test of the health of a town; for, as had already been pointed out, in proportion to the salubrity of a place, invalids resorted to it, often *in extremis*, thus helping to swell the death-rate. The very fact that a place was healthy often caused it to exhibit the highest death-rate.

Mr. G. F. DEACON said he had had considerable experience of tide-locked sewers, and that the strong tendency to silt up was a constant source of difficulty. Such sewers were usually made of the same sectional area as would have been adopted if they had not been tide-locked; and silting took place until the sectional area was reduced to the extent necessary to gorge the sewer, create an artificial head, and thus to increase the velocity at low water to the scouring point. It was true that during heavy rainfall this silting tended to cause flooding by backwater, and without mature consideration it would appear that any reduction of the sectional area of such a sewer would have the same tendency. If, however, the sectional area had been in the first instance made but little greater than the effective area of the silted sewer, the silting would never have taken place, and the reduced sewer would have discharged more water than the original silted sewer. He had applied these considerations in practice. He had reduced the tide-locked portion of a large outfall sewer to between one-half and one-third of its full section, with the result that silting was entirely obviated, and that greater discharging power was obtained. He believed there were few cases in which reservoir sewers were to be preferred to constantly discharging so-called tide-locked outfalls when properly designed. The death-rate of Liverpool had been referred to in the course of the discussion. Long ago it was excessive; but it had been for some time rather below what might be expected. Mr. Rawlinson

Mr. Deacon. had stated that in hilly towns the death-rate was generally larger than in flat towns. There was only one town in England, viz., Manchester, which for population and industry was comparable with Liverpool. Liverpool was a hilly town; Manchester was a flat town. Liverpool had a density of population of 103·3 per acre; Manchester had only 84·3 per acre. *Cæteris paribus*, therefore, Liverpool should have the higher death-rate, but the mean figures for the last decade were:—Liverpool, 29·2 deaths per 1,000 persons living; Manchester, 29·3 deaths. But the death-rate from those zymotic diseases, which were generally believed to be directly influenced by sanitary improvements,¹ showed a more remarkable result in favour of Liverpool. Having had occasion to work this out for the years 1870 to the first quarter of 1878 inclusive, he was enabled to give the following results. The years 1870 to 1874 inclusive were those immediately preceding certain improvements in the sewers, and the prevention of the waste of water and restoration of constant supply. These were, therefore, adopted for comparison with the succeeding years. As compared with these years, the zymotic death-rate in Liverpool for the succeeding years had diminished 46 per cent., while in the corresponding period the mean diminution in the other seventeen English towns,² specially enumerated in the Registrar General's report, was only 23 per cent. The weather of the latter group of years might be credited with much of this change, but the excess of the change in Liverpool was fairly attributable to other causes. The diminution in the Liverpool death-rate was still greater if ten years back from 1874 instead of five were taken. Again, in only seven of the seventeen towns already referred to was the zymotic death-rate for the latter period lower than in Liverpool, though the density of the Liverpool population was three times as great as the mean of the other towns. It was, therefore, evident that the charge of exceptional unhealthiness could not be properly made against Liverpool; but that, on the contrary, so far, at least, as concerned those diseases upon which such an investigation should be based, Liverpool compared favourably with other large towns. With reference to the Ingersoll rock drill, he could speak of its advantages in the case of a heading $\frac{1}{2}$ mile long, which he had con-

¹ The zymotic diseases upon which these remarks are based were scarlet fever, diphtheria, fever, and diarrhoea.

² The seventeen towns enumerated were London, Portsmouth, Norwich, Bristol, Wolverhampton, Birmingham, Leicester, Nottingham, Manchester, Salford, Oldham, Bradford, Leeds, Sheffield, Hull, Sunderland, and Newcastle-upon-Tyne.

structed a short time since. The rate of progress was increased about Mr. Deacon three times, as compared with hand-labour, by means of the drill.

Mr. R. RAWLINSON observed that before Mr. Deacon had charge of Mr. Rawlinson the Liverpool sewers, they were, as a rule, unventilated. Mr. Rawlinson had urged upon him in the strongest terms the necessity of beginning at once to ventilate the Liverpool sewers upon his appointment, and he believed that he had done so.

Mr. DEACON said that the Liverpool sewers had been ventilated during his time, but they were unventilated before.

Sir JOHN COODE remarked that he was the first engineer to use the Ingersoll rock drill in this country, and he could confirm the statement of Mr. Deacon that it would do three times the work done by hand. He would supplement this, however, by adding that foot for foot of length of holes drilled, the work would be done at one-half the cost. Sir John
Coode.

Mr. J. N. DOUGLASS asked Mr. Chatterton to give the amount of coal consumed per hour in working the Ingersoll rock-drill. It was stated that the boiler power was equal to 22 HP., but that was a vague statement as to the cost of the work. Before employing a rock-drill he had inquired into the relative merits of the Ingersoll and other drills. He considered the "Eclipse" drill, which had been introduced just before the Paris Exhibition, was a great advance. In the Ingersoll drill a tappet valve was used, which was not a suitable valve for rapid motions of that description in machinery going one thousand strokes per minute. In the other case there was a separate self-acting valve on the top of the cylinder; the compressed air or steam was perfectly cushioned at the end of each stroke; and one thousand strokes per minute could be made in any direction, with very slight vibration. The steam was admitted at each end of the piston, and when the latter was near the end of the stroke the slide valve was reversed by the compressed air or steam, without any additional mechanism. He had one of the drills continuously in operation all last summer, and it needed no repairs whatever. He understood that the Ingersoll drill required considerable repairs, as might be anticipated, at the tappet valves. Hitherto there had been little information as to the application of the rock-drill to works like those carried on at Torquay, and the members were therefore much indebted to Mr. Chatterton for the information he had given.

Mr. C. F. GOWER said in reply that the cost of the preparation of the land at Abingdon for wide irrigation was £70 per acre, and for intermittent filtration £85 per acre. The ordinary level of the water in the river was 162 feet above Ordnance datum, but it

Mr. Gower.

sometimes went down to 161 feet. The highest part of the land was 168 feet, leaving a difference of 6 feet; the lowest part was 166 feet, leaving a difference of 4 feet available for under-drainage. 167 feet was the highest known level reached by flood in the town; at the land it seldom reached 165 feet, and the time it remained at that level was inconsiderable. From the pumping station there were delivery conduits on to the land consisting, for the first portion, of 15-inch pipes, and further on of 12-inch pipes. They were laid underground and connected together with chambers for the distribution of the sewage. There were $6\frac{1}{2}$ acres laid out for intermittent filtration, and $17\frac{1}{2}$ acres for wide irrigation, the former being laid out almost on a dead level in ridges and furrows were of special use at times when the tenant did not require to employ the sewage for his own purposes on other parts of the farm. The difference in the cost of preparing land for filtration and for irrigation did not exceed from £10 to £15 an acre. For wide irrigation the land was only turned up with the plough after having been roughly levelled; while in the filtration areas the work was done partly with the plough and finished with the spade. All the sewers in the town were thoroughly ventilated by manholes or lampholes not more than 50 or 60 yards apart; there was but little offensive effluvia at any of them, except in hot weather, when it was almost impossible entirely to prevent it. Mr. Baldwin Latham had referred to the pumping, and calculated from the power of the engines the quantity of sewage delivered on to the land at 30 gallons per head per day. The engines, however, did not always work up to 400 gallons per minute, nor did they always work eight hours, sometimes not more than six or seven hours in dry weather. There was no doubt, however, that the water was in excess at Abingdon, due, he believed, in part to the influx of the subsoil water into the house-connections. Some of those house-connections joined the main sewer, almost at the level of the Thames. The subsoil water-level in the town itself of course rose gradually from the Thames, so that a considerable proportion of the sewers and house-connections were under permanent water-level. As to the latter, whatever supervision was exercised, it was almost impossible to see that all of them were perfectly water-tight, and he had no doubt that a certain amount of subsoil water got into the sewers in this way, but he did not think it would reach 50 or at most 100 gallons per minute even in times of flood. The amount pumped out during the construction of the works was 600 gallons per minute, so that unless the sewers in the public streets had been made

as watertight as practicable, it would have been impossible to deal with it in the way that had been done. The reservoir sewer could be emptied in about five hours by one engine working at full speed, and was always emptied before 5 P.M. except in floods. This also proved that the influx of subsoil water was not great. He agreed with Sir Joseph Bazalgette as to the separation of surface waters. It was not possible to lay down a rule that would be applicable to all towns; but he thought that the sewers in Abingdon would have cost more if the existing drains had not been used for surface water, as they would have had to have been made larger. In many towns where there was an outfall sewer of 2 or 3 miles in length, and where, as was often the case, there was a river or stream running through the town, he believed it would be cheaper to carry the surface water by independent conduits down the line of steepest inclination into that river or stream. At Barnsley, where he had been associated with Mr. Bailey Denton, that had been recommended, and was, he believed, being carried out, for the amount of surface water there coming down into the sewer would increase the volume of sewage, which was about 1 million gallons a day, to 20 or 30 millions after heavy rains, an amount impossible to deal with upon the land prepared for the sewage. Sir Joseph Bazalgette had made some remarks about the subsoil water getting into the sewers at Abingdon. This might get into the house-connections, but he did not believe it got into the sewers. The lowering of the subsoil water in the wells was not due to the sewers, but to the drains which had been laid beneath the sewers in some parts of the town. The subsoil water-level was formerly kept up by the river Ock, at about 6 feet above the level of the Thames. In the neighbourhood of Ock Street and other streets in Abingdon, in wet weather, the water rose in the basements of the houses almost to the surface of the ground, and was a source of injury to the health of the inhabitants. It had now been reduced, and he believed that the subsoil water would never rise to its former level. The quantity of land purchased by the Abingdon corporation was 48 acres; but only 34 acres had been laid out, and the remainder, possibly, would never be laid out. The cost of the 48 acres, including all expenses, was, in round numbers, £7,500; the cost of the laying out was £2,500, making a total of £10,000. The land was let to a tenant at £4 10s. per acre, a rate which would produce $2\frac{1}{4}$ per cent. on the above outlay. The amount represented a reduction from the rates of about $3\frac{1}{2}d.$ in the pound. The total cost of the land, sewerage works, and every expense, including engineers' charges,

Mr. Gower. had amounted to £23,000, equal to a rate of 1s. 7d. in the pound on the rateable value. He exhibited samples of the effluent, of the sewage, and of the water taken from the centre of the river. These samples showed the difference between the filthy outflow formerly sent into the Thames from the Abingdon sewers, and what was now flowing in as effluent water from the sewage farm. The depth of the drains varied from 6 to 4 feet.

Mr. Chatter-
ton.

Mr. CHATTERTON observed in reply upon the discussion that he thought Mr. Shelford had not understood his remarks as to the effect of the sewage at the outfall. It appeared to him that the success of the Torquay drainage system depended on whether at the point of discharge any nuisance had grown up or was likely to be created. At present there certainly was not a nuisance of any sort at the outfall, and it must be evident that such a thing was not likely to occur. Mr. Shelford had confused the effect of sewage flowing into a river highly charged with matter in suspension, and of sewage flowing into the open sea. With regard to the original outfall at Torquay, when the sewage was discharged into the bay at the west of the harbour, there was no tide to take it away. The tide went round in a small eddy, and the sewage promoted the growth of the seaweed, which in hot weather was very offensive. Since the sewage had been removed to Hope's Nose the seaweed had not accumulated to the same extent. With regard to the theory of the light organic matter of the sewage being taken up by the suspended matter in the water, he did not think that such suspended matter existed at Hope's Nose. He thought Mr. Shelford alluded to what had been called the "marriage theory," but that could not be applicable at the outfall at Torquay. The scour there was strong, and it was evident that the set of the tide must take the sewage either one way or the other out to sea. The dilution that the sewage underwent was enormous. He agreed with Mr. Douglass's remarks as to the rock-drill. He did not contend that the Ingersoll drill was the best that had been or ever would be constructed, as improvements in machines of the sort were being made every day. The drill referred to in his Paper was that to which Mr. Douglass had alluded—the "Eclipse." It was, he believed, an excellent drill, and had not the defects of the Ingersoll with regard to tappet valves. The repairs required by the Ingersoll drill were trifling. Six drills were employed, and there was only one fitter to look after them. He had always a couple of drills in hand in the event of repairs being needed. All the parts required could be got ready made. A drill might be completely broken up, and in four or five

days it could be repaired and put to work again. The expense of the working parts was small. He was afraid he could not give the required information as to the steam-power compared with the actual power obtained for drilling purposes. There were so many ways in which power was lost, that the effective power for driving holes in the rock was small compared with the amount that should be theoretically obtained from the quantity of coal consumed. They had not been able, like Sir John Coode, to get three times the amount of work done by the drill as compared with hand-labour, but nearly that amount; nor were they able to reduce the cost by one half. The case, however, was an exceptional one, and the cost could not be compared when the modes of application were so various. As to the explosives used, where a tunnel had to be driven in hard rock, nothing was to be compared to dynamite. Some years ago the miners in that part of the country were afraid of it, but now they carried it about in their trousers-pockets, and took it with them wherever they went. The actual quantity of water used by the water-pressure engines in 1879 was 6,593,000 gallons. At 4d. per 1,000 gallons this would amount to about £110 per annum, which was a small sum for pumping the sewage of 2,000 people about 13 feet high. Had a system been carried out at Torquay by which the sewage was removed by gravitation and none of it pumped, the main sewer must have been constructed 14 feet lower than at present; it would have been a tide-locked sewer, and the cost of constructing such a length of tunnel below the level of high water would have been very serious.

Correspondence.

Mr. HENRY J. COLES remarked that the use of piston valves, Mr. Coles. actuated directly by air or by steam, for working rock-drills, was introduced into this country in 1863 by Mr. Edwards Crease. Since then many attempts had been made to utilize this mode of regulating the ingress and egress of the air into and from the cylinder, but they had generally ended in failure. In the early part of 1873 he was connected with a series of experiments of an exhaustive nature, which were carried out by Mr. Darlington, a mining engineer of large experience, to ascertain the practical value of this description of valve for rock-drills; and valves of all forms and designs were made for the purpose. Ultimately, although working results of a fair character were obtained, yet the general experience gained was such as to lead to Mr. Darlington