Mr. RAWLINSON admitted, that his paper might be considered loose and discursive, but he had written it chiefly for the purpose of eliciting opinions on a question of great social importance, and he was ready, in answering the questions put to him, to afford any additional information in his power. It might be said, that there were some positions unduly assumed; if so, they would be overthrown, and the erroneous conclusions would be pointed out.

Perhaps the best method of opening the discussion was to state a few facts, in connexion with the drainage of a town, where, from local circumstances, only earthenware pipes had been used. He alluded to the town of Hitchen, where upwards of 60,000 feet of pipe sewers, from 20 inches down to 4 inches diameter, and 2 feet 6 inches long each, had been in action for four months, with perfect success; the average depth below the surface was 8 feet, and the outlet of the main sewer, which was 5000 feet in length, and only 20 inches in diameter, was laid, in part, beneath the bed of the river, at an inclination of one in eight hundred. This was designed for the sewerage of one thousand houses, of which only two hundred were at present connected, and for eleven hundred acres of urban and suburban drainage. He admitted, that some of the pipes, laid to a pumping engine, had been broken, from being laid in bad ground, but after being relaid in wooden troughs, no further fractures ensued. He was aware, that the system of pipe sewerage had been, and must be, modified in practice, to adapt it to certain localities; that in a rocky uneven bed, improperly loaded pipes would break, and if of large dimensions, they were very liable to be split longitudinally, or be fractured transversely, as it was very difficult to get them accurately made and burned, and the false bearing at the sockets caused breakage. If in the case of Hitchen, the rule laid down in Mr. Roe's tables had been followed, the outlet must have been 5 feet diameter, instead of 20 inches diameter.

No attempt had been made to divert the natural flow of the surface-water; the street gullies being connected directly with the pipe sewers. In this, as in the arrangements for all towns, an engineer must modify his practice to meet local circumstances. He was satisfied with the general results at Hitchen, and as the

earthenware pipes, supplied by Messrs. Doulton, and put together with clay joints, both of the full, and half socket forms, had supported an internal pressure of a head of 4 feet, there was not much reason to find fault.

Pipe sewers had been in use at Manchester, for seven, or eight years, and Mr. Francis had expressed his satisfaction with the result; the only difficulties had arisen from a few cases of the choking of some of the smaller-sized pipes. In that instance, where a great extent of oval pipe drains, 25 inches by 18 inches, had been laid, with success, it should be explained, that they were 2½ to 3 inches in thickness, and were laid with great care in strong ground. The maximum size at which, even these thick pipes were preferable to brick sewers, was 30 inches by 24 inches. The smallest size made for small streets was 12 inches by 9 inches, and for foul water 6 inches by 4 inches. The largest area draining into a pipe sewer was about fifty acres.

On the authority of Mr. Harper, and quoting from a communication relative to some houses in Back King-street, Bury, he stated, that though they had formerly been in so bad a state as to be untenantable, in consequence of fever constantly raging there, they had been rendered perfectly habitable, by being drained with earthenware pipes, and that the experiment had been quite successful, as regarded the general amelioration of the district.

Mr. G. Donaldson said it was generally admitted, that partial failures had occurred in almost every locality where earthenware pipes had been used; the causes were, fracture of the pipes in unsound ground, and choking up, wherever there was not a rapid fall. Now the frequent occurrence of these fractures would render the pipe system eventually more expensive, than that of good brick sewers, and the annoyance and inconvenience to the public, from continually opening the streets to discover the stoppages and clean out the pipes, would become unbearable. Common sense and practical experience dictated the course of having good brick main sewers, and well-burnt earthen pipe drains, of sufficient diameter leading into them, from the houses. By this means such failures as had occurred at Croydon, and the accompanying annoyances and ill effects on

the health of the inhabitants, would be avoided. He had visited Croydon and satisfied himself, as to the correctness of the statement, that in several places the pipe sewers were crushed, and the workmen, in charge of the repairs, stated, that several thousand feet of the larger pipe sewers were also fractured; indeed it was difficult to say how much remained in a fit state for conveying away the sewage. In several instances he observed, that a covering of clay was put, and half-brick arches were turned over the pipes, to preserve them from the pressure of the earth; in almost all cases, the pipes were split from end to end, and the clerk of the works, on the spot, informed him, that the broken pipes were very tender and friable, when first taken up out of the trenches, but on being dried by exposure to the air the substance became hard and comparatively strong again. Now it did appear to be false economy to push, to excess, the use of a system, which, if applied with judgment, was calculated to be extremely useful.

Mr. RAWLINSON hoped, that as he had not been professionally engaged at Croydon, he should not be held, even remotely, responsible for any failures there. He had been informed, that the pipes used there were thin and of bad quality. He quite concurred in the proposition, that if pipe sewers could not be laid so as to be permanent, and to keep themselves clear without being opened, to do away with stoppages, it would be better to abandon them. Experience had enabled him to arrive at some conclusions, as to the extent to which they might be used, and he had decided never again to lay down socket pipes larger than 12 inches diameter, especially if approaching a depth of 10 feet. He had experienced considerable difficulty with socket joints, and did not believe it was possible to lay them, so as to avoid occasional failures, if the diameter exceeded 12 inches. He preferred "butt" joints; and he thought that sewers constructed of hollow bricks, with radiating joints, would be great improvements on the ordinary system; in good ground the half brick would be a sufficient thickness, and in bad ground the headers would impart strength, whilst the lower range of perforations would serve as land-drains.

Mr. G. DONALDSON disclaimed any intention of connecting Mr. Rawlinson's name with the sewerage works at Croydon; he spoke of the failures there from personal inspection, and

from information obtained on the spot, and as instances of the result of the injudicious use of pipe sewers.[1]

Lord Ebrington, M.P., said it was well known, that he had felt much interest in the important question of the sewerage of towns, but of course he could only look at general results, and leave to professional men the discussion of the means to be employed. Taking into consideration the great weight of the cylinder of water, contained in a large pipe sewer, when full, and the tendency, whenever there had been any carelessness in laying, to allow all that weight to rest upon the projecting sockets and joints, he conceived there would be considerable practical difficulty in laying large pottery pipes so accurately as to avoid fracture, and he had been surprised to observe, at St. Thomas-Exeter, how satisfactory the result had been, although the soil was not favourable, the supply of water was inadequate, and the outfall was bad; yet, after being at work for nine months, the pipe sewers appeared to be clear from deposit.[2] In that locality, a pipe sewer, 18 inches diameter, had been laid, where a more expensive brick construction would never have been placed at all. There were many instances in the metropolis of large brick sewers being crushed, and he apprehended, that in the construction of sewers through the made ground of streets, it was impossible to guard against such contingencies, therefore the occasional fracture of the pottery pipes should not be used as an argument for preventing their use, wherever practice showed they might be advantageously employed; and he hoped the result of the discussion of the question here, and elsewhere, would be to induce the introduction to the metropolis of a complete system of sewers, by which the drainage of the houses and streets would be more cheaply and effectually accomplished than at present.

[1] In the "Reports by Neil Arnott, M.D., and T. Page, C.E., on the Prevalence of Disease at Croydon, and as to the Plan of Sewerage," 4to. 1853, it is said—"We regret to state, that the result of our investigations, is a conviction, that the operations of the plan for the sewerage have been influential in producing the disease, and that the absence of proper provisions in that plan, for some of the general requirements, in town drainage, and the especial requirements of Croydon, has been productive of misfortune to the inhabitants."—[Editor.]

[2] For an account of the actual state of the sewerage of St. Thomas-Exeter see the "Report to the Metropolitan Commission of Sewers, by Mr. Bazalgette February, 1854;" Page 30.—[Editor.]

Mr. RAWLINSON, in answer to questions, stated, that generally he would prefer constructing a brick sewer 20 inches diameter, to using a pipe sewer of that size, and he believed it would be cheaper. At Ormskirk, earthenware pipes, 20 inches diameter, would have cost nine shillings and sixpence per yard, where a brick sewer, 30 inches diameter, cost six shillings and six pence per yard. At Hitchen, he could not use brick drains, because it was necessary to lay only short lengths at a time, and under circumstances of difficulty, he had, therefore, in that case, waived his preference for a brick sewer above a certain size. The pipe sewer was more expensive, but it had been adopted, because a length had to be laid beneath the bed of the river, and pipes were more convenient for that locality; there was not, however, any heavy pressure upon them. With another outfall he should probably have used a brick sewer, 3 feet diameter. He objected to the system of sending men into sewers to cleanse them, and thought they should be so constructed as not to require manual labour for clearing them.

The dimensions of pipes could only be decided with reference to the nature of the material of which they were made, and the mode of manufacture. The limit of thickness for good London-made pipes was 1 inch, but those used at Manchester were 2 inches to 2½ inches thick. He believed the failures must be generally attributed to the bad material, or the careless manufacture of the pipes; some of those at Croydon were, he believed, only five-eighths inch thick, and many lengths had been laid in headings alternating with trenches, so that there were very unequal degrees of pressure upon these thin pipes, and hence the failures. The real limit of thickness was that which could be thoroughly and equally burned in the kiln, without employing such a temperature as would distort the clay. The pipes at Manchester were made of fire-clay, generally of an oval form, and upwards of 2 inches thick; which could be completely burned through. Whereas the clay used in London required considerable admixture of extraneous substances and great working, to produce pipes of such quality as were now understood to be manufactured by the best makers.

Mr. HAYWOOD said he was glad to perceive, that the propriety of an engineer exercising his own judgment in matters of sewerage, was admitted by the Author of the paper; he had

carefully perused a number of reports emanating from the Board of Health, and they certainly left on his mind, an impression, that the empirical rules therein laid down, were required to be implicitly followed; it was satisfactory to find that this was an erroneous supposition.

The real question at issue was that of size, which would also determine that of the material to be employed, in the construction of the sewers, as there was a manufacturing limit to the dimensions of pipes, which, of course, did not exist with regard to brick structures. Up to a certain size pipes might be advantageously employed, but for the main sewers of towns, larger dimensions and other materials must be adopted. He did not concur in the principle enunciated in the Paper, which was to the effect, that the sewers of towns should not be adapted to receive excessive flood-waters, or to provide for carrying off a heavy rainfall, but that such water should pass off, over the surface, as before the construction of the sewers. It must, however, be remembered, that the condition of a town, when sewered, was very different from that of its site, previous to the building of the houses and forming the streets; artificial levels had been created, and a rainfall, or flood, which might previously have passed off innocuously, could not do so, under the altered circumstances, unless the sewers were of sufficient capacity to receive and convey away the excessive rainfall. If they were only of limited capacity, the effect would be, that as soon as they became charged and ran full bore, the excess of water, would rise in the gullies, to the level of the street, which would be flooded,—the sewers would be under considerable pressure, —the water would be forced back, up the house drains, and the basements of the houses would be inundated. It was, therefore, evidently necessary to provide for large rainfalls; and he contended, that, as a general rule, it was a better system to convey all the surface drainage, with the house sewerage, into one good sewer, rather than into two, or more pipe sewers, as in the cases of the separation of surface water from house drainage, which, he considered, it was almost impracticable to effect in a satisfactory manner.

As to the apprehended danger to the adjoining houses from the construction of large sewers, that was not a valid objection, as it was only a case of degree of width of the trench,—in both

cases the depth must be very nearly identical, and the skill of the engineer ought to enable him to guard against any casualties arising from the excavation. Mr. Haywood had laid many miles of sewers and drains, through very narrow spaces, without doing any injury to the houses.

It would only lead to error to quote the Paris system of sewers, as an argument for separating the surface-water from the house drainage; erroneous ideas prevailed as to the condition of the Paris sewerage; formerly there was an entire prohibition to any fæcal matter going into the sewers, and that prohibition existed legally to the present time; but, by degrees, exceptions were made in favour of the prisons, the barracks, the hospitals, the markets, and other public buildings, all of which had for many years communicated directly with the sewers, which debouched in the Seine, in the middle of the city. Between the Pont de Jena and the Pont de Bercy, there were the outlets of seventy sewers, discharging into the Seine. Probably all of them did not convey fæcal matters; but that a large number did so, was clearly evidenced, by the streams of sewage, running on the open shore, between the mouths of the sewers and the water-line, during the summer, when the river was low; the effluvium was intolerable in hot weather. Dr. Parent Duchatelet[1] gave copious details of the state of the sewerage of Paris, and the system adopted there, which were not only interesting in themselves, but, as proceeding from so high an authority, might be used to contravene many of the erroneous statements so industriously promulgated at the present time.

The construction of sewers generally should be looked at, with a view to the ultimate total cost; and he must contend, that if a system of town sewers was only laid down, and proportioned in size, to the house drainage-water and sullage, and entirely upon what had been very happily designated "the telescopic system," instead of the leading sewers being made large enough to carry away the storm waters, and also to admit workmen to cleanse them, it would be eventually found, that a serious and very expensive error had been committed.

Mr. Haywood was not opposed to the use of pipe sewers in

[1] Vide "Hygiène Publique," par A. J. B. Parent Duchatelet, 8vo. Paris, 1836.

proper situations, and under certain limitation, but he was decidedly opposed to the abuse of substituting them for brick sewers, in positions for which the latter only were adapted. He made extensive use of pipe drains for houses, taking care that they were never below 4 inches in diameter; he had, also, within the last few years, laid more than two miles of pipe sewers, within the City, and he still continued to use them, where he thought they could be employed with safety; but he was still of opinion, that a system of pipe sewers was open to serious objections, the principal of which was the liability to stoppage from deposit; in the pipe sewers, he had laid, there had been only three cases of stoppage,—the first from some deposited rubbish, the next from some fish cleanings, and the third from a breakage of the pipe; none of these would have occasioned the slightest inconvenience, if the sewers had been of larger dimensions. He did not admit, that the experience of two, or three years in provincial towns, afforded any criterion of the probable success of their application to the sewerage of the metropolis, where the conditions were as totally different as the scale of the work to be done. With a new system under trial, or, it might be said, almost under experiment, the attention of the engineer would be unremitting, but when that ceased, or diminished, the stoppages from accretion, and from other causes, would be commencing. The great objection, against pipe sewers was, that the only method of discovering the precise locality of a stoppage was by examination of the neighbouring house drains, to enable a guess to be made as to the spot; then it was necessary to open the street, to dig down to the pipes, and take up a length, and if, fortunately, the accretion was within reach of a rod, it might be removed, but if not, it became requisite to open other places, until the stoppage was discovered and remedied. Now with main sewers, sufficiently large to allow a man to pass along, the precise spot of the stoppage was discovered, without delay, or expense, or any annoyance to the neighbourhood. It was admitted, that it was not desirable to send men up sewers, and even that accidents had occurred; but neither was it pleasant for a miner to be obliged to go daily down a pit, where there was generally more, or less, of inflammable air; society was, however, so constituted as to demand for its necessities, or its luxuries,

much that was not pleasant, and, in the case of sewers, if they were ventilated and maintained under such a system as would enable them to be traversed at given periods, so as to prevent accumulation, there was less objection to the labour, than might be imagined, and, even with a considerable first outlay, it would eventually be found a cheaper system, to have sewers of adequate dimensions and certain action, than pipes of restricted dimensions, if their action produced only uncertain results.

In practice he found, that pipes once removed, or broken into, could rarely be relied on again, as it was difficult to make good the joints, and to maintain the original level; especially where the gradient was slight, and the accretions were, therefore, likely to take place again. Where there was not a rapid fall, a pipe of 4 inches diameter could not evidently afford any margin for accumulation, and in cases of limited fall, he had almost invariably found a tendency towards stoppage, where there was not a very considerable flow of water. It was admitted, that the pipes required great care in laying,—that in many cases it was requisite to bed them in cradles, to prevent their being broken,—and that it was requisite to establish ventilation for them, although it had been originally stated, that it was not necessary.

In the published accounts of works, at various provincial towns, there appeared some good illustrations of the practice of experienced engineers who had devoted time and attention to the subject. At Liverpool, Mr. Newlands (Assoc. Inst. C. E.) the Borough Engineer, had only used pipe sewers to a limited extent, and under circumstances apparently precisely analogous to the practice hitherto adopted in the metropolis.

In three years, beginning in 1847, and ending December 1850, there had been constructed at Liverpool:—

	Ft.	In.		Lineal Yards.
Brick sewers	6	0	high	1,103
,,	4	6	,,	3,467
,,	3	6	,,	6,594
,,	3	0	,,	11,493
,,	2	9	,,	6,749
			Total	29,406
Pipe drains 15 inches diameter				252
,,	12	,,	,,	335
			Total	587

These figures indicated significantly Mr. Newland's opinion, and it was understood, that he still used pipe sewers, only in exceptional positions, where he was convinced there would be little liability to stoppage.

At Leeds, Mr. J. W. Leather (M. Inst. C. E.), the Engineer for the town, only used pipe sewers for courts and minor streets, and then almost invariably in positions where they could be connected directly with sewers, up which men could pass.[1]

At Birmingham, in the extensive and well-conducted system of sewerage, under the control of Mr. J. Pigott Smith (Assoc. Inst. C.E.), the Borough Engineer, pipe sewers had been tried and were only used to a very limited extent. The practical experience of large towns only had been cited, because, as had been repeatedly stated, the "telescopic system," of pipe sewers, which might, under favourable circumstances, suffice for a small country town, could not form a precedent for the sewerage of the metropolis, which, at last, was the main consideration.

It was necessary to allude to the opinions of Mr. John Roe (Assoc. Inst. C.E.), who, for a very lengthened period, held the post of Surveyor of the Holborn and Finsbury district of sewers. His Reports showed, that the cost of cleansing small drains, was greater, than the expense of constructing an efficient sewer; and that no amount of water sufficed to cleanse a small pipe drain, if it once became stopped; but that in a large sewer, flushing and other means could be effectually adopted, without any inconvenience being experienced on the surface. Mr. Haywood then read the following extracts from Mr. Roe's Reports:[2]—

"*January* 29, 1847.

"The desire of some persons to effect a further saving has led to the advocacy of drains, or small sewers to be placed in streets, or roads without discrimination. Others advocate two lines of small sewers, or pipes, one on each side of a street, to receive the drainage; but as two such small sewers would not carry off the surface drainage, in all cases, other parties con-

[1] The "Report by Dr. Arnott and Mr. Page on the Prevalence of Disease at Croydon" gives an interesting comparison between the pipe sewers used at Leeds and at Croydon. Pages 41 and 42.—EDITOR.

[2] Vide "Report to the Commissioners of Sewers for the Holborn and Finsbury District," 8vo, London, 1847, page 6.

sider, that one line of sewer should be formed for the surface, and another for the house drainage. In practice this would be found unnecessary, as regards any advantage to the sewer water for manure, and as regards expense, it would, besides causing an immediate extra outlay, entail a perpetual annoyance and charge. A fact that will serve to illustrate this, is that of the new sewer lately built in Hoxton Town. On each side of Hoxton there was a line of small sewers in front of the houses. The cleansing of these and other small sewers have cost, on an average, one shilling and threepence per foot lineal, each time of cleansing. Taking fifteen such sewers, the average time of cleansing has been four years and a half, and reckoning the first cost of the two small sewers, with the cleansing, the cost, in about twenty years, would have amounted to the expense of constructing an efficient sewer."

"This Commission has caused a new sewer to be built in Hoxton Town, which will require no repairs for more than a century. The saving to the public, therefore, by constructing an adequate sewer, and thereby doing away with the two inefficient ones, will be double the amount that the new sewer has cost."——

At page 7 of the same Report it was said, "After many years' experience your Surveyor begs to state, that except a sewer has an extraordinary inclination, or has a body of water passing along it, with a considerable velocity, deposit will accumulate. If a small sewer, or drain be choked with filth, no water will wash it clear, but the deposit must be raised and removed by manual labour; but if two, or three feet (in depth) of deposit is accumulated in a sewer, large enough for a man to pass through, (your new sewers ranging from 3 feet 6 inches to 5 feet in height in the streets), such deposit could be washed away in the manner adopted in your own sewers."——

Again, in an extract from Mr. Roe's report upon the sewerage of Southampton, in 1845, quoted in Mr. Ranger's subsequent report upon that borough, February 1850, it was stated, "I would observe generally, that in an extended drainage it will be found ultimately a saving to the public, to make them large enough for a man to pass through them occasionally, except where the inclination is so great, and the supply of water so plentiful, as to insure their never requiring to be opened."——

Such were Mr. Roe's opinions in 1845 and 47; as, however, the extract had been read as given in Mr. Ranger's report, it would only be proper to add a statement, made by Mr. Ranger, upon the same subject, as in that report, directly after the above quotation of Mr. Roe's opinions, it is said, "It is due to Mr. Roe to state, that I have good reason to believe subsequent experience has convinced him, that the system was not the correct one, and he would now adopt a different mode."

Now Mr. Haywood thought, that if Mr. Roe had really altered his opinions, it must have been very recently, and only since he became one of the officers of the Metropolitan Commission, and was retained by the Board of Health, and it was important to inquire into the reasons which, after so many years' previous practice, had so suddenly convinced him, that the system he had previously acted upon was so utterly erroneous. Indeed he was inclined to suspect there must be some error in the statement, and until Mr. Roe himself stated his recantation of those principles and gave his reasons, Mr. Haywood would prefer remaining in the belief, that Mr. Roe's real opinions were still those which he had recorded, when he was an independent officer of the Holborn and Finsbury commission, perfectly unfettered and free to pronounce his opinions, whether they clashed with those of other persons, or not. But even admitting, for the sake of argument, that Mr. Roe had changed his opinions, he could not alter the facts with which his reports abounded, and all of which were strongly in support of the opinions he originally entertained.

It had not been stated, by Mr. Rawlinson, what formulæ he had used, for calculating the sizes of his pipe sewers, although he had recorded his non-accordance with certain accepted formulæ and tables, on the ground of their giving too large a sectional. If this uncertainty as to the correctness of formulæ was admitted, the profession would soon be at a loss to determine whose formulæ should be used; whether those of Phillips, Roe, Austin, Cowie, Cresy, or Ranger, or those derived from the experiments made by Messrs. Lovick and Medworth, for the Metropolitan Commission of Sewers; all these gentlemen objected to hitherto-received formulæ, although it did not appear, that anything very uniform, or satisfactory had been substituted for the results of the researches of Du Buat, Eytelwein, Prony,

Hawksley, and others, which it was the fashion now, either actually, or inferentially to condemn; and it was of vital importance to ascertain, whether these experimenters, whose works had hitherto been looked upon as of standard character, were really still deserving of confidence. It was incumbent on those who unsettled creeds to supply worthier articles of faith.

Mr. RAWLINSON said, he feared some parts of the paper had failed to convey the impression he had intended. It must be borne in mind, that there were still many places of considerable population, without any adequate system of sewerage, where the rainfall passed away by surface drainage to the natural outfall; now if that was not improperly tampered with, but rather assisted by artificial means, the excessive rainfall might be provided for in such a manner, as also, eventually, to assist any system of house drains and sewers which might be constructed. In fact, the question of applicability of system to situation should never be lost sight of.

Mr. J. MURRAY said, that tubular drains had lately been extolled, as being superior to brick sewers, because their form, their interior smoothness and other qualities, rendered them capable of discharging greater quantities of water, and also less liable to accumulate deposit. This opinion was based upon the results supposed to have been arrived at by a series of experiments, instituted by and made for the former Metropolitan Commission of Sewers, ostensibly for the purpose of testing the correctness of the accepted hydraulic formulæ. It was stated, that the quantity of water, discharged through the pipes, had been accurately measured, and the actual discharge had exceeded the calculated quantity in the ratio of 3 to 2; this result was accepted and it was concluded, to reduce the capacity of the sewers in that proportion. In consequence, these experiments had been published in the Reports, issued by and under the sanction of the General Board of Health, and had been acted upon by the Inspectors, in their official capacity.[1]

It appeared, that the experiments were made on lines of pipes of 50 feet and 100 feet in length, and of 3 inches, 4 inches,

[1] Vide "Report on the Supply of Water to the Metropolis," Appendix No. 2, page 185; and "Minutes of Information," General Board of Health, 1852, page 39.

and 6 inches diameter; laid perfectly straight, and at different gradients; consequently the quantity of water discharged from them would, necessarily, exceed the volume which could pass through lines of pipes, having curves of such various radii as would be met with in the streets of a town.

The experiment at Hitchin[1] was equally fallacious. An earthenware pipe 15 inches diameter was there temporarily laid, with an inclination of 8 inches in a length of 235 feet = a fall of 1 in 352½; the stream of water was stated to have been wire-drawn, at 10 feet from the upper end, to 14 inches,—at mid-distance to 11 inches, and at the outlet to 6 inches, when the inlet was just covered with water. The velocity of the stream was measured at 188 feet per minute, and the quantity of water discharged was 1025 gallons, or 164 cubic feet per minute. This pipe was also laid perfectly straight and at a uniform inclination, and therefore the result would be greater, than if there had been the ordinary practical irregularities of bends, &c. The discharge according to Prony's formula would be 210 cubic feet per minute.

Mr. Murray was not prepared to admit either the accuracy of the results, or that such diminutive experiments could impugn the formulæ of Du Buat, which were based on an extended series of experiments, performed with all the care and skill of men of acknowledged scientific attainments, and accustomed to minute observation; whereas the operators for the Board of Health evidently did not possess the necessary qualifications for the investigations which had been intrusted to them. The simple formula of Prony, was founded on a selection from the experiments of Bossut, Couplet, and Du Buat; the formula of Eytelwein was deduced from the same source, and that of Poncelet, investigated by Navier, gave similar results.

Mr. Murray had prepared the following table, showing the delivery of water, by pipes of small and of large dimensions, through moderate and more extended lengths and under various pressures, and he contended, that far from throwing discredit upon the researches of the experimenters, whose works he had mentioned, the accuracy of the formulæ had been satisfactorily confirmed by practice.

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[1] Vide "Minutes of Information," General Board of Health, 1852, page 78.

DISCHARGE THROUGH PIPES, calculated by several Formulæ.

Diameter of Pipe.	Length.	Head or Pressure.	Discharge per Minute.	Calculated Discharge per Minute.	——
Inches.	Feet.	Feet.	Cub. Feet.	Cub. Feet.	
2	3,300	12·75	1·617	1·507	Du Buat.
—	—	—	—	1·609	Prony.
—	—	—	—	1·509	Eytelwein.
—	—	—	—	1·59	Poncelet.
4½	14,930	51·00	11·333	11·252	Du Buat.
—	—	—	—	11·491	Prony.
—	—	—	—	10·784	Eytelwein.
—	—	—	—	11·281	Poncelet.
12·789	3,837	12·90	155	158	Du Buat.
—	—	—	—	155	Prony.
—	—	—	—	145	Eytelwein.
—	—	—	—	141	Poncelet.
12·789	14,963	21·582	111	99	Du Buat.
—	—	—	—	102	Prony.
—	—	—	—	99	Eytelwein.
—	—	—	—	98	Poncelet.
19·184	5,052	4·929	217	223	Du Buat.
—	—	—	—	230	Prony.
—	—	—	—	215	Eytelwein.
—	—	—	—	226	Poncelet.
30	5,280	9·00	880	926	Du Buat.
—	—	—	—	932	Prony.
—	—	—	—	865	Eytelwein.
—	—	—	—	910	Poncelet.

In explanation of the table it was stated, on the authority of Dr. Robinson,[1] that water was brought into the town of Dunbar, in East Lothian, from a spring, through pipes, the first length of which was 1100 yards, of 2 inches diameter, with a declivity of 12 feet 9 inches;—

The actual quantity discharged was 1·617 cubic foot per minute.

The mean calculated quantity was 1·5539 cubic foot per minute.

Again it was shown by Mr. Jardine,[2] that the main pipe of the Edinburgh Water Works, extending from the fountain head, at Comiston, to the reservoir at the Castle Hill, Edin-

[1] Vide Robinson's "Mechanical Philosophy," vol. ii., page 441.

[2] Vide Brewster's Encyclopædia, Art. "Hydrodynamics," page 526.

burgh, was of lead throughout, 14,950 feet in length, 4½ inches in diameter, and the head was 51 feet above the point of delivery.

The maximum discharge, during five consecutive years, was 11·333 cubic feet per minute.

The mean calculated quantity was 11·202 cubic feet per minute.

The next three results were taken from Bossut's Treatise on Hydrodynamics, brought into English measures, and they were stated to be his own experiments, combined with those of Couplet. The pipes were of iron with several horizontal and vertical bends, which were taken into account in the lengths mentioned :—

	Cubic Feet per Minute.	Mean calculated quantity.
The first yielded . . .	155	150 cubic feet per minute.
The second	111	99·5 „ „
The third	217	223·5 „ „

The last statement of the table was obtained from the late Mr. Chapman, C.E. of Newcastle; but whether it was derived from actual measurement, or was simply the result of his experience, was uncertain. From a pipe of 30 inches diameter, with a fall of 9 feet per mile, the actual quantity discharged was 880 cubic feet per minute.

The mean calculated quantity was 908 cubic feet per minute.

The following were the formulæ employed in the calculations of the table :—

Du Buat's Formula reduced to English Measure.

$$V = \frac{307\left(\sqrt{R} - 0{\cdot}1\right)}{\sqrt{S} - L\left(\sqrt{S} + 1{\cdot}6\right)} - 0{\cdot}3\left(\sqrt{R} - 0{\cdot}1\right).$$

V = velocity in inches per second.
R = hydraulic mean depth = ¼ diameter.
S = slope or difference of level.
L = hyperbolic logarithm, and found by multiplying the common logarithm by 2·3026.

In the following formulæ English feet were employed :—

V being the velocity per second.
D „ diameter
H „ head or pressure } of the pipe.
L „ the length

Prony's simple Formula.

$$V = 48{\cdot}449\sqrt{\frac{DH}{L}}.$$

Eytelwein's Formula, as given by Tredgold.[1]

$$V = 45{\cdot}5\left(\sqrt{\left(\frac{DH}{L + 47D}\right)}\right).$$

Poncelet's Formula.

$$V = 47{\cdot}95\sqrt{\left(\frac{DH}{L + 54D}\right)}.$$

Mr. HAWKSLEY had also repeated some of the experiments, for his own satisfaction, and in all cases had found them accord with the results anticipated by the calculations, based on the formulæ, which appeared now to be condemned. In the same manner he had repeated some of the Board of Health experiments, and had, in their case, been as unfortunate in the results, as he had been happy in the previous cases, for in all instances he had found the experiments, based on the Blue Book reports, entirely wrong and totally at variance with fact. As a proof of the correctness of the formula he was in the habit of using, he stated, that where Mr. Roe's practical tables would lead to the adoption of a sewer of 48 inches in diameter, his formula gave 49 inches, and in another case, the approximation was as near as 120 inches to 124 inches. Some trials, on a main of pipes 13 inches diameter, and nearly 3 miles long, near Whitehaven, had also verified the accuracy of the formula, in which he was able to place implicit confidence. He could not agree with Mr. Rawlinson's proposition, that the size of the sewer outlet should be in proportion to the number of houses; this might be the case, if all surface drainage was rigidly excluded from the sewers; but in almost all cases the real question was, the area to be drained, and whether that surface was covered with roofs and paved courts, or roads and gardens. In case of sudden storms, the water would pass off rapidly, and must be conveyed away by sewers, or else the basements of the houses would be flooded. The documents issued by the Board of Health, instead of furnishing practical rules for enabling a district to be cleared of the water falling on it, appeared to be chiefly occupied with the attempt to discourage the application of previously accepted rules, and to be devoted to persuading the

[1] Vide Tredgold's "Tracts on Hydraulics," page 215.

public, that the only sewage to be conveyed away was the foul house-water; now it must be admitted, that this was too limited a view for the present age, in fact it was a deplorable state to be left in, and would not be suffered to prevail. Partial success might, for a time, be obtained; but the undue substitution of small pipes, for proper-sized sewers, would eventually lead to serious failures and accidents, and after considerable expense had been incurred, they would be obliged to recur to main sewers of properly-proportioned sections; and he believed there was no instance of any town, so sewered, having been permanently inconvenienced by any amount of rainfall. The most serious inconvenience had not always been found to arise from a sudden and heavy fall of rain, of short duration, but more frequently from a prolonged fall, of less hourly amount; and, in such a state of things, the limited capacity of pipe main sewers had, already, been productive of serious inconvenience. The experienced practical Engineer would, therefore, provide sewers of sufficient dimensions for the conveyance of water, under all the ordinary circumstances of heavy and continued rains, and be governed by the amount and value of the property to be endangered, or improved, in determining the magnitude requisite to meet special necessities.

Mr. RAWLINSON stated, that other Engineers, besides those connected with the Board of Health, were in the habit of using pipe-drains;—for instance, they were employed at Durham, to a considerable extent, by Mr. Hawksley.

Mr. HAWKSLEY explained, that earthenware pipes were, in his opinion, very useful for the drains of houses, courts, and minor thoroughfares, but not for main sewers. Durham was not an instance in point, because that city was, for the most part, built upon ridges, and the streets were, in consequence, so precipitous, that the sewers were required for little more than conducting away the drainage from the houses, and the surfaces of comparatively narrow streets. There were also many outfalls into the river, and the separate drainage areas were therefore small. Yet, notwithstanding these peculiarities, the system, so rigidly enforced by the Board of Health, had compelled him to employ pipe drainage to a greater extent than he thought advisable, and it was only by so far adopting the dicta of that Board, and after a serious loss of time, that he had been enabled to get his plans passed by the General Board, as a preliminary

to their consent for power to borrow the money necessary for the execution of the work.[1] He must contend against the manifest injustice of this system, and it was easy to predict the serious consequences that would inevitably result from it.

Mr. NETHERWAY said, that as the success, or failure of pipe sewerage principally depended on the strength of the earthenware pipes, he had tried some experiments, with the view of ascertaining what weight they would bear. Each experiment was tried upon two pipes laid parallel to each other, with an interval between, and bedded in gravel, up to two-thirds of their diameter. A saddle of the length of the pipe, curved to fit the surface, was laid in each, so as to distribute the weight throughout the length, and the load was increased gradually. It would suffice to give the results of two trials. Two Staffordshire blue pipes (Haywood's make), each 2 feet 4 inches long, 12 inches diameter, and $\frac{5}{16}$ths of an inch thick, sustained a load of 46 cwt., or 23 cwt. on each pipe; under this weight one of the pipes gave way, and split longitudinally into four, nearly equal, portions. The other pipe was only slightly crushed on the top, at one end.

Two London glazed pipes (Doulton's make), each 2 feet 2 inches long, 12 inches diameter, and of a mean thickness of nearly $\frac{3}{16}$ths of an inch, were tried in a similar manner, and one of them was crushed exactly as in the previously described experiment, but with a much less load, being only 28 cwt., or 14 cwt. on each pipe.

Mr. DOULTON said, it must be borne in mind, that the manufacture of earthenware pipes, for sewers and house-drains, was of recent introduction, as they had not been generally used, until within the last four, or five years; the first demand being rather sudden, and exceeding the supply, the manufacture was undertaken by persons only imperfectly acquainted with it, and it was only by experience that improvements had been introduced, and the present quality had been attained.

Considering the quantities of earthenware pipes now made, the failures had been very few; and some idea of the extent to

[1] Vide, on this subject, "Remarks on the Dictatorial Interference of the General Board of Health," &c., 8vo, Tract, London, 1852; and "A Letter to the Marquis of Chandos, M.P., in relation to the exercise of some of the extraordinary powers assumed by the General Board of Health," &c., by T. Hawksley, 8vo, Tract, London, 1853.—EDITOR.

which they were adopted might be arrived at, from the statement that Messrs. Doulton now produced, at their various manufactories, about 18,000 yards per week, and had for the last four years made very large and increasing quantities. Other manufacturers had also manufactured similar pipes very extensively, and it would be strange, considering the novelty of the application, the inexperience of those using them, and other causes, if some failures had not occurred; they did, however, bear but a small proportion to the very large quantity used. The chief demand was from those who had partially introduced them, and claimed to have had practical experience of their efficiency.

There was not any practical difficulty, in making stoneware pipes up to 18 inches diameter, true in form and sufficiently strong to resist any pressure they were at all likely to be exposed to; but in the present state of the manufacture, it was not desirable to go beyond that size.

Many pipes, particularly of the larger sizes, had been made of insufficient strength, arising either from bad material, imperfect vitrification, or insufficient substance. Thousands of pipes of 18 inches diameter, and of little more than half an inch thick, had been laid, and failures, in many cases, had naturally resulted. Thickness alone was not a correct test of strength, and unless the body of the pipe was of close texture and well vitrified, it would be weak as well as permeable. It was easier to make a very thick pipe, of loose and open substance, than to produce a pipe of moderate substance, close and well vitrified throughout, which would resist more pressure, than one much thicker, only imperfectly vitrified. There was a danger, that if pipes were required too thick, the material would be deteriorated and more would be lost, by looseness of texture, than would be gained by the additional substance. The quality of pipes should be tested by an examination of the body after fracture. A good surface was no indication of a good pipe; when broken it should resist all attempts to scratch, or cut it with a knife.

Complete impermeability was stated to be a necessary qualification for good sewer pipes, and could only be secured by thorough vitrification; in that respect stoneware drain pipes had an advantage over the most perfectly constructed brick sewers, which were generally porous. Mr. Rawlinson thought

an impermeable brick could be obtained, if so, it would lessen the objection to brick sewers, though it was impossible to overcome the difficulty arising from the joints.

From their internal smoothness and regularity, pipes could be used of smaller sizes, than brick sewers, under similar circumstances.

There were numerous causes of failure, apart from the manufacture of the pipes,—such as improper application, imperfect laying, and the system of partly tunnelling and partly trenching. The latter practice was very objectionable, in consequence of the irregular settlement of the earth, when filled in, the pressure bearing only on some parts of a long line of pipes, rigidly laid; they were, therefore, liable to be broken, by the powerful leverage.

Lengths of 3 feet each were not so strong as those of 2 feet each; and the occasional introduction of half-socket pipes would relieve the pressure, where the settlement was irregular.

Actual works had been referred to, as giving the best test of the efficiency of pipes. Messrs. Doulton had supplied pipes for the complete drainage of nine, or ten towns, all of which were stated to have succeeded; among them was St. Thomas-Exeter, referred to by Lord Ebrington, as a very satisfactory work.[1]

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[1] Mr. Bazalgette (the Engineer to the Metropolis Sewers) has since examined and given an account of the condition of this and other towns, in his "Report to the Metropolitan Commission of Sewers, upon the Drainage and Water Supply of Rugby, Sandgate, Tottenham, St. Thomas-Exeter, and Barnard Castle (1854)." It is therein stated, "I am now enabled to report, that the result of my inquiries and observations, on the application of the tubular system of drainage, in these five places, affords no proof of its applicability to the Metropolis, and no evidence of the cheapness and efficiency of the works at these five places, which should entitle the system to serious attention, with reference to the works to be undertaken for drainage in London."——

"The Reports (of the Inspectors of the General Board of Health) to Viscount Palmerston, upon Rugby, Sandgate, Tottenham, the parish of St. Thomas-Exeter, and Barnard Castle, would appear to give the result of the experience of the house drainage of those places, through pipe sewers, for the last two, or three years; but upon a more close investigation, it appears, that the main sewers only were, during that period, completed,—ready to receive, it is true, but not then actually receiving, the house drainage, or at most but an inconsiderable portion of it. About two years since, the drainage of the houses only commenced being turned into the pipe sewers, and this work is not yet completed; so that up to the present time, those places, even if no failures had occurred, would afford no real experience upon the subject."—EDITOR.

Rugby was among the first towns completely drained by tubular earthenware drains; upwards of 6000 feet of pipes, 18 inches and 20 inches diameter, were laid in cuttings, even as much as 28 feet deep; they had been down about eighteen months, and though less in substance, than those now being made, they had resisted perfectly all pressure on them.

Mr. Doulton then read an extract from a letter from Mr. Phillips, the local Surveyor, dated Rugby, 27th November, 1852:—

"As far as our system of drainage has been adopted, the result has been highly satisfactory. What the exact number of houses may be, whose sewage matter traverses the new sewer, I cannot say, as during the laying of the pipes a vast number of houses were necessarily connected, in consequence of the old system of drains having been taken up; there are however upwards of four hundred houses enjoying the combined system of drainage and water supply, which have been connected under my own supervision, the drains being all newly laid with pipes exclusively. We have not yet had more than one instance of fracture in the sewer, and that owing to a fall of earth, the substratum having been washed away by an old culvert; this is also the only case of stoppage."[1]

[1] The following extracts from a "Report to Viscount Palmerston, upon the System of Drainage pursued in the Metropolis; by R. Jebb, Chairman of the Metropolitan Commissioners of Sewers, 8vo, London, 1854," convey considerable information respecting Rugby, St. Thomas-Exeter, and the other towns; as also valuable opinions as to the use of tubular pipe sewers for large cities:—"By order of the Commissioners, their Engineer, Mr. Bazalgette, visited Rugby, Sandgate, Tottenham, St. Thomas's, Exeter, and Barnard Castle, and in his Report, are embodied the results of his observations with regard to the nature and expense of the works there executed; those results being such as to qualify the conclusions which might, without explanation, be drawn from the Reports of the Local Boards of the places named. From his Report the following facts may be collected: that in each of the five towns there is a double system of sewers,—1°, a set of old brick sewers, originally constructed for surface drainage, and now maintained for that purpose, out of the public rates; 2°, a set of newly-constructed pipe sewers, chiefly, or exclusively for the reception and discharge of house-drainage. The entire sewerage of the town comprehends both sets of sewers; and its cost is really the cost of both, and not the cost of the new pipes merely, as a person deriving his sole information from the Reports, sent to your Lordship, might possibly suppose. I may here remark, that a like observation applies to several other places, drained under the supervision of the General Board of Health, where pre-existing brick sewers are still maintained, and used as a part of the system of sewerage;

In order to satisfy himself as to the strength of well-made pipes, Mr. Doulton had caused a series of trials to be made, of

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whilst the Reports, holding up the drainage works in those places as models of cheapness, make mention only of the new works.

"At St. Thomas's, Exeter, as respects a considerable part of the town, the average cost per house of putting in house-drains, &c. would appear, on the face of the Report from that place, to be exceedingly low. This apparently low average is obtained by dividing the entire cost of all the house-drains amongst the houses, whether drained, or *undrained*. Mr. Bazalgette (Report, p. 33) estimates the proportion of the undrained houses at about half the entire number.

"It further appears from Mr. Bazalgette's Report, that the cost of executing works of the same character is necessarily greater in London, than in the five towns referred to. This arises from two causes:—First, all kinds of workmanship are dearer in London, than in country towns. This observation cannot apply to Tottenham, but it applies to the other places. Secondly, and chiefly,—in London there are several heavy items of expense, which either do not occur at all, or occur in a very slight degree, in country towns. In London, sewers, whether of pipes, or of brick, must generally be laid at a much greater depth; the trenches carefully fenced, watched, and lighted; the large and weighty and closely-packed houses shored up; gas and water pipes protected and made good; and costly pavements removed and restored. These, and like matters, add very materially to the expense of making sewers in London; and the amount is but little affected by the nature of the structure."

"It is important to observe, that the cost of sewering a town is not simply in the ratio of its size."——

"As to the alleged efficiency of the works: from Mr. Bazalgette's Report it appears, that in none of the five towns named have the works of *private* drainage been commenced more than two years and a half; in some they have been commenced much more recently; and in none are they yet complete. In none has sufficient time elapsed to give the system a full trial. In four, out of the five, towns there have been failures; at Sandgate to a considerable extent."—

"In a small country town, not already provided with surface drains, you may often, with comparative safety, allow the rain to a great extent to flow over the surface of the streets, or along the open side channels, till it reaches the nearest ditch, or brook, especially where, as is frequently the case, there are no basements to the houses. In London, the *whole* of the surface drainage is, or ought to be, carried to its ultimate destination in covered channels under ground, which must be deep, on account of the basements, and for other reasons."

"The amount of surface drainage is measured by the quantity of rain which falls. Whatever may be the case in small country towns, in London it will not answer to provide sewers for merely ordinary rain-falls, not exceeding at any time a quarter of an inch per diem: provision at the rate of two and a half inches per diem must be made for storms. This rate will give for the entire metropolitan area 114 square miles, under the jurisdiction of the Commissioners, 662,000,000 of cubic feet per diem, the quantity for which surface drainage sewers ought to be provided."——

"Assuming, for the moment, that all the London sewers could at all times be rendered 'self-cleansing' and self-repairing, so as to render it unnecessary for

more severe character than tubes would ever be subjected to practically. The pipes experimented on were 2 feet long;

men ever to enter them, then the question of size becomes simply an hydraulic question."——

"The Commissioners have not accepted the hydraulic tables which are understood to be adopted by the Board of Health, those tables being in a large measure at variance with the results both of science and experience, English as well as Continental, and being such as, if adopted for London, would entail the most serious consequences to the health and property of its inhabitants, by giving rise to the construction of sewers too small to answer the purposes intended."——

"When deposit does form in the large brick sewer (and this will now and then happen, not only in brick, but also in pipe sewers), the means are at hand of entering it, and removing the obstruction, without the necessity of breaking up the street,—a highly inconvenient as well as costly expedient in London."—

"For those sewers near the river, the justification of their size rests upon the absolute *necessity* I have before pointed out, of men being enabled to enter and cleanse them; for those higher up, a good reason is offered, in the general principle advocated by Engineers—that inasmuch as every machine, however perfect, is liable to occasional derangement, each part of it ought, if possible, to be rendered easily accessible for the purpose of repair, or adjustment."——

"The Commissioners have no objection to back-drainage abstractedly: their substantial objection is to the dangerous and disastrous notion, of attempting to substitute it for the important street sewers already described. They permit it in many cases. Applications for leave to adopt it are made almost daily, and the Engineer has very seldom been obliged to refuse permission for its adoption. But, in truth, the system is not a favourite one with the more respectable London builders, who prefer a separate drain for each house, running under the latter, and then half way under the street, into the sewer in front."——

"It is found, that the 4-inch pipe stops, and the 20-inch pipe breaks. The Commissioners have come to the conclusion that it is not expedient to use pipes smaller than 6, or larger than 12 inches in diameter."——

"The Commissioners prefer 6-inch pipes, because, whilst the difference of cost is very trifling, and whilst the loss of scouring power is practically insignificant, the 6-inch pipes allow more readily of the passage of those innumerable substances, which are so often 'improperly admitted,' and which will continue to be improperly admitted by careless, or mischievous persons."——

"The restriction, placed by the Commissioners, upon the use of pipes for small sewers, except in certain favourable situations, has been based, not upon any objection to pipes abstractedly, but upon their proved insufficiency in point of strength. The manufacture of them, however, has, within the last twelve months, been materially improved, owing to the regulations of the Commissioners themselves. A year ago, the best pipes procurable were generally too thin, to be safely used under roads: they are now better, the Commissioners having succeeded in inducing the manufacturers to make them of good material, and well burnt, $1\frac{1}{4}$ inches thick; and the Lambeth manufacturers are now preparing to make them still thicker. When this is accomplished, it may fairly be anticipated, that the use of them may be safely extended, to situations where the Commissioners have been hitherto under the necessity of constructing small half-brick barrel sewers."—EDITOR.

each pipe was supported at the ends on blocks ; a piece of wood 12 inches long was then laid on the middle, and the weight was gradually increased until fracture ensued.

The following were the results :—

Diameter of Pipes.	Thickness.	Weight on 12 inches square. — Broke.	Weight over the entire surface of the Pipe.
Inches.	Inch.	Cwt. qrs.	Tons. cwt. qrs.
18	$\frac{7}{8}\frac{1}{16}$	53 3	14 2 1
15	$\frac{7}{8}$	31 3	7 1 1
12	$\frac{3}{4}\frac{1}{16}$	53 3	8 13 2
12	$\frac{3}{4}\frac{1}{16}$	71 0	12 12 0
9	$\frac{3}{4}$	64 3	8 18 3

Mr. RITCHIE had taken great interest in the sewerage of Edinburgh, and had carefully watched the trials of the new system; after the experience of a year it had been declared to be an entire failure, chiefly on account of the silting up of the pipe drains, which were too small,—of the repeated stoppages and the consequent inconvenience to the public, from breaking up the streets. A report of a sub-committee of the Paving Board, of Edinburgh,[1] gave some useful information, as to the employment of pipe drains in some of the wynds of the city. It stated, that the complaints were generally well founded; the tubular drains, especially where there was only little declivity, though laid at considerable depths below the surface, had been repeatedly choked up,—and had occasioned considerable expense and inconvenience, in opening the ground to remedy the defects ;—the effluvium traps, though numerous, were defective, and were constantly stopped up by surface mud ; —the bent tubular drains, serving as connexions with main sewers, where the latter existed, were inefficient, as the matter hardened within the bent portion, and it became necessary to open the ground and break the pipes, to do away with the stoppage and then to replace them. The Report stated the Committee to be of opinion "that the tubular system of drainage

[1] Vide "Report on Surface Drainage, by a Sub-Committee appointed by the City of Edinburgh Paving Board," 20th September, 1852, R. Ritchie, convener.

does not appear applicable, or well adapted to many portions of Edinburgh, where no constant supply of water exists to flush the drains, as the liquid which finds its way into the drains, from the street gutters, is always mixed with refuse and mud, which must soon choke up any small tube, more especially if there be bends in it, or if its position be at all horizontal. The Sub-Committee think it proper to state, that from every inquiry they have made, probably all the tubular drains, laid down under the provisions in the Police Act, are liable to the objections pointed out, and may ultimately entail, from their liability to obstruction and difficulty of being cleansed, considerable expense upon the inhabitants." And it recommended, that all main sewers should be so constructed as to be accessible for manual cleansing, if necessary.

Mr. PARKER was of opinion, that the most probable cause of the failures of the tubular drains might be traced to carelessness in laying them; it not unfrequently occurred, that they were merely laid down in the bottom of the trench, with the shoulder of the socket resting on the ground, no care being taken to ascertain whether the ground was rammed under, so as to pack up and support the body of the pipes, and of course fracture ensued, when any weight was brought upon them. Now all pipes should be well bedded in mortar, in clay, or in screened sand; and the sides of the trench should batter, or incline towards the surface, in order to receive some of the pressure of the ground, when filled in and rammed.

He had seen such extraordinary instances of accretion in sewers, and drains, that he feared cases of stoppage would constantly occur in small tubular drains; and the substances found in them were so heterogeneous, that it was impossible to conceive how they arrived there. In most cases they caused accretion, which could only be removed by opening the street and breaking the pipes.

Mr. BAZALGETTE fully coincided with that portion of the paper, where the Cloaca Maxima, with its massive ashlar, dovetailed joints and pozzuolana mortar, was held up as an example of that stability and durability, which, he admitted, was most desirable for the sewers of cities, on account of efficiency, of public convenience and of ultimate cost; but he was surprised to find, that this just admiration of the solid structures of ancient

Rome, dwindled into the recommendation of the use, for the sewers of modern London, of fragile clay pipes, which, instead of enduring for centuries, were not unfrequently crushed, within a few months of their being laid, and, if they escaped that fate, were generally stopped up by deposit, and were obliged to be broken and be replaced, within a few years.[1] Such a system could not obtain for the main sewers of a great city, even if it might, in some instances, be made to answer for a small country town,—there could be no analogy between such cases, and he was convinced, that it would be eventually cheaper, for the authorities in London, to construct good accessible sewers, through which men could pass at stated periods, to prevent, or to remove accretion, than to be under the necessity of constantly opening the streets to search for stoppages, without regard to the cost and the inconvenience entailed on the public. He believed it was the want of scientific and practical knowledge, upon this difficult subject, which had induced unprofessional amateurs to adopt and propound theories, which, however plausible, were at variance with the laws of Nature, and to attempt to lay down general rules as applicable under all circumstances; forgetting, that the natural features and the variety of wants of different towns, continually called into requisition the deepest science and experience of able engineers, who had devoted their lifetime to the study of the subject, and that the application of any general laws was thus precluded.

He denied, that, as a general rule, pipe sewers were, as had been asserted, more "economical and efficient," than brick sewers, or that a saving in the first outlay, supposing it could be effected, by the construction of pipe sewers, must tend to ultimate economy. He contended, that the assertion of pipe sewers being "self-cleansing," and brick sewers being "sewers of deposit," was incorrect, and he undertook to prove, both by theory and fact, that the advantage, in point of self-cleansing powers and non-liability to obstruction, was in favour of the system of brick main sewers. He totally dissented from the statement, of the

[1] Vide "Report to the Metropolitan Commission of Sewers, relating to the Application, State, and Examination, of Tubular-Pipe Drains, or Sewers in the Metropolis." By J. W. Bazalgette. 4to. London, June, 1835. Also, "On the Main Drainage of London." March 3, 1854.

bad effects on the health of the men, employed in sewer works; both in London and in Paris, the average duration of life, of that class, was as great as that of any other labouring men, and larger than in many trades, producing only the luxuries of life. Dr. Parent Duchatelet gave excellent testimony on this subject.

If the principle of 'back-drainage' by pipes was adopted, there would be, on an average, five times the number of sewers required, as by the system, of each house communicating independently with the one main sewer, and there would be a proportionately increased liability to stoppage, and with not only inconvenience to one house, but also to all the others combined with it.

It was not fair to institute a comparison, between the expense of laying down a series of pipe drains, incapable of carrying away both the surface water and the house drainage, and that of the cost of a good brick sewer, of capacity to receive and convey away all that might be led to it, and not liable to be stopped up by deposit.[1]

Mr. Bazalgette had used pottery-pipes, to some considerable extent, for house drains, and in courts and small streets, and when of good quality, of adequate dimensions, well laid, and opening independently into brick sewers, they might be efficiently employed, but he complained of the too indiscriminate use, or abuse of them, and of the attempt to employ them in situations, for which they were not fitted, or for which they had not been intended.

Mr. Haywood explained, that he had been careful, in all the pipe sewers he had constructed, to provide shafts at their heads, so as to have the power of flushing them periodically, with a considerable body of water. For the sake of experiment, this periodical flushing of the pipe sewers, had been discontinued for some time, and although most of them were laid with excellent gradients, some had accumulated deposit varying from 1 inch to 3 inches in depth, measured at their outlets; but as to the condition of the pipes higher up, it was impossible to say

[1] Vide "Report to the Metropolitan Commission of Sewers, upon the Drainage and Water Supply of Rugby, Sandgate, Tottenham, St. Thomas-Exeter, and Barnard Castle." By J. W. Bazalgette. 8vo. London, February, 1854.

anything, as no examination of them could be made without considerable expense and inconvenience in opening the streets.

Mr. DUNCAN gave an instance, at Kilburn, where there had been a line of pipe sewer laid, at some considerable depth; it was soon found to be stopped up, and on digging down, it was discovered, that the clay had been washed in through a comparatively small hole, and had filled a length of nearly 100 yards, that several pipes were split, or crushed, and in fact, that it was necessary to lay the whole again, with better pipes. It appeared, that the unequal ramming of the clay, into the trench, had been prejudicial, or that slips of the earth had occurred, after the work had been apparently completed.

Mr. LOVICK, in reference to the failure of the pipes at Kilburn, said, he considered it due to the Engineer who advised the use of pipes in that situation, to state, that they were crushed by the falling of the earth upon them, in consequence of the giving way of the sides of the trench, arising from the improper removal of the timber shores. It should also be stated, that those which had failed were, for the most part, condemned and rejected pipes, of 15 inches diameter, very many being cracked before they were laid down, and they were crushed at the time of laying; these remarks applied to the whole length, of nearly 1000 feet of pipe-sewer, mentioned by Mr. Duncan.

Mr. DUNCAN said the whole line of sewer had failed, and was then being reconstructed, at a very considerable expense. It was not correct to state, that all the pipes were defective; some of those, of 15 inches diameter, were of indifferent quality and were previously cracked; they were laid at a depth of 16 feet from the surface, and could not bear the weight of earth upon them; the other pipes, 9 inches and 12 inches diameter, were sound when laid. His objection was, not to the use of pipe drains, in proper situations, nor to the material of which they were manufactured, but to the system of constructing main sewers of such dimensions, as precluded the possibility of men passing up them, to clear away deposit, to make good the junctions for the houses, and to do general repairs, which would inevitably be required in time, in all sewers; when that period arrived, if pipes were used for the main sewers, the expense would be terrific for the ratepayers.

Mr. TOULMIN SMITH said he had heard the Paper, and had

listened to the discussion with attention, as he had taken great interest in the sanitary part of the question; and although not an Engineer, he believed that he understood enough of the subject, to enable him to demonstrate some fallacies, which had been already widely promulgated, and which, unless they were contradicted, might be very prejudicial to the community. In doing this, it would be necessary to mention the General Board of Health, and to take exception to the proceedings of that body; but he would confine himself, carefully, to the statements and doctrines contained in the published Reports of that Board, and he would beg his remarks might be so understood.

He thought, that in order to examine fully into the question of the drainage of towns, it was necessary to do more than merely discuss the respective merits of pipe drains, or of brick sewers. The means to be employed were subordinate to the general plan; and the public, whose welfare was deeply concerned, had a right to understand the principles, forming the basis of the system pursued; particularly when a Government Board reserved to itself the power of (*de facto*) rejecting all plans, which did not appear to be in accordance with the published rules, or were disapproved by the examining Engineers, appointed by that Board; for this was the actual result of the power, under the Public Health Act, of refusing consent to borrow money, for the execution of works, unless the report of the Inspecting Officer was favourable.

In the Paper which had been read, certain propositions had been laid down; and it was, he conceived, the object of the Meeting to examine into their soundness, or their fallaciousness. It would not be sufficient that they were dogmatically dictated in Blue Books: if they were sound, their foundations should be clearly defined and understood; but if unsound, it became highly important to ascertain on what data and on whose authority they had been founded and were promulgated.

These propositions were—

1st. It was not necessary, that a system of town drainage should provide for carrying off flood-water, or urban rain-fall.

2nd. It was equally unnecessary to construct sewers large enough for men to traverse; and small-sized drains were in all cases preferable.

3rd. All drains should be constructed of materials impervious to water.

Now Mr. Toulmin Smith differed entirely from all these propositions; and he disputed both their theoretical and practical accuracy. As to the first, the Author admitted, that the original object of sewers had been, not to convey away house-drainage, which was a modern refinement on the system, but to carry off the surface-water, which it was now proposed to exclude. It must not be forgotten, that Nature, who sent the rain-fall, also provided for its passing off by the natural inclination of the surface. Much had been said about preserving the natural outfall; but wherever man interfered with the natural drainage, (and it was impossible for him to avoid it, in grouping together houses in towns, and arranging altered levels of streets,) some artificial system, superficial, or subterranean, must be provided. If the latter, then either the house drainage must be combined with it, or two sets of sewers must be constructed to maintain the separation, at a greatly-increased cost, as well as at the chance of greater annoyance from the increased risk of stoppage of a double set of drains, one set of which would be dry, when there was no rain, and the other would, generally, have only such a quantity of water passing through it as would scarcely suffice to keep the contents in a fluid state, and be wholly inadequate to scour the drains out, as was effectually done in ordinary sewers, whenever a heavy fall of rain occurred. The Paper protested altogether against the use of gully-holes, although it might have been imagined, that the most superficial investigation would have demonstrated the fallacy of such a proposition. It would only be requisite to quote one instance, in support of the necessity for them; he alluded to the case of Highgate Hill, where, in consequence of the steep declivity, the rain-flood rushed over the surface, accumulating in its passage, until it formerly inundated and committed serious damage in the low grounds; but by the construction of drains, and the insertion of a large number of gully-grates, (in one part as many as nineteen, in a distance of three, or four hundred yards,) the water was effectually conveyed away without difficulty.

As to the second proposition; it must be obvious, that a body of water unnecessarily expanded in a thin sheet, over a wide surface, was retarded by the extra friction, and had a tendency,

with the loss of velocity, to deposit the matters held in suspension; and also that, if the channel was contracted, the friction was diminished, the course of the fluid became clearer and more rapid, and the tendency to deposit was diminished. It was, at the same time, equally obvious, that whether this contracted watercourse was 12 inches diameter, or 5 feet high and 12 inches wide, (the form of the bottom remaining identical in either case,) there could not be any difference in the facility for the flow of water, or in the friction over the bottom; but the latter form (the brick sewer) possessed the manifest advantage of permitting free access for inspection and repair, whilst the former, (the pipe drain,) had the evident disadvantage of being liable to be choked by deposit, and of its being necessary to open the ground to discover the position of the stoppage. Hence, as also in every case of laying on new junctions with houses, there arose great breakage of pipes, as well as general dislocation of the system. It was admitted, that pipe drains, in order to insure efficiency, required to be laid with the greatest nicety and accuracy,—a thing practically impossible. It was further admitted that, above a comparatively small size, brick sewers were cheaper than pipe drains. If this were so, common prudence dictated the use of such subterranean conduits as might be cleansed and repaired, without causing annoyance to the public, and at an infinitely less cost, than by digging down to and replacing broken pipes. Besides, with the larger sewers, all possible contingencies of rain-fall, &c., were provided for, without the liability to such instances of false economy as had been recently exhibited at Holloway, where a pipe drain of 12 inches diameter, which had been laid only about four years previously, was now being taken up and replaced by a brick sewer of 4 feet 3 inches diameter.[1] This was not only a public annoy-

[1] The following letter was given as the authority for the statement:—

"*Sewers' Office, Great Alie-street, Whitechapel,*

"SIR, *13th December,* 1852.

"During the discussion at the Institution of Civil Engineers, reference was made by you to the 12-inch pipe sewer in Holloway-road. The statement was correct; but such pipe was laid down by the Engineer previously having charge of the Finsbury Division. I am, as you perceive, taking up the 12-inch pipe, and placing, in lieu thereof, a circular sewer 4 feet 3 inches in diameter; and even this will be full in heavy storms, as

ance, but an unjustifiable waste of money, inasmuch as it resulted from the dictatorial enforcing of certain dogmas, which were put forth, in defiance of scientific investigation, or practical facts, and entailed on the public heavy and uncalled-for cost.

As to the third proposition; it appeared to be lost sight of, that, for the sake of health, it was as requisite to drain the subsoil of the site of houses, as it was to convey away the artificial foul house-water. Now for the former purpose, glazed, or vitrified pipes were entirely unfitted, unless the joints were left open, when the fœtid contents would ooze out. Therefore, if they were used, the keeping dry of the cellars, or basements could not be promoted, although in a sanitary point of view that was of the utmost importance. The subsoil moisture would then have a tendency to saturate the ground, would undermine the pipe drains, and allow them to sink and be fractured; and, as another incidental result, the sewage matter would exude, and add to the causes of disease-bearing miasma. Such was not the case, where properly constructed pervious brick sewers were used, with the inverts laid in cement. These not only conveyed away the sewage, but they drained and kept dry the soil, through which they passed, rendering the lower portions of all the adjoining houses healthy and habitable, and the neighbourhood less likely to be flooded by sudden rains falling on a saturated soil.

The other practical objections, that might be urged against the newly introduced system of pipe drainage, were far too

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of late. In taking up the pipes in question, I found three of them broken. In almost every case where we have to put in junctions to these pipe-sewers, the same is the result. On a recent occasion, in Mile End, in an 18-inch pipe, laid down about four years since, under the supervision of another officer, in every opening that has been made to the same (which are many) the pipes are found split down the centre. My object in writing you is that you may set the matter right at the Institute. Many may consider, that the pipe was laid down by me; whereas this sort of thing is in opposition to my practice, and to that of my respected father, who was Surveyor to these districts many years, and who has constructed more brick sewers than any person in the kingdom.

"I remain,

"Yours respectfully,

"GEORGE ROE,

"*Engineer for Finsbury Division, Tower Hamlets, Poplar, and Blackwall.*"

"*Toulmin Smith, Esq.*

numerous to be descanted upon, within the limits of a discussion at the Institution; especially as there were other points of equal importance to be noticed. One of these was, why had the public submitted without inquiry, and almost without remonstrance, to the dictation of the General Board of Health? The reply would be best given in the words of a petition from the local Board of Health of Swaffham, Norfolk, to the House of Commons, in 1851, wherein it was stated, "That the General Board of Health has the power of refusing to any Local Board the privilege of borrowing money; thus having a veto on every act of any Local Board, unless the rules and regulations laid down by the General Board are fully carried out." This allegation was confirmed by the text of the Public Health Act, and also by the statements in all the blue-books published, at the public expense, by the General Board of Health. Thus it was expressly declared (Report 1849, p. 72) that "works should be carried out, upon approved plans by the Local Surveyor, under the Superintendence of the Inspector;" and again, new works must be "under the Superintendence of the Inspector;" and again, it was declared, that the Board of Health "adopts, as a principle, to sanction the mortgage of rates, and the distribution of charges, only on conditions such as the following:—

"1st. That plans and estimates have been prepared in detail, and submitted for examination to an Inspector.

"*a* And upon his Report found to be deserving of approval, &c.

"2ndly. That the works shall be executed upon contracts, on the following conditions:—

"*a* That before they are covered up, or put in operation, they shall be examined by the Inspector.

"*b* That they shall be further examined by him when in action, and be certified by him."

And the characteristic tendencies of the same Board were well shown, in the same Report, when they "rely on compulsory powers being given, adequate to the enforcement" of their schemes; and represent to Parliament that the "Board should be entrusted with the power of prosecuting, for the neglect of its regulations."

The foreign system of centralization was gradually pervading

all branches of the administration, and producing the most pernicious effects; the opposition offered by the Admiralty and the Railway Department to many useful enterprises, was notorious, and would ere long no doubt be noticed publicly; but the General Board of Health, profiting by an unaccountable supineness on the part of the profession, had already succeeded in reducing the Engineers,—to the triumphs of whose enterprise and skill England owed so much of her wealth and prosperity,—to the position of mere clerks of works, mere subordinates to the obedient retailers of its own procrustean dogmas and bureaucratic crotchets. It required, that its own express sanction should be given to every system of drainage adopted in any town that came under its jurisdiction; thus interfering, altogether, with the independence of inquiry, enterprise, and action both of Engineers and of those who called in their assistance. The immediate, necessary, and fatal effect of this circumstance, upon the realizing of just views, or real progress, in the question of the "Drainage of Towns," was very obvious. Mr. Toulmin Smith could not but call attention, as immediately illustrative of the subject, to the well-known fact of how, one after the other, different schemes, in reference to the drainage of towns, had been promulgated by the same authority; each in its turn put forth with equal positiveness and pretences to infallibility, and then, by the same authority, discarded and denounced, after great and useless expense had been incurred in many places. Thus it had been with the system of flushing, with that of contour lines, and with that of 5 feet-to-the-mile surveys.

A great deal had been said, of the success of the pipe system at Tottenham; now with respect to that place, it should be known, that only about two hundred houses were connected with the pipe sewers, and that the works were still proceeding; so that neither from the small number of houses, nor from the length of time the works had been in action, could any correct result be assumed.

From the considerations which had been brought forward, these general conclusions were to be drawn:—

(1) That tubular drains were useful for house-drainage, and for short distances, under special circumstances,—but that glazed, or vitrified pipes should not be used, unless where actually within walls:

(2) That they were not usefully applicable, as part of any system of arterial drainage:

(3) That drains should be made of such size as to enable them to meet all probable contingencies; whether of increased town-drainage, or of flood-waters and rainfall;—while their form should be such, that a clear and rapid flow of the ordinary run should be insured:

(4) But the most essential point, for securing efficient town-drainage, and promoting sanitary and other improvements, was, that Engineers and those who engaged their services, should maintain themselves independent of the dictation of Government Boards, and should be guided, as in other cases, by the accepted opinions of acknowledged competent authorities, and by the practical results obtained and recorded, as the fruit of the most careful inquiry, enlarged experience, and unfettered skill, of the ablest professional men of self-earned reputation.

Mr. HOLLAND said, that after the disparaging observations just made, it might seem to require some courage to avow himself an advocate of pipe sewers, were it not for the remarkable circumstance, that the manufacture of these pipes, which, until within a few years, had scarcely been heard of, had grown into such an important branch of national industry, that one manufacturer alone produced 18,000 yards a week, and that was of course but a small portion of the whole quantity made. In the face of such a fact, it would be as useless to attempt to persuade the public, that pipe sewerage was a failure, as to make a Manchester-man believe, that calico was an unfit article for clothing.

It had been remarked, that all were agreed as to the utility of pipe sewers; the difference of opinion then was, as to the extent to which they should be used, or the manner of their application. Mr. Holland was glad to hear that great admission, but still, all, did not appear to be agreed; for by some it was contended, that though pipe sewers were cheaper to construct, they were dearer to keep in order, although no proof of the correctness of that assertion had been offered.

It had been said, that it was most desirable to attain some form and material for the construction of sewers which should not require to be opened twice in a year. He trusted it was

not meant to assert, that this was anything like a fair representation of the case, with respect to pipe sewers. (It was here explained, that no statement had been made to the effect, that pipe sewers generally required to be opened twice in a year, but that some of them had required to be so opened.)

Mr. Holland contended, that the statement, as quoted in the authorised reports of the proceedings, was calculated to produce such an impression, and that impression was contrary to fact. In Manchester, pipe drains had been extensively and satisfactorily used for several years. In the City of London, there had been only three stoppages, in about one hundred pipes, during eighteen months; and at Richmond, on inquiries made at one hundred houses indiscriminately, no failures were met with, nor any stoppage, that had not been cleared away by water alone. But even supposing that pipes were expensive to keep in order, which however had not been proved, the question was, whether that expense was so great, as to counterbalance the economy of the original construction. The town of Rugby had been drained with pipes, at a cost of £3,600, now if the same length of brick sewers had been made, according to the scale, for general adoption, given by the former surveyor of the City Sewers' Commission, the cost would have been £15,000, or £11,400 more than the actual cost. The interest of the difference (£570) would pay for replacing nearly one-sixth of the pipes every year, and nothing approaching to such a proportion of repairs could possibly be required.[1]

In spite of the violent opposition to which the new system had been exposed, it was making rapid progress, and many of those who had opposed it, and appeared still to oppose it, were now using certain portions of the system. This improvement had been, like every other great innovation, at first disregarded, and despised,—next abused as quackery,—and at length gradually adopted, whilst the proposers were abused; eventually it would be discovered that the invention was a good one, and

[1] The state of the drainage of those parts of the Metropolis and of numerous towns, where tubular pipe sewers have been used, is shown in the "Copies of Reports and Communications in reference to the Drainage of the Metropolis, &c.," Parliamentary Paper, folio, 11 April, 1854, and the Reports of Mr. Bazalgette on Tubular Pipe Drains and Sewers, &c., Parliamentary Paper, folio, 24 June, 1853.—EDITOR.

that its proposers should have been praised and its opponents censured.

Mr. A. Francis said, that unglazed earthenware, might, he thought, be as advantageously used for pipe drains as the most impervious glazed pipes; besides, the cost of the latter was about double that of the former. He exhibited specimens of red unglazed pipes, found at Chester, and which were believed, from the inscription, to have been laid by the 12th Roman Legion. The Babylonians also employed unglazed ware for tubular drains.

Mr. Joseph Cliff, through the Secretary, said he had, for some time, been making considerable quantities of large-sized pipes, or tubes, at the Wortley Fire-brick Works, for the drainage of the towns in the district. The pipes were generally egg, or oval-shaped, and the largest sizes were 20 inches by 15 inches, 25 inches by 18 inches, and 30 inches by 21 inches. Of this latter size, nearly 7000 yards had been already laid down, in the streets of Leeds, since the drainage commenced. In consequence of a doubt, as to the advisability of the system of pipe drainage, men had been sent up the sewers, to examine them and to report upon their condition. They had been exposed, in many parts, to the heavy traffic of the streets, and the late heavy rains having caused subsidence of the ground in the trenches, and in several instances filled the tubes themselves full of water, they had been as severely tried as it seemed probable they ever could be. After a minute investigation, the pipes were found sound and good, and not one single failure was discovered in the whole line, which had the appearance of being self-cleansing.

These pipes were made of a strong metallic fire-clay, which by resisting an intense heat in the kiln, allowed the inner and outer surfaces to be vitrified and to receive a good glaze, still retaining their shape and not splitting, or cracking in cooling. They were made about 2¼ inches in thickness, and if it was found, by experience, that greater strength was required, there could be no difficulty in making them thicker. Those used in Leeds, were all socket-pipes; while those laid in Manchester and that neighbourhood, had only plain butt-joints. It appeared, that many of the gentlemen, taking part in the discussion, were not aware of pipes of that size and thickness being made, and

their objections to pipe drainage were founded, to some extent, on the size, nature and thickness, of the London-made pipes, with which they were alone familiar. It was impossible to make the London pipes of the sizes and thickness mentioned; the quality of the clay forbidding it, and appearing to involve the necessity of their being made thin and merely as pottery-ware, or pot-pipes, and therefore possessing the ordinary characteristic of pottery-ware,—a liability to snap, or break, by sudden concussion, or under heavy pressure. Large sizes, of the necessary strength, could not, therefore, be made from London clay. In the Leeds district, however, there was not any difficulty in making pipes of almost any size, and strong enough to bear any external pressure. The pipes, he had mentioned, were made under pressure, by Spencer's machine, the socket being made at the same time, and not being put on afterwards as was often the case. If required, still larger pipes could be made, up to 36 inches, and of any requisite thickness. Mr. H. Wrigg had used large quantities of these pipes, at Preston; he preferred having them of circular section, giving to them the dimensions of 1-8th inch in thickness to each inch of the diameter; thus a pipe 24 inches diameter would be 3 inches thick.

It might be considered as a fact, that oval pipes could be made even up as high as 3 feet by 2 feet 4 inches, and of proportionate thickness, without difficulty.

Mr. CAWLEY stated, through the SECRETARY, that at Manchester, the substitution of pipe drains made of fire-clay, for all sewers of less than 2 feet diameter, had been successful; and he believed, that few breakages had occurred, except in cases where the pipes had not been sufficiently covered, and the concussions of the wheels of heavily-loaded carts had affected them. He had used earthenware pipes, of 12 inches and 20 inches diameter, for conveying pure water to a reservoir, laying them at depths varying from 3 feet to 6 feet, and without any case of breakage. It was true, that the pipes in Manchester were, for the most part, laid in hard gravel, or strong clay, and he could not conceive why any fracture should occur, if the pipes were well bedded, and the earth was well rammed around and above them. If there was unequal pressure, fracture must ensue.

He had received from Mr. John Francis, the Surveyor of the Paving and Sewering Department of the City of Manchester, the following reply to questions proposed to him, in consequence of reports as to the state of the pipe drains at Manchester:—

"The main, or street drains, are laid at various depths, from 9 feet to 30 feet; the passage and branch drains at all depths, from 2 feet to 10 feet.

"The ordinary inclination, for main drains, is half an inch per yard, but a few are laid at a quarter of an inch per yard. I do not remember any with less than that inclination. Branch, or house drains, have an inclination of 1 inch per yard and more, according to circumstances.

"The largest size we have used is 25 inches by 18 inches, and the maximum size, at which tubes are likely to be preferable to brickwork is, I think, 3 feet by 2 feet.

"The largest area drained into a tubular sewer, is about 50 acres;—but the whole area is not yet drained, and the tube, at its outlet, has never been half full. With respect to areas of drainage, my experience is in accordance with the recent 'Minutes of Information of the General Board of Health' as to the sizes of sewers required. But in practice I have adhered to sizes in excess of any formula. I think this should be done for the smaller areas, and greater exactness be observed, as you approach the larger areas.

"I am now constructing an oval sewer 64 inches by 48 inches for a brook, having a drainage area of 550 acres, with an inclination of 1 in 300;—(commenced before I saw Mr. Roe's table and agreeing very closely with it.)

"The smallest tube I have used, for main drains, in small streets and passages, is 12 inches by 9 inches, and the smallest branch drain, for foul water, is 6 inches by 4 inches. There is a principle which appears to me inimical to the use of very small tubes for foul water, or water loaded with solid matter; viz. the ratio of the periphery to the transverse area, increases inversely to the size; therefore also the friction and liability to stoppage; other circumstances being similar.

"Our drains and sewers are intended to take off storm waters, and no case has come within my knowledge, where our tubes have appeared to be incapable of this duty.

"We have not had one case of breakage from pressure, where the tubes were laid 2 feet, or more, below the surface. The laying and packing well with earth is the main point. All decay in sewers arises (within my experience) more from the stream within, than from the pressure outside. Our soil here, both clay and gravel, is tunnelled for sewers, ordinarily, without timber, therefore, when the soil is laid compactly about the tube, the pressure upon it is next to nothing. We use no sockets to our oval tubes, for the drains, but have them to the round pipes, which form the vertical shafts, connecting the surface with the main drains. I am more satisfied, every day, with our rejection of the socket joint. I am not aware of any disadvantage from its absence, and I partly attribute, to that cause, our immunity from breakage. It is easy to see, that in pipes having sockets, carelessly laid, the said sockets become so many points of unequal pressure. We have had many cases of stoppage, at the upper extremities of our drains, which soon caused me to adopt universally a syphon trap to every grating; but upon the whole, and taking into consideration, that we were left to acquire our experience unaided,—I think our success, in the use of tubes, has been most signal,—and for minor sewers and drains, glazed fire-clay tubes are preferable to anything else."

Mr. J. EVANS, through the SECRETARY, said that, as Borough Surveyor of Salford, he had paid considerable attention to the working of the pipe-drain system, and had given it a fair trial himself. He had not used any pipes of less dimensions than 6 inches by 4½ inches, nor larger than 12 inches by 9 inches, and those only for conveying the surface water from court-yards,—passages,—and streets, into the egg-shaped main sewers, which were built of brick-work, and varied in size from 42 inches high and 32 inches wide, down to 24 inches high by 18 inches wide. In fact, the Committee would not permit any earthenware pipes to be used for main sewers, as they had individually suffered, from having allowed them to be laid down on their private properties, in Manchester, where they found, that the trouble and expense of keeping them clear, and the difficulty of connecting branches into them, formed serious objections to their use. It was even broadly stated, by men who appeared to have experience, that the pipe-

drain system had been carried to an extent in Manchester, which would eventually cause serious inconvenience.

Mr. B. Baylis, through the Secretary, said the extensive system of egg-shaped brick sewers, varying from 3 feet 6 inches to 2 feet high, constructed under his direction at Chester, had proved thoroughly effective, and were found to be less costly, than any other system that could have been adopted. He had tried a few pipe drains in mews and back streets, but none of less than 12 inches diameter. In the course of the sewering operations, it had been necessary to take up several old pipe drains, 9 inches in diameter, in consequence of their proving ineffective and being choked up, although generally having good inclinations, and in all cases he had substituted larger pipes, or brick sewers, as being the cheapest at last.

From his experience, he believed earthenware pipes, if not less than 6 inches in diameter, to be well adapted for house-drains, but totally unfit for the main, or even the subsidiary sewers of a town of any importance, unless the inhabitants were prepared to submit to the expense, and the annoyance, of having them taken up once in three, or four years. The system of sewerage in Chester, had been in operation for some years, without there having been a single failure, or stoppage, since the completion of the work.

Mr. Plum said, if it was considered advisable, to go to such expense in the subsoil drainage of agricultural land, how much more important was it, to use such forms, capacities, and materials for the sewers, as should secure the perfect drainage of town areas, at the same time that the conveyance both of the surface-water, and of the house-sewage was provided for! He agreed in the disadvantages of the glazed pipe drains, because, being impervious, they could not aid in drainage, unless, as with common drain-tiles and pipes, the joints were left open, which in town drainage could not be permitted; it appeared, also, that the gradual deposit, in some cases, and the presence of extraneous substances, in other cases, were the causes of the stoppages in both pipe drains and brick sewers; it became then a grave question, whether the solid matters of house drainage should be permitted to pass, unchanged in their character, into the pipes, or the sewers, and whether the house drainage should be mingled at all with the surface-water; the latter might, in

all cases, be permitted to flow into the natural outlet,—the adjacent river, at the nearest points,—but the former should not be allowed to pollute streams, especially if the matter could, as was stated, be advantageously used for agricultural purposes. That part of the question was, in his opinion, the most important, and to that the attention of the Meeting should be devoted.

Mr. MAY said the broad question had not yet been adequately treated, and he apprehended the hesitation arose from an unwillingness to attack the doctrines which had been so authoritatively promulgated; as, however, he thought there should not be any scruple in publicly examining public questions, or the acts and opinions of public Boards, and it was the duty of Engineers to canvas this town-drainage question very freely, he ventured to direct attention to the general question.

It appeared to him, that one of the great errors committed had arisen from the apparent advocacy, by the Board of Health, of the schemes for the preservation of sewage refuse for ultimate use. Now it must be evident, that the primary consideration should be, as stated in the Paper, the best method "of the instant removal, from the vicinity of dwelling-houses, and from the sites of villages, towns and cities, of all refuse," foul-water and surface-water, accumulating among the habitations of man, in order to avoid those exhalations, which were known to be so prejudicial to health, and were admitted to be most frequently caused by sewer deposits. If the contents of the sewers could, ultimately, be beneficially employed for agricultural purposes, they should not be neglected; but he thought a very exaggerated value had been attached to that kind of manure; and, from all he could learn on the subject, he believed there were very few situations, where the attempts to combine sewage manure schemes, with the drainage of large towns, had been found practicable. In some small towns and villages the system might be successful, but they were exceptional cases, which could scarcely be used as arguments in favour of the adoption of the system, and the drainage of the Metropolis, or that of other large cities and towns, should not be tampered with for such purposes. It did not appear to be proved, that the method of having separate conduits for the surface-water and for the house-sewage was either the best, or the cheapest; inasmuch as

the opponents of the scheme asserted, that unless the occasional action of flushing by storm-water was permitted, gradual deposits occurred, and the pipe drains became choked; and no fair comparison of the relative expense of the two systems could be obtained, because the separate method had only been tried where old sewers previously existed, but which were now entirely devoted to surface-drainage, and the outlay was really only that of small pipes, of just sufficient area to carry away the house-sewage.

He took exception to the accuracy of the statement, in the Paper, as to the rate of mortality at the Portland Convict Establishment; if that statement was to be received as accurate, it would lead to the assumption of the extension of human life to one hundred and fifty, or two hundred years; and though the decrease of mortality, resulting from a general improvement of the sanitary condition of towns, might be admitted to the fullest extent, yet he could not credit such results as those given for Portland, and he thought great injury would arise from the promulgation of statements, which when analyzed, would be found to exhibit untenable inferences and impossible results.

Mr. R. STEPHENSON, M. P., V. P., said it had not been, originally, his intention to take part in the discussion, but so much had been said, that was either wide of the subject, or dictated by preconceived notions, to be supported at any rate, that he could not resist attempting to bring back the discussion to a useful track.

It had been said, that converts were rarely made by discussion;—that might be true, with respect to questions in which the passions became excited; but when, as should be the case, in considering all scientific questions, truth was the only object sought, he must submit, that honest statements of facts, must carry conviction with them, and would eventually produce effect; time might be required for consideration, before conviction was induced; but even if discussion only produced repetition of experiments, or more careful analyzation of known results, the end was fully answered and good must result. Now in such a question as the present, honest facts had an amount of weight, which mere unproved theoretical schemes never could possess; and it was admitted, by unquestionable practical authorities, that mere abstract principles did not hold good, in questions of

the sewerage of towns, where so many local circumstances and domestic occurrences interfered with the perfect working of even the best-designed general plan.

When he first joined the Commission of Sewers, he believed that he did understand the subject and could have designed any work of the kind, to the perfect satisfaction of the inhabitants; but he soon discovered, that his previous engineering experience, although it naturally aided him, did not suffice to enable him to take into immediate consideration all the numerous bewildering local circumstances and the domestic difficulties with which the subject was surrounded; and he must say, that he almost envied the self-confidence, whilst he was astonished at the daring of the Board of non-professional men, who had not hesitated to lay down definite rules, to meet all cases of this most indefinite branch of professional practice. When he attempted to procure information from the published reports and accepted data, he became still more confused, by the discrepancy of the various statements; so he resolved to examine personally and judge for himself, and the result was, the conviction that for certain localities, if pipe drains were sufficiently strong to resist fracture, and sufficiently large to avoid being choked up, they might be advantageously employed, to form the connexions of houses, courts, and other small localities, with the main sewers, which should be constructed of brick, of such dimensions as to admit of easy internal inspection, and repair, and be of such form, (except where the flow of water was, at all times, considerable,) that the radius of the curved bottom should be able to gather a small supply of water into a sectional area, affording the same hydraulic mean depth as in a pipe drain, of a diameter merely adapted to discharge the minimum flow. The removal of obstacles, or accumulations, from the main sewers, by manual labour, was not more dangerous, or noxious, than the ordinary employment of most working engineers, or of men engaged in the execution of constructive works; indeed there were numerous callings, rendered necessary by the present wants of society, which were much more injurious to health, and it only required proper attention to the ventilation of the sewers to provide against any accidents which were likely to occur. Besides, in comparing the sweeping of chimneys by boys and the cleansing of sewers by men, it must be remembered the former was com-

pulsory, under a bad system, and the latter was the voluntary act of free agents, and it was a mere exhibition of false sentiment, to put forward such an argument in favour of the introduction of pipe drainage.[1]

The best practical arrangement for any machine, was not, invariably, that which gave the most economical application of its power, but frequently that, which, with the due direction of its force, combined the greatest facility for its erection, for its being kept in order, and for its rapid and effective repair, in case of accident.

So with a system of drainage, the small pipe-drains might be efficient, if circumstances never changed and accidents never occurred; but the Reports to the Commissioners of Sewers, showed, in many instances, that notwithstanding every care, the most extraordinary articles found their way into the small conduits, and their entire failure ensued;[2] besides, that unless a heavy pressure of water was used, in conjunction with pipe-drains, stoppages would occur, and this pressure system, like a great influx of storm water, for the conveyance of which pipe-drains were not adapted, caused such an accumulation of back water, as flooded the basements of the houses. Scarcely a day passed, without there occurring complaints of flooding, during rain, or of stench during dry weather; and it was observed, that, in the majority of cases, the complaints proceeded from places where the system of combined back drainage had been

[1] It is stated by Dr. Parent Duchatelet, in his "Hygiène Publique," that "Les maladies, occasionées par le sejour dans les égouts, sont en petit nombre, une seule peut occasioner la mort, c'est l'asphyxie; les autres n'offrent pas de danger, il est même rare qu'elles acquierent un haut degré de gravité; ce sont l'opthalmie et les rheumatismes. On s'étonne qui les affections cutanées, que les ulcères aux jambes, ne soient pas comptées au nombre des maladies des égoutiers; non-seulement ces hommes n'y sont pas exposés, mais ils régardent l'eau des égouts comme un remède efficace contre les plaies, les ulcères et les éruptions chroniques."—Vide "Notice Historique," sur A. J. B. Parent Duchatelet. "Hygiène Publique," p. x. 8vo, Paris, 1836.—EDITOR.

[2] In the "Report of the General Surveyor of Works, under the Metropolitan Commissioners of Sewers," February, 1853, Mr. Bazalgette gives a detailed account of his examination of part of the pipe sewers laid in the metropolis. The Report comprises 122 cases, in various districts;—69 cases on the north side, and 53 cases on the south side of the Thames. He found, that in 113 instances the pipes contained deposit, varying in depth up to 7 inches, and 9 pipes were completely choked. In 23 cases, also, the pipes were either split, or broken.—EDITOR.

adopted. This was evidently an erroneous system, and, if ever pipe-drains were to be effectively used, it would be found imperative to have a distinct drain from each house, opening into a sewer, of sufficient dimensions to allow a man to pass along, to remove any accumulation, and to make any necessary repairs.

One of the supposed advantages of the pipe-drains, most prominently put forward by their advocates, was the greater amount of velocity, pronounced to be given to the flow of the contents of the pipes, by the cylindrical form and the smoothness of the interior. This he contended was a fallacious view, originating, probably, from some experiments, made when the pipes were running quite full and under some amount of pressure; but it was when they were about half full, that the observations should be made. Suppose for instance a pipe-drain 12 inches diameter, conveying only such a quantity of water as would half fill it, or make the stream 6 inches deep; and compare with it an egg-shaped brick sewer, whose bottom was formed to a radius of 6 inches, and whose sides widened gradually upwards, to a sufficient height for admitting a man to pass along. Now he contended, that, at similar inclinations, a stream of water also 6 inches deep would flow as freely in the brick sewer, as in the pipe-drain, and that when the stream filled up the entire area of the pipe-drain, the same quantity of water would pass more freely through the brick sewer, on account of there being less lateral friction, and there being a greater hydraulic mean depth. This was self-evident, and proved, that if a proper sectional form was adopted for the large sewers, a small quantity of water was as effective in them, as in pipe-drains, with the additional advantage of providing for sudden falls of rain, for accidental stoppages, and for the contents of the sewers being pounded up. Suppose the case of the south side of the Thames, where a part of the land was below low-water mark, and consequently, where there was a stoppage by the tide, of the discharge from the sewers, for sixteen hours out of every twenty-four hours; if the dimensions of the sewers were reduced by rule to just the sectional area calculated for the discharge, and no provision was made for the accumulation, during the period of inactivity, the contents of the pipe-drains must either be forced back, up into the cellars and basements,

or the pipe-drains must be burst. This would not occur, under ordinary circumstances, with proper-sized sewers; and, after careful consideration of the subject, Mr. Stephenson had arrived at the conviction, that there was danger and inconvenience, as well as extra cost, to be apprehended, from the indiscriminate and too general employment of pipe-drains; although they were applicable for special localities, and purposes, and he deprecated the publication of empirical rules and formulæ based on the assumed results of experiments, which had neither been well designed, nor carefully performed.

Mr. BIDDER fully concurred in the observations just made; and he agreed with some few remarks in the Paper, particularly where the importance of permanency, in the construction of the sewers, was impressed, as an axiom; he was, however, convinced, that as great durability must not be expected from earthenware pipe-drains, as from sewers properly built of sound bricks; not the hollow, thin gimcracks, frequently proposed for imaginary cases. The ultimate expense of maintaining sewers, should be as much considered, as the first cost, and the drainage of a town could not be considered to be properly executed, if it was not an enduring, as well as an effective work. Instances had been given, of towns being well drained for a time; but when the stoppages once commenced, there was no telling to what extent the expense, or the public inconvenience, might extend. It was admitted, that a brick sewer of 36 inches diameter was, in some localities, as cheap as a pipe-drain of 20 inches diameter, and was not liable to the same casualties of fracture, or crushing. There could not be any hesitation as to which should be adopted by Engineers. It must be admitted, that permanency and durability should be the first consideration of an Engineer, in designing drainage work; and it was well known, that at inclinations, mentioned by the Author of the Paper, the abrading action of grit, on the bottom of pipes, or even on ordinary bricks, would soon wear them away, therefore thin pipes and hollow bricks were not to be used for main sewers, in great thoroughfares, or where tearing up the streets would be prejudicial to public convenience, or cause danger to the adjoining buildings.

The greater healthiness of a district, consequent on improved drainage, was no new discovery; but the result was exhibited

chiefly by the young lives; the benefit being almost inappreciable after sixty, or seventy years of age.

It was wrong to call in question the results of Mr. Roe's great experience, although opposed to the views of a public Board, as that Board had deemed the records of the observations of sufficient value, to warrant their paying a large sum for the possession of Mr. Roe's information, and had published them, for the benefit of the country.

He thought there had been some exaggeration in the statements with regard to the results obtained at Hitchen. If the stated quantity of water had really passed through pipes, of the area mentioned, the velocity must have been nearly twenty-five miles per hour, and it would have required a head of 20 feet, to force the water through the pipe-drains.

An unnecessary difficulty, of magnitude, had also been imposed upon Engineers, in consequence of the apparent determination of the General Board of Health, to render sewerage works subservient to their impracticable schemes, for the distribution of liquid manure, by pipes and mechanical means, over great extents of country, not merely adjacent to, but at considerable distances from the towns intended to be drained. As an instance in point, he might mention, the proposition, in 1849, to pump sewage water from London to Brentwood, a distance of 16½ miles, to an altitude of 420 feet above Trinity H. W. level, through pipes of 7 inches diameter, for the purpose of irrigating an estate, and thence to continue the same sized pipes for upwards of 50 miles further, because it would "be easy to send the sewage on, as far as Colchester, or Ipswich, that being all down hill." It would be wasting the time of Engineers, to expatiate on the absurdity of schemes, betraying such entire ignorance of the effect of friction of fluids in pipes, but it was lamentable to see such documents proceed from public Boards having authority.

The plan now in course of trial at Leicester, under Mr. Wicksteed (M. Inst. C. E.), for separating the fertilizing matter, in a solid state, from the sewage water, by which the latter was deprived of its noxious properties, deserved to be mentioned with praise;[1] and if they were successful in producing at ade-

[1] In the Reports by Mr. Wicksteed "On the most advantageous mode of dealing with the Sewage Matter of the Metropolis," 8vo tract, London, 1854;

quate cost, a substance which could compete with ordinary manure, a great problem would be to some extent solved; although there would be great difference between operating upon the sewage of a town with a population of seventy thousand persons, and upon that of the Metropolis, with nearly three millions of inhabitants: still, for the south side of the Thames and all flat districts, where pumping must probably be had recourse to, under any circumstances of even moderate success, the system deserved attention.

Mr. NEWLANDS said, reference had been made to his operations at Liverpool, in a manner calculated to convey an erroneous impression as to their nature and extent. In giving, from the Report to the Health Committee of Liverpool, the statement of works completed in December 1850,[1] there had been mentioned seventeen miles of brick sewers and only 487 yards of stoneware pipe sewers, and it was quite true, that those were the respective lengths of brick and pipe sewers, laid in the public

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in "Observations upon the Nature, Properties, &c. of Solid Sewage Manure," 8vo tract, London, 1854; and "Preliminary Report upon the Sewerage, &c. of the Borough of Leicester," 8vo tract, London, 1850; it is stated, that Mr. Aikin found, by experiments on the London sewage water, that by the addition of about the three-thousandth part, by weight, of lime, the quantity of precipitate obtained was double that which had previously resulted from the simple precipitation of the solid matter, held mechanically in suspension, in the sewer-water; and, also, that the addition being much more valuable, as a fertilizer, the whole produce was thus rendered superior. In practice, on a large scale, these results were fully confirmed. The process of completely separating the solid matter from the water was very rapid; and the latter, being rendered pure and inodorous, was returned into the river, whilst the solid manure, after being subjected to the desiccating action of a centrifugal machine, was soon rendered fit to be packed up, and sent away for agricultural purposes.

Mr. Stothert, in an account of some experiments on his system of deodorizing sewage-water, states that "the deodorant employed (of which, however, the constituents are not described) is a powder composed of materials—abundant—readily obtainable—and inexpensive." "The process consists in the intermixture with the sewage of a comparatively minute quantity of powder,—itself composed of valuable fertilizing agents;—the effect is instantaneous." "Having been exposed to the influence of the deodorizing powder for a few minutes, the sewage matter, or cesspool contents, are rendered free from smell, and the ammonia and other gases are entirely fixed." "The water passes off from the precipitate as clear as crystal, and free from odour."—EDITOR.

[1] Vide "Report to the Health Committee of the Borough of Liverpool," by James Newlands, C.E., Borough Engineer, 1851.

streets up to that date; but on referring to page 32 of the Report it would be found, that what were there shown as main drains were in reality sewers, and without adverting to the difference in the nomenclature, adopted in the Report, where only the sewers in the streets, made at the public expense, were designated as sewers, the court and passage conduits being called main-drains, it had been stated, that the extent of pipe sewerage completed up to December 1850, was only 487 yards. Now these main drains from the houses were made at the expense of the owners of the property, and not out of the sewer-rate, and they consisted entirely of stoneware pipes from 9 inches to 12 inches diameter. He could not exactly state their aggregate length, but it considerably exceeded forty miles.

When a drain exceeded 12 inches in diameter, it was as cheap to use brick as stoneware, and he thought the former was also better and safer. In a place like Liverpool, where sewers had to be carried through streets only partially built, and where (there being no regulation as to the size, or description of houses, which might eventually be built,) the sewers had to be cut into, for connecting the branch drains, as the necessity for them arose. Stoneware pipes were very objectionable for main sewers, independently of the difficulty of obtaining them true in form, when of large size.

He perfectly concurred, in the importance of getting rid of the sewage with the utmost practicable rapidity, and in constructing the main sewers of such dimensions as to permit free access for inspecting and cleansing them, and for ascertaining the position of any stoppage in the tributary drains. For these tributaries the earthenware pipes were well adapted, if their diameter was large enough; he considered, that 6 inches was the minimum diameter to be used, except for branches; and it was essential, that each house should have its own distinct drain into the sewer. In the Report already alluded to, he had fully explained the system of 'house-draining' adopted at Liverpool, where the peculiar arrangement of the blocks of houses and of the streets, rendered the back-drainage for soil-water of easy attainment. He had also entered into a comparison of the system employed in Liverpool, with that recommended by the General Board of Health for universal

adoption, and it would be found, that the former plan worked uniformly well; but that if the latter was attempted to be used at Liverpool, any accidental stoppage, occurring in the receiving-pipe, could not be removed, without trespass on private property, and inconvenience to all the houses above the stoppage. The rain-water pipes from each house communicated with the house-drains, and aided in keeping them open, by flushing them during rainy weather; it must be evident how essential it was to avoid very small earthenware pipes, as their area should always be such, as to render them capable of conveying away heavy storms of rain, without flooding the premises.

The greater part of the town of Liverpool being situated on the sandstone, which was easily worked, the invert of the main sewers was generally cut in the rock, and brick arches turned over them. Where the ground was bad the sewers were entirely constructed of brick, and good hydraulic mortar. Near the Docks, where the sewers became elongated cesspools, for a certain period during each tide, precautions were taken by relief sewers, sluices, &c., to prevent the flooding of the basements. It was very important so to arrange the lines of sewers, as to intercept the drainage from the upper parts of the town, and not to allow it to pass into the sewers of the lower levels: this was a point to which he paid great attention. In general, he thought, that, as far as it at present extended, the system of drainage adopted at Liverpool might be stated to be quite successful.

Mr. Simpson, V.P., would not, at the end of so long a discussion, enter upon the consideration of many points which still admitted of much argument; he must, however, from long experience, warn the advocates of small sewers, with sharp gradients and a rapid flow of water, that the abrasion of the grit debris, &c., on the bottoms, would soon cut deep into the material, and therefore that earthen pipes, and thin hollow bricks were inapplicable for permanent works. The velocity of 7 feet per second, and the gradient of 1 in 60 mentioned as requisite, or desirable, for the passage of sewage through pipe-sewers, were objectionable for many reasons, and were generally unattainable in towns; and wherever the road sweepings entered into the drains, the abrasion would be found very

destructive, particularly with such a velocity as had been just mentioned.[1]

The selection of the outfall, although generally pointed out by nature, required very careful consideration, and many of the plans for town drainage had failed, in consequence of inattention to that point; in fact, local circumstances must, in all cases, guide the Engineer in the general outline, and the details of application, of any plan of drainage, as also in the nature of the materials to be employed in the construction of the sewers.

He could not agree with the proposed system, of constructing sewers, for part of the Metropolis, at such levels, with respect to the natural outfall, that it would be necessary to pump up the rain water, as well as the sewage. The examples of Holland and of the Fen districts of England, had been quoted as authorities; but, he contended, the circumstances were not analogous; in those agricultural districts the dykes formed large reservoirs, whence the rain-fall was pumped at a slow rate, probably about 1 inch per week; what would be the state of a town, where as much as 1 inch of rain per day had fallen, for several days consecutively? The amount of mechanical power requisite to lift that quantity of rain-fall, independent of the ordinary sewage, was very apparent, and the consequences to be anticipated from the floodings of the low parts of towns, were as evident, as the cost of providing and maintaining the pumping power; besides, the risk of flooding being so great, there must be a large surplus power, or duplicate machines, to guard against accidents, which might, otherwise, arrest the whole system.

It was sufficiently obvious, to persons acquainted with the subject, that some spot in the river Thames, below Blackwall, was the most proper position for the outfall of the London sewers; and with an ebb of tide of 15 feet in that part of the river, he contended, that the plans should not involve the necessity of employing artificial means for raising the rain-water and sewage. In cities and towns situated near the sea, or on the banks of rivers, where the rise and fall of tide was below 5 feet, the adoption of mechanical power, to pass off the

[1] The "Preliminary Report upon the Sewerage, &c., of the Borough of Leicester, by T. Wicksteed, C.E.," 8vo tract, London, 1850, page 17, &c., contains some useful remarks as to the velocity of fluids in pipes and sewers, and the dimensions to be given to the latter.—EDITOR.

sewage, would be justifiable, and in many cases a matter of necessity; but even then the judicious course would be, to divert the bulk of the rain-fall and storm-waters, at high levels, by means of the surface channels, or of separate catch-water drains.

He agreed, that no system should be condemned as entirely unworthy of trial; and in the case of the pipe-drains, there were localities in which they might be very advantageously employed; the great error was the indiscriminate application of the system, to places for which pipe-sewers were unsuited.

He had used with great success, a length of one mile of iron pipe, 2 feet diameter, for a sewer, in a district where the foundation was so bad and liable to move, that he should not have had any confidence in the duration of a brick sewer, and still less in that of earthenware pipes. The line of iron pipe had been down for sixteen years, without any stoppage, but he did not believe the result would have been the same with an earthen pipe-drain.

He believed the power of internal inspection of all sewers, was indispensable, and it would be found, but too soon, how great a mistake had been made, in using small pipe drains instead of accessible sewers, in great thoroughfares, where the public traffic, already seriously inconvenienced, by the lifting of the pavements, for the unavoidable repairs to the gas and water pipes already laid.

Mr. GIBBS said, his experience in drainage, which extended over thirty years, induced the conviction, that no Engineer, nor Board of Commissioners, could lay down any special principle for drainage works, which should be of universal application; each work, and even each part of the detail, must be judged of separately, with respect to the nature of the soil, the surface water-shed, the situation of the houses, and above all the density of the population.

No system could be perfect, which did not comprise, house-, surface-, and rain-fall drainage. It appeared, that the errors, promulgated by the Board of Health, in their hydraulic dicta, arose principally from their having adopted isolated experiments, which fitted their previously-expressed opinions.

One of the most evident of these erroneous data, was, that new inlets might be made into a pipe, without increasing the

sectional area of the vein; this, on the face of the assertion, was incorrect calculation and reasoning; velocity of course increased, as new accessions of water were applied; but velocity did not increase to an amount equivalent to the new accession of water, otherwise a pipe would never arrive at its maximum capacity of flow, nor would a river ever rise above its banks.

The mistake originated in the observations of the surface level of the water, between the minimum, or maximum velocity, not having been carefully made; the curvature of the surface of the water between these two points, constituting, in fact, the inclined plane of greatest velocity, and every accession of new sources of supply must alter this curvature, and the angle of the inclined plane, until the ultimate capacity of the conduit was arrived at.

These considerations were not new; it had always been known, that accessions of water did not increase the sectional area of water, in a ratio equivalent to the body of water admitted.

Frisi in 1762[1] discussed this subject in a most learned and methodical manner, and his observations obtained great respect, even at this day.

The Board of Health recommended,[2] that the dung in slaughter-houses, garbage and other filth, should be passed down the pipe sewers. It was surprising, that rational and thinking men should have devised instructions of this character; —first to recommend the reduction of the size of the sewers, to their minimum dimensions, even to an extent which rendered their efficiency most questionable, and then, that materials be sent down them, which must reduce the fluidity of the water, and thereby lessen the velocity in a corresponding ratio.

Mr. NEWTON said, he was well acquainted with the town of Hitchin, and had carefully examined the drainage works executed there, under the system recommended by the Board of Health. Without entering into details, which were fully understood by all around him, he would state his conviction, that glazed earthenware pipes were not applicable for the main sewers, even of small towns, and much less for large cities;

[1] Vide "Traité des Rivières et Torrens;" par R. P. Frisi. 4to. Paris. 1774.

[2] Vide "Minutes of Information. General Board of Health Report." 1852, page 122.

although they might be used for house drains and branch conduits, where there was a good inclination. The glazed surface and impervious substance of the pipes were both objectionable, as the absorption and conveying away of the moisture from the earth was precluded; the result was, that the ground around became saturated with water, like a morass, the houses became damp, and the pipes were fractured, by the superimposed weight, and the subsidence of the mud in which they were imbedded. Such was not the case, where brick sewers were constructed, as they permitted a certain amount of absorption of moisture, and with them, there was not the annoyance of being obliged to dig down to them, in case of a stoppage occurring, as was constantly the case with pipe drains.

The SECRETARY, by permission, read the following extracts from communications, which had been examined by the Council:—

Extract from a letter from Mr. JOHN ROE (Assoc. Inst. C. E.), dated December 3, 1852:—

"I have received a letter, in which the writer says, that Mr. Rawlinson stated, 'that he had drained a town in Herefordshire, area 1500 acres, the outlet pipe being 20 inches in diameter, which he considered ample; but that, had he followed the rules laid down in Mr. Roe's table of outlets, it should have been 60 inches.'

"Were it not, that the subject is of the greatest importance to the public at large, I might take no notice of the comparison with the table, which I furnished to the General Board of Health, at their request:—that table being formed from repeated observations, during a period of twenty years, I can conscientiously and safely leave it to the test of time.

"That differently formed localities will require different applications, I have taken care to point out, in the notes I sent with the table; but when a theoretical opinion, differing so widely from observed facts, is not only put forth, but acted upon, I feel it right to say a few words on the subject.

"To render Mr. Rawlinson's theory a safe one, in practice, there should not be more than about 2 cube feet of water, per minute, come from an acre of the surface of a town, during a rain-fall of 1 inch in the hour, which fall produces rather more than 60 cube feet per minute per acre.

"On the other hand, I have observed 25 cube feet of water, per minute, per acre, reach the sewers from an inch fall of rain in the hour, from a surface, where the houses have much garden ground attached, and in another case, where the houses were nearer together, 33 cube feet, per acre, per minute.

"To pass the latter quantity of water through Mr. Rawlinson's 20-inch pipe, there must of necessity be a velocity of current exceeding 4 miles per minute, or 240 miles per hour: and if more than a fall of 1 inch per hour be expected, the velocity will need to be increased accordingly.

"That greater falls of rain do take place, and that not unfrequently, is a well-known fact. I have known ten instances of the kind, during the period of my observations, in the Holborn and Finsbury sewers.

"Mr. Rawlinson, in his report on Birmingham, gives an instance of a fall of rain of nearly 2 inches, in little more than half an hour; and a main sewer was shown to Mr. Rawlinson, on his visit, which a rain-fall had filled, a short time before, to within 3 inches of the roof; the area draining to it not exceeding 700 acres; yet the transverse section of that sewer had an area very nearly eight times larger than Mr. Rawlinson's 20-inch pipe, which he thinks ample for the drainage of 1500 acres.

"Facts are stubborn things, and in this case, the facts I am acquainted with (and they are legion) tell a tale the very reverse of Mr. Rawlinson's theory.

"When the importance of the question is considered, it becomes the duty of every one to endeavour to throw light upon the subject, and I hope the discussion of this matter, at the Institution, will enable the Council to send forth a practical report of the discussion thereon, for the benefit of the kingdom at large."

Extract from the Annual Report of Mr. JOHN ROE, surveyor to the Holborn and Finsbury sewers, January 29th, 1847:—

"Some have been led to the advocacy of drains, or small sewers, to be placed in streets, or roads, without discrimination.

"Others advocate two lines of small sewers, or pipes—one on each side of a street, to receive the drainage; but as two such small sewers would not carry off the surface drainage in all cases, other parties consider, that one line of sewer should be formed for the surface, and another for the house drainage.

"In practice this would be found unnecessary, as regards any advantage to the sewer-water for manure; and as regards expense, it would, besides causing an immediate extra outlay, entail a perpetual annoyance and charge.

"A fact that will serve to illustrate this, is that of the new sewer built in Hoxton Town. On each side of Hoxton there was a line of small sewers in front of the houses. The cleansing of these, and other small sewers, has cost, on an average, one shilling and threepence, per foot lineal, each time of cleansing. Taking fifteen such sewers, the average time of cleansing has been four years and a half, and reckoning the first cost of the two small sewers, with the cleansing, the cost, in about twenty years, would have amounted to the expense of constructing an efficient sewer.

"This Commission has caused a new sewer to be built, in Hoxton Town, which will require no repairs for more than a century. The saving to the public, therefore, by constructing an adequate sewer, and thereby doing away with the two inefficient ones, will be double the amount that the new sewer has cost.

"After many years' experience, your Surveyor begs to state, that except a sewer has an extraordinary inclination, or has a body of water passing along it, with a considerable velocity, deposit will accumulate. If a small sewer, or drain, be choked with filth, no water will wash it clear, but the deposit must be raised and removed by manual labour; but, if 2 feet, or 3 feet in depth of deposit, is accumulated in a sewer large enough for a man to pass through (your new sewers ranging from 3 feet 6 inches to 5 feet in height, in the streets), such deposit could be washed away (by flushing) in the manner adopted in your own sewers,[1] where, for five years, all the foul deposit found in the sewers, where a man can work, has been washed away, although varying in depth from 9 inches to 4 feet.

"There will be few localities, whose outlets for drainage will be so situated as to afford, in every instance, such an inclination, or fall, to the sewers, as would enable occasional rains to clear them from deposit, and the water from the common house drainage would prove of little use for such purpose, unless dammed up for flushing, and the cost to supply water sufficient

[1] Vide Minutes of Proceedings Inst. C. E., Session 1842, vol. ii., page 132.

to keep a constant stream (as has been suggested in some cases), would soon amount to more than the expense of a proper-sized sewer, and the keeping it flushed in the ordinary way.

"In August last, the Surveyor had occasion to report, that 4 inches in depth of rain had fallen in one hour, on the first of that month; a circumstance that cannot be too extensively known, at a time when much sewer work is likely to be executed in this country; for having once experienced such a fall of rain, it is right to expect and provide for the like occurrence in future."

EXTRACT from a list of recorded casualties which have occurred to pipe drains in and near the metropolis:—

"George-row, Bermondsey.—Iron pipes substituted for the earthenware drains.

"Compton-street, St. Luke's.—The earthenware pipes 6 inches diameter had been taken up, and a brick sewer built.

"Rye-lane, Peckham.—Pipe drains 18 inches diameter failed, and the repairs cost £200.

"Camberwell Grove.—Pipe drains 12 inches diameter failed, and the repairs cost nearly £70.

"Orme-square, Bayswater.—The repair of the pipe drains cost about £50.

"King-street, Chelsea.—The repair of the pipe drains cost about £42.

"New Church-street, Edgeware-road.—The repair of the pipe drains cost about £14.

"Urinal in Covent Garden.—Stoppages cost about £12.

"Little Pulteney-street.—Stoppages cost about £25.

"Cherry Tree-alley.—Stoppages cost about £14.

"Elliott's-row.—Stoppages cost about £8.

"Holloway-road.—Stoppages cost about £7.

"Vine-street, Westminster.—Stoppages cost about £6.

"Hayes' Mews, Berkeley-square.—Stoppages cost about £25.

"Brunswick-street, Stamford-street.—Stoppages cost about £84.

"Pheasant-court, Gray's Inn-lane.—The stoppages are almost constant.

"Parker-street, Drury-lane.—Pipes failed and the brick sewer, to replace them, cost about £250.

"George-street, Hammersmith.—Pipes failed and the brick sewer, to replace them, cost about £15.

"Carrier-street.—The catch-pit, to the pipes in Harvey's-yard, costs about £80 per annum, to prevent the pipes from being choked up.

"Sydenham Common.—Pipes 18 inches in diameter are taken up, and a brick sewer is substituted for them.

"East-lane, Greenwich.—Pipes 18 inches in diameter are taken up, and a brick sewer is substituted for them."

Many other places are enumerated, where failures, or stoppages of pipe sewers have occurred.

Mr. RAWLINSON said, he should not attempt a reply to the strictures upon the system of pipe sewers, or to the attacks upon the proceedings of the General Board of Health, because in his own practice, as an Engineer, he used his powers of discrimination and his experience, for determining the plan of his proceedings and the materials to be employed, and, also, because he thought the meetings of the Institution should rather be devoted to the discussion of professional practice, than to controversial disquisitions on the proceedings of public Boards.

In many of the statements made, he fully concurred; and he was ready to admit, that an indiscriminate application of the pipe-sewer system, could not be maintained. If, in his own practice, he had to treat a locality, where there was a sufficient water-flow to fill the cloaca maxima, he would give corresponding dimensions to his sewers; but if a sewer of 2 feet diameter would relieve a district of its sewage, he would not increase the dimensions merely for the purpose of internal inspection; in fact, he was so strongly impressed with the unnecessary inhumanity of causing men to enter sewers, that he would use any means rather than permit such a system; he would rather see the streets ripped up every year. The accretions, in sewers, were generally caused by the detritus from the roads and pavements; therefore it was important to devise a means of arresting it from going into the sewers. He conceived the question would be most convincingly settled by facts; and it was shown, that at Manchester there were many miles of pipe sewers, which had been in use for six, or seven years, without stoppage; at Liverpool there was also a great length of tributary pipe sewers; and in the Metropolitan districts there had been laid nearly two hundred miles of tributary pipe-drains. At Manchester the form was oval and the thickness considerable; but at Liverpool and in London, they were the ordinary tubular pipes, of the regular thickness.[1] With these, and numerous other corroborative facts before him, he could not forego his expressed opinion, of the applicability of pipe sewers, under certain circumstances and in localities adapted for them.

[1] Vide also, "Report to the Metropolitan Commissioners of Sewers, on the Drainage of Manchester and Leeds," by J. W. Bazalgette, 4th February, 1853.– EDITOR.

He contended, that floodings were not the result of pipe sewers alone; for instance, on the south side of the Thames, there were very large sewers at low levels; but no district was more inconvenienced by floods. There were many towns in the kingdom so situated, with regard to their outfall, that if the sewers were to be adapted to accommodate the storm water, as well as the house-sewage, they would not be drained at all.

He denied, that there were no means of discovering the position of stoppages in pipe sewers; by a careful examination of the state of the house-drains on each side of the sewer, the approximate locality of the stoppage was soon discovered, the ground could be opened, a pipe be removed, and another be laid down. It was true, that the obstruction might be more rapidly arrived at, from the nearest man-hole, and the accretion be removed from within, if the sewer was large enough, but there was, in his opinion, an insuperable objection to sending men down into sewers.

He had laid, and still continued to lay down, considerable lengths of sewer and drain pipes, as far as he knew, without the occurrence of any serious failures, or fractures; and, if due precautions were observed, such might always be the result. He had also constructed several miles of brick sewers, varying from 4 feet 6 inches by 3 feet, down to 18 inches in diameter; and he found, that if hollow bricks were used, the perforations being longitudinal, and the bricks laid as stretchers, not only was a good sewer constructed, but an efficient land drain was also provided.

In no instance had he attempted to separate the surface water from the foul house-water sewage; and the gullies, both from streets and yards, communicated direct with the sewers and drains.

As far as was practicable, pipe-sewers, of equal diameter, were never connected; but those of lesser section were joined into those of larger area; such as those of 6 inches into those of 9 inches diameter,—those of 4 inches into those of 6 inches diameter, &c. All secondary and house drains were joined to sewers, at as high a point as was practicable, an increased fall being given to them at the junction. Great attention to these points was required, as it was found, that a sewer, doing much work, was liable to become choked, if all the branches joined

on the same bottom level, and had not a corresponding volume of fluid passing through them.

Fig. 1.

Manhole, with junctions in Pipe Sewer. Section on the line A A, of Plan Fig. 2.

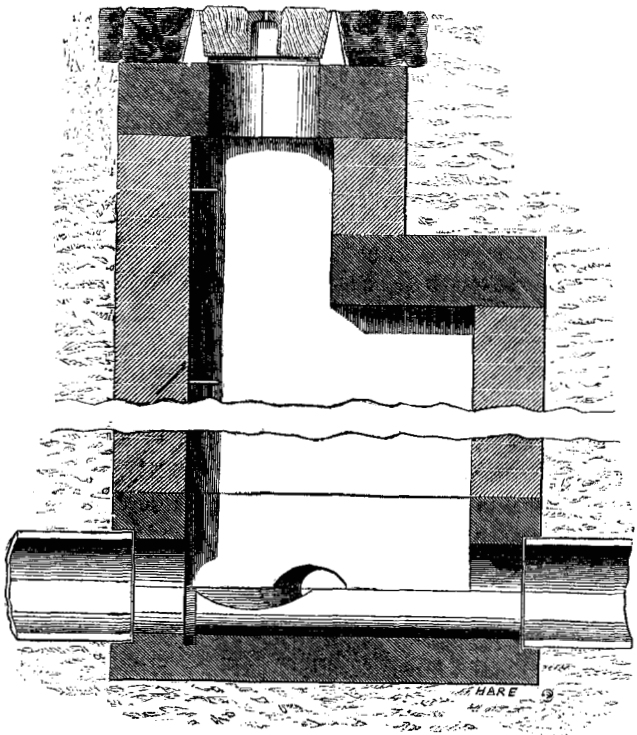


Fig. 2.

Plan of Bottom.

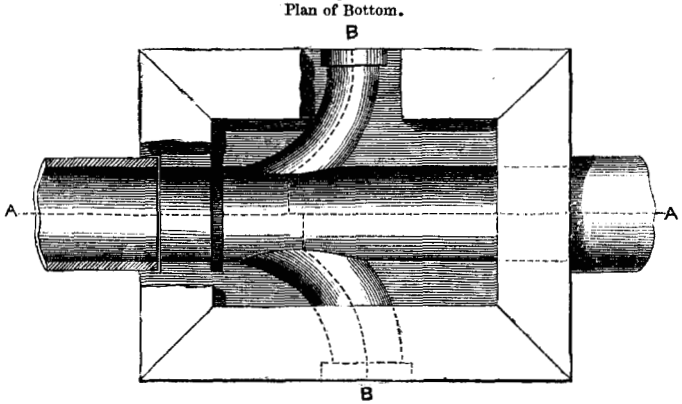


Fig. 3.
Lamphole on Pipe Sewer. Vertical Section.

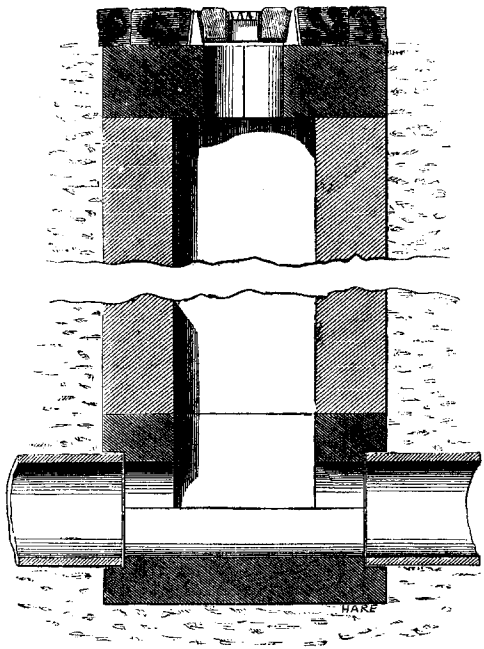
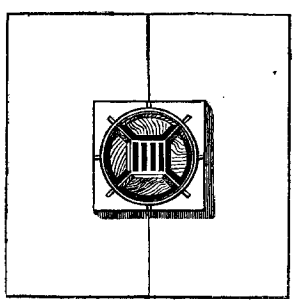


Fig. 4.
Plan of top of Lamphole, showing the cover.

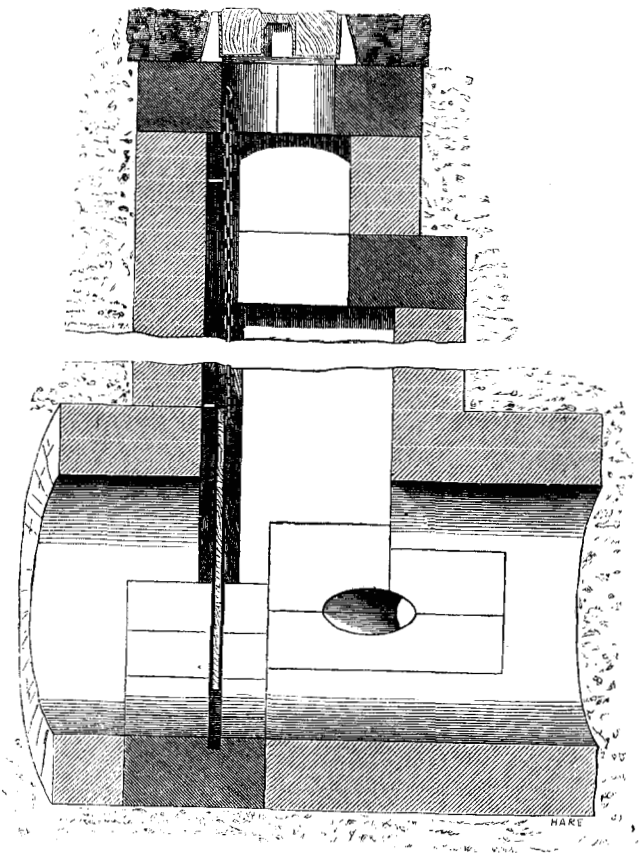


Manholes and lampholes, at short intervals, were requisite on lines of pipe sewers, and each intermediate length should be quite straight, in order that they might be examined and cleansed, if and whenever it became needful. At each manhole there should be an arrangement for flushing; and, in some

instances, a depth of 7 inches of deposit had been flushed out of a pipe of 15 inches diameter, in ten minutes, leaving the pipe-drain perfectly clean.

Fig. 5.

Manhole and Flushing Chamber, with junctions on Brick Sewer.
Section on the line A A, of Plan Fig. 6.

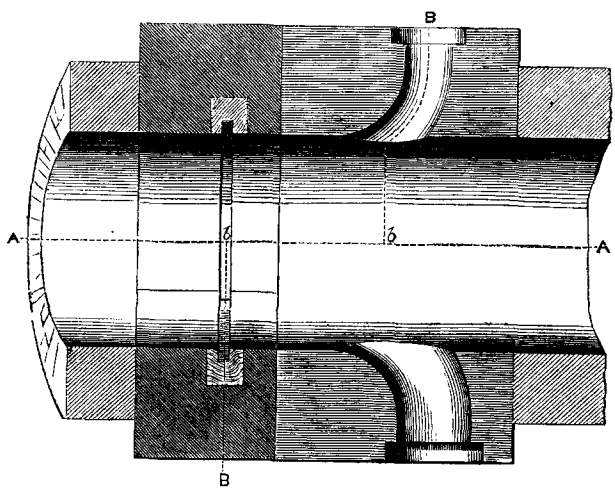


Precautions were necessary, to prevent sand, mud, or rubbish being introduced into the pipes whilst they were being laid; and the surfaces of roads, streets, and yards should be kept well cleansed, in order to prevent the dirt from being washed by heavy storms into and being deposited in the pipe sewers.

Woodcuts, Figs. 5, 6, 7, and 8, exhibited the details of a

manhole in a brick sewer, with side junctions from pipe-drains; and with a loose flushing-board fitting into a groove sunk in masonry. The manhole-cover could be lifted off by means of a key, in order that the sewers might be examined. Step-irons were fixed in all the manholes. All side junctions of pipe-sewers, or drains, with brick sewers, were made with stone. Junctions were also now made of earthenware, and were preferable. The lamphole-cover was removable, so that a lamp, or light, might be lowered opposite the end of the sewer, in order to discover any stoppage.

Fig. 6.
Plan of Invert.



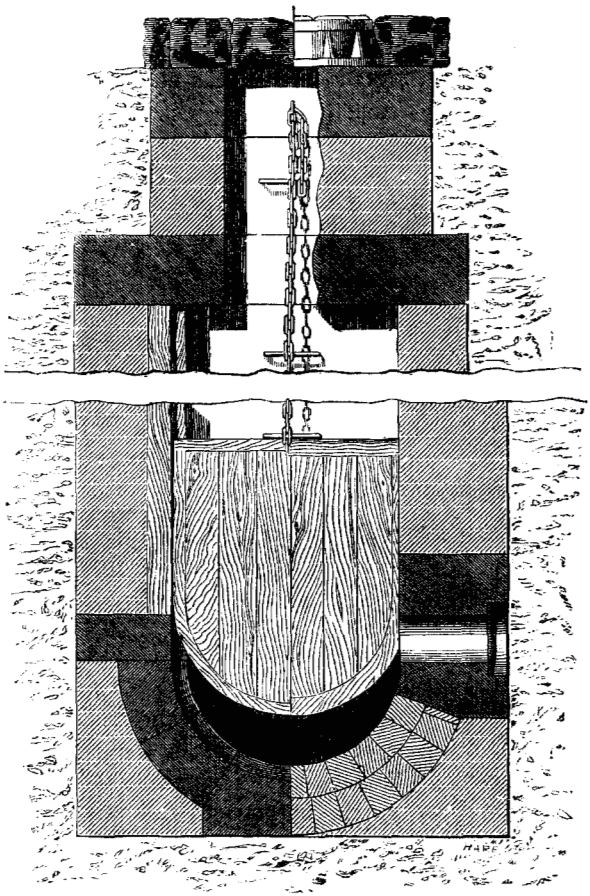
Mr. Rawlinson thought, that considering the lengths laid down, there had been very few failures in the pipe-drains, of the Surrey side of the Thames. He must still express his conviction, that pipes, for the purposes of drainage, offered the advantages of impervious substance, of smooth internal surfaces, of few joints, and of a quick flow, with cleansing power; instead of the permeable material, the rough surfaces, and the numerous joints of brick sewers, with the inherent sluggish motion and the natural tendency to accumulation.

He was not wedded to any system; but in practice he used such means as appeared best adapted to meet each case, and though, like other Engineers, he had not been exempt from

failures, he must give as the result of his experience, that they had occurred quite as often, in using the ordinary system, as with that which he had been accused of unduly advocating.

Fig. 7.

Section on the line B *b* B of Plan, Fig. 6.

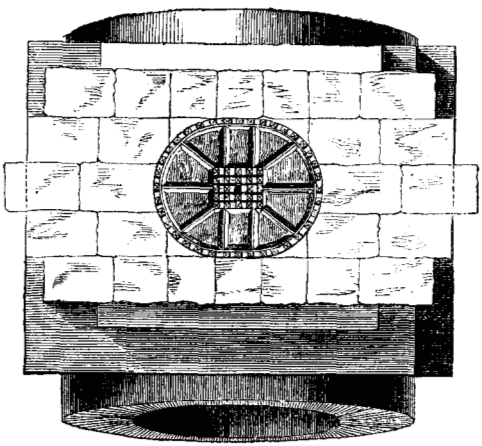


Mr. RENDEL,—President,—said although the Paper only professed to deal with the generalities of the question of the drainage of towns, it had been necessary to consider the materials employed in the execution of the works, as to Engineers the practice was as essential as the theory, and in fact it

appeared, that the failures had chiefly occurred from want of the former; although it was contended, that the latter was not by any means faultless.

Fig. 8.

Plan of top of Manhole, showing the Cover.



It had not been practicable to avoid direct allusions to the General Board of Health, and frequently in rather strong terms; but they were addressed to the official body and not to individuals, and then only for the published opinions, and the acknowledged practice of the officials, which were fairly open to animadversion; whereas, the strictures of the Board of Health, on the received practice of the profession, were as uncalled for and erroneous, as the theories promulgated in the blue-books published 'by authority.'

The object of the discussion had been, not to determine whether large sewers were superior, or inferior to pipe-drains, but to consider the broad question, of the most efficient system of drainage for towns, to ascertain the value of the general maxims that had been laid down, and the influence they might have on the sanitary condition of the country. In doing this, any allusion to public Boards had only been made, by quoting from their published documents, and to the extent only of the opinions they had given, in their public capacity.

It had been assumed, that several of the speakers had come to the consideration of the question, not only with preconceived

notions, but with a determination to condemn the pipe-drain system; this was so contrary to the spirit usually manifested at the meetings of the Institution, that he could not admit such a position, and the general tenor of the discussion proved, that the Engineers felt they could not receive as correct, either the statements put forth 'on authority,' or the deductions from the experiments; they had gone into the question of drainage, equally untrammelled by previous opinions, or by official dictation, and only animated by a desire to discuss the question on scientific and practical grounds, and for the ultimate benefit of the public.

The choice of the various qualities of the materials for pipes and bricks, for sewers, must be left to the judgment and experience of the Engineers; it was of considerable importance to the durability of the work; but so much depended on locality, that considering it would be better, not to import that branch of the subject into the chief question, which was the consideration of the system of town drainage to be recommended, and that the details of construction could be considered on another occasion, he had rather discouraged the discussion of the relative qualities of materials, and would suggest it as a good subject for a Paper during the next session.

The general question of sanitary reform was almost based on the adequate drainage of towns, and, it appeared to be admitted, by all who had directed attention to the subject, that the works, for the purpose, should be comprehensive and permanent, even at almost any reasonable cost, and with the example of Croydon before them, the authorities of even moderate-sized towns should hesitate, before, for the sake of economy, they submitted the drainage of the habitations of their fellow townsmen, to the risk of dependence on a system of inaccessible drains, instead of constructing adequately-sized main sewers. The investigations into the causes of the epidemic at Croydon, as well as the Reports ordered by the Metropolitan Sewers' Commissioners, relative to the results of the pipe-drain system in other localities, would materially aid, in arriving at the correct solution of this vital question, if undertaken with a right spirit, and from the character of the professional men who were engaged in them, there was little doubt of the valuable and impartial evidence which would be obtained.

The President trusted, that the subject would be soon again brought practically before the Institution, by an account of the complete sewerage of some large town, where both the systems of brick sewers and of tubular drain-pipes had been impartially tried.

November 30, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

THE discussion upon the Paper, No. 880, "On the Drainage of Towns," by Mr. Rawlinson, was renewed, and extended to such a length as to exclude all other business.

December 7, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

THE following Candidates were balloted for and duly elected: James Brunlees, Modèste Gallez, and John Willet, as Members; and John Boyd, Charles John Brydges, Pierre Hippolyte Boutigny (d'Evreux), Richard Rous Ellicombe, William Hawes, Alfred Charles Hobbs, William Jackson, M.P., Jabez James, Joseph Jopling, Jun., William McCormick, John Warner, and William Watson, as Associates.

The discussion upon the Paper, No. 880, "On the Drainage of Towns," by Mr. Rawlinson, was renewed, and continued throughout the evening, to the exclusion of any other business.

December 14, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

THE renewed discussion upon the Paper, No. 880, "On the Drainage of Towns," by Mr. Rawlinson, was continued throughout the evening, to the exclusion of any other subject.