November 23, 1852.

JAMES MEADOWS RENDEL, President,
in the Chair.

No. 880. "On the Drainage of Towns." By Robert Rawlinson, Assoc. Inst. C. E.[1]

The Drainage[2] of Towns is so comprehensive a subject, that its full and complete treatment, within the limit of a communication to be read at one evening meeting, would be a useless attempt; the object of the present paper, therefore, is restricted to furnishing topics for a discussion, during the course of which, it may be anticipated, that the merits, and demerits, of the different systems of sewerage, will be fully developed and freely canvassed.

Town drainage may be considered historically, politically and socially. The historical portion of the question need not be entered into, further, than to say, that remains of what appear to have been drains are found in the long-buried cities of Syria, and the sewers of ancient Rome partake of the fame of "The Eternal City;" indeed the Cloaca Maxima is asserted, by some authors, to have been the work of a people older than Romulus. Livy, however, gives the reign of Tarquinius Superbus, as the date of its formation.

Politically—the question of the best system of town sewerage and of house drainage, is very urgent, and at no period has it ever been of greater importance, than at the present time. It may be clearly shown, that the progress, if not the permanence of civilization is dependent upon a correct appreciation of its merits; as the healthy existence of town populations must ever be influenced by their sanitary condition. Misery, pauperism, vice and crime find a forcing-bed in the unsewered parts of towns, and amidst the foul air of undrained houses.

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[1] The discussion upon this Paper extended over portions of four evenings, but an abstract of the whole is given consecutively.

[2] Drainage and sewerage, as connected with towns, are treated in this paper as synonymous. Sewerage is, probably, the proper term, as applied to towns, and drainage to the country.

This may not be self-evident, on a cursory consideration, but facts and figures, which will not admit of contradiction, can be brought in aid of the assertion.

The tendency of modern civilization has been to congregate the human race in masses, and in Great Britain, the extension of towns is unprecedented. In 1841 the population in one hundred and seventeen districts, comprising the chief towns was 6,612,958 souls. In 1851 in the same districts the number was 7,795,882, being an increase of 1,182,924 in ten years. When it is remembered, that the greater portion of the area, thus populated, is comparatively low and flat; such as in seaports, on the banks of inland rivers, or in valleys intercepted by canals, it is not surprising, that this crowding should produce disease, as is proved by the almost constant presence of fever, and a recurrence of the more deadly cholera. It is quite true, that disease, in some terrible form, or other, has ever been associated with man, when thickly congregated, whether in cities, in towns, or in armies—but it may also be shown, that much of this disease has been of that class, which, by due precaution, might have been averted. A full elucidation of this portion of the subject, belongs rather to the medical department, than to that of Engineering; it may, however, be stated, that the averages of mortality, though much higher in town, than in country districts, do not reveal the worst feature of the case, as the annual number of deaths, in the most unhealthy parts of a town, are frequently as ten to one, compared with the better parts of the same town. That is, if ten out of each thousand die annually, in one district of a town, one hundred out of each thousand perish, in another quarter of the same place—so that a statement, of any given average of deaths, per thousand, would be liable to mislead. The average number of deaths, in English towns, ranges from twenty to thirty per thousand. In country districts, the average does not exceed seventeen, or eighteen, per thousand—and amongst the well-regulated classes, only about ten to fifteen deaths, per thousand, occur annually. In the convict prison, on the Isle of Portland, the annual average of deaths is only about five per thousand. There are, however, in that establishment, neither infants, nor very old people, to swell the mortality.

This portion of the subject may be closed, by a quotation from a valuable Report, on Cholera in England, recently issued by the Registrar-General, in which he says:—"A large portion of the next generation of Englishmen will be born in town-districts, some of which are high and healthy, while others low, insalubrious, subject to inundations and to the incursions of cholera, present many of the circumstances in which a degradation of race is inevitable. In the dense districts of Lancashire, where the health of parents is depressed, and the circumstances are often so prejudicial to their offspring, that, of the coming generation five, instead of two, of every ten born, are destroyed in the first five years of life, and the survivors, with a few happy exceptions, are left with shattered, feeble, febrile and disorganized frames—degeneration is as inevitable, as the degeneration of horses, oxen, and sheep, in circumstances equally unfavourable." The might of a nation consists in the health and strength of the people—therefore the supremacy of a country is, in a degree, dependent upon its general sanitary condition.

It is, however, to the social effect of town drainage, that the attention of Civil Engineers will be most naturally directed, as under that head, the leading principles of actual practice, and those modifications which have been proposed for adoption, must be brought forward and discussed. So much has been recently said and written upon town drainage, that it will be quite impossible to strike out either a new, or an independent course, nor is it advisable to do so, as to study precedent,—to learn from experience,—and to correct from practice, are the chief duties of an Engineer.

The much-disputed question of, "in what good town drainage consists," can only be answered by the exhibition of actual works, which do fully answer their intended purpose. The forms and dimensions of sewers, the materials of which they may be constructed, and the depths below the surface at which they should be laid, admit of some moderate difference of opinion; but certainly not to the extent, now permitted in practice. In one position a brick sewer 5 feet high by 3 feet wide will be constructed, at about £2 10*s.* per lineal yard, whilst in a similar situation, there will be laid down an earthenware tube, 1 foot 3 inches in diameter, at an expense of 8*s.* or

10*s.* per lineal yard. There must be something positively wrong in such discrepancy of practice as this, and the sooner the truth is discovered and proclaimed, the better will it be for all parties. If that man is a benefactor to his race, who makes two blades of wheat grow, where one only grew before, he is likewise so, in a degree, who constructs two lineal yards of effective sewer, for the price that has before been expended upon one yard; if the cheaper sewer performs its functions more, or even as, perfectly, then is the achievement so much the more worthy; but if it does not perform so well, then the innovation becomes an injury.

It has been asserted, that no street sewer ought to be less than will allow a man, or a boy to pass along it. The Legislature has passed an Act to prevent boys being sent up chimneys, and, better arrangements being made for providing water for flushing, it may, some day, be inclined to pass an Act to prevent men from entering sewers. The latter will be more humane than the former; as, it is asserted, that more lives have been destroyed in foul sewers, than ever were lost in crooked chimneys.

In town drainage there are three primary considerations:—

1st. The line for the outlet sewer, or sewers, if more than one such be necessary.

2nd. The dimensions of these outlet sewers, and their form.

3rd. The materials of which sewers may best be made.

The position of the outlet, or outlets will in some measure be governed by natural conditions. They must be in such a relative position as shall least endanger health; and wherever it is practicable, only one outlet should be formed, as the refuse will then be concentrated, either for natural removal, or for agricultural use.

The size of outlet-sewers must be fixed by the number of houses to be drained, and the extent of the area upon which they stand.

The site to be drained may consist of flat alluvial land, impervious mud, or pervious gravel shingle; or the town may stand on the banks of a tidal river, the surface being very little above the high-water line,—or it may be actually below the level of high-water of spring tides. Then there are inland cities and towns, through a part of which, flow rivers liable to excessive land floods, and the waters may be impeded by locks, for the purposes of navigation, and by weirs, for mills.

The site to be drained may be partially a flat plain and partially rising land inland, showing a tolerably straight front, or being convex towards the plain. The land may rise on both sides, as in a creek, or bay—or may consist of several such creeks, with natural water-courses passing through each, bringing down the surface-waters of suburban areas, much larger than the town itself—these, and other innumerable combinations, which need not be specified, are all questions, for the treatment of which no fixed rules can be given ; each individual case will demand special study, and must have local knowledge and care.

That the question may however be discussed, certain rules relative to town sewers will be assumed, which may, or may not be established.

1. They cannot receive the excessive flood-water, even of the urban portion of the site.
2. They ought not to be combined with the natural water-courses, which drain large areas of suburban land previous to entering the urban portion.
3. They should be adapted, exclusively, for removing all the liquid and soil refuse from the houses, in such a manner as to cause the least possible nuisance to the inhabitants.

Where the site of a town is a plain, only little elevated above the tidal water-line, the delivery of the refuse from the sewers, must either be by pumping, to render it constant, or it must be intermittent, and, therefore, leaving the refuse, for a time, stagnant in its channels of conveyance. Sewers and drains are frequently required, in situations where high tides, land floods, or both combined, cover to a considerable depth the surface beneath which such sewers must be laid ; or, if the area is embanked, the waters rise above the level of the land and the outlet. These circumstances frequently serve as excuses for not attempting the formation of any sewers, or drains, and most certainly it is much safer to the inhabitants, that there should be no sewers, than that there should be sewers of deposit. That towns so situated may, however, be perfectly, and even economically drained, is proved by the condition of Holland, where the land is almost all below the level of the sea, and yet it is the most densely populated country in Europe. In England, great portions of Lincolnshire, Cambridgeshire and other counties, with large areas of agricultural land only worth from one hundred to two hundred pounds per acre, are drained either by intermittent action, or to a great extent by pumping machines, designed by and erected under the direction of Members of this Institution.

That which is done profitably for agricultural land, may assuredly be carried out for town sites, where the intrinsic value of the land and of the property placed upon it (exclusive of the importance of preserving human life) is, in many instances, as one hundred to one, or even more.

Inferentially it may therefore be stated, that town sites may be profitably drained by pumping, independently of any commercial value attached to the sewage refuse.

Where a town site is partially a plain and partially rising ground, sloping towards the level, or low portion, the formation of intercepting lines of sewer, to receive the contents of the sewers and drains of the higher portion, and to prevent their falling into the lower level, will save much pumping.

The sewers formed in level, or low districts should be of minimum dimensions,—they should be laid as near the surface as is consistent with their safety, and should be constructed of a material capable of bearing external pressure, without crushing, and internal pressure, without leaking, or bursting. If sewers, connected with a pumping establishment, are much larger than corresponds with the lifting power employed, the current through them will be sluggish, and deposit will take place. It will be evident that such sewers should not be unnecessarily deep, in order that the artificial lift should be as little as possible; and they should be capable of resisting hydraulic pressure, as they will be liable to be filled above the crown, either through an extraordinary rise of tide, or through heavy land floods. This latter consideration involves the question of sluices and valves which however need not be entered upon in this Paper.

Another reason, why sewers in flat districts, liable to surface flooding, should be of minimum dimensions, is that maximum volumes of water, in such places, cannot be provided for in sewers. The River Eden, at Carlisle, rises about 20 feet, and the River Ouse, at York, rises about 18 feet, above summer level, laying under water, areas of many miles square. Large sewers, in such districts, would give no relief, at such times, and in dry weather they would be a nuisance.

The assertion that, "Town sewers should not receive suburban waters, or excessive suburban rain-fall," requires some explanation. The area drained by natural streams may be much larger than the urban area,—and, therefore, any arched channel, or sewer, to convey away, safely, the flood-waters of such a district, must be in proportion to such area. The cost, of course, being in proportion to the sectional dimensions of the tunnel, or sewer formed. Another consideration, which ought, also, to have great weight, is, that the flow of flood-waters is intermittent, whilst the flow of sewer-waters should be constant, —that is, the sewers should be as much as possible self-cleansing, by the daily action of the fluids passing through them. This cannot be the case, if a small body of water is spread out over a wide bottom, or invert. There must, in such a case, be a deposit, which will be increased by such obstructions, as stones, sticks, road-sand, gravel, etc., which will be carried from the open water-courses into all sewers, or tunnels, receiving the flood-waters of a suburban district, because the channels leading to the sewer, and the end of the sewer itself must be open. The stagnation of sewage refuse, in such places, will also be greatest, during the driest period of the year, when the evaporation will be most injurious.

Several reasons may be given for the assertion, that "Sewers, other than main outlets under particular circumstances, should not be calculated to contain the flood-water of an excessive rain-fall,"—though one only ought to suffice, namely, that the waters of an excessive rain-fall cannot be passed through any ordinary gully-grates, into the sewers. In Birmingham, on the evening of Sunday the 6th July, 1845, there fell 1·945 inch of rain, in little more than half an hour. This was equivalent to 9·091 gallons upon each square yard of surface, or 44,000 gallons, to each statute acre.[1] This is, no doubt,

[1] *Vide* Report to the General Board of Health on the Town of Birmingham. By R. Rawlinson, May 1849, Page 9.

such a flood as is seldom met with, but equal volumes of rain have fallen in the metropolis, and in other places in England. Those who have any given area to drain, for town purposes, taking these figures as multipliers will ascertain about the maximum, if they premise, that sewers ought to be of sufficient capacity to receive the storm-waters, and to retain, or pass them off below the level of the cellars. In many cases the storm-waters will pass over the surface, after the formation of sewers, just as they flowed away before the construction of any artificial conduits.

The dimensions of sewers ought, in some measure, to fix their depth below the surface, as there ought to be a fall of not less than one in sixty, from the deepest house, or cellar-drain, to the highest water-line, to which a sewer can safely be allowed to be filled.

In arranging a system of town drainage, an Engineer must consider the following questions:—

1. How has the flood-water hitherto passed away, seeing that there never has been such a work as a sewer in the district?
2. What has been done on the surface, in the formation of quays, roads, or streets, or in any other way to impede the free escape of the surface-water?
3. What are the effects experienced during land-floods?
4. Is it practicable to construct sewers, large enough to pass the whole volume of a maximum rain-fall, at such a level, as shall not inundate the cellars with back-water?
5. What additional length of outlet will be involved, to secure the fall required for large and deeply-laid sewers?

These are all questions of the utmost importance, involving economy and efficiency; but there are other minor questions, which an Engineer should settle, before finally deciding on a system of town drainage.

There are sites upon which houses ought never to have been built, and cellars have been dug, where the natural outlets, upon the surface, have been contracted, or destroyed, instead of being preserved and improved. In such cases an Engineer should constitute himself Nature's journeyman, and by carefully observing the natural features of the locality, and using them as much as possible, attain his end more readily than by attempting any forcible control.

There are cases in which it is the province of an Engineer, in some degree to oppose Nature, but this must ever be a costly and dangerous undertaking, and nothing short of actual necessity will justify the attempt. The greatest men in the profession have shown, by their works, that they never undertook an opposition course, when they could accomplish their purpose in an easier manner.

In town drainage, Nature must first be consulted, and effective assistance may then be given to her operations at the least cost. Where there has never been a sewer, it may not be considered necessary to construct one 5 feet deep by 3 feet wide, at a depth of some 15 feet, or 20 feet below the surface of the street, to the great danger of all the adjoining property, and, in many instances, to the certain destruction of the natural outlet.

If it shall be decided, that town sewers are not to convey away the drainage waters of suburban districts, and if it shall, further, be granted, that they cannot be made of sufficient capacity to contain even the urban waters, during maximum rain-floods, it may naturally be asked, of what dimensions should town sewers be constructed? and this may be partially answered by considering *the principal intention in constructing* town sewers.

If it be for house and yard drainage, then to these they should be adapted,—and there will be reliable data from which to calculate their dimensions. The sewers and drains will be of minimum size, and will, consequently, not require either very wide, or very deep excavations to be made, and the cost of the work will also be reduced to a minimum.

It will be admitted, that many large sewers were not originally constructed to serve the purpose to which recent practice has adapted them—namely, to receive and convey away the contents of water-closets for an entire population.[1] The asser-

[1] The Cloaca Maxima was designed and used by the Romans for conveying away both fluid and solid sewage.

tion may sound strange to the dwellers in this metropolis, where the practice of water-closet drainage has prevailed for some time; but few even of the metropolitan sewers, were designed solely with reference to house-drainage. This duty has been subsequently imposed, but even now there are miles of sewers which do not receive the drainage of one-tenth of the houses in the district.

In Paris the contents of water-closets are generally excluded from the public sewers, and it is only recently, that the law has been repealed in Liverpool, forbidding the turning of water-closet refuse into the sewers. The architect of St. George's Hall was obliged to arrange for the construction of large cesspools beneath the foundations, to receive the contents of the water-closets, proposed to be erected in that building.

There are, in many towns in England, great lengths of sewers, which do not receive the adjoining house-drainage.

In discussing the best form for sewers and drains, it is necessary to consider carefully their dimensions, and the materials of which, under all local circumstances, they can most advantageously be made. The nature of the subsoil must first be well ascertained, before either the form, or the material can finally be decided upon; that is, the Engineer will frequently have to modify both the form and the material, in order to overcome some natural difficulties which could not be foreseen, but which will induce more, or less alteration, from the first design, and not unfrequently occasion even partial failure, in the works of the ablest and most watchful Engineer.

In existing sewers and drains may be found almost every sectional form, of which such constructions are capable; they are V shaped, square, oval, and circular, and also partake of every intermediate combination of these figures;—V bottoms have been defended;—flat floors, or inverts, have been advocated, and the egg shape has been insisted on, even down to drains of 4 inches in diameter. There have been as varied assertions, relative to diameters; but that question need not be discussed here, as actual works, the great test of Engineering, can alone give a practical solution to this question. Beyond all dispute, there are many miles of sewers in existence, very much too large and there may be some too small.

Rules have their use, and that man who works without rule will seldom be right; but he who works by rule alone may also sometimes be wrong.

Rules for the diameters of sewers, and drains, to remove, not only the ordinary flow, but also the storm-water of districts, have recently been published,[1] and, as these rules are within the reach of every Member of this Institution, more need not be said relative to them, at present.

If the materials, of which sewers may be constructed, are to be subjected to local contingencies and conveniences, the sectional forms may be more definitively settled.

Sewers, having a transverse sectional width of more than 2 feet, should have a circular invert, in order that the minimum flow of water may be concentrated.

For sewers, less than 2 feet in diameter, the strongest form is the circle, whether they be constructed of pipes, tiles, or bricks. There may be an advantage in the egg shape, when sewers exceed 2 feet in diameter, but practically, that form possesses none for lesser dimensions, and should not, in practice, be adopted for small sewers, or drains.

The best material for the construction of main sewers, is a question only to be determined by practical results. Brick, stone, and cast-iron, either used singly, or variously combined, have each their partizans; recent practice has however indicated earthenware pipes as (apparently) the most economical and effective, for all sewers and drains, under ordinary circumstances, and within the capacity of the material. They have been made from 3 inches up to 30 inches in diameter; the former are too small for any drain,—the latter are too large for the material of which they are made.

It is self-evident, that theory alone cannot be followed, in determining the sectional area of house-drains; if it were, they might be reduced, in some cases, to the size of a quill, as more water will pass through such an aperture, in the course of twenty-four hours, than is used in a cottage; but drains are devoted to other uses than the mere passage of fluids through them, and their sectional dimensions must be adapted accordingly. It will probably be eventually shown, that 4 inches in

[1] *Vide* "Minutes of Information on Sewerage and Cleansing of the Sites of Towns;" General Board of Health Reports. 1852. Page 67.

diameter is the minimum sectional area to be given to house-drains, and that they should not be laid at a less gradient than one in sixty.

This question of size may, however, now be left to be settled by practice; discussion rarely makes converts; but facts are stubborn things, when they can be arrived at without any colouring of prejudice.

The theory of pipe-sewers has been recently much agitated, and without undue advocacy of extreme views it may be asserted, that no discovery of modern times is more fraught with benefit, if properly applied, than the use of pipe-sewers for town and house drainage. Streets have been effectively sewered, and houses efficiently drained, by earthenware pipes, where neither sewer, nor drain would have existed, if costly brick constructions had alone been available.

Earthenware-pipes cannot, however, be beneficially used, as sewers, beyond certain limits, which can only be settled by practice; temerity will lead to failure, and failure will correct theory; the Engineer who is anxious after truth will not denounce a system, because some men push it to extremes, and hence he will use the mistakes of other as his beacons.

Various forms and modes of jointing earthenware-pipe sewers have been tried; there are plain ends, or "butt-joints," rebate-joints—full-socket joints—and half-socket joints. There are also both circular and egg-shaped sections. About fifty miles of pipe-sewers are laid in Manchester, the majority of which are egg-shaped, with plain, or "butt" joints, finished with clay. These pipes range from 4 inches to 30 inches in height and are laid with the narrow side down. In twenty-five miles of main sewers, also laid with pipes, there has not been a single case of failure, and in the lateral drains, wherever a few failures occurred, their causes were easily discovered; indeed at Manchester, the pipe-sewer system may be said to have proved most successful, and in a recent report of the Town Council it is stated, "The economy effected by the use of tubular sewers is palpable, and the result will be, no doubt, a great extension of the practice of draining, and consequent improvement of the public health."

The maximum dimensions of pipe-sewers, must be governed, in some measure, by contingent circumstances. At present

15 inches, or 18 inches diameter, is the extreme size to be recommended for socket-pipes, and in laying these, great care must be taken, or through unequal bearing, the pipes will break each other at the joints.[1] Pipes with plain ends may be laid of as large dimensions as the material of which they are made will allow; care being taken to secure fair fitting and equal joints. Full-socket, or half-socket pipes, of 12 inches in diameter and under, may be used with advantage; where they are restricted to these dimensions, the pipes are much more uniform in shape, the relative strength of the material is much greater, and there is little danger of such pipes fracturing each other. The difficulty in moulding, drying and burning pipes increases, probably, as the squares of the diameters. If large pipes are moulded too thin, the finished sewer is liable to be crushed, and if they are moulded of extra strength, the wet pipe collapses by its own weight in drying.

The side-junctions, as moulded by the best makers, are a great improvement upon the direct entrance of brick-sewer branches, at right angles with the mains. A well-made pipe-junction increases the velocity of the current, by passing the sewage into the main, in the direction of the flow, and all side-junctions should have a quick descent, for the last 3, or 6 feet, before reaching the main.

Good and cheap sewers may be made with either solid, or hollow radiated bricks, having their beds in the radius line of the curve. Bricks of this description cost very little extra; they may now be moulded of such dimensions as are required; —for instance, sewers of 2 feet diameter, may be made with bricks 4½ inches on the bed; those of 2 feet 6 inches diameter, with 6 inches on the bed; and those of 3 feet diameter with 7 inches on the bed and so on upwards;—the limit being the capability of moulding the bricks with economy and of the workman handling them with facility. Hollow bricks may be used advantageously for the external ring of sewers, constructed

[1] In recent practice, the Author has discontinued the use of full-socket pipes, above 9 inches in diameter, and has either adopted half-sockets, or used butt-joints laid on earthenware chairs. Unequal bearing at the joints, has chiefly caused the fracture of the pipes, which has been so much complained of, and which should be specially guarded against.

of more than one brick in thickness; the horizontal perforations forming channels for the land drainage.

Sewers of radiated bricks, set in cement, are cheaper than large pipes; that is, a brick sewer of 3 feet in diameter is cheaper than one of pottery 20 inches in diameter; the capacity of the sewers being as the squares of the diameters. There is no reason why brick-sewers may not be made as smooth and as impervious to wet, as pottery pipes—either by selecting bricks of peculiar quality, or by having the surfaces prepared with asphalte. It is difficult to arrange perfect side-junctions in brick sewers, as every inlet should curve in the direction of the sewage flow; but pottery junctions may be worked into the brick sewers, or, in some cases, cast-iron inlets may be used.[1]

In a system of sewers and drains, man-holes, at intervals, will be of great service. These may be simple shafts of brick-work 2 feet 6 inches or 3 feet in diameter, carried up over the line of sewer; if placed at intervals of one, or two hundred yards apart, they enable the Engineer to examine the action of the sewers, and, should a stoppage take place, the exact spot is more readily indicated and discovered. They are especially useful at street junctions.[2]

Street gullies are generally trapped, and there is a receptacle for the heavy detritus of the roads. Here again, local contingencies will affect the application of rules. Small towns, with paved streets where there is little wear and a good fall for the sewer, need not have any elaborate gully arrangements; the surface water may pass at once into the sewer, or into a well, or receptacle for the grit, out of which a plain bent pipe passes to the sewer; which latter will be all the gully arrangement required. Gully-grates should be tolerably fine; that

[1] Since this paper was written, the Author has used stone inlets. The beds of the stones are worked to suit the radius of the brick sewer, and the inlet for the pipe drain is formed out of the solid stone. Messrs. Doulton have since made a pottery inlet, which must supersede the use of stone.

[2] In all the work done, since this Paper was prepared and read, the sewers, whether of brick, or of pipes, have been laid in straight lines, from point to point, in lengths as great as were practicable. At the change of direction, or of gradient, there is a man-hole, or hand-hole, to allow of examination, so that the light is never lost through a sewer.

is, the apertures should not exceed $\frac{3}{4}$-inch, and if there is a kerb-stone, the grate may dish towards it and be continued up the side; so that, should the surface become choked, the water will pass off by the vertical side. Large openings into pipe-sewers should not on any account be permitted.[1]

Sewers which require trapping, are either faulty in construction, or their action, in use, is imperfect. House-drains may be trapped by a plain bent pipe; mechanical traps of every kind ought to be avoided, they are a delusion and a snare; hinged traps impede the flow of sewage and do not prevent the escape of foul gases.

There should be full and free ventilation of the sewers, at all the highest and most convenient points of a town, and where any escape of foul gas will be the least nuisance. Ventilating chimneys may be of much service in flat districts of great extent, or the steam jet may be applied; but furnaces should be used with caution, as the gases of a foul sewer are liable to explosion.

In some districts cast-iron pipes may be used for sewers, with great advantage, as, for example, where there is partial flooding, by land-floods, or by tides; or, in heavy ground, in quicksands, and to cross intervening spaces, where towns stand upon alluvial shingle, within tidal influences. Externally they may be laid in clay,—internally the metal will be protected by the fatty matter of the sewage.

The question of Town Sewerage, or Drainage, has of necessity been very briefly and imperfectly treated in this paper. Each branch of the subject might be made a text, which would require an entire essay, with many diagrams for its illustration; but as the Author's principal object has been to elicit opinions in a discussion, he has merely ventured to treat generalities.

Certain rules may, however, be given for Town Drainage:—

Sewers should be below the level of cellars, and they should be adapted to the especial work they have to perform.

Rivers, brooks, and natural streams should not be made part

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[1] A gully grate has been invented and used by the Author, which effectually traps the drain, and yet allows a direct communication with the sewer. It enables the drain, or sewer to be flushed with the full force of any water at command, as a hose-pipe can be passed direct into the drain leading to the sewer.

of a system of sewers, and the sewers themselves, in low districts, should be capable of resisting internal pressure.

Wherever it is practicable, the sewage of high districts should be intercepted, so as to preserve a free outlet at all times, for this portion of the system.

Small sewers and drains should be circular; large ones should be oval, or egg-shaped.

The longest practicable radius, should be adopted, in laying out curves on lines of large sewers, and there should be an extra fall in the curve, especially at a junction with a main sewer.

All sewers and drains should be impervious to water, and should present even and smooth surfaces; special arrangements being made for land-drainage.

The gradient, or fall of large sewers, in steep ground, should be modified; that is, the gradient should be interrupted, or, the sewer should be made of such material as will resist the tendency to rapid wearing away.

Wherever it is practicable, the outlet, or delivery of sewers should be free, and in every case there should be full and free ventilation.

Cesspools within a town, and either beneath, or attached to houses, are subversive of sewerage and drainage; indeed, no town, or city can be considered as drained, in which cesspools are permitted to exist.

Cesspools, or manure tanks, at, or near an outlet, are nevertheless admissible; care being taken, that such outlet, or delivery of the sewage refuse is not blocked, or impeded, and that there is no in-draught, or back-draught, through the sewers.

The true purpose of town sewers is the instant removal, from the vicinity of dwelling-houses and from the sites of villages, towns, and cities, of all refuse liable to decomposition, and which is capable of being conveyed in water. The more fully this is accomplished, the more perfect will be the system. Efficiency, durability, and economy should never be lost sight of, and though the drainage of towns may not, at first, appear to be an attractive occupation, yet if the works are well designed and executed, it will neither be the least noble nor the least useful pursuit of the Civil Engineer.