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GENERAL BOARD OF HEALTH.

MINUTES

OF

INFORMATION

COLLECTED WITH REFERENCE TO WORKS

FOR THE

REMOVAL OF SOIL WATER OR DRAINAGE OF DWELLING HOUSES AND PUBLIC EDIFICES

AND FOR THE

SEWERAGE AND CLEANSING OF THE SITES OF TOWNS.

Ordered to be printed for the use of Local Boards and their Officers, engaged in the Administration of the Public Health Act, and of the Nuisances Removal and Diseases Prevention Act.

JULY 1852.

Presented to both Houses of Parliament by Command of Her Majesty.

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APPENDIX.

GENERAL BOARD OF HEALTH.

Minutes of Information on the Drainage and Cleansing of Houses and Public and Private Edifices, and the Sites of Towns.

The testimony of such medical men as have duly observed the antecedents of disease is now unanimous to the effect, that no population living amidst cesspool-emanations, or in air rendered impure by such causes, can continue to be healthy. The strong may withstand these noxious influences for a time, but even their general health is eventually lowered, and their constitutions undermined by continued exposure to such emanations, while the effect, especially when concentrated upon the weakly and susceptible, is, in certain atmospheric conditions, extensively and rapidly fatal.

The presence of atmospheric impurity produced by the decomposition of animal and vegetable matter is now established as a constant concomitant of the excessive ravages of typhus and other epidemic diseases in towns; and a proportionate exemption from such maladies has marked the removal of the sources of aërial pollution. In proportion as perfect cleanliness has been obtained in prisons, the gaol fever has ceased to exist; and a comparative exemption from the entire class of zymotic * diseases has followed the progress of purification in every description of habitations.

These sanitary views are in conformity with great primitive religious ordinances, both for household and personal purification. For instance, by the law of Moses it was forbidden that even the open camp should be defiled with human ordure, which it was expressly ordained should be deposited at a distance, and immediately covered with soil. Many of the positive observances directed by the Mosaic law had a similar sanitary purpose. The ultimate object of the chief engineering appliances for the sanitary improvement of towns is precisely the same as that of

* The term zymotic (from ζυμόω, I ferment, *zymosis*, fermentation), is applied to designate that class of diseases which are conceived to owe their origin to causes which act upon the system in a manner analogous to the action of yeast upon the gluten of flour; (not that there is any evidence that this is a real operation, but the idea may be admitted as a convenient means of classification); the class includes the diseases usually considered to be epidemic, endemic, or contagious.

the Mosaic ordinances for the preservation of the camp from defilement; and the result of those engineering operations will be the practical fulfilment of the Mosaic regulations for the cleanliness of the person, and for the cure or removal of the "leprous house."*

The habits of a people with respect to cleanliness, and more especially with respect to their care to protect their habitations from pollution by excrementitious matter, are a clear indication of their progress in civilization.† Archdeacon Paley was accustomed to direct the particular attention of travellers in foreign countries to the mode in which the people dealt with their excreta, stating that from this single fact a greater insight might be gained into their habits of cleanliness, decency, self-respect, and industry, and in general into their moral and social condition, than from facts of any other class.

It is a deplorable proof of the want of information and of due appreciation of the circumstances on which the improvement of the moral as well as the physical condition of the population depends, that the existence of filth in houses and towns, the prevalence of filthy habits among the people, and the efforts to remedy or mitigate the attendant evils, are often treated with

* *Vide* Lev. xiv. 33—48; and the commentaries of Michaelis on the Mosaic ordinances.

† In a state of nature animals will not, when at liberty, remain near or sleep over their own droppings. Some animals are endowed with instincts to cover them up. When attention is paid to the proper keeping of animals, it is found to be injurious to allow them to lie amidst the fumes of their own dung. Formerly the Zoological Society suffered heavy losses among the animals kept at Regent's Park from neglect of this law, as, *e.g.*, in the case of the carnivora, which were originally confined in a roofed and enclosed building, the atmosphere of which, during a single night, became strongly impregnated with ammoniacal exhalations. A marked improvement has followed the keeping of the same order of animals in dens exposed to the open air, together with the practice of immediate removal of the excrement. Skilful trainers of horses for hunting and racing have their stables carefully cleansed, and all dung as well as the urine removed, three times a day, to such a distance that no fumes from them may reach the animals. But the common practice in towns is to keep the dung in the stables for weeks, during which time not only the animals, but the neighbourhood, are subjected to insalubrious effluvia, the effects of which are strikingly visible in the pallid countenances and inferior stamina of the grooms and stable boys. On an investigation of the disease among hunting dogs called "kennel lameness," it was found that mere change of the sites of kennels did not avert it; and eventually its cause was ascertained to be defective cleansing, including the want of a due supply of pure water, and of effectual drainage. A person having much experience on the subject lays it down as an axiom, that the removal of all foul matters from within or beneath the kennels, must not only be constant and complete, but distant; and that no opening of a drain should be allowed within at least 100 yards of the kennel.

unconcern, as if the subject was of no consequence, or fitted only to excite disgust. It may not be needful that persons on whom no duties in this behalf devolve should enter closely into the details in question, but it is incumbent on the local administrators of the law for improving the sanitary condition of the people to show by their manner of dealing with its provisions that they regard them as the means of fulfilling, and as being, in fact, when completed, the practical fulfilment of the primitive ordinances for personal and household purification; and it is important that they should treat even the minutest and most repulsive details with the like scrupulous and anxious care with which physicians deal with the most offensive particulars attendant upon sickness, suffering, and mortal disease.

Superior Economy of the Removal of Refuse by Water.

Apart from all social, moral, and sanitary considerations, requiring the *immediate* removal of all excrementitious matters from the neighbourhood of dwelling-houses, assuming merely that all such matter must eventually be taken away, the arrangements should be at least made on the basis of the most economical and convenient means of removal.

Early in the progress of these investigations, the proposed system of cleansing, by the removal of ordure in suspension in water, was objected to on the ground of the supposed loss of manure which it would occasion. To this it was and still may be replied, that if there were a total loss of the money now received, or which might reasonably be expected, for manure, that loss would be trivial as compared with the expense entailed by the retention of ordure amidst habitations during the usual intervals between its removals by the common means. Where the householders, instead of paying for the removal of ordure, receive money from the farmers, for the accumulations, as in some of the provincial towns they do, the utmost payment does not cover the increased expenses occasioned by excessive sickness, apart from the bodily disability, the loss of work, and premature decay and death, inevitably occasioned by constantly breathing the impure air diffused over the premises. *Vide Sanitary Report*, 1842, p. 226, and *Supplement*, 1843, p. 72.

Professor Liebig objected to water-closets, (which he supposed to be peculiarly English,*) on the alleged ground that they necessitated the entire loss of the most valuable manure, assuming as an unavoidable consequence, that the whole of the manure must be poured, as at present, into the rivers on which

* The water-closet apparatus has been found at Herculaneum.

towns are seated. All such waste is, however, unnecessary. Except under extreme circumstances the alternative of polluting natural streams may be prevented. In the Minutes of Information on the Application of the Refuse of Towns to Agriculture, it is shown that in no mode can the refuse be so well received, so completely preserved, and so productively applied, as in suspension in water; while the greater expense of cesspools is shown in a Report which Mr. Rammell, one of the inspectors of the Board, was requested to make of the "Cesspool System of Paris," in which metropolis it is developed on the largest scale, under the most systematic management. The facts set forth in that report prove that by the adoption of the soil-pan or water-closet principle, and the tubular mode of drainage in the course of introduction into English towns, a saving might be effected in Paris of a million francs per annum. In the Minutes on the Application of the Refuse of Towns to Agricultural production, it is further shown that the fertilising power of the excrementitious matters would by the same means be enormously augmented.

But if, on the contrary, the substitution of water-closets for cesspools would necessarily involve the loss of the manure, the change would nevertheless be economical, since the annual cost of a cesspool, including interest, depreciation, repairs, and expenses of emptying and carrying away the refuse, considerably exceeds the annual cost of a water-closet, on the assumption that the first cost is repaid by an annual charge, and that the water is supplied at a fair price, that is, at a price proportionate to the expense of obtaining the water.

It appears that the quantity of cesspool refuse, including ordure and other animal and vegetable matter, is from one to two cubic yards per house per annum;* and the cost of its removal in London (including openings, and making good the cesspool, and cartage out of town) was stated by contractors, and proved upon a house-to-house inquiry, to be, on an average, about 20*s.* per annum.† The annual cost of the construction of a cesspool (including interest and depreciation), is estimated

* There are various estimates which give the night-soil and urine at one cubic yard and half per family of five persons; but other refuse, washings, animal and vegetable matter, thrown down water-closets or into cesspools make up the larger quantity.

† In many country towns, where night-soil is kept in shallow uncovered pits (called midden-holes), the cost of emptying is less than where deep cesspools are used, but although the emanations as being more diluted may be less noxious than those arising from covered cesspools, the sight of the exposed ordure is offensive and degrading, and the open midden-steads are in other respects serious nuisances.

to average not less than 10*s.* per house. When cheap cesspools are made, from which percolation is not prevented, the injury to the foundations of the houses would more than make up the difference.

This annual cost of 30*s.* per house is moreover the balance of loss above the value of the manure which those who take it away may retain for use if they please; and in country towns, farmers often pay a small sum for liberty to take the night-soil away; which, however, diminishes but in a small degree the cost of retaining it. The fœtid smell caused by the disturbance of night-soil in the vicinity of houses has led to the extensive use of apparatus for artificial dilution with water, so that it can be pumped through moveable pipes to the nearest sewer or stream. Though in addition to the expense of the operation, there is in this mode of removal a sacrifice of the entire agricultural value of the matter removed, the alternative is gladly adopted to avoid the nuisance of emptying by hand labour; and it is therefore fair to add the intrinsic value of the manure thus sacrificed to the necessary expenses of the cesspool practice.

This sacrifice is carried to such an extent that often where there is sufficient open ground, a pit is dug and the contents of the cesspool are at once buried; and in London it requires much vigilance by the police to prevent the men who are paid for removing ordure, from discharging it surreptitiously into the sewers through the gully-shoots, where, in its undiluted and highly concentrated state, it is a very dangerous nuisance. These facts prove that the value of the manure as now dealt with does not equal the cost of its removal, though that value, if the refuse were removed and applied in the most economical and efficient manner, would as to cottages be often equal to a moiety of the rent.

To obviate the nuisance and danger of cleansing cesspools, the use of moveable receptacles has been extensively adopted in Paris and other continental cities, and the expedient has been proposed for this purpose, and also for the saving of manure, in this country. But although the nuisance of emptying cesspools is prevented by the use of these receptacles, they are not found to arrest decomposition, or to prevent the loss of the most valuable part of the manure, and they are found to be more expensive than properly-constructed water-closets.*

* M. de Piorry, a French writer on Hygiene, whilst admitting the failure of the moveable cesspools to confine the noxious emanations, and the fact that they had been reported against as having proved injurious to the health of the inhabitants and the public, shows, nevertheless, that they are less expensive than the old fixed cesspools; and his statement as to

The more expensive form of water-closet, and the connected drainage arrangements by which the constant removal of all excrementitious matter is effected, would not, as a distributed charge, usually exceed 6*s.* per annum; and the proper charge for the water consumed for the supply of an efficient water-closet should not be more than 6*d.* per annum; (*vide Report on Water Supply*, p. 293) for even when the water is supplied by a company, this, under public contract, would, almost without exception, be a remunerative price. No separate charge should be made for water-closets; the supply for such appurtenances being necessary for all, should be included in the general charge for the house.

Where a constant supply of water under pressure is given, of course no expense for a cistern need be incurred, the force of the water direct from the pipe being found abundantly sufficient for the removal of all the soil, &c. through a syphon of four inches diameter into the tubular drain. Where the shell of a closet, or a suitable privy, exists, all the apparatus necessary for perfecting this indispensable sanitary improvement will, therefore, be a service-pipe, a tap (self-acting or with lever handle), an earthenware basin, and a syphon-pipe, the cost of which, if distributed, need not exceed 3*s.* or 4*s.* a year. This is a rate of expense for the complete removal of refuse, with which no hand labour in emptying, and cartage in removal, can ever compete;* and it is very far below

this economy will be available, and may be used as showing the yet greater economy of the water-closet connected with a tubular system of drainage. "A cesspool of the simplest construction costs from 39*l.* to 120*l.* as the first expense, according to the size and the nature of the soil. To repair a cesspool often costs much more. We will admit that the first cost is 43*l.*, which at 5 per cent. will be an annual expense of 2*l.* 7*s.* 6*d.* Moreover, according to the size of the receptacle, it will require to be emptied every two or three years, and this will cost from 3*l.* 19*s.* 2*d.* to 5*l.* 19*s.*, or 1*l.* 19*s.* 10*d.* a year, which, added to the 2*l.* 7*s.* 6*d.*, the interest on the first outlay, will amount to 4*l.* 7*s.* 1*d.* per annum. Moveable cesspools are let for 2*l.* 7*s.* 6*d.* or 3*l.* 3*s.* 4*d.* per annum; hence there is an economy of from 1*l.* 3*s.* 5*d.* to 1*l.* 19*s.* 10*d.* a year in the use of the latter. It must be further remarked, that when landlords have to repair old receptacles they will avoid by the use of the moveable cesspools, 1.—the risk to the foundations of the houses in forming a new cesspool; 2. the expense of future repairs; 3. the discolouration of the paint. Houses have sometimes been entirely destroyed by the repairing of a cesspool. Now, then, we have a case where the material interest of the proprietor coincides with the health of the inhabitants. It is to be hoped, therefore, that when this fact is more generally known, that the public health will gain immensely.'

* In Belgium, the estimated expense for carting the manure of a whole town to a depôt three miles and three quarters distant, was at

the expense of the keep of the men and horses required by the farmer, where he undertakes the labour of clearing and removal for the sake of the manure.

The Removal of all Cesspools from amidst Habitations the first Duty of Local Boards.

As soon as a proper survey and system of levels (*vide* Minutes of Instructions on Surveys) have been obtained, the first duty of a Local Board of Health will be the prosecution of measures requisite for the entire abolition of all cesspools, and the prevention of their future formation, by the complete drainage of every house in the town.

All the available sources of water-supply having been examined, the most eligible finally determined upon, and works for its distribution arranged, means for the immediate removal of waste water will be next in order for consideration.

Waste water consists of house-sewage, *i. e.* foul water from house-drains and soil-pipes, and roof and surface drainage, with water from land-springs; and it will be a matter for special consideration in each case how much of these should be conveyed away in separate channels, or together.* It will be generally found

the rate of 6*s.* per house per annum. *Vide* a Report made to the "Conseil de la salubrité publique de la province de Liège, sur des moyens de recueillir et d'utiliser les engrais, qui se perdent dans les grands centres de population, au detriment de la salubrité publique et de l'agriculture. Par J. P. Schmit, architecte, professeur agrégé à l'Université de Liège; Membre du Conseil de salubrité publique de la province, &c. Rapport, fait à la suite d'un circulaire adressé à M. les Gouverneurs des Provinces, sous date du 8 Avril 1846. Par M. Ch. Regier, Ministre de l'Interieur, 1850."

* In thoroughfares of considerable traffic in large towns, as in the main streets of the metropolis, as much ordure is dropped on the surface of the highway as is deposited in the cesspools of the corresponding houses. Thus it is reported that the quantity of dung removed daily from a space of 68 acres of paved roadway surface, including the bye streets of little traffic, as well as the crowded streets of the city of London, varied from 505 to 596 loads per week, or was on the average 92½ loads per diem, nearly all of horse-dung. To strangers these streets often smell of dung like a stable-yard. The water collected from some of the streets after rain-falls has been analysed by Professor Way, from which it appeared that its addition to the sewage would enhance its value as liquid manure.—*Appendix* III. *to the Report on the Supply of Water to the Metropolis*, p. 142.

The soluble matter contained in the sewer-water with which the meadows near Edinburgh are irrigated, was found to contain, when put on, 82 grains of matter in the gallon in solution, and 244 of solid matter in suspension; whilst the rain-water running from one part of the paved surface in Oxford-street, London, contained 276 grains of matter in solution, and 537 of solid matter in suspension; and from another portion it contained 194 in solution and 390 in suspension; from Gower-street 126 most economical to construct the channels for sewage large enough to convey the drainage during moderate rain, and to have in the valley lines large conduits chiefly, if not exclusively for storm-water.

In the channels for sewage thus contracted, all solid or semi-fluid matter will be carried immediately away. House-drains or sewers which accumulate deposit are, in fact, extended cesspools giving off poisonous emanations, and to expend money in their construction is rather aggravating than removing the chief evil to be remedied.

Improved town-drainage then is twofold; 1st, the drainage of the sub-soils, from the surplus rain-water falling on the uncovered area, and from surplus spring-water, by arrangements of permeable drains, (which are treated of in separate Minutes of Information, and *post*, p. 82;) 2dly, the immediate removal through impermeable channels of foul water from the interior of houses and premises, as well as rain falling from roofs, yards, pavements, and roadways.

The main object of the present paper is to give heads of practical information, in relation to the arrangements by which the last-recited objects may be effected most economically and completely.

Works for the abolition of cesspools and the drainage of houses form the greater part, requiring usually two thirds of the outlay necessary for the drainage of a town. Until house-drains are provided for the removal of the waste water, the introduction of additional supplies of water may increase the dampness of the foundations, and of the floors and walls of the houses, to an extent greater than would be produced by an additional rain-fall, as the cause of dampness will be constantly

grains in solution and 3 of matter in suspension; from Hampstead-road, above the canal, 96 of soluble and 84 of insoluble matter; and a general average of soluble matter above that of the sewer-water of Edinburgh, when it had passed through the irrigated meadows, and contained yet considerable irrigating power.

To the washings of the dung from roadways are added deposits of soot and birds' dung from roofs, and the dung of animals from yards, and the dried dust blown from the roadway, which contains much valuable matter available as manure. In the principal highways of provincial towns, where there is less traffic, there is less cleansing, and frequently much accumulation at the time of rain; and though the proportion of soluble road matter is less, yet with the deposit of soot and other matter, it is sufficient to be utilised as manure, and to justify conveyance away with the ordinary house-drainage through the common sewers. Where the interiors of sewers of deposit had been cleansed, foul smells were found to arise from the animal and vegetable matter discharged from the surface of the streets and roadway, but detained by ill-constructed traps, (*vide post*, p. 97,) or ill-cleansed cesspits.

in action. Until house-drains are constructed, and in action, main-drains are of little use, and the cost of their construction wasted. Moreover, if but a small proportion of the sewage they are constructed to convey is brought into them, the stream, instead of being deep and rapid, will be shallow and slow, and consequently there will be greater liability to deposit; for which reasons, as well as to prevent pollution of the air and percolations from cesspools, Local Boards should exercise the powers with which they are invested by the 49th section of the Public Health Act, and insist upon all houses being effectually drained at the same time that a street-drain is being constructed.

The whole plan should proceed upon the assumption that the systematic drainage of all the houses will be complete. Unless the main-drains or sewers are laid out upon this assumption, and receive the drainage from the whole of the houses, the flow in the drains will be diminished, the frictional areas, the times of discharge, and the chances of obstruction may be more than doubled, and the expense augmented three or fourfold. On these grounds, primary consideration should be given to the principles of constructing house-drains, which form, as it were, the capillaries of a system of improved town-drainage.

Systematic house-drainage includes arrangements—

First—for the constant removal of the waste or dirty water from chambers, as well as from kitchens, sculleries, and outer offices.

Secondly—for filling-up cesspools (in old houses), and for the constant removal of human excreta from, upon, beneath, or near, the premises.

Thirdly—for the discharge of rain-water from the roof or from the courts and surfaces outside of the house.

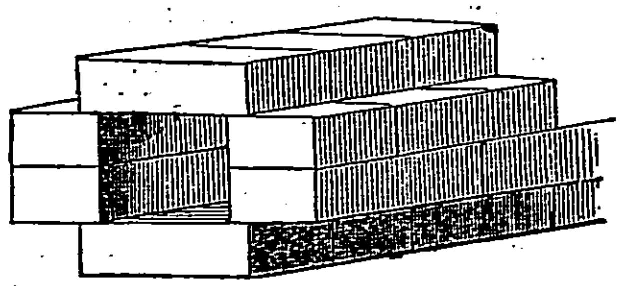
The consideration includes—

1. The construction of house-drains;
2. The materials of which they may be best made
3. Their shape;
4. Their size;
5. Their direction and fall;
6. Their connexion with the outfalls, through the branch sewers; from which will follow the consideration of the connexion and arrangement of the branch and main sewers for the clearance of the whole site.

It will be convenient for the elucidation of the subject, to state the course of investigation which led to the development of the chief settled principles of improved house and town drainage. This will be the more necessary, inasmuch as many of the objectionable practices are yet maintained, and are frequently introduced into new districts, where their attendant evils and expenses are unknown or disregarded.

Materials and Construction of old House Drains.

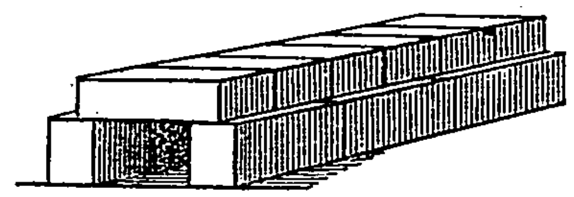
The materials of which house-drains are commonly constructed are burnt clay bricks; and of these bricks for the great majority of houses, (as with that portion of bricklayers work in general which is out of sight,) any inferior rubbish that can be put away is used. The common "place brick" is so absorbent and permeable, that each brick will usually absorb about a pint of water. It is rough and ill-formed on the surface, so as to impede the flow of the sewage. The bottoms of the drains of houses occupied by the poorer classes are not always formed of whole bricks, brick-bats being often used for the purpose; which are frequently put together dry, or the mortar used for their connexion is inferior, soluble, and permeable to water as well as to gases. The following are common forms of permeable brick-drains, which let out offensive liquid to spread beneath the premises, but detain, like sieves, the solid or less soluble matter:—



"These," say the Metropolitan Sanitary Commissioners, "and the flat brick house-drains, are generally put in 'dry' at the bottom, or without mortar, to let in the water of the land drainage, but they commonly let out at their bottoms or sides, instead of the ends, much of the sewer-water, which permeates the foundation and site of the house, leaving the solid refuse deposited in the surface of the drain to decompose, and ultimately choke it up. It is rare to find any house-drains of this description without deposit. They are, indeed, made on the hypothesis that they will accumulate deposit, and the construction of brick is preferred that the drains may be more readily opened, and the deposit from time to time removed. One of the surveyors of the Surrey and Kent sewers, the author of an 'Encyclopædia of Architecture,' prescribes a size of drain of 5 square feet for a moderate sized mansion, to enable a man to get at it to cleanse it from time to time. The Metropolitan Building Act prescribes that the *least* size of house-drains shall be 9 inches; the hypothesis being, that, inasmuch as even these drains accumulate deposit, drains still larger are desirable."

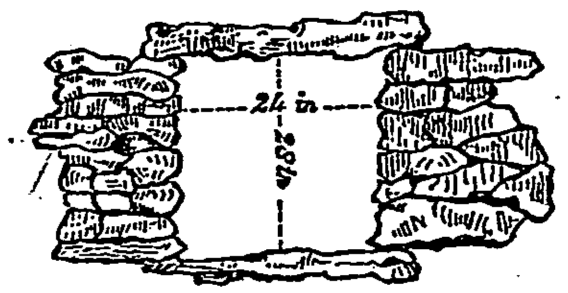
So thoroughly wet, spongy, and rotten do these descriptions of drains become in flat, low-lying, and wet districts, that the workmen find it necessary to be very careful when digging trenches near them, lest the sides should fall down, and let out the ordure detained and accumulated by them.

In many of the large provincial towns visited, still inferior drains are constructed. The following are two specimens:—



The first consists simply of two bad bricks placed edgewise on the bare ground and covered with other bricks.

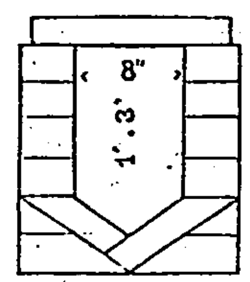
The next is constructed of rough stone without lime, and is of a size frequently used in the north of England for two or three cottages:—



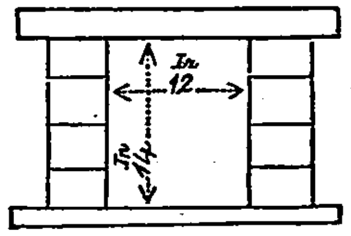
The former will often be choked up in a few months, especially if some other owner, as is often the case, drains into it. The latter, it must be obvious, will ultimately have the same fate, notwithstanding the supposed advantage of its large size,—should it not sooner collapse, and become a confused mass of rubble stone, and black stinking filth.

In some districts stone is used with lime, but generally of the like construction; in others wood is used.

The following is an example of a drain constructed of stone, or brick and stone, and one of the best forms of the kind:—

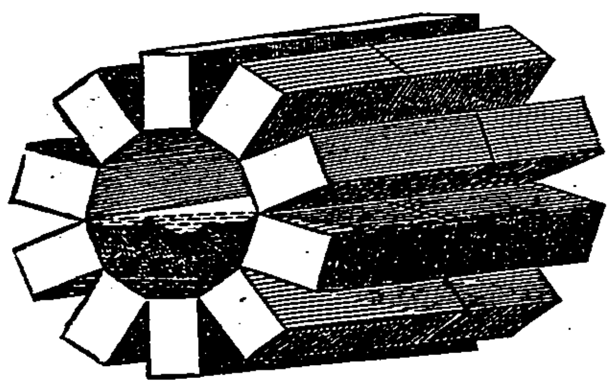


But for the poorer description of houses they are more commonly made with flat bottoms, like the following:—

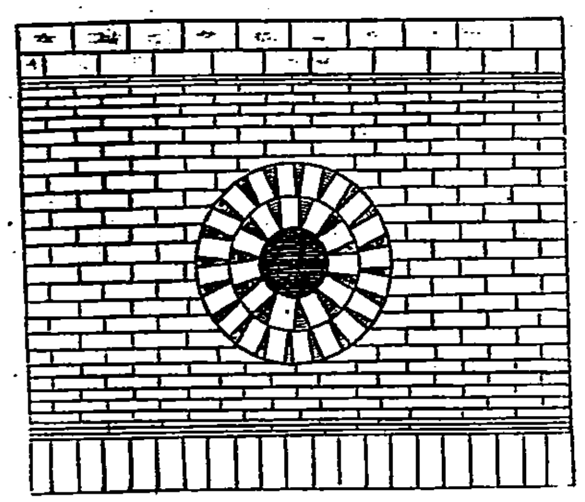


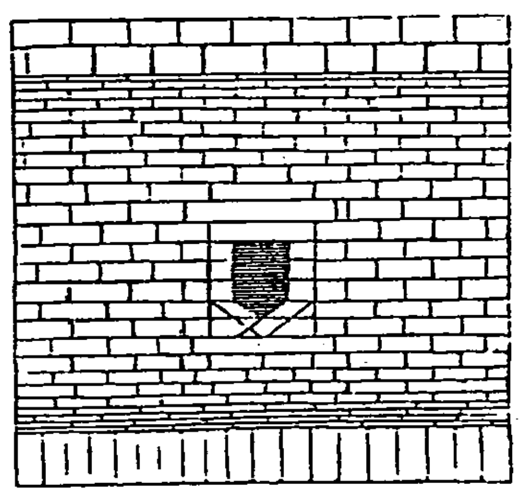
The drains for the higher class of houses are sometimes of a better construction, being lined with Roman cement to "keep out smells"; but still from their shape and size they accumulate deposit; for although the smells may be prevented by the cement from escaping at the sides, it escapes in greater quantity and intensity at the ends; and even if the entrance of the drain into the house is trapped, which it rarely is effectually, the products of decomposition find vent in the common sewer, and thence escape to the pollution of the air outside.

The following is a common form of construction of brick barrelled house-drains:*—



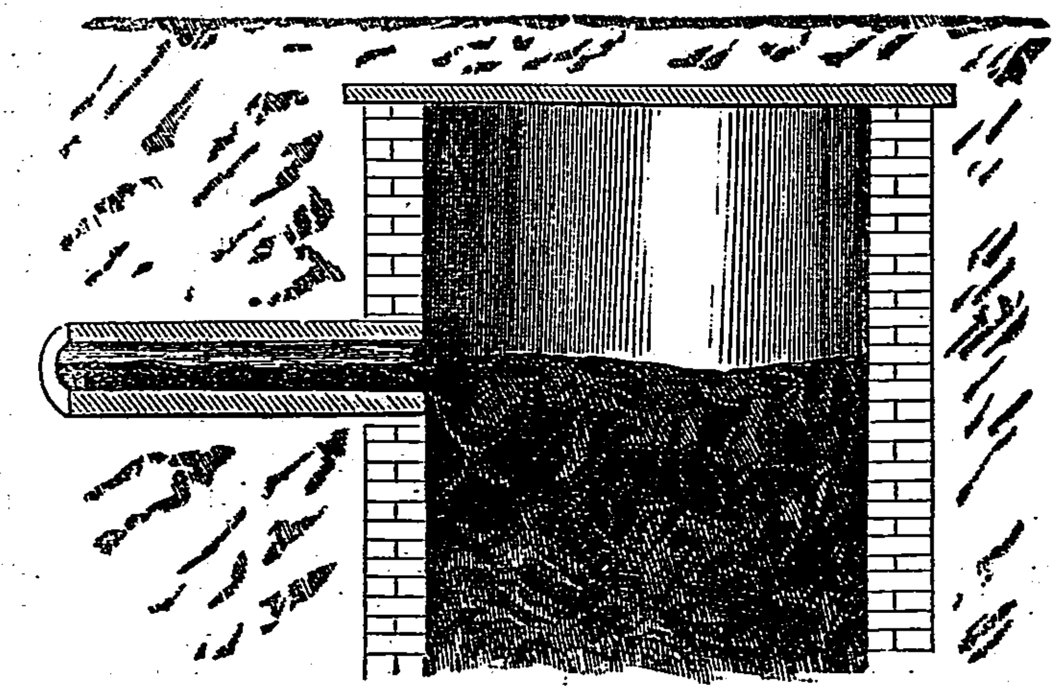
The following are views of the junctions of such drains with the larger sewers:—





* In some few provincial towns radiating bricks have been used for circular drains, but generally the use of flat bricks is continued in London, even for drains of small diameter. While the inner edges of the bricks are in contact, the outer edges are of course widely apart, and the wide gaping joints must be filled with mortar or other soft matter; a mode of construction necessarily defective and insecure.

House-drains, constructed as described, commonly convey the sewage into cesspools, from some of which the overflow is carried away into the sewers, but often there is no overflow-drain, and the liquid percolates into the soil beneath and adjoining the building. When the cesspool becomes filled with the solid filth detained, it is not unusual, instead of emptying it, to form another. Beneath many of the more moderate-sized houses as many as three cesspools have been found; their ordinary state is displayed in the following sketch:—



So perverse had been the former practice in respect to house-cleansing, that when water-closets were introduced, and when it might have been conceived that the ordure removed from sight would be immediately conveyed from the premises, it was only accumulated in a cesspool beneath them. A large proportion of the best houses * in this metropolis have cesspools provided beneath, and when one has been filled up another has been opened, until much of the site is thus occupied.

In some of the towns visited, where the practice of using cesspools has been long in operation, and where the subsoil is

* During the first labours of the General Board of Health much illness prevailed amongst the clerks, until on one occasion foul smells arising more severely than had before been noticed, the state of the foundations was examined, when it was discovered that there were two very large cesspools immediately beneath the Board's offices. This is the description of houses of which it is generally reported by house agents and others that they are well drained and in good condition; but it may be advised that it is absolutely unsafe to take any house without a thorough examination of the site beneath it, nor when any cases of fever, typhoid or gastric, have occurred amongst persons living in the lower offices of a house, is it safe for those who value their own health to remain in the premises without such an examination, nor until the cesspools are removed.

becoming wholly saturated with excrementitious matter, it has already become very difficult to find a spot of earth capable of receiving further percolations.*

In all these closed receptacles, whether fixed or moveable, decomposition is always in progress, commonly through all the stages of chemical change, and no effectual trap exists nor can reasonably be expected to succeed, in popular use, that will prevent the escape of the noxious gases.

From these magazines miasma are extensively liberated and diffused, particularly in those barometric states of the atmosphere when the air is light; a state when the bodily strength is most depressed, and when the system is most susceptible to any external cause of disease.† In districts which are in a low sanitary condition, extraordinary changes in the weather are often foretold by the emission of worse stenches than usual from drains and cesspools.

Probably no capital in Europe is cleaner on the surface of its streets than Paris, where the cesspools are the most carefully constructed, and covered. It is, for the most part, well paved, and the surface of the streets well cleansed; the atmosphere is comparatively free from visible smoke, but the superior cleanliness only renders the emanations from its cesspools the more distinctly and offensively perceptible. There are few who have

* In Mr. Lee's Report on Reading (p. 48), Mr. Billing, the borough surveyor, says, "That is already the case in one or two instances that I know, where a whole garden is a cesspool. Ground cannot be found in some places from which the night-soil will be absorbed and pass away. I know several cases of actual death, and others of disease, arising from each of these causes."

† Mr. Charles Oldfield, a builder of the highest class of houses, at the west end of the metropolis, thus describes his practice in relation to them: "I am frequently called upon to examine houses where they say they are oppressed by unpleasant smells. Some time ago, I was called upon to examine a house in one of the principal streets in London, belonging to a gentleman of distinction, who was about to abandon it in consequence of the unpleasant smells which were continually arising. He was particularly annoyed, because this smell arose in the greatest strength whenever he had parties; the drains had been opened, and there was no lodgment of soil in them. People commonly imagine that when they get rid of the soil they have got rid of the stench; they do not see, and do not conceive the effect of the foul air, which is so much lighter than atmospheric air that it escapes where the atmospheric air would not. On examining the drains of his house I found that they were imperfect, and that the foul air filtered through them. Whenever he had a party there was a stronger fire in the kitchen, and stronger fires in other parts of the house, and the windows and the external doors being shut, and a greater draught created, larger quantities of the foul air from the sewers rose up. These stenches arise in the greatest strength in private houses when the doors and windows are closed, the fire and column of light air in the chimney being at work." *Vide Sanitary Report*, 1842.

visited that city who have not experienced, even in its finest streets and most sumptuous hotels, a peculiar and almost indescribable sensation from the offensive atmosphere around. It is felt in the court-yard, but it is produced in the greatest force on some staircase, passage, or landing leading from a common water-closet. It is caused by emanations from the foul cesspool into which all the refuse of the establishment is passed, and from which the dangerous gases of decomposition force their way through the whole atmospheric space around. To set open doors and windows is of little avail; that does not bring relief, the sensation remains. The refuse must be removed at once if there is to be safety to health; and such removal will be economical as well as healthful.

Houses occupied by the poorest classes in London often afford examples of the utmost perversity of construction in the lower offices. Mr. Lovick thus describes the condition of some tenements in a place called Tyndall's-buildings; a locality distinguished by the number and malignity of the cases removed from it to the Fever Hospital:—*

"'At No. 15, the privy is in the front vault; the vault flooded to a height of between 2 and 3 feet with soil and human fæces, ashes, ground, dead animals, green stuff, and other offal saturated with water, the privy (afterwards ascertained to be an open one) concealed

* The 50th Report of the London Fever Hospital (for the year ending 31st December 1851) contains the following description of the principal fever localities:—

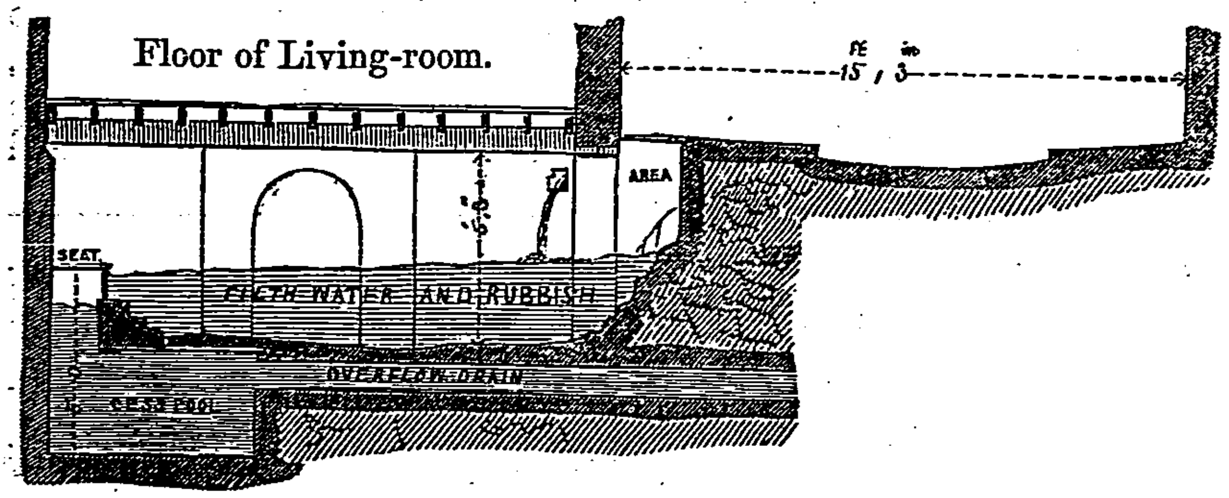
The localities from which the patients have been sent extend over nearly every part of the Metropolis; but by far the largest number have been received from the Holborn district. No fewer than 211 patients (out of 877 received in 1851) have come from courts and alleys on the eastern side of Gray's-inn-lane, such as Tyndall's-buildings, Pheasant-court, &c. In several instances 10 or 12 of these have been received from a single house, and in one instance as many as 20. Thus it appears that one side of a single street, with the courts that branch off from it, have afforded nearly a fourth part of the total number of patients admitted during the year; but to this number should be added 50 more persons, who were removed to the hospital from the adjoining courts in Saffron-hill; so that, in fact, this circumscribed spot has supplied the hospital with nearly one third of its total number of patients. When the state of these fever nests is considered, this result will appear no matter of surprise; in Tyndall's-buildings and the adjoining courts, for example, the floors of the cellars are some feet beneath the main sewer, so that the drainage of the houses is impossible; the privy and the water-butt are commonly both together in the cellar; heaps of dust and decomposing matter are accumulated *within* the houses,—and in the whole of this locality overcrowding is carried to such an excess, that commonly three or four families occupy a single room, into which it is no unusual thing for 20 persons to be huddled together; one patient, indeed, stated, that, in the room in which he lived 27 persons lived by day, and slept at night.

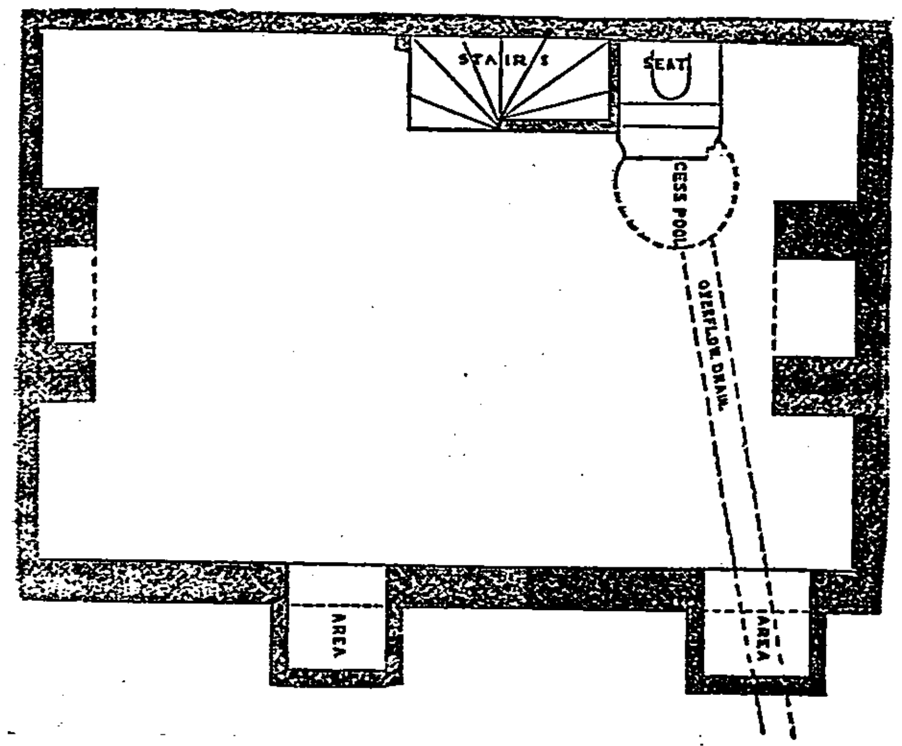
from view, and completely submerged by the noxious matter (the inmates, of course, cannot use it); the steps leading into the vault were covered with human fæces; the smell truly horrible.' The strongest terms I could employ would be inadequate to convey an idea of the exceedingly loathsome character of the emitted effluvia, or of the external appearance of the aggregated filth.

"'At No. 16, the privy, an open one in front vault, has a cesspool covered over with boards only, these can be shifted by any person; the cesspool is full: ashes, rubbish, human fæces, and offal of various kinds in great quantities in vault. Vault used apparently indiscriminately by all the inmates; condition most filthy; smells truly disgusting. Had there been an overflow of water in this vault, it would have scarcely been in a better condition than No. 15.'

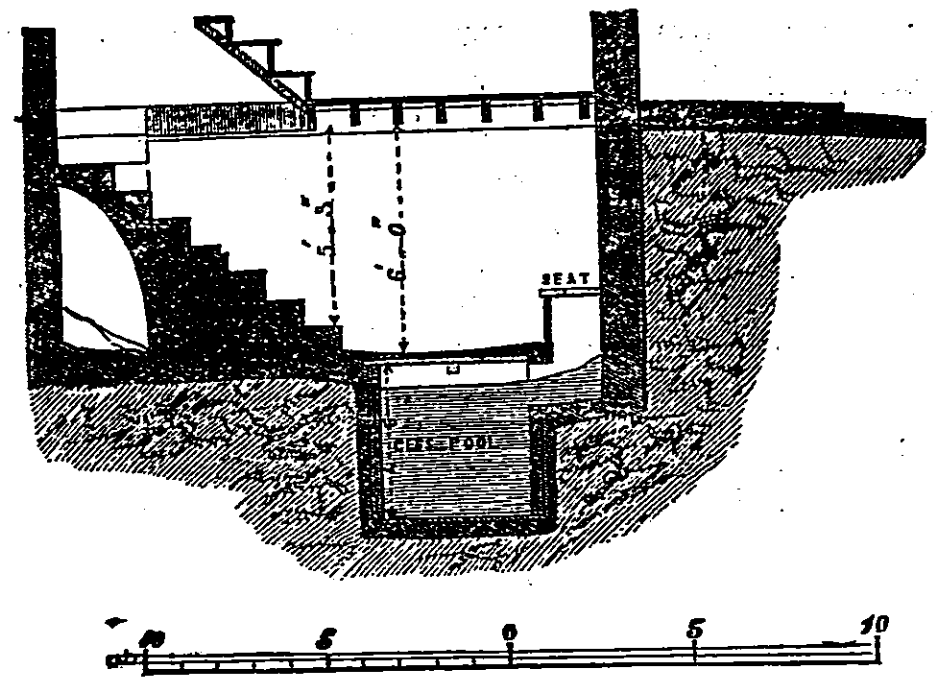
"'At No. 17.—Privy in vault, cesspool full, the soil oozes through ground, same as No. 16 in every other respect, only that it is a degree less offensive.'

"'At No. 18.—Privy in vault and at back of house, accessible only by trap-door, descending by wooden steps into vault, cesspool full—swarms of flies—very bad smells. There is a range of vaults; they are exceedingly close. The privies are quite open, being nothing more than seats; those using them are quite exposed to view.' The annexed are sketches of the basements Nos. 15, 16, 17."

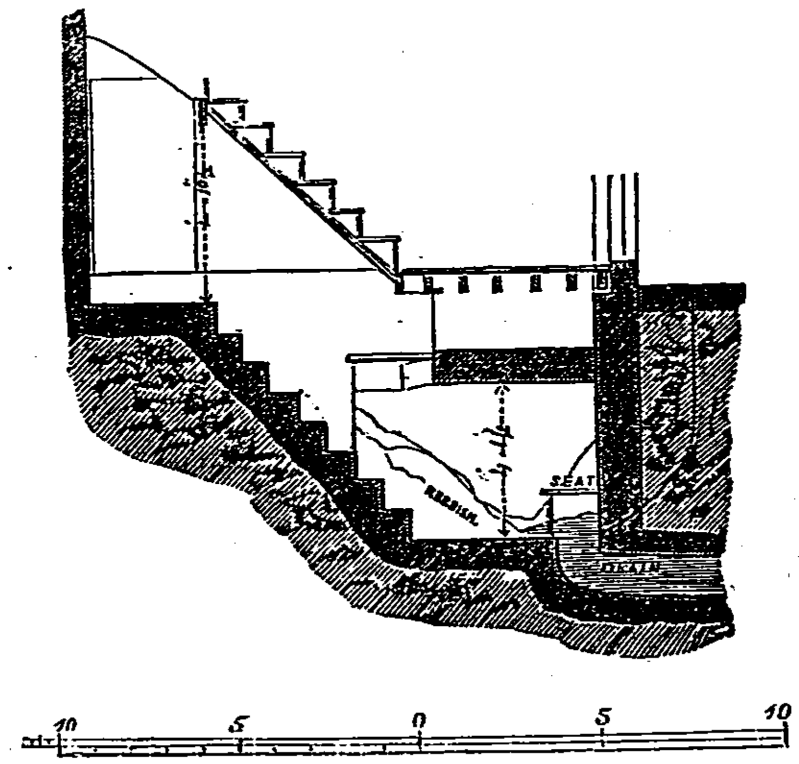




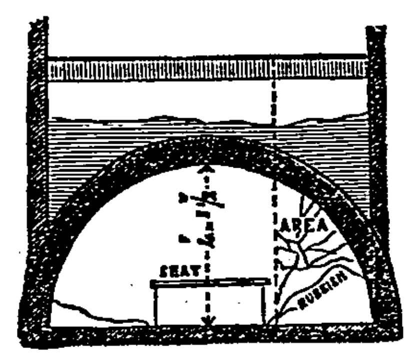
Plan of Basement.



Section of Cesspool, &c. in Basement.



Section of Privy, &c. under Arch in Basement.



Section of Arch over Privy in Basement.

In most country towns the arrangements for the removal of the excreta from the houses of the middle and lower classes are in the same bad state. In the Report on Lancaster, *e. g.* (Report of Commissioners on the Health of Towns, 1845), which has the superficial appearance of a cleanly town, and enjoys an unquestionably healthy site, the fever hospital rarely lacks inmates, from localities such as those described in the subjoined passages from Professor Owen's Report:—

"Chapel-court, a space about 60 feet in length and 7 feet wide, is enclosed at both ends, as well as at the sides, by houses from 20 to 30 feet high: it is entered by a covered way, about 3 feet wide and 7 feet high. The privy-accumulation or midden-stead was exposed within the court; it contained the usual accumulation of decomposing excrementitious and other matters, the soakings from which filled a stagnant kennel traversing the court, and slowly escaped by an untrapped gully-hole, near the entry, into the adjoining sewer. The noxious emanations from these sources are greatly aggravated by the obstruction to free ventilating currents of air. The court is the occasional seat of febrile and phthisical disorders.

"My medical guide conducted me to a court called Croft's-yard, where several cases of fever had occurred. We entered it by a covered passage, or tunnel-entry leading from St. Leonard-gate, 1 yard wide and 2 yards high, and about 20 feet in length, opening into a small square court, built up on three sides, and closed on the fourth, opposite the entry, by walls, propping up the soil of a garden above the level of the first floor of the houses. The privy and midden-stead occupied one side of this enclosed space, abutting against the first story; its oozings infecting the walls of the dwelling, and also contributing to the morbific character of the stagnant water which accumulates in wet weather at the bottom of the court, whence it drains off sluggishly by an open kennel to the untrapped grated opening of the sewer at the entry. The removal of the midden-heap was described as a grievous aggravation of the habitual noisomeness of the confined atmosphere of this court. It is first thrown out by hand labour upon the floor of the court, then wheeled by barrows-full down the narrow passage into the street, whence it is finally carted away. The farmer is willing to give 2*s.* in addition to the labour for this manure. The water for cleansing the court after this laborious and noisome operation is fetched from a public pump at some distance."

No one seemed aware of the inevitable effect of the percolation of liquid filth into the soil upon the wells, from which many houses derive their supply of water. The effect is indeed for a time disguised by the power of certain soils to absorb a portion of organic matter, and to effect the decomposition of much more, so that the result appears in the form of a nitrate

of lime or other base. Nitrates are very commonly found in the well-water of towns, and doubtless owe their origin to the decomposition of organic liquid filtering through the soil.* As the soil becomes more completely saturated, the contamination of the water becomes more evident to the senses, till at last the wells are abandoned. In one district where many houses have been drained with tubular drains, and cesspools abolished, an evident improvement both in the appearance and taste of their well-water has been frequently noticed by the inhabitants with some surprise; it was a result, from the abolition of cesspools, for which they were not prepared.†

Of the Sizes of Mains and Sewers.

The general practice with respect to the sizes of sewers constructed previous to the investigations made by the Commissioners, and even yet very commonly adhered to, is concisely given in the evidence of Mr. Kelsey, then surveyor of the City Sewers Commissioners, taken before the Commissioners for inquiring into the means of improving the Health of Towns:—

"For the ordinary purposes of one house an 18-inch main drain receiving collateral 9-inch drains may, with fair usage, last many years without cleansing, but when it has to be cleansed the trouble

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* *Vide* Report on Water Supply, p. 91. Dr. Angus Smith examined a number of wells both in Manchester and London, and found nitrates in nearly all. When in considerable quantity they give to the water a very unpleasant taste.

† On the subject of the pollution of wells from the permeation of the contents of cesspools, Mr. Quick made the following statement in evidence before the Health of Towns Commission :—

"Within a few days we have had an instance at Battersea of permeation of the cesspools in six new houses. They were supplied with water from springs sunk to the same level as the cesspools. As the springs were lowered by the consumption of the water, it was found, to the surprise of the inhabitants, instead of coming up clearer it was more discoloured, by the equalization of the water levels. One of the inhabitants, a baker, who drew harder than the rest, applied to the Company to lay on the water, giving me to understand that the people began to complain of the quality of his bread, the cause of which he could not make out, except it arose from the quality of the water, which somehow or other, was very bad; all his neighbours who drew from the same spring complained that the water was very bad. The cause was, on examination, undoubted."

and the cost of digging pits from the surface and raking out the filth will be considerable.

"But for the use of a line of houses in a public street, wherein some one or other will treat the drains unfairly, it may be laid down as a first principle that no common sewer should be so small that an ordinary-sized man could not get in to cleanse it; for if it were so small it would not only soon become choked up, but opening the surface to cleanse it would stop or more or less impede the traffic of the street.

"Taking a man of ordinary size, it will be found that a height of 1 foot 11 inches will just allow him to squeeze through on hands and knees, and 3 feet 3 inches will admit him crouching, and 4 feet stooping. To these must be added two or three inches to allow of the raising of the body when moving forward, and there should be some additional allowance for indurated soil in the bottom of the sewer.

"Taking these data, one can scarcely allow less than from 2 feet 4 inches to 2 feet 6 inches for a man to crawl through, and 3 feet 6 inches for a man to crouch through, and 4 feet 4 inches to 4 feet 6 inches for a man to stoop through; and as few men are less than 21 inches across the shoulders, it will not be unreasonable to say that 2 feet is the least width in which a man can work effectually although he may pass sideways through 14 inches.

"Applying these to the question of what is the best-sized sewer that ought to be built in any street, one is compelled to admit that it ought not to be less than 30 inches by 24 inches, and its depth not less than 12 feet in its shallowest part.

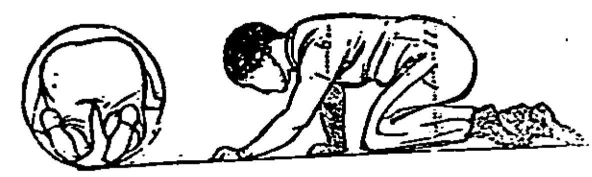
"The thickness of the brickwork cannot be less than 9 inches, nor would it be prudent to leave fewer than two tiers of strutting and planking in the ground.

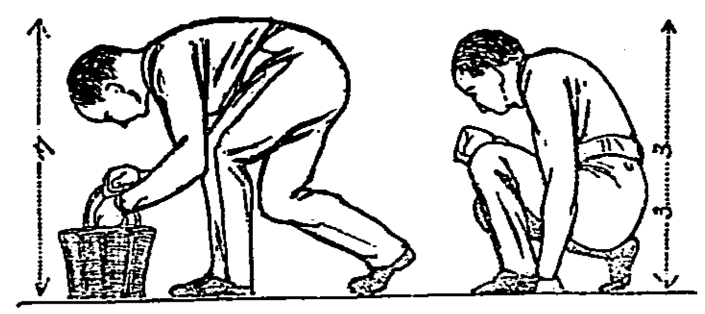
"The cost of such a sewer would probably be about 9*s.* 9*d.* a foot, being somewhat less than half the cost of a sewer 4 feet 6 inches high, and 2 feet 6 inches wide.

"But this assumes that the work is done under the most favourable circumstances, and at the present low prices; and the calculation, of course, does not include gullies, man-holes, &c., nor securing the houses of a narrow street.

"The term 'common sewer' (as for more than one house) is used in contradistinction from public sewer (as unfit for more extended purposes), and taking the limited height of 20 inches from the bottom of a public sewer to the bottom of a drain, as a fair and reasonable allowance for the accumulation of soil in such sewer, before the private drains can be obstructed, and the sewer said to be foul; by adding 2 feet 6 inches to that, we shall find that 4 feet 2 inches is the least height which it is advisable to give a *public sewer*, but 4 feet 6 inches is better, as allowing freer space for cleansing."

In illustration of this evidence Mr. Kelsey put in the following sketches:—





Plans of works were generally found to be as destitute of sanitary considerations, both with reference to the nature of the effluvia generated from such deposit, and the operations for its removal, as indicated by the above-recited passage.

There are some descriptions of labour which it is improper for human beings to perform, and which ought to be forbidden, as being false in principle, and belonging to a low state of art, and as being ignorant or interested excuses for the avoidance of the trouble and expense of practicable and efficient substitutes. Putting men to crawl or creep through channels filled with foul ordure, and to breathe noxious gases, as above described, is one example of such labour. Putting children to crawl through channels, filled with soot, to cleanse them, is another. By a clumsy and inartificial construction of a chimney-flue in the form of a large parallelogram (which often follows an irregular course, with sharp bends and corners, always gathering soot,) the naturally circular current is widely spread and impeded, and additional deposits of soot occasioned. The chimney-flues are made, in England, additionally large to admit children to cleanse them, and this increased size, by increasing the quantity of cold air admitted, and by extending the surface which proportionally abstracts heat, and retards the ascent of the smoke, augments the quantity of foul deposit requiring removal. By these erroneous constructions the discharge (or flow) of the heated air is often so much impeded as to produce, besides the extra quantity of deposit, the evil of smoky chimneys. One means adopted of mitigating or remedying this evil, and occasionally of lifting the current of heated air out of descending currents or eddies of wind, is visible in almost every district, in additional lengths of flue of a more appropriate or circular form, contracted to one half the cubic capacity of the common parallelogram, or less. One architect bethought himself that if, instead of fixing the contracted length of tube at the top, he put it down the interior of the old chimney, it would answer as well, and that he should thus save the risk of its being blown over, and the expense of holdfasts. He tried, and he found it answer better; he would have found it answer completely if he had continued it down to the fire-place, when he would have produced a complete flue, such as is in use on the continent, and requires no climbing boys to cleanse it, but is usually cleansed by a heavy iron ball with a circular brush at the end of a chain, with which a servant of the house performs the work.* The cruel and degrading practice of cleansing chimneys by the labour of children was defended in this country, on the allegation that it was impossible to cleanse chimneys in any other mode. It was forbidden. It was then found to be practicable to cleanse even the chimneys of the old and vicious construction by machinery, without waiting for those improvements in heating by which it may be confidently predicted that the use of smokeless fuel will be found economical for towns.

It would be better that sewers of deposit, in their frequent condition, should be required to be opened to the surface, as house-drains of deposit are, for cleansing, rather than that it should be permitted to continue the practice of sending men to crawl up them amidst foul ordure, to the certain injury of their health, and at the hazard of their lives.† But it appeared upon investigation, as will be shown, that with properly-constructed sewers, combined with supplies of water, no deposit will be occasioned, and obstructions become so rare as to need no special provision for cleansing. Complete measures of sanitary improvement and

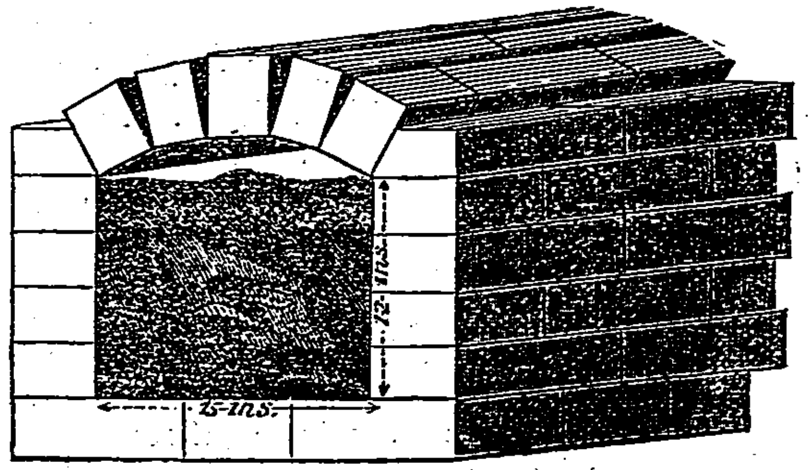
* In Dresden circular chimneys of little more than five inches are found to serve well for coal fires for the great majority of buildings for which the large parallelograms were in use. By the better adaptation of size and form, with a better draught of air and better combustion, less coal is consumed as well as less soot deposited. Moreover, by the better draught, much of the heavier offensive and pernicious gases from the decomposition of coals, more particularly the inferior coals such as are used by the poorer classes, which escape and pervade the living rooms when the draught is sluggish or the chimney smokes, is cleared away. For the larger-sized houses flues of $8\frac{1}{2}$ inches are used; and flues of $11\frac{1}{4}$ inches are found to answer for kitchen ranges and very large establishments.

† Instances occur of the death of men from the mephitic vapours encountered in this disgusting labour, which are made known to the public, but instances are numerous which are not heard of, where men are rescued in a state of insensibility, and sustain severe and permanent injuries. When the survey of the condition of the existing sewers in the metropolis, called the Subterranean Survey, had been determined upon, the members of the Board urged that special precautions should, for all such future labour, be taken, under the guidance of a competent medical officer, for the protection of the men employed; but this was opposed by some of the old Commissioners on the ground of expense, and as wholly unnecessary, and lives were actually lost which the precautions recommended would certainly have saved. The following extracts from the reports made upon this survey show the nature of the gases generated in sewers of the vicious construction proposed directly with a view to the continuance of such labour:—

"$69\frac{1}{8}$ miles of sewers have been surveyed in the Surrey and Kent district." . . . . "The surveyors find great difficulty in levelling the sewers of this district; for, in the first place, the deposit is usually about 2 feet in depth, and in some cases it amounts to nearly 5 feet of putrid matter. The smell is usually of the most horrible description, the air being so foul that explosion and choke-damp are very frequent. On the 12th January (1849), we were very nearly losing a whole party by choke-damp, the last man being dragged out on his back (through two feet of black fœtid deposit) in a state of insensibility. Another explosion took place on the 12th February in the Peckham and Camberwell-road sewer, and one on the 21st February in the Kennington-road sewer; in both cases the men had the skin peeled off their faces and their hair singed. Two men of one party had also a narrow escape from drowning in the Alscot-road sewer, Rotherhithe, on the 24th instant; but, fortunately, none of the foregoing cases have been attended with serious damage. The sewers on the Surrey side are very irregular; even where they are inverted they frequently have a number of steps and inclinations the reverse way, causing the deposit to accumulate in elongated cesspools. In must be considered very fortunate that the subterranean parties did not first commence on the Surrey side; for, if such had been the case, we should most undoubtedly have broken down. When compared with Westminster, the sewers are smaller and more full of deposit, and bad as the smell is in the sewers in Westminster, it is infinitely worse on the Surrey side." . . . . "February 12th. The Peckham-road sewer has about 1 foot 7 inches of deposit at side of entrance opposite Peckham House. In advancing towards Southampton-street the deposit deepens to 2 feet 9 inches, leaving only 1 foot 11 inches of space in the sewer. At about 400 feet from the entrance the first lamp went out, and 100 feet further on the second lamp (not being a safety one) created an explosion, and burnt the hair and face of the person holding it. The cause is supposed to be the foul and filthy state of the sewer." . . . . "From this description, and an examination of the accompanying illustrated map of the sewers, and the weekly progress reports, it will be found, as a general conclusion, that much of the sewerage of the city of Westminster itself is in the rotten state, and contains a large amount of foul deposit; that in the more modern district of Belgrave and Eaton squares, although the brick-work of the sewers is generally sound and good, they contain several faulty places and abound with noxious matter, in many cases stopping up the house-drains and smelling horribly; that in the district of Grosvenor, Hanover, and Berkeley squares, as a rule, considerable deposit is found in the sewers, emitting much effluvia; that the same remark may be made of the sewers in the neighbourhood of Clare-market, Covent Garden, Soho-square, and Fitzroy-square; that much of the work north of Oxford-street, about Cavendish, Bryanstone, Manchester, cleansing by means of water will prevent the necessity of much injurious labour.

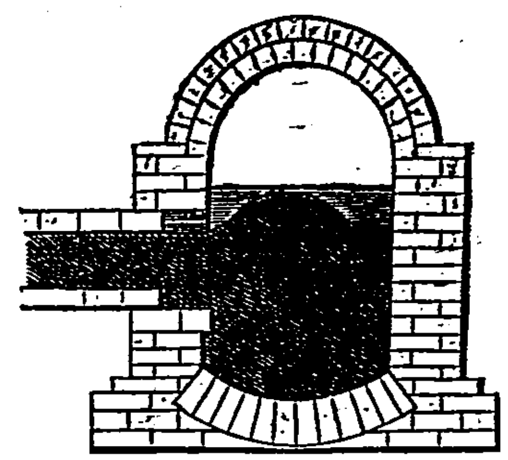
Those whose lot it is to perform offensive and filthy labour have their perceptions blunted; their work, rendering them filthy in their persons, excludes them from the society of more cleanly and respectable artizans; their occupation is supposed to necessitate and to justify the constant use of ardent spirits, and they become degraded in condition, and a separate caste. The prevention of such degradation, and the disuse of the degraded class, by superseding the necessity of such service, is of itself a matter of social and civic gain. As is usual, however, in the operation of really correct principles, it will be found to be attended also with pecuniary saving.

Main sewers were very generally found to be of larger sizes, with the certainty of containing greater accumulations than those in the circular form constructed for the city of London. For the convenience of working in them, they were commonly made with nearly flat segmental bottoms, and with upright sides, and spreading footings, in the manner displayed on the next page. Circular work, being more difficult or troublesome, it was found that the builders commonly preferred a similar construction for the smaller sewers, as the whole were built upon the hypothesis that deposit must accumulate; and except in the case of main sewers in valley lines, with considerable runs of water, it does so. The following sketch shows the condition of a flat-bottomed drain 15 inches wide, which drained 20 houses:—



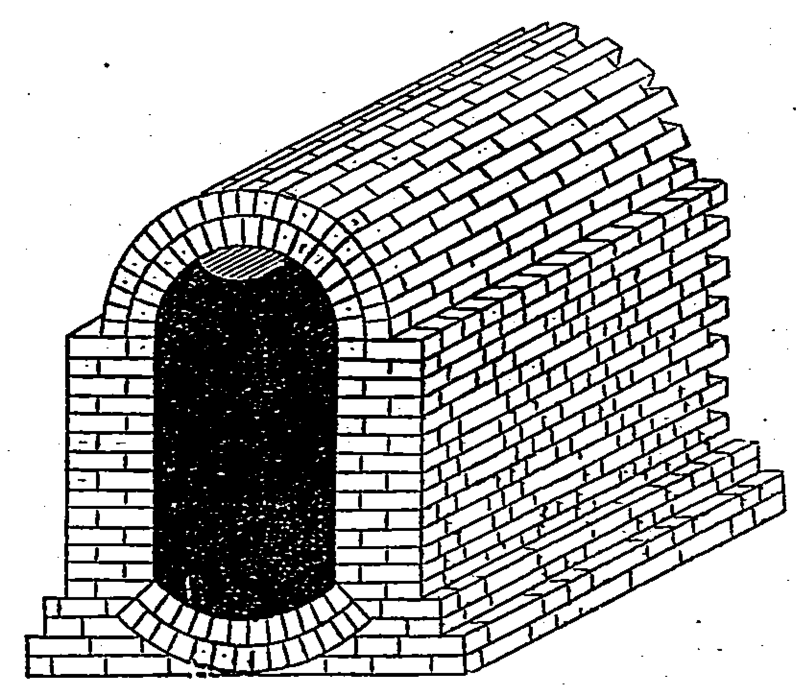
and Portman squares is in such a state of rottenness and decay that there is no security for its standing from day to day; that there is a large amount of the most loathsome deposit in these sewers, but the act of flushing might bring some of them down altogether; that even throughout the new Paddington district, the neighbourhood of Hyde-park-gardens, and the costly squares and streets adjacent, the sewers abound with the foulest deposit, from which the most disgusting effluvium arises."

The ordinary condition of sewers, in their connexion with house-drains, is shown in the sketch* subjoined:—



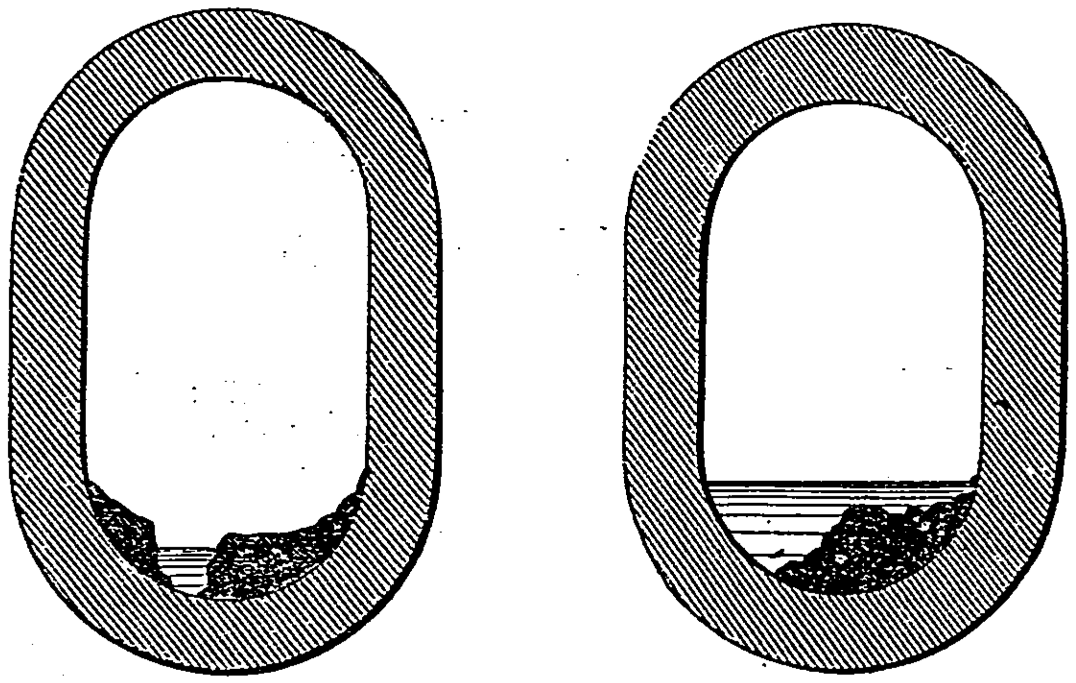
The whole evaporating surface of stagnant and pestilential matter beneath the houses and streets of the metropolis has been estimated to be equal to a canal 50 feet wide, 10 miles long, and above 6 feet deep, such as, if spread out 6 inches deep, would form a putrid swamp nearly 800 acres in extent, being nearly three times as large a surface as the whole population could lie down upon.

Sometimes large sewers as well as large drains are filled nearly to the top with deposit. The following cross section displays the condition in which one of them was found. The space occupied by the ordinary run of the sewerage to be removed, and the shape of the bed which it had worn for itself, are shown near the crown of the arch:—



* It may be mentioned, as a reason for the several illustrative cuts not being to one scale, that they originally appeared in different reports, from which they have been taken.

The actual space required for the removal of an ordinary run of sewer-water, and as far as the material will admit, somewhat of the shape of the channel formed by it, is often found displayed, in a lesser amount of deposit, as in the following examples:—

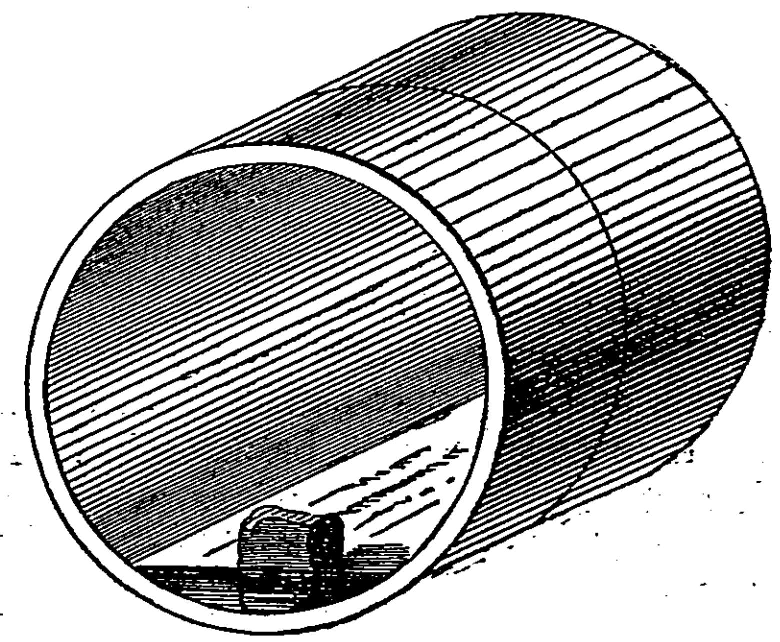


In many lines of sewers irregular accumulations were found to have been deposited in consequence of uneven bottoms, junctions at right angles, or other causes. (*Vide* Reports upon the Subterrenean Survey, directed under the Metropolitan Sewers Commission.) When large bodies of water, from sudden and extraordinary storms, have been driven into sewers containing such accumulations, the sewers have become completely choked, and have caused flooding, not, as was commonly supposed, because they were too small to convey away the storm-water, but because they were too large to be kept clear by their usual streams. The instances cited to prove the insufficient capacity of sewers, really proving their extravagant sizes, or their bad construction, or both.

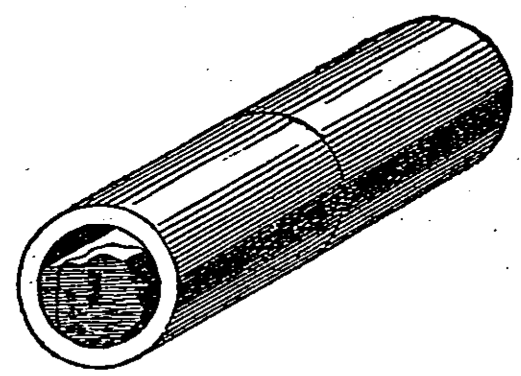
It is important that the result of inquiry on this point should be understood,—namely, why a small channel or drain, properly adjusted to the run of water to be discharged, will be kept clear, while a large channel, with the same quantity of water to be discharged, and with the same fall or inclination, will accumulate deposit.

In large drains, a given run of water is spread in a thin sheet, which is shallow in proportion as the bottom of the drain is wide; hence friction is increased, the rate of flow retarded, and, according to a natural law, matters at first held in suspension, and which a quicker stream would have carried forward, are deposited. If there be any elevated substance, the

shallow and slow stream, having less velocity and power of floating or propelling a solid body, passes by it. Thus, if by any neglect substances not intended to be received by a drain enter it, for instance, if a scrubbing-brush or hearth-stone has been allowed to get into, say a 15-inch drain, the height of water in regard to such substance may be as in the following sketch:—



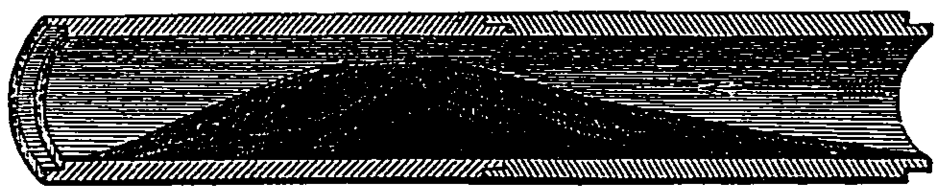
But if it were a 4-inch drain, the same quantity of water would assume a very different relative position, as in this smaller sketch:—



and it will be readily understood that the deeper stream of the contracted channel would be more powerful to remove any obstructing body.

Instead of concentrating the flow of small streams, and economising their force, the common practice is to spread them over uneven surfaces, which "deadens" and "kills" them.

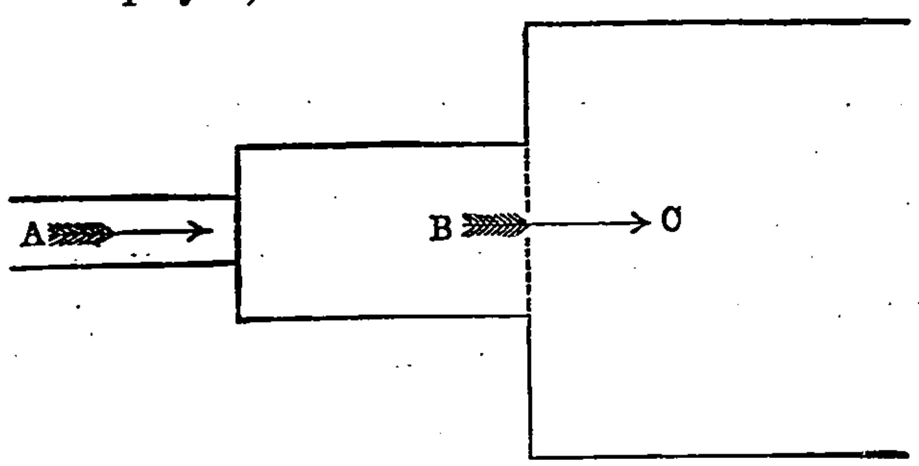
In a small drain an obstruction raises an accumulation of water immediately, which increases, according to the size of the obstruction, until four, five, or six times more hydraulic pressure is brought to bear for its removal than could by any possibility be the case in a large drain; for in a large drain of three or four times the same internal capacity, the water can only be dammed up to the same relative height by an accumulation of matter three or four times higher, and therefore 27 or 64 times greater, which will gradually lengthen out, as shown in the following sketch, and then be beyond the power of removal by the water:—



Earthenware pipes, if properly constructed, and non-absorbent, wear away less than brick drains do, and much less frequently want repair.

From their reduced size less earth has to be excavated from a narrower trench, and they may be laid more quickly and with more certainty than the common brick-drains. Rats cannot work through earthenware pipes, and as, when properly laid, they detain no deposit, and when smoothly made, give no foot-hold, they afford neither food nor shelter for such mischievous vermin.

In the course of investigating the primary and more important works, those within the house,—house-sinks for example,—the question was frequently put to architects, builders, and plumbers, "Why, to receive the water which passes through a 2 inch pipe, should you place a pitcher-drain of 9 or 16 inches square?" To this no satisfactory answer was received. In the following diagram Mr. Ranger illustrates the progressive increase at present given to pipes, drains, and sewers connected with each other, and used in the drainage of courts (where drainage is employed):—



A, denotes a 3-inch drop or soil pipe.
B, the intermediate 9-inch drain between A and C., or 9 times the area of A.
C, being the common sewer, 2 feet 2 inches diameter, or $8\frac{1}{3}$ the area of B., and 75 times that of A.

The chief, if not the only reason assigned for making B, the intermediate drain, 9 inches diameter, is that of *preventing* its stopping or choking, an effect which its large size and sluggish flow almost inevitably occasions.

Observation of the laws of moving water, or the conditions under which water in slow motion deposits matter in suspension, and, with increased motion, lifts and removes, first, fine sand, then, with accelerated motion, coarser sand, then pebbles, then large stones, and, lastly, boulders and vast masses of rock; and the consideration of the inclinations by which velocities might be regulated, should have prevented the expensive errors which are displayed in the sewage arrangements for towns. But such investigations have yet to be made and recorded, at least as respects flows on the scale of rivers; though authentic and trustworthy experiments, made under varied circumstances would be a work of national importance. The data usually referred to as governing practical applications, were found upon inquiry to be wholly unsatisfactory, as for example, those in Professor Robison's Treatise on Rivers, which proved to be largely at variance with other observations.* Some of these discrepancies appear to have arisen, from partial investigations, from the omission to notice, amongst other things, that the power of water to suspend and to remove solids, along the same line of inclination or fall, is as the depth or head of water flowing. Thus a stream of water 4 feet wide and 1 inch deep, with a fall of 1 in 150, is sluggish; the same water, if passed through a pipe of 12 inches diameter, having the same rate of fall, would be comparatively a rapid stream. The one would deposit silt or sand, the other would certainly remove both.

The state of knowledge from which builders and common labourers derive instruction and guidance in their practice is displayed in the following portions of examinations cited in the First Metropolitan Sanitary Report:—

"Another surveyor of the Kent and Surrey District, Mr. Joseph Gwilt, author of the 'Encyclopædia of Architecture,' was questioned on this topic, on which so important a part of town drainage depends.

* He states, for example, as a general proposition, that a velocity of a stream of half a mile an hour, will separate and lift up particles of coarse sand, and of about three quarters of a mile fine gravel; whereas an instance was given of the velocity of water in the Bridgewater canal, towards the locks at Runcorn, of a velocity of about one mile an hour, at which silt is *deposited* by the water. Rivers in many parts of the world deposit silt so as to raise the surface of their waters above the adjoining land.

"'It appears that there were in the metropolis in the year 1841 270,000 houses. Now, if each were to have at the least a 9-inch drain, as you and other architects recommend, it appears that the area of the stream or river required to keep them full and flowing, would be a stream 1,132 feet in width by 105 feet in depth?—Yes.'

"'It is estimated that a supply of water for the whole of the metropolis, supposing each house to have a supply of 125 gallons per diem, or 25 gallons per head, would be given by a circular tunnel or aqueduct 12½ feet diameter. There are in the Kent and Surrey districts 55,000 houses, and the supply there would be given by an aqueduct of proportionate size to your number of houses, say one fourth. Such being estimated to be the size of conduits required to bring in water, it is presumed that the sectional areas of the drains and sewers would not be required of vastly greater size, supposing them to have as good a fall, to carry away the same water. Can you prove any addition of rain-water, or even of extraordinary storm-water, requiring a system of drainage of a sectional area more than five times that of the Thames at Waterloo-bridge at high water, or nearly one thousand times the area of the aqueduct that would furnish the whole supply of water to the metropolis?—I apprehend, in providing drains for a house, you are to provide against accidents, therefore I should say it would be prudent always to have drains larger than are actually necessary, to guard against stoppages. A stoppage in a small drain stops up the whole orifice, a stoppage in a large one is partial. There may be most likely a means of its running off in some way or other.'

"'It has been stated that the smaller the pipe is, generally, the less likely will deposit be to accumulate, the greater will be the force of water concentrated upon the resisting medium, and the less likely is the resistance of that medium to be effectual. What is your opinion upon that subject?—My opinion is this; I will take the case of a washer to a sink being open, and the cook throwing down anything that comes to hand; it comes against a 4-inch pipe, and blocks it completely up; but the end of a cabbage-stalk will pass into a 9-inch drain, and there it will lie and decompose.'"

No more account is here taken by the architect, than by the engineer or surveyor, of the effects of the decomposition of that deposit, for the retention of which he provides. It will be seen, however, that it would be far better, were it necessary, for the inhabitants of many houses to pay for new tubular drains every year, and run the risk of having them stopped up every month, than to have large drains, detaining and spreading deposit, and facilitating decomposition within the walls and beneath the floors of their dwellings.

The necessity of the construction of house-drains with better materials and forms became immediately manifest upon the sanitary inquiry in 1842, but at that time nothing of the kind existing or being known in the house-building trades, Mr. Roe

was requested to get some pipes made. Being afterwards asked to ascertain experimentally, for the immediate purposes in view, the difference of the run of water in an earthenware tubular drain, as compared with that through a tubular or barrelled brick drain, he found that the gain of velocity in favour of the better formed and less inexact surface was not less than one third; there would consequently be, with the same quantities of water, nearly a doubled power of cleansing. But the tubular drains, of the description tried, though the best that could then be obtained, were by no means perfectly true in shape, and they may still be rendered much more exact by a pressure applied by a machine when half dried. With this increase of exactness, and with but slight variation in diameter, it appears that they discharge one fourth more water in the same time even than the rude hand-made pipes first tried.

It appeared to be a common doctrine which governed the construction of such works, that it mattered little whether the surface of sewers or drains was smooth or rough; that even if they were made of rubble stone the only practical effect would be to diminish the diameter of the drain to the space between the points of the protuberances. Upon investigation this doctrine was found to be wholly erroneous, in respect to sewers as well as house-drains; Mr. Roe showed that brick sewers, whenever the surface was made comparatively smooth with cement, were kept clear of deposit, whilst the sewers having rough brick surfaces, with the same inclinations and the same quantities of sewerage, accumulated it.

Subsequently other trial works were directed to be made to ascertain the correctness of the existing hydraulic formulæ, and their applicability for determining the sizes of underground channels which might serve for town-drainage. The chief results as respects the house-drains are thus described in an examination of Mr. Medworth, the surveyor appointed to make the trials:—

"Among other things, were you not directed to try the flow of water from pipes of different constructions—some formed with pressure and some formed in the common way?—I was.

"Did you not find that making the pipes smooth in the interior gave an increase of velocity of a third or fourth through a 3-inch pipe?—I did. These experiments were made with redware pipes, smooth, but not glazed.

"What quantity of water would be discharged through a 3-inch pipe on an inclination of 1 in 120?—Full at the head, it would discharge 100 gallons in three minutes, the pipe being 50 feet in length. This is with stoneware pipe, manufactured at Lambeth. This applies to a pipe receiving water only at the inlet, the water not being higher than the head of the pipe.

"What would be the rate of discharge supposing the whole 100 gallons to pass through the drain from the back to the front of the house, say some 60 feet, and how soon would the water be clear of the premises?—All that could be swept away by 100 gallons would be discharged clear of the house at the rate I have already stated.

"What would be the power of sweep?—Sufficient to remove any and even more than ordinary and usual semi-fluid deposit that is found in house-drains; that is, supposing the whole of the 100 gallons was to be discharged in the time stated.

"What water was this?—Sewage-water, of the full consistency, and it was discharged so completely, that the pipe was perfectly clean.

"At the same inclination what would a 4-inch pipe discharge with the same distances?—Twice the amount (that I found from experiment); or, in other words, 100 gallons would be discharged in half the time. This likewise applies to a pipe receiving water only at the inlet, and of not greater height than the head. In these cases the section of the stream is diminished at the outlet to about half the area of the pipe.

"Then a 4-inch pipe will discharge a 24 hours supply of sewage-water a distance of 50 feet in a minute and a half?—Yes; taking the 24 hours supply to be 100 gallons.

"Did you not try the force of this discharge with sand? and, if so, with what proportions?—Yes, with sand in proportion of from 1-16th to 1-40th the volume of the water, and the whole was entirely removed.

"But the different construction of the pipe with respect to smoothness will make full a fourth difference in the rate of velocity?—Yes; with the redware pipes formed by pressure, the accelerated velocity due to regularity of form and smoothness of surface was one fourth.

"What pipes did you use in these experiments?—In some experiments, including those previously referred to, we used redware pipes, but principally glazed stoneware pipes were used in the experiments at Greek-street.

"Have you not found that exactitude in the make is more important than the glaze?—Yes, the exactness of form and ACCURACY of JOINT are very important, so that the pipes may run into each other and form a complete cylinder. As an instance of the importance of exactness of joint, I had a case happen at one of my houses within the last few days. The tenant complained of the stoppage of the drain from the closet, &c. Upon sending a man to make an examination, it was found that the trap contained several oyster-shells, and one had been discharging into the drain, where it was arrested by an imperfectly formed joint.

"Then you found on experiment that this exactness of form expedited the discharge full one fourth?—Yes. As before stated in the case of the redware pipes.

"Before these experiments were made, were there not various hypothetical formulæ proposed for general use?—Yes.

"What would these formulæ have given with a 3-inch pipe, and at an inclination of 1 in 100? and what was the result of your experiments with the 3-inch pipe?—The formulæ would give 7 cubic feet, the actual experiment gave 11⅕ cubic feet; converting it into time, the discharge according to the formulæ, compared with the discharge found by actual practice, would be as 2 to 3.

"Or, putting it into another form, if there were a given quantity of detritus or fæces to be removed, it would, according to the formula, require nearly double the quantity of water that was found absolutely requisite in practice?—The proportionate discharges were found to be as 2 to 3, therefore the power required would be in those ratios.

"How would it be with a 4-inch pipe?—The formula would give about 14·7 cubic feet per minute, whereas practice gave 23 cubic feet per minute.

"Take the case of a 6-inch pipe of the same inclination?—The result, according to Mr. Hawkesley's formula, would be 40¼ cubic feet per minute; from experiment it was found to be 63½ cubic feet per minute.

"Will you convert that into time, and consider the 6-inch pipe as a small branch sewer? Within what time would 100 gallons be discharged at the same inclination over 50 feet?—It would be discharged in 15 seconds.

"That is to say, that the actual experiments prove how much less water can be made to suffice than these formulæ prescribe?—Precisely so.

"Then with respect to mains and drainage over a flat surface, the result of course becomes of much more value as the difference proved by actual practice increases with the diminution of the inclination?—Certainly, to a very great extent. For example, the tables give only 14·2 cubic feet per minute as the discharge from a pipe 6 inches diameter, with a fall of 1 in 800; practice shows that, under the same conditions, 47·2 cubic feet will be discharged.

"Will you give an example of the practical value of this when it is required to carry out drainage works over a very flat surface?—An inclination of 1 in 800 gives only 14 cubic feet per minute according to theory, while, according to actual experiment, and with the same inclination, 47 cubic feet are given.

"Then this difference may be converted either into a saving of water to effect the same object, or into power of water to remove feculent matter from beneath the site of any houses or town?—It may be so.

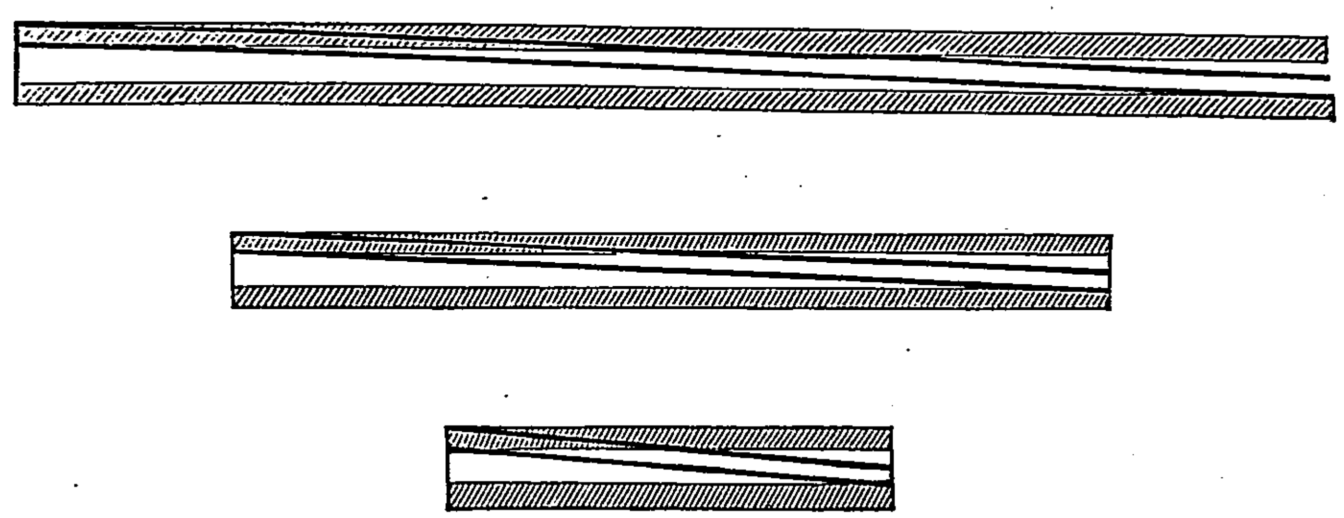
"And also the power of small inclinations properly managed?—Yes. For example, if it was required to construct a watercourse that should discharge say 200 cubic feet per minute, the formula would require an inclination of 1 in 60=2 inches in 10 feet; whereas experiment has shown that the same would be discharged at an inclination of 1 in 200, equal to $\frac{4}{8}$ths of an inch in 10 feet, thus effecting a considerable saving in excavation, or a smaller drain would suffice at the greater inclination. The practical importance of knowing the precise value of inclination is incalculable, and will be found so in laying down drainage for a flat district, or through loose and wet soils, where the extra labour in excavating the last few inches in depth to obtain a given level will often exceed in cost as many feet. I have frequently met with such cases. To name one, I will state that, during the progress of a sewer contract I had in 1842 for the Commissioners of the Holborn and Finsbury district, the depth of the trench was about 9 feet, and perfectly dry; the cost for labour was 8*d.* per cubic yard; the invert of the sewer, according to the levels given by the surveyor, required to be about 6 inches lower, and this proved to be in a running sand of the most troublesome nature, and cost me at the least 10*s.* per yard in the removal before the invert could be laid down."

Gain of Fall on the same Levels by small Tubular Drains.

Besides so much gain in the force of sweep at similar inclinations, obtained by the use of tubular drains, gains in fall are obtainable from their reduced size, improved form, and smoother surface. In level districts this will frequently be a most important advantage.

The height from the top of a 9-inch barrel drain to the bottom of the opening is $13\frac{1}{2}$ inches, while that of a 4-inch tube is only 5 inches, consequently, if the former must be level the latter may have a fall of 8 inches; this, in a drain of 90 feet in length, would give a fall of 1 in 135. If a brick drain 60 feet long must be level, a 4-inch pipe may be laid with a fall of 1 in 90; if 30 feet long, with a good working fall of 1 in 45; whilst with the shorter lengths of discharge fall of 1 in 45; whilst with the shorter lengths of discharge available by means of back drainage, say of 10 feet, the fall would be 1 in 15. This is of great consequence, as the velocity of discharge and its cleansing power increase proportionately with the fall.

The following diagrams illustrate the gain of fall. The outer lines represent large brick drains laid level. The inner black lines show that from and to the same points small pipe-drains would have a considerable inclination:—



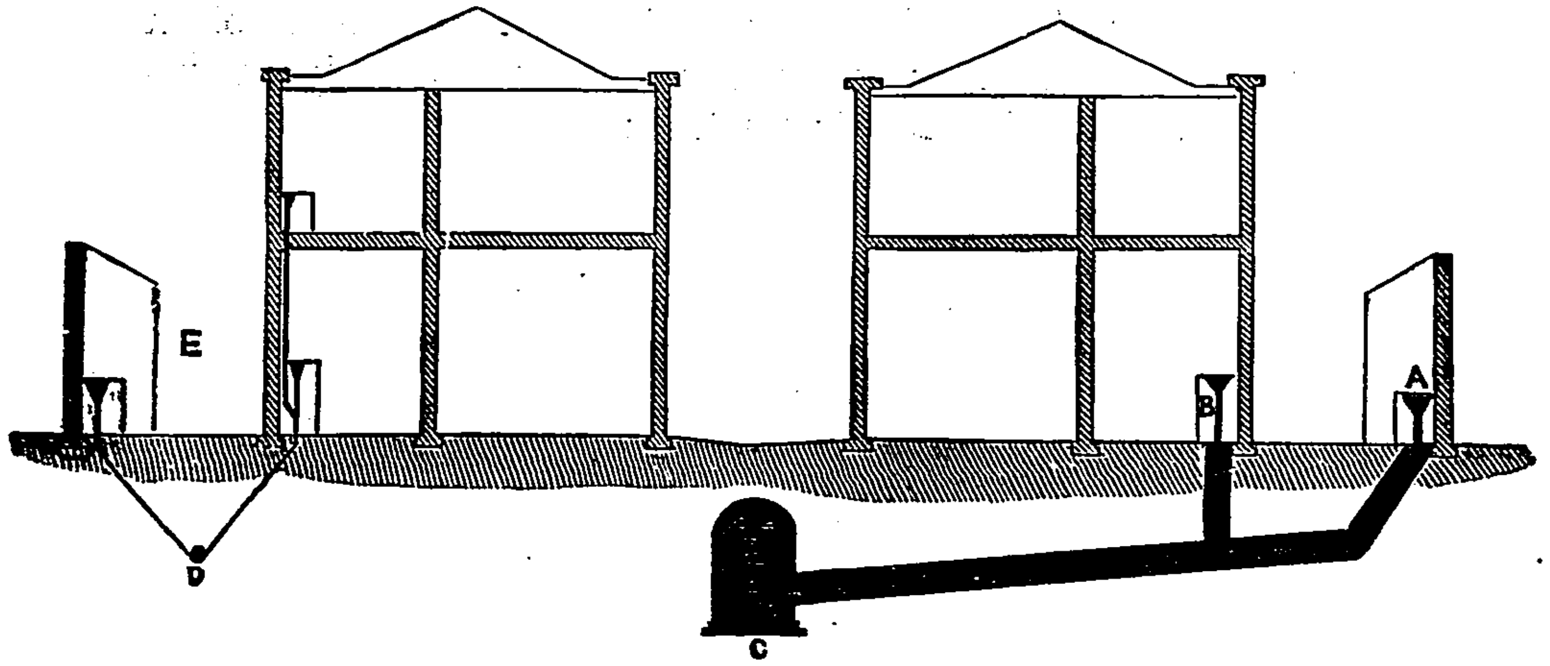
Gain in Fall and diminished Friction of House Drains by Improvement in their Direction.

Besides reducing the sizes of house-drains, it appeared upon investigation that great alterations were required to improve their inclinations, or fall, and also to reduce their length.

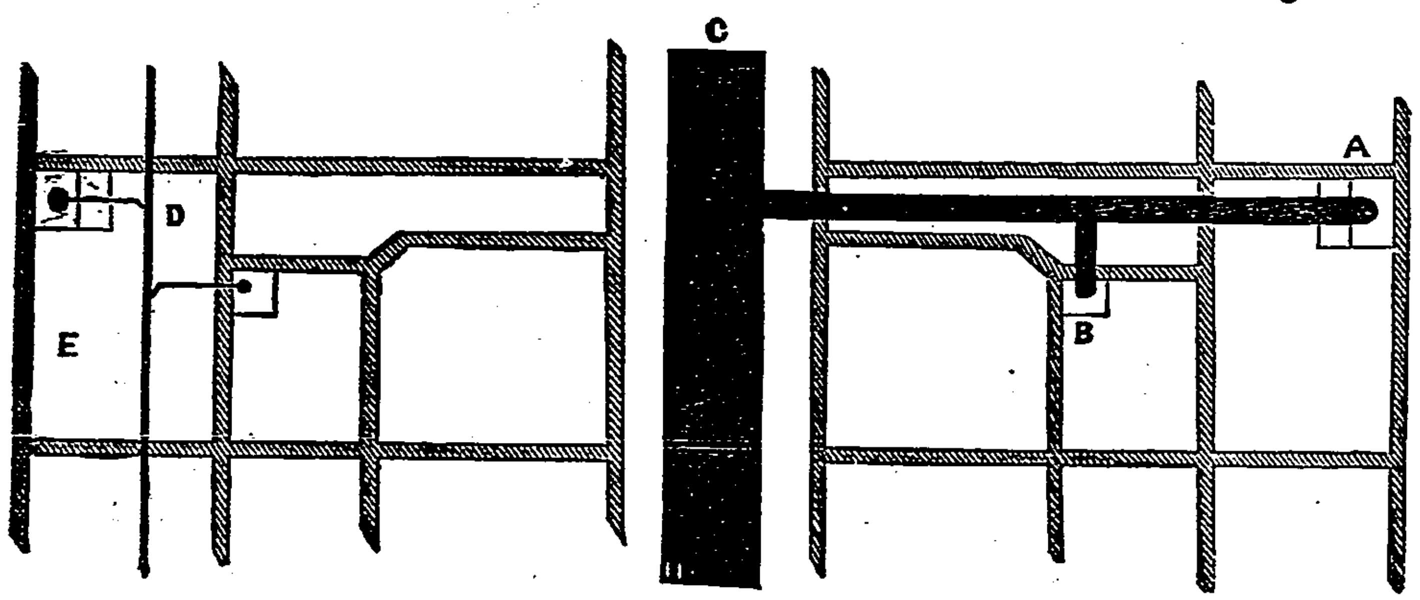
Water is chiefly used in and about the back offices of houses; water-closets are generally situated there, and thence the discharge of waste water will principally be.

The common or general practice has been to place sewers for the reception of house-drains so as to compel the passage of the refuse by a drain across the court-yard, underneath the back room or kitchen, underneath the front room, front pavement, and half the carriage pavement, to the centre of the street; whereas, if sewers had been laid at the back of the premises, frequently a house-drain of about one third the length would have sufficed, and by the same means more rapid falls would have been obtained. This is shown in the following plans and elevations, of a house with back premises on one side of the street, with the drainage from the privy A, to the sewer C, in front of the house, and of a similar house and premises on the opposite side of the street, with a main drain-pipe D, or pipe-sewer, brought to the back yard at E:—

Section No. 1. Back drainage. Section No. 2. Old drainage.



No. 1. House and yard drained. No. 2. Old drainage.



The water-closet or the scullery being situate at E, if the branch sewer were brought up from D, the length of the drain for the discharge of the fæcal matter would frequently not be more than one sixth of that which would be required if the house-drain were carried to the centre of the street, as at C, and the increase of inclination would be in the same proportion. The rapidity, however, with which the fæcal matter would be discharged from beneath the premises from E to D, by the back drainage, would be increased in much greater proportion; while with drains of the old construction, the increased friction, and the smaller flows of water, would frequently leave the more solid particles behind. The frictional area over which the refuse must be carried, by placing the sewers in the centre of the streets, will be many times greater than that which would occur in carrying the branch-drains to the back of the premises.

Plan No. 2. displays, from A and B to C, the actual proportion of noxious evaporating surface formed by house-drains and by sewers to the smaller houses in courts and bye-streets.

The lines from A to C, in the cross section No. 2., show the frequent actual proportions of the capacity, as gasometers or reservoirs of foul gas, of so much of the sewer and of the house-drains as are unoccupied by the ordure detained in them.

Plan No. 1. displays the reduced extent of evaporating surface obtainable by tubular earthenware drains, supposing them proportionately occupied by ordure; but if properly constructed and adjusted for the discharge of refuse they will be kept clear of all deposit.

By the common practice of draining houses separately from the back, through the house, into the sewer placed in the centre of the front street, the offensive and noxious matter is carried completely under the house, instead of directly away from it, and the chances of stoppage are increased in proportion to the increased frictional area, and to the diminution of the fall. By these ignorant and mischievous arrangements, when a stoppage does occur, it can frequently be remedied only by taking up the floors of the front as well as the back room, and opening the foot and carriage pavement to the sewer in the centre of the street, all which work must be done at great inconvenience, and at oppressive expense.

The openings made by rats, through defective brick-drains, permit the escape into houses, not only of noxious effluvia from deposit in the house-drains, but also from that in the still further elongated cesspools,—the sewers—as commonly constructed. A house-drain, as commonly constructed and arranged, acts as the neck of a retort, of which the sewer is the bulb, containing decomposing matter, which is discharged in the gaseous form into the premises. Medical men, who are called into houses to visit the sick at all hours of the night, have given strong testimony in relation to these offensive smells, and the excessive state of impurity in which they frequently find the air in dwelling-houses at that time.*

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* Almost innumerable instances are brought before the Board in the Reports of their Inspectors, similar to the following, stated by Mr. Lee, in the Report on Ashby-de-la-Zouch (p. 10):—

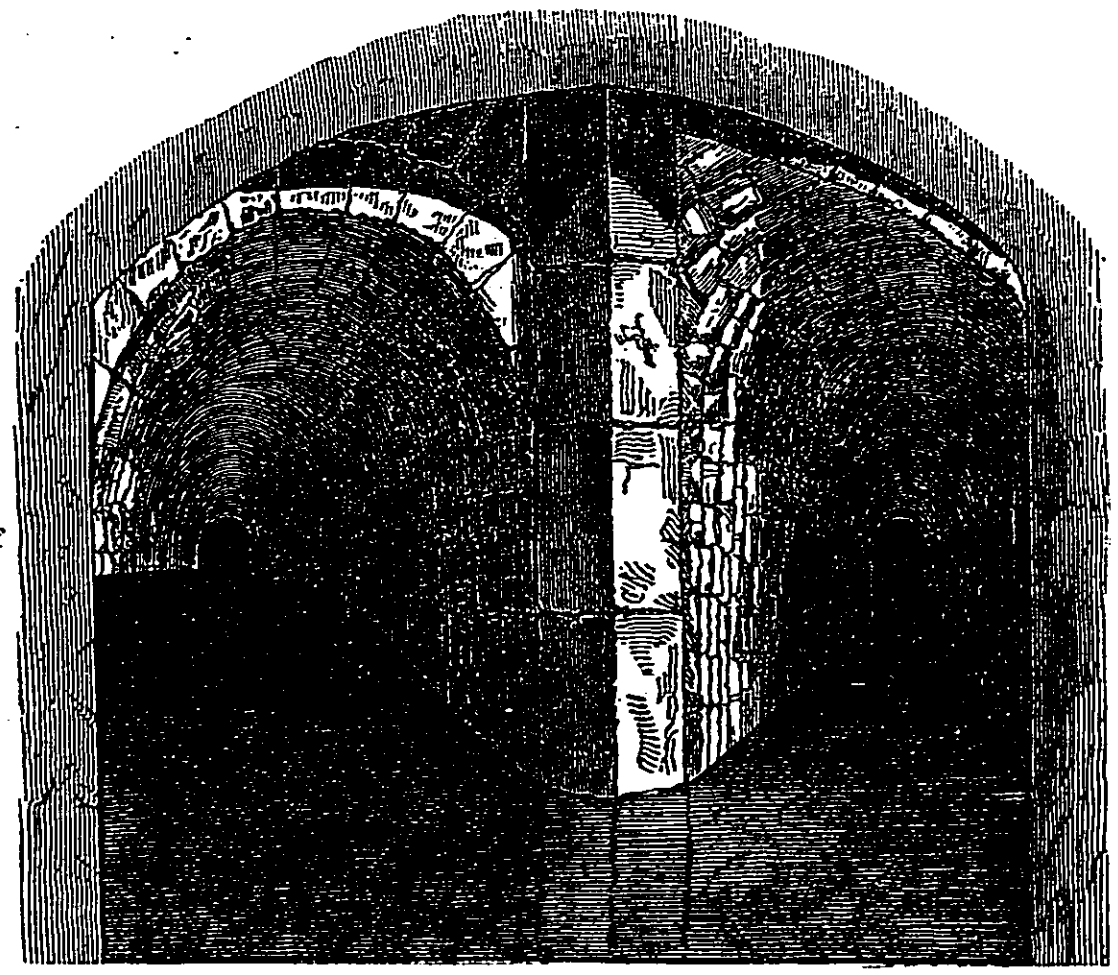
"A drain passes through many of the houses situate between Market-street and Ivanhoe-road; and I was informed that in a time of flood, the refuse frequently forces up the stones of the house-floors, and that the floors of the houses have to be taken up to cleanse the drain. It became choked in 1847, and Mr. Dalby, surgeon, informed me that he had three cases of typhus at the time, on the spot where the obstruction took place."

Trial of Tubular House Drains.

The great majority of a town population do not differ so much in their habits, either as to the use of water,—or in other respects affecting this question,—to prevent the well-observed experience of an average group of houses sufficing, as to the main points, for general comparison; and the first trial works, which were made under the careful attention of the Dean of Westminster, were by him considered to afford a decisive proof of "the efficacy of draining by pipes, and of the facility of dispensing entirely with cesspools and brick sewers."

A severe epidemic fever had burst out in the houses connected with the cloisters at Westminster. Thirty scholars and inmates had been attacked, of whom several died. The houses had nearly all cesspools, and the inmates, during the variations of the weather, were beset with foul smells. On examination, it was found, that beneath the houses in which the fever raged there was a net-work of cesspools, old drains, and sewers. From beneath 15 houses which were the chief seats of fever, 150 loads of ordure were taken; and from drains and cesspools connected with the houses, upwards of 400 loads were taken.

The following is a view of the branches of a private sewer, under the schools. It usually contained several feet in depth of cesspool matter, which in one part was nine feet deep, and afforded a never-failing source of noxious exhalations into the school:—


Height of Deposit.

These cesspools and old drains were all filled up, and an entire system of tubular house-drains with water-closets, substituted.

The changes in the sizes of the drains are thus stated:—

"At the outlet, the main sewer in the old works was 4 feet high, by 3 feet 6 inches wide, varying in width to 6 or 7 feet, and in height in one part to 17 feet. In the new drainage substituted there are two 9-inch stoneware mains, the united sectional area of which is but one sixtieth of the area of the smallest part of the old sewer, and not more than one half the area of the average of old single house-drains. We state that the secondary pipes are of 6 inches diameter, and the branches of 4 and 3 inches; 4-inch pipes were however used in many parts where 3-inch would have amply sufficed for all the requirements of the drainage, from an apprehension that the irregularity of the pipes would tend to create a certain amount of obstruction. This new drainage conveys the refuse and rain-water from 15 houses, the Westminster School Buildings, the Chapter House, and Cloisters of the Abbey, Little Dean's Yard, &c., comprising an area of about two acres. There is a total length of drain of upwards of 3,000 feet. The cubical capacity of the interior of the whole of the new main and branch drainage is about one thirty-second part of the cubical capacity of the interior of the old sewers; or the capacity of a portion of the old system is 32 times the capacity of the whole of the new system, exclusive of the old house-drains and cesspools; or the capacity of the old sewers is equal to a depth of water of more than two inches on the whole surface drained of about 87,120 square feet, or two acres; and they would have retained a rain-fall of this depth on the whole area."

In this block of buildings, the noxious evaporating surface underneath the area was upwards of 2,000 square yards. The flow of gaseous emanations from such matter in certain thermometric or barometric conditions was such as, in a stagnant atmosphere, would have filled the school in about three hours, the houses in about 16 hours, and the abbey itself in about 93 hours. It would have been a great gain to the inhabitants and scholars had the extent of the evaporating surface been merely diminished in proportion to the reduced cubical capacity of the tubular drains, but the whole of the old deposit was removed; with that deposit, the foul and noxious smells arising from beneath the premises have ceased, there has since been no epidemic fever, and a greater improvement in the general health of the population has succeeded than might be reasonably expected in a small block of houses, amidst an ill-conditioned district from which it cannot be completely isolated.

With respect to the action of the pipes, the result of this change, which has now (1852) been in operation more than three years, proves that, notwithstanding intermittent and ill-applied supplies of water, the force of the sweep in 4-inch tubular drains, properly laid, keeps them clear of all deposit, and also further proves that they require no extraordinary flushings.

An accumulation of noxious deposit under houses, appeared upon investigation to be often due even more to the vicious construction of house-drains than to the bad falls produced by the defective arrangement of the system of sewers.

One of the Inspectors states, that in Sheffield a difference of 10*s.* in one particular case, between the tender of a responsible contractor, and one upon whom no dependence could be placed, determined the drainage of some valuable buildings in favour of the latter. In six months, the whole length of drain was full of deposit, and had to be reconstructed, at his own price, by the more responsible person. The proposed saving was about 3 per cent.; the eventual loss was 106 per cent. The owner was wealthy, and a clever business man. Similar cases frequently occur, and are not confined to any one locality.*

The clearance of common house-drains, as well as sewers, when made on the hypothesis that they will accumulate deposit, s a source of constant expense. On an inquiry as to the cost of

* In places where, under Local Acts, tubular house-drains are now introduced, the expenditure for the purpose of drainage is not much better provided for. The following is an extract from the Report of the town surveyor of Liverpool:—

"Besides the difficulty of getting the parties who are most deeply interested to entertain proper views as to the position of the drains, I have frequently had to complain to the Committee of the difficulty of ensuring the proper execution of the work in private drainage, unless assisted by the co-operation of the owners of property. Under a false notion of economy, an owner will employ a contractor whose sole recommendation is his assertion that he can do the work more cheaply than a man of character who intends to pay honestly for his labour and materials; and, as a matter of course, he is deceived. The work is performed and the street tunnelled under, it may be by night, and without the control and supervision, and, as easily may be supposed, without even the knowledge of the officers of the Committee.

"After a time complaint is made that the drain does not fulfil its purpose, the house is damp and pervaded by bad smells, which did not exist before; an inspection is ordered, and it is discovered, on examination, that there is no connexion with the sewer, that pipes have been put in with dry joints, that there is no trap, and that, as a natural consequence, when water has been turned into the mock drain without an outlet, it has followed the natural law of fluids, and first filled it and then overflowed.

"It is sufficiently surprising that a man should be at all guilty of the folly of injuring his own property; but it is almost incredible that, having done so once, and suffered by the act, he should be found to repeat it; but such is the case."

cleansing the brick-drains of 8,000 middle-class houses in the metropolis, it was found to be, on the average, nearly 1*l.* each per annum, which, as it included the expense of making them good, as well as of opening and cleansing, may be said to include the expense of repairs. If the expense of cleansing the brick street sewers were charged upon each house according to the frontage, at the average expense of about 29*l.* per mile per annum, it would amount to 6*s.* or 8*s.* per house, in addition to the expense of cleansing the brick-drains.*

If the expense of removing all the stoppages which have occurred either in tubular house-drains or sewers were to be taken as a necessary and constant charge, it would be very trivial in amount as compared with the expenses above referred to. But stoppages in earthenware pipes are found to be due to want of care or skill, and are preventible. The stoppages in pipe-sewers, where they have occurred, have been chiefly from the bad quality, the thinness, and the breakage of the pipes in sandy or slippery soils, where they have been laid without proper protection,—from the inlets not being properly protected,—from not putting cesspits to prevent the admission of granite detritus into pipes, sewers provided with only very small or intermittent runs of water,—from the inlets of the house-drains not being protected against the admission of large solid substances,—or from the drains being badly laid, with insufficient fall, or through ignorance or gross carelessness laid with reverse inclinations. In the metropolis, however, during the years 1849, 1850, and 1851, there have been laid down about 50 miles of pipe-sewer, and upwards of 150 miles of private pipe-drains, or a total of 200 miles, which keep clear by the action of their ordinary runs of water, where the older constructions—large sewers and brick drains—regularly accumulate deposits. The expense of cleansing the old brick sewers in the metropolis has been from 17,500*l.* to 18,500*l.* per annum. The same extent of cleansing, if it had been performed by hand labour or cartage, would, at the former contract prices, have been more than ten times as much. In the metropolis upwards of 18,000 houses have been pipe-drained.†

* The stoppages and cleansing of the house-drains were extremely irregular, some going on with accumulations for years; the expenses of opening and cleansing varied from 3*l.* to 30*l.*, and much higher sums.

† In a recent Report of the Council of the Borough of Manchester is the following remark:—

"It will be seen from the last statement, that the cost chargeable to owners of property for paving and sewering has been materially diminished during the last four or five years; and your Committee would observe that

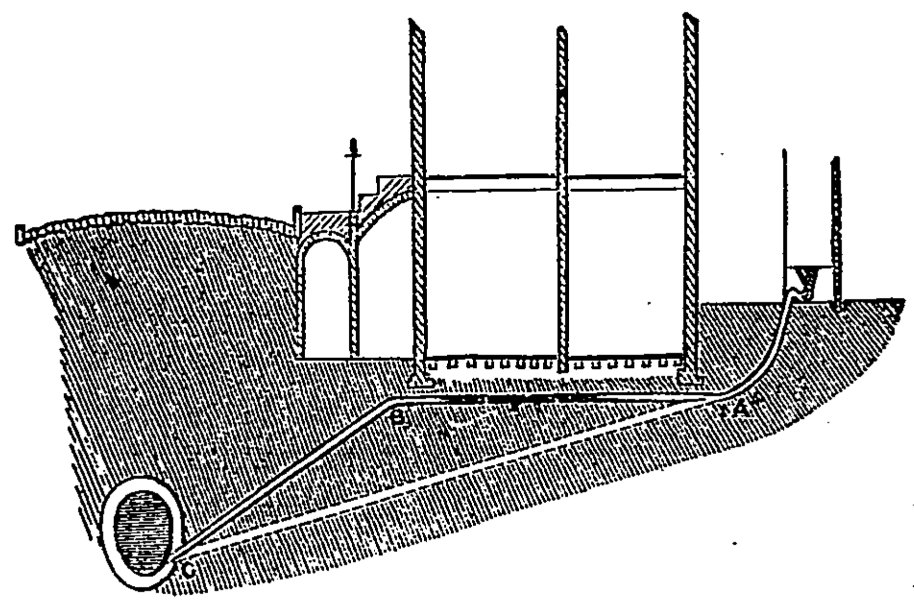
But tubular drains have frequently been laid under the most ignorant and careless arrangements; the work in the street being done by one man, the work in the house by another; probably at different times, sometimes with water and at other times without it; sometimes even when pipe-drains are laid, foul cesspools are retained upon the premises.*

this is in part resulting from the use of tubular sewers, and in part from the paving by public tender. Your Committee continue to use glazed tubes for sewers and drains, in all cases where their size is applicable, and their use has been hitherto remarkably successful. They have been used as main sewers to the extent of about 25 miles, without a single case of failure by breaking in, or displacement. There have been two or three cases of partial stoppage near the upper end of a drain, obviously the result of a defective supply of water to the sewer; and in the branch or surface drains, a few cases of failure of the pipes have occurred. In these cases the tubes had been laid too near the surface, and not well packed, and consequently were broken by the heavy weights passing over them, and it has been necessary to replace them at a greater depth. With increased experience, it is to be expected that these cases of failure or defect will become still more rare, or cease altogether. Several tubular sewers, laid in 1847, have been recently examined, and found to remain clear of deposit, nor has there been a single instance during violent storms of rain, where the tubular sewer has appeared to be insufficient for the passage of the water. If such had been the case it would have been evidenced by the flooding or backing-up of the water to adjacent premises. The economy effected by the use of tubular sewers is therefore palpable, and the result will be, no doubt, a great extension of the practice of draining, and consequent improvement of the public health."

To show the extent of progress of the new system, it may be mentioned, that one manufactory alone turns off between 10 and 11 miles of glazed earthenware pipes for sale weekly. It is stated that probably not less than 50 miles of sewer and drain pipes are now made weekly, or upwards of 2,600 miles per annum, equal to 13,728,000 feet; and that the sale is fast increasing.

* The manufacture of sewer and drain pipes being of very recent date, and having been undertaken by persons using most imperfect means and possessed of little capital, pipes have been made of clays and marls unfitted for the purpose, badly tempered, worse formed, and imperfectly burned; such pipes when taken from the kiln have been rough on the surface, porous and absorbent in substance, and untrue in section; to such an extent that two pipes of 12 inches diameter, placed with their ends together in work, show an unevenness of joint to the extent of an inch or more. Then as to the character of joint: there have been made butt-joint, socket, half-socket, and rabbet, several varieties of each; some of the sockets have been imperfectly joined to the pipe, and many of the pipes have been so imperfect in sectional form that the plain end of a pipe could not be inserted in a socket. Such pipes have been laid in very large quantities throughout the country, and without any skill or judgment. Pipes 9 inches in diameter have been jointed on to others of 6 or 4 inches; and not unfrequently a pipe-sewer or pipe-drain has been divided or continued by means of a sewer or drain of larger dimensions, square on section, and formed with bricks set dry, or with dry rubble. During the recent prevalence of cholera, in 1849, every tile-pipe maker's yard was cleared out, and even

In some districts the sewers with which these drains are connected are charged with a greater or less amount of decomposing deposit, and are water-logged during two thirds of the day. The relief, therefore, from foul smells, must from such imperfect works be (as forewarned) only partial. Three fourths of the stoppages of the tubular house-drains are however, upon inquiries which the Board have directed to be made as to the working of the new system, found to have been occasioned by bad laying of the pipes, at wrong levels, or at reversed inclinations; of which the following cross section presents an example of not unfrequent occurrence; in which, instead of the



fall being made uniform or regularly progressive from the point A, to the outlet C, to save a slight additional expense of extra digging the drain is brought close under the floor from A to B, and the greatest fall is given at the outlet.

pipes which had been thrown by as refuse, were, by persons not over scrupulous, eagerly purchased, and were hastily laid by parties utterly ignorant of any rule of correct drainage. The causes of failure from mere ignorance and want of skill have been sufficiently numerous, but it has been found that to these have been added others, arising from the hostility of interests, in the more expensive forms of works, and from prejudice against alteration; that many pipe-drains have been so laid as to create obstructions, and these failures, though the causes were obvious and gross, have been eagerly held forth as proofs of the failure of the principle. Experience has generally been most unfavourable to employing for the execution of new works men habituated in the practice of old works, which it is necessary to supersede. Though the demonstrations of the errors of former works were admitted at every step by such men, and although they have themselves proffered illustrations of such errors, yet no sooner was any authoritative direction of new works withdrawn than the old practices were immediately reverted to.—*Vide Appendix:* Paper as to Pipe Construction.

The new practice of bringing main drains up close to the back of houses, instead of placing them in the centre of a front street, does not offer the same temptation to do the work imperfectly. The present mode must cause obstructions, and perpetuate occasions for periodical repairs.

In the trial works with smaller-sized drains, it was found that stoppages generally commenced by the detention of large or small substances at the joints, and therefore, the less numerous and more perfect the joints, the less the probability of such obstructions. Pipes, as generally made, present one joint only at every length of 3 feet, but a yard length of a 15-inch drain constructed of 76 bricks, has 69 feet of joints; and a yard length of 18-inch drain has 92 bricks, and 83 feet of joints. The joinings between bricks, besides being so much more numerous, are much less perfect than those of well-made pipes, and yet it is important that those should be made as perfect as possible.*

Increased Power of the Sweep of Water gained by Alterations in the Forms of Sewers.

It appeared on examination that accumulations were greatly influenced by the shape of sewers, where the conditions as to run of sewer water or fall were the same.

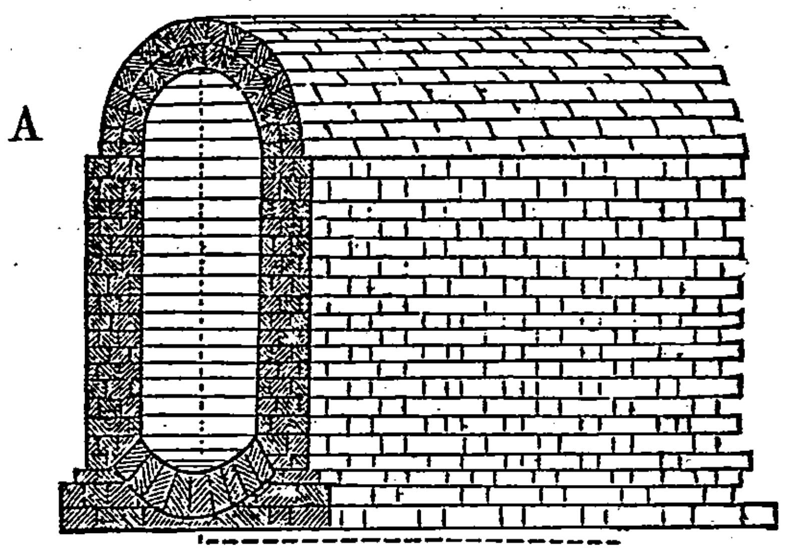
The trial works prepared in respect to sewers are here adverted to as illustrative, on a large scale, of the principles of construction previously noticed.

Mr. Roe, surveyor of the Holborn and Finsbury division, who made one of the earliest advances in the improvement of the construction of sewers, had shown that, by an alteration of the form of sewer from a flat segment to an egg-shape,—with the same quantity of water, at the same inclination,—the deposit was reduced one half.

As a point of pecuniary economy accompanying improvement in construction, it was shown that the number of bricks required to construct a sewer, A, with upright sides, 75 inches long, would suffice for the construction of an egg-shaped sewer, B, with the same sectional capacity, 122 inches long.

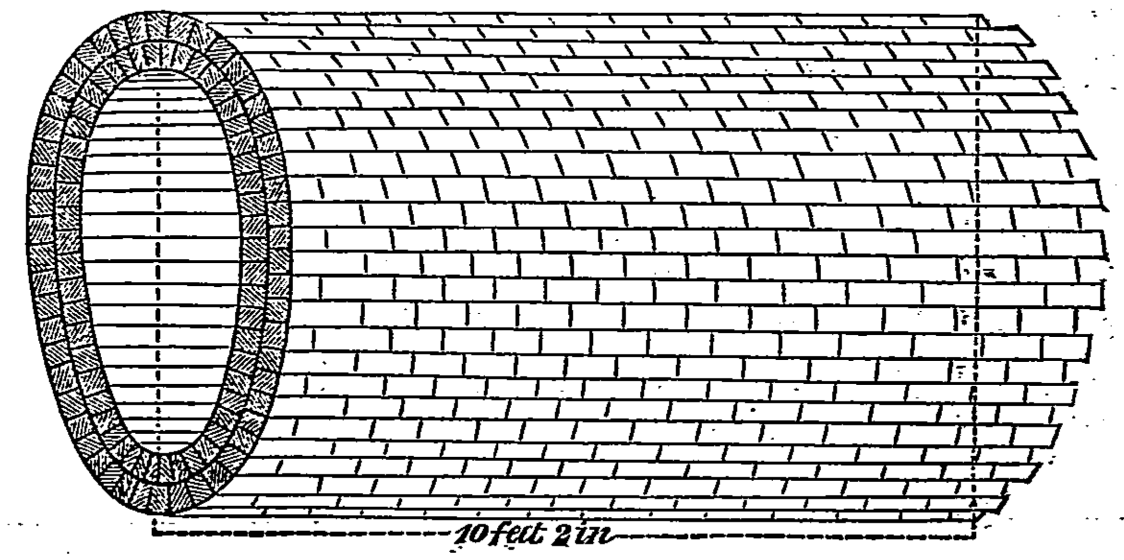
* The greater rapidity of discharge and the diminished friction through pipes is proved by the fact of pieces of paper being carried through the pipe-drains of Croydon, and discharged at the outfall; but paper is scarcely ever seen at the outfall of brick-drains, being detained in them until reduced to pulp.

A



6 *feet* 3 *in.*

B



Other examples might be adduced of improved results obtained by variations in form, without any change of the internal capacity of sewers.*

The egg-shape possesses an advantage over the circular sewer in the increased scouring action derived from the greater rapidity of flow when the stream is small, and occupies only a small proportion of the area; and this is the general condition where sewers are made large enough for men to traverse them, without

* The diagrams already given (*ante*, p. 32) displaying narrow and deep channels frequently cut by streams in the surface of the soft deposit accumulated in flat-bottomed sewers, were demonstrative of the very little observation on which eminent engineers have declared that the form of the bottom of a sewer is of no consequence. It was declared, at the outset of the investigation, that a sewer with upright sides and wide-spreading footings was the best and most certain form of construction. The examinations, directed in the subterranean survey, have proved the erroneous doctrine, in extensive failures of that form of sewer when carried through

reference to the quantities of sewage which they have to convey; but it should be observed, that wherever good inclinations are obtainable, and the ordinary flow would be sufficient to keep the circular form of sewer clear of deposit, that form is to be preferred. It is stronger and more economical, it presents less frictional surface, and is more capacious, with the same amount of material.

The special advantage of the egg-shape diminishes moreover with the size of the sewer, so that in the smaller areas it becomes scarcely appreciable. For pipe-sewers and drains the circular form is on the whole to be preferred, because the greater risk of unevenness of form, and the difficulty of obtaining the same accuracy of joint with the egg-shape, more than counterbalance the advantage of the small increase of flow which would be acquired.

For intermittent purposes, where the house-sewage occupies only a small portion of the area, but the sewer is liable to be filled with storm-water, the egg-shape is undoubtedly the best. In proportion as the flow can be equalized and adjusted, and the principles of drainage reduced by practical science to an approximation of constants, to the same extent the egg-shape must yield to the circular, as the best form of sewer, without reference to size.

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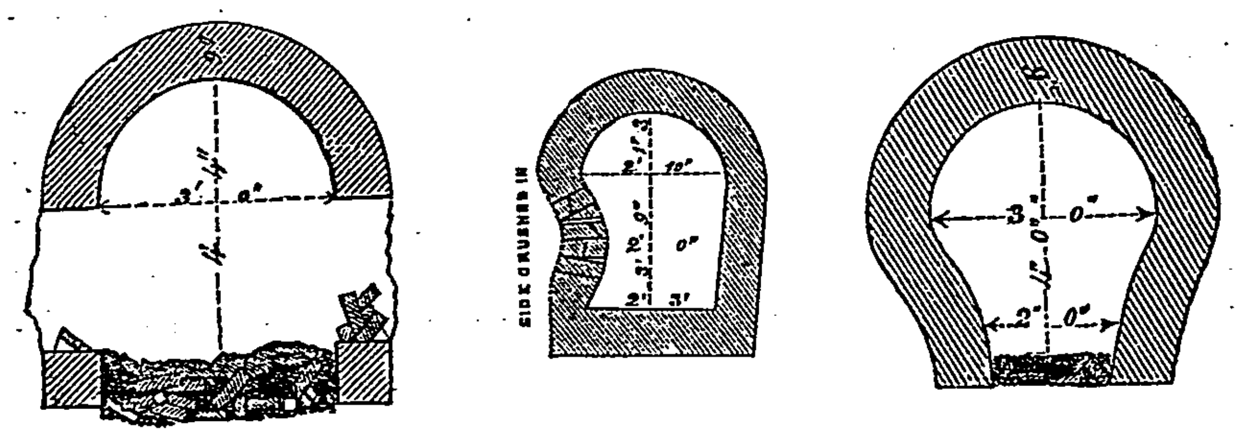
slippery ground. In some instances whole lines have been found driven in at the sides, thus:—



Trial of Tubular Sewers. Increased Power gained by Alteration of Size, as well as Alteration in Form of Sewers.

The following is an account of several trial works, and illustrates the effects of altering the size as well as shape of the channel of conveyance, with a better adaptation to the run of sewer water, and the service to be performed. It is contained in a Report of Mr. Hale, the surveyor, who was directed to make the trial.

"The main line of sewer in Upper George-street is 5 feet 6 inches high and 3 feet 6 inches wide, and runs from the Edgeware-road to Manchester-street, where it falls into the King's Scholars' Pond sewer. I have laid a 12-inch pipe 560 feet long upon the invert of this main line, and have built a head wall at the end of it, so that the whole of the sewage discharged by the collateral sewers above the pipe, as well as what sewage may find its way independently into the upper part of George-street, is forced to pass through the pipe.

"The whole area drained by the sewers running into the 12-inch pipe in George-street is 213,778 square yards, or about 44 acres. Observations are being continually made on the work, and the results are as follows: The velocity of the stream in the pipe has been observed to be four-and-a-half times greater than the velocity of the same amount of water on the bed of the old sewer.* The pipe has not been found to contain any deposit, but during heavy rains stones have been distinctly heard rattling through it. When the pipe is nearly filled, the velocity and concentration of the water are sufficient to clear away any matter which may have been drawn into the pipe from the large sewers, and much of which matter it may be presumed would never enter a well-regulated system of pipe sewers; also the force of the water issuing from the end of the pipe is sufficiently great to keep the bottom of the old sewer perfectly clean for 12 feet in length; beyond this distance a few bricks and stones are deposited, which increase in quantity as the distance from the pipe increases. Beyond a certain distance mud, sand, and other deposits occur to the depth of several inches, so that the stream there is wide and comparatively sluggish, and being dammed back by the deposit, exerts an unfavourable influence on the flow of water through the pipe. On the invert of the original sewer, which now forms the bed of the pipe, deposit was constantly accumulating, and was only partially kept under by repeated flushings. The superficial velocity of the water

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* As the force of a stream is proportionate to the square of its velocity, the cleansing power of the concentrated stream in the pipe would be above 20 times as great as that in the wide sewer, consequently stones, &c. which might rest in the latter, would be swept away by the more rapid flow.

in the pipe is generally three, four, and five times greater than the superficial velocity which obtained *under the same circumstances*, in the original sewer, and the velocity of the *whole mass of water* in the pipe approximates much more to its surface velocity, as ascertained by a float, than does the velocity of the *whole mass* of water in the sewer approximate to its own surface velocity.

"On one occasion I had the sewer in Upper George-street carefully cleaned out immediately below the pipe, and then caused a quantity of deposit, consisting of sand, pieces of bricks, stones, mud, &c. to be put into the head of the pipe; the consequence was, the whole of the matter passed clear through the pipe (560 feet long), and much of it was deposited on the bottom of the old sewer, at some distance from the end. When the pipe was flowing nearly half full, two pieces of brick, one weighing one pound and three quarters, and the other one pound thirteen ounces, were impelled by the force of the water through the whole length of pipe, and struck the legs of the man at the end of the pipe with considerable force. A live rat was also washed with great violence through the pipe, and struck the legs of a man with such force as proved the rat had no control over its own motion. When the water was only 5 inches deep in the head of the pipe, nearly a whole brick, weighing four pounds, was put in it; it was heard for a few seconds moving down the pipe, but was not caught at the end.

"(The bulk of the stream at the head of the pipe is diminished to about half its dimensions when it arrives at the end, the velocity being greater.)

"A great number of irregular-shaped stones, each of several ounces weight, were washed through the pipe with the same apparent ease as marbles, and the distinct rattling noise I occasionally heard them make might convey a correct notion of the considerable force with which they must have been impressed.

"All the foregoing results were effected when the pipe was either only half full, or less than half full of water, which have been gauged in the pipe. The following is a statement of the quantities of water:—

September 28 and 29.—Very wet both days and nights; there was at this period 96 hours' continuation of rain, and the pipe was never observed to be more than half filled.

October 19.—Morning, depth of water in pipe, 3 inches; afternoon, depth of water in pipe, 2 inches.

October 21.—Heavy rain, and rain all day; depth of water in the pipe, 4 and 5 inches.

October 23.—Morning, 3 inches; afternoon, very heavy rain, when the pipe filled.

October 24.—Morning, depth varied from 2 to 2½ inches; afternoon, from 2½ to 3 inches.

October 25.—During the day, depth of water varied from 2 inches to 3 inches.

October 26.—Morning, depth varied from 4 to 3 inches; afternoon, from 2½ to 3 inches.

During the above three days the weather was mostly fine. The *considerable* variations are due to the times of the water being 'on' at the houses; the sewage at such times is much clearer, as well as increased in quantity.

October 27.—On this day a storm occurred, which for a short period was very violent, the waters filled the pipe and rose above it 18 inches, but did not reach the top of the head wall; when the waters had obtained this maximum height, they receded to nearly the level of the pipe in 20 minutes.

It may be here observed, that vitreous pipe-sewers, if properly made, will bear very considerable internal pressure. The smaller sized stoneware pipes have been tested to several hundred feet. Common redware clay pipes of 6 inches have been tested to between one and two hundred feet of pressure. Pipe sewers and drains, properly laid, and cemented with Roman cement, may therefore be used under pressure. Experience as well as a consideration of the difference of structure, shows that it is not safe to use sewers of the common brick and mortar construction full.*

Oct. 28.—Depth during the day varied from 3 inches to 1½ inches.

October 30.—Ditto, 2 inches to 2½ inches.

October 31.—Ditto, 1½ inches to 2 inches.

November 1.—Variation of depth, from 1½ inches to 2½ inches.

November 2.—Ditto, 2 inches to 2½ inches.

"The house-drains connected with the experiment in George-street are in most respects like the rest of the house-drains of the metropolis; the general characters of the whole are great size, irregularity of form, and filthy and bad-smelling condition. The variations in size are from nearly half a square foot to four square feet cross section, and the different forms include the circle, the square, and square bottom and sides with semicircular top; their inclinations seem not to vary more than from horizontal to a fall of two inches in ten feet. Their condition with respect to quantity of matter deposited in them does not seem to be regulated by their inclinations. This may be accounted for by the fact, that their wide and irregular inverts

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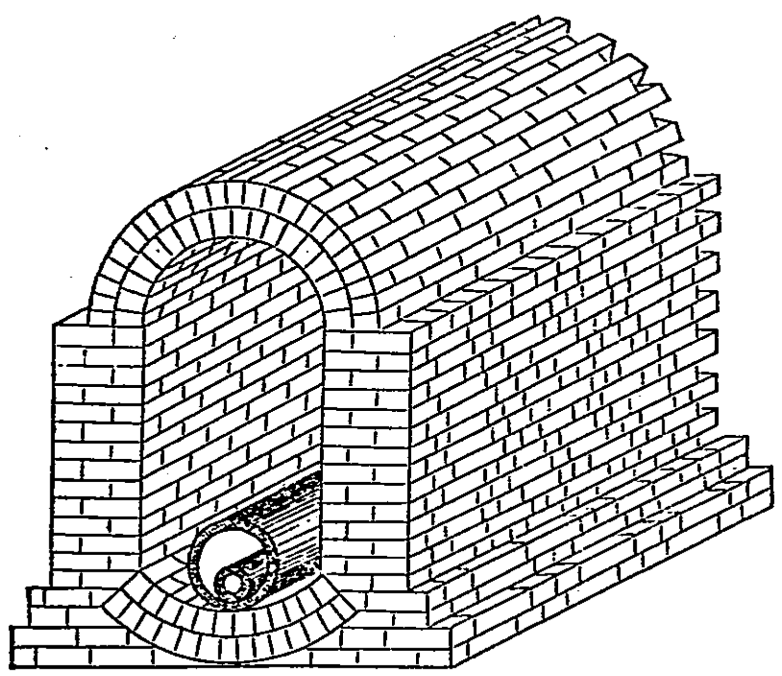
* With respect to a great number of the recently built and most expensive brick sewers in the metropolis, it is reported by the officers engaged in the subterranean survey, "that with one fourth the strength of a man, you may drive a searcher through the brickwork and several feet beyond; then by using the searcher as a lever, you may shake the whole sewer for a yard round;" and that the works cannot be reasonably expected to stand for more than ten or twelve years, much less any full flows of storm-water.

spread the small streams and destroy their force, and cause matter to lodge with greater security. Many of the ends of the drains are so dilapidated, that their original form cannot easily be distinguished; but enough can be determined to know that the sum of all their areas (480) would exceed the area of a circle of 30 feet in diameter.

"Much of the rubbish and obstructions in the house-drains have been found to consist of heaps of pieces of brick and mortar which from time to time have fallen from the soffits and sides of the drain, as it has progressively become dilapidated. Various species of fungi shoot out from the interstices of the brickwork; and the existence of old cobwebs around the sides, and sometimes nearly covering the mouth of the drain, furnishes another proof, in some instances, that the drain has not been for a long time, if ever, half filled with water. These old drains are the special harbours of rats and other vermin."*

The following is a view of a sewer, in which another trial work was most carefully conducted by Mr. Lovick, Surveyor, to determine accurately the amount of sewage from 1,200 average-sized houses in the metropolis, on the days when there was an intermittent supply of water from the different water companies; *vide Report on the Water Supply of the Metropolis*, p. 188.



* An inquiry was directed to be made as to the expense of laying down a mile of 16-inch pipe in an old sewer, with junctions of 4-inch branch pipes to every house-drain made good, when it was estimated that the expense would be 254*l.* 14*s.* 5*d.* per mile; and it appeared that in many such situations as those where, according to the views of various engineers, cleansing by flushing or hand labour would be required, such a line of pipe would keep the sewer entirely clear of deposit, and, so far as the sewer itself was concerned, clear of smell, while it would greatly diminish, if not prevent, the circulation of foul gases from the house-drains through the sewers. According to the report of Mr. Lovick the present expense of flushing in some districts is 2*l.* 10*s.* per mile per week. In the newly-cleansed districts it was 29*l.* per annum per mile. Even this expense was owing to old accumulations now in course of removal. In the Holborn and Finsbury division, where the flushing is regular, the average expense of keeping the sewers clean by flushing, at piece-work, is 17*l.* 5*s.* per mile per annum. Now, the total cost (assuming the practicability of arrangements for the manufacture of redware pipes, such as are described in the Appendix, which could only be done on a very large scale,) of such a tubular sewer as that above described by Mr. Hale, allowing for a 16-inch pipe instead of a 12-inch one, and spreading the payment over twenty years, would not be more than 19*l.* 8*s.* 5½*d.* per mile per annum, if executed on a large scale at the prices herein described. (See *Appendix*, Cost of Tubular Drain-pipes.) Under the flushing system in the least uncleanly sewers district, the expense of flushing represents the expense of removal of 517 loads of detritus and decomposing refuse at 8*d.* per load, spread in portions over a mile of surface 3 feet wide on the average, until it is removed at weekly and fortnightly intervals. At an extra annual expense of 2*l.* 3*s.* the retention and spreading of a proportionate part of these 517 loads may be prevented in streets where there happens to be a sufficient fall.

In this sewer, which had a flat segmental bottom 3 feet wide, a sectional area of 15 feet, and an average fall of 1 in 118, the deposit from the 1,200 houses regularly accumulated at the rate of 6,000 cubic feet per month. But a pipe of 15 inches diameter placed along the bottom of this sewer, with a somewhat less inclination, (1 in 153), kept it perfectly clear of deposit. The average flow, without rain-fall, was about 51 gallons per house per diem; the absolute drainage, apart from rain-water, from all the 1,200 houses would have passed through a 5-inch tube, (of the relative size of the smaller one shown, within the 15-inch tubular pipe, placed along the bottom of the brick sewer), or not one third the area of the minimum sized drain, which had, up to the time of the investigation, and upon the advice of professors of architecture, been declared and enacted in the Metropolitan Building Act to be necessary for a single house; namely, one of not less than 9 inches diameter.

On the same rate of flow, the whole of the mere house-drainage from all the houses in the metropolis might be discharged through a sewer of 3 feet in diameter.*

* It will be obvious that by this calculation it is not intended to convey the meaning that a 3-feet sewer would suffice for the drainage of the metropolis, but merely that assuming the average of the whole of the house-drainage alone to be that which was found in this experiment, and that the whole were flowing in one channel, at the same rate, a 3-feet sewer would suffice to convey it.

Expedients in default, or in substitution of improved Works for the Removal of Cesspools.

One of the first projects urged upon the Commissioners of Inquiry, in respect to the mass of matter in cesspools, drains, and sewers (assuming its presence to be inevitable), was to disinfect it, for which purpose various patent preparations were proposed. This subject is fully examined in the Second Report of the Metropolitan Sanitary Commissioners (*vide* pp. 33—71, 125), by whom it was considered that the whole were unsatisfactory as "disinfectants," and that the most successful were entitled to the designation of "deodorizers" only; and it was subsequently proved that much time was often lost before they could be applied; that, when applied, their effects were incomplete; and that their application on a large scale would be far more expensive than effectual cleansing.*

Another set of expedients, (still assuming the inevitable presence of the matter,) urged as cures or palliatives in respect to this mass of ordure, was its ventilation by various means, one of which, the steam jet, was tried, and at the immediate spot proved very efficient; but although the steam jet gave relief to a particular sewer, yet it diffused a proportionate amount of gaseous matter, which, even if decomposed and altered by combustion, was yet not pure air, and was a less effectual remedy than entirely avoiding the evolution of poisonous vapours by preventing any accumulation of decomposing refuse. (*Vide First Report*, p. 66.) The expense, moreover, of the construction of furnaces and high chimneys, and the working expenses, were on several plans as great or greater than the expense of improvements, by which the removal of the matter, before it could enter into stages of decomposition, were ensured.

A third set of expedients, called for by private individuals,

* At the prices charged for Sir William Burnett's fluid, and with the quantities for deodorizing the cesspool matter in drains and sewers as well as in the cesspools weekly, the expense would be 644*l.* per week, or 34,000*l.* per annum for the metropolis for the fluid alone. The expense of a sufficient quantity of another fluid (Ellerman's) would have been 43,700*l.* per annum. When to this expense that of the labour is added, the total cost would have been certainly much greater than the cost of proper works for the non-offensive and continuous removal of the refuse. For deodorizing night-soil, it is stated that one ton of peat charcoal would suffice for two tons of excreta. With this material, therefore, the requirements for the metropolis would be about a ton per house, or in round numbers 300,000 tons per annum. The sale price of the peat charcoal is 2*l.* per ton. The annual expense of an improved water-closet would be much less than one fourth of the present price of the material alone proposed to be used for deodorizing the contents of a privy.

was arching over uncovered sewers, and trapping openings into the streets; but this, although it might sometimes screen particular houses, it was proved, only masked the evil, and often, by confining the noxious gases generated, made the sewers themselves more dangerous; and, moreover, occasioned such additional escapes through the house-drains as no traps could withstand, and thereby augmented the diffusion of impurities in private dwellings; whilst the expense of arching over some of the wider sewers was greater than that of proper tubular drainage works, by which the whole of the noxious deposit might be removed. *Vide ante,* p. 28, note; and Report on Suburban Land Drainage, p. 14 to p. 16.

A fourth set of expedients, urged especially by engineers, was the abatement of the evil by systematic flushing.

Most of these plans assumed the faultlessness (at least to any very important extent) of the present constructions, and several eminent engineers signed a report to the corporation of London approving of large sewers, and proposing the introduction of a river as means of their effectual cleansing. Extensive flushing was, indeed, recommended by the Metropolitan Sanitary Commissioners on the approach of cholera, but only as an immediate means of mitigation, and such means had been adopted, at the instance of Mr. Roe, in one division of the Metropolitan Commissions of Sewers. It had been the general practice, and continued to be so, in a majority of the old sewer districts of the metropolis, when the accumulations in the sewers were allowed to go on until the mouths of the house-drains were covered, to remove them by hand labour and cartage, at an expense of from 10*s.* to 11*s.* per load. By flushing, the removal of the refuse was effected more rapidly and completely at about 8*d.* per load.* The temporary extension of this process was,

* One circumstance which first directed the attention of Mr. Roe to the necessity of having recourse to flushing was, the effect of clearing out foul deposit upon the health of the men employed in such labour. He gave an instance of a man, who the moment he arrived at the effluvia from the deposit, was obliged to leave it immediately, and go home, where he was ill of fever for a month. The men were also in many cases afflicted with dysentery. The operation of flushing was thus performed:—The sewage was first penned up so as to *cover* the refuse; the refuse *underneath* was then loosened and stirred up, diluted with water so as to abate the intensity of the effluvia; the head of water was increased, and the penstock being liberated, the whole was flushed away, and a draft of air down the sewers was also created. The whole process diminished the noxious evaporation, and gave immediate relief; but on hearing that something was going on during the cholera, certain parishes petitioned against the process of cleansing, ascribing to it the extension of the pestilence.

therefore, recommended, notwithstanding the additional pollution of the river, on the ground that the matter was less injurious there than when retained beneath or among the houses.

The prospect of the continuance of decomposing accumulations underneath habitations, even with the possibility of an intermittent removal, appearing to the members of the Board exceedingly unsatisfactory, they pursued the investigation farther. In each of the proposed remedies the state of the sewers themselves was assumed to be the whole or the main evil, whereas, supposing them to be in a foul state, they present only one fourth of the whole surface evaporating noxious gases, the cesspool being another fourth, while private house-drains supply fully two fourths of the noxious surface, which portions most closely beset the dwelling-house, and from which, were the sewer itself completely cleared, noxious smells would continue to be emitted.

Adjustments of the Sizes of Tubular House Drains and Main Drains required for the Discharge of Storm Waters.

Whilst the drains for the discharge of soil-water from within houses are made of 3 or 4 inches diameter, (not, as already shown, that even such a reduced capacity is required for the removal of the usual quantity of waste-water, but because such are the smallest convenient sizes,) the main-drains and sewers will require some enlargement (beyond the space required for the ordinary waste-water from the houses) to receive variable quantities of rain-water.

The necessity of provision for the reception of these variable quantities of water was alleged as one justification of the enormous sizes of the sewers as, until recently, constructed; but on examination the data were found to be wholly insufficient to warrant such dimensions.

The greatest storm which need be considered,—such a storm as occurs in England only in the course of years,—would be a fall of about 2 inches in the hour, or 44,789 gallons per acre. Now it was proved by the trial works that a *three*-inch tube, at an inclination of 1 in 120, will clear away more than this amount of rain-fall from 10 squares, space enough for three labourers cottages, classed as fourth-rate houses under the Building Act in the metropolis; at a fall of 1 in 80 it was found that it would clear away the rain-fall from 12 squares, or one first-rate and four fourth-rate houses; at a fall of 1 in 40, from 17 squares, or five fourth-rate houses; and with a fall of 1 in 20, it would serve for 25 squares, or the space of two first-rate houses, or eight fourth-rate houses. A 4-inch tube would carry away nearly twice as much water ($\frac{16}{9}$) as one of 3 inches diameter. That size is, therefore, for such an area, more than sufficient for the greatest contingency.

Observation of the flow of any outfall of storm-water, and of the tributaries from a hill-side, offers to an unscientific person some approximate conception of the sizes of the channels or tubes which would be required to convey it away; so in a town, the observation of the flow of storm-water in the rough kennels or channels of streets, where there is no under-drainage, would be suggestive of the maximum sizes of the underground sewers required for its removal. But it was found on investigation that, for side streets, and streets where the storm-water never rises above the side gutters, enormous sewers had been constructed of a capacity sufficient to receive water enough to cover the whole surface several inches deep, and to give it the appearance—which it never had—of a river.

The occasional bursting of large sewers has been referred to as a proof of the necessity of their large size for the discharge of storm-waters; but it appeared upon investigation that the burstings were caused by accumulations occasioned by the large sizes of the sewers, by their irregularly-constructed bottoms, their junctions at right angles, and by other causes. On the occurrence of a sudden storm, one accumulation is rapidly driven up the incline of another, occasioning a complete stoppage. When the internal condition of the sewers was examined, at the places where these burstings occurred, it became a matter of surprise that such accidents had not more frequently happened. *Vide ante*, p. 30 and 31, for illustrations of the common condition of sewers, for bursting under accumulated heads of water from extraordinary storms, for the prevention of which, it was frequently recommended that such sewers should be made yet larger.

One plea often urged in justification of the extravagant sizes of the old drainage works, even for lines of streets in which but little extension could be reasonably expected was, that they were made so large to meet an assumed probable extension of the population. Such outlays are open to the objection, that immediate and certain levies ought not to be made, upon the present population, to provide for contingencies altogether remote and uncertain. It is overlooked in such expensive provisions, that the reduced rates at which improved works may be constructed, as compared with former defective works, will pay for their removal, within very short periods. Further, it is presumptuous to say that no improvement can be reasonably expected upon existing works, and that they will for ever be the most eligible. Moreover the plea cannot be sustained, even as regards the future, for reason has been generally found for believing that the same lines of sewer would admit of considerable additional heads of water without any increase of size whatsoever.

The provision of extra capacity for such purposes has, however, been frequently made on the assumption, that the increased area required would be proportional to the population, whereas it appeared that an additional head causes, by the increased velocity, the discharge of the additional quantity through the same sized sewer; an effect not then understood, but which was displayed in the trial works. It would be in exceptional cases only that the drainage area would be increased with increase of population.

Neither is the formation of a *whole* system of sewers of extraordinary sizes justifiable on the pretext of their being required on the occurrence of extraordinary storm-waters.

In many cases an increase in the number of the higher branch lines may ultimately necessitate an increased size in the valley lines; but in respect to all the branch lines it may be concluded that the concentration and economy of the ordinary flow, and the most rapid and complete daily sweep of the sewers preponderates in importance over the inconvenience occasioned by extraordinary storms, occuring at intervals of many years, and sometimes only at intervals of generations, such as the storm which fell upon parts of the metropolis in 1846, of four inches in the hour.

Various formulæ were presented to the Commissioners for inquiring into the means of improving the Health of Towns, as furnishing the means of obtaining greater certainty in the construction of town sewers, and plans for the sanitary improvement of large town districts were prepared upon those formulæ; but the sewers thus designed were still so large, and consequently so very expensive, as to offer very formidable obstructions to the extensive voluntary adoption of works of sanitary improvement. These plans were apparently thought repugnant to common and empirical observation of natural outfalls of the nature above referred to, and therefore it was found necessary that trial works should be instituted for the better determination of the proper sizes. The chief results of these trials, made with the smaller and more manageable channels for the removal of sewage or drainage water, have been already described in the evidence cited (p. 37).

In respect to the larger channels, the branch and main sewers, there occur elements not ascertainable by any readily manageable trial works;—such could be determined only by observation, from an ascertained rain-fall upon a given town area, how much did really reach the outfall, and within what time.

To test compendiously the statements as to the alleged necessity of such large sizes, for the removal of varying quantities of storm-water, observations were directed to the flows of water at the outfalls from large districts. after rain. The following portions of an examination of Mr. Roe exemplify the course and results of these investigations:—

"Have you carried on any set of practical observations as to the flow of sewers of different sizes and capacities under different circumstances?—Yes, I have. Ever since I have been in the service of the Commissioners of Sewers for the Holborn and Finsbury divisions, I have carried on observations as to the velocities of water in the river Fleet sewer; subsequently I have, at Mr. Chadwick's suggestion, extended the observations to branch and collateral sewers of different descriptions.

"Can you furnish the result of these observations, or tables founded upon them?—I have begun to form tables, which I hope to live to complete.

"What area is drained by the river Fleet?—About 4,400 acres, of which 1,888 acres are covered, or town area, and 2,512 acres uncovered, or rural area.

"What is the capacity of the river Fleet sewer, and what its inclination?—The sewer is 12 feet high and 12 feet wide, with a sectional area of 120 feet in the largest part in the Holborn and Finsbury divisions; but the capacity of the whole line varies generally according to the quantity of surface drained by each portion. With regard to its inclination, it varies from 1 inch in 100 feet to 1 inch in 2 feet, whilst some portions are on a level.

"What is the sum of the capacities of all the sewers that fall into it?—About 550 feet.

"What is their number?—Sixty, that are called sewers.

"Then the capacity of the main would be as about 1 to 4 of the capacity of the sewers, of which it is the general outlet?—Yes.

"Can you furnish an approximation to the average inclination of the sewers which fall into the Fleet?—In most instances they vary; some of them are a quarter of an inch in 10 feet, others are 3 inches in 10 feet.

"Suppose that every house within the district had a drain of 9-inch diameter, what proportion would the sum of the capacities of the house-drains bear to the sum of the capacities of all the sewers?—About 16 to 1.

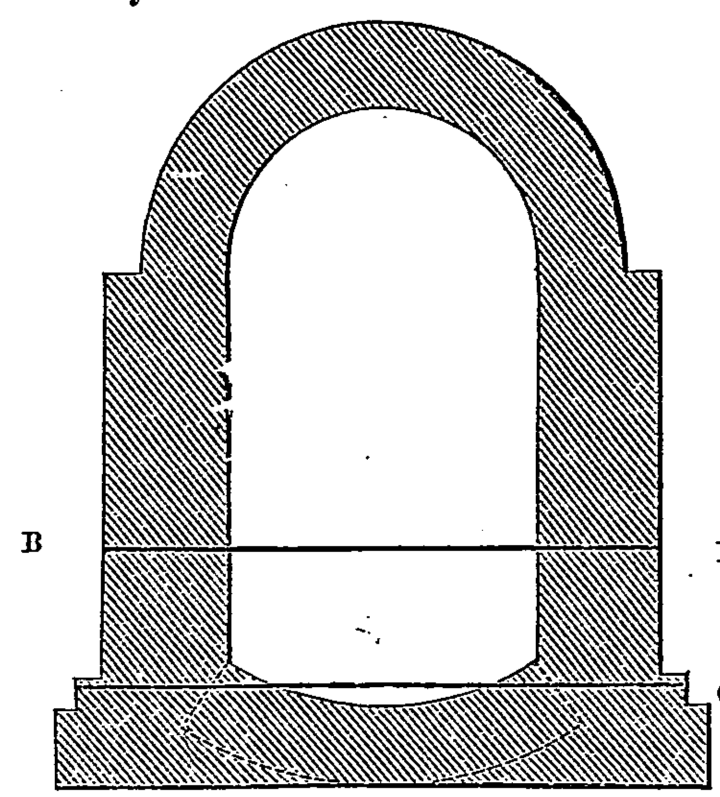
"And to the capacity of the main outfall?—About 75 to 1."

"Engineers and theoretical writers have set forth various formulæ as to the flow of water; and in the Second Report of the Health of Towns Commission there are some tables, by Mr. Hawksley, on the capacity of sewers required for various areas of drainage; how do you find those tables to agree with your actual measure?—Taking the table No. 1., I find that the sizes recommended for sewers to drain certain portions of land are larger than the actual requirements; for instance, the quantity of acres that a cylindrical sewer 48 inches in diameter is, by the table, allowed to drain, when the inclination is 1 in 240, is 47; whereas in practice it is found that such a sewer, with that inclination, drains more than 100 acres of town area at a similar fall of rain to that on which the table is formed. Again, a sewer, with a similar inclination, to drain 129 acres of town area, should (by the table) be of the capacity of about 28 feet; but in the great storm of August 1846, the water from 215 acres of town area, and 1,785 acres of rural district, occupied only 30½ feet of the superficial area of a sewer with that inclination. With respect to larger sizes, the table shows that, at an inclination of 1 in 480, a sewer to drain 329 acres of town area should have a capacity of about 78 feet: whereas, in a sewer with a similar inclination, the area occupied in the storm of 1844 was only 79 feet; and to this sewer there drained 1,181 acres of town area, and 2,656 acres of rural district."

In the formation of the tables for showing the proper size of sewers, it has usually been assumed that a certain large proportion of the rain falling upon a town area will flow into the sewers as quickly as it falls, and that the channels for its conveyance ought to be large enough to carry that quantity away, supposing it all to enter at the head. Mr. Roe finds from long continued observations that a very much smaller part of the rain runs off into the sewers in the same time than has been assumed, (*i. e.*, that very heavy falls of rain are much shorter in continuance than the floods they occasion), and that sewers receiving along their course the confluence of many smaller channels will convey away far more water than if it all entered at the head. He consequently finds that sewers of much smaller section than the usual tables indicate are amply sufficient, and therefore that the use of such tables, or of the formulæ on which they are constructed, has led to large unnecessary expenditure.

The observations, already referred to, as having been carefully conducted at Earl-street by Mr. Lovick, of the outfall drainage of 1,200 houses, included the discharge of storm-waters from 43 acres of paved or covered surface, afforded similar results, as to the wide variation between the sewers provided up to the time of the investigation, and the actual

sizes practically needed. The upper line B, of the following cross section, marks the greatest height to which the storm-water rose at any one time:—



Since Mr. Roe gave the evidence already cited, he has been compelled by illness to resign his office of chief surveyor to the Metropolitan Commission of Sewers; but he has since his retirement, and during his convalescence, occupied himself in completing for the Board a table of dimensions of sewers, founded upon his observations, in the Holborn and Finsbury district of the metropolis, of branch as well as main lines of sewers: observations the most extensive of any which have yet been made. The runs of water through the smaller-sized pipes are corroborated by the results of trial works, promoted in pursuance of the investigations directed by the Metropolitan Sanitary Commission.

The discrepancies of the formulæ adopted by various eminent authorities for calculating the run of water through pipes are well known. Some mathematicians appear to have deduced their constants from experiments on a scale so small as could be tried in a room, and to have assumed that empirical formulæ so obtained were of universal application; but the results of such calculations are frequently at variance with fact, and with each other. And correct though certain formulæ may be, for determining the discharges of water through simple pipes or channels, under certain conditions, it is quite certain, from all the most recent and careful investigations, that the ever-varying conditions connected with the complete drainage of a town or district renders the application of any of the formulæ hitherto used not merely impracticable, but productive of serious constructive error. The objections to the use of all the tables prepared from such formulæ for determining the sizes of sewers were stated in evidence before the Metropolitan Sanitary Commission (*vide* Appendix to the First Report, p. 320.) Their entire inapplicability for this purpose is strikingly confirmed by Mr. Roe's table, founded upon the only observations of considerable extent, in the sewers themselves, which are known to have been yet made; and the circumstances of the flow in the larger sizes, and of most extensive lines of sewers, are such as could be corroborated by no trial works obtainable with any available means, or within reasonable time and cost.

The size of a stream which would be produced by a given fall of rain upon a given area admits of calculation, assuming that all or a given proportion of the water arrives at the drain at a given rate; but it would appear, that, notwithstanding the enormous expensiveness of drainage works, persons directing the outlay had never determined by actual observation the greatest rate at which the water did really run off, and consequently could not know of what size drains should be made.

The proportion of the flow which actually reaches the sewers differs greatly under different circumstances of season, soil, and surface, and especially of different rates of rain-fall in a given time. In long-continued rains, and in heavy storms, for which the table is calculated, a much larger proportion reaches the sewers than on ordinary occasions, the greater flow from the covered portion of the surface usually having time to pass away before the rain falling on an absorbent surface of garden, meadow, or arable land, reaches the sewer.

The Rev. J. Challis, in his report on hydrostatics and hydraulics to the British Association, remarks, that the latter department of science is in an extremely imperfect state, and that "the motion of fluids in pipes and vessels has not been treated with any success, except in the cases in which the condition of steadiness is fulfilled;" that is to say, under circumstances of much less complication than in the case of flow through sewers.

In respect to the uncovered portions of area, it was frequently found, that after even considerable rain-falls of short duration in summer, not any arrived at the outfall, the whole being absorbed. In the course of the official examinations, when the sizes of capillaries for land-drains were attempted to be

deduced, from the facts admitted in respect to the observed flows at the outfall, similar discrepancies were found to those displayed in the graduation of sizes for town drainage. It is necessary, therefore, to guard Local Boards and their officers, with reference to special and complicated works of town drainage, against the errors that would necessarily be committed from the empirical use of formulæ which at the best can only be safely applied to some isolated and normal circumstances of velocity and discharge. The hypothetical dogmas founded upon a display of algebraic signs and quantities, cannot always be called in question by the members of Local Boards; the results of actual experience in such matters, upon a large scale, are therefore presented in a much more intelligible form for their guidance.

The following is Mr. Roe's Table, and his account of its formation:—

TABLE showing the Quantity of Covered Surface from which Circular Sewers (with Junctions properly connected) will convey away the Water coming from a Fall of Rain of 1 inch in the Hour, with House Drainage, as ascertained in the Holborn and Finsbury Divisions.

	DIAMETER OF PIPES AND SEWERS IN INCHES.											
	24.	30.	36.	48.	60.	72.	84.	96.	108.	120.	132.	144.
	acres.	acres.	acres.	acres.	acres.	acres.	acres.	acres.	acres.	acres.	acres.	acres.
Level -	38¾	67¼	120	277	570	1,020	1,725	2,850	4,125	5,825	7,800	10,100
¼ inch in 10 feet, or 1 in 480	43	75	135	308	630	1,117	1,925	3,025	4,425	6,250	8,300	10,750
½ inch in 10 feet, or 1 in 240	50	87	155	355	735	1,318	2,225	3,500	5,100	7,175	9,550	12,400
¾ inch in 10 feet, or 1 in 160	63	113	203	460	950	1,692	2,875	4,500	6,575	9,250	12,300	15,950
1 inch in 10 feet, or 1 in 120	78	143	257	590	1,200	2,180	3,700	5,825	7,850	11,050	14,700	19,085
1½ inch in 10 feet, or 1 in 80	90	165	295	670	1,385	2,486	4,225	6,625				
2 inches in 10 feet, or 1 in 60	115	182	318	730	1,500	2,675	4,550	7,125				

"The table is formed from results obtained from observations extending over a period of 20 years in the Holborn and Finsbury divisions.

"In some instances the observations were carried on during the whole period of heavy rains, being commenced as each storm began, and continued until the effect had ceased in the sewers, the depth of water being taken every five minutes, and the velocity of the current repeatedly noted at every depth.

"In some instances the observations were continued day and night for several months in different years, and in others they were conducted day and night for a period of two years; rain-gauges being kept to ascertain the depth of rain that fell.

"The particulars from which the table is compiled fill upwards of 100 memorandum books.

"The first saving which these observations enabled me to make was about 4,000*l.*, by lessening the size of a proposed portion of main line, by which a reduction of two guineas per foot lineal was effected in a length of nearly 2,000 feet. In other sewers of smaller size, savings were effected to the amount of several thousands per annum for many years.

"In 1843, I was called upon to report on the best means of saving the town of Derby from the disastrous effects of floods.

"It was from the knowledge obtained during the course of these observations, that I was enabled to suggest the size of the sewers which would convey the flood-water of the Markeaton-brook, the overflowing of which shortly before had not only caused damage to the amount of many thousand pounds sterling, but also loss of life. From the time of the completion of the sewer to this date, it has answered every expectation, no flooding having been complained of, although in August 1846, more rain fell in a short space of time than I find on record at any other period.

"This knowledge also enabled me to judge of the size required for a main line of sewer in the town of Birmingham some years since, and which has also answered every requirement.

"The necessity of carefully forming the sewers, so that no obstruction to the passage of the water may obtain, cannot be too strongly impressed on the minds of all connected with such works.

"At the head of the table I have named, 'junctions properly connected,' nor will the respective sewers drain the area stated, unless this important matter be duly attended to.

"Every junction, whether of sewer or drain, should enter by a curve of sufficient radius. All turns in the sewers should form true curves, and as, even in these, there will be more friction than in the straight line, a small addition should at curved points be made to the inclination of the sewer. I may mention a case or two in illustration. In 1844, a great quantity of rain fell in a short space of time, over-charging a first size sewer and flooding much property. On examination, it was found that the turns in the sewers were nearly at right angles, and also that all the collateral sewers and drains came in at right angles. The facts and suggested remedy were reported to the Holborn and Finsbury Commissioners, and directions given by them to carry out the works. The turns and junctions were formed in curves of 30 feet radius, and curved cast-iron mouths put to the gully-shoots and drains; the result was, that although in 1846, a greater quantity of rain fell in the same space of time than in 1844, no flooding occurred, and since then the area draining to this sewer has been very much extended without inconvenience.

"In another case flooding was found to proceed from a turn at right angles in a main line of sewer. This was remedied by a curve of 60 feet radius, when it was found that the velocity of current was increased from 122 (as it was in the angle part) to 208 (in the curved part) per minute, with the same depth of water.

"In the winter season, on meadow ground 82 acres in area, having a clay subsoil, 3 feet per acre per minute was the greatest quantity that came at one time from a fall of rain of half an inch in depth, and this amount did not reach the sewer until three quarters of an hour after the rain had ceased.

"From similar ground during the summer, when a greater fall of rain took place, no water ran off the surface, and that which percolated to the land-drains did not reach the sewer until after the greatest flow from the streets and houses had passed away.

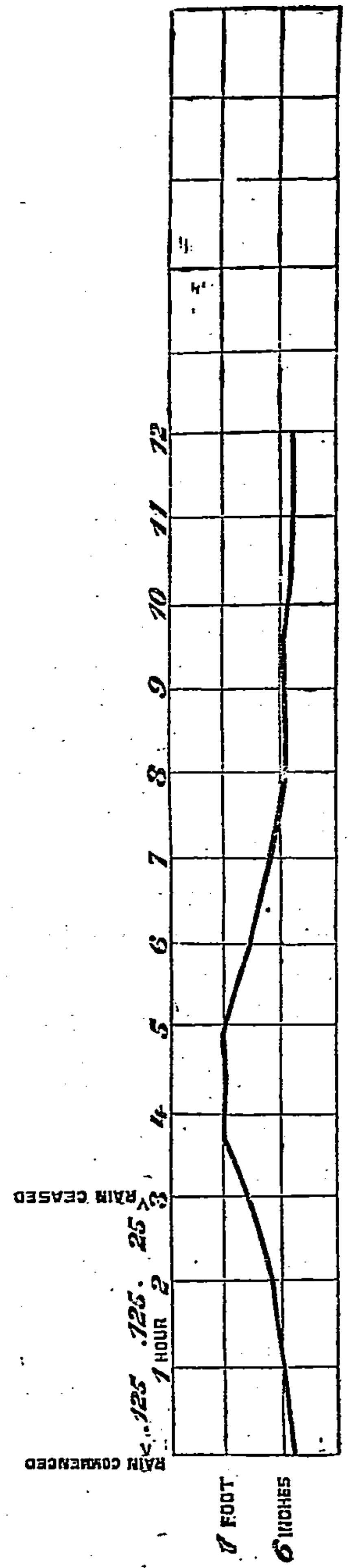
"In applying the table to localities where the inclination of the surface is greater than that of the Holborn and Finsbury divisions, a modification of the sizes of sewers will be required; for instance, in one case that came under my notice, where the general inclination of the surface of the streets was about 1 in 20, the greatest flow of water from a thunder-storm came to the sewer at the rate of one third more than it did to a sewer draining a similar fall of rain from an area with a general surface inclination of 1 in 132."

In examining this table, two points of error must be guarded against, into which the ordinary calculations would lead, and which constitute the striking difference between the results here noted, and those which have been hitherto put forward for guidance; namely, the error of calculating the discharges obtained only from pipes running full at the head; and the error of assuming, without observation, that the given quantity of rain falling in a certain time would be discharged within the same period.

The effect of junctions on the line of sewer constitutes a most material difference in the discharge. The experiments and observations show, that with a pipe laid at an inclination of 1 in 60, with junctions along its line, the capacity of discharge is upwards of three times greater than if the flow were merely from a full head; and in the larger sizes it will be found that the quantity accumulated increases to upwards of eight times that which would be discharged if received only from a full head.

On the question of the period of discharge of a given quantity of rain, Mr. Roe gives the following illustrative diagrams, from actual observations :—

No. 1.



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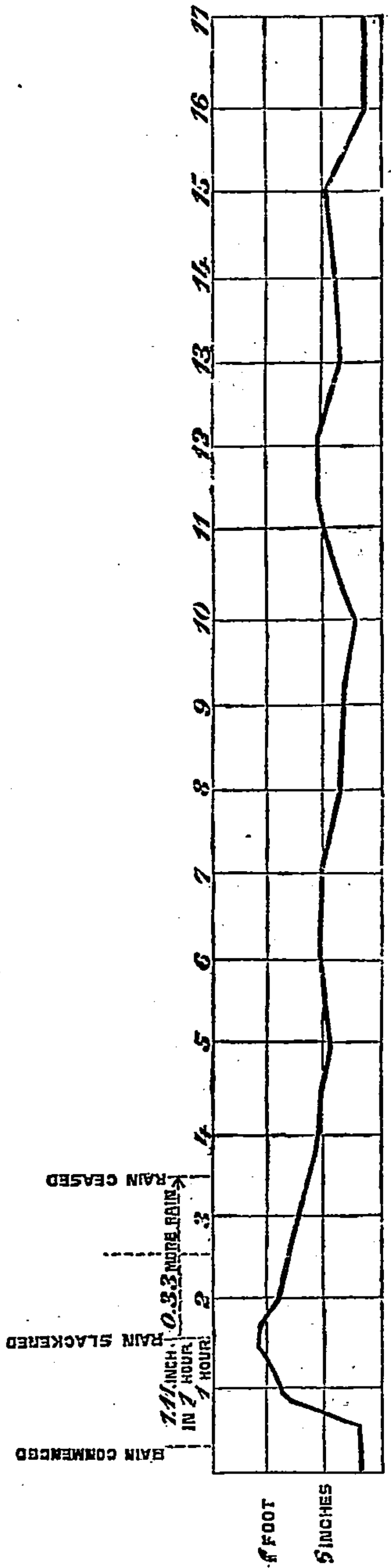


From the first, it will be observed that a rain-fall of half an inch in 3 hours took 12 hours in discharge, that is to say, 12 hours elapsed from the commencement of the rain, before the flow in the sewer resumed its ordinary level. In the second case, a rain-fall of 1·11 inch in about an hour, with an addition of 0·33 in the next two hours, being nearly an inch and a half in 3 hours, occupied in discharge 15¾ hours from the commencement of the rain.

It is desirable to point out that the conditions of drainage are so various that no table of sizes of sewers can be used empirically for all cases; but the conditions being given under which a table is formed, it may at all times be adopted as a valuable guide, if the modifications to suit the varying circumstances are carefully and judiciously considered, with the aid of skill and experience.

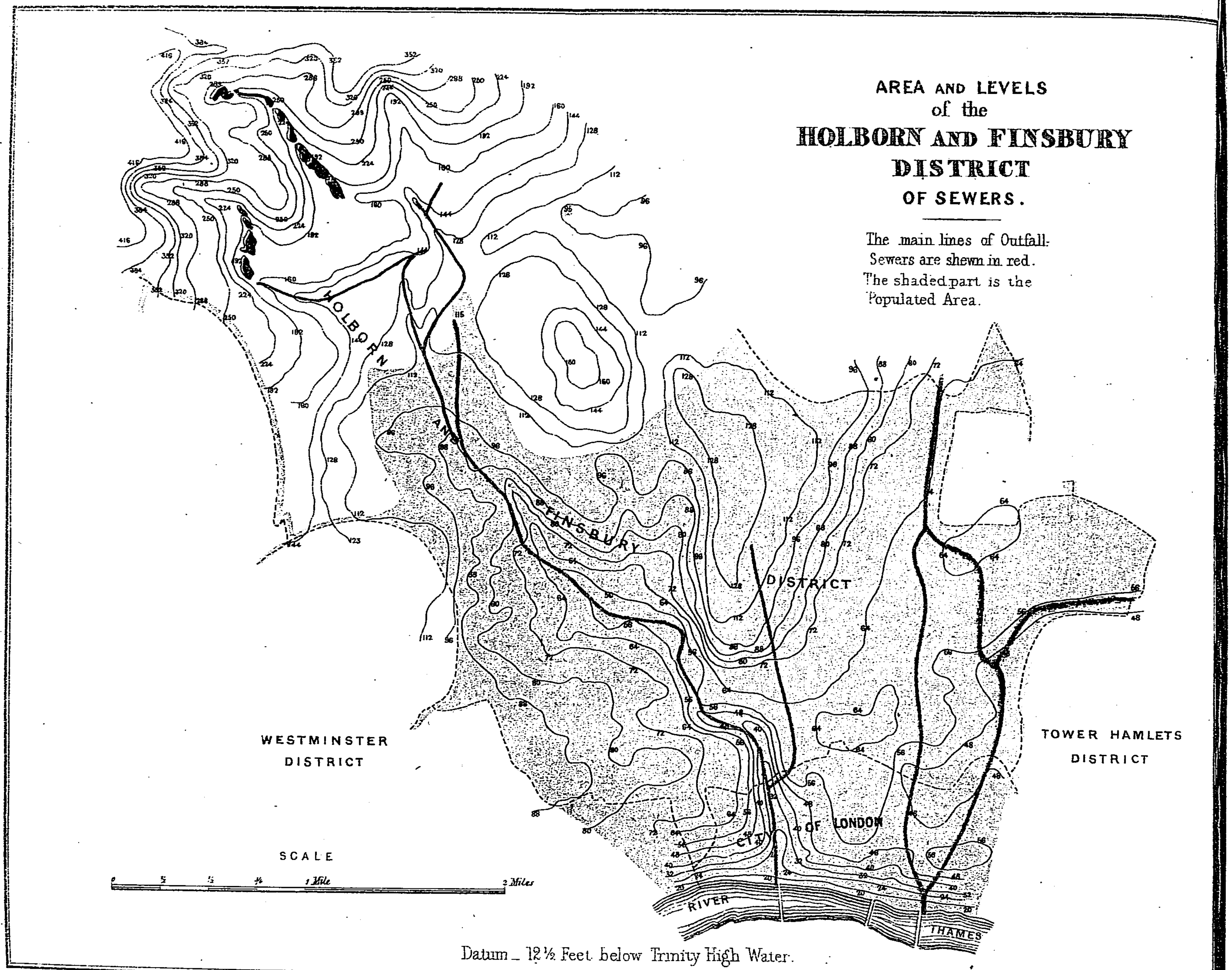
The following will be points for consideration in the application of the table here given to different cases. The table is formed upon the calculation of an inch fall of rain in the hour. It is only in thunder-storms, occurring at distant intervals, that this amount of rain-fall takes place in the southern parts of England; but where greater falls are of more frequent occurrence, corresponding allowance may be made in the sizes of the sewers.

It is true that instances are on record in the metropolis of considerably greater falls of rain within the hour than that upon which the table is calculated, but it would not be judicious to incur a greatly increased cost throughout the whole system of drainage, and risk of its efficiency for ordinary use, to avoid the inconvenience of an hour or two, which will only occur at intervals of many years. At the same time it should be stated, that a margin has been left, even in calculating for an inch of rain, and the pressures which would occur in the sewers when fully charged would compel a greatly increased flow before any flooding could occur.

The form, surface inclinations, and condition of the area, will be material points also for the modification of sizes.

Annexed is a sketch of the contours of the Holborn and Finsbury district, where the observations have been conducted which form the basis of the table.

The general inclinations of the surface, and of the valley lines are shown, the form of the district, and the proportion of covered and of rural area. This will serve for guidance in the use of the table for other places. If the district or part of a district



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under consideration is compact in form, has considerable inclination, and is mostly covered with houses, the size of the outfall must be proportionately increased, as the rain-fall would flow towards it the more rapidly, unless the inclination which can be given to the outfall or receiving sewer would compensate for the difference.

On the other hand, if the area is lengthened and distant, with little inclination towards the main, and there is a considerable portion of rural area, the conveying sewer may be proportionately less. In such cases the flow from the nearer portion of the district will frequently have been discharged before that from the distant area will have reached the main, and at all times the rain-fall on the rural portion will be proportionately longer in reaching the sewers.

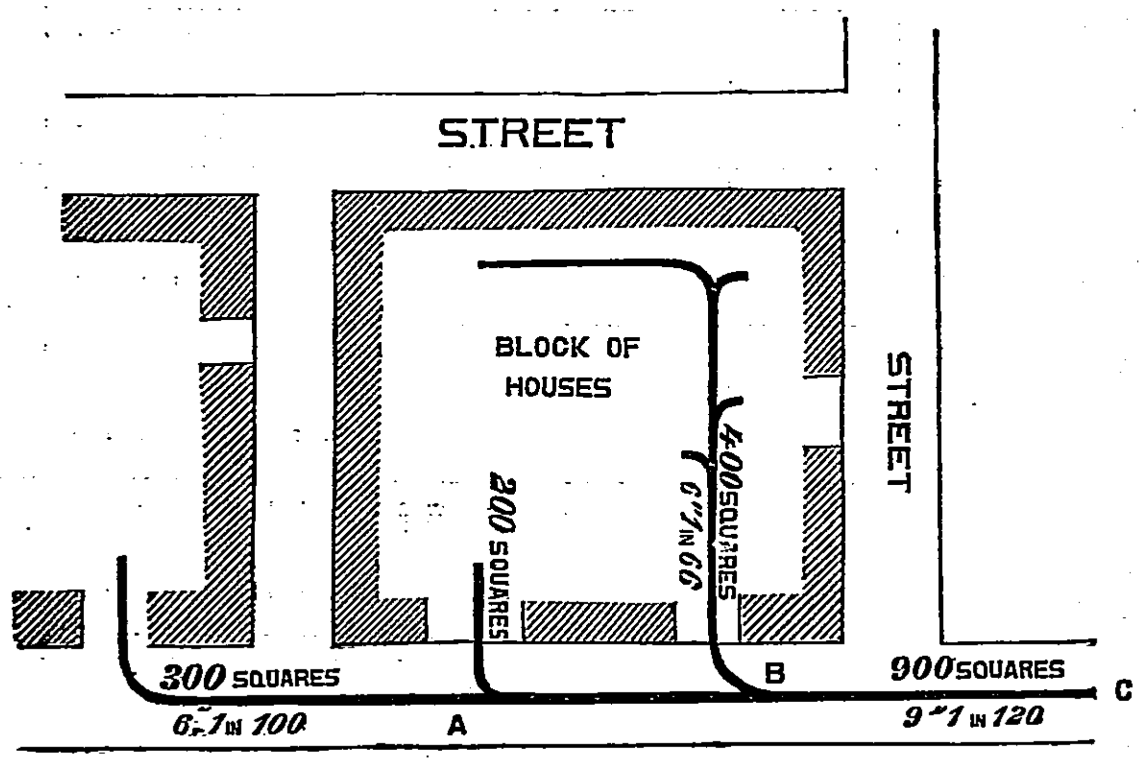
It should be observed that although the actual sizes given in the preceding table would more than suffice for the drainage of the areas stated, with the houses thereon, yet in relation to the smaller sizes, for the drainage of courts and collections of houses, some modifications will be found necessary. In these cases, many of the reasons alluded to, which are seen to operate in great reduction of size of sewer for larger areas, and for space from which several connexions would be formed, more or less distant, will not be in action. The rain-fall from the smaller spaces will flow more immediately to the drains, and their capacity must be equal to its discharge with corresponding suddenness. The pipes themselves, moreover, are often not of the full sizes which they are stated to be, and their greatest effect is not obtained from unevenness of form. The risk of carelessness in laying and jointing is greater also in the smaller sizes, where it is of the most importance, and operates still further in reducing the available capacity of the pipes. These points have so far influenced the practice that 3-inch tubes have scarcely been used hitherto, except for branch house-drains.

For these reasons it is considered advisable to admit of greater margin in the calculation of sizes, for this purpose; and the following separate table has been prepared by Mr. Roe for special application to house and court drainage:—

TABLE showing the SIZE and INCLINATION of MAIN HOUSE-DRAINS for given Surfaces, and the Number of Houses of either Rate thereon, calculated from Mr. Roe's Table for a Fall of Rain of 2 inches in the Hour, as obtaining in the Holborn and Finsbury Divisions.

Surface occupied.		Number of Houses of either rate, either of which may respectively be drained.				Diameter and Inclination of Tubes.									
Acres.	Squares of 100 feet.	1st.	2d.	3d.	4th.	3-inch.	4-inch.	5-inch.	6-inch.	7-inch.	8-inch.	9-inch.	12-inch.	15-inch.	18-inch.
$\frac{1}{8}$	54	1	2	3	4	1 in 120									
$\frac{1}{4}$	112	2	4	6	9	„ 20	1 in 120								
$\frac{7}{16}$	195	3	7	10	15	. .	„ 40								
$\frac{1}{2}$	224	5	8	13	18	. .	„ 30	1 in 80							
$\frac{6}{10}$	265	5	9	15	21	. .	„ 20	„ 60							
1	448	10	15	26	36	. .	. .	„ 20	1 in 60						
$1\frac{1}{5}$	528	11	17	29	40	. .	. .	. .	„ 40	1 in 120					
$1\frac{1}{2}$	648	15	23	39	54	. .	. .	. .	„ 20	„ 60	1 in 120				
$1\frac{4}{5}$	814	19	28	49	67	. .	. .	. .	. .	. .	„ 80				
$2\frac{1}{10}$	912	21	32	55	76	. .	. .	. .	. .	. .	„ 60	1 in 120			
$2\frac{1}{2}$	1,094	25	38	65	90	. .	. .	. .	. .	. .	. .	„ 80			
$2\frac{3}{4}$	1,200	27	42	71	99	. .	. .	. .	. .	. .	. .	„ 60			
$4\frac{1}{2}$	1,970	45	68	117	162	. .	. .	. .	. .	. .	. .	. .	1 in 120		
$5\frac{3}{10}$	2,308	52	79	136	189	. .	. .	. .	. .	. .	. .	. .	„ 80		
$5\frac{4}{5}$	2,534	59	88	150	208	. .	. .	. .	. .	. .	. .	. .	„ 60	1 in 240	
$7\frac{4}{5}$	3,432	79	118	205	284	. .	. .	. .	. .	. .	. .	. .	. .	„ 120	
9	3,976	90	135	234	324	. .	. .	. .	. .	. .	. .	. .	. .	„ 80	
10	4,404	101	152	263	364	. .	. .	. .	. .	. .	. .	. .	. .	„ 60	1 in 240
17	7,400	169	253	439	608	. .	. .	. .	. .	. .	. .	. .	. .	. .	„ 120
$19\frac{9}{10}$	8,700	200	300	520	720	. .	. .	. .	. .	. .	. .	. .	. .	. .	„ 80

The following diagram will at once illustrate the use of this table in laying out the detailed drainage of the various blocks of houses*:—



The area shown is supposed to consist of 900 squares laid out in courts, and containing upwards of 50 houses. The fall of the ground, and the relative depths of sewer required, admit that an inclination of 1 in 120 may be given to the line of sewer from B to C, which will receive the drainage of the whole area; and on reference to the table, it is seen that a sectional capacity of pipe of 9 inches diameter is sufficient for the drainage under these conditions. An area of 400 squares will fall into the branch-drain, coming in at B, to which an inclination of 1 in 60 may be given; and the table shows that a pipe of 6 inches diameter will be sufficient for the drainage. Into the line above A, the sewage from 300 squares will fall, and an inclination of 1 in 100 may be obtained; and it is found that a pipe of 6 inches diameter is also required for the drainage. In distributing the inclinations, which a given fall in any continuous length will admit of, it should be borne in mind that it is always desirable to graduate them, so that the utmost inclination which may be practicable should be given to the upper part of the line, where there will be the less current and force of sweep. The drains should always be laid at the greatest inclinations which can be obtained; and this should always be kept in view, therefore, in selecting the sizes from the table.

* The sizes of the drains will require modification according to variations in the area and inclinations of the ground, and the number of houses to be provided for.

From this table it will be perceived, that the sewer formerly proposed as the smallest size admissible for the drainage of a "mansion," viz., 15 inches, would at a fall of 1 in 120, drain 179 of the largest mansions, or 284 of the smallest houses; that a 9-inch drain, (the minimum size prescribed by the Building Act, for the drainage of a single house,) would at the same gradient remove the storm-water from 21 of the largest mansions, or from 76 of the smallest houses; or, at a fall of 1 in 60, would drain nearly 100 of the smallest, or an area of nearly 2¾ acres of covered surface.

An 18-inch sewer, less than that prescribed as the minimum size into which a man might crawl for cleansing, would, at an inclination of 1 in 80, remove the storm-water from nearly 20 acres; and a sewer of 3 feet (less than the minimum size formerly recommended for the smallest street,) would, at the same inclination, remove the drainage from 295 acres.*

* Proofs of the empiricism and want of principle in the construction of works for the objects in question have been afforded as it were by chance. Thus a 6-inch earthenware pipe having been laid down for the drainage of one detached house, the drains of one house after another, as they were built, were joined to the same pipe, until at the end of several years this one 6-inch pipe was, to the surprise both of surveyors and builders, found to be clean, in perfect action, carrying away the drainage of 150 houses, and doing the work for which a sewer might have been provided of sufficient size for the entrance of a man to remove the deposit. In another case a labourer, by a blunder, put down for the outfall of a large block of houses a drain-pipe intended by the architect for a single house, and elicited evidence similar to that obtained by the trial work at Earl-street. Similar illustrations have been obtained accidentally in respect to apparatus for the distribution of water. Thus in some of the northern towns it was the common rule to put in a service-pipe of an inch diameter for the supply of a single house. A pipe of that diameter was led to a single house, and thence continued from one house to another, as new houses were built, until it was found that it served as a main, and supplied perfectly a row of 40 houses. Now a branch-main of three quarters of an inch diameter is found to be ample for the constant supply of courts containing more than 13 houses. (*Vide* Report on the Supply of Water to the Metropolis.) In respect to the larger distributory apparatus, as a temporary make-shift during some repairs, a short length of 7-inch pipe which had been put in at the bottom of a 3-feet stand-pipe for the purpose of emptying it, was used to pass whatever quantity of water it would. To the surprise of the engineer it was found to pass a quantity adequate to the supply of 34,000 houses. Until the late investigations no conception had been formed of the quantity pumped in worse than waste under the intermittent method of distribution—a quantity exceeding the annual rain-fall upon the covered area supplied. Even where the constant supply had been adopted, it appeared to be unknown what was the actual domestic consumption of the population; and it was proved upon inquiries and admeasurements by the Board's Inspectors in various places, that many of the common estimates, presented to Parliamentary committees as scientific truths, were in excess more than double. (*Vide* Report on the Supply of Water to the Metropolis, Appendix III., Report of Dr. Sutherland.) No conception appeared to be

Special Arrangements requisite for the Drainage of low-lying Districts, and Economy of the constant Removal of Sewerage from them by Steam Power.

In the course of the inquiries made under the Public Health Act, in towns already provided with waterworks, it has been proved, that where additional supplies of water were carried into houses unprovided with proper channels for its removal, not only were the foundations of the particular house surcharged with the excess of water, and the walls by absorption rendered more damp, but by the neglect of proper means for removing the surplus water, it became a cause of nuisance to other houses. The

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entertained of the deterioration in the quality of water by its stagnation and exposure in open reservoirs or receptacles in the vicinity of towns, or of floodings from the surface-washings of lands. Many large arrangements for the supply of towns were proposed, on assumptions that they were founded on exact data of hydraulic science, practically applied; whereas, the data, for the most important works, continue in a very loose state. In Italy, for instance, where the measurement of the quantities of water distributed for irrigations has been the subject of dispute for centuries between the government, the distributors, and the owners and occupiers, the consumers throughout the irrigated districts, no completely satisfactory water-meter, or mode of measuring the quantities delivered, has yet been invented. (*Vide* Report of Captain Baird Smith on the Irrigations in Italy.) The institution of varied and adequate trial works for the complete and authentic settlement of a number of such questions of economical arrangement would be of national importance. Many undertakings are in progress at the present moment for which immense outlays are required, with reference to which the state of knowledge as to the strength of materials, is similar to that displayed in the declarations by large majorities of professional men, to the effect that the Crystal Palace could not bear the weight of its visitors, and must give way before the first storm; or to those which rested in such arrangements of materials as have led to fatal catastrophes. For all this want of practical data and real science the public has frequently to pay the penalty of a double and treble expenditure beyond what would have been required had the estimates been formed on exact and proved data. Already, however, examples of contracts taken and works performed within the estimates, have been afforded by means of surveys and other necessary information obtained previously to the commencement of works, under the Public Health Act.

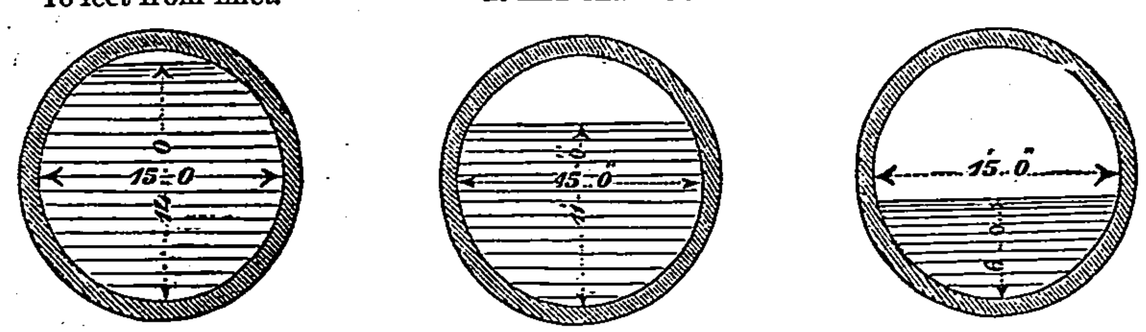
It accounts, in part for the singular want of agreement among the opinions and reports put forth, even by persons whose duty it was to understand the subject well, respecting the laws of water currents in open or close channels, to observe, that, as in hydrostatics, some of the phenomena depending on the mere weight and diffused pressure of water appear so extraordinary to persons beginning the study, or imperfectly acquainted with the laws, that such phenomena have been called "hydrostatic paradoxes;" so in hydraulics, some simple consequences of the well-known laws of falling bodies, and of atmospheric pressure, are so unexpected and unintelligible to ordinary conception as to deserve similarly the appellation of "hydraulic paradoxes." One of these last is the fact that a uniform, sufficiently sloping, open channel, which at its top is freely receiving from a reservoir, or a meeting of currents, so much water as completely to fill its mouth, can yet receive into its stream lower down, large additional quantities of water through lateral inlets, and will then discharge from its bottom opening, which is of the same size as the top opening, even several times as much water as entered at the top. Another of these "paradoxes" is the fact, that if a common funnel or a short piece of tube with a gaping mouth be held under a water-cock, and as much water be allowed to fall into it as to maintain it nearly full, and if then a pipe of the same diameter as the lower outlet of the funnel, or piece of tube be joined to it so as to lengthen it below, the quantity of water passing through, instead of being lessened by the friction of the additional downward pipe, as happens when an addition is made of horizontal pipe, will be increased in a proportion to the length of pipe added, until that length reach a level of about 34 feet below that of the mouth of the apparatus. A water column of 34 feet has a pressure nearly that of the atmosphere.—The first of these remarkable facts is a simple consequence of the law known to everybody, that a body falling freely is always increasing its speed, whether its course be directly down, as of an apple from a tree, with increase of speed of 32 feet per second, or be oblique, as when a railway carriage carelessly left loose at the top of a steep slope gets away, and soon has a velocity which dashes it to pieces against any obstacle met below (the increasing speed in such a case being proportioned to the steepness of the slope or incline); and whether the descending body be solid, as in the cases just mentioned, or fluid as in the water of a perpendicular cascade, or in that of rapids shooting along sloping portions of a river channel. The phenomenon of the acceleration of a fluid current under the continued influence of gravitation is well shown where a viscid fluid like treacle is poured from a height. A mass at first slow moving, and as bulky as a man's wrist may be seen gradually tapering as it descends to the size of a finger or less, the diminution of size being everywhere exactly proportionate to the increase of speed; and however long the experiment be continued, the tapering cascade retains the same form. Similarly, a water stream, in a sufficiently sloping uniform channel, becomes less bulky as it descends, and as the speed increases; although of course the same quantity of water passes along every portion of the channel; and hence, a larger space, or area of the uniform channel is left unoccupied by the water, as the speed of this increases, and so more room is left for additional streams to enter the channel from around its descending course. Because, however, friction of the water against the sides of the channel increases rapidly, as the speed of the current increases, while the force of gravity tending to accelerate remains the same, a state of equilibrium is soon reached between these opposing forces, after which the stream, however long, goes on uniformly, with speed proportioned to the slope. This is seen in all rivers of uniform current. In the annexed woodcut, are sketched sections at three points of a sloping pipe in which a stream was running and becoming less bulky as the speed increased. The other hydraulic paradox above mentioned, of a common funnel or gaping short piece of pipe, (and in certain cases of water-drains,) being caused, by having an addition of pipe made at the lower opening, to transmit much more water than what fills the mouth, which pipe may be either perpendicular or oblique, is owing to the disturbance of the atmospheric pressure which is acting on all things at the surface of the earth, and therefore on the top and bottom of the column of water in the pipes. It happens thus:—in the cases supposed, the descending stream, if free, would quicken its speed, and become lessened in bulk in its descent, (as already explained above for open channels, or for free descent in the air,) but in a long tube, artificial supplies of water to a closely-occupied town district are commonly nearly equal to a rain-fall upon its surface; consequently, where the neglect to provide proper drains for the removal of the pipe-water is common to blocks of houses, or to the districts occupied by the poorest classes, the waste water thus introduced amounts to a daily rain-fall, which, from its constant recurrence, keeps the premises always damp, and aggravates the evil of stagnant flood-water at the periods when the rain-fall is excessive. (*Vide Report on the Supply of Water to*

having openings only at the top and bottom, and both openings filled with water, the stream cannot lessen its bulk without leaving a vacuum in the tube, which vacuum, the pressure of the atmosphere at the top and bottom tends to prevent. Thus, therefore, the part of the tube below, as well as that above is kept full of water, the weight of which balances or destroys more or less of the upward atmospheric pressure at the lower opening, and lets the undiminished atmospheric pressure above act, as an unopposed force, to urge more water through. If the tube below had its mouth exposed to the air, (that is, were not immersed in water,) and were roomy enough to allow a stream of air to ascend by the sides of the stream of water descending, no increase of water flux through the general tube would be produced by an addition of tube below.

In illustration of the above, may be given the following instance of one trial:—

"*Velocity* and *amount* of water flowing through 235 feet of 15-inch earthenware pipe, temporarily laid at Hitchin, at an inclination of 8 inches in the 235 feet, or, 1 in 352½, an opening being made for the admission of air at the centre of the pipe."

No. 1.	No. 2.	No. 3.
Sectional area of water 10 feet from inlet.	Sectional area of water at mid-channel.	Sectional area of water at outlet.



Water being 14 inches in the pipe.	Water being 11 inches in the pipe.	Water being 6 inches in the pipe.

"The velocity of stream was about 188 feet per minute, and the amount of water discharged 1,025 gallons per minute, or, 1,476,000 gallons in 24 hours.—The gauging of No. 1 section was taken 10 feet from the inlet to secure the fair current of water, the pipe being full at the outer end."

In respect to town drainage, the practice of architects and engineers was to enlarge the area of any main pipe in the proportion of the sectional area of each junction into it; whereas, it was found, by the trial works, that the addition of eight junctions, each of three inches diameter, into a main line of pipe of only four inches diameter so increased the velocity of the stream, that there was no increase of its sectional area.—(Appendix No. 2. to Report on Water Supply; Medworth, p. 191.)

Enormous works have been constructed in neglect of these principles, and at worse than double cost to the public.

the Metropolis, p. 127 to 137.) When the site of a town is undulating, waste water accumulates at the lower levels; for which reason, even if both occupier and owner, from a false notion of pecuniary economy, agreed to bear the excess of dampness themselves, they should be debarred from inflicting the nuisance upon others.

Very numerous instances might be cited from the reports of the superintending inspectors, showing that where court-yards and premises extend laterally along the sides of rising ground, as they do to a very great extent in many districts (the property of the several owners respectively forming steps one below another,) if without proper drainage, not only is the value and durability of each property diminished, but the health and lives of the poor occupiers endangered.*

Since experience has proved that the *smallest* tubular house-drains, which have, in proportion to the flow of water, the most friction, are kept free from deposit without special supplies of water in flushing,—we may be perfectly certain that the larger mains, when due adaptations are made in respect to form, size, material, and inclination, having, in proportion to the run of water, much less friction, will be kept clear by the same, but more concentrated, runs of water. This has also been established by the evidence of actual practice, where there are sufficient natural inclinations for the discharge of the sewage. The end accomplished is in fact *natural* and *constant* flushing, for the prevention of deposit, to supersede *artificial* and *occasional* flushing for its removal.

It frequently occurs in the low-lying river-side districts of towns, particularly in towns on the banks of tidal rivers, where there are no sufficient natural inclinations, or where the outfalls

* In speaking of two of the most unhealthy places in Newcastle-under-Lyme, Mr. Lee says (*Report*, p. 25), "In Friar-street and Church-street, which rise considerably, the privy cesspools are placed successively one above another at the backs of the houses, and there is an offensive drainage from many of them to the premises next below. There has been much fever and cholera there." In the Report on Rotherham and Kimberworth (p. 11), he says, "The privies on Mr. Ward's property are above the roofs of two houses belonging to Mrs. Holland, and occupied by Scott and Pearson. The filth percolates down and under these cottages into Wellgate. The liquid from five piggeries drains the same way. This is another instance of property undrained on a hill-side. I examined the house occupied by Scott, and found his wife just recovering from fever, after being ill between two and three months. I saw night-soil on the floor of the kitchen, and oozing through the wall." These two belong to a large class of cases in which both the owners and occupiers of one property are injured by those of another, and in their turn injure the next below, and yet with a fall which, with proper arrangements, would effect the perfect removal of all refuse.

are below high-water mark, that the flow is interrupted, and the sewer water pent up, until a discharge can be obtained at the fall of the tide.

This is peculiarly injurious, for as the sewage accumulates in these sewers, the foul gases with which they were previously filled is displaced and forced, some into the streets through gully-holes, some into dwellings through house-drains. The nuisance thus occasioned is sometimes felt at a considerable distance from its source; for when the lower part of the sewer is filling, the air may escape at openings from the upper sewers communicating with it. Thus persons at above a mile distance from the sewer have been made aware that the tide was rising, by the extra quantity of foul air forced from the sewers.

As it was the general practice in respect to house-drains not to alter their form, or principle of construction, but to provide mud-traps to be cleared periodically; so in respect to the sewers, where deposit was accumulated, from inordinate size, insufficient inclinations, or interrupted flow, or from any other cause, it was the practice to recommend the removal of refuse by immense flushes of water.

It appears, however, that this practice was founded in the absence of proper estimates of the quantity of water to be removed, and that on the like principles of arrangement on which water is collected, and pumped into a town, and distributed there, it may, and at similar rates of expense, be as constantly pumped out of a town, to be re-distributed where wanted; and that with respect to the cases of interrupted flow by the action of tidal rivers, and the common practice of detaining the sewage during high water, and allowing the deposit to settle and accumulate in the interval, the cheapness of the removal of water by steam power has been overlooked.*

* At the opening of the investigation the general feeling of the majority of engineers appeared to be to treat the rivers as being, of necessity, the only outfalls of all town drainage; and several eminent engineers, at the Metropolitan Sewers Commission, spoke of and against the use of pumping, as opposed to what they called the "natural" method of discharge, without pumping. But on reconsideration, the sanitary consideration prevailed, and the following resolutions were, amongst others, eventually adopted by them unanimously:—"To maintain a continual and unintermitting flow, with the aid of lifts where necessary, in all the sewers along their whole length, by which the evils arising from pent-up sewage, viz., the generation of noxious gases, and the unavoidable formation of deposit in the sewer during its stagnation, may be avoided:" "To construct the sewers at inclinations so proportioned to the volume of fluid to be carried off by each, that the velocity of the current shall keep them clear of deposit, without the need of regular periodical flushing, which experience has shown to be not only troublesome and expensive in its operation, but also very injurious to the sewers and drains in which it is practised."

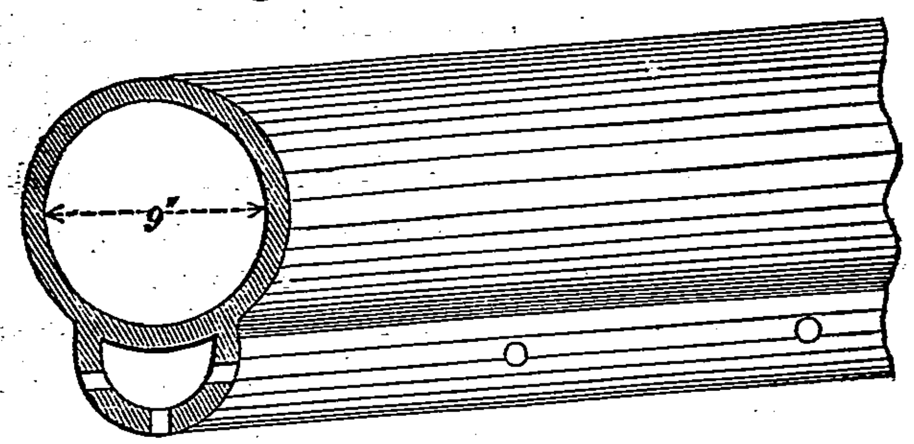
The cost of ensuring a continuous flow in such cases is merely the cost of steam power for giving a continuous lift. The working expense of lifting 30,000 gallons 10 feet high, with a steam-engine of 25-horse power, is only 1*s.*; and with an engine of 180-horse power, less than half that sum, coals being about 12*s.* per ton. (*Vide Report on Water Supply, Appendix* II. p. 25.)

Many extensive fen districts are by steam power kept clear of surplus rain-water, at an expense of from 2*s.* to 5*s.* per acre per annum, including all expenses; and it has been estimated that the expense of pumping out the sewage, as well as the whole rainfall from a difficult district on the Southwark side of the metropolis of 4,000 acres, by a lift 31 feet high, and discharging it at Deptford, would be about 1*s.* per house, or 2*d.* per inhabitant per annum; and little more than twice that sum, if the surplus water were discharged at 12 miles distance, for a work which, as a mere house charge, would be a great economy, by preventing dilapidation from dampness. Moreover the expense of excess in the sizes of sewers and works requisite to contain the sewage impounded during high tide, which might be saved, would of itself be a large set-off against the expense of pumping, and in some cases would exceed that cost; and further, the default of pumping at the outfall, to produce a continuous flow, must be remedied by the expensive alternative of pumping at the other extremity of the works, to supply for the sewers additional quantities of water in sufficient volume to move and flush away the matter deposited and indurated during the time when the discharge at the outfall is intermitted; so that, apart from the sanitary evils and inconvenience from detaining masses of stagnant sewer-water, and decomposing deposit amidst habitations, the continuous discharge of sewage by pumping is, in such cases, the more economical alternative.

By pumping, it is practicable to amend the defects of fall upon any table land, and, if needed, to accelerate any natural fall to the extent to which it may be considered necessary, so as, by properly stationing the pumps, to secure the great desideratum of a good fall throughout every part of the system, and that with any desired current or inclination. With a proper and complete system of combined works of water supply and tubular house-drains, connected with properly-adjusted branch and main sewers, there is, therefore, no exception to the rule that refuse need not, nor should be permitted, to remain underneath or near houses, beneath streets, or near the sites of towns. All might be in a constant state of inoffensive and entire removal at a rate of about three miles an hour, and in a current of such velocity no deposit could remain to accumulate.*

The impermeable and the permeable Lines of Drainage not always coincident.

In the course of the sanitary inquiry it was suggested, that, by means of machine-made pipes, the impermeable and the permeable systems,—the channels for the conveyance of foul or sewer water, and for the removal of spring or plain surface water,—might be united, and put down in the same trenches; in accordance with which suggestion, house-drains were prepared of the following form:—



Sewers were proposed to be constructed on the same principle, of hollow bricks, with perforations in the sides. *vide* p. 94.

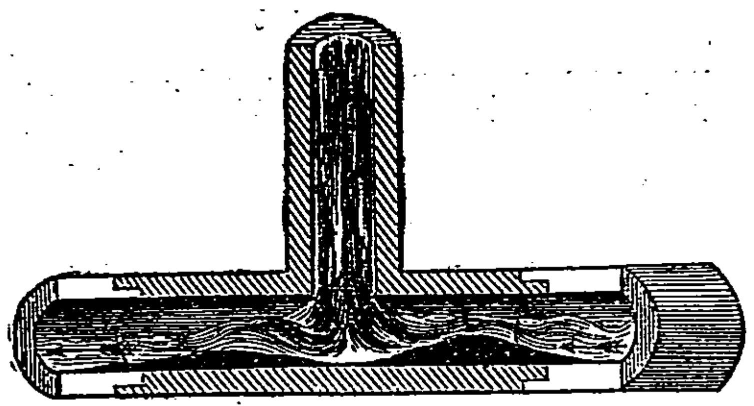
* It is an illustration of the insensibility, as to any existing evils, of those who are most impatient of any new annoyance, (however slight or fanciful,) that the most strenuous opposition was made to the discharge of cesspool matter into the sewers, and thence into the river Thames, and also to flushing of the sewers, on the ground that the pollution of the river would be increased thereby; though the objectors seemed quite insensible to the far greater evils arising from the retention of ordure beneath their houses, and the vast swamp of subterranean filth existing in their sewers, and discharging the products of decomposition into their streets and houses. It is, no doubt, very desirable that the pollution of the river should be reduced to the minimum, though at the best it would be quite unsuitable for drinking, for washing, or other domestic purposes. Again, whilst no objection was made to the pounding up of foul water in the sewers, and the accumulation of deposit there,—both of which practices cause the extensive diffusion of poisonous emanations,—*vide* notes, *ante*, p. 28, and *ante*, p. 45,—the most violent opposition was raised to the formation of small pumping establishments, or sumps for removing the sewage, which could not possibly cause *addition* to the filth,—must have immensely reduced the evaporating surface of sewage water and cesspool matter,—and would have facilitated the removal of that which did and does exist, and that too in a manner far less objectionable than that now practised. When the sewerage is removed properly, it is removed before decomposition can take place, and before it becomes in that state in which it now usually is when removed, and when the act of removal, as commonly performed, is, for the time, a nuisance.—*Vide* pages 80 and 99.

The objections which on consideration prevailed against this mode of construction were chiefly these:—that the conditions requiring the removal of spring or surplus rain-water from land were by no means coincident with those requiring the removal of foul or waste water from houses; that it appeared to be frequently expedient to collect and remove land-spring water at higher and sometimes at lower levels than sewer water; that it did not appear to be frequently necessary that the permeable drains should be laid co-extensively with the impermeable drains, and that it would commonly suffice to lay down the permeable drains much wider apart than the impermeable drains, as the land-drainage of the covered area of a square of houses may frequently be effected by a single line of pipe outside the square; and that the distances of the permeable drains would, moreover, be widely varied by the differences of the nature of the substrata. It is also to be considered that a large portion of the storm-water from the covered area of towns, will, on account of its containing surface-washings of the streets, and of the roofs of houses, be removed with the ordinary sewer-water through the impermeable drains. Moreover, the construction of the present simple pipes is still very imperfect; and the proposed arrangement would have occasioned additional difficulty in placing and jointing, as well as in construction. For which reasons it has not been recommended, (without deciding that there might not be cases in which it would be expedient and practicable,) that the suggested principle of construction should be generally prosecuted. (As to the general conditions of permeable drainage, *vide* Minutes of Information, on the Drainage of Lands forming the Sites of Towns, and Road Drainage.)

The Junctions of Drains and Sewers.

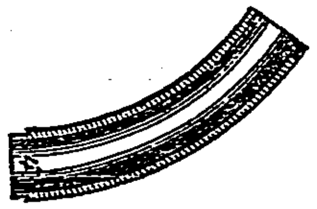
It appeared on examination that the general practice of the engineers and surveyors who designed and executed this class of works, was to make the junctions of sewers, as well as of house-drains, at right angles. Mr. Roe, who greatly improved the shape of the sewers within his district, proved experimentally that when equal quantities of water, with equal falls, in a sewer, were running *direct* at a rate of 90 seconds, an equal discharge required, with a turn at *right angles*, 140 seconds; whilst with a turn or junction in a true *curve* the discharge was effected in 100 seconds. (*Vide Sanitary Report*, 1842, p. 57.)

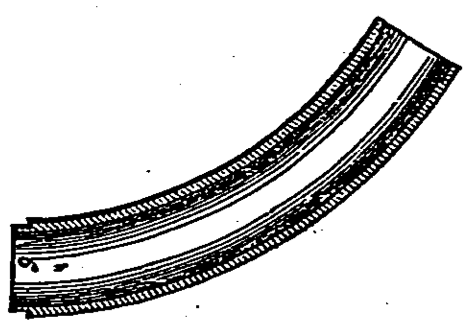
The effect of junctions of house-drains at right angles, whether horizontal or vertical, is greatly to retard the flow, and to cause accumulations. With the drop junction at right angles, the effect of the splashing of soil and refuse is such as that displayed in the following diagram:—

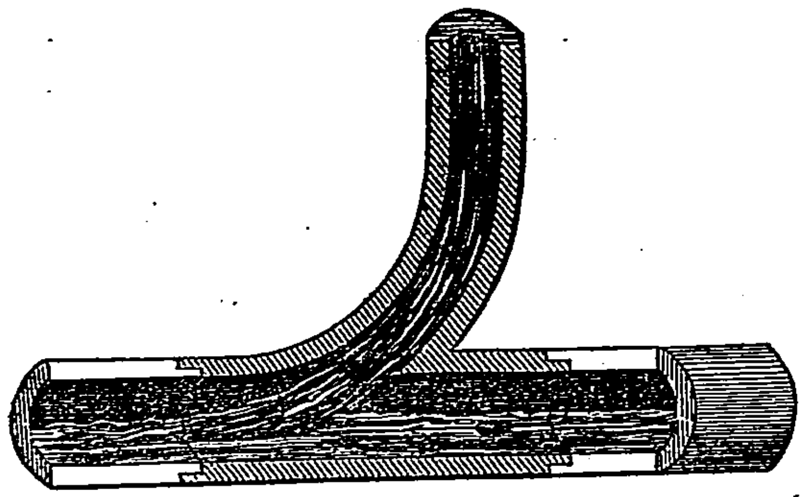


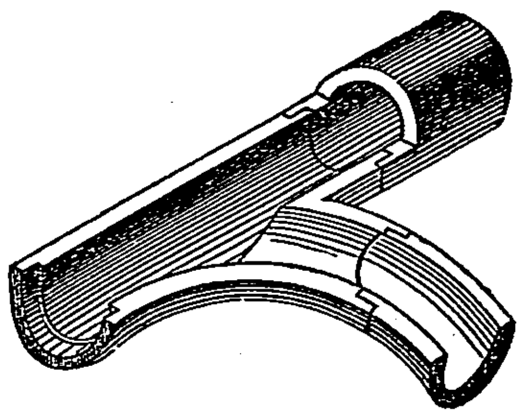
With horizontal junctions similar retardations occur.

The following are eligible curves for the bends of drain-pipes, whether mains or branches:—



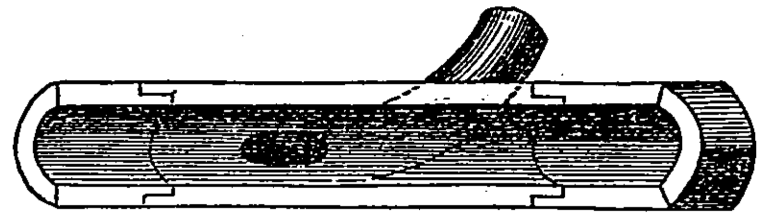




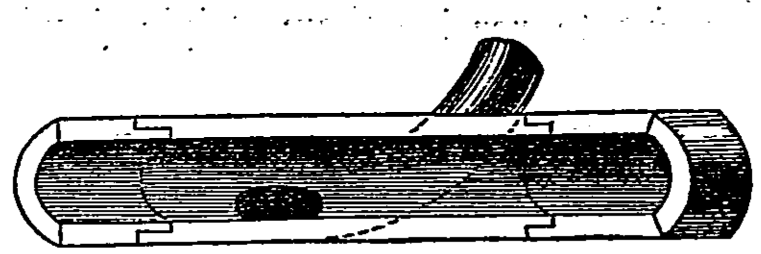


The smaller the flow of water to be conveyed, the more carefully ought the power of the flow or sweep to be economized, for the sake of preventing, or, if formed, of clearing away any deposit. Exactness of workmanship is most important for small pipes which are spread within dwelling-houses; and the arrangements ought then to be most carefully considered, with reference to the entire system:—whereas in practice, they are the least so, because they are left to the most ignorant and incompetent

hands. The construction of tubular pipes has been exceedingly careless. For example, junctions of pipe-drains were often effected at the middle of the side, thus:—

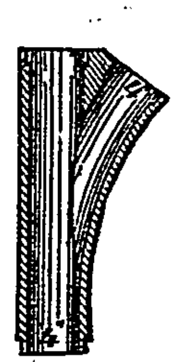


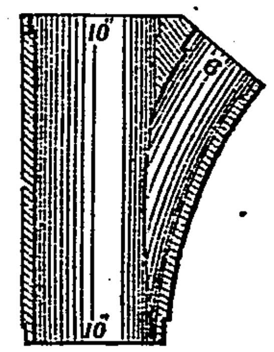
instead of level with the bottom, or bell-mouthed, as in the following diagram:—



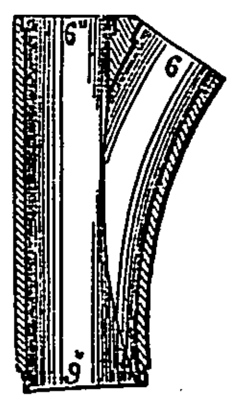
Improved Curved Junctions.

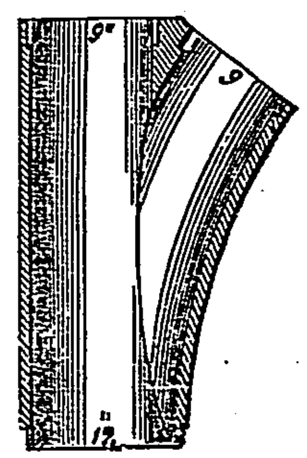
Where the main line can under no circumstances be so full, at the point where the branch would enter, as to require additional space for its reception, a junction of an equal capacity should be used:—



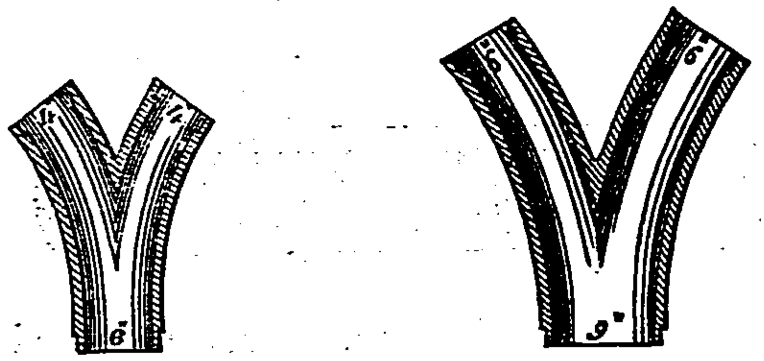


But where additional capacity in the main line would be required to receive any branch, a tapering length should be used:—

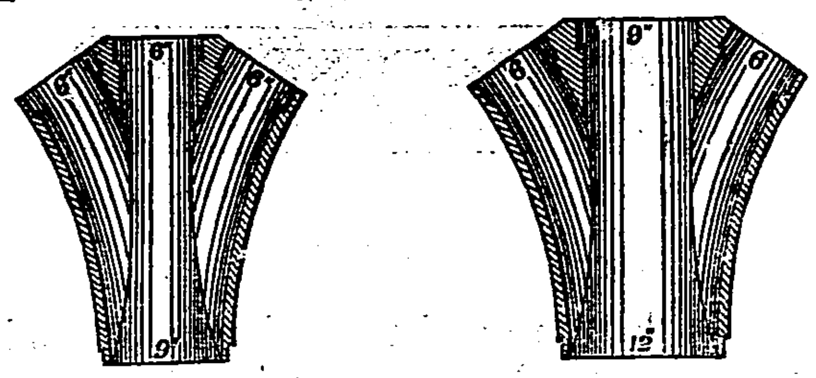




Where two equal drains unite to form the head or commencement of a main, double junctions, as thus, should be used:—

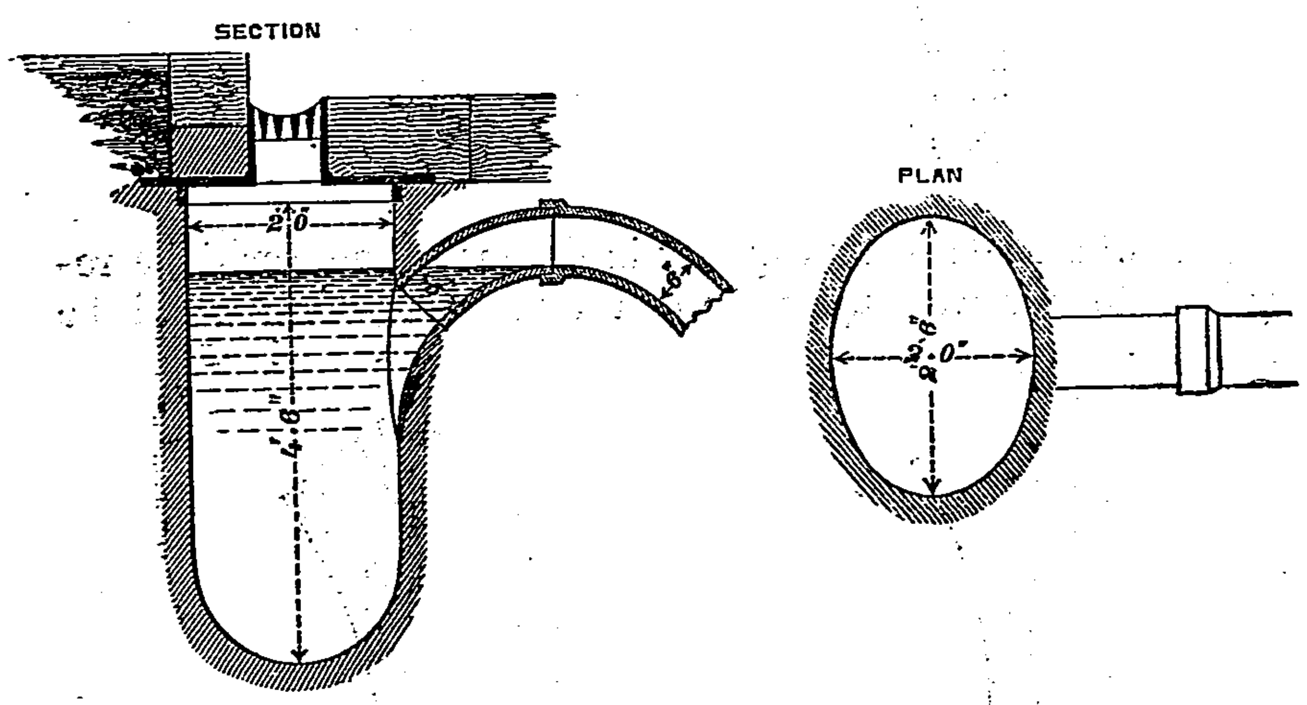


Where opposite branches fall into a main which would require enlargement to receive them, triple junctions should be used:—



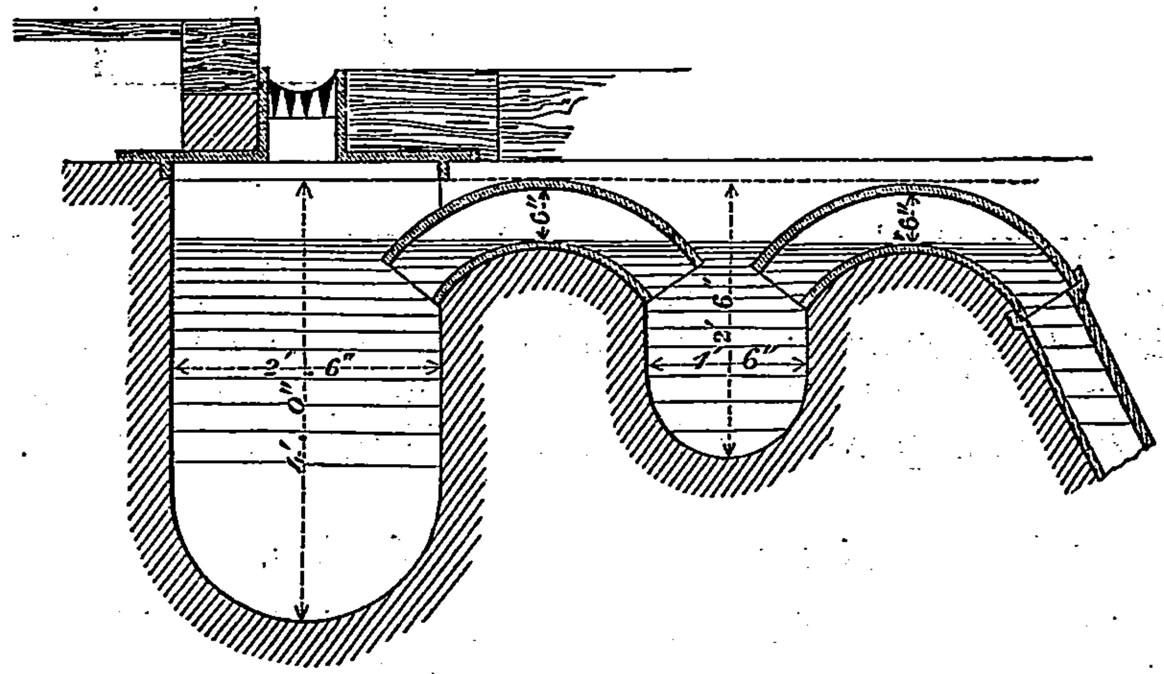
Cesspits for the Detention of Road Detritus.

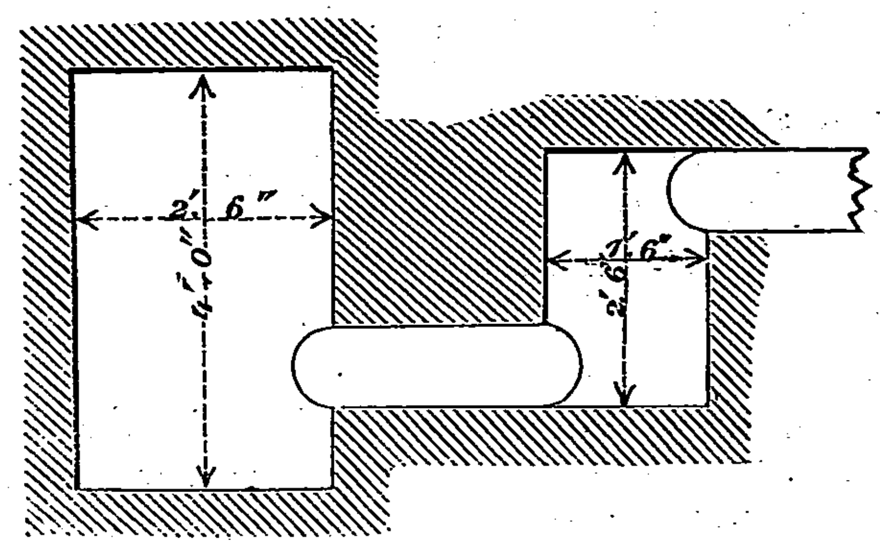
The following is one form of cesspit for arresting street detritus. Of the use of this, with frequent water cleansing, very favourable reports have been made:—



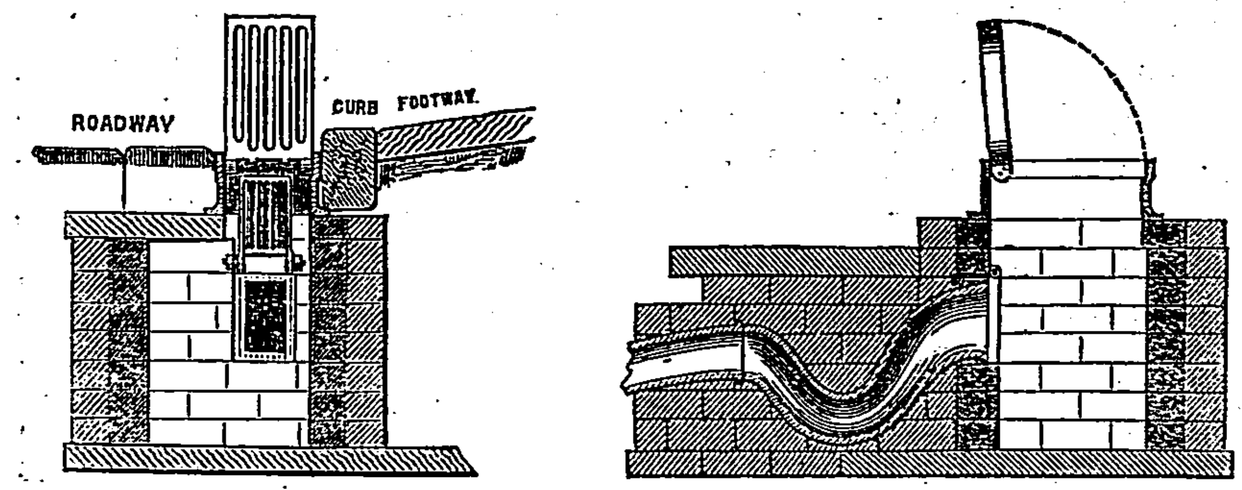
In macadamized roads, the detritu from which so readily concretes that it is most desirable to prevent its entrance into

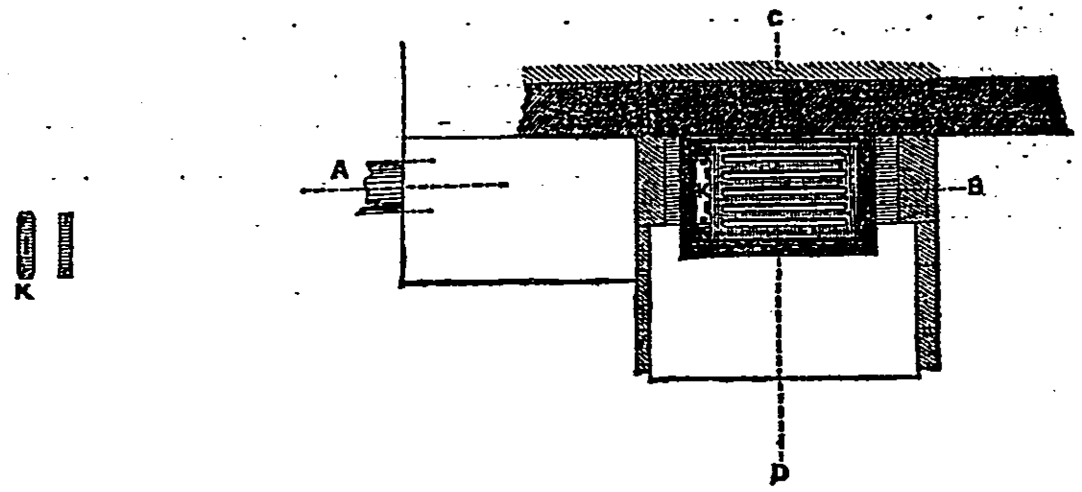
the drains, a double cesspit and connecting curve, according to the following sketch, has been used with advantage, and forms an additional security; but whether a single or double trap be used under such circumstances, they should invariably receive periodical attention.





An extra grating, placed within the cesspit, in a vertical position over the mouth of the shoot, has been adopted by Mr. Wrigg, the surveyor to the Preston Local Board.





The great advantage of this second grating is, that it will allow of the street grating being of such a width as not to be liable to be choked. The additional cost of the inner grating is only 1*s*. A perforated plate would probably be better than the long bars, as preventing the passage of large flat substances.

Accuracy in the Form of Pipes.

Accuracy in the form as well as in the jointing and laying of pipes, so as to preserve the true line, is of great practical importance to the well working of a proper system of town drainage. With such small flows of water as require to be removed from houses even small irregularities are apt to detain matter in suspension, and to cause deposit. It was proved by experiments tried at the instance of the members of the Metropolitan Sanitary Commission, that the power of the sweep by the same quantity of water was, by evenness of construction, increased one half, *i. e.* in the ratio of 25 to 16.

The manufacture of earthenware pipes for the drainage of houses dates only since 1842, when the first earthenware glazed pipes for house-drains were made in consequence of the sanitary inquiry. The demand has been so great, and the profits so high, that any large improvement in construction has not yet been entertained. There has been only limited machinery, and less science, applied to the manufacture, which is susceptible of great improvement, and of considerable reduction in price.

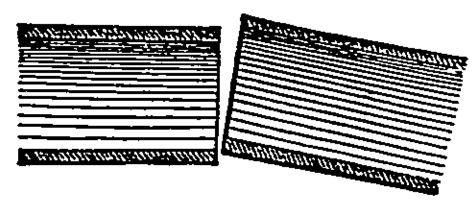
Some of the best pipes yet manufactured, and the most accurate in form, have been those manufactured in Staffordshire by hand. The clay is beaten, and the pipes are formed by rolling the clay over a wooden cylinder. After the pipes have been partially dried, they are again rolled upon the cylinder, when any inaccuracy in form, or twisting, caused by irregular drying, is rectified. Although the expense of making pipes by hand labour is greater than that of making them by machine, yet from the clay being better beaten and worked,—from a less

moist clay being used than that which must be forced through a die by pressure, a far smaller proportion of the pipes are distorted and spoiled in burning. This reduction of the proportion of spoiled ware, and increased accuracy in form, has hitherto rendered the difference of expense in favour of the machine inconsiderable. From experiments which have been made, it appears that by this simple method, it is often practicable to use a finer clay for the interior of the pipes,—a sort of veneer of finer-worked clay,—giving a smooth and even, as well as impermeable surface, instead of a glaze.

Considering the high prices paid for pipes, the Local Boards should be extremely particular in insisting on compactness, and impermeability of material, freedom from inequalities, perfectly smooth interior surface, straightness of cylinder, evenness and uniformity of section, and sufficiency of substance throughout their whole length.* It is essential that the separate lengths should join truly with each other, so as to maintain a perfectly uniform and true line throughout. With perfect accuracy in form, the longer the lengths, the better, as the joints will be fewer.

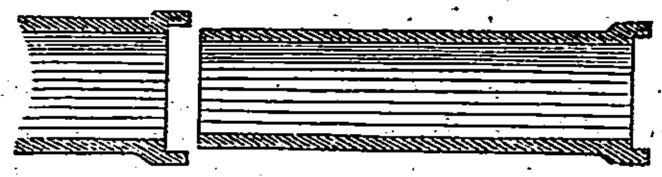
Joints for Tubular Drain Pipes.

The first joint used was the butt-joint. The objection to this joint is, that unless it be laid with care, in a compact and even soil, in a bed excavated with great exactness, and unless it be covered in with care, it is very apt to get out of the true line; when one length rises above the other at the joint, in the manner shown:—



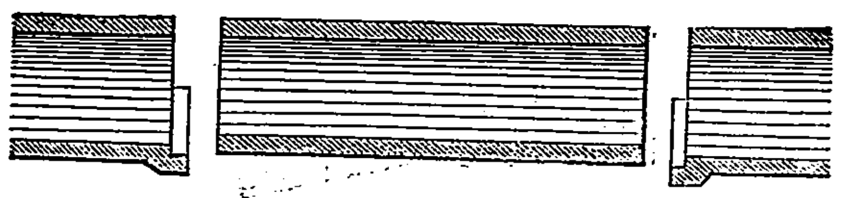
* The inferior makers, whilst competing with each other in price, have reduced the substance of the pipes, to make some gain in the saving of the stoneware clay (which when worked up costs as much as 10*s*. per ton), and also to save carriage. They have made the pipes so thin that they will not bear the pressure of shifting soils, or the rough usage of workmen unskilful in pipe-laying. Of the stoppages of tubular pipes which have occurred, next in number to those occasioned by the common builders putting in the pipes at wrong inclinations, are the stoppages occasioned by the breakages of the pipes from their being made too thin. It is proposed as a practical rule, even with respect to the best stoneware pipes, that the pipe should have one twefth of an inch in thickness of material for every inch of internal diameter. One reason, perhaps, for rabbet-jointed pipes answering so well for water carriage, is, that they are necessarily made with a thick body, or a body sufficiently thick to enable the rabbet to be formed.

And in this state the flow is interrupted, substances detained, accumulations of deposit formed, and an opening left for the escape of the liquid, causing saturation of the soil. The joint now most commonly in use, is the socket-joint, which from its frequent inaccuracy in form is liable to the like displacement as the butt-joint:—



In pushing the end of one length of pipe into the socket, the cement is apt to be squeezed into the pipe itself, where in careless workmanship it has been found in ridges, creating permanent obstructions and accumulations. This defect is apt to be occasioned by careless workmanship with any cemented joints; well-worked clay is therefore found to be a better material for jointing; but in any case the surveyor should take care to obviate any defect of this kind by having an instrument passed down the pipes as they are jointed, to remove any superfluous material. The joints should be examined as the work proceeds.*

To obviate these inconveniences, Mr. Austin proposed a half socket-joint, which might be manufactured either with the half-socket at one end only of each length of pipe, or at the lower half of both ends, and used alternately with a length without any socket:—



The half-socket forms a bed or foundation, which keeps the respective lengths in place; as each successive length is *laid* in the half-socket, and not *pushed* in, the cement is not raised in ridges, and every joint may be inspected, and the faulty ones rejected after the pipes have been laid. It has the further advantage of allowing any length of pipe to be taken up without difficulty.

One objection to any description of socket-joint is the projection formed by the socket itself, which acts as a sort of fulcrum for

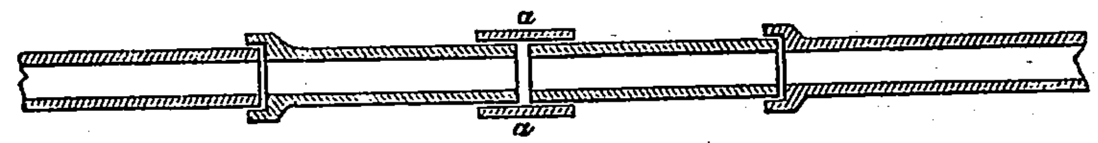
* In laying socket-jointed pipes, great care must be used to give the pipes a full bearing, and not to allow the plain ends of the pipes to "*bind,*" or rest solely on the socket, as, by doing so, pipes are frequently broken.

leverage, with the length of pipe, in any disturbance of shifting beds, or any vibrations, such as occur in turns and streets. The effects of these disturbances and vibrations are most seriously felt in the joints of iron water-pipes. To obviate them a ground cone-joint is in some places used, when the joints are smeared slightly with paint or cement, and simply run up close into each other.

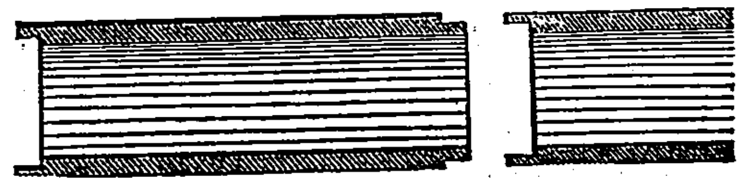
The report of the working of these joints in streets of considerable traffic is very good.—(*Vide Report on Water Supply*).

In cases where it is especially desirable to keep the drainage-pipes water-tight they should be laid on a bed of well-wrought puddle and gently pushed down into place, after this the space on each side and up to a level of 6 inches above the crown of the pipe should be filled up with the same material, thus forming an uniform and impervious matrix (similar to a mould of wax) all round them.

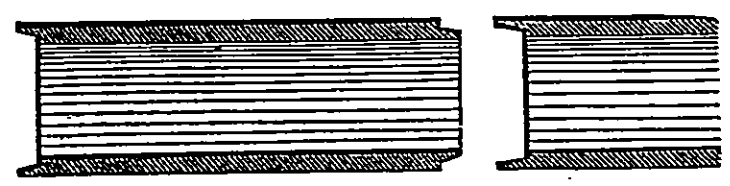
Long collars over butt-joints are used to stiffen and carry pipes safely through irregular strata. They are sometimes used to repair breakages in lines of pipes with socket-joints; as at *a a.*



In earthenware the rabbet-joint is sometimes used,—

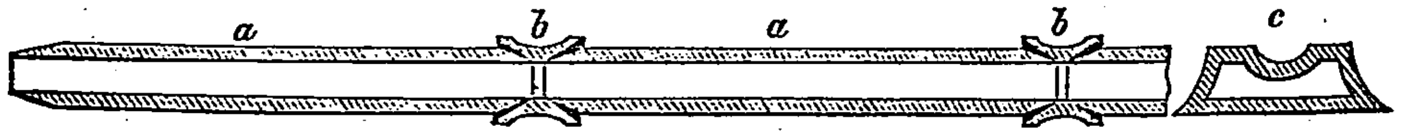


The advantage is, that these joints form one continuous line, lying evenly in the beds, and vibrating more evenly than pipes with the protuberances of socket-joints. To give room for the formation of the rabbet-joint, more clay is required; they must be thicker than with the common socket-joint; but the labour in making them is less than in making the socket-pipe, and they ought to be produced as cheaply. Pipes of red clay, with a rabbetted cone-joint, thus—



well connected with Roman cement, have been in use many years at Weymouth, for the distribution of water.

The sinking of the earth, or an unusually heavy vibration of it, as by the rapid passage of heavily-laden vehicles, will often exercise a powerful leverage on a very long and perfectly rigid line of pipe, and even iron pipes are often subjected to dislocation and breakage from such causes. For the less certain strata, and for cases where the more stiff collar jointed pipes were found to be subjected to breakages, in Switzerland, pipes with conical joints inserted in sheaths, as displayed in the following cut, are used for the distribution of water; and they may be commended, as of frequent service, for the removal of soft water:—

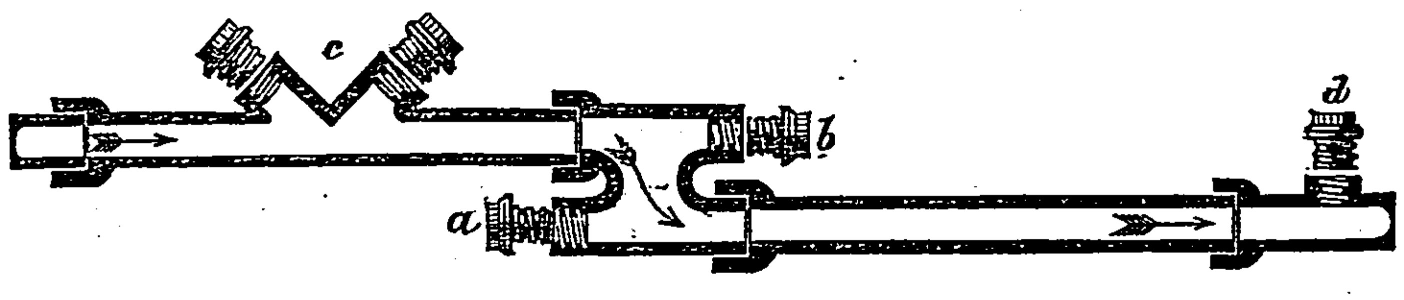


They are thus described:—

"The straight pipes *a a* are finished uniformly at both ends in a cone shape, and fit into the conical mouths of the joint pieces, *b b*, which are, however, bored rather wider, in such a manner that the end of the pipe touches or stands against the bottom of the interior of the sheath, whilst except at that part, a small space is left between, in which the cement is to be well worked in. The object of this contrivance is that the cement may present as small a surface as possible to the pressure of the water. The cementing by this method becomes a very easy process, and consists merely in rubbing both ends of the pipe and the inside of the sheath or rings several times with cement, and in covering them with a thin layer of cement, in fitting them into each other, and in carefully turning them at the same time the pipe is being pushed forward, so that all the superfluous cement may be pressed out."

In order to spread the base in very uncertain ground, these pipes are laid upon a sort of sleeper or cradle formed as at *c*.

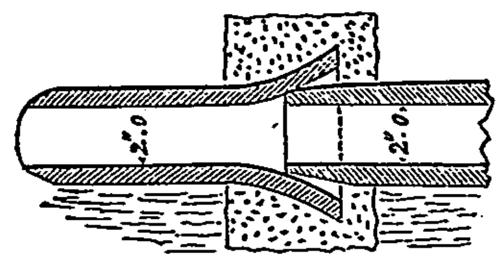
As showing an advance in the manufacture of earthenware pipes as an expedient for pipe-water distribution, which may frequently be applicable (as part of a complete system of tubular drainage) for the application of soil-water as liquid manure, with full pipes and under pressure, the following arrangement, also in use in Switzerland, is deserving of attention:—



They are thus described, as made and used from the manufactory of Mr. Ziegler, at Winterthur, near Zurich:—

"When straight pipes are laid down for great distances, intermediate pieces are introduced at certain intervals. They are provided with screws, *a b*, or, if there be no pressure, with simple stoppers, and are for the purpose of emptying the pipes when required. To let the air escape to remove any trifling stoppage, side openings are made in the pipes, and fitted with one or two screws. These screws, which are likewise made of clay, and glazed, afford the advantage that the flow of water can be readily shut off even at a high pressure.* The thread of the screw is rubbed with a mixture of resin, oil, and tallow, and a small roll of cement is laid carefully round the head of the stopper, so that in screwing it down into its place none of the cement may get between the threads and render the unscrewing difficult."

* The precautions with which the distribution of water is effected in France under intermittent pressures, often of between 100 and 200 feet, is by the proper distribution of air cushions, and by using screw-down taps, which cannot be suddenly closed. The Roman distribution, under average pressures of 100 feet, was often with very common earthenware. At the points of extreme pressure, at the bottom of valleys, it was their practice to strengthen a line of earthenware pipes, by continuing it through banks of perforated stone. In France, they arm the lower portions of syphoidal lines of earthenware pipes by short lengths of iron. A Continental correspondent, giving an account of the use of earthenware pipes for the distribution of water, says: "I can furnish you with satisfactory evidence of their almost imperishable durability, when properly made and bedded, in the remains of an ancient Roman water conduit in our own neighbourhood (about 10 miles from Zurich), where a spring is carried from a hill of about 500 feet in height, called the *Lagern*, to a village where formerly a Roman station and highroad was situated. Here the water is carried in earthenware pipes laid into the ground through a distance of several miles, great part of which is not only still in existence, but actually doing service. The perpendicular height of the column of water is not less than 200 feet, and the pressure, therefore, equal to about seven atmospheres. The pipes are roughly made, but not glazed inside, but with that attention to sound practical objects, disclaiming useless ornament, and choosing the simplest and shortest means to accomplish their purpose; the Romans paid particular attention to the joints. There is no separate coupling-ring as in Mr. Ziegler's pipes, but they are stuck into one another, the lower (receiving) pipe being trumpet-mouthed, and the upper one slightly conical, thus:—



"But what is more remarkable, and wherein they differ from the moderns, is the care with which they secured the joints; these are inclosed in an

Before information was obtained of the manufacture and uses of screw joints in earthenware on the Continent, the use of the expedient was suggested to some of the chief potters at Stoke-upon-Trent, but they doubted their practicability. They have, however, been since exceedingly well made for other purposes by Messrs. Doulton, potters, at Lambeth. Screws are so easily made that they may be commended to the attention of gentlemen who have tile-kilns of their own, and desire to improve the manufacture of pipes. They will be found to be of frequent use for the pipes used for temporary purposes, to be screwed up in washers, and after use to be unscrewed and removed.

Long lengths of pipes, formed true in the inside, are great desiderata in town drainage, particularly for vertical drain-pipes to lay close to outside walls, for the drainage of high tenements let off in flats, for soil-pipes, &c. &c.

The Materials for the Construction of Sewers.

In the early period of the official investigation, attention was directed to the unsuitability of the ordinary form of brick for sewer construction, and to the advisability of substituting other forms and arrangement of material. A reference to some of the sections already given will fully illustrate the impossibility of obtaining strength and efficiency of construction with the common form of brick in the smaller sizes of sewer. Radiating bricks have been used for some years with great improvement,

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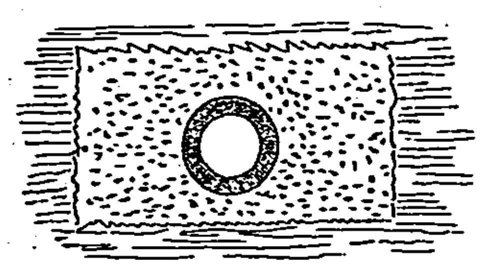
envelope of mortar, composed of pounded brick (the same material as the pipes themselves are made of), and forming at the same time the bed and roof for it, as seen in cross section:—

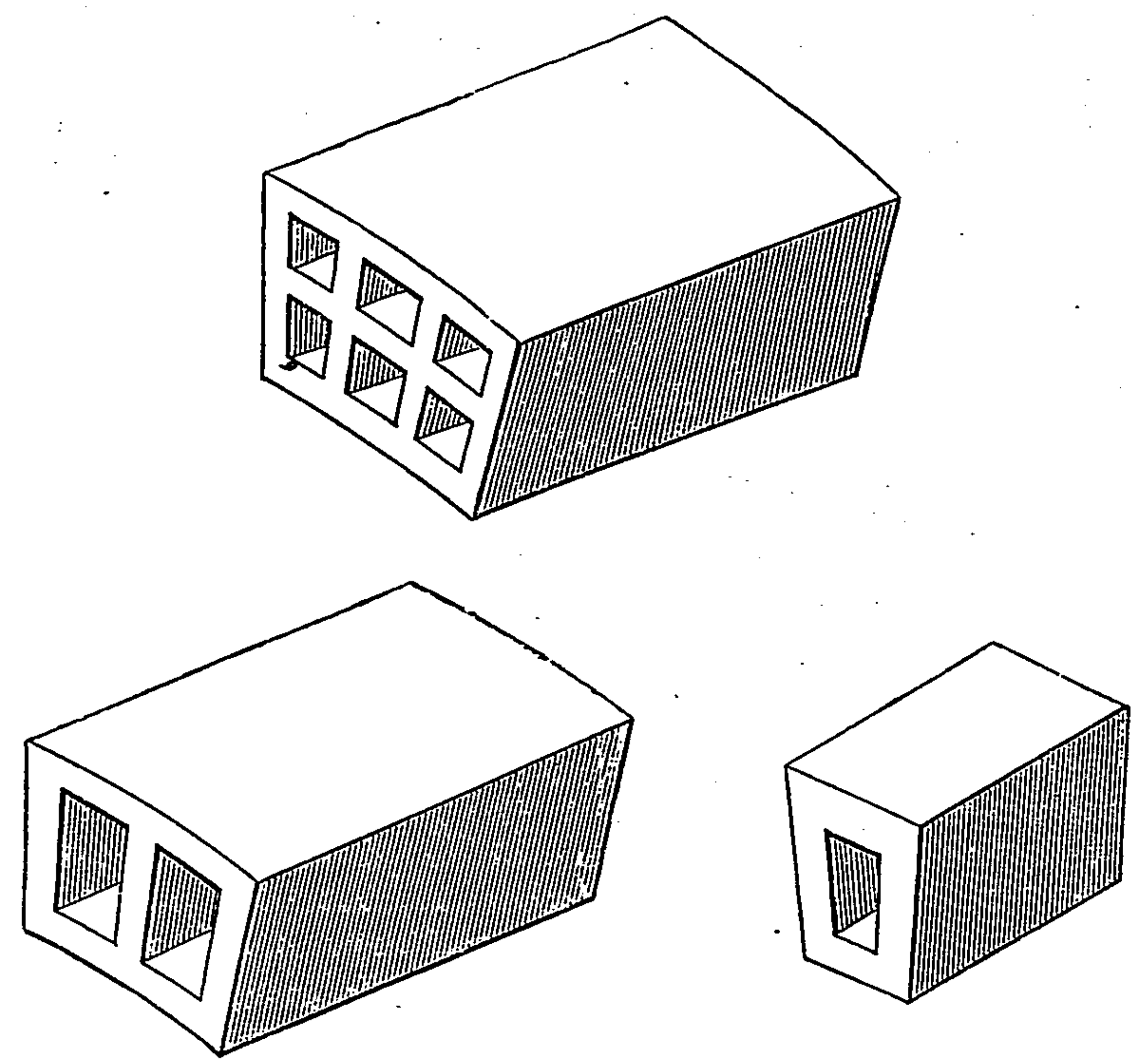


"This casing of mortar when old becomes as hard as the pipe itself, and forms but one mass. Otherwise, the pipes are laid into the loose soil, with the exception of a slightly hollowed-out bed at the bottom, made of broken pieces of pottery, united with a little mortar. These joints have hitherto proved immoveable, and in order to take two pipes asunder, it is necessary to break them. This method seems to me commendable, especially in similar situations, viz., on the slope of a steep hill. The pipes are not above 2 inches diameter. I shall try to send you a specimen along with the rest, merely as an historical curiosity in the arts of manufacture."

but probably owing to some trifling difference of cost, their introduction has been most partial.

Proposals were made during the inquiries by the Health of Towns Commissioners, to construct sewers of slabs of earthenware formed to the required shapes and sizes. On the reconstitution of the Metropolitan Commission of Sewers, some trials of this kind were directed, and also for the preparation of hollow bricks for the purpose.

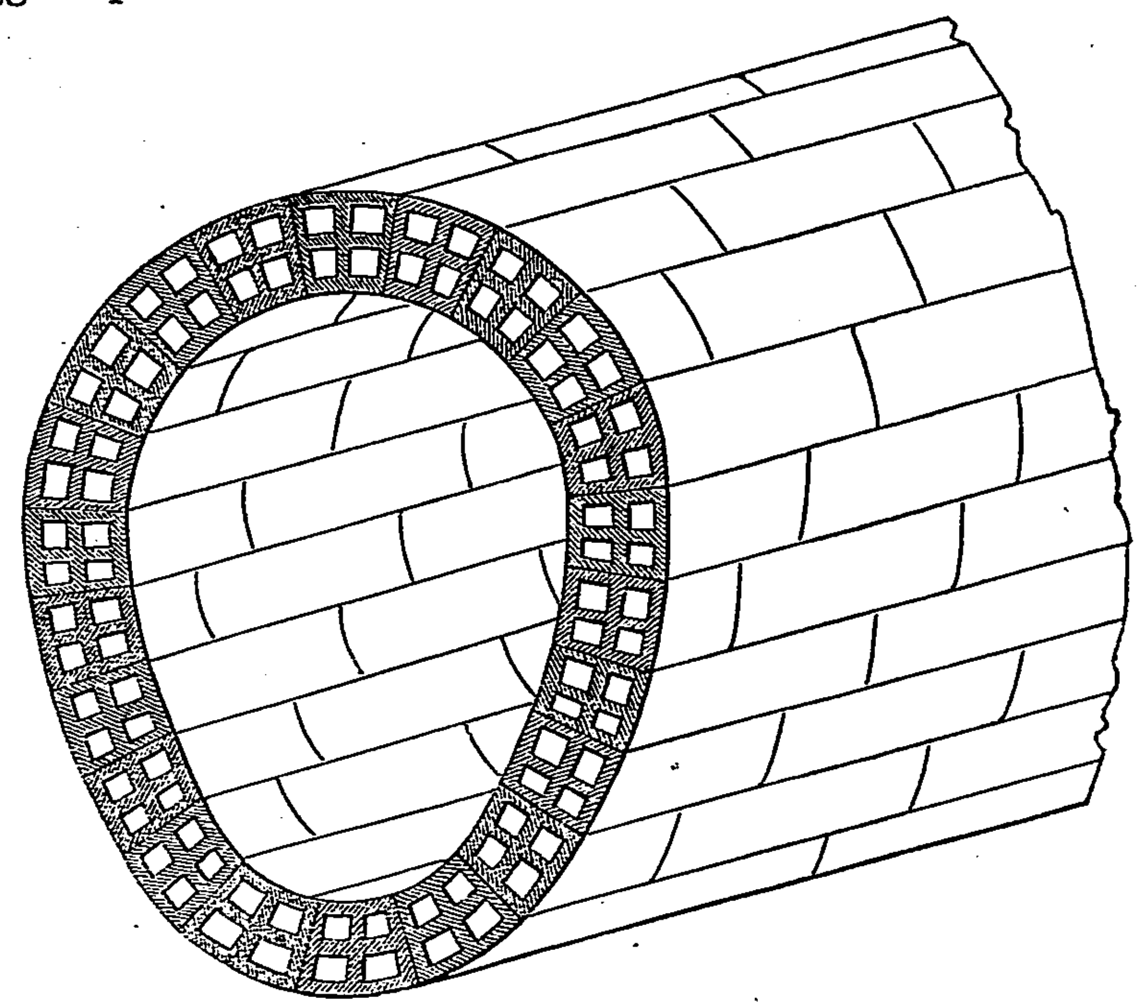
Among others, the following form of hollow bricks were prepared, and experiments tried, under the direction of Mr. Roe,

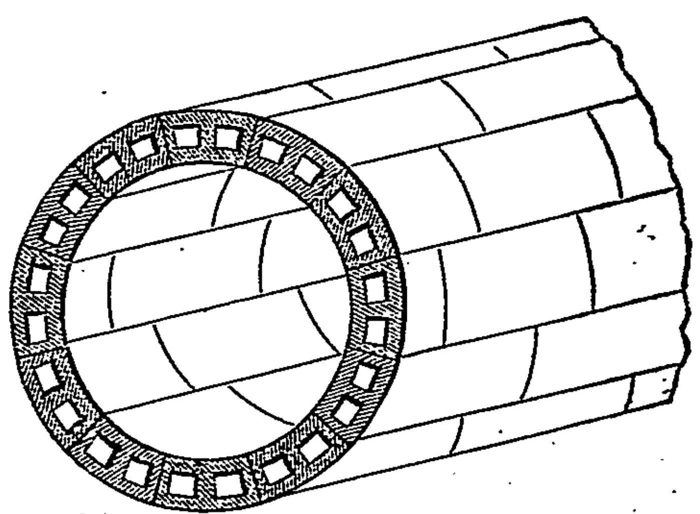


(*vide* Table of Results, Appendix, No. 13), which proved that they were capable of resisting enormous pressure. The attention of the manufacturers appear to have been since that period so entirely absorbed by the large demand for pipes, that little or no progress has been made in the introduction of better material for the larger class of sewers.

The many advantages obtainable from the hollow brick, the greater density of material, increased strength, impermeability, and economy, would appear to recommend this principle (which has been subsequently brought into use for house construction), with various forms and sizes specially adapted to the construction of the larger sewers, and the covering of the larger tanks.

Forms of the following character were designed for the purpose, which being drawn to a few different radii, would accommodate themselves to a complete graduation of circular and egg-shaped sewers of the required sizes:—



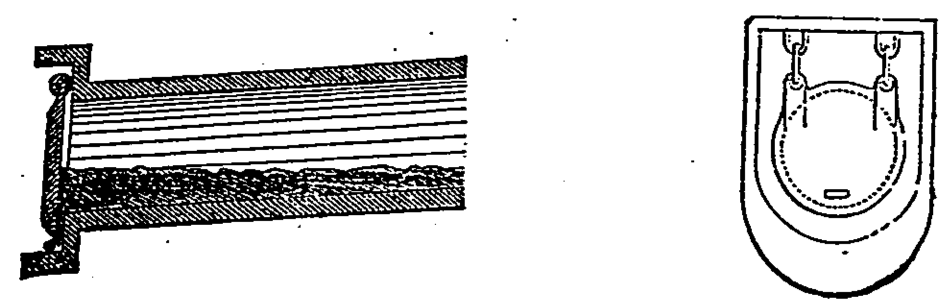


Lock-joints were proposed for the sides. On consideration doubts as to their utility prevailed; but trial works were proposed as to the end-joints, which there was no opportunity of completing. It appeared probable, that when manufactured on a large scale, impermeable structures on the principle herein described might be made at little more expense than hollow brick wall; in respect to which it was shown that hollow wall of 4 inches thick, set in Roman cement, might be constructed at 1*s.* per superficial yard, and 9-inch wall at 2*s.* 6*d.* per superficial yard, also set in cement.

Expedients to prevent the Ingress of foul Gases into Habitations.

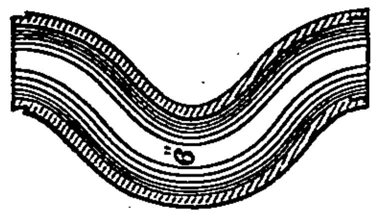
Valves or traps, to impede the passage of effluvia, are necessary parts of a system of drains for the removal of foul matter On the first examination of town districts, even where the openings into the sewers, the gully-shoots, had been trapped, and at great expense, it was found that offensive smells nevertheless arose from them. It then appeared that these gully-grates were trapped with heavy cast-iron flaps, hung with shackles, some of them between two and three hundredweight, (made heavy possibly on the hypothesis of making the trap more secure,) but their effect was, as in the cesspool or plug-trap, to detain solid garbage, vegetables, or the insoluble portions of ordure; and the traps often detaining the foul water itself, the sewers became also a series of cesspools, arranged along the streets, and opening into them. Some of the worst of these artificial cesspools were constructed in districts where, although the main sewers were under one jurisdiction, that of the Commissioners of Sewers, these gully-shoots were by local Acts placed under the charge of another jurisdiction, that of the parochial vestries. As a further consequence of their construction, it became necessary to incur further expense by appointing men to look after the gully-shoots and cleanse them, which was done by forcing open the traps, and letting out the matter detained by them.

Lighter flaps, weighing from two to ten pounds, were placed at the openings of common house-drains, but the lightest of them would detain orange-peel, leaves, &c., and gradually accumulate decomposing matter, as displayed in the following cross section:—



The stoneware flaps which were attached to stoneware pipes were often well ground, so as to make an effectual air-tight fitting; but, if a straw or stick be detained at the mouth of the trap, or if viscid matter accumulate at the mouth of the drain, it becomes untrapped; the valves might, like curtains, obstruct powerful currents, but they were of little avail to prevent the entrance and diffusion of the more subtle and poisonous gases.

The best form of trap, the most simple, the least liable to derangement, and the most economical, and, therefore, the one to be recommended for house-drains, and for general adoption, is the syphon water-trap. For the ends of drains, the syphon-traps will be formed thus:—



These traps should, when practicable, be placed a little below the openings, so that the force of the fall of water may effectually discharge the previous contents. It must be always borne in mind, however, that the efficiency of this trap is dependent on the regularity and sufficiency of the supply of water. In respect to other forms of syphons, *vide seq.* But no trap is to be relied upon for the protection of dwelling-houses or rooms against the pressure of volumes of gases arising from decomposing deposit.

Water rapidly absorbs gases evolved by decomposition; this property renders it of the more service when the quantity of gas is moderate, but where it is considerable, the water is rapidly saturated, and then is found to give off and to diffuse the gas on the one side, as it is absorbed on the other. The only effectual protection is the removal of all refuse matter, before it can get into a state of advanced or active decomposition, to such a distance that its fumes may not reach dwellings; and this important object is effectually accomplished where the several principles herein set forth are practically applied.

A tubular system of drainage, in combination with constant water service, properly applied, has no decomposing deposit, no evaporating deposit, which is appreciable in house-drains, or in sewers. On this system, when all refuse liable to run into decomposition is immediately received in water, and carried along with considerable rapidity, it will be removed from beneath houses, and from the whole site of a town before decomposition can have advanced, and before any of it can get into those ultimate stages of decay which, in the present methods of town-drainage it now usually reaches before removal. Under such arrangements the cold and recently fouled water does not diffuse wide-

spread emanations.* Even at the outfall itself, there are no such odours as those which are diffused from the old sewers and drains into the houses and streets of the metropolis, and other ill-drained urban districts. When the pipes are tolerably full, and the discharges rapid, instead of diffusing upward currents, the friction of the water upon the air carries with it a downward current of air, which is strong in proportion to the velocity of the stream. Under the ordinary circumstances of the drainage of houses, and the removal of soil-water by properly arranged tubular drains, the syphon-traps are found to be perfectly effectual.

The prevention of the more offensive smells by the altered arrangements, which avoid masses of decomposing matter beneath or near habitations, though it renders unnecessary the use of double traps, (which are often found only to occasion an accumulation of foul air between them,) cannot however be practically carried to the extent of abolishing the necessity of any traps whatsoever. Some odours may be expected from the soil-water smear or deposit, however slight, on the sides of the earthenware drains, such as may be left on the sides of pails or vessels from which foul water has been discharged. It may be

* On this subject Mr. Cuthbert Johnson, chairman of the Croydon Local Board, speaking from his own observation, says, "I have found, by the experience of about three years, that house-sewage drained through impermeable pipes into a water-tight tank may be stored even for four or five days without becoming offensive, when, in the summer months, owing to our cutting the grass, and irrigating the cleared space almost daily, the sewer-tank is so regularly and completely emptied, at least once in every 48 hours, that upon removing the lid of the tank there is no more, or perhaps not so much, odour perceptible as from a London water-butt. The house-sewage retained in an impermeable receiver for even a few days, differs very strangely indeed in its degree of fluidity and other qualities from the noxious contents of an ordinary cesspool, from which the more fluid portion of sewage is constantly oozing. From these and other observations I am led to the conclusion, that town sewage conveyed on to the the land, not from overflowing cesspools, but direct from the houses, through impermeable pipes, will not possess any properties offensive to the adjoining inhabitants." Since this was written, Mr. C. W. Johnston has added (March 23, 1852):—"The truth of these observations on the inoffensiveness of rapidly-discharged house sewage has been confirmed by the result of our experience with the town sewage of Croydon. This is conveyed through glazed stoneware pipes, with impermeable joints, to one common outlet, which is at a place where, under a covered building, the sewage is passed through strainers before it is discharged by other pipes into the river Wandle, at a place about half a mile from the town. In visiting this straining-house, every person is impressed with the almost total absence of even the slightest odour. It is only when the strainers are cleared of the matters which will not pass through them that any smell is evolved, like that from an ordinary brick sewer."

anticipated that these odours will arise and accumulate so as to be appreciable (if the air in the pipes be confined) upon the water-traps in upper apartments. Therefore, whenever a water-closet, even with the best sort of syphon-trap, is introduced into a house, it will be well to provide an escape into the outer air. Where several soil-pans or sinks from the apartments of a large house are discharged into a common soil-pipe, or vertical main, the main should be continued up to the roof and opened to the air, and, if practicable, it should be carried near the chimney. Pipe sewers must also have ample ventilation provided at all available points. If the air is confined, it is most dangerous when it breaks forth, which sooner or later it will do.

Where soil-water is conducted to a covered reservoir, and there is occasion to store the contents, the mouth of the pipe leading into the tank should be so low down, as to be always covered, and an evaporating surface no larger than the sectional area of the pipe exposed towards the houses; the communication towards the houses should be carefully guarded by additional water-traps; and vent should be given to the products of any decomposition into open space, where it may be rendered innocuous by dilution with pure air, otherwise the tank will form a species of retort for the generation of noxious gases, spreading through the connected pipes, and bearing upon all the traps so as to pass those which are inefficient. If the quantity of sewage stored be large, or the emanations offensive, they may be decomposed and rendered innocuous by passing them through a fire.

The Principles of the Construction of the Water-closet.

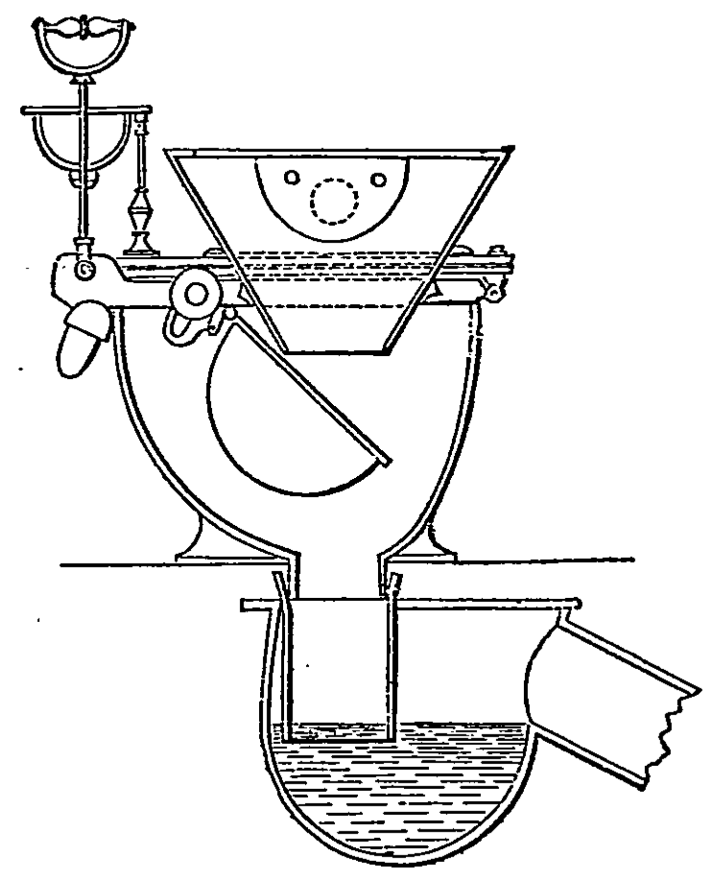
It is now necessary to revert to the construction of the chief apparatus for the decent and efficient sanitary arrangement of every household, an apparatus to which but little attention is usually paid, but which requires the most serious consideration, as one of the primary works for the sanitary improvement of houses and towns; namely, the water-closet.

The particular points to be sought for in the construction of the apparatus in question, appear to be,—

1. A scour for the complete removal of the soil.
2. The best trap against the ingress or regurgitation of effluvia from the general system of drainage and sewerage with which each soil-pan or house-sink must communicate.
3. The consumption of the least quantity of water for a complete scour and perfect trap.

4. Durability, or freedom from the liability of—
   - *a.* Breakage in consequence of frost.
   - *b.* Derangement of the machinery.
   - *c.* Breakage by careless usage.
   - *d.* Stoppages.
5. Easy repair.
6. Cheapness when manufactured on a large scale.

In the original statements as to the superior economy of a systematic removal of all decomposing town refuse in suspension in water, as compared with the cost of retaining it in cesspools, cleansing them by hand labour, and removing the accumulation by cartage;—and, to obviate any chance of under-estimating the expense of the improvement proposed, it was assumed, that the most expensive form of water-closet, costing 10*l.* each, would be used for even the poorest descriptions of houses in towns. (*Vide Sanitary Report*, 1842, p. 223.) And for all towns, the superior economy even of this form of apparatus over the common modes of cleansing is demonstrated. But apart from its expense and the complexity of the machinery, it is objectionable from its inefficiency as a trap to prevent the return of effluvia into the premises, and its difficulty of repair. The following is a transverse section of the common apparatus in use in first-class houses, with a statement of the objections to it, by a working plumber.*



* Mr. Crump, of Derby.

"One great objection to its (the pan-closet's) use is the impossibility of freeing it from the offensive effluvia escaping into the room whenever the contents of the pan are discharged into the cast-iron receiver; and the longer the closet is in use, so also the smell becomes the greater. This arises from the cast-iron receiver being coated so repeatedly with soil delivered from the dish or pan, and the construction of the closet not admitting the water to wash any part of the apparatus, excepting the earthenware basin and dish. In numerous instances the coating has so accumulated in the receiver behind the dish as to prevent its being worked at all, until taken down and properly cleansed out.

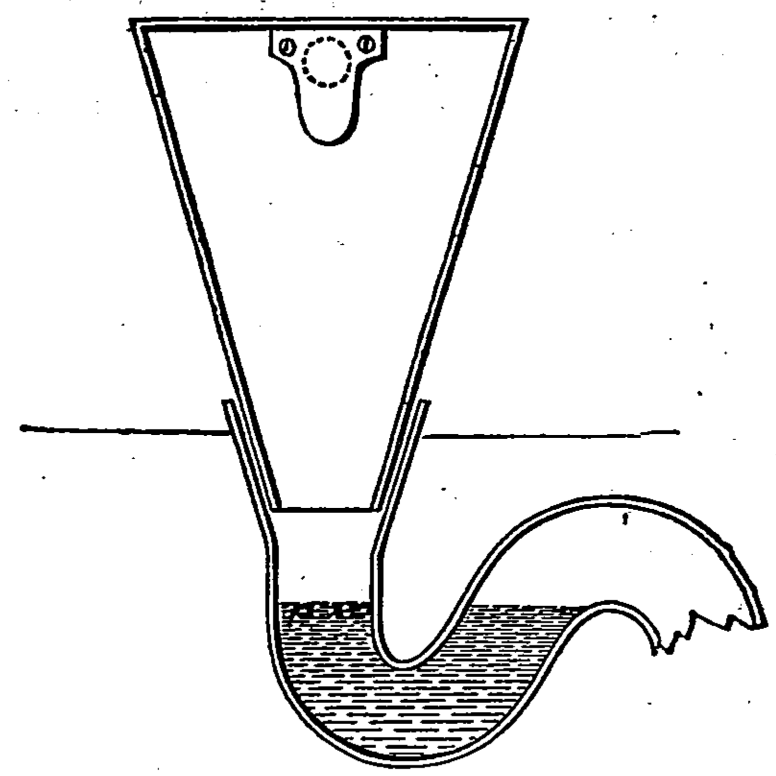
"In no instance should this description of closet be fixed without thorough ventilation. There must at all times escape effluvia, although the seal of water in the trap below, and also the dish, is secure, the escape being constant through the bush of the axle to which the dish is attached, and as the receiver between the two becomes foul, the smell finds its way through it. This closet, from its peculiar construction, is extremely liable to choke up in the trap or soil-pipe. Servants emptying into it the contents of chambers and buckets, flannels, scrubbing-brushes, combs, and other improper things have repeatedly found their way into the trap and produced the stoppage.

"Servants, ignorant of the construction of the closets, imagine that in discharging the contents of the dish into the receiver they have disposed of any article improperly thrown into it; but though cleared from the dish, it merely finds its way into the trap, and leads to its being stopped up.

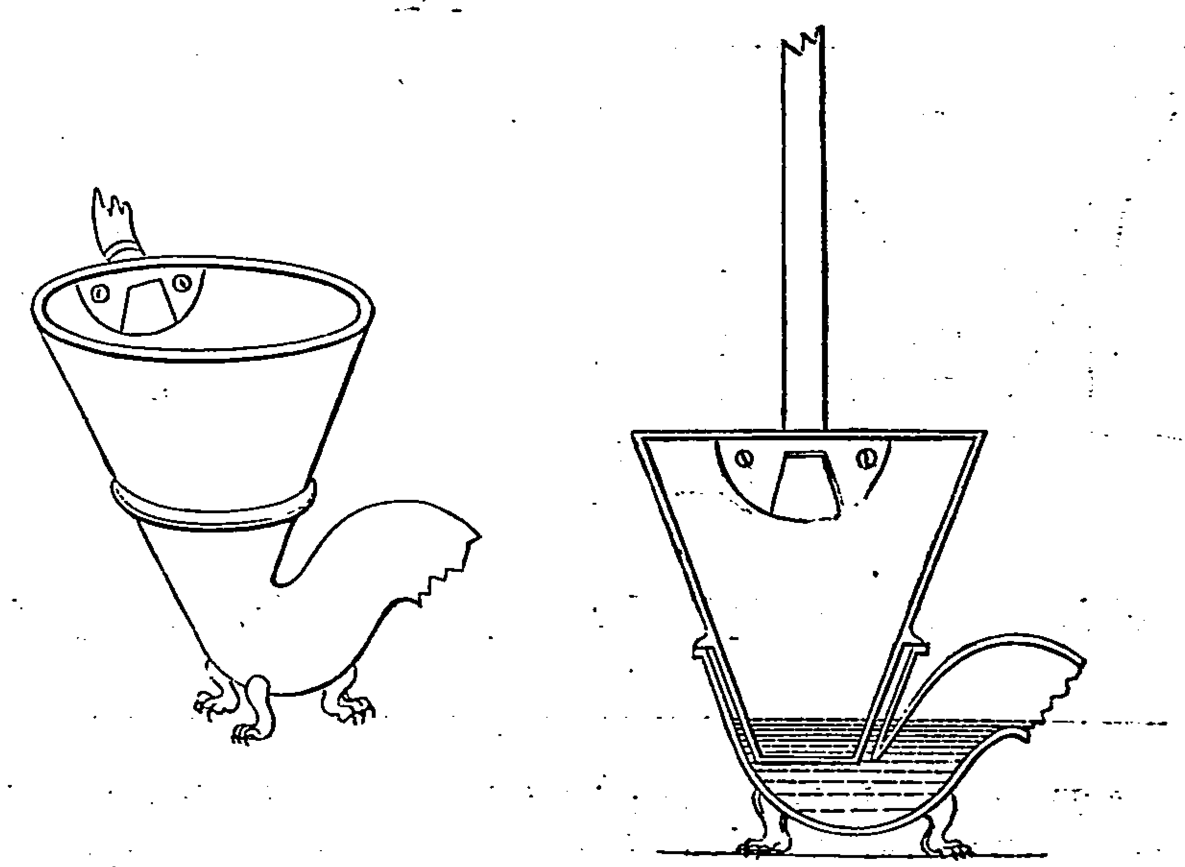
"In confirmation of the preceding remarks relative to the escape of noxious gases, it may be mentioned that the copper pans in these closets are frequently destroyed by the action of the sulphuretted hydrogen in the course of a few years; although in some instances they are placed two feet above the seal of the trap.

"The cranks, tumbler, shoe-valve, and machinery part of the apparatus are all liable to speedy derangement."

The more simple apparatus, which is now coming into extensive use, is on the principle of the syphon-trap; the first form of which used (the long-pot closet) is shown on the following page:—



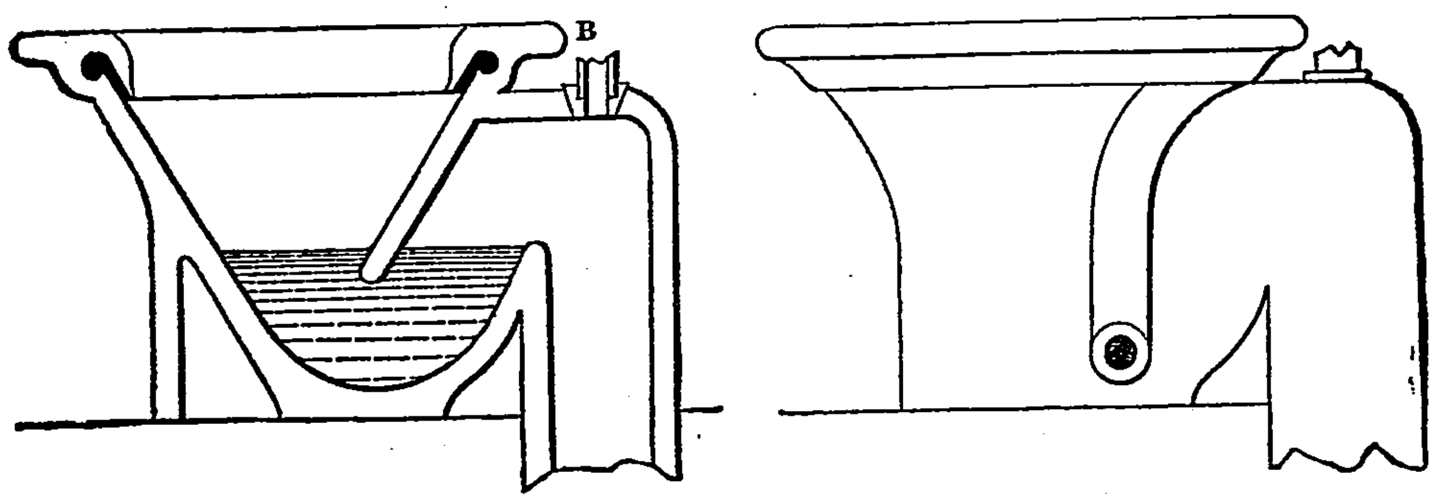
The defects in the first construction of this form of closet were, that the water did not come sufficiently high up the pipe from the trap to meet the earthenware basin; therefore, and because the water was otherwise inadequately applied, a coating of soil was left inside the pipe. The following, by the same witness, is an example of the more simple forms since introduced:—



With a small quantity of water at high pressure, a *force* of sweep is given which is only effected by a large quantity when the supply is from a cistern slightly elevated. The adjustment of the force of the sweep at varying pressures, at the different levels of houses, and altitudes in a town, will require much attention from the surveyor. The closet should be so constructed and adjusted as to act completely with not more than half a gallon of water.

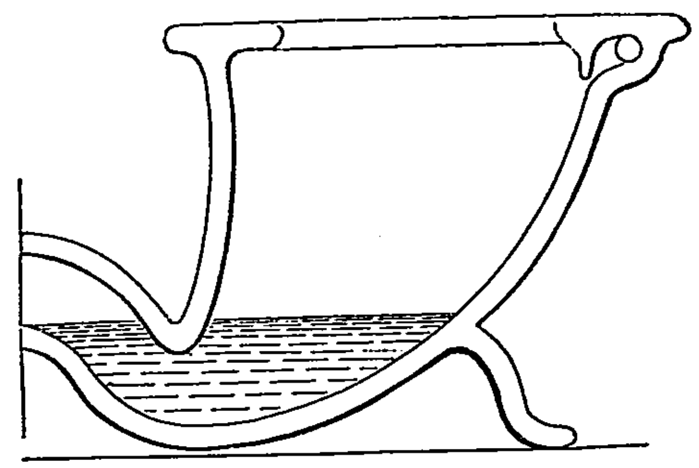
The prevention of waste of water is not the only advantage sought. Though it is always desirable to accomplish any object with the least possible expenditure, and important to prevent waste in each of many thousand cases, the avoidance of unnecessarily diluting the sewage, and thereby increasing the difficulty and expense of its application, must not be lost sight of.

Spreaders have been so adjusted in properly-constructed apparatus of this description as to effect a clean and complete removal of the excreta, with less than half a gallon of water, and yet to leave a sufficient trap. The plan suggested in 1847 by the Metropolitan Sanitary Commission,* for general use, was a syphon closet, made wholly of earthenware, with the top of the pan spread out about four or five inches, so as to form a sufficient self-sustaining seat, needing no woodwork for fixing; thus :—



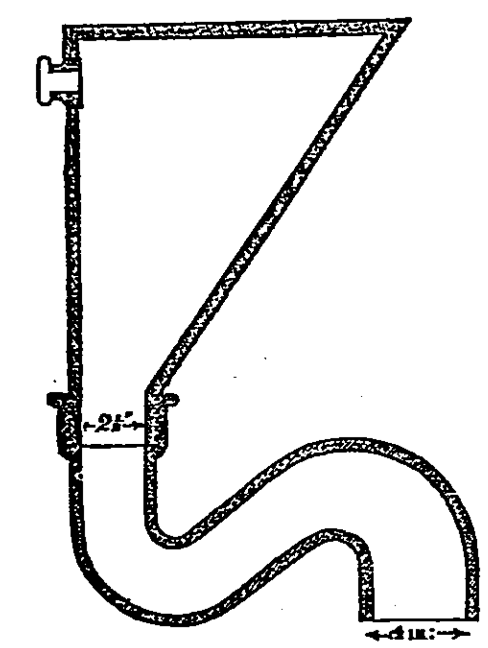
B is the entrance of pipe for escape of effluvia. *Vide postea.*

* These several plans were printed for consideration in 1849, and circulated for the public service. The plans of the fountain basins and sinks (*vide postea*), of earthenware were also prepared and circulated for public use by the Board; they are, therefore, open to the use of all manufacturers, and no subsequent registrations or patents for them are of any validity.

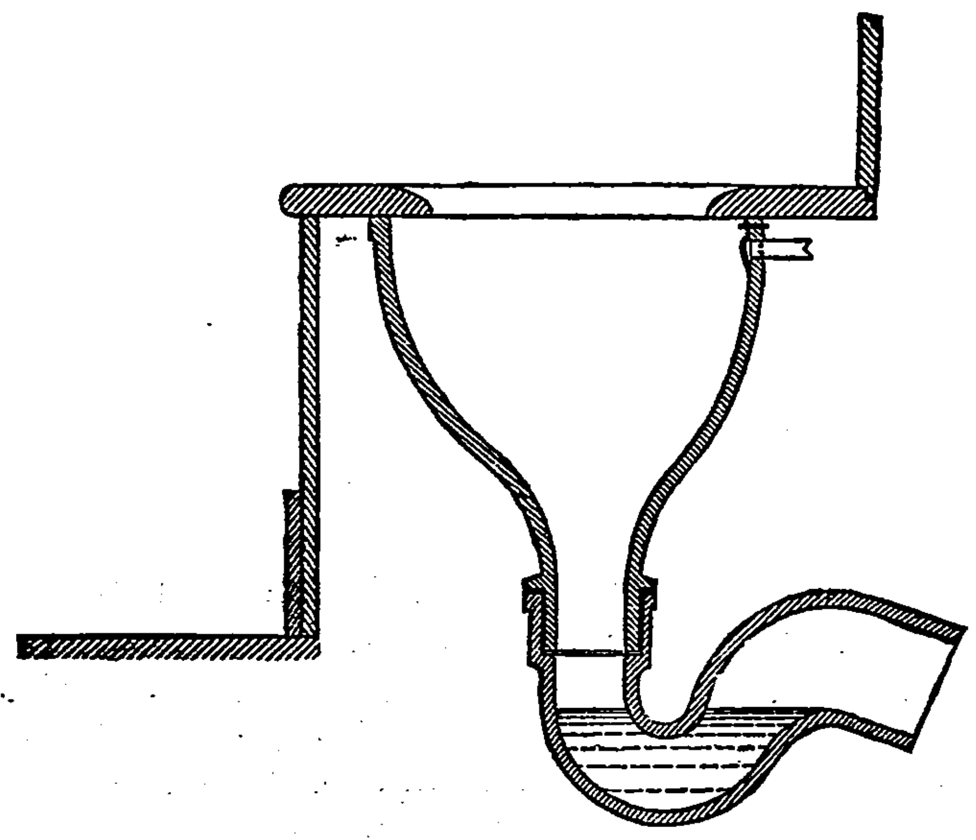


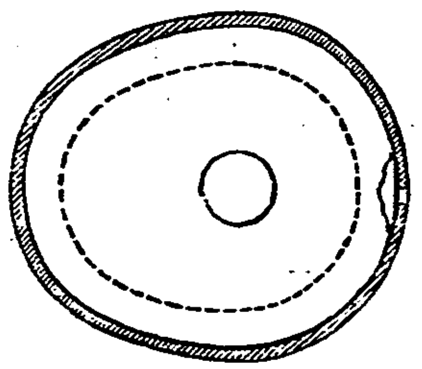
This form, when properly constructed, and with an ordinary service-pipe for water, constantly on, and under pressure from the main, is found, as already stated, to answer completely. The cost is about 20*s.* for all that is requisite; to which must be added the cost of the water-pipe and soil-pipe; but if the distance be short, this cost will be inconsiderable.

A highly favourable report has been given of apparatus on the following plan, with a tapering pipe, which prevents the admission of any substances that, having once passed through the lower part, could not be cleared away through the larger area into which it enters :—



The following is a plan of the apparatus in use for the cottages at Rugby, which is stated to answer excellently. *Vide* Appendix, as to the expense of its construction as part of a set of combined works for house-cleansing and drainage, and the supply of water :—





There are various other forms of apparatus combined on the same principles; some of those in use for the higher classes of houses are very complete and efficient, and only want more economical construction to render them applicable for general use.

The object of the statements herein-before made is less to commend any one particular form, than to show the principles of construction on which it is desirable that improvements should be made, so that no house need be without so convenient an appurtenance.

It is of advantage that the seat should be low,—lower than those in common use. The height of the seats of the common privies and water-closets is objectionable on physiological grounds, and the lower seat is also more convenient for children and young persons.

In respect to materials, cast-iron pans are found to be objectionable; they oxidise rapidly by the action of wet and air. This bad quality is attempted to be remedied by glazing; but if there be any part of the glazing defective, or as soon as it becomes so, the pan is rapidly destroyed. The stoneware pot-

tery soil-pans are free from these objections, and they are not liable to injury from frost.

Where parties choose, either wood or cloth might be put over the seat, and it might have a double wooden cover on the principle of a seat in a frame to be lifted, and vessels emptied into the sink or trap without wetting the seat. It is desirable to dispense with wood-work as much as possible, not only on account of expense, but also because it is absorbent of filth and gases, and not so readily cleansed as earthenware.

For cottages, not having in-door convenience for privacy, this apparatus can be easily adapted to the present privy building, so as to abolish the offensive and disgusting state of such places, described in every report presented to the Board, as among the most injurious and demoralising features of provincial towns. It is most important also that the apparatus should occupy but little space, so that it may be conveniently introduced amidst old and confined habitations.

Arrangements should be made for cleansing the improved privies, urinals, and sinks in lodging-houses, by means of jets of water instead of the broom. For this mode of rapid and complete cleansing, earthenware will be highly convenient.

Under the constant system of water supply required for the proper execution of the objects of the Public Health Act no cisterns, such as are rendered necessary by the intermittent supplies by trading companies, will be required; but it will be requisite that the surveyor should advise as to the adjustment of the water for such apparatus, according to the force of the sweep with varying levels. He should not allow any house-drain to be introduced into the common pipe-sewer until he has inspected the condition and action of all closets, sinks, and other tributaries, with their several traps, and certified to their efficiency and conformity to the general system. This will be protective of the occupier or owner of the property against the culpable ignorance, as well as reckless waste, of tradesmen and workmen, which have spread the sources of pestilence amidst town populations.

Considering the degraded condition of a portion of the population, the general use of self-acting apparatus of various kinds, acting from the seat or footboard, has been urged as necessary; but though in the instance of common privies such an apparatus may be desirable, it is not indispensable, for soil-pan apparatus as above described, and without such mechanism, has now been in use in improved model lodging-houses and dwellings, and in old houses, occupied by upwards of 2,000 of the poorest classes: in one district it has been used by common colliers, and in another by the poorer Irish. In these instances the supply of water by the trading companies was intermittent, and it was otherwise badly applied. In a very large proportion of cases where the soil-pans were cleanly, they had to be kept so by cans of water, in consequence of the defective application of the intermittent supplies. Where a stoppage had been occasioned it was easily removed; and out of the whole of the cases, in four instances only had it been necessary to take up the pipes, and in two of these the stoppage was occasioned by brick-bats having been thrown into the pipe whilst being laid down, during the temporary absence of the workman; a third stoppage was occasioned by a brick enclosed in a thick piece of flannel, and the fourth by a large accumulation of rags, flannel, and hemp. The self-acting apparatus would, therefore, appear, so far as experience has gone, to be far less necessary than was anticipated, and its necessity may as yet be said to be confined to the cases of the common lodging-houses, public privies, and places where a perpetual succession of untaught and unteachable occupants may be expected, and where perverse ignorance as well as carelessness must be guarded against. Self-acting apparatus attached to the door is a convenient arrangement; but all such places should be subjected to the inspection of some one under the direction of the surveyor.

In order, however, to check excessive waste of water, one or other form of self-closing valve appears to be essential.*

Whilst providing this soil-pan apparatus, provision for the covering of it, that is to say, for "the privy, properly so called," must, with respect to many neighbourhoods, be considered, so as to secure the means of privacy and decency.

In suburban districts the cesspool and the privy are, in the fourth-rate houses, often placed at the end of gardens. When the cesspool is filled up, and the soil-pan apparatus substituted, one reason of the site of the privy being so far distant from the house will be obviated. The expense of carrying separate water-pipes and separate drain or discharge-pipes to so distant a site renders it ineligible.

* In one district where new combined works have been executed, and where the consumption of water was excessive, it was found upon investigation, that, from neglect of the surveyors, many water-closets and soil-pans, being of bad construction, did not clear away the soil, and that the occupiers kept the common taps open, allowing the water to run constantly, to keep down the smells, whereby the general consumption of water was made more than twice as great as where self-closing valves or taps, attached to proper pans, were required before any junctions with the main water supply were permitted.

Privacy, but above all the convenience of the feeble and the sick, especially in inclement weather, require that the site, if not within the house, should be brought near to it.

It is only when the house and main drainage is completely amended, and then with care, as recommended (*Vide ante: effluvia traps*), that the apparatus should be brought within the house. The water-closet being generally placed at the back part of the premises, it is suggested for the consideration of owners, whether they could not in most cases form the privies on the outside of the back part of the house, with a communication through the back wall from the landing of the staircase, or elsewhere.

In suburban cottage tenements and small dwellings, it is desirable that whenever the weather admits of it, washing should be done out of the house, in a shed which may be very conveniently constructed near the privy.

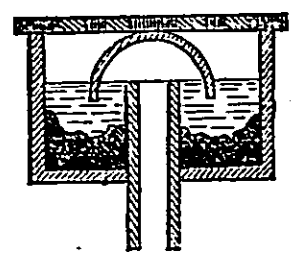
The pan-trap and ground-valve of water-closets may be continued in the better class of houses, where they already exist, and their cost is not a barrier to their use; but no water-closet so supplied should be allowed under any circumstances to communicate with the new drainage without the addition of the syphon-trap also.

In new houses, however large and costly, erected within districts in which there is constant water service and tubular drainage, the lever-tap, basin, and syphon may be safely recommended.

Means of removing waste Water from Kitchens, Outhouses, and Yards.

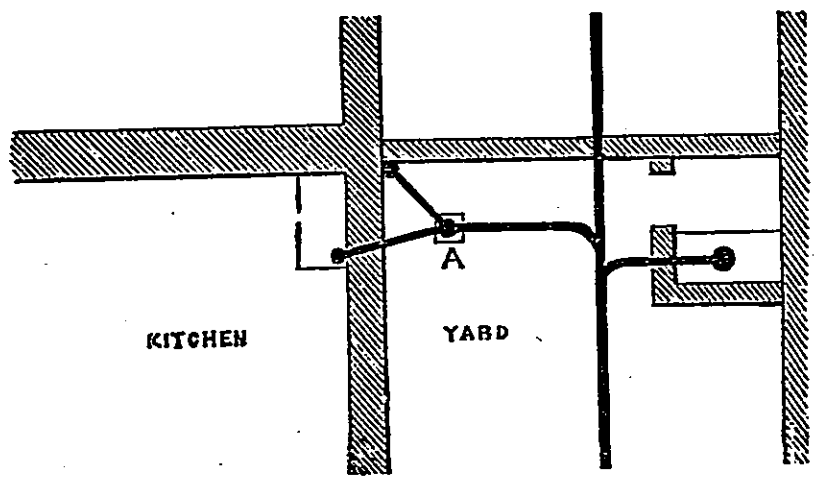
Unless sinks convenient for the reception and removal of refuse to its appointed receptacle be provided, the fronts and back yards of cottage dwellings will be kept in a constant state of wet and filth from the slops and waste water which will be thrown out upon them.

The usual trap employed for kitchen sinks and drains is the bell-trap,



and the method in which it is applied renders it little better than useless, while at the best it would be far inferior to the syphon. The bell-trap is mostly made so small, that the little water it contains must be immediately overcharged with the foul gas to which it should form a barrier. It is so constructed as to favour the constant accumulation of deposit, and requires such incessant clearing out that it is necessary to make the bell and grating a separate loose appendage, which being constantly taken up, is seldom found in its right place.* The employment of this trap under such circumstances is most mischievous, and is a constant source of annoyance and trouble. If the bell-trap is to be used at all in sinks, it should be made very considerably larger, of better form, and with fixed bell, even if the grating be moveable; but as under these circumstances the cost would be three or four times that of the syphon, with no single advantage, its discontinuance altogether may be safely advised. It appears to be thought necessary to apply the principle of the bell-trap to the heads of gully-shoots from streets as well as roads, to detain silt and other detritus, apt to be carried from the surface in excessive quantities; but in streets care should be taken, by means of the water-jet, to change the water, and cleanse them frequently.

Various forms and sizes of syphon-traps are shown in drawings No. 13 and 14, all of which would be useful under varying circumstances. Economy and advantage would arise from the use of the double and triple syphons shown in the drawing No. 14, where the various branches could be readily conducted to one point. This may very frequently be accomplished.



At A in the sketch the rain-water pipe, kitchen-sink, and yard-drain would be all trapped by one syphon; an arrangement cheaper and more efficient than the adoption of separate syphons to every branch. While the drains are thus quite as effectually trapped, their combined action upon one point affords greater security for keeping the syphon clear, the water frequently renewed, and the trap at all times charged.

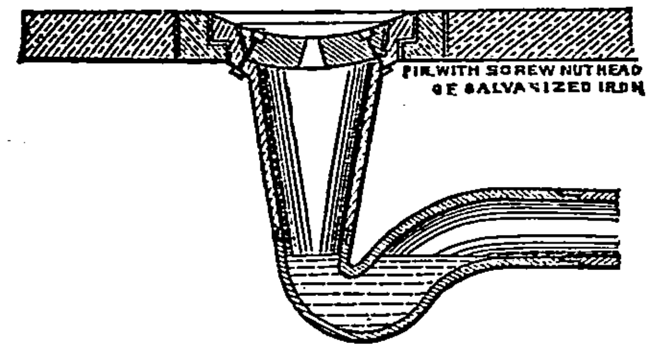
* This objection does not apply to a form of this trap patented by Mr. Lowe.

On looking at the extraordinary substances that are now and then found in the sewers—rags, bottles, broken china, cloths, brushes, and other matters,—apprehension is frequently expressed that small drains never can be successful: but when it is seen that not the slightest precaution is taken to guard against the admission of such improper substances, it is wonderful that so little solid matter of this kind finds its way into the sewers. There is scarcely a single opening in the present house-drainage that is permanently protected. The gratings and sink-stones of yards and areas are often either entirely loose, or so placed that they may easily be made so. The bell-traps of sinks are almost invariably separate, and are often opened by servants in order that the solid matter may with greater facility be sent down the drain. Rain-water heads have seldom any fixed protection, and lumps of mortar, tile, slate, and rubbish frequently enter them.

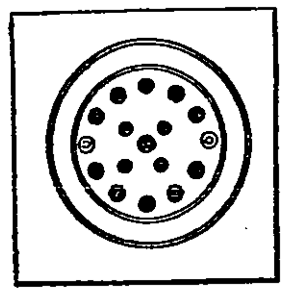
It is, therefore, recommended that for the future no drain whatever should be allowed to be without a perfect protection to every opening, that the protections should be so secured and arranged as to be immovable, and the drains rendered inaccessible for surreptitious and improper purposes. The ordinary form of water-closet in the better class of houses is found a ready opening for servants to dispose of inconvenient articles, and the practice of throwing matters down them is sometimes an amusing pastime for mischievous children. As the pan-basin is for the most part used without any security against such an evil, it is to be expected that such abuses should be met with.

Where the syphon-trap is used alone, as in the poorer class of houses, it will be essential that the opening should be as small as possible, and that the syphon should be sufficiently far from the opening to prevent substances being introduced by hand, by mischievously-disposed persons. A 3-inch syphon, communicating with a 4-inch drain-pipe, will be found a safe arrangement, when the syphon is near the pan. Nothing would then pass but such matters as would be carried through by the force of the water, and no danger need be apprehended. As the traps themselves, however, might frequently get choked by substances thrown down (especially in the first instance, before tenants became aware of the inconvenience to themselves), the traps should be accessible to the workmen of the Local Board without great labour or inconvenience. It is therefore suggested that a cap should in all cases be adapted to them, but not readily removable, lest improper substances should in that way be surreptitiously introduced.

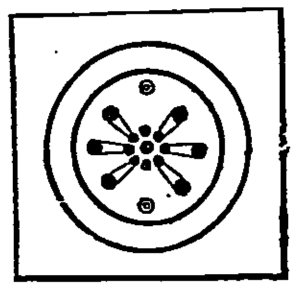
The following drawings exhibit forms of stoneware heads and inlets to drains, for use in yards, areas, sculleries, and other similar places, with the covers so arranged as not to be readily removed. The holes or openings of discharge should be so small on the upper surface as practically to answer the purpose of preventing the entrance of obstructing substances, and should be enlarged or countersunk beneath, to the extent that the substance of the material will allow, in order to prevent the clogging of the aperture. Gratings, or covers with slits, or long openings, through which sticks and flat substances likely to choke the drain would readily pass, should be avoided.



PERFORATED STRAINER



CHANNELED & PERFORATED STRAINER



The drawings at pages 116, 117, and 118 show different kinds of kitchen-sinks, or wash-hand-stands of stoneware for bed-rooms or chambers; but other sizes and forms may be manufactured, as convenience or taste may dictate. The branch-drain from the kitchen sink is that which at all times would probably be the most liable to stoppage, by reason of the grease and small refuse matters constantly discharged from culinary operations. Especial care should be taken, therefore, to guard against this difficulty. The sink-holes should be small and well countersunk, but they should be much more numerous than they usually are, and the strainer should be invariably a fixture. Bell-traps should be disused where syphons are put in, as they impede the force of the discharge, and are themselves constantly liable to become choked. Where single syphons are used, they should be no larger than the waste-pipe of the sink with which they are connected otherwise the force of the water is destroyed. They should be placed near the floor, where they would be sufficiently removed for the water to acquire a flushing

power, and yet not so distant that the greasy water would be cooled before reaching the syphon and be deposited within it.

With drains well constructed and their inlets properly secured, stoppages will be very rare; but in case of accident, all appliances should be immediately at hand for the removal of obstructions, on application being made to the surveyor. For this purpose an important use might be made of the water supply-pipes. By having a length of flexible tube, which could be readily attached to any tap and applied to the inlet of the obstructed drain, when that inlet is at a distance from the tap, the whole pressure of the column of water in the supply-pipes might be brought to bear in any drain, and a most powerful auxiliary obtained for clearing it.

As a general rule, however, it is desirable that the taps should be so placed as to act directly upon every inlet of drain that may be likely to receive any substance capable of causing a stoppage.

Provisions for the Supply of pure Water into, and the Removal of foul or waste Water from upper Rooms and Flats, or separate Tenements in Houses.

The same sanitary reasons for the removal of all foul water and refuse from the lower parts of houses in towns, suggest that it should be as constantly removed from all upper rooms. Indeed, the larger houses occupied by separate families, in floors or flats, (and far too extensively in single roomed separate tenements,) are to be considered and treated as elevated courts or alleys, the staircase as a common passage, and each distinct occupancy, whether floor or single room, as a separate tenement, and each should have at least its water supply-pipe and sink, or waste and return pipe.

The retention of waste water in such rooms until it may be convenient for the occupant to remove it, is a great sanitary evil. The mother may be sick or unable to carry down waste water, and, as a consequence, impurities are retained just at the time when the condition of the inmates renders them most noxious. The superior salubrity and comfort of the rooms in the model lodgings and dwellings is in a great part ascribable to the conveniences of sinks, as well as to the water supply contained in each set of rooms. Under circumstances ordinarily advantageous, a water-pipe may be carried into every separate room or tenement, giving a constant water supply, and a convenient sink may be fixed up and maintained in good action, at an expense of from 1*d*. to 2*d*. a week.

If a poor woman can occupy herself with any of the worst-paid labour, even making shirts, and can obtain upon the upper floor occupied by herself and family, an abundance of pure water,—a hundred pailsful carried to the top of the highest house, if they choose to use it, for 1*d*., and, for the like payment, the removal of the waste water,—it becomes an extravagant waste of time and labour, *i. e.*, money, on her part, to fetch water from the ground floor, even if she could obtain it and the use of the pump gratis; and, so in respect to the economy of carrying down stairs the foul or waste water. The labour of carrying water up and of carrying slops down, is a great impediment to the free use of water, and a great discouragement to cleanliness.

The proposal to lay on water into separate rooms may excite surprise, and it will be alleged that it is not demanded by the tenants; and it is perfectly true that poor tenants have little idea of the practicability of such conveniences until they learn that they are introduced at a cheap rate, and with much advantage to health and comfort, into model dwellings and lodging-houses. As a general principle, it may be repeated, as stated in the Sanitary Report of 1842,—

"The interposition of the labour of going out and bringing home water from a distance acts as an obstacle to the formation of better habits; and it is an important principle to be borne in mind, that, in the actual condition of the lower classes, conveniences of this description must precede and form the habits. It is in vain to expect of the great majority of them that the disposition, still less the habits, will precede or anticipate and create the conveniences. Even with persons of a higher condition the habits are generally dependent on the conveniences; and it is observed, that when the supplies of water into the houses of persons of the middle class are cut off, by the pipes being frozen, and when it is necessary to send for water to a distance, the house cleansings and washings are diminished by the inconvenience; and every presumption is afforded, that if it were at all times requisite to send to a distance for water, and in all weathers, their habits of household cleanliness would be deteriorated.

"In Paris and other towns, where the middle classes have not the advantage of supplies of water brought into the houses, the general habits of household and personal cleanliness are inferior to those of the inhabitants of towns who do enjoy the advantage.

"The whole family of the labouring man in the manufacturing towns rise early, before daylight in winter-time, to go to their work; they toil hard, and they return to their homes late at night. It is a serious inconvenience as well as discomfort to them to have to fetch water at a distance out of doors from the pump or the river on every occasion that it may be wanted, whether it may be in cold, in rain, or in snow. The minor comforts of cleanliness are, of course, foregone, to avoid the immediate and greater discomforts of having to fetch the water."

These necessities as to the drainage of houses and rooms, have, however, been perceived at periods of less civilization. Mr. Layard found at Nineveh, drain-pipes laid from single rooms, leading towards what was presumed to be a general system of sewers. Drains are found from the *rooms* of Roman edifices, particularly from the tesselated pavements of the hollow floors of dwelling-rooms as well as of baths. Vitruvius gives instructions for the construction of these floors with an incline, that the waste water might run off to the sink or the drain provided.

In the higher classes of houses, pipe distribution of water into separate floors and into separate rooms, with proper return pipes, is not less economical of the labour and time of servants. In a first-class house almost the entire service of one servant may often be saved by proper arrangement of distributory and return apparatus. Where these conveniences are introduced *de novo*, even in the poorest houses, an increased rent will be justified and obtained for them. It is improper, indeed, to represent these works as burthens to any one; they are, when efficient, means to the reduction of existing burthens, and will be willingly paid for by those who are benefited, namely, the occupiers.* It will be a proper course for Local Boards to effect these objects, by private improvement rates and distributed charges. An obstacle to such arrangements is, the trouble they give to the officers, who, especially the older officers, are therefore apt to avail themselves of technical difficulties for avoiding them.

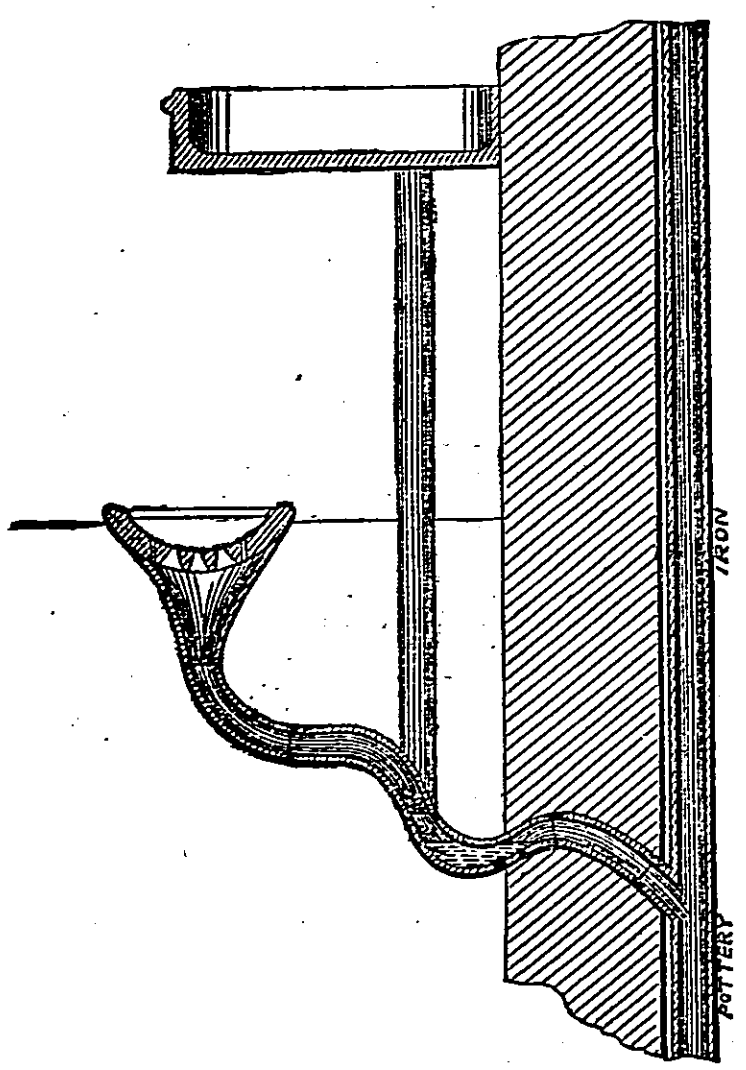
A labourer at Barnard Castle, having been told that the cost of laying on water to the upper floor, which he occupied, would be $\frac{3}{4}$*d.* a week, and being asked if he would pay it, with a proper spirit, replied, "Do you think I would make my wife a beast of burden for the sake of three farthings a week?"

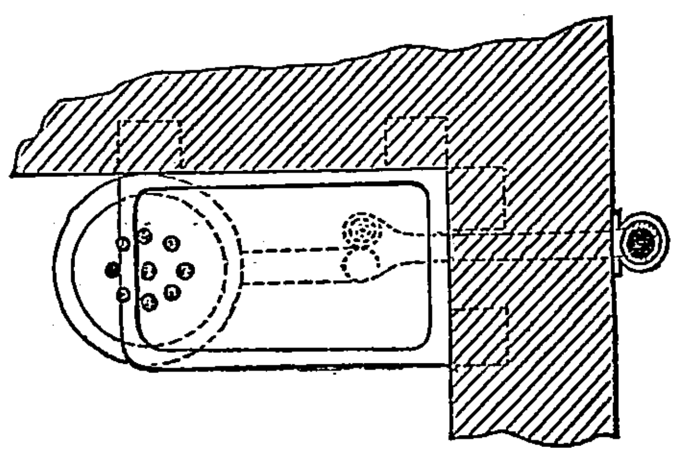
* It has repeatedly happened, that improvements increasing the healthfulness of dwellings have been amply paid for, not by increased rents, but by rents better paid; for the sickness or death of a tenant is one of the most frequent causes of a landlord's loss of rent.

Supplying water to any part of the population by means of public stand-pipes should be entirely discontinued, for they act as discouragements to the proper provision of water for the poorer class of houses, which ought to be supplied individually. The supply obtained from stand-pipes is very generally insufficient, and the waste excessive, while resorting to them is attended with great inconvenience, and leads to constant disputes and quarrelling. These objections do not apply to a provision of drinking-water to wayfarers, by means of very small self-closing taps, nor to troughs kept full of water for horses, cattle, dogs, &c., which animals suffer much in towns for want of water in hot weather.

Earthenware sinks may be made cheaper than stone ones, and harder than those of common stone. They are better shaped, have more complete traps, and can be made more sightly, and be more easily and completely cleansed. The waste-pipes to the sinks may have plugs, or washers, as well as syphon-traps.

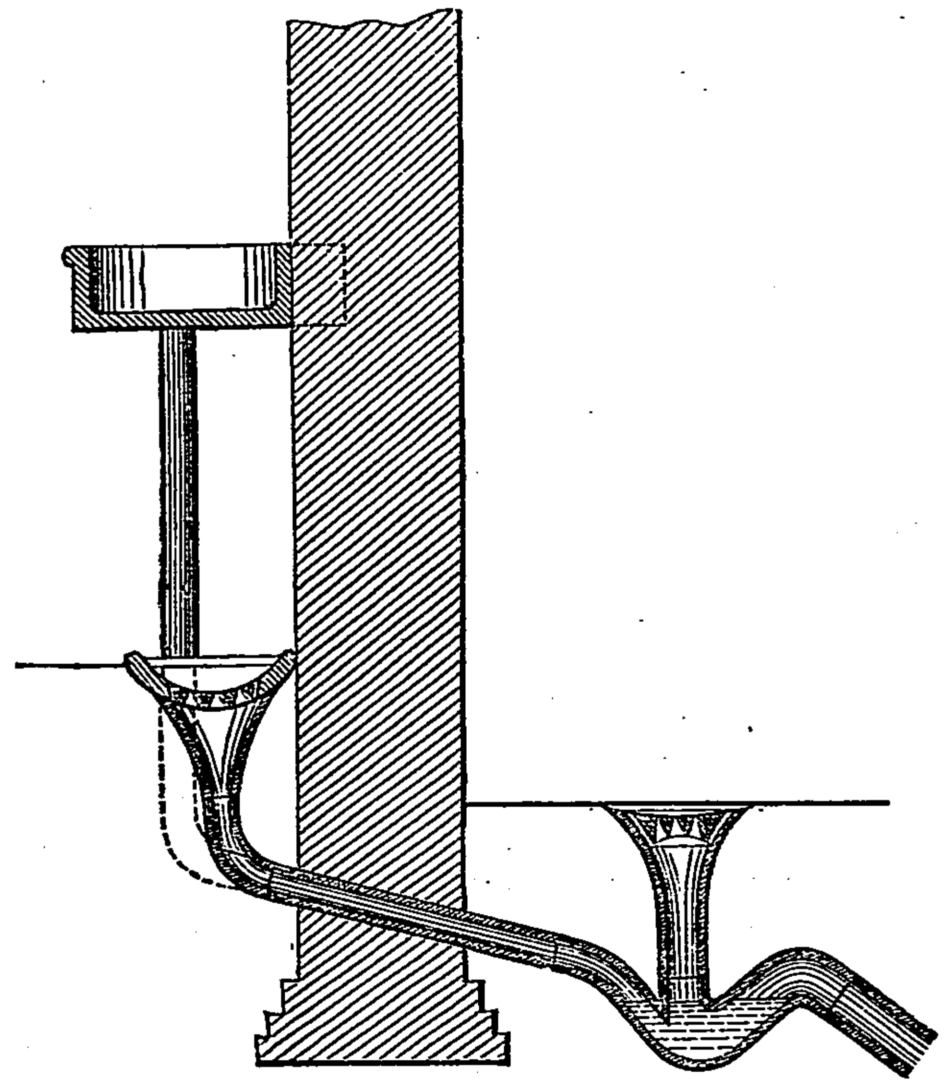
Where sinks in upper rooms communicate with vertical main drain-pipes which receive the waste water of several departments, it is desirable to have a plug for each opening. At the foot of the sink there should be a syphon-trap in addition, as in the annexed section:—



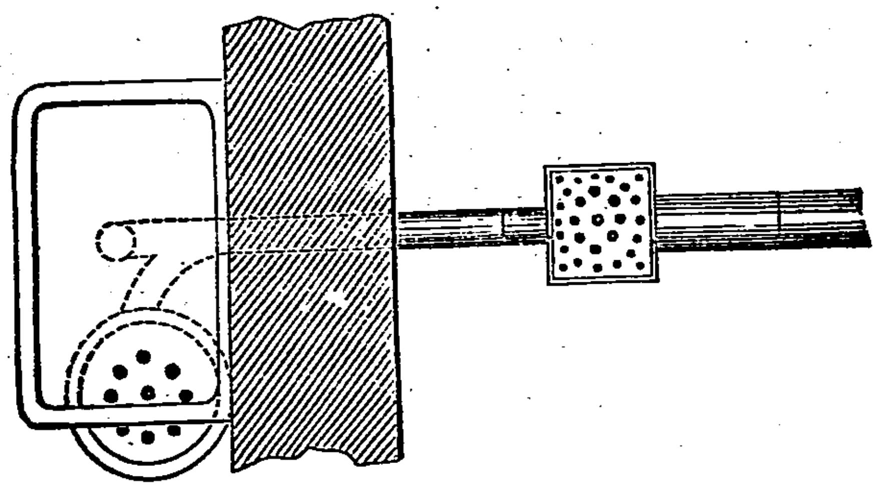


It is not an eligible arrangement to have the evaporating surface, even of a syphon-trap, opening into a bedroom or a dwelling-room, although that may be better than having the whole of the waste water itself there. Under a proper system of drainage, there will be no such pressure of noxious gases as there now is from the drains of deposit, or from the sewers of deposit, or other forms of cesspools, with which the house-drains communicate. There may still be ascending vapours from the stains on the sides of pipes, which, however slight, should be kept out by having a superior exit provided for them, so as to avoid their bearing upon the upper orifices.*

The sinks in rooms will be used for washing upon, and in bedrooms as wash-hand-stands. As it is inconvenient to lift tubs of water or baths used for washing children, it will be proper for that and other purposes to have a second sink at the foot of the stand, as shown in the subjoined plan:—



* The dust-shafts in the model dwellings are found to need alteration, so as to avoid inconvenience from escape of effluvia into the rooms from the heaps beneath, which are improperly kept upon the premises for several days by the authorities at present charged with that portion of the arrangements for town-cleansing. The inconvenience would be diminished if the dust-flues had superior openings, so as to lead the emanations above the roofs, away from the habitations. But this, though it would dilute, would not prevent the emanations, which can only be done by avoiding the retention of refuse.



The water service-pipe should be of small bore, and made of tin, glass, earthenware, or other innocuous material; and self-closing valve-taps, though a little more expensive at first, will be found economical by preventing the waste of water from carelessness.*

Provision for the frequent Removal of Solid Refuse from Dwellings.

In several places the General Board provided, during the continuance of the Diseases Prevention Act, for enforcing as a regulation the daily removal of refuse; and they are of opinion, as already stated in the circular on the cleansing of towns, that such a regulation ought to be made permanent. It is a common practice to throw into the dust-bin, along with coal-ashes, the garbage of meat, fish, bones, cabbage-leaves, and vegetables, which are apt to pass rapidly into

* In many cases it would be inconvenient, and in all expensive, to conceal from view pipes carried into the upper rooms of old houses, if so large as those usually employed for the conveyance of water. To avoid this cost and inconvenience, Mr. Holland has suggested the substitution of very small pipes, one eighth of an inch in diameter, or less, through which an ample supply of *filtered* water might be delivered; but as the rate of discharge would be inconveniently slow, he proposes to provide an air-tight vessel, into which the water would enter until the air contained is so far compressed as to balance the pressure of the water. On the tap being opened the water will be driven out by the air-spring as rapidly as if supplied by a pipe as large as the plug-hole of the tap. It is necessary that the air-vessel shall be large enough to contain as much water as will be required at once; it will gradually fill again between the intervals of drawing, and in a few minutes a fresh supply may be obtained. The water, being in an air-tight vessel, is not exposed to any risk of pollution. The pipes need not be larger than a tobacco pipe, and may be made of earthenware, glass, gutta percha, or other incorrodible material. Such pipes are very inexpensive, and may be concealed as easily as bell-wires.

decomposition, in which state they become alike offensive and injurious; and it is this bad practice which renders frequent removal indispensable. Dust-heaps, containing such garbage, are the usual sources of flies and other insects which infest the interior of houses, betoken impurity of the air, and befoul meat, provisions, and furniture. The refuse is sometimes thrown into cellars, and allowed to collect for months together, or it is cast into the privies and cesspools. Although this is not a subject directly connected with house-drainage, it is an essential consideration with respect to the health of the population, and one especially demanding proper provision in order to secure the house-drains and their appliances from improper usage; for it is highly probable that, in these confined spots, where cesspools are now improperly used as dust-bins, if no other convenience were afforded, the water-closet basins would too often become (at all events in the first instance, and as far as they could be used for such a purpose) the dust-bins hereafter, and that considerable expense, annoyance, and trouble would ensue in emptying and cleansing them.* By proper arrangements, the time and labour of more frequent collection and removal of such refuse may be greatly diminished. Increased frequency of collection causes no addition to the bulk to be carted away, or within certain limits, to the expense of cartage, and under proper arrangements, frequent removals, from house to house, need be little more expensive than infrequent removals of larger quantities from houses, made at a distance from each other. The cost of collecting might be diminished by providing moveable dust bins or boxes capable of holding the usual accumulation between the intervals of the cart being sent round, the box being lifted at once into the cart, so as to avoid the dust and dirt occasioned by filling the dust into baskets, and throwing the contents into the cart in the

* In houses where the separate floors are let to different families, arrangements might frequently be made for providing dust-shafts, much to the comfort and health of the inhabitants. This provision has, in the model dwellings and lodging-houses been found to be a very great boon to the poor, and is duly appreciated. It is yet an inconvenience in those dwellings that the dust is not more frequently removed by the dustmen from the bottom of the shaft, *vide ante*, p. 116. The evils and inconveniences which the population suffer from accumulations of refuse are sorely oppressive; and the proverbial insolence and neglect of dustmen, often only to be overcome by bribes, amount to a direct tax upon the poor tenants, who, when they have scarcely wherewithal to buy bread, are found clubbing their halfpence together as inducements to these men to do their duty.

street, arrangements being made for changing the full receptacle for an empty one, at such short intervals as may be found most convenient. The dust-boxes may be advantageously provided by the Local Board, otherwise they will not all be of convenient or uniform size, and cannot, therefore, be packed so closely in the cart in which they are carried; while it would be difficult to avoid occasions for dispute if the boxes belonged to private individuals; besides, they can be supplied more cheaply in large numbers than singly.* The byelaws may, therefore, properly provide—

That ashes and other kinds of refuse shall be placed ready for removal at the times appointed, such refuse being put into a convenient receptacle, ready to be given to the dustman when the dust-cart passes by.

That no dust or dirt shall be thrown on the surface of any court, yard, or passage, or out upon the footpath, or swept into the street during the day, after such shall have been cleansed, persons being required to retain all such refuse until the next time the scavenger passes.

In respect to the cleansing of stables, a provision for the constant removal of dung should be made, similar to that for the removal of house refuse. Mews and quarters where horses and cattle are kept in towns, are often what have been properly called "fever nests," to which the attention of the General Board has been strongly directed, and evidence has been received from eminent veterinary surgeons that frequent and complete cleansing, and other sanitary measures, are as important and economical for cattle as for human beings. The stable-keeper who permits stable-dung to accumulate and rot in or near the stables, until he can dispose of it in a heap, is generally guilty of a false economy. Late reports of agricultural associations have incontestably proved that disease and epidemics amongst cattle are most rife in filthy, close, ill-cleansed, and ill-ventilated byres and stables. The pallid complexion and low health so

* A dust-shaft, or even box, beneath the ashpit of the kitchen fire, covered by a grid to prevent the entrance of coals or cinders, saves fuel considerably, and prevents much of the annoyance of dust-bins. It has been proposed to add to this a receptacle in which vegetable refuse may be placed to dry, the vapours from which would pass up the dust-flue into the chimney, and the dried remains might be burnt. Such arrangements would greatly reduce the quantity and the offensiveness of refuse to be carried away. It would be wise for those who keep horses at livery to be more careful than they usually are in choosing stables which are kept in a salubrious condition.

common among stable-keepers denote the unwholesomeness of the atmosphere thus created. Whatsoever may be the farmer's usual practice as to the fetching of dung, its accumulation in the vicinity of crowded dwellings should be rigorously prevented, and provision should be made for its due removal by the scavengers appointed under the Local Board. The detention of dung until it dries, giving off offensive gas, to the pollution of the air, is moreover injurious to the dung itself, for many farmers have now become aware that recent, or, as they call it, "fresh dung," is the most powerful as manure, and they will therefore pay more for it.

But were the interest of stable-keepers, in having perfect cleansing, less in accordance with that of the town, as no one has any right so to conduct his business as to make it annoying and injurious to others; no accumulations of dung near dwellings ought, therefore, to be permitted beyond what can be contained in a covered receptacle of limited dimensions, provided with a trapped drain to carry off the liquid manure, and emptied at short intervals.

The occupiers of stables and slaughter-houses, who are in the habit of what they call "saving" the manure, that is, keeping it a long time, at such real expenses as those adverted to, may object to frequent removals of refuse as interfering with their means of selling it. If they choose to retain such accumulations in disregard of the health of their own servants and the condition of their cattle, they should not be allowed to to do so to the annoyance of other inhabitants and the injury of the public health. But owners of such refuse would, for the reasons already given, find it to their interest to remove it more frequently, and an arrangement might be made with the contractor to make for it a fair allowance.

The retention of decomposing refuse in slaughter-houses, and the neglect by butchers of frequent and complete cleansing, is also proved to be not only dangerous to health, but even, in a pecuniary sense, an error. Offensive odours, and a close and stagnant atmosphere, injure the quality of meat, dispose it to taint, and promote its rapid putrefaction. It has been demonstrated, that meat killed in slaughter-houses where a degree of cleanliness and freshness is maintained above the average, "keeps" beyond the ordinary time; whilst meat killed in slaughter-houses where there is excessive filth and closeness, becomes sooner tainted, occasioning great loss. Professor Owen has pointed out that,—

"Another advantage (of well-conducted slaughter-houses) was, that the butcher, getting the meat in better condition, was able to keep it fresh much longer than it could generally be kept in London. I have seen in Clare Market fine joints of meat thrown on the offal heap, and carted away in thirty hours after the slaughter of the animal; this had been the case with carcases which had been suspended for only one night in the tainted atmosphere of the slaughter-house. The owners of these places appeared not to know that a piece of fresh meat placed within the atmosphere of tainted meat would rapidly partake of the corruption, and seemed also not to be aware that their filth and ignorance combined to make them pay a large fine out of their own pockets, in the shape of meat thrown away, if it could not be forced by its cheapness on the poor inhabitants of the district."

The dung in slaughter-houses, the blood, and much of the garbage heretofore removed by hand, might be removed by convenient apparatus on the principle of a water-closet. For this purpose arrangements should be made for easy access to one of the branch or main lines of sewer, having an adequate flow of water, for the removal of most of the manure which is now collected and removed by cartage. By such arrangement, almost all, if not literally all, filth liable to decomposition, that is, liable to become annoying and injurious, might be at once got rid of, leaving scarcely anything but coal-ashes and perfectly dry substances to be removed by hand.

Similar means would be applicable, to a considerable extent, for the removal of the remains of fish and other garbage, and the cleansing of markets, as well as for the removal of dung and the cleansing of stables.

It should be the duty of the inspector of nuisances, or of some other officer under the direction of the surveyor, to communicate information to stable-keepers, fishmongers, and other inhabitants as to the conveniences available for such purposes, and to give instruction as to their use; the object being not to increase labour and trouble, but to diminish them as much as possible. All practicable conveniences should be provided, and full information given, before attempts for the enforcement of a change by means of penalties are resorted to.

The Local Board may fairly provide, as a byelaw, that the cleansing of the interior of all yards and premises whatever shall be so frequent and complete as to prevent any offensive odours being diffused, so as to be perceptible to the neighbours or passers-by.

Public Conveniences.

It will be the duty of Local Boards of Health to provide public water-closets and public urinals, as important means of preventing the deposit of filth on the surface of the streets or on walls. Such conveniences may be considered as indirect means of surface cleansing, and should be erected near markets and places of large resort, as good at least as those provided at railway stations, or with improved construction, giving more light and air, and better means of cleanliness, and placed under proper care. Public water-closets should be examples of the most perfect cleanliness and freedom from offensive odour. In some places an arrangement has been sanctioned of a small payment for a superior order of accommodation.

The Surface cleansing of Streets and Edifices.

One important mode of applying the principle of the removal of all town refuse in suspension in water, is that of cleansing streets by means of the jet d'eau.

The broom without water loosens and removes a large proportion of the indurated filth; but in some states of weather it smears and spreads ordure, and increases the surface evaporation from it, leaving the filth between the interstices of stones untouched. In dry weather, it raises dust; and the operation of street cleansing by sweeping alone is very incomplete.

The cleansing by jet is, on the contrary, complete; it cleans interstices and removes everything. Slight showers soften the surface dung and dirt of streets, and render it adhesive. A proper jet scours and clears all perfectly away. Properly applied, it leaves neither loose mud nor puddles of stagnant water; it moreover scours away the filth from side walls,* and may be used to

* Mr. Seymour Tremenheere, in his Notes on Public Subjects in the United States, p. 108, thus describes the improvements in the supply of water in American towns, and the usual process of applying the jet:—"The luxury of cold water is one which certain of the great companies seem to think unnatural to man; of cold water, at least, in abundance and purity. It is rather tantalizing to one who leaves London in the beginning of August to find himself in ten days in cities across the Atlantic where bath-rooms are almost as numerous as bed-rooms in every private house of any pretensions to comfort, that even a moderate competency can command, and where the purest water is let in at the highest habitable part of every building in unlimited quantity and for a most moderate payment. It is somewhat amusing, too, to see the Irish maidens in Philadelphia (in their usual vocation of housemaids there as elsewhere) tripping out in the early morning upon the broad brick foot-pavements, and screwing a small hose of an inch in diameter to a brass cock concealed under a little iron plate near the kerbstone; then, with an air of command over the refreshing element,

clean the fronts of houses. When applied by means of fire-engines, during the prevalence of cholera, to the cleansing of close courts and alleys, there was a decided check given to the virulence of the disease. When used in such courts and alleys in sultry weather, the effect is most grateful to the senses. The operation of cleansing by the jet is far more rapid than by hand-sweeping, or even than sweeping by machine, and is less expensive by nearly one half than hand-sweeping. The apparatus is, moreover, available for the extinction of fires in towns more rapidly and effectually than by any other known means; and where skill in its use has been acquired, losses and risks from fires have been diminished more than one half. The hose and jet is also an important means of removing any stoppages from house-drains and pipe-sewers.

For such cleansing, no less than for the proper sanitary condition of the dwellings, the existence of a good surface pavement is presumed. The available experience for the construction and pavement of courts, alleys, streets, and roads, will form the subject of separate minutes of information; but it may be observed here, that unpaved and uncleansed surfaces near crowded habitations, especially in closed courts, back-yards, passages, and other close and ill-ventilated localities, are often more noxious in their influence on the health of the population, even than cesspools. Where the surface is unpaved, it becomes the depository of

directing a copious shower against the windows, shutters, front door, white marble steps, elegant iron railing, green shrubs, small and much-cherished grass-plot, heavy-blossomed creepers hanging on neat trellis-work, and finally upon the graceful acacias, or the silver maple, or the alanthus, or the mountain-ash above her head. Next advances a graver character, whose business is to 'lay the dust.' He drags after him a snake-like hose, some 50 feet long, one end of which he has screwed upon the stop-cock fixed by the side of the pavement, while from the brass pipe of the other end he throws a strong jet over the street, and to a considerable distance beyond the point at which he has arrived when he has come 'to the end of his tether;' he then removes the screw-end to the next cock, which is at the proper distance to enable him to reach by the jet from the hose the point where he left off. The jet is also eminently serviceable in cleansing streets, courts, and alleys, which can never be sufficiently purified by mere sweeping, and also for clearing out drains and sewers, and preventing accumulations which cause offensive and noxious exhalations. It is recommended for that purpose in the Report of the General Board of Health on the Supply of Water to the Metropolis (London, 1850, page 231), and experiments with it are adverted to which had been made at Sheffield and elsewhere, apparently without a knowledge of the fact of its successful and very popular use in the United States." He speaks emphatically, and in concurrence with other witnesses, of the superior "comfort and luxury of an abundant supply of fresh, sparkling, cool, and what is of more consequence than all, most agreeably soft water, in the hotels and private houses."

ordure, of animal and vegetable matter, as well as of slops and waste water. Although the emanations from the foul, wet, and miry surfaces thus occasioned are less intense than those from cesspools and drains of deposit, yet the people, and especially children, are longer exposed to them, and the evaporating surface is much wider. The most marked improvements of the general health and habits of the inhabitants of the poorest classes of houses have followed the substitution of good pavement for such miry surfaces. The surfaces should be properly levelled for surface drainage, and also channelled where necessary; but channelling is not an advantage where there is sufficient fall to the street. Impermeability to moisture, or non-absorbency, is an important quality for surface cleansing and surface washing.

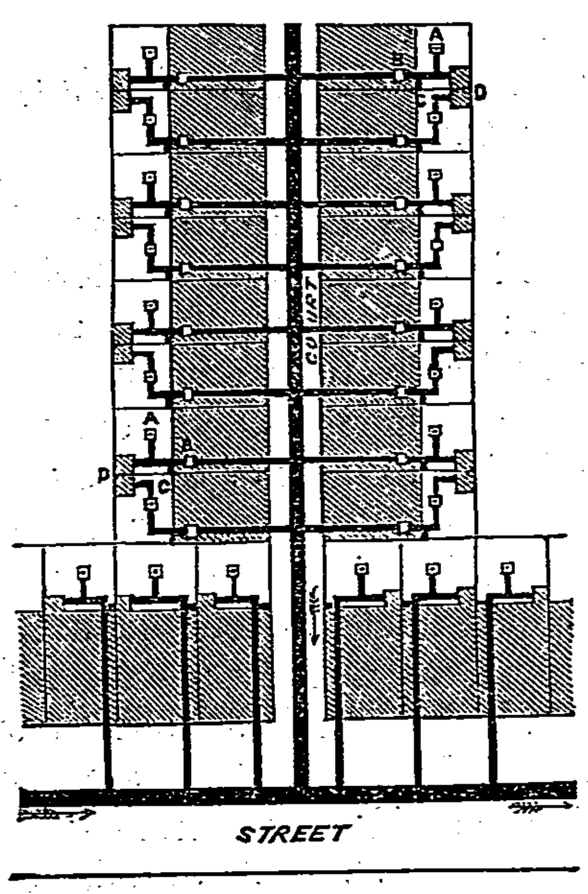
General View of combined Works of House and Town Drainage; Principle of Back Drainage.

Having described the tubular system of house drainage, the apparatus for the reception of refuse in water, and the materials, forms, sizes, inclinations, junctions, and directions of the channels for its removal, it is now desirable to exemplify some important improvements in the arrangement and connexion of branch-pipe drainage with house-drains, as part of one general system to abolish the chief sources of the filth in or near houses, and to prevent gaseous or aërial impurities in towns.

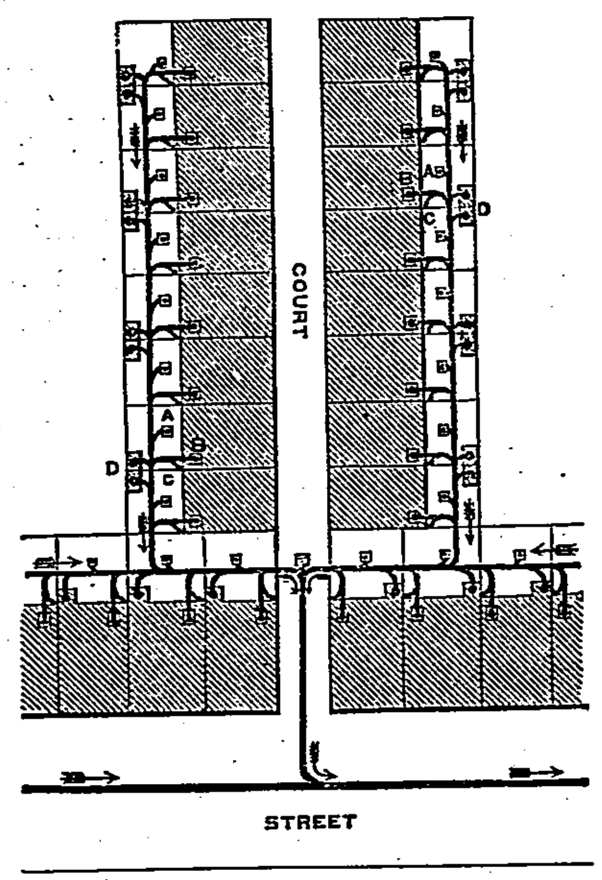
The first trials of earthenware pipes, made in consequence of the sanitary inquiries of 1842, were, as already stated, with pipes of very rude workmanship, which were laid down upon the lines of the old house-drains, carried from the back premises through each house to the sewer in the middle of the front street. Now, although the impermeable pipes (which, as first used, were more than double the proper size, and were also of unnecessary lengths and with defective falls) remove what the old permeable brick-drains detain, and keep themselves clear of deposit, without cleansing by flushing or otherwise; yet it appeared on further investigation that considerable economy of material and expense might be obtained by a closer application of the principles herein-before set forth, by adapting the capacity of the pipes to the service they have to perform, by obtaining with the shortest lengths, the best fall, by diminishing the frictional area, by concentrating the flow, and by obtaining the quickest discharge practicable, and therefore the greatest force of sweep.

The economy of materials has indeed been already shown (*vide ante*, pages 41, 42, 43,) from the application of these principles to the drainage of a single house, particularly from bringing the branch sewer itself to the back of the premises, and as near as practicable to the sinks and the several discharge-pipes, instead of taking it to the greatest distance from them, that is to say, into the centre of the streets, as was previously the general practice. The following plans display the arrangements as applied to a block of houses, or a court or alley, in contrast with the practice of the drainage of such a block of houses, or such court or alley, with a brick sewer large enough to enable a man to enter and remove the deposit:—

Old System.



Improved System.

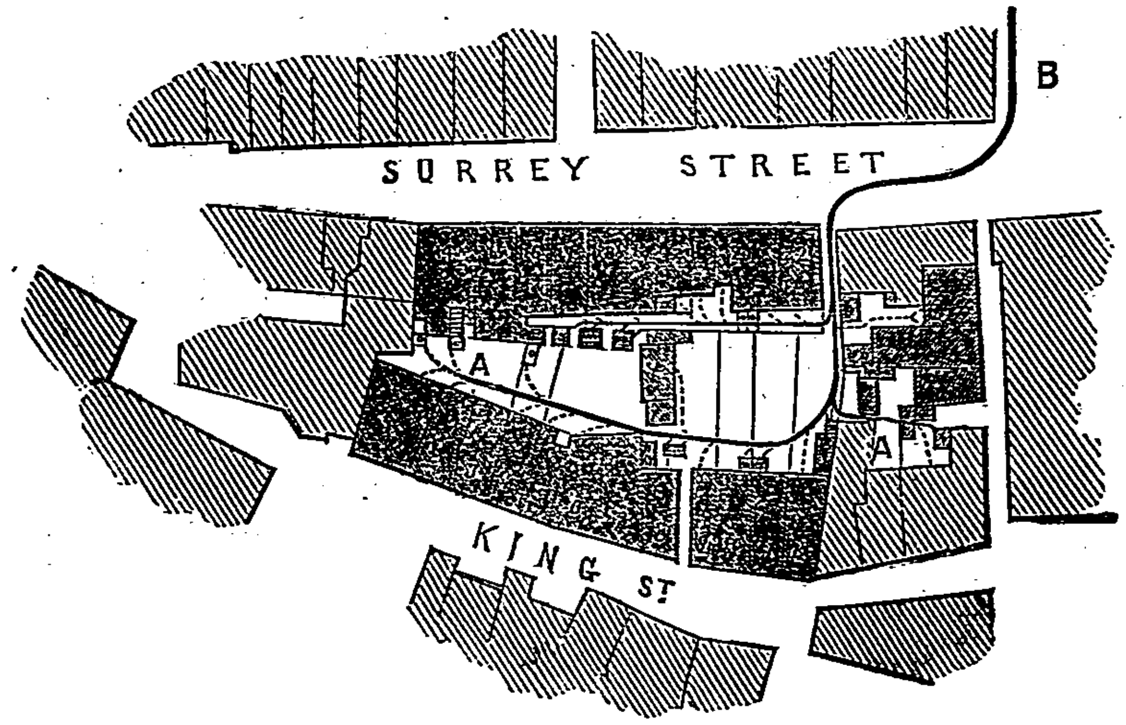


On the measurement of these two methods of house drainage, it appears that by the new arrangements the *lengths* of the whole of the drains would be as 1 to $2\frac{1}{4}$;—the *inclination* of the house-drains would be 10 times greater;—the sectional *area* of the house-drains would be one tenth;—the *inclinations* of the mains would be doubled;—the *area* of the mains would be only one thirtieth;—and the *cubic capacity* of the whole system would be reduced to one thirty-seventh.

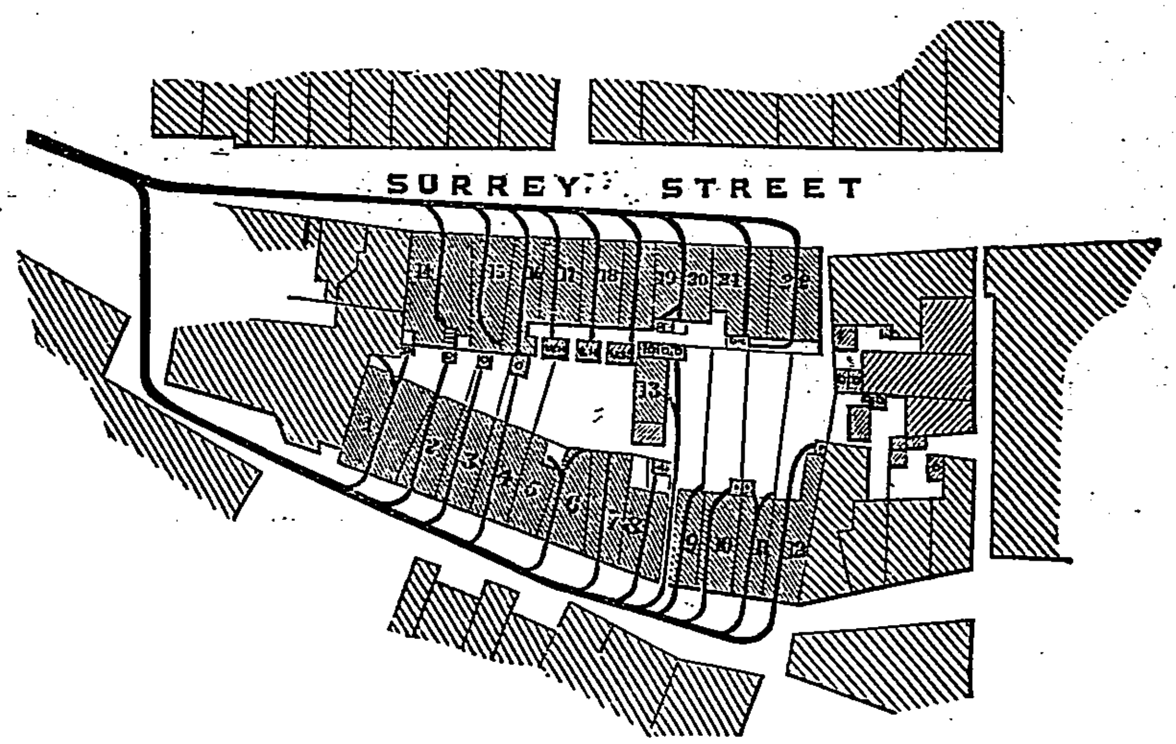
As compared with the intermediate system of tubular drainage of the houses separately, from the back premises to a sewer in front, by the improved method, refuse is cleared away from beneath the premises in at least one fourth the time, with proportionate increase of the power of sweep, by the same quantity of water.

Now, these engineering results, combined with a reduction of nearly four fifths of the previous ordinary rates of expense, are applicable, under proper management, to two thirds of the works needful for complete house and town drainage, and cleansing.

The following are varied exemplifications of this system, as executed under the Public Health Act; the first shows the plan of draining from the backs of houses, adopted for a block of houses at Croydon:—

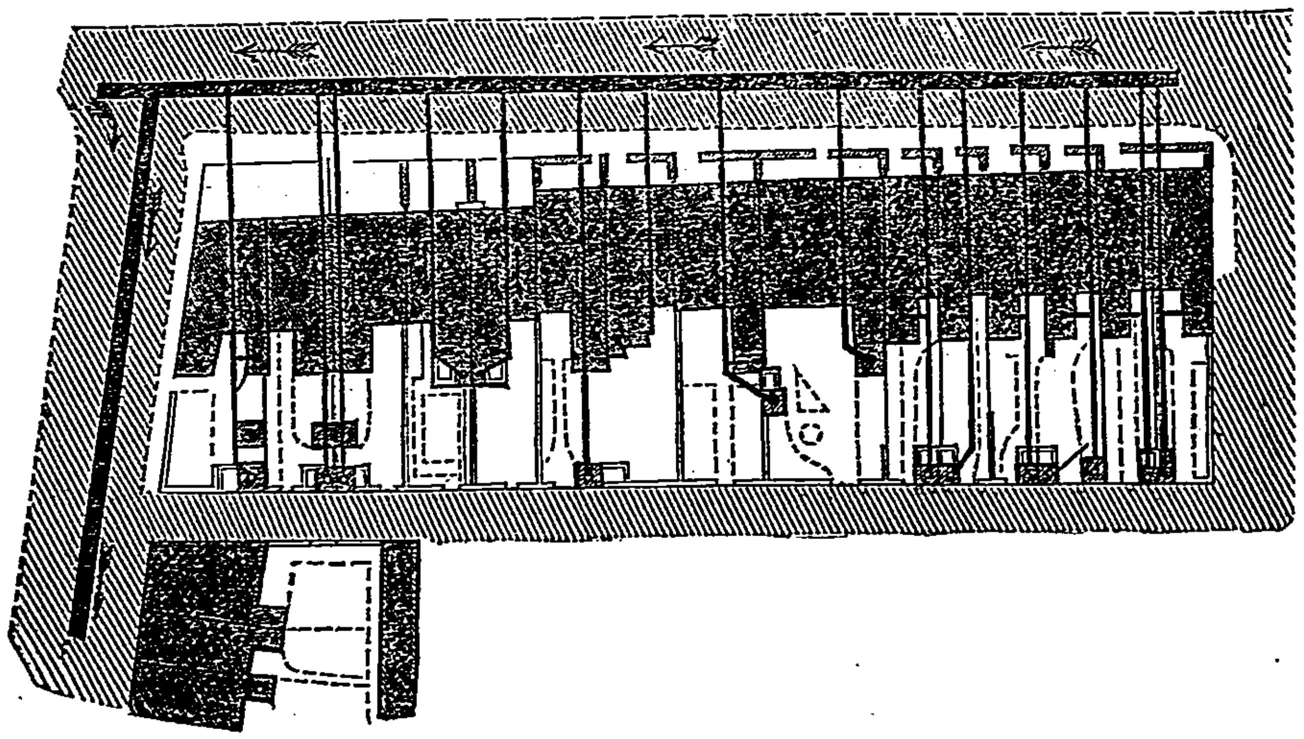


The second shows brick house-drains laid through the houses into sewers along the centre of the street, and in front of the premises, as these lines would have been laid down on the old plan for the same block of houses:—

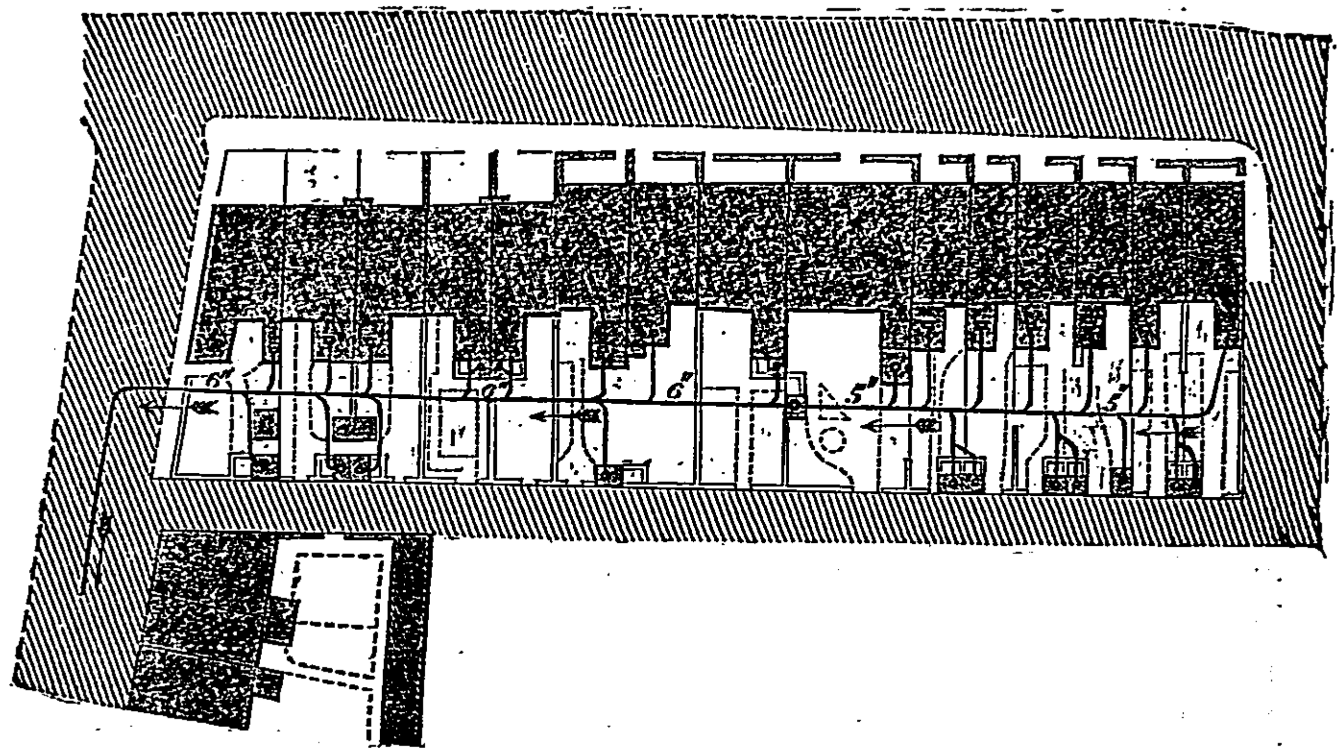


The comparative lengths and frictional areas of the channels of removal of the two systems will be evident from comparison of the two plans. It appears from the actual estimate in detail for the particular block as given by Mr. Ranger for the improved works, that the cost is an average of 2*l.* 17*s.* 10*d.* for the drainage of each of these 22 houses, and 11*s.* per house "frontage," making the total share of contribution for pipe sewerage, 3*l.* 8*s.* 10*d.* per house; for the repayment of which a rate of 1*d.* per week would suffice; whilst on the old practice of separate drainage for each house into a brick sewer carried through the centre of each street, as shown in the last plan, the proportion of payment from each house, for its frontage to the brick sewer, would have been 1*l.* 9*s.*; and the average cost per house for drainage would, according to the estimates of the quantities of materials and work, have been 5*l.* 14*s.*; making a total of 7*l.* 3*s.* each house, or more than twice as much, for the original cost, apart from the expense of cleansing and repairs.

The following comparative estimates, explanatory of the application of the same principle, have been furnished by Mr. Rammell:—



Old system of Brick-drains and Sewers carried in the fronts of houses.



Tubular Drainage from the backs of houses.

Here the comparative expense of execution, according to the lengths and quantities on the old plan of front drainage by brick sewers, would have been 8*l.* 10*s.* per house; the estimated expense of the drainage with tubular drains to the pipe-sewer at the back of the house will be 2*l.* 7*s.* 9*d.*, repayable by an annual instalment in 30 years, with interest at 5 per cent., by an improvement rate of 3*s.* 1¼*d.* per annum, or an addition of ¾*d.* weekly, to the rent.

A table is given in the Appendix, from the experience of houses already drained in this manner in the metropolis, which shows the quantities of materials and work required for single houses of each chief class. A consideration of this table may enable the owners and occupiers of houses, the members of Local Boards, and new contractors, to see their way more distinctly as to the cost for which, according to the local prices, complete works of sanitary improvement ought to be executed, contrasted with the prices of old works for houses of the same class.

Comparison of the Cost of Old separate Works of Water Supply and Brick Drainage with improved Works of Water Supply and Tubular Drainage.

	House and Main Drainage.				Water Supply.				Total cost of Old separate Works and New combined Works of water supply and drainage.		Average cost of Works for carrying water to and waste water from each additional floor.
	Works within the House, including water-closets and sinks.	Proportion of cost of main drains.	Total cost of house and main drainage, per House.	Weekly charge per House.	House apparatus.	Main service.	Total cost of house and main water service.	Weekly charge per House.	Gross charge.	Weekly charge.	
	£ s. d.	£ s. d.	£ s. d.	s. d.	£ s. d.	£ s. d.	£ s. d.	d.	£ s. d.	s. d.	£ s. d.
4th Class Cottage—											1 5 9
Old Works . .	9 3 0	7 2 6	16 5 6	0 4 7/8	7 0 9	0 15 0	7 15 9	2 1/11	24 1 3	0 7 1/4	
New Works . .	2 18 8	0 17 6	3 16 2	0 1 1/7	0 17 5	0 10 0	1 7 5	0 3/7	5 3 7	0 1 4/7	
3d Class House—											1 5 8
Old Works . .	17 15 2	8 11 0	26 6 2	0 7 7/8	19 19 0	1 2 6	21 1 6	6 1/8	47 7 8	1 2 1/6	
New Works . .	3 8 0	2 14 0	6 2 0	0 1 4/5	2 3 3	0 15 0	2 18 3	0 7/8	9 0 3	0 2 2/3	
2d Class House—											2 5 11
Old Works . .	24 8 8	12 7 6	36 16 2	0 11	27 8 3	1 13 0	29 1 3	8 3/4	65 17 5	1 7 3/4	
New Works . .	4 12 4	4 19 0	9 11 4	0 2 7/8	2 18 6	1 2 0	4 0 6	1 1/4	13 11 10	0 4 1/12	
1st Class Mansions—											2 15 11 1/4
Old Works . .	35 5 7	15 3 9	50 9 4	1 3 1/6	35 1 9	2 0 6	37 2 3	11	87 11 7	2 2 1/10	
New Works . .	4 18 0	6 1 6	10 19 6	0 3 1/4	3 13 2	1 11 6	5 4 8	1 1/3	16 4 2	0 4 6/7	

In respect to the charges for cottages it is to be observed that they include prices much beyond what sufficient works have been executed for on a large scale. For example, in the statement of particulars, 17*s*. 5*d*. is set down for service-pipes and taps; whereas it is reported that where the main has been laid close to a house, a sufficient half-inch service-pipe and tap has been put in upon large contracts for less than half that sum, and that, generally, complete works have been executed for that important class of house at 30 per cent. below the total amount set down. The cost of complete works of water supply for a cottage, (including house service-pipes of block tin instead of lead), and of complete drainage works, including a water-closet and a sink for the house,—the whole public and private charges, including the water rent, are accomplished at a charge of less than 2½*d*. per week. *Vide* particulars in the *Appendix*, p. 166.

As the estimate stands, however, in the above table, the cost of these works may be contrasted with the cost of a common pump and well, and with the original cost of a common cesspool with its repairs, which are greater in both instances than the charges for the apparatus in question.*

Where from any particular circumstances it has been found to be absolutely necessary to carry the tubular drainage from the back premises to an existing sewer in the centre of the front street, the use of the tubular pipes has generally effected a saving of one half of the former charge for brick drainage, over the same lines.

The expense of an extension of combined works, for providing water-service apparatus, and a sink or return-pipe or drain for each additional floor, is set forth in the table at 1*l*. 5*s*. 9*d*. for a cottage or a fourth-class house. This is an arrangement of great importance to the health and comfort of families occupying flats and model dwellings in towns, and one, indeed, of great economy for the higher class of houses, for which the charges would be double those stated.

Pipes of properly-made vitreous earthenware will be as durable as those found by Mr. Layard at Nineveh, or those at the Colosseum at Rome, and when they are properly laid,

* A common price for sinking a well eight yards, and steining it, is about 4*l*.; pump and wood frame 7*l*.; stone trough 1*l*.; total 12*l*.; interest and depreciation at 6½ per cent. 15*s*. 7¼*d*. per annum. The expense of wells of brick construction, is frequently 16*l*.; and the total annual expenses 1*l*. 10*d*. The average expense of a common cesspool including cleansing, repairs, and interest on capital, has been stated at 1*l*. per annum; but the original expense of water-tight cesspools for the middle class of houses is sometimes 25*l*.; and the annual cost, including interest and depreciation, 3*l*. per annum.

there are no accumulations of refuse within them. But on a house-to-house inquiry in the Metropolis, which may be taken as a fair average of the whole (*vide Report on the Supply of Water to the Metropolis*, p. 282), it appeared, in answers from nearly 8,000 householders, that the private expenses per house, (apart from the public sewers rate), upon an average of five years, was (in addition to the expense of making, repairing, and cleansing the brick sewers of deposit) as follows, with the contrast practicable where the Public Health Act is properly executed:—

	Old System. Annual Expense.			Old System. Weekly Expense.		Under the Public Health Act.
Mending and cleansing brick house-drains	0	19	$8\frac{3}{4}$	0	$4\frac{1}{2}$	abolished.
Cleansing cesspools - - -	1	0	4	0	$4\frac{3}{4}$	abolished.
Repairing water-butts, and cisterns -	0	19	2	0	$4\frac{1}{2}$	abolished.
Making house-drains - -	2	0	4			
Cost of an intermittent water-supply -	2	1	9	0	$9\frac{3}{4}$	
Cost of a constant water-supply	-	-	-	-	-	2*d.* weekly.

Thus, whilst it is perceived that up to the time of making the official investigations an intermittent supply of inferior water alone cost $9\frac{3}{4}$*d.* per week,—that mending and cleansing defective house-drains cost $4\frac{1}{2}$*d.* per week, the making of them double the sum, and cleansing cesspools $4\frac{3}{4}$*d.* per week,—in the places where combined and improved works have been executed, and the charges distributed over a term of years, on the system adopted under the Public Health Act, cesspools have been filled up, and a soil-pan apparatus substituted, and kept in good action, at little more than half the ordinary expense of cleansing a cesspool. The expense of cleansing the brick house-drains and the cesspools for four or five years, would pay the expense of properly constructed water-closets and pipe-drains for the greater number of old premises.

With respect to the comparative prices of tubular main sewers and brick sewers of the former construction, a practical illustration may be taken from the new main sewers laid down for the town of Rugby. They are of glazed stoneware, of sizes varying from 6 to 20 inches (for the trunk main), laid at depths varying from 3 to 28 feet, the average being 10 feet 6 inches; the total length, converging upon a single outfall below the town, is 6 miles 2,880 feet. The total cost, including all charges whatsoever, was under 3,600*l.*, being at the rate of 2*s.* 1*d.* per lineal foot, or about 550*l.* per mile. Now had that town been drained with brick sewers of deposit, made sufficiently large for men to cleanse them, as arranged by the late surveyor to the City of London, in three classes, and at the contract prices for such sewers as laid down by the Metro-

politan Commissioners of Sewers, the following would have been the cost of the system:—

	£	*s.*	*d.*
1st. Of brick sewer, large enough for a man to crawl through, 2 feet 6 inches high by 2 feet wide, 11,520 feet at 6*s.* - - - -	3,456	0	0
2d. Of brick sewer, large enough for a man to crouch through, 3 feet 6 inches high by 2 feet 3 inches wide, 11,520 feet at 8*s.* - - -	4,608	0	0
3d. Of brick sewer, large enough for a man to stoop through, 4 feet 6 inches high by 2 feet 6 inches wide, 11,520 feet at 12*s.* - - -	6,912	0	0
Total 6 miles 2,880 feet of brick sewer -	£14,976	0	0

But to the annual charges for this outlay, in most cases, must be added the expense of removing the accumulations of deposit, which would be at the rate of 29*l.* per mile per annum, and also the cost of dilapidations, which the subterranean survey of the metropolitan sewers proved to be considerable. Brick sewers are often cheaper in the construction than the larger sizes of tubular earthenware pipes at their present prices; but the brick sewers of the same internal diameter are dearer in action, in consequence of the current expenses attendant upon them, from their liability to choke, and from their permeability and dilapidations, than proper tubular sewers. Assuming, however, the reverse of the fact, that permeable brick and mortar sewers are permanent, and vitreous earthenware pipes perishable, the latter would be the cheaper; and without incurring any greater annual cost than for drains on the old system, the whole of those laid down at Rugby might be pulled up and renewed every four years,* and the house-drains within even a shorter period, and the occupiers would, during their continuance, enjoy an exemption from the noxious emanations arising from drains or sewers of deposit.

The expense of tubular drainage at Rugby as well as at Croydon, has been from various circumstances greater than an average. The town of Barnard Castle contains about 750 houses, and

* The annual instalment to repay 14,976*l.*, say 15,000*l.*, in 30 years, with interest at 5 per cent. per annum, is 975*l.*, which sum, added to 300*l.* a year for cleansing and repairs, would amount to an annual charge for sewerage of 1,275*l.* The annual instalment to repay 3,600*l.*, the cost of the pipe sewerage of Rugby, in four years, would be 1,015*l.* 4*s.*, to which if there be added the large sum of 180*l.* a year for repairs, the total annual cost (upon the extravagant supposition of one fourth of the pipes requiring renewal every year) would still be 80*l.* a year less than the large brick drains would cost, which according to the old practice would have been constructed.

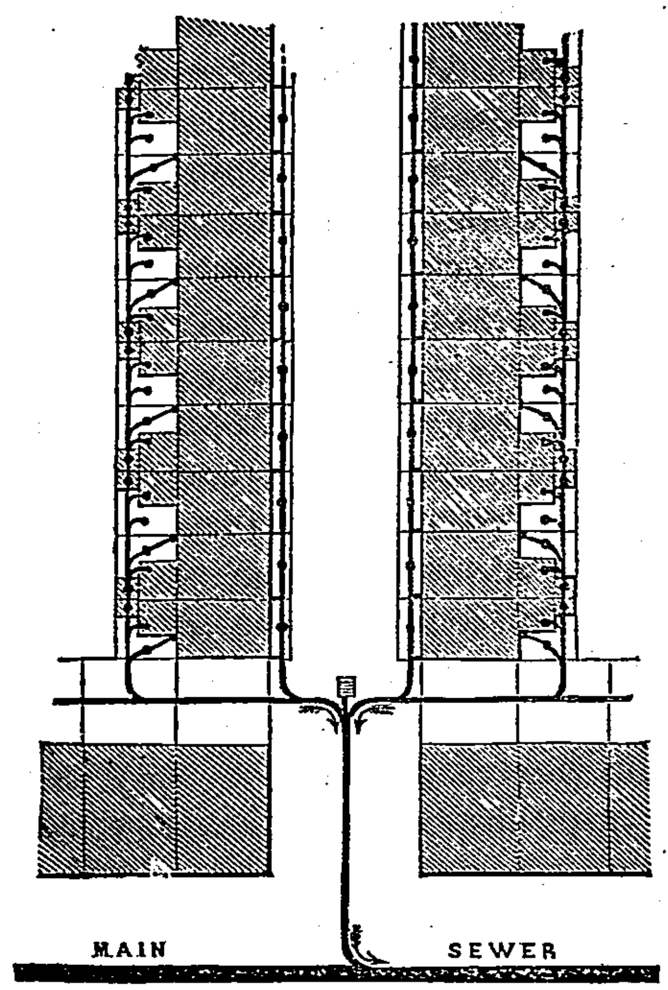
covers nearly 120 acres. It is drained under the Public Health Act, by 4 miles of pipe drain sewers, the diameters of which vary from 4 to 15 inches, at one outfall, at an average depth of from 7 to 8 feet; in some parts through rock. The average cost is 1*s.* 8*d.* per lineal foot, or 439*l.* per mile; being at the rate of 2*l.* 6*s.* 10*d.* per house, or $\frac{3}{4}d.$ per week, for main drainage. The main water supply, instead of being taken from the river Tees, according to the former practice, is collected from soft-water springs nearly five miles distant, and brought to a covered reservoir in an earthenware pipe of 9 inches diameter, and thence to the town in an iron pipe of 7 inches diameter. The water is only brought into the light in the room where it may be drawn, in a constant supply as fresh as at the spring-head. The cost will be 1·37*d.* per week per house, or for the total combined public works 2·032*d.* per house per week. For the town of Ottery St. Mary, Devon, where the water supply is similarly collected from springs, the combined works of drainage and water supply are now in the course of completion, at less than 1*d.* per house per week. For Tottenham, where the water supply is obtained from borings, and is raised by steam power, the combined works of drainage and water supply have been constructed at less than $1\frac{1}{2}d.$ per house per week. The combined works of drainage and water supply at Sandgate, which have just been completed, amount to 3*d.* per house per week. In this town the number of houses is extremely small, and their size and value above the average. For Hitchin, where spring sources are obtained, the estimate is 1*d.* for the water supply, and $\frac{3}{4}d.$ for the public drainage works: for Penrith, a like charge; all being below the average rates of charge of trading companies for separate waterworks alone. At Ely, the expense of the combined public works will be $1\frac{1}{2}d.$ per week.

The average estimated expense of other towns drained under the Public Health Act, (and the contracts have hitherto been taken within the estimates,) has been 5*s.* $4\frac{7}{8}d.$ per house per annum, or $1\frac{1}{4}d.$ per week for combined works, or $\frac{11}{16}d.$ per week for main drainage works, and $\frac{9}{16}d.$ per week for a main water supply.

It was however found in the course of the inquiry under the Sanitary Commission, that other inconveniences besides those herein-before recited, were attendant upon the common practice of town drainage; viz., the grievous disadvantages and dangers from stoppages of the public highways for road repairs. At present the perforations of sewers and the breaking up roadways from time to time, for cleansing house-drains, as well as for repairing water-pipes, are liable to be as numerous as the houses. Under the improved system of combined works of

tubular back drainage, the perforations into main sewers for the reception of house-drainage, and the occasions for breaking up the carriageway, instead of being proportionate to the number of separate houses, will often be only as the number of the blocks of houses.

Rain-water falling on the surface of the pavement in courts and alleys would be carried away as at present, by a surface channel on the pavement to a grating at the end of the court, and the drainage of sunk areas in front would be accomplished in a continuous line,* as indicated in the following plan:—



SCALE 80 FEET TO 1 INCH

One chief objection to the practice of laying branch sewers

* The arrangement by which a water-main is laid in the centre of a wide street, instead of a small main at each side, or where practicable, at the back of the premises, is illustrative of the expense caused by the separation of what ought to be parts of one arrangement. The trading companies, by laying a pipe in the centre of the street to save a small portion of their capital, occasion a much larger expenditure of capital by the ratepayers. This is exemplified in the course of an examination of Mr. Mylne, Engineer to the New River Company:—"Did the plan of comprehending the tenant's communication-pipes, and the whole machinery under one general system, (*i.e.* a plan for a new supply for Paris,) offer any advantages in respect to economy and sufficiency in laying down the iron pipes?—In a new town there would often be much public economy in laying pipes on both sides, instead of in the centre of the streets; there

at the back of houses, and draining from them, instead of of from the fronts and the centre of the streets is, that in case of the occurrence of a stoppage in a branch-pipe sewer, the stoppage may affect several houses of persons who are not to blame for having caused it. In practice, however, where the pipes have been tolerably well laid, with proper water supply, such stoppages are not found to occur; and they may not be expected to occur, because from the greater falls and more concentrated runs, they are necessarily kept more clear of any deposit or obstruction. If, however, a fault does occur in the line of the house-drain itself, it does not, as at present, affect the interior of the house, or compel the breaking up of all the lower floors, but is confined to the back premises. If a stoppage occurs in the branch sewer at the back of a house, the difficulty in getting it removed is reduced to a very trifling matter, as the surveyor will be responsible for the good working of the branch sewer, and exercise the same control in relation to it when brought to the back of the premises as when carried through to the front street.

In point of fact, however, entrance for back drainage is urged as an objection only by persons interested in existing practices, not by the people themselves, who are not so unwise as to pay for a defective drainage four or five times the expense of an efficient one, for the sake of a fallacious independence. The intrusion objected to is less annoying than that now customary; it is an intrusion on the back premises only, outside the houses, and not by any neighbour or proprietor of contiguous property exercising apparently questionable rights, but (with consent as to convenient times) by a common servant, a public and responsible officer; and the people, when left to choose for themselves, wisely prefer this to the intrusion of bricklayers inside their houses, the ripping up of floors, the cutting of joists, and the disturbance of foundations, followed by heavy bills, and continued intrusions to open up the drains when stopped, or out of repair.

The real intrusion upon privacy is therefore occasioned by the present practice of carrying drains underneath the living-rooms and through the houses; for the workmen must follow them there for repairs as for construction. By restricting their

would be saving of lead pipes; saving of repairs to these lead pipes; avoidance of inconvenience and expense of breaking up roads for that purpose; saving of inconvenience to tenants in the event of frosts, from there being less of their smaller pipes exposed. In a street of 60 feet wide, the saving of lead pipes would be about 20 feet to each tenant; that is, if the street is built upon each side, there would be 40 feet of leaden pipe saved in a house-frontage of, say, 20 feet; therefore 20 feet of iron extra would avoid the use of 40 feet of lead."

extension to the back yards, or the back offices, intrusions are confined to the parts where they must be least inconvenient and objectionable, and the dangers of accidents from want of skill, as well as the expense and inconvenience, in cutting through the walls and foundations of old houses are avoided. By laying down the drain as well as the water-pipes at the same time, in the same trenches, and carrying both, wherever practicable, through the same openings, double earthwork and other work is saved, and also double annoyances and intrusions of workpeople. By carrying the water-mains to the back premises instead of through the centres of the streets, the saving of the lengths of house service pipes and of the expense of repairs, is proportionately great to the saving of the cost of house-drains. Where soil-pans and pipe-drains, on a proper system, are laid down, and kept in action by due supplies of water, the work and the intrusion in respect to it, and the charges for cleansing and repairs, now constant, will be reduced to a mimimum.

Neither religious duty, nor the existing law, nor private, social, or public morality, recognizes the existence of private rights at the expense of the health and well-being of others. By all the recent general as well as local legislation upon the subject of the removal of filth from private premises in towns through public agency (by dust contractors and scavengers), the law is universally compulsory. It is impossible that any one person should be allowed to retain ordure, or cesspools, or filth of any kind, upon his own premises, in a town, or amidst closely-packed habitations, without polluting the common air, and thereby injuring his neighbours. And although he might be left to injure his own health, he has no right, even if he lived in a detached dwelling, to injure the health of his children, or of others dependent upon him.*

It is, moreover, most to the interest of individual occupiers, that the cleansing should be constant, complete, and to the greatest extent self-acting; that it should be done with complete regularity and economy;—which objects can only be attained by a general system, executed by a responsible and public

* In many of the Local Acts for the improvement of towns, passed prior to these investigations, the conservation of filth was carried to such an extreme as the following:—"That nothing herein contained shall extend or be construed to extend to any ashes, cinders, dust, *dirt*, manure, *filth*, soil, *dung*, or rubbish, which any of the inhabitants of the said limits shall have occasion or shall think fit to preserve, or keep within their own respective *houses*, yards, and gardens." Under the influence, however, of an enlightened public opinion, a great number of such "*Improvement*" Acts, drawn up in the most perfect ignorance of sanitary principles, have already been superseded by the provisions of the Public Health Act.

agency, that is to say, when, as under the Public Health Act, the primary works, the house service-pipes for the common water supply, the channels for the removal of the waste water, the house-drains, as well as the branch and main sewers, are managed and kept in order as parts of one general system.

It was usually the case up to the time of these investigations, and is so now in towns where the Public Health Act has not been applied, that the first notice which a householder or the owner of house property received of the construction of a sewer, intended for the service of all houses without exception, was the raising of a large earthwork in front of his house. Even when time was allowed, no provision having been made for the distribution of the charges of the new works between the various classes of owners, between lessees and tenants-at-will, yearly tenants, or weekly tenants, notices to the owners were of little avail towards voluntary adoption. Joint notices to the occupiers as well as the owners often served only as notices of a dispute between them, which there were no means provided for settling equitably and cheaply, the owner disputing the justice of the requisition for an immediate payment for a new work not expected or stipulated for at the time the tenement was let, and the occupier or the lessee objecting to the payment of the expenses of a work for permanent improvement of premises in which he had only a temporary interest. If the grounds of dispute as to the justice of the charge, or as to the legal liability were settled, separate notices to separate owners, each to drain their respective tenements, would be nevertheless notices to set about a work of which they probably know nothing, and of which, (judging from the defective state of the drainage and the extravagant cost of the drains of large public buildings, and the erroneous doctrines contained in professional books,) it is highly improbable they will be well informed by the common builders. Such notices to private owners are usually notices to them to incur expenses, to which they see no reasonable limit, and of the extent of which they may well be apprehensive.

One main cause of the very small number of house-drains voluntarily joined to the sewers in the metropolis, and in provincial towns, under the practices pursued up to the time of the official investigations, was, besides the fees, and the expenses to which the opening of the roadway and the formation of the junctions gave rise, the costs entailed by the construction of a house-drain itself, and which are yet maintained under the few local or private Acts, which contemplate house-drainage at all. When the newly-constructed sewer has been covered

up, the owner or occupier is not only put to the expense of unpaving the footpath and the roadway, and re-opening the ground in order to make his communication with the sewer; but, beyond this, by the position in which the sewer is in the front of the house, and in the middle of the street, he is, often unnecessarily, put to from four to six times more expense than need have been incurred under other arrangements; and in many cases the drainage of cellars, and the foundations of the buildings are impaired, from the length of the drain that would be necessary, while under better arrangements the public drain might have been laid of the same depth, and yet sufficient fall have been obtained to dry the foundations and cellars.

Under these circumstances a small proportion only of the houses in the poorer districts are drained into the sewers; and one of the pecuniary consequences of this restriction is, that the majority of ratepayers, who by these defective arrangements are practically excluded from the chief use of the sewers, are nevertheless compelled to contribute to the expense of the main sewerage works, from which they do not derive benefit proportionate to their share of contribution.

One engineering consequence of such defective administrative arrangement, which excludes a large proportion of the tributaries from the mains, is, that sewers receiving only a small proportion of the house-drainage for which they were intended, are deprived of the force of the sweep of water which would have kept them more clean; they receive mere dribbles; and greater deposit in the sewer is thereby occasioned, so as to increase the extent of surface constantly giving off noxious evaporation.

House-drains of deposit not only occasion smells, but lead to considerable waste of water, used, though seldom effectually, to cleanse them. By re-placing such drains by proper earthenware pipes, in which no deposit will be formed, the excessive expenditure of water for cleansing drains will be prevented, by being rendered unnecessary.

It will be the duty of the Local Board to protect the public health from the noxious influence of defective private works, as well as to protect owners and ratepayers from unnecessary exactions, which are a great source of irritation and local opposition to sanitary improvement. This may be done by the previous preparation of proper plans of house drainage and cleansing works, and previous estimates of the expense at which they may be provided, under common contracts, for private improvement rates, *i. e.* payments by annual instalments of principal with interest. (*Vide Forms* in the *Appendix.*) Such explanations should accompany the orders for filling up cesspools, and for proper drainage and cleansing of houses; and should set forth, that for what is termed a private improvement rate,—of from 1*d.* to 2*d.* per week,—for terms not exceeding thirty years,—and which will be a reduction of existing charges,—cesspools may be filled up, and complete house-drains laid down, and kept in good action and repair. The rates for which combined works may be constructed and maintained upon private premises are properly called improvement rates, for the works have been found to produce improved rentals, as compared with other properties which are destitute of them; and they, moreover, are directly remunerative in the saving of dilapidations. It should also be explained that the owner will be at liberty either to pay off the whole of the immediate outlay, or to construct the works himself, as he may think fit, provided that, before they are covered up, their efficiency in all respects shall be tested by the Board's surveyor, who must be satisfied that they are neither bad from liability to accumulations of deposit, nor from connexion with objectionable cesspools, nor are of an inclination or construction and arrangement, or in other respects, unconformable to a general system.

The policy of the Public Health Act is to diminish individual chargeability and individual trouble; and for the sake of economy, as well as efficiency, to comprehend under one system all works effected by it—works of water-supply from spring-heads to the taps in the house, and works of drainage from house-sinks, or soil-pans, to the outfalls of the trunk line of sewer; the expense of combined works within the house being defrayed by distributed charges under private improvement rates, and those common to several houses by special district rates. Formerly it was the practice to charge as much as practicable of the branch sewers, and first cost of all works carried through private lands, upon private individuals or owners. Under the Public Health Act no such immediate levies should be made, but the whole cost of the works, as in the plan (*ante*, p. 127), from A to B, should fall upon the special district rate, the dotted lines only, which form the actual private house drains, being chargeable to the individual owners.

The term "branch drains" is frequently used in relation to the tubular pipes substituted for the former brick sewers. But these branch drains are, in fact, public sewers, and part of the public system of drainage, though carried through private premises. By the Public Health Act interpretation clause the term "drain" means "any drain used for the drainage of one building only, or of premises within the same curtilage," and would include any pipe, from a single house, communicating with a sewer into which the drainage of two or more buildings or premises, occupied by different persons, is conveyed.

The word "sewer" includes "sewers and drains of every description, except drains to which the word 'drain,' interpreted as aforesaid, applies." It is within the power of Local Boards, sec. 45, to carry their sewers, after reasonable notice in writing, through any lands whatsoever, where it may appear upon the report of the surveyor to be necessary, while the expenses shall be charged upon the special district rate, by which the cost should be equally distributed over a period of years.

Conclusions.

In addition to the conclusions set forth in the Report on the Sanitary Condition of the Labouring Population, and confirmed and adopted by the Commissioners for inquiring into the means of improving the Health of Towns, namely,—

That no population living amidst aërial impurities, arising from putrid emanations from cesspools,—drains,—or sewers of deposit, can be healthy, or free from the attacks of devastating epidemics; and

That as a primary condition of salubrity, no ordure and town refuse can be permitted to remain beneath or near habitations;—and, that by no means can remedial operations be so conveniently, economically, inoffensively, and quickly effected as by the removal of all such refuse dissolved or suspended in water; may be enumerated the following:—

That it has been subsequently proved by the result of draining houses with tubular drains, in upwards of 19,000 cases, and by the trial of more than 200 miles of pipe-sewers, that the practice of constructing large brick or stone sewers for general town drainage, which detain matters passing into them in suspension in water, which accumulate deposit, and which are made large enough for men to enter them to remove the deposit by hand-labour, without reference to the area to be drained, has been in ignorance, neglect, or perversion of the above-recited principles.

That whilst sewers so constructed are productive of great injury to the public health, by the diffusion into houses and streets of the noxious products of the decomposing matter detained in them, they are wasteful from the increased expense of their construction and repair, and from the cost of ineffectual efforts to keep them free from deposit.

That the house-drains, made as they have heretofore been of absorbent brick or stone, besides detaining substances in suspension, accumulating foul deposit, and being so permeable as to permit the escape of liquid and gaseous matters, are also false in principle, and wasteful in the expense of construction, cleansing, and repair.

That it results from the experience of works constructed upon the principles developed in these inquiries, that improved tubular house-drains and sewers of the proper sizes, inclinations, and material, detain and accumulate no deposit, emit no offensive smells, and require no additional supplies of water to keep them clear.

That under a proper system of works for water supply combined with house and town drainage, such as is contemplated and sanctioned by the Public Health Act, no ordure is detained so long as to allow it to enter into advanced stages of decomposition, either in the house-drains or in the public sewers; but that all refuse is put in course of constant and inoffensive removal, at a rate of discharge of about three miles an hour.

That where the absence of a natural fall impedes the continuous removal of town refuse, and of surplus rain or spring water, an artificial fall may be obtained by steam power, at a rate of cost (on a scale for a large district) which is inconsiderable compared with the evils it would obviate; and that, at such rate of cost, or from 1*s.* to 2*s.* per house per annum, in many cases, not only may the house-refuse be removed from near habitations, but the foundations of houses and the whole sites of towns may be relieved from the damp of low-lying districts, and the consequent excessive unhealthfulness and decay of habitations thereon diminished.

That all offensive smells proceeding from any works intended for house or town drainage, indicate the fact of the detention and decomposition of ordure, and afford decisive evidence of malconstruction, or of ignorant or defective arrangement.

That the method of removing refuse in suspension in water, by properly combined works, is much cheaper than that of collecting it in pits or cesspools, near or underneath houses, emptying it by hand-labour, and removing it by cartage.

That by a proper system of combined works, and properly adjusted tubular drainage, three districts at the least may, under ordinary circumstances, be drained and supplied with water completely at a rate of expense heretofore incurred in one for imperfect works, which accumulate decomposing deposit, and gave off offensive and injurious smells.

That under ordinary circumstances, where new and combined works are properly executed, the expense of the main water supplies, and the main drainage works have, on the average of the whole town, been less than at the rate of 3*d.* per house per week.

That where combined works have been properly constructed, a service-pipe has been introduced from the water-main for the conveyance of a constant supply of water, a sink and dust-bin provided, the cesspool filled up, and an apparatus of the nature of a water-closet substituted, connected by a house-drain with a main drain or sewer, and put in good action, at a charge under ordinary circumstances, and for the greatest number of habitations, payable by an improvement rate of little more than 3*d.* weekly, being less than the ordinary rates of expense for forming and keeping in repair common pumps, and the expense of cleansing cesspools attached to houses in towns.

That where combined works have been properly executed, the expense of the complete works has not hitherto exceeded the average expense of cleansing and repairing house-drains, and of cleansing cesspools, as declared upon a house-to-house inquiry, including 8,000 houses, in three average parishes of the metropolis.

That it is important, for the sake of economy, as well as for the health of the population, that the practice of the removal of refuse in suspension in water, and by combined works should be applied to all houses, especially to those occupied by the poorest classes.

It is to be hoped that the due consideration of the facts upon which the general conclusions above recited are based will lead to the voluntary adoption and wide practical application of the principles evolved; but it is proper to observe, that, whilst those facts prove the eminent practicability of the chief measures contemplated by the Public Health Act, they equally show the duty of enforcing, in places where the Public Health Act has not been brought into operation, the provisions of the Nuisances Removal and Diseases Prevention Act: in all cases "where it appears that any dwelling-house or building in any city, town, borough, parish, or place, within or over which the jurisdiction or authority of the town council, trustees, commissioners, guardians, officers of health, or other body to whom such notice is given, extends, is in such a filthy and unwholesome condition as to be a nuisance to, or injurious to the health of any person; or, that upon any premises within such jurisdiction or authority there is any foul and offensive ditch, gutter, drain, privy, cesspool or ashpit, or any ditch, gutter, drain, privy, cesspool, or ashpit *kept* or *constructed* so as to be a nuisance to, or injurious to the health of *any* person;"—then, upon proof thereof before two justices, the nuisance may be ordered to be abated, that is to say, the viciously-constructed drain, or other work to be removed; and the neglect to obey such order subjects the owner or the occupier to penalties, while the work may be done by the authorities, and the parties offending may be charged therewith.

The subject is by the common law entitled to protection against anything as a nuisance, which is offensive to the senses, although no injury to the health results from it, nor any other injury than the discomfort of offensive smells, or of filth and other matters offensive to the sight.

House drains, or branch or main drains, which detain and accumulate deposit, can scarcely fail under ordinary circumstances to give off emanations offensive to the senses, which will make them nuisances within the meaning of the act, and such emanations are often fatal, and are always injurious, by lowering the general tone of health, even when they are so diluted as not perceptibly to produce specific disease.

It cannot be too often impressed on Local Boards, that it is their duty to cause such sewers to be made as may be necessary for effectually draining their district for the purposes of the Public Health Act, and that this duty is not discretionary but compulsory. Nor must it be forgotten that a Local Board may incur penal consequences as well from the improper discharge of their duty, as from the "unlawful omission" of it. Whatever discretion the Act may have allowed with respect to the form of works, or their mode of construction, they must be so executed as neither to create a nuisance, nor incur wasteful expenditure,—the very objects which it was the intention of the Statute to prevent. The legislature having charged Local Boards with the duty of executing its beneficent provisions for the protection of the public health, they are subjected not only to moral, but also to legal responsibility for any private or public injuries which they may occasion, whether by their acts of commission or omission. They may create nuisances by constructing bad works, or by allowing nuisances to accumulate in consequence of constructing no works at all, when, by the Statute, they are under legal obligation to provide them. If they allow nuisances to remain, when they are bound to remove them, they incur legal responsibility for neglect of duty, or, in legal phrase, for "nonfeasance;" if, from insufficient attention or culpable negligence, they create nuisances in the attempt at removal, the offence arising unwittingly or from negligence, they incur responsibility for "misfeasance;" and if they create nuisances by wilful neglect or defiance of previous available information and experience, they incur reponsibility for "malfeasance."

Signed by order of the Board.

C. Macaulay, *Secretary*.

Whitehall, 25th June 1852.

APPENDIX.

(No. 1.)

Elementary Maxims to be kept in view in the Drainage and Cleansing of Towns.

Ascertain, if practicable from any existing or previous experience of storms within the district, with what modifications the tables herein-before given may be applied to the district.

Where drainage works have already been laid down, observe the outfalls and the branches, both in the discharge of pipe water and of rain-water, and the quantity of deposit left; and from such observations judge of the corrections requisite in the sizes of tributary pipes.

In laying down main drains or sewers in any street, let it be ordered at the same time that all cesspools on the premises in such street shall be filled up; that tubular house-drains shall be provided, and that a sufficient flow and sweep of water shall be secured to keep such drains free from deposit.

Provide that blood, semi-fluid offal, garbage, and refuse of every description, which may be capable of safe removal in the drains by suspension in water, from slaughter-houses, markets, shambles, stables, cow-houses, or manufactories, be conveyed into the drains on the principle of the soil-pan apparatus, taking care that such refuse be led as directly as possible into those main-pipes which have the largest, quickest, and most constant flow.

Provide such gullies or openings into the sewers that the surfaces of streets, foot pavements, roads, yards, markets, or open spaces where there is much traffic, or droppings from cattle, or other filth, may be promptly cleansed by means of the jet.

Make proper provision for the ventilation of all sewers and drains in such manner that there may be a free current of air through them in the direction of the sewage flow.

To adjust the drains to the service they will be required to perform, calculate for extraordinary storm-waters in those valley or outlet lines only where it will be necessary to accommodate them.

Take care that in laying socket-jointed pipes great caution is used to give the pipes a full bearing, and not to allow the plain ends of the pipes to "*bind*," or rest solely on the socket, as, by doing so, pipes are frequently broken.

Whilst proper provision is made for the discharge of storm-waters in valley lines, where there is a natural descent, do not provide for taking them into the sewers of streets and places where storm-waters can flow on the surface without inconvenience, and thus, at increased cost, incur the certainty of weakening and impeding the ordinary discharges by the use of sewers too large for them.

To provide an efficient drainage where a natural outfall is wanting for a continuous discharge of sewerage, as in the case of lands near tidal rivers and below high-water mark, pumping should be resorted to; but in order to economise power, cut off the upper districts wherever practicable by a line of catch-water sewer for discharge by gravitation, so as to avoid any unnecessary quantity flowing down to a depth whence it must be pumped up again.