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AUTHOR'S ADDENDA AND CORRIGENDA.

SINCE going to press Major Moore has kindly furnished us with the following corrections and omissions overlooked by him in proof :—

Page 31, line 37, for "Botly," read "Batley."
,, line 38, for "with," read "whilst."
Page 40, line 39, for "approached," read "approaches."
Page 41, line 27, for "of refuse," read "of the refuse."
Page 43, line 3, for "*Destruction*," read "*Disposal*."
Page 56, line 21, for "D, P," read "D P."
Page 66, line 10, for "House drains," read "*House drains*."
Page 70, line 11, after "and where for," insert "very smooth channels, sides of smooth."
Page 70, line 12, after "for," insert "smooth channels, sides of."
,, line 13, after "for," insert "rough channels, sides of."
Page 71, line 7, after "new pipes," insert "glazed pipes, and drawn wrought or smooth cast-iron pipes."
Page 71, line 9, after "old pipes," insert "(iron) with light incrustations."
Page 72, line 3, for "$\sqrt[5]{\frac{Q}{s}}$," read "$\sqrt[5]{\frac{Q^2}{s}}$."
,, line 11, for "$\sqrt[5]{\frac{Q^2 \zeta}{\pi^2 \zeta}}$," read "$\sqrt[5]{\frac{Q^2 \zeta}{\pi^2 s}}$."
Page 100, line 26, after "entering," dele "by."
Page 101, line 35, after "breathed," insert "*Fig.* 42, and *Plate* V*a.*, *Fig.* 1."
Page 104, line 23, after "*Fig.* 18," insert "page 77."
Page 111, line 21, for "(four inches)," read "(three inches) (see *Plate* XV., *Fig.* 8)."
Page 122, line 4, for "Messrs. Jennings & Co.," read "Mr. G. Jennings."
Page 123, line 7, for "w.c.'s," read "w.c. apparatus."
Page 125, line 7, after "*Fig.* 114," insert "page 161."
Page 127, line 1, after "cup," insert "(P)" and after "basin," "(B)."
,, line 3, after "container," insert "(R)."
,, line 8, after "D trap," insert "(T)."
,, line 10, dele "lower."
,, line 14, dele "also."
Page 128, line 5, for "Tyler's," read "Tylor's."

Page 130, line 2, for "Tyler," read "Tylor."

,, line 9, after "cleaned," insert "This form of closet pan is, however, advantageous when the stool has to be examined for medical purposes."

Page 131, line 7, for "*Figs.* 1 and 4," read "*Figs.* 1, 4, 5, and 6."

Page 133, line 19, for "A disinfecting apparatus," read "*A disinfecting apparatus.*"

Page 136, line 6, for "should," read "they should."

Page 137, line 4, after "*Fig.* 72," insert "page 127."

Page 144, line 6, dele "of."

,, line 7, for "them," read "the two compartments."

,, line 9, for "and afterwards the lower one is opened," read "and the lower valve is opened, so as."

Page 152, line 3, for "begins," read "begin," and for "their," read "the."

Page 176, line 18, for "lines," read "line."

Page 229, line 45, first column, after "Depth of sewers, 56," insert "81."

Page 231, line 21, first column, for "69," read "194."

Page 234, line 43, second column, after "Sewers, depth of, 56," insert "81."

EDITOR'S PREFACE.

THE present volume of the *Occasional Papers*, No. XVII., for 1891, contains only one paper, but recent enquiries into the sanitary condition of some of our existing barracks have shown, if indeed were proof necessary of the fact, that Sanitary Engineering merits a place second to none among the many duties that fall to the lot of a Royal Engineer.

The sanitation of our barracks does not present a field for reaping renown, but it cannot be denied that on it depends in great measure the health of our troops in peace, and their consequent efficiency for war, and we feel sure that the officers of the Corps will fully appreciate the care and trouble Major Moore has taken in the compilation of his paper at a time, too, when he is occupied in the onerous duties of an Instructor at the School of Military Engineering.

W. A. GALE, CAPT., R.E.,

Secretary, R.E. Institute, and Editor.

PREFACE.

THE necessity for obtaining information on Sanitary Engineering in a fairly concise form has been forcibly brought to my notice when engaged in preparing lectures on this important subject to deliver to officers' classes at the S.M.E. There is no one book that treats of it as a whole, and thus quite a library has to be consulted before the general opinion of experts on any point can be deduced. The books for this purpose are also not always forthcoming; I have, therefore, endeavoured to obtain the latest information on the various points involved, and beg to submit these notes as the result of my researches and personal knowledge, in the hope that they may prove of use to some of my brother officers.

I have received much valuable assistance in my work, which I take this opportunity of acknowledging.

I am indebted to Mr. Santo Crimp, C.E., Engineer to the London County Council, for several of the plates on Sewage Disposal, including the drawing of the Dortmund Sewage Tank; to Mr. H. P. Boulnois, C.E., City Engineer, Liverpool, for much useful information; and to Mr. Charles Jones, C.E., Borough Engineer, Ealing, for the plates on Destructors. Mr. W. B. G Bennett, C.E., Borough Engineer, Southampton, kindly furnished the description of sewage disposal works at that place.

My thanks are also due to Colonel Slacke, R.E., for permission to use portions of his *Notes on Drains and Drainage;* and to Mr. W. C. Tyndale, Sanitary Engineer to the War Department, for the plans of drainage at Warley Barracks, with details of straining chamber and rock-concrete manholes. Major Love, R.E., has also kindly permitted me to extract from his book on hydraulics the table of coefficients of friction for pipes.

In order to increase the usefulness of these notes, and at the same time to acknowledge still further the sources of my information, a list of works of reference is given. A separate list of manufacturers of special appliances, with their addresses, has also been added.

E. C. S. MOORE, Major, R.E.

Chatham, January, 1892.

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BOOKS OF REFERENCE.

Name.	Author.	Price.	Publisher.
Agricultural Drainage	J. Bailey Denton, C.E.	1s. 6d.	E. & F. N. Spon, London.
Annotated Model Bye-Laws	Knight & Co.	10s. 6d.	Knight & Co., London.
Architectural Surveyors' Handbook	J. T. Hurst, C.E.	5s.	E. & F. N. Spon, London.
Army Sanitation	Sir D. Galton, F.R.S.	4s. 6d.	R.E. Institute, Chatham.
Building Construction Materials, Vol. III.	Maj.-Gen. Percy Smith, R.E.	21s.	Rivington, London.
Dangers to Health	Pridgin Teale, M.A.	—	J. & A. Churchill, London.
Drainage of Lands and Towns	Dempsey, revised by D. K. Clarke, C.E.	7s. 6d.	Crosby Lockwood & Son, London.
Drainage for Profit	G. E. Waring, Jun.	—	Orange Judd & Co., New York.
Domestic Sanitary Drainage and Plumbing	W. R. Maguire	10s.	Kegan, Paul & Co.
Draining and Embanking	Scott	1s. 6d.	Crosby Lockwood & Son, London.
Earthwork Slips and Subsidences upon Public Works	J. Newman, C.E.	7s. 6d.	Spon, London.
Encyclopædia Britannica, 9th Edition, Part 47 ...	T. Spencer Baynes, LL.D.	7s. 6d.	A. & C. Black, Edinburgh.
Farm Drainage	J. French	7s. 6d.	Orange Judd & Co., New York, and Spon, London.
Handbook of Hygiene	G. Wilson, M.D.	—	J. & A. Churchill.
Healthy Dwellings	Sir Douglas Galton, F.R.S.	—	The Clardn. Press, Oxford.
House Sanitation	J. Bailey Denton, C.E.	—	Spon, London.

Name.	Author.	Price.	Publisher.
Hydro-pneumatic Sewerage System	Hughes & Lancaster	—	Phillipson & Golder, Printers, Eastgate Row, Chester.
Hygiene and Public Health	Dr. L. Parkes	9s.	H. K. Lewis, 136, Gower Street, London.
Hydraulics, Madras College of Engineering Manual	Capt. (now Major) Love, R.E.	—	College of Engineering, Madras.
Local Government Board Instructions to Local Authorities	Sir R. Rawlinson, C.E.	—	Knight & Co., London.
Municipal and Sanitary Engineers' Handbook	H. P. Boulnois, C.E.	12s. 6d.	Spon, London.
Manual of Health	A. Wynter Blyth, M.R.C.S.	17s.	Macmillan & Co., London.
Our Homes	Shirley Forster Murphy, M.R.C.S.	21s.	Cassell & Co., London.
Plumbing Practice	J. W. Clarke	8s.	The Engineering & Building Record, 92, Fleet Street.
Plumbing, Practical	P. J. Davies	10s.	Spon, London.
Pocket Book of Engineering Formulæ	Sir G. Molesworth, C.E.	6s. 6d.	Spon, London.
Practical Hygiene	Parkes, revised by De Chaumont	15s.	J. & A. Churchill & Co., London.
Purification of Sewage by Magnetic Spongy Carbon Process (*Professional Papers, R.E.*, Vol. XIV.)	C. H. Beloe, C.E.	1s. 4d.	R.E. Institute, Chatham.
Plumbing: a Text-book	William P. Buchan	3s. 6d.	Crosby Lockwood & Son, London.
Plumbing and House Draining Problems	H. C. Meyer	10s.	Engineering and Building Record, 92, Fleet Street.
Refuse Destructor (*Proceedings of Municipal and Sanitary Engineers and Surveyors*, 1887).	C. Jones, C.E.	10s. 6d.	Spon, London.
Road-Making (*Professional Papers, R.E.*, Vol. XVI., 1890)	H. P. Boulnois, C.E.	1s. 4d.	R.E. Institute, Chatham.
Sanitary Engineering	J. Bailey Denton, C.E.	21s.	Spon, London.
" "	Baldwin Latham, C.E.	30s.	Spon, London (out of print).

Name.	Author	Price.	Publisher.
Sanitary Institute Catalogue	E. White Wallis, F.S.S.	6d.	Sanitary Institute, 74, Margaret St., London, W.
Sanitary Work	J. Slagg, C.E.	—	Crosby Lockwood & Son, London.
Sewage Disposal	Professor H. Robinson, C.E.	5s.	Spon, London.
,, ,,	W. H. Corfield, M.D.	—	—
Sewage Disposal Works	W. Santo Crimp, C.E.	25s.	C. Griffin & Co., Exeter Street, Strand.
Sewerage and Land Draining	E. Waring, Jun.	52s.	Orange Judd & Co., New York, and Spon, London
Sewage Treatment, Purification and Utilization	J. W. Slater, F.E.S.	6s.	Whittaker & Co., Paternoster Sq., London.
The Plumber and Sanitary Houses	S. S. Hellyer	6s.	B. T. Batsford, 52, High Holborn, London.
Treatment of Sewage by the Iron Process (*Professional Papers, R.E.* Vol. XIII., 1887)	F. R. Conder, C.E.	1s.	R.E. Institute, Chatham.
Treatment of Sewage (*Professional Papers, R.E.*, Vol. XVI., 1890)	W. Santo Crimp, C.E.	1s. 4d.	R.E. Institute, Chatham.

MANUFACTURERS' LIST.

Adams & Co., York.
Archer Pipe Company, Avenue Mansions, Shaftesbury Avenue.
Ashford & Co., Essex Street, Birmingham.

Banner Sanitation Company, 24, Craven Street, W.C.
Bailey & Co., Fulham.
Beck & Co., Limited, 130, Great Suffolk Street, S.E
Bolding, J., & Son, South Moulton Street, W.
Botting, F., Baker Street, W.
Boyle & Co., Holborn Viaduct, E.C.
Bowes, Scott & Western, Broadway Chambers, Westminster.
Baithwaite & Co., Swinegate, Leeds.
Broad & Co., Wharves, Paddington, W.
Burn & Bailie, 14, New Castle Street, Farringdon Street, E C.
Bostel, D. T., 73, Ebury Street, London.

Calvert, F. C., & Co., Bradford, Manchester.
Cliff & Son, Baltic Wharf, Waterloo Bridge, and Wortley, Leeds.
Craig, I. & M., Kilmarnock.
Crapper & Co., 50, Marlborough Road, S.W.

Dent & Hellyer, 21, Newcastle Street, Strand.
Doulton & Co., Lambeth, London, S.E.
Durrans, T. H., & Sons, 43, Upper Baker Street, N.W.

Fell, J., & Co., 36, Bloom Street, Manchester.
Filmer & Mason, Guildford.
Flower, T. J. Moss, Liverpool Chambers, Bristol.

Hughes & Lancaster, Chester.

Jennings, George, Stangate, Lambeth, S.E.

Jones, John, 40, Sydney Street, Chelsea.

Kite, C., & Co., Chalton Street, N.W.

Moule's Patent Earth Closet Company, 5*a*, Garrick Street, Covent Garden.

Oates & Gunn, Halifax, Yorkshire.

Pain, James, St. Mary Axe, E.C.

Sanitary Engineering and Ventilating Company, Victoria Street, S.W.
Sharp & Co., Swadlincote, Burton-on-Trent.
Sharp, Jones & Co., Poole, Dorset.
Spongy Iron Company, New Oxford Street, W.
Stiff & Sons, London Pottery, Lambeth.
Stone, J., & Co., Deptford, London, S.E.

Twyford, T., Hanley, Staffordshire.
Tylor & Son, 2, Newgate Street, E.C.

Watts, J., & Co., Broadweir Works, Bristol.
Winser & Co., Buckingham Palace Road, S.W.
Ward, O. D., 194, Upper Thames Street, London, E.C.

SANITARY ENGINEERING NOTES.

CHAPTER I.

SEWAGE DISPOSAL.

Definition.—The object of sanitary engineering is to promote the healthiness of any locality by the proper removal of those conditions which are hostile to it, and in supplying those which are necessary to health, such as pure air and water; a pure sub-soil must, at the same time, be secured.

The ventilation, warming, and lighting of inhabited buildings, although important branches of sanitary engineering, are not touched on in these notes.

Advance in Sanitary Science.—Very great strides have been made of recent years in sanitary science. Serious outbreaks of zymotic disease at various times have necessitated careful investigation of their causes, the result being traced, as a rule, to inattention to sanitary principles, involving defects either in the system adopted, or in the apparatus employed.

Constant improvements are being effected, so that a great deal that found favour some few years ago would not be tolerated for a moment now that further light has been let in on the subject.

Disposal of Sewage of Great Importance to Health.—A very important part of sanitation is the proper disposal of the sewage of a community. It is most essential to health that adequate means be provided for the efficient removal of all decomposing refuse, as well as the foul water from houses and factories. Its final disposal must also be carefully attended to before putrefaction sets in, as it is then deprived of its power to cause injury to health; care being taken, of course, to select a system which adapts itself best to meet the particular circumstances of the case both as regards efficiency and economy. It is best to make this selection before the method of collection or removal of the sewage is decided on, as the latter is necessarily governed by the method chosen for its final disposal.

The methods usually adopted for this purpose are:—

I. The dry earth.
II. Discharge into the sea or tidal estuary.
III. Irrigation.
IV. Filtration.
V. Precipitation.
VI. Destruction.

I. *Dry Earth.*—In eastern countries, for the most part, the natural method of using dry earth obtains. The excrement is collected at once and buried daily. The foul water finds its way along open channels to a pit provided for the purpose, and being attacked by the oxygen in the air, and also well dusted, loses its injurious qualities as far as any emanations from it are concerned. Channels of this description are readily cleansed. The pits are also emptied daily, and the liquid buried with the excrement.

In more humid climates there is a difficulty in applying dry earth, at any rate on a large scale, as the earth would have to be dried.

Ashes are sometimes used in place of dry earth, but are not so satisfactory.

II. *The Sea, or Tidal Estuary.*—Many engineers of high standing maintain that where practicable, the sea, or the tidal estuary of a river, is the right place, as no costly works are then necessary. It consists of the direct discharge of the sewage at ebb tide, so as to carry out the sewage to a good distance from the shore, and diffuse it into the sea before the tide begins to flow. Great care is, however, essential to secure this result. Float observations should be made not only of the surface tides and currents, but also of those at different depths, and the effect on the sewage, in consequence of the difference between its specific gravity and that of salt water, carefully considered. The rise and fall of the tides, and the configuration of the coast line, must also be studied as bearing on the question.

Where tidal currents exist, the point of discharge should be situated below the place, in the direction of the falling tide, and not above it.

The greatest difficulty with such outfalls is at neap tides, and consequently it is the effect of these tides on the discharge that should be considered. As, however, the flow of sewage in sewers towards the outfall is continuous, it is usual to form storage tanks or reservoirs in which the sewage is accumulated during the rise of the tide, and from which it is discharged at the beginning of the ebb.

This system is only available in a limited number of places (*e.g.*, towns near the sea coast), and cannot be efficiently employed for the disposal of sewage of inland towns at such distances from the outfall that the sewage would take longer than six hours in reaching the point of discharge.

Sewage discharged into land-locked harbours and deep bays soon becomes a nuisance, as is evidenced by many seaside towns.

Sea water delays the oxidation of organic matters, so that the foul constituents of sewage, which in river water would be liberated and got rid of in a short time, are preserved in sea water, which causes them to accumulate and form dangerous deposits ready for the quickening action of the summer sun, when gases injurious to health are evolved.

In tidal estuaries the sewage seldom travels a sufficient distance out to sea and away from the shore, owing to the currents and rise of tides; the sewage is frequently carried back and deposited above the outfall. At the present time many complaints are being made of the condition of the mouth of the Thames, which is being seriously affected by the London sewer outfalls at Barking and Crossness.

Some types of sewer outfalls are given in the accompanying *Plates* I. and II. Careful ventilation is requisite.

III. *Irrigation.*—Another system is that of irrigation, which consists in passing the sewage over land, in order to use its fertilizing properties, and at the same time to purify it before running the liquid into a river or other watercourse.

Loamy porous soil is the best for sewage irrigation from a sanitary point of view.

Unless the sub-soil is sand or gravel, it is usual with the denser top soils to provide some sub-soil drainage, increasing it in amount and depth with the density of the soil to be utilized, so as to give a free exit for the water, and prevent the ground from getting water-logged.

Where the land is of a stiff clayey nature, there are considerable difficulties in adapting it for irrigation. In undrained clay land, under ordinary circumstances, cracks one and two inches wide and five feet deep are sometimes met with, and it has been found that these are intensified in drained land, with the result that direct passage of sewage and surface water into them has occurred on sewage farms of this nature, so that the effluent is not purified as intended. It is thus very unsuitable for irrigation, unless the surface is specially prepared, as mentioned under the head of broad irrigation, and chemical treatment should be resorted to.

Different soils vary very considerably in their power to decompose sewage by utilizing the ammonia (the principal fertilizing agent) and other constituents, which are capable of nourishing vegetable life, as well as at the same time effecting its purification.

The following conclusions from the researches of Dr. Voeckler, an eminent chemist, are quoted from the *Journal of the Royal Agricultural Society*, No. 28, page 544 :—

"1. All soils experimented upon had the power of absorbing ammonia from its solution in water.

"2. Ammonia is never completely removed from its solution, however weak it may be. On passing a solution of ammonia, whether weak or strong, through any kind of soil, a certain quantity of ammonia invariably passes through. No soil has the power of fixing completely the ammonia with which it is brought into contact.

"3. The absolute quantity of ammonia which is absorbed by a soil is larger when a stronger solution of ammonia is passed through it; but relatively weaker solutions are more thoroughly exhausted than stronger ones.

"4. A soil which has absorbed as much ammonia as it will from a weak solution, takes up a fresh quantity of ammonia when it is brought into contact with a stronger solution.

"5. In passing solutions of salts of ammonia through soils, the ammonia alone is absorbed, and the acids pass through generally in combination with lime, or when lime is deficient in the soil, in combination with magnesia or other mineral bases.

"6. Soils absorb more ammonia from stronger than from weaker solutions of sulphate of ammonia as of other ammonia salts.

"7. In no instance is the ammonia absorbed by soils from solutions of free ammonia, or from salts of ammonia, so completely or permanently fixed as to prevent water from washing out appreciable quantities of ammonia.

"8. The proportion of ammonia which is removed in the several washings is small in proportion to that retained by the soil.

"9. The power of soils to absorb ammonia from solutions of free or combined ammonia is thus greater than the power of water to re-dissolve it."

Thoroughly drained land has the property of converting the nitrogenous organic matters in the sewage into nitrates, but only those which are absorbed rapidly by vegetation are utilized, the remainder are carried through the ground, so that an excess of sewage cannot be taken up by the crops; notwithstanding this, the land may act well as a purifier for sanitary purposes.

It is necessary to give the soil sufficient time to get thoroughly aërated—from four to eight days—as otherwise nitrification often ceases altogether, and even percolation is stopped by the soil getting clogged.

Aëration is effected by atmospheric air following the last part of each dose of sewage as it sinks through the filtering material, and so oxidizes the organic matter retained in its pores.

If under these circumstances the quantity of sewage is not in excess of the power of the soil to deal with, it does not appear, even when unaided by vegetation, to lose its power or become saturated.

Mr. R. Warrington examined the question of the action of soil on sewage, and in 1884 presented a paper on the subject to the British Association for the Advancement of Science; the following is an extract:—

"*The Theory of Nitrification.*—Till the commencement of 1877 it was generally supposed that the formation of nitrates from ammonia, or nitrogenous organic matters, in soils and waters was the result of simple oxidation by the atmosphere. In the case of soil, it was imagined that the action of the atmosphere was intensified by the condensation of oxygen in the pores of the soil; in the case of waters, no such assumption was possible. This theory was most unsatisfactory, as neither the solutions of pure ammonia nor any of its salts could be nitrified in the laboratory by simple exposure to air. The assumed condensation of oxygen in the pores of the soil also proved to be a fiction as soon as it was put by Schlœsing to the test of experiment.

"Early in 1877, two French chemists, MM. Schlœsing and Müntz, published preliminary experiments, showing that nitrification in sewage and in soils is the result of the action of an organized ferment, which occurs abundantly in soils and in most impure waters. The evidence for the ferment theory of nitrification is now very complete. Nitrification in soils and waters is found to be strictly limited to the range of temperature within which the vital activity of living ferments is confined. Thus nitrification proceeds with extreme slowness near the freezing point, and increases in activity with a rise of temperature till 37° C. (99° Fahr.) is reached; the action then diminishes, and ceases altogether at 55° C. (131° Fahr.). Nitrification is also dependent upon the presence of plant food suitable for organisms of low character. Recent experiments at Rothampstead show that in the absence of phosphates no nitrification will occur. Further proof of the ferment theory is afforded by the fact that antiseptics are fatal to nitrification. In the presence of a small quantity of chloroform, carbon bisulphide, salicylic acid, and apparently also phenol, nitrification entirely ceases. The action of heat is also equally confirmatory. Raising sewage to the boiling point entirely prevents it undergoing nitrification. The heating of soil to the same temperature effectually destroys its nitrifying power. Finally, nitrification can be started in boiled sewage, or in other sterilized liquid of suitable composition, by the addition of a few particles of fresh surface soil, or a few drops of a solution which has already nitrified, though without such addition these liquids may be freely exposed to filtered air without nitrification taking place.

"The nitrifying organism has been submitted as yet to but little microscopical study; it is apparently a micrococcus. . .

"*The Distribution of the Nitrifying Organism in the Soil.*—Small quantities of soil were taken, at depths varying from two inches to eight feet, from the freshly-cut surfaces on the sides of pits sunk in the clay soil at Rothampstead. The soil removed was at once transferred to a sterilized solution of diluted urine, which was afterwards examined from time to time to ascertain if nitrification took place. From the results it would appear that in a clay soil the nitrifying organism is confined to about 18 inches of the top soil; it is most abundant in the first six inches. It is quite possible, however, that in the channels caused by worms or by the roots of plants, the organism may occur at greater depths. In a sandy soil we should expect to find the organism at a lower level than in clay, but of this we have as yet no direct evidence."

The results of more recent research is that the nitrifying organisms have actually been discovered to exist in porous soils, at depths of from three to four feet below the surface.

It is apparent from the foregoing that the presence in sewage of refuse from chemical works may form a great hindrance to its purification by the soil, in consequence of its sterilizing power.

Broad Irrigation.—Consists in passing the sewage over large tracts of land so as to purify it. The difficulty in this case, very often, is to find sufficient land conveniently situated for the purpose.

Almost any soil is suitable for irrigation if well and properly drained.

When the surface of the land is relied on for the purification of the sewage, it should present a gentle slope, in order that the sewage may travel slowly forwards in a lateral direction, and thus admit of the surface being regularly wetted throughout, and of the liquid draining off readily, so that the surface may dry after the application of the sewage. Not only does the top soil require levelling to effect this, but the surface of the sub-soil should be similarly disposed parallel to it, the top soil being carefully removed for this purpose, and afterwards replaced.

Broad irrigation was practically carried out at the sewage farm at Wimbledon, where the soil is clay. The ground was divided into plots of about four acres, by means of roads 12 feet in width; under the centre of each road a drain was laid to a depth of six feet.

The surface was very carefully levelled to avoid ponding, and was ploughed up to a depth of nine inches, being afterwards covered with three inches of screened town ashes; the result was that a porous surface, about one foot in thickness, was obtained, through which the sewage could pass in a lateral direction. The ground was cropped and ploughed every other year, so that porosity was maintained. The sewage was applied intermittently, and was not allowed to exceed 20,000 gallons per acre per diem.

Plate II*a.* is a plan of Beddington Irrigation Farm, Borough of Croydon, Surrey. It consists of 525 acres, of which 420 acres are laid down for broad irrigation.

The remaining 105 are occupied by four farmsteads, 14 cottages, the manager's house, etc. The sub-soil consists of gravel, very open in some places, and sand.

The soil varies from loam to a light, free, open soil, but it is all very suitable for irrigation. The aspect of the farm is a gentle slope from east to west, averaging about 1 in 175.

The sewage flows on to the farm by gravitation through two outlets. There are no storm overflows, and the whole of the storm water is delivered on the farm. The effluent water passes into the river Wandle.

The cost of the works, under-drainage, effluent outfalls to the river Wandle, farm buildings, cottages, etc., has been £18,000. The working expenses are covered by the sale of produce.

The population of the districts draining on to this farm is about 80,000. Water-closets are in general use.

Settling Tanks.—Before applying the sewage to land, it should be allowed to settle, so as to get rid of the heavier portions, as well as the silt, grit, etc., derived from the streets and roads. To effect this, settling tanks have been adopted.

Settling tanks are constructed on two principles: that of "absolute rest" and "continuous;" the latter is found to answer best, provided the sewage is not less than two hours in passing through the tank. These tanks should be cleaned out once in three days. The odour from them is very unpleasant, and to obviate this a suitable deodorant or disinfectant should be used.

General Form of.—In this country settling tanks are generally made rectangular in plan, the proportion of width to length being 1 to 4. The maximum flow per hour of sewage from a town has been estimated at 8 per cent. of the daily flow, and to admit of the above rate of flow through the tanks, they should be capable of holding 16 per cent. of the total amount of sewage to be dealt with.

This again should be multiplied by three, bringing the total capacity to be provided up to nearly 50 per cent., and should be divided amongst three sets of tanks. One would stand empty whilst being cleaned out, and the two others would provide for the sewage and excessive fluctuations in the rainfall. A set of small tanks is much more convenient than one large one.

In *Fig.* 1 sewage enters at C, passes under the scum-boards G, and over the cross valves F; the liquid overflows at D, or is carried off by the floating arm E. The sludge collects at the bottom and is transferred from the upper compartments by the sludge doors

H, until it is eventually drawn off by the valve B, through the pipe at A.

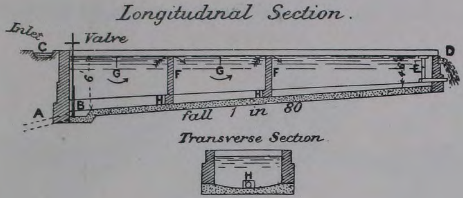


Fig. 1.

Improved Settling Tank (*Plate* III.).—An improved settling tank has just been tried at Dortmund, in Germany. The sewage is passed through the ordinary pattern settling tank in the first instance, and is thus freed from floating impurities, lime and sulphate of alumina being added successively. The sewage then passes down a vertical zinc pipe to a depth of about 30 feet, through the axis of a cylindrical tank; the pipe is provided with radial arms, to distribute the sewage evenly over the area, and below them the tank is cone-shaped. The sludge settles at the bottom, and is gradually pumped out as it consolidates by a 6-inch suction pipe, led down inside the supply pipe to near the bottom of the tank. The clear effluent is drawn off by troughs, so arranged as to sub-divide the surface equally, and thus avoid setting up a current. The flow is kept at a uniform rate of about 15 feet per hour.

Distribution over Land.—The distribution of the sewage over the land is effected in various ways, three of which are illustrated. *Fig.* 2 is the "catchwater" method, and is only suitable for steep

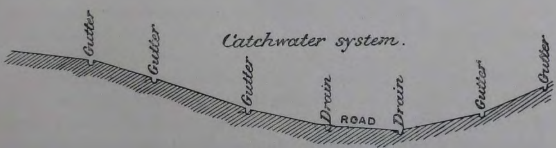


Fig. 2.

ground; the gutters are laid along the contours to receive the surplus liquid from the upper slopes, and distribute it again by overflow to those below.

Fig. 3 shows the "ridge and furrow" system, for use on flat and

Ridge and Furrow System.

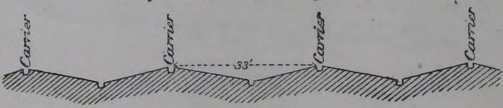


Fig. 3.

heavy soil; it consists of a series of shallow ridges with gentle slopes falling between them, and channels or "carriers" following the ridge-lines. The ridges should be about half a chain apart, and a longitudinal fall given to the furrows.

The Preparation of the Land for irrigation should be as simple and cheap as possible; the main carriers, or channels, may be constructed substantially in concrete, brick laid in cement, or stoneware, as in *Fig.* 4; but the tributary ones, as a rule, are made by hand, or by

Doulton's Stoneware.

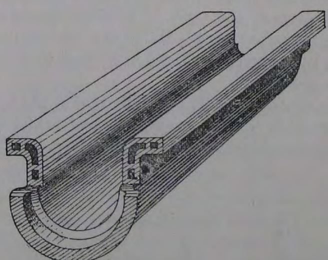


Fig. 4.

the plough, though occasionally, in exceptional cases, carriers of the form given in *Fig.* 5 are of advantage.

Main carriers should have a fall of about 1 in 400, and the distributing carriers of about 1 in 300.

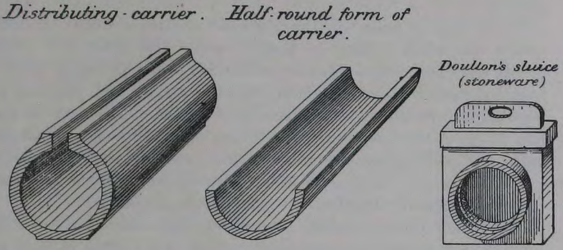


Fig. 5.

Sluice-valves may be of wood in stoneware chambers (as above), or as made by Doulton & Co.—of metal. "Stops" of metal or wood can also be placed, wherever needed, in the surface carriers by farm labourers, to divert the flow from those parts of the land that require it.

Acreage.—The acreage employed varies considerably, from one acre to 55 inhabitants, as at Leamington, to one acre to 208 at Blackburn ; the number of gallons per head per diem being 38.

An acre is covered one inch deep by 100 tons of sewage.

Crops Suitable.—The best crops are all kinds of market garden produce, rye grass, mangolds, beetroot, cabbages, carrots, wheat, oats, and barley.

Grazing can also be carried on, as the sewage does not affect the milk.

Sewage may also be passed through land thickly planted with anacharis, or American weed, duckweed, sedges, rushes, reeds, etc., or through beds of osiers or alder trees.

Capacity of Land.—An acre of such land is said to purify more than 3,000,000 gallons per diem.

In climates where the average temperature is high, and the rainfall is small in comparison with the amount of evaporation from the ground, or where the rainfall is intermittent with periods of drought, irrigation is the most efficacious for the disposal of sewage. In humid climates, where the average temperature is less than

50° Fah., and evaporation is not great, the land becomes quickly saturated with the large quantity of liquid passed daily on to it, and thus favourable results are not realized from the employment of this system.

When the question of the disposal of the sewage by irrigation was taken in hand in England some few years ago, great profits were anticipated from its utilization; and although sewage is said to have a value of from ½d. to 2d. a ton, or 10d. per head of population per annum, yet the results of all the experiments of the last 20 years tend to show that it has practically no commercial value, so that irrigation cannot be made a profitable undertaking.

IV. *Filtration*—Another method of irrigation, known as intermittent downward filtration, is sometimes employed.

Mr. Bailey Denton defines intermittent filtration as "the concentration of sewage at *regulated intervals* on as few acres of land as will absorb and cleanse it, without preventing the production of vegetation."

He states that the sewage of 1,000 persons can be applied to an acre of such soils as are most suitably constituted, and of 250 to those badly constituted.

Heavy clay soils are not adapted to this purpose.

When land is to be used as a filter, the surface should be laid out in level beds, and the sewage applied to each bed then passes vertically downward through the pervious stratum, from which, in a more or less purified condition, it escapes by means of sub-soil drains, or an existing porous sub-soil of sand or gravel, into a stream or watercourse.

Ridge and Furrow System.
(for intermittent filtration.)

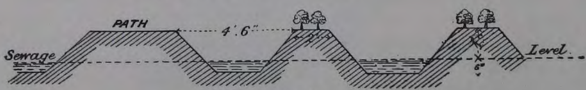


Fig. 6.

When the filtration areas are very porous, and the sewage is applied in small volumes by gravitation from towns not provided with storage tanks, the distribution would be made by ridge and furrow, as recommended by Mr. Bailey Denton (*vide Fig.* 6), so as to ensure uniformity of application.

Constant Aëration Required.—Land thus used as a sewage filter requires constant aëration by being dug or ploughed over.

Filters.—By this system the sewage is clarified by removing all organic or inorganic matters suspended in it by mechanical means. It has been supposed that the liquid in passing through the pores of the filter beds carries a quantity of atmospheric air with it, which tends to oxidize the animal and vegetable matters, and prevent them from becoming injurious. Some of the organic compounds are also decomposed. Filters are generally formed of beds of sand, gravel, burnt clay, coke, charcoal, moor-earth (sand and peat), sawdust, pumice, polarite, etc., and other hard vegetable substances exposing considerable surface.

It is evidently possible, from the evidence on page 5, to construct filter beds superior in oxidizing power to that possessed by any ordinary soil and sub-soil, *e.g.*, the porous substratum required might be formed of a system of sub-soil drain-pipes, and over these a few feet of soil might be placed. The soil selected should be of a porous nature, and contain a considerable proportion of carbonate of lime and organic matter; it should be taken from the upper six inches of a good field.

Sewage contains the organisms necessary for its own destruction, and under favourable conditions these may be so cultivated as to effect the purpose. A filtering medium of pure sand and limestone, treated intermittently with sewage, will, after a time, display considerable purifying powers, the surface becoming covered with oxidizing organisms derived from the sewage. No such medium, however, will equal in effect a porous soil rich in organic life.

Where the amount of manufacturer's refuse is largely in excess of the excrementitious matter, in consequence of the foul water containing acids and metals in solution, it is preferable to adopt filtration in place of irrigation, as the liquid would destroy the crops. Filtration may also be applied after precipitation, when extreme purity of effluent is required before delivery into a river.

Plate III*a.* is a plan of land laid out for intermittent downward filtration at Hitchin, Hertfordshire.

The quantity of land in this farm is 22 acres, of which 19 acres are devoted to filtration (see *Plots* I., II., and III., *Plate* III.*a*), and surface, or broad irrigation (see *Plots* IV. and V., *Plate* III*a*.).

The sub-soil is peat of a boggy nature, mixed with gravelly clunch (lower chalk).

The sewage is distributed through the filtration areas by means of furrows, the position of which are altered every winter or early spring, care being taken that they are not placed directly over the under-drains. By the use of these furrows (*Fig.* 6) the liquid is not allowed to come in contact with the leaves of the growing vegetation, but spreading laterally reaches the roots, and can thus be applied at any stage of growth without disadvantage.

This farm was laid out from plans, etc., of Mr. Bailey Denton, at a cost of £2,300.

The population is about 10,000, and water-closets are in general use.

Standard of Purity.—Rivers Pollution Commissioners.—In the two latter cases (III. and IV.) the effluent has not been sufficiently pure, not coming up to the standard of purity fixed by the Rivers Pollution Commissioners, which was that the fluid should not contain more than 0·3 parts by weight of organic nitrogen in solution in 100,000 parts by weight of effluent.

V. *Precipitation.*—The method of precipitation is more properly called the chemical treatment of sewage; it means the formation

WALLER'S VALVE.

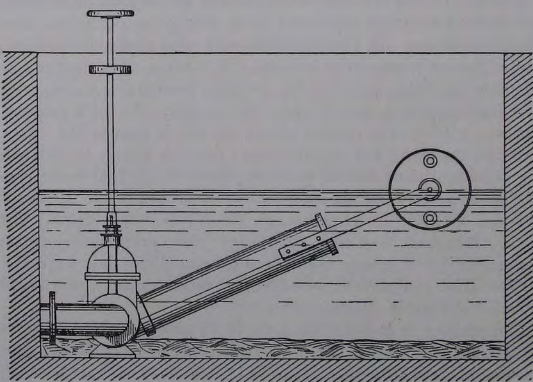


Fig. 7.

of solid compounds by introducing chemical substances into the sewage. The solids so formed, in settling, drag down with them the suspended matters held in solution in the sewage, together with a small proportion of the polluting matters; the proportion, of course, varies with the amount of solid matters deposited. The effluent from the tanks then flows at once into a river or stream, or may be passed over land, or be filtered through it. It may be drawn off from the surface by floating outlets, as in *Fig.* 7.

The conditions for a good precipitating agent are as follows:—

1. It should be cheap and abundant.
2. It should cause rapid subsidence of the precipitate formed.
3. It should be neither actively nor cumulatively poisonous.
4. It should not have any distinct colour, nor generate one with the substances it may encounter.
5. It should ensure the production of a precipitate of minimum bulk with maximum defecation.
6. The resultant effluent should not be alkaline.
7. The precipitate or sludge should part with moisture readily.

It may be further noted that sewage is more easily precipitated when warm than when cold, and also when the precipitating agent is added to it *hot*.

A vast number of processes have been tried, of which the following are the principal:—

Lime Process.—The lime process consists in the addition of lime in a perfectly caustic state, in the proportion of 12 grains per gallon, after a preliminary straining of the sewage.

The lime is first of all well slaked with water, and ground in a mortar mill, or lime mixer, so as to be in a finely divided or creamy condition; it is then necessary to thoroughly incorporate it with the sewage, and agitate it well before allowing the mixture to settle. It should afterwards be allowed to lie quietly for one hour at least; the precipitate should be consolidated and deprived of its water as soon as possible, as putrefaction soon sets in and creates a nuisance.

The purest lime should be used, such as that obtainable from the upper chalk and the crystalline limestones of Derbyshire and other counties.

The addition to the above of $\frac{1}{3}$-grain of chloride of lime per gallon of sewage is supposed to have beneficial results, especially in hot weather, in preventing the growth of fungus.

The cost of this process has been found to be about 8d. per head of population per annum. This precipitant, however, renders the effluent alkaline, and its discharge into rivers favours decomposition, and is very destructive to fish.

The A.B.C. Process.—The A.B.C. process consists in the use of alum, blood, clay, and charcoal, in certain proportions, as a precipitant.

This process is used at Aylesbury, and the sewage is converted into what is called native guano. Opinions differ about the commercial value of this product, as the special local circumstances vary so greatly.

The effluent is very pure, and is produced without any nuisance.

This process does not, however, seem to grow in favour among sanitary engineers.

The International Process.—In the international process a magnetic precipitant and deodorizer, called ferozone, is used, and the liquid is afterwards filtered through a polarite filter.

Ferozone, or magnetic ferrous carbon, is prepared from the same mineral that forms the basis of polarite, but is treated in a different manner. It is rich in ferrous iron, and contains also alum, calcium, sulphate of magnesia, and rustless magnetic oxide of iron.

The soluble portion of the material, when mixed with the alkaline sewage, forms a slight precipitate, and the insoluble portion (spongy magnetic oxide) assists in the rapid subsidence, and, from its porous nature, also acts as an absorbent of some of the organic matter; the particles of oxide, being porous and magnetic, part with their polarized oxygen, thereby assisting in the disinfection and deodorizing of the sewage and sludge.

Polarite is the trade name for magnetic spongy carbon; it is prepared from a peculiar description of iron found in certain parts of South Wales. In its original state it is hard, non-absorptive, and non-magnetic. It is carbonized in retorts, and treated by a patented process, and then granulated to the degree of fineness required. This mineral has been tested by Sir H. Roscoe, M.P., F.R.S., etc., and he states that the "porous nature of the oxide, its complete insolubility, and its freedom from rusting, constitute its claim to be considered a valuable filtering material." It contains no poisonous metal, is very hard, porous, and absorptive. It extracts iron and lead from water, and destroys organic matter in solution. It is a powerful deodorizer by virtue of the polarized oxygen contained in its microscopic pores. It is extremely durable and magnetic to a remarkable degree, and, notwithstanding that iron is the chief element in its construction, it will not rust. In the pores of this material a process of combustion takes place, and by this means impurities may be said to be actually burnt out of the water when brought into contact with polarite.

The filter is formed with a layer of burnt ballast six inches thick, with three inches of washed sand over it; this is then covered with an 18-inch bed of polarite and washed sand, in equal proportions, with a final layer of eight inches of soil over all. The polarite acts simply as a carrier of oxygen, and a rest of a few hours is sufficient to restore its action.

A section of the filter used at Acton is shown in *Fig.* 8.

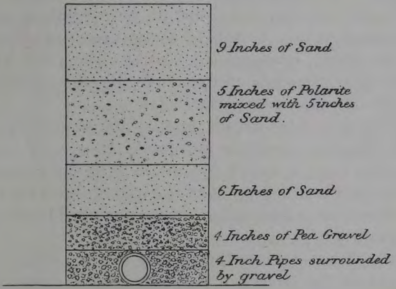


Fig. 8.

Ordinary top soil might be used in lieu of the upper bed of sand. The surface of the topmost layer in either case soon gets clogged with suspended matter, and requires to be skimmed off.

A filter thus made will filter sewage at the rate of 1,000 gallons per square yard in 24 hours with better results than can be obtained from land, which filters about $1\frac{1}{2}$ gallons per square yard per 24 hours ; thus one acre of filtering area, containing a layer of polarite, will do more efficient work than 666 acres of land.

The cost of adopting this system at Acton was the sum of £136 for the polarite used in the filter bed, in addition to sand and gravel to form the bed; the ferozone costs £3 per ton, and the quantity used varies from 7 to 10cwts. per million gallons.

In order to treat sewage successfully by the international process, it is essential that the works be properly designed, to ensure economical working and the most satisfactory results.

Plate III*b*. shows a general arrangement of a model sewage works for a large town. The size and number of tanks and filter beds will, of course, depend upon the volume of sewage to be dealt with. The sewage, on entering the works, should first pass through strainers arranged in duplicate, which remove matters floating in the sewage, such as corks, rags, brushes, etc., etc. These strainers are so arranged that the sewage can be excluded from either of them to enable them to be lifted out of the channel. Far too little attention is generally paid to this subject of straining. The bars of the strainer should be vertical only, and not in the form of a grating, to enable them to be readily cleansed with a rake, and should be placed sufficiently close together to prevent any large pieces of solid matter passing through them. It will be found necessary to cleanse the strainers frequently, otherwise the flow of sewage will be impeded, and by the arrangement shown on *Plate* III*b*. this cleansing can be most readily and effectually performed.

From the strainers the sewage flows to the automatic mixers, by means of which the magnetic precipitant ferozone is added to the sewage. The sewage coming in contact with the precipitant, dissolves it and carries it away. As the depth of the sewage increases, more precipitant is submerged, and the quantity added to the sewage increased accordingly.

In large works, and where the velocity of the current is sufficient for the purpose, it is preferable to use an apparatus patented by Mr. C. H. Beloe, C.E., in which a small undershot water-wheel is placed in the sewer, and revolves in direct ratio to the velocity of the current. This water-wheel actuates a worm placed in the hopper containing the ferozone, whereby the exact quantity of precipitant required is added to the sewage.

A dry store should be provided for the ferozone, as it possesses great affinity for moisture, and if damp becomes caked.

The sewage, after receiving the precipitant, passes through a mixing race to incorporate the materials thoroughly. It is then admitted into one of the subsidence tanks by means of a floating trough provided with battens placed across the bottom to break up and aërate the sewage as much as possible. As the sewage rises in the tanks, the trough floats to a flatter angle, and thus admits the sewage quietly on to the surface of the liquid in the tank. It is of great importance to avoid as much as possible disturbing the sewage while it is undergoing the process of precipitation, so that a continuous flow through the tanks, and making the sewage pass over and under walls and divisions, which is frequently done, defeats the very object in view, and prevents the more perfect formation of the coagulum and the deposit of the sludge.

After a tank is full, about one hour should elapse before any sewage is drawn from it. The most suitable depth for tanks is from five to six feet, but this may have to be modified to suit the site. Across the tank, at about one-third of its length, a floating scum-board is placed to arrest any floating matters, such as paper and leaves, that may have passed through the strainers.

After the period allowed for subsidence has elapsed, the sewage is drawn off by means of a floating arm, surrounded by a floating sill, to prevent any matter from passing into the arm. The floating arm, as usually made, has an open mouth kept submerged about 12 inches below the surface of the sewage by means of a float. The other end of the arm communicates with the outlet pipe through a stuffing box, and the arm rises and falls with the sewage, drawing it off always at the fixed depth below the surface, a valve placed on the outlet pipe being opened when it is desired to empty the tank, care being taken to close this valve when the tank is empty and before any more sewage is admitted to it.

An improved form of floating arm has been invented by Mr. C. H. Beloe, in which the sluice-valve is rendered unnecessary, as the mouth of the arm floats above the surface of the sewage when the tank is being filled. When the tank is full, the mouth of the arm can be submerged either automatically soon after the tank is full, or it can be done by hand, in order to regulate more carefully the time allowed for subsidence. Air is admitted to the improved arm while the sewage is passing through it, and the sewage is aërated on its passage to the filter, by which the active properties of the filter and the consequent purification is materially enhanced. On leaving the tank, the sewage is conveyed by an iron pipe to any one of the filter beds.

Assuming three tanks to be used, it is recommended that the filtering area be divided into four beds, arranged in two pairs. By this plan one filter can always be at rest for the purpose of cleansing the top layer of sand, and for the revivification of the polarite, which takes place as soon as the effluent has drained away, atmospheric air following it, and being rapidly absorbed by the polarite. This is an important provision, and one that should on no account be neglected.

In order to provide for the cleansing of the filters, they are arranged in pairs, having only one common outlet, closed by a sluice. The walls of the filters should be carried up to a height of about two feet above the top of the sand. When the sluice on the outlet is closed, the tank effluent flows on to one of the pairs of filters, passes through it, and after filtration rises *up* through the other filter. A paddle is then opened leading from the filter to an open channel, which communicates with every tank by means of a sluice-valve.

The flocculent matter deposited on the top of the sand is thus washed off, and conveyed into any one of the tanks that may happen to be empty, and becomes mixed with the sewage when this tank is next filled, and the solids are deposited and drawn off as sludge at the next cleansing of the tank. The sand on the filter can be raked and brushed, and occasionally the top layer, to the depth of two or three inches, removed and replaced with fresh sand. The dirty sand can be washed at leisure with the pure effluent from the filters, and used over and over again. The outlet from the filter must then be opened and the filter allowed to drain ; this only occupies from two to three hours, when it is ready for use.

The bottom of the tanks must be made with a slight inclination from the sides to the centre, where a sludge gutter must be formed, the bottom having a tolerably rapid fall towards the end of the tank, where the sludge is to be dealt with. The valve connecting the wash-out channel from the filters with the tanks is placed at one end of this sludge gutter. Another valve at the opposite end of the tank being opened, the sludge flows usually into a sludge-well or reservoir, although in some cases it is proposed to convey it direct to the land and there to utilize it as manure. In the majority of cases the sludge-well is preferred ; the sludge is allowed to settle in it, and the supernatant water should be pumped back to the ferozone mixers, where it receives with the sewage a fresh dose of precipitant, and passes into the tanks to be dealt with in the same manner as the ordinary sewage, so that nothing escapes except the purified effluent. The sludge is then either pumped into lagoons and the moisture it contains evaporated, or, in the case of large works, the sludge is treated to another small dose of ferozone, and pressed by means of filter presses into cakes. At Acton these cakes are dried and ground to powder in a mortar-mill, and sold to market gardeners and others in the vicinity for thirty shillings a ton.

For the treatment of villages, barracks, etc., the arrangement shown in *Plate* III*c*. may be generally adopted.

There are only two tanks and two filters, and a sludge-well.

As the area of the filters would be small, no provision is made for washing the scum and top layer of sand back into the tanks, but it could be scraped off from time to time by hand and deposited in the sludge-well.

This process has a great advantage over the lime process, as it can be carried out without committing any nuisance.

Conder's Sulphate of Iron Process.—Sulphate of iron was advocated by the late Mr. F. R. Conder, M.I.C.E., as a precipitant. The process consists, briefly, in treating the sewage of each house to a dose of solution of iron, by which it is claimed "that the putrescible, or putrescent, matter that it contains is immediately split up into its innocuous elements; the liberation of gases ceases, and the mineral matter thus set free subsides as a fine black silt, that is easily swept along by a current of half-a-mile per hour."

The solution of iron is to be added to the sewage of each house by means of an instrument termed a ferrometer (*Fig.* 3, *Plate* III*d*.), through which a small stream of water constantly flows, and by dissolving the sulphate of iron, carries it into the sewers, a slice of lemon being placed every week in the instrument to add a vegetable acid. In addition to this, small receptacles, or trays, of sulphate of iron, are provided in the manholes, through which water is allowed to flow, or they may be placed in the sewer, as shown in *Figs.* 4 and 5, *Plate* III*d*.

Plate III*d*., *Fig.* 3, illustrates the ferrometer above mentioned. It consists of a glass tube, marked A, in which the sulphate of iron is placed; there are three holes at the bottom of this tube, which admit of the iron being dissolved by the water in the porcelain cup, B, into which the tube dips. The porcelain cup is partitioned off into two unequal parts by a perforated tin-plate at C.

The depth of the dip of this tube, A, can be regulated at pleasure by a brass clamping collar, G, so as to regulate the quantity to be consumed.

Water is admitted into the porcelain cup through the tap, E. The liquid flows off through the partition into the smaller compartment, from which it escapes by the pipe, D, to the drain or w.c. pan, etc. In the new pattern ferrometer an extra tap, F, is supplied at the bottom of the porcelain cup for discharging the iron disinfectant over sinks, etc. The tube contains 3lbs. of prepared sulphate of iron, and by regulating the depth of immersion, and flow of water, this quantity may either be dissolved in 12 hours, or may last for three weeks.

The proper quantity to be dissolved depends upon the number of contributors to the sewage to be treated.

Soft, or warm water, dissolves the copperas, or sulphate of iron, more rapidly than hard or very cold water.

In most cases it is recommended that one ferrometer should be fixed in the highest w.c. in the house, and that a second should be fixed to command the back kitchen sink, in order to extinguish any smell arising from the water used for boiling vegetables, etc.

The tap, E, may be connected with a small cistern of four or five gallons capacity, so as to disconnect it from the main supply of the house, but this is said to be, by the manufacturers, Messrs. Filmer & Mason, Guildford, unnecessary, and that it may have a direct connection with the house-water supply.

This system is believed to have answered well on a small scale, *e.g.*, at Chichester barracks, but there are evidently practical difficulties in the way of its adoption for the drainage of a town.

The chief difficulty is the accumulation of deposit in the sewers, consisting of a mineral matter which, although inoffensive, might, in channels of low velocity, form an obstruction to the ordinary flow. To get over this difficulty, catch-pits have been recommended, which, if cleared out once a week, need only be of a capacity of 30 cubic feet per 1,000 inhabitants.

The expense of installation and royalty, exclusive of cost of catch-pits, is £36 5s. per 100 inhabitants.

The cost of chemicals is about 6d. per unit of population per annum.

The cost of labour is an essential item in an estimate for this system, as it is necessary to charge the cylinders, or other apparatus, with copperas once, twice, or thrice a day, according to circumstances.

The cost of removal of precipitate from the catch-pits above quoted is said to be covered by the value of the precipitate obtained.

The treatment of Chichester barracks is effected by porcelain cylinders, placed in a 10-gallon iron tank, with a regulating outfall pipe leading into the barrack sewer (see *Figs.* 1 and 2, *Plate* III*d.*) just before it leaves the barrack, 680 feet from the outfall. The sewage runs into a 15-inch pipe, which, on leaving the barrack, falls 12 feet 3 inches in the distance (680 feet) above mentioned, and discharges its contents into an open ditch.

The ordinary population is about 500 in all. The flow from the sewer pipe was gauged in February, 1886, at 15,000 gallons per day. The analysis of this flow was 15·62 grains of organic, and 27·96 grains of inorganic matter in each gallon of sewage.

After the apparatus above quoted had been in operation six weeks, samples of the effluent, on analysis, were found to contain ·63 grains of organic, and 2·87 grains per cent. of inorganic matter, in suspension.

Dale's Muriate of Iron Process.—Sulphate of alumina and perchloride of iron have long been known as disinfectants of sewage, and a concentrated solution of the latter has given good results, under a system known as Dale's muriate of iron process.

Electrolysis.—Precipitation by electrolysis, which is also known as "Webster's" process, for the electrical purification of sewage, has been tried successfully at Crossness, and gives very promising results, both as regards the purity of the effluent and the eventual cost of the process.

Webster's Process for the Electrical Purification of Sewage.—The following is a description of the method employed by Mr. Webster:—

The first experiments were conducted with platinum plates, but their cost was prohibitive, besides which there was a very slight action on the positive plate pointing to its ultimate destruction; there was no precipitation in the sewage of the matters in suspension, and, as this is absolutely necessary, the more complete this is, the better the ultimate result. It was found that oxidizable plates produced the desired results. These plates must be of such material that they have no poisonous after effects, either on land or in rivers. The metals should be either aluminium or iron, but the first-named is out of the question owing to its cost, and then iron, besides having the advantage as regards price, has, in the form of oxide, many valuable qualities, one of the chief being that sulphuretted hydrogen cannot exist when ferrous, or ferric oxides, are present.

The success of the laboratory experiments was such that Mr. Webster asked for and obtained permission to set up plant at Crossness, near the southern outfall of the Metropolitan sewage into the Thames, for the purpose of demonstrating on a practical scale the advantages of the process, and it was conclusively proved that cast-iron plates of the commonest quality employed as electrodes give the best results. For treating sewage, or impure water, the fluid is allowed to flow through suitably constructed channels containing iron plates set longitudinally, the alternate plates being connected respectively with the positive and negative terminals of a dynamo. The sewage, or impure liquid, in its passage through these channels becomes entirely split up by the electric action. The matters in suspension in sewage, and part of the organic matter, are not only removed by precipitation, but the soluble organic matter is oxidized and burnt up by the nascent oxygen, and chlorine oxides evolved, and this oxidization may be carried to any extent, according to the amount of purification required.

The fact that water is easily decomposed, provided the current of electricity is of sufficient intensity, and also that the effects produced are precisely in accordance with the chemical equivalents of the substances electrolysed, is practically the explanation of the whole system, for the chemical changes that take place in sewage when it is electrolysed depend chiefly on the well-known fact that sodium, magnesium, and other chlorides (which are always present in sewage), are split up into their constituent parts. At the positive pole the chlorine and oxygen given off combine with the iron to form a salt, which Mr. Webster believes is a hypochlorite of the metal, but it immediately changes into a chloride, which, in its turn, is deprived of chlorine to form ferrous carbonates and oxides. During the chemical action carbonate of iron exists in solution, and its formation is due to the presence of carbonates in the sewage, chiefly carbonate of ammonia. In samples that are absolutely free from dissolved oxygen the ferrous oxide in the white form is precipitated, and, on shaking up with air, it changes to the usual pale green colour. The carbonate of iron at the same time being oxidized, the ultimate precipitate is red, known as ferric oxide ($Fe_2\ O_3$), and it is noticed that sometimes this changes, after a time, back again to the ferrous state ($Fe\ O$), thus showing that it has acted as a carrier of oxygen to the organic matter present.

The organic matter in solution of the particular sewage treated with ·23 ampères per gallon showed a reduction of 61 per cent.

In other cases a purification of as much as 87 per cent. was obtained. If a lesser purification be sufficient the horse-power can be proportionally reduced. During another run that lately took place at Crossness 19 horse-power was sufficient for the treatment of one million gallons in 24 hours, the resulting purification of organic matter in solution amounting to 50 per cent.

The great reduction of organic matter in solution obtained by electrolysis cannot be produced by chemicals except at a prohibitive cost, besides entailing a large addition to the bulk of sludge and inorganic matters in solution, which inevitably produce secondary putrefaction. A point of immense importance is that by this process the bulk of the sludge is reduced to a minimum. Where suitable land is available for irrigation or filtration, a smaller reduction of organic matter in solution is sufficient, settling tanks are unnecessary, and the expense of the electrical treatment can be much reduced.

Where suitable land is not available for this purpose, settling tanks are required. After the separated solid matter has been allowed to precipitate, the effluent so obtained is fit to discharge into any river. This effluent contains about three grains of suspended matter per gallon, which, as it consists almost entirely of iron oxide, is quite innocuous. But where this is objectionable from a sentimental point of view, it can be entirely removed by filtration through a few inches of sand, and the effluent is then fit to be discharged into a stream. Sir Henry Roscoe's report shows that the unfiltered effluent is in no degree less pure chemically as regards organic matters than the filtered effluent.

Where a still higher degree of purification is required it can be obtained by using an electric filter, which is arranged as follows:— Alternate layers of small coke free from sulphur are separated, either by layers of sand or perforated tiles; by suitable connection these layers of coke form positive and negative electrodes—the first layer of material being sand, so as to mechanically separate matters in suspension. It is impossible for disease germs to propagate, owing to the nascent oxygen and chlorine produced when the filter is in action.

The bacteria question is one which has probably still to be settled; but being anxious to have some information as to the action of the iron compound produced by electro-chemical decomposition, Mr. Webster had some experiments carried out, with the result that after a given treatment the whole of the bacteria were killed. In the case of experiments carried out in Paris with ordinary treatment by means of iron electrodes, the results were as follows:—

	Raw Sewage.	Effluent.
Organisms per cubic centimètre ...	5,000,000 ...	600

Another experiment, in which the effluent was treated still further, so that a slight odour of oxide of chlorine was perceptible, destroyed all organisms, and the liquid remained sterile.

A thorough investigation of the process has quite recently been carried out at Webster's experimental works by Sir Henry Roscoe, M.P., F.R.S., and by Mr. Alfred E. Fletcher, F.C.S., F.I.C. (H.M. Inspector under the Rivers Pollution Prevention Act for Scotland) the quantity of London sewage operated upon in each experiment being about 20,000 gallons.

Sir Henry Roscoe reports as follows :—

"The reduction of organic matter in solution is the crucial test of the value of a purifying agent, for unless the organic matter is reduced the effluent will putrefy and rapidly become offensive.

"I have not observed in any of the unfiltered effluents from this process which I have examined any signs of putrefaction, but, on the contrary, a tendency to oxidize. The absence of sulphuretted hydrogen in samples of unfiltered effluent which have been kept for about six weeks in stoppered bottles is also a fact of importance. The settled sewage was not in this condition, as it rapidly underwent putrefaction, even in contact with air, in two or three days.

"The results of this chemical investigation show that the chief advantages of this system of purification are:—

"*First.*—The active agent, hydrated ferrous oxide, is prepared within the sewage itself as a flocculent precipitate. (It is scarcely necessary to add that the inorganic salts in solution are not increased, as in the case where chemicals in solution are added to the sewage). Not only does it act as a mechanical precipitant, but it possesses the property of combining chemically with some of the soluble organic matter, and carrying it down in an insoluble form.

"*Second.*—Hydrated ferrous oxide is a deodorizer.

"*Third.*—By this process the soluble organic matter is reduced to a condition favourable to the further and complete purification by natural agencies.

"*Fourth.*—The effluent is not liable to secondary putrefaction."

Mr. Alfred E. Fletcher reports as follows :—

"The treatment causes a reduction in the oxidizable matter in the sewage, varying from 60 to 80 per cent. The practical result of the process is a very rapid and complete clarification of the sewage, which enables the sludge to separate freely.

"It was noticed that while the raw sewage filters very slowly, so that 500c.c. required 96 hours to pass through a paper filter, the electrically treated sewage settled well and filtered rapidly.

"Samples of the raw sewage having but little smell when fresh, stank strongly on the third day. The treated samples, however, had no smell originally, and remain sweet, without putrefactive change.

"In producing this result two agencies are at work: there is the action of electrolysis, and the formation of a hydrated oxide of iron.

It is not possible, perhaps, to define the exact action, but as the formation of an iron oxide is part of it, it seemed desirable to ascertain whether the simple addition of a salt of iron with lime, sufficient to neutralize the acid of the salt, would produce results similar to those attained by Webster's process.

"In order to make these experiments, samples of fresh raw sewage were taken at Crossness at intervals of one hour during the day. As much as 10 grains of different salts of iron were added per gallon, plus 15·7 grains of lime in some cases, and 125 grains of lime in another, and the treated sewage was allowed to settle 24 hours; the results obtained were not nearly as good as by the electrical method.

"The result of my examination of this process has been to convince me of its efficiency in clarifying sewage, of removing smell, and in preventing putrefaction of the effluent. I am of opinion that such an effluent as I saw at Crossness can be discharged into a river, or, after passing through a thin layer of sand, even into a stream, without causing any nuisance."

Webster's electrical process seems to prove that by its means sewage is effectually purified, clarified, the smell removed, and secondary putrefaction prevented, the bulk of sludge being reduced to a minimum.

The necessary plant consists of electrolytic channels containing the iron plates, the copper conductors and measuring instruments, dynamos, engines, and boilers. Thirty effective horse-power should be provided for treating one million gallons of sewage in 24 hours (representing a town of 30,000 inhabitants), assuming that about 450 tons of iron are laid down. This is estimated as 10 years' supply, the iron consumed having been ascertained to be about 45 tons per million gallons per annum. But as the amount of iron laid down is in inverse proportion to the horse-power required, these two factors can be varied to suit the special requirements of each case. It should, however, be borne in mind that the larger the quantity of iron laid down the longer it will last, and the cheaper it will be in the long run.

For one million gallons of sewage in 24 hours the cost of the above plant (not including iron) would be about £2,000; this would allow for three engines and dynamos (direct driving), and two boilers, any two engines and dynamos, and one boiler, being capable of doing the full load. For dealing with larger quantities of sewage the cost of plant is proportionately less; for instance, for 10 million gallons the cost of electrolytic channels, dynamos, engines, and boilers, would be about £10,000. With modern machinery the coal consumption may be taken as not exceeding 2lbs. per indicated horse-power. The annual cost of maintenance would comprise only coal, iron consumed, and labour. Two shifts of two men each would suffice for one million gallons. To this must be added interest on capital and depreciation of machinery. For 10 million gallons the coal and iron consumed would be in proportion to the amount of sewage treated, but the labour required would but little exceed that for one million gallons, two shifts of three men each being sufficient.

Disposal of Sludge.—The disposal of the sludge obtained under III. to V. is always a great difficulty. Efforts have been made, in connection with the chemical processes, to utilize the sludge as manure. At Birmingham, the sludge, as produced, is simply dug into the land, a sufficient acreage having been purchased for the purpose.

The best method of utilizing the sludge is by separating the liquid from the solid matter, so as to reduce the bulk as much as possible. It is essential that this be done early, to prevent the sediment fermenting, and thus spoiling the purity of the effluent. Generally, a few hours rest will be sufficient to ensure perfect settlement; the water should then be run off quietly to about the level of the deposit. The deposit, or mud, thus formed is drawn off into suitable receptacles for further treatment and conversion into a portable manure. There are two methods of effecting this, viz. :—

(*a*). By evaporation.

(*b*). By mechanical treatment

(*a*). Evaporation. This may be done in dry climates, where the soil is porous, *e.g.*, sandy, by forming large shallow reservoirs with earth bottoms and sides, or by the use of tanks. The moisture is given off by evaporation, but in the former case chiefly by absorption, into the soil below, and the bulk is reduced to 20 per cent.

Such a method should not be adopted in England, as the sludge would not dry for months, and would soon become a nuisance.

Evaporation by artificial heat has also been tried; it is carried out with either Borwick's, Forrest's, or King's machines. The two former are in use in Manchester. It is, however, said to be expensive in both labour and fuel, and there is a liability of nuisance through offensive odours. It is desirable, also, that before heat is applied the filter press should be employed.

(*b*). Mechanical treatment is that by means of filter presses (see

Plates III*e*. and III*f*.). A filter press consists of a number of narrow cells held in a suitable frame, the interior faces being provided with appropriate drainage surfaces communicating with an outlet, and covered by a filtering medium, generally jute or hemp canvas, or other suitable material. The interiors of the cells so built up are in communication directly with each other, or with a common channel, for the introduction of the matter operated upon, and as nothing introduced into the cells can find an exit without passing through the cloth, the solid matter fills up their interior, the liquid leaving by the drainage surfaces. The cells of the machine are subjected to pressure, which increases as the operation goes on. The cells must of necessity be made mechanically true on the outer touching surfaces, so as to prevent the material operated on escaping as the pressure increases.

Fig. 1, *Plate* III*e*., gives an elevation of a filter press plate, and *Fig*. 2 a section of three such plates. They may be either circular or rectangular in shape.

Plate III*g*. shows the arrangement adopted at Wimbledon Sewage Works, by which the sludge is run off from the settling tank into the sludge reservoir, from which it gravitates into the iron receivers, each of which contains one charge. A small quantity of lime, varying from 3½ to 5 per cent. of the volume of the sludge, is then thoroughly mixed with it, and air at a pressure of 60lbs. per square inch is applied at the surface of the sludge, by which it is forced up the dip pipe (see *Plate* III*e*.) and into the presses, where the separation of the liquids from the solids is effected. The operation of filling the press and removing the sludge cake takes about one hour. By this arrangement every five tons of wet sludge, containing about 90 per cent. of water, can be deprived of the bulk of its moisture, giving a residue of one ton of hard-pressed cake, containing from 45 to 50 per cent. of water. The cake so obtained is easily handled, is practically inodorous, becomes air-dried rapidly, and does not again enter into fermentation. To reduce the water in the cakes, they may be loosely stacked on racks in a shed open to the wind, but secure from rain, or they may be dried upon drying floors, in kilns, or by the machines previously mentioned; the latter process, however, increases the cost, and is not always resorted to.

Professor Robinson has suggested the following formula to calculate the weight of sludge cake formed from a given quantity of sludge taken from the tanks :—

Let W = weight of sludge from tanks,

P = percentage of water remaining in pressed sludge,

X = weight of sludge cake.

Then $$X = \frac{10\,W}{100 - P}.$$

Plate III*e.* shows the arrangement of plant by Messrs. Johnson & Co. for dealing with the sludge (about 30 tons daily) from a population of 30,000, comprising the following apparatus :—Air compressor; air accumulator; two sludge filter presses, 3-foot diameter; two sludge forcing vessels, with their fittings, and the various distributing pipes for sludge and air; a tip-truck and tramway for the removal of the pressed cake discharged from the machines.

The cost of such a plant, with the requisite boiler power (about 10 horse-power actual), is about £1,000. Thirty tons of wet sludge can be easily pressed into cakes containing 50 per cent. of moisture, equalling six tons, or one-fifth of the original bulk, consisting of five charges from each machine, of 12cwt. each, in 10 hours.

The cost of the operation, determined from actual work extending over two years at Coventry, amounts, with all expenses included, to sixpence per ton of wet sludge, or half-a-crown per ton of pressed cake.

Messrs. Manlove, Alliott & Company's filter press (*Plate* III*f.*) is of more recent design than that of Messrs. S. H. Johnson (*Plate* III*e.*), and possesses some improvements, the chief of which is that the wheel (see *Plate* III*e.*) is superseded by a small cylinder (C in *Plate* III*f.*), the piston of which is worked by compressed air, thus economizing time in opening and closing the press.

The sludge, being reduced to cake, is easily transported, pulverized, and used as manure, whereas in its original state it is a material which cannot be stored, nor conveniently removed by farmers who may be willing to take it.

The value of the sludge cakes as manure will, of course, depend directly on the quality of the sewage, and the nature of the chemicals used for precipitating. Several authorities state that sludge cake gives about the same results as ordinary farmyard manure.

At present there is not a very large demand for this class of manure, and it is fast becoming recognized that sludge is an enemy to be disposed of in the cheapest way possible.

Even the sludge, therefore, cannot be relied on to yield a profit on the outlay, and consequently systems III., IV. and V., can only be viewed as methods for getting rid of a serious difficulty in the most economical manner attainable.

VI. *Destruction.*—Under this heading may be classed the system patented by the late General Scott, R.E., by which he utilized the sludge to manufacture Portland cement in connection with the lime process. The sludge was precipitated in tanks, by adding lime and clay, afterwards dried, and finally burnt in kilns similar to those used for making ordinary Portland cement. The resulting clinker was then ground to powder.

This process was carried out at Burnley, but its use has for the most part been discontinued.

Within the last few years a system of precipitation, by using lime as a precipitating agent, has been adopted at the Metropolitan sewer outfalls.

The precipitant thus formed is passed into special settling tanks, from thence pumped into the sludge vessel, and discharged, under water, a good distance from land.

At Ealing, Southampton, and other towns, the sludge is removed from the settling tanks, after being treated with suitable precipitating agents, and burnt, in connection with house refuse, in "Fryer's" destructors (see *Plates* III*h*. to III*m*.).

The clinker resulting from this process is valuable for many purposes (*e.g.*, concrete, artificial stone, etc.), and the heat from the process of burning provides sufficient steam to drive the machinery for pumping, etc., necessary at the works.

In all towns, in addition to the sewage, there is the refuse from dustbins, etc., to be disposed of. At one time shoots were without difficulty provided, leading, however, to unsanitary conditions, and annoyance to the neighbourhood. The absolute necessity of dealing with this growing difficulty is constantly forcing itself on the attention of local authorities.

Destructors have been introduced with this object in many large towns during the last 20 years; Manchester and Birmingham were about the first, and then Leeds, in 1877; Blackburn, Bradford, and Bury, in 1881; Bolton, Hull, Nottingham, and Salford, in 1882; Ealing, in 1883; London, 1884; Newcastle, Preston, and Whitechapel, in 1886; and Bournemouth, Botly, Longton, and Battersea, in 1887, with other towns, are either erecting, or upon the point of erecting, destructors. There are several kinds of destructors, but the best is apparently Fryer's patent destructor (*Plates* III*h*. to III*m*.).

It consists of a group of furnaces, or cells, lined with fire-brick, and tied with iron rods; the height is about 12 feet. An incline leads from the adjoining road to a platform against, and higher than, the top of the destructor, on to which the refuse is carted, and another inclined road leads from the same adjoining road down to the level of the firing floor, by which means the products are carted away. Each cell consists of a sloping furnace, with hearth and fire-grate covered in by a reverberatory arch of fire-brick, with one opening at the top for the admission of the refuse, and another opening at the side near the top for the gases to escape into the flue. A furnace frame and doors are provided for the withdrawal of the clinkers. The refuse, which is tipped from the platform on to the top of the cells, is pushed down the incline, or throat, with a long iron prong, and slides forward on to the sloping hearth, whence, when sufficiently dry, it is helped forward on to the fire bars, where it burns, the fire-brick arch above concentrating the heat upon it. The opening for the entry of the refuse is divided from the opening for the exit of gases by a partition wall, with a bridge. This prevents the refuse, which is heaped up immediately below, from finding its way into the flue also. At intervals of about 2½ hours the clinkers are withdrawn from the furnace doors, but the charge of refuse is maintained permanently at the top. The effect of this is that no doors are required, the charge keeping down all smoke. The result of the process is that everything is consumed, or converted either into clinkers or a fine ash. Openings with doors are provided for the introduction of infected mattresses, diseased meat, etc., on to the fire. The chimney-shaft is usually from 120 to 180 feet high.

The gases from the furnaces on the way to the chimney-shaft can be utilized by dampers, so as to pass through a multitubular boiler to generate steam, and supply an engine which works mortar-mills, etc.

The cost of construction varies, but is on the average from £700 to £1,000 per cell.

At Ealing Sewage Works (*Plate* III*i.*) the destructor has been developed and improved by Mr. Charles Jones, C.E., so that he is able to burn the sludge from the precipitation tanks with the aid of the refuse, without previous pressing. Mr. Jones' view is that every town produces sufficient refuse to burn the sludge, and in order to effect this he mixes the sludge with the house refuse. A very few days after the sludge has been pumped into the ash-beds

(*Plate* III*i*.) all the draining and drying necessary has taken place, and the material burns readily.

In 1887, with the aid of four cells, the destructors at Ealing dealt with the sewage sludge of a population of 19,000, and the house refuse of 22,000. It was found at first that the smoke from the chimney created a nuisance, in consequence of a certain amount of vapour given off by the fresh fuel passing into the flue without coming into contact with fire. This led to the invention of Jones' fume cremator (*Plates* III*j*. and III*k*.), which consists in the introduction of a "muffle" furnace, intermediate between the cells and the main shaft. Thus everything coming from the cells, burnt or unburnt, has to pass through an intermediate furnace, producing absolute combustion. This cremator is kept going at a cost of 1s. 6d. per day, the fuel being coke-breeze, and the increased combustion gives additional steam for engine purposes, and, by accelerating the draught, assists very materially the combustion in the cells themselves. The total cost of the destructor, cremator, and chimney was about £2,000.

The report of Professor J. A. Wanklyn on the result of the system at Ealing is as follows:—

"On 9th December, 1887, I paid a visit to the Ealing (Southern) Sewage Works, where all the house refuse and nine-tenths of the sewage from the Ealing district (population, 22,000) is dealt with.

"At these works there is in operation a 4-cell 'Fryer's Destructor,' together with certain adjuncts designed by Mr. C. Jones, C.E., the engineer to the Ealing Local Board. 'Jones' Fume Cremator' especially attracted my attention. Readings of the temperature were made at the time as follows:—

In passage from cells to "Fume Cremator"	610° Fahr.
In "Fume Cremator"	1,270° ,,
After leaving "Fume Cremator"...	1,100° ,,

"At these temperatures, and in presence of the accompanying air, all septic poisons are destroyed, and organic compounds are resolved into carbonic acid, water, and nitrogen gas; only the minutest traces of empyreumatic products could survive and pass away through the shaft into the general atmosphere. No harm to the health of the community is to be expected or feared from these products."

The cells more recently made are two feet three inches longer than shown in the plate, and give better results; the single blocks (*Plate* III*j*.) are also considered better than double blocks, back to back (*Plate* III*h.*), being more readily accessible both at back and front.

The following detail of the cost of working the destructor at Ealing is taken from a paper read by Mr. C. Jones, C.E., before the Association of Municipal and Sanitary Engineers and Surveyors, at Leicester, in July, 1887 :—

Ealing.—Disposal of sewage sludge and house refuse, etc., for the year ending March 25th, 1887 :—

DETAILS OF QUANTITIES AND COST.

	Tons.
Quantity of dust, house refuse, etc., received at works during the year 1886. This includes the dust tipped direct to the destructor, about two-thirds of total amount received ...	3,267
Quantity of sludge (after deducting 50 per cent. for moisture drained off) produced per annum from the population of the district...	4,421
Total of ashes and sludge when mixed, per annum	7,688
Quantity of ditto carted away by market gardeners per annum	1,565
Net quantity of sludge and ashes to be dealt with by destructor	6,123
Annual working expenses	£230 3 10

$$\frac{£230\ 3s.\ 10d.}{6,123} = 9d. \text{ per ton nearly.}$$

ABSTRACT OF EXPENSES AND RECEIPTS.

	£	s.	d.	£	s.	d.
Labour	380	0	0			
Coke-breeze	36	8	0			
Repayment of loan and interest on prime cost of destructor shaft, etc.	115	13	4			
				532	1	4
CREDITS.						
The heat from destructor and cremator gives us sufficient steam to work our machinery, thus saving six chaldrons of coke per week. £3 6s. per week for 52 weeks	171	12	0			
1,960 yards of hard clinker (25 per cent. of material put into destructor) at 1s. ...	98	0	0			
Sale of rags, bottles, etc., from dust... ...	32	5	6			
				301	17	6
Total working expenses				532	1	4
,, saving				301	17	6
Annual working cost				£230	3	10

Gross annual expenses in connection with the treatment of sewage sludge and ashes combined :—

LABOUR.

	Per Week.	£ s. d.	£ s. d.
3 men stoking and feeding, 2 at day and 1 at night. Total time...	21 days 2 hours at 3s. 10d.	4 1 3	
1 man screening ashes	3 ,, 0 ,, 3s. 8d.	0 11 0	
,, ,, ,,	3 ,, 0 ,, 4s. 2d.	0 12 6	
Sludge—			5 4 9
1 man loading trucks	6 ,, 0 ,, 3s. 8d.	1 2 0	
,, ,, ,,	6 ,, 0 ,, 3s. 4d.	1 0 0	
			2 2 0
			£7 6 9

The foregoing represents the house refuse and sludge, which, taken together, give

£7 6s. 9d. × 52 weeks = £381 11s., say £380.

The above statement as to labour includes more than should really be charged to the destructor, as the men are engaged part of the time in the yard, pumping out and other general work. Half the foreman's time is also charged to destructor.

For about six weeks in the year the fires are banked up, and there is little labour on the destructor; but no credit is taken for this, nor is there for the hard core from dust, such as tins, etc., although the labour of picking over is charged in "expenses."

The furnaces are seldom banked up on Sunday, but when this is done the furnaces are filled with refuse and the dampers nearly closed.

Cost of destructor, etc. :—

	£ s. d.	£ s. d.
Chimney-shaft	730 0 0	
Cost of 4 cells, fume cremator, and boiler	1,270 0 0	
		2,000 0 0
Repayment of principal and interest per annum on £100, 30 years at 4 per cent.		5 15 8
Repayment of principal and interest on £2,000... ...		115 13 4

Two of our cells and the cremator were built out of current account, and not out of loan, so there are no annual repayments in respect of these, but the author has included the cost in above amount. For the destructor itself no machinery is necessary, but, of course, if it is desired to utilize the heat given off to raise steam, a boiler is required. Other machinery, of course, depends upon the requirements of the works. At Ealing there is a six horse-power engine, which drives the liming machine, clay mixer, works' lift, chain pump, special pump, etc., atmospheric ejector, sludge ram, mortar-mill, etc., and there is steam sufficient to work all the above and additional machinery if required.

At the present time a considerable saving is being effected by using the hard clinker as a base for tar paving, thereby causing a saving of 30 per cent.; also on a concrete paving, which can be laid for 3s. per yard sup., York paving costing 6s. 4d. per yard sup. The finer material from ashpit, which contains a good deal of recalcined lime, makes a splendid mortar mixed with one part of lime to five of ash, and the clinker, when ground, makes a good mortar with usual proportions. In the above account no special credit has been taken for these items.

*Battersea.**—"This is another district adjacent to London, and having a population of 150,000. At this town they also burn the house refuse, and have erected one of Manlove, Alliott & Co.'s patent destructors, with 12 cells constructed back to back, provided with Jones' patent fume cremators, and with a chimney stack 150 feet in height (*Plates* III*l.* and III*m.*). The works were completed in February, 1888, at a cost of about £11,400, including the chimney-shaft, mortar-mill house, engine house, two incline roadways, and a multitubular steel boiler, 12 feet long by 8 feet in diameter, attached to one of the flues, and which is to be heated with the waste heat from the destructor, and it is estimated that this will create a steam power of 60lbs. pressure to the square inch, sufficient to drive an engine of from 50 to 60 horse-power, for working the mortar-mills, etc., attached to the works, and without any additional cost. The boiler is suspended from heavy cast-iron girders, supported upon walls surrounding the boiler and flues. Each cell consumes about $7\frac{1}{2}$ tons per day of 24 hours, or 28,000 tons per annum for the 12 cells, the fires being banked up on Sundays. This destructor is situated in a populous district, but operations are conducted so successfully that there is no complaint of any nuisance arising from burning the refuse. The residuum is here dealt with in several ways. New stables, workshops, and manager's house have been built at the depôt, and the yard being paved from the manufactured

* *Report on the Destruction of Towns Refuse, and Disposal of the Residuum, to Aston Manor Local Board,* 1889, by W. A. Davies, H.A.I.C.S., Engineer and Surveyor to the Board.

clinker, the whole of the buildings present a very pleasing and durable appearance. Artificial stone slabs for footpath paving are also very extensively made here, as well as a large quantity of materials prepared for laying tar paving, many footpaths having been satisfactorily laid with both kinds. An inspection was made of specimens of the paving laid, which had a nice cleanly appearance, and compared very favourably with other methods. The surveyor also stated that they were prepared to undertake private paving at 2s. per yard, which, after all expenses had been paid, would leave them a good margin of profit. Mortar is also made from the clinker, but up to the present the whole of it has been required for their own purposes. The house refuse is here satisfactorily dealt with at a cost of 1s. per ton per annum."

Sewage Disposal of Southampton.

The following is a brief description of the new sanitary and sewage disposal works carried out in this borough :—

"Early in 1885, the Corporation considered it expedient to introduce a more efficient system of collection and disposal of house refuse, and about the same time they found it desirable to clarify the sewage of a district of the town, which was discharged into the Southampton Water at the Town Quay in its crude state.

"Mr. W. B. G. Bennett, C.E., the Borough Surveyor, was instructed to devise a scheme to accomplish these objects, and accordingly proposed the adoption of Messrs. Manlove, Alliott, Fryer and Co.'s refuse destructor, to serve the double purpose of destroying the ash-bin contents and garbage, and of disposing of the sewage-sludge deposited, in the process of clarification, in two existing reservoirs adapted for the purpose, each 100 feet long and 60 feet wide, and at the lowest end 10 feet deep. Formerly the sewage of a district of the town, amounting to 500,000 gallons in twenty-four hours, from a population of about thirteen thousand, for the most part flowed by gravitation into these reservoirs, from whence it was discharged into the tideway at low water; whilst a small portion, coming from a low-level sewer, passed through iron pipes, laid under the reservoirs, direct into the tideway. The reservoirs act alternately, one being left still for precipitation of the sewage, whilst the other is being filled.

"In order to render the discharge of the effluent from the reservoirs independent of the tide, and to raise the low-level sewage into the reservoirs for treatment with the rest, two of Shone's pneumatic ejectors were put down, one of 360 gallons capacity, placed below the invert of the low-level sewer, which serves for discharging the sludge as well as for raising the low level sewage, and the other of 700 gallons capacity placed in the east reservoir. There is also a third ejector of 360 gallons capacity which deals with the sewage of another district of the town near the works, operated also by the destructor, which raises the sewage from a low-level sewer to a higher one about 18 feet above, the compressed air required being 12lbs. to the square inch. This ejector was formerly worked by an independent steam engine, costing for coals about £120 per annum, which is now saved. In each reservoir there is a floating sewage inlet consisting of a pipe connected with the large ejector, and shackled to a buoy, which makes the pipe rise and fall with the water-level, keeping its mouth, which is covered with perforated plate, a few inches below the surface of the effluent, to prevent the passage of any floating matter. Directly the clarification by precipitation has been effected to a certain depth, a valve is opened, admitting the effluent into the ejector, whence it is at once discharged into the tideway. A supplementary sewage outlet is also provided in each reservoir for discharging the effluent by gravitation when the tide is low enough. When the whole of the effluent has been thus drawn off, the buoy, resting now upon the floor of the reservoir, keeps the mouth of the inlet sufficiently high tc prevent the admission of any sludge; and the sludge is then admitted into the ejector by opening a valve, and is transmitted by pneumatic force through a line of 4-inch cast-iron pipes, nearly a mile in length, to the destructor erected on the Chapel Wharf. Ferozone supplied by the International Water and Sewage Purification Company is used for precipitating the sludge; it is mixed with clean water into a stiff paste, and led through a shoot into a box with perforated sides, placed in the sewer. The sewage flowing past washes the ferozone gradually out of the box, and is thoroughly mixed with the ferozone by the time it discharges into the reservoirs at a manhole 150 feet off. A small stream of water falling down on the ferozone prevents its consolidating. The box is filled three times in twenty-four hours, and this method of dosing the sewage has proved quite efficient and satisfactory. A pressure of air 40lbs. on the square inch is required for working the sludge ejector, and 10lbs. for the effluent ejector.

"The sludge is discharged into a cell, from whence it is drawn as required through a valve-pipe, and after mixture with road-sweepings or sorted house refuse, in an incorporator, is transmitted by a specially arranged conveyor to an elevator, which loads it into trollies, as a good dry portable manure, which has all been readily bought up by agriculturists, since the commencement of the works, at 2s. 6d. per load delivered at the works, and large quantities of this manure are shipped to the Channel Islands, where it is in great demand, and is used with most favourable results in the cultivation of market produce, which finds a ready sale in the London markets and elsewhere. A 6-H.P. steam engine drives the incorporator and elevator. On an average 60 cartloads of ash-bin contents are daily collected and disposed of. Twenty-five tons of refuse, when burnt, generate sufficient steam for the carrying on of the works for one day. The road-sweepings are never burnt. In wet weather the road-sweepings are stored and dried, and the fine ashes from the destructor are incorporated with the sludge in their place; but frequently during the winter, to keep pace with the demand, the sludge is run into bays made of and filled in with, road-sweepings, and amounts in twenty-four hours to the amount of about eight tons. Arrangements were provided for burning the sludge. It was discharged into a tank on the floor of the destructor, and drawn out through ports in the front opposite the feed-opening of the cells, where its moisture was absorbed by the ash-bin contents, backed up against the ports with this object, and the mixture was then raked into the fires. Large quantities of sludge have been thus destroyed, but the process has been discontinued owing to the ready sale of sludge when prepared for manure.

"The refuse destructor has six cells, or furnaces, each capable of burning eight to nine tons of garbage per day. The products of combustion pass through a 30-HP. multitubular steel boiler in the main flue to a furnace shaft, which is of circular brickwork 160 feet in height from the ground line, inside diameter at the top six feet, ditto at the bottom seven feet, constructed upon a pedestal 14 feet 6 inches square and 24 feet in height, of brickwork three feet thick, then in four sections as follows:—

1st in 27-in. brickwork		... ...	30 feet high.
2nd in 22½-inch brickwork		... ...	30 ,,
3rd in 18-in.	,,	... ...	38 ,,
4th in 14-in.	,,	... ...	38 ,,

"The first 30 feet is fire brick lined, with a cavity of $4\frac{1}{2}$ inches behind, ventilated to the outer side.

"The foundation is loamy clay, upon which is laid a bed of concrete 30 feet square and 10 feet thick.

"The footings commence at 23 feet 2 inches square, and step off in regular courses up to 15 feet square, at a height of six feet. The concrete was filled in continuously until completion. The pedestal was then run up and allowed to remain for nearly three months during the winter, after which the works proceeded until completion, which occupied about six months.

"The cap is white brick in cement, with a string course about 20 feet below the top.

"Foot irons are built inside in a winding lead to the top.

"The shaft is provided with a copper tape lightning conductor, with inch rod and crow's-foot seven feet above the cap. The tape is about 215 feet long, the end being carried into a well.

"In August, 1888, the shaft was damaged by lightning, but was easily repaired, owing to the provision of the foot irons referred to. At this time the shaft was plumbed and found to be quite vertical. The fires were only damped down during the repairs, which occupied about eight days. With the exception of this interval they have been constantly burning for nearly four years.

"The repairs have been almost nil.

"There is also a by-pass in which a smaller boiler is placed, to enable the works to be continued during cleaning and repairs. No obnoxious fumes from the combustion have been perceived. The steam generated in the boiler is employed for driving a pair of engines, of 31·5 indicated HP., which compress air into two large receivers, whence it passes in a 5-inch main to the Town Quay, where it is automatically supplied to the ejectors when required for working them; and it also serves for driving the preciptated sludge through the main to the destructor before referred to, being led from the receiver by a pipe to the head of the main at the Town Quay, and also the 6-HP. engine before mentioned, and the engine used in connection with the machinery for the preparation of the horse fodder at the Corporation stables.

"All obnoxious matters are collected throughout the borough in specially constructed, covered, iron tumbril-carts, which go up the inclined roadway approached to the destructor, and discharge their contents out into the cells. The road-sweepings are discharged into a hopper over the incorporator, and are mixed with the sludge as required.

"The residue from the continuous day and night combustion consists of about 20 per cent. of good hard clinkers and sharp fine ashes; the clinkers are used for the foundation of roadways and the manufacture of paving-slabs, which have already been used in paving several footpaths of the town, at a cost of 2s. 6d. per yard; the fine ashes are also employed for making mortar, with which the stables and swimming baths have been erected, and for many other purposes. ... .

"The waste heat from the destructor is also utilized for producing electricity. The engines before referred to drive a dynamo sufficiently powerful to feed either ten arc lamps of 3,000-c.p. each, thirty 1,000-c.p., or two hundred glow lamps of the ordinary 16-c.p. type. At the present time the works are lighted with two 3,000-c.p. and 12 glow lamps, and frequently four streets in the vicinity of the works are lighted, but this has only been done experimentally for the information of the Corporation, who have from the successful results obtained unanimously resolved to extend the installation to the municipal offices, the church clock opposite, the Hartley Institution, and the Town Hall at the Bar Gate. For this purpose it is proposed to place accumulators in the basement of the municipal building, and charged through a cable from the works. This lighting will be more economical than the gas, as it will be seen no cost will be incurred for fuel, as we have ascertained that the house refuse will be sufficient to maintain the steam. In order to show that further use can be made of refuse destructor and the utilization of town refuse in connection with sewage treatment, nothing will be easier, as soon as Mr. Webster has perfected his system, than to employ it for the electrical treatment of our sewage; for we shall only have to place the electrodes in our existing reservoir, and charge them from the dynamos at the destructor works by cable.

"The destructor is also employed in giving a helping hand to a neighbouring authority.

"The Corporation supply the Local Board of Shirley and Freemantle, about two miles from here, with sufficient compressed air to work ejectors which they have put down in connection with the disposal of their sewage sludge after precipitation. The compressed air is conveyed through a 4-inch main between the two works, thus saving them the cost of a pumping station, and bringing to the Southampton Corporation a return of £200 a year, which is paid for the compressed air.

"The initial cost of the destructor, including engine house, inclined roadway, chimney shaft and boiler, and ironwork complete was £3,723; and the sewage disposal portion of works about £3,000.

"The annual expense for burning refuse is as follows:—

	Per Week £ s. d.	Per Annum. £ s. d.
Two stokers, £1 5s. each, 1 day and 1 night	2 10 0	182 0 0
One feeder, day only	1 0 0	
Half time of Superintendent		39 4 0
		£221 4 0

"Maximum quantity burnt per day of 24 hours is 50 tons, which is less than 3½d. per ton for burning.

"The minimum quantity burnt per day of 24 hours is about 25 tons.

"This quantity has maintained the steam for the purpose of our work for 24 hours. The indicated HP. of the engines being 31·5, or ·80 of a ton of refuse per HP. for 24 hours, or 75lbs. of refuse per HP. per hour.

"The annual expenditure for the sewage clarification and disposal works is £308, as follows:—

	£ s. d.
365 days (precipitating material average 8s. 2d. per day)...	149 0 0
Labour attendants at reservoirs	65 8 0
Two men at wharf manure mixing	93 12 0
Total	£308 0 0

"The amount received from the sale of manure and supply of compressed air during the last year was £800.

"The products from the destructor, which include the concrete slabs before referred to, steps for police station, clinkers used for concrete foundations, fine ashes for mortar and foundations for footwalks, and clinkers sold for new cycle track, represent about another £300.

"To which could also be added the saving for coal required for working the engines."

Objection has been taken to this system on account of the destruction of the organic matter existing in sewage, which, as it contains nitrogen, phosphoric acid, and potash, is very suitable as a manure, and should, therefore, be employed as such, instead of being uselessly destroyed. However, in spite of all objection to the contrary, the difficulty of disposal is readily surmounted by this process.

Destruction of Household Refuse.—Very recently a system for the disposal of household refuse has been adopted by the "Refuse Disposal Company, Limited," at their works, Salopian Wharf, Chelsea. The system is essentially a sorting process, which is all done under cover and mainly by the aid of machinery. By means of exhaust fans, all flying particles of dust evolved in the process of turning over are drawn into the furnace draughts, and so prevented from becoming a nuisance to the neighbourhood. One great merit of the process is that it deals with the refuse as quickly as it is brought on the spot, and no accumulation of undealt with refuse is allowed to take place.

The following is a report by Sir Douglas Galton on the process:—

"The dust carts deliver their loads into a revolving cylinder 10 feet diameter by 12 feet long.

"This cylinder is made of iron ribs placed about 10 inches apart, upon which are fixed wooden bars, between each of which is an opening of $2\frac{1}{2}$ inches wide, so that anything less than 10 inches by $2\frac{1}{2}$ inches will pass through.

"The wood is used to prevent bottles from being broken.

"The cylinder is supported on friction wheels, and is driven by external gear.

"It has no internal spindle, or arms, as these would catch the materials and clog the working.

"It has a tilt of about nine inches in its length.

"There is a worm carried round the inner surface of the cylinder, with an interspace of two feet six inches for the purpose of assisting the material in travelling through the cylinder. Thus, material thrown in from the dust cart will pass out at the further end in from two and a-half to three minutes.

"The material which does not drop through the meshes of the cylinder is taken out and sorted by hand as it arrives at the further end, consisting chiefly of cardboard boxes, bottles, fuel, tin boxes, clothes, and other various matters; these are all sorted into separate baskets, the vegetable and animal refuse being taken to a mill to be ground.

"The material which falls through the first screen passes into a second screen, which consists of a cylinder of iron, eight feet diameter, 16 feet long, covered with wire-work having a mesh of $1\frac{1}{4}$ inches square.

"This cylinder is also supported on friction wheels, and driven by external gearing, and is provided with a worm to carry the materials which do not fall through the meshes from one end to the other.

"This material, as it falls from the end of the second cylinder, is met by a powerful blast of air, which blows the paper away from the heavier material into an iron chest, where it is subjected to heat from the exhaust steam which is passed through the pipes in the chest.

"The other heavier material is raised by an elevator into a slide placed at such an angle as to regulate its descent on to an iron horizontal plate, or table, which is constantly revolving, and which brings the material to a series of boys sitting round, who sort what lies on it.

"Thus coal is all saved, so is iron and metal, also boots and shoes, whilst nondescript material, such as bread, vegetable and animal refuse, broken crockery, etc., is all taken to the grinding mill and ground up with similar refuse from the first cylinder.

"The material which drops through the second cylinder is delivered by an endless band into a third cylinder, also of iron, six feet in diameter and 15 feet long, covered with wire-work having a mesh of three-eighths of an inch.

"This cylinder is also furnished with a worm. What passes through this mesh is called fine ash, and is sold to brickmakers.

"The refuse which is delivered at the end of this third cylinder, and has not passed through the $\frac{3}{8}$-inch mesh, but has passed $1\frac{1}{4}$-inch mesh, forms the fuel for working the engines for the operation, and also is sold as fuel for brickmakers.

"This latter refuse contains much vegetable matter.

"It would appear, from statements made as to the quantity required under the boiler, that its value was about one-seventh that of coal; but its heating power is much increased by washing, which removes potato peelings and other vegetable refuse; and, indeed, part of the process is to expose the material to a stream of water which carries off the lighter organic matter.

"It should have been mentioned that the dust, which is occasioned by the process of working in the cylinders and in the spaces below them, is removed by a powerful exhaust acting through apertures which open into the centre of the cylinders and into the other spaces where the movement of the material generates dust.

"The exhaust carries the dust through the fire, which is under the boiler. By this means the operators are relieved from exposure to the dust caused by the operations.

"A market is said to be found for all the sorted refuse.

"For the ground-up material from the mill there appears to be a demand from manufacturers of manure.

"The paper, after it has been dried at a high temperature, which can be made sufficiently high, if desired, to remove chances of infection, is sorted and freed from dust, and is then pulped for conversion on the premises into brown paper or cardboard.

"There seems to be no reason, if care were taken to sort out the best white paper, why this better material should not be converted into white paper, instead of all being converted into brown paper and cardboard, as is now done.

"The dust which is drawn by the exhaust from the cylinder and from the paper chest, and from other parts, is all drawn through the boiler fire, the accelerated draught of which assists the combustion of the vegetable refuse in the breeze, and enables the gases from the fire to be passed through a scrubber with water spray, so as to prevent offensive odours.

"It may be mentioned incidentally that the works are lighted by electric light, generated by the fuel obtained in these operations.

"The question of dealing with this class of refuse has always been a troublesome problem.

"The plan of burning the refuse does not do away with a certain amount of preliminary sorting; this sorting, as usually practised, is necessarily an insanitary occupation, and the wholesale burning of refuse is undoubtedly wasteful.

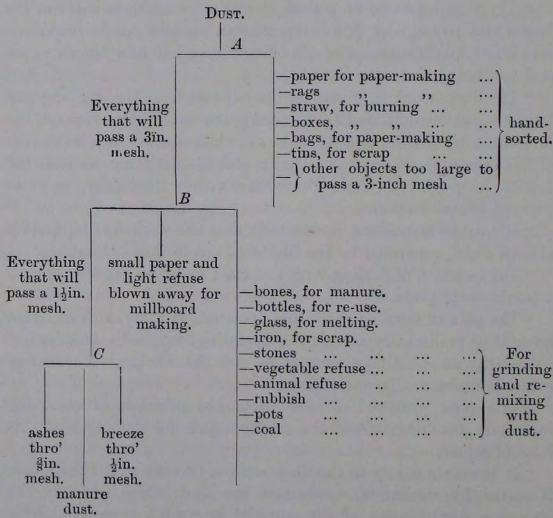
"The plan proposed is based upon the principle of removing insanitary conditions from the arrangements for dealing with this class of refuse.

"It prevents injury to the dust sorters, because whilst the refuse is sorted by mechanical appliances, the dust which arises in the necessary manipulation of the material in sorting is removed by a powerful exhaust, and thus the atmosphere in which the operations take place is kept pure.

"The method adopted for mechanical sorting saves all those portions of the refuse that can be utilized, and it employs for the purpose of its own operations that part of the material which cannot be sold, but which has finally to be disposed of by burning.

"In fact, whilst it utilizes the waste products, it aims at placing the method of disposing of this class of house refuse in the category of a healthy occupation; and it may be safely asserted that it has achieved this object even in the rough preliminary arrangements which have been made at the Salopian Wharf—arrangements which might, no doubt, be greatly improved in any fresh installation."

The following is a typographical diagram, of which the top, beginning with the word "dust," represents the point of commencement of the process, *A* representing the revolving receiving cylinder :—



CHAPTER II.

COLLECTION AND REMOVAL.

It is, as already stated, most essential for the health of any community that an adequate system for the removal of their sewage be adopted. The following are the systems at present in use :—

I.—Sewerage (Water Carriage).

(*a*). *The Combined System.*—By which all sewage, surface water, sub-soil water, and manufacturer's refuse are carried into the same sewer.

(*b*). *Modification Excluding Sub-soil Water.*—The next system is a modification of the preceding, in so far as that the sub-soil water is carefully excluded from the sewers.

(*c*). *Absolutely Separate System.*—The absolutely separate system involves the use of three sets of drains, one for foul water or sewage, one for surface water, and another for sub-soil water.

(*d*). *Partially Separate System.*—Then we have the partially separate system, which is a combination of the "combined" and "absolutely separate" systems.

II.—Pneumatic.

(*e*). *Shone's Hydro-Pneumatic Ejector System.*—The Shone system of sewerage is applicable wherever the sewage of a town or district requires to be lifted, and may be described as a system of distributed stations for the lifting of sewage.

(*f*). *The Liernur System.*—This system of sewerage was introduced by Captain Liernur, a Dutch engineer. It is in operation in several

Continental towns, amongst which may be mentioned Amsterdam, Prague, and St. Petersburg.

It consists in removing the fœcal matter from water-closets, and the foul water from kitchen sinks, by pneumatic agency.

The air-pumps and collecting reservoirs are situated in a central station. The town is divided into districts, with a central air-tight iron tank, to which the water-closets are connected with air-tight pipes; these tanks are in their turn connected with the central station.

There are special arrangements for regulating the removal of the excretal refuse from the different districts. There is a constant in-draught in the closet pans. As little water as possible is used on this system, or allowed to enter the drains, so as not to dilute the sewage.

The liquid manure thus collected is mixed with from 1 to $1\frac{1}{2}$ per cent. of sulphuric acid, and transferred to a steam concentrator, which is heated to about 100° centigrade, and the sludge is then brought to the consistency of syrup.

In some instances the farmers take it, but there is not much demand for it, and in Holland it is conveyed by barges to the suburbs, where it is mixed with ashes and made into semi-dry manure.

The working expenses amount to about 4s. 10d. per head per annum.

III.—Interception.

Where a dry method is in force for the collection of the excrementitious matter, it is called interception. There are a great variety of appliances for effecting it, such as earth closets, pails, and tubs.

Under this head are also included middens and cesspits, as they have to be periodically emptied.

(*g*). *Cesspits.*—In places where no main sewers exist, and where there is no river or other conduit into which the drainage of a house may be led, it may be necessary to have recourse to a cesspit. It is, of course, a very objectionable method.

Such pits should be sufficiently large to contain all the drainage for several months, but it will be well to remove it frequently by pumping; there is usually some garden ground to which the sewage can be applied.

The best and least offensive system for emptying a cesspit is the pneumatic system.

The pneumatic system acts as follows:—A large air-tight cylinder on wheels, or what answers equally, a series of air-tight barrels, connected together by tubes about three inches diameter, placed on a cart, is brought as near to the cesspit as is convenient. A tube of about the same diameter is led from the stop-cock on the cylinder, or nearest barrel, to the cesspit. The air is then exhausted in the barrels or cylinder, either by means of an air-pump, or injected steam, which, on condensation, forms a vacuum. The stop-cock is then opened, and the contents of the cesspit is drawn through the tube by atmospheric pressure into the cylinder or barrels.

Cesspits should be placed as far as possible from any dwelling, and cut off by a disconnecting trap, and properly ventilated with inlet and outlet shafts provided with suitable cowls, such as those made by Messrs. Boyle & Son. In such a position cowls would be most useful, as there would be no alternating current of air to deal with.

Means of deodorization should be provided when the pit is emptied.

The iron process would appear well adapted for use with cesspits.

(*h*). *Soakpits.*—If made in porous soils so that the liquid soaks away, they are called *soakpits;* they are dangerous to neighbouring wells, and lead to saturation of the soil. In some cases, when formed in chalk, gravel, or other porous soil, with a low level of sub-soil water, and the water supplied is not obtained from wells, no injurious results may follow.

(*i*). *Middens* are simply shallow receptacles in the ground, formed of masonry; their capacity should not be greater than 40 cubic feet, and they should be lined on the inside with cement to prevent soakage. The floor level of the interior should be slightly above that of the adjoining ground. They require periodical cleaning at least every three months, and are, of course, most objectionable from a sanitary point of view.

(*j*). *Pails and Tubs.*—The pail and tub systems are simply improvements on middens.

Some of the forms adopted are shown in *Plate* V.

The pails used at Rochdale are made from petroleum casks cut in two, restained and hooped. When finished they are 18 inches in diameter at the top, 15 inches at the bottom, and about 16 inches deep. Special carts are employed for collecting the pails, with compartments to receive them; the pails are at the same time replaced with clean ones. Specially coloured pails are supplied to houses where cases of infectious disease exist.

Each pail lasts about two years.

The pails may also be made of iron, and provided with air-tight covers.

On the Goux principle, used at Halifax, the pails have an absorbent lining of dry refuse, which is shaped by means of a mould for the purpose (*Plate* V.). The pails are re-lined at the works after emptying.

(*k*). *Earth Closets.*—Earth closets, properly so-called, are, for the most part, either Moule's or Taylor's. They are made to act by pulling or raising a handle, or else automatically, by which means a discharge of dry earth or ashes is intended to take place each time they are used (*Fig.* 9).

MOULE'S EARTH CLOSETS.

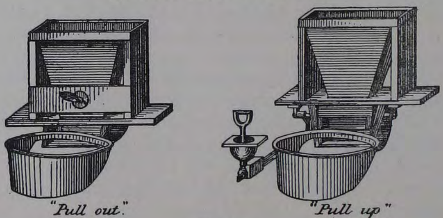


Fig. 9.

Fig. 10 is the automatic arrangement, and the ordinary pail used.

An improved form of pail is sometimes used with these closets, as shown in *Fig.* 11.

The buckets have to be emptied when full, and replaced by clean ones.

Temporary Latrines.—In latrines for the use of troops and for temporary purposes, the earth is very often kept in boxes on the floor of the various compartments, a scoop being provided with which to supply the earth; but the application of dry earth in this manner is, as might be expected, too often neglected, so that it is not a very perfect arrangement. In connection with it, sheds must be provided to store the earth, and also hot plates to dry the latter when required.

Plate IV. gives the necessary details for a temporary latrine of this description. A permanent latrine on this system might be made

MOULE'S AUTOMATIC EARTH CLOSET.

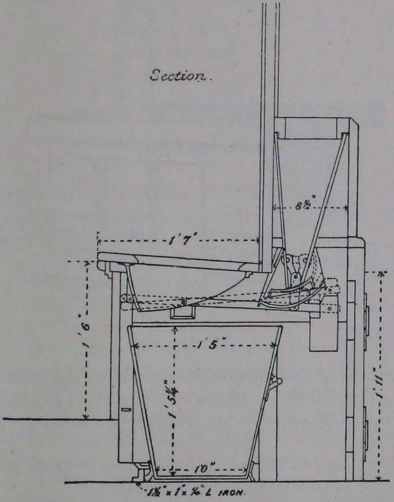


Fig. 10.

with seats in two rows, and back to back, with a passage between

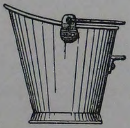


Fig. 11.

for the removal of the pails. An arrangement for drying earth on a small scale, is shown in *Fig.* 12.

Plate IV*a*. illustrates a building suggested for drying and storing a considerable quantity of earth, which should be sifted after being dried.

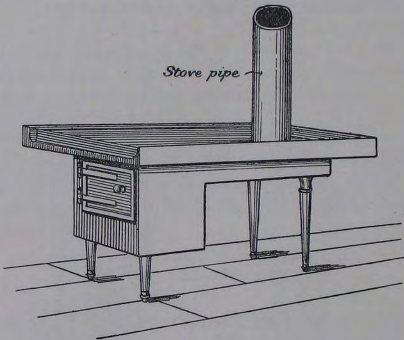


Fig. 12.

Cost of Removal of Excrement.—The removal of the excrement thus collected by the different methods of interception entails considerable labour and careful supervision, especially if carried out on a large cale.

The average cost o the pail system, when properly carried out, has been found to be 20s. 6d. per pail per annum.

Comparison of Systems.—The pneumatic system (Liernur) requires drains to convey waste and storm-water, in addition to those used for the removal of the sewage. Expensive works, consisting of district reservoirs and central collecting stations, with machinery etc., are also necessitated. Both systems (II. and III.) involve the use of drains of some description to carry off the bulk of the liquid refuse, so that sewerage or water-carriage by gravitation is apparently the most economical method for the collection and removal of sewage, and it is certainly the most effective in temperate climates.

CHAPTER III.

SEWERAGE.

Choice of System.—It is necessary, before preparing a design for the sewerage of any locality, to decide which of the water-carriage systems already mentioned is to be adopted.

The "absolutely separate" system is undoubtedly the most perfect when carried out in its entirety, the great advantage being that the number of traps required to prevent the escape of dangerous gases from the foul-water drains is reduced to a minimum; and, of course, no sewer-gas can escape at the gratings for surface water; thus the dangerous area is materially reduced, and may, to a great extent, be isolated. The size of the sewers may also be more easily adapted to the quantity of sewage they will have to convey, and greater facilities are afforded for their regular supervision and cleansing, the tendency of deposit and formation of foul gases being minimized. The quantity of foul water, owing to the exclusion of the surface water, is uniform in composition, and much reduced, therefore its purification and utilization are less difficult.

The disadvantages of this system are that two sets of pipes (one for sewage and one for surface water) would be required, and might lead to mistakes being made by workmen in connecting new drains to the wrong system, and also that the surface water from yards and streets is often very foul, particularly when a storm succeeds a period of drought, unless the yards and streets are constantly cleansed and well scavenged.

Some authorities consider that the separate system is less expensive than the combined, as although two sets of drains are involved, yet those provided for surface water need not be so elaborate as those for sewage, *e.g.*, old culverts, water-courses, etc., may be utilized, and expensive traps and ventilating apparatus of large proportions are not required.

It is not, however, always convenient to carry out the system completely, as it might necessitate a long length of pipe being laid to carry off the surface water of a small courtyard in an out-of-the-way corner, where the existence of a foul-water trap might be considered as unlikely to be prejudicial to health.

The "partially separate" system thus recommends itself, if judiciously applied, and the principles, on which the absolutely separate system are based, are at the same time, carefully kept in view. Care must be taken in the arrangements for the sites of the gullies that slops and foul water shall not be thrown into gratings intended for surface water only.

Drains and drainage may, therefore, be considered under the following separate heads :—

(*a*). Sewerage, including foul water from w.c.'s, urinals, sinks, wash-houses, etc.

(*b*). Surface drainage, comprising water from roofs, roads, pavements, etc.

(*c*). Sub-soil drainage.

The following definitions of the terms used in various works dealing with the subject are useful :—

Definitions.—Drains may be defined as conduits for carrying off liquids of any kind in any position, but the term is understood to refer specially to underground pipes of metal, stoneware, brickwork, or concrete; the liquid consists of sewage, and sub-soil or other water.

The Rivers Pollution Commissioners defined the term sewage as being applicable to water mixed with any refuse that may affect public health. This refuse consists of a variety of matters, some held in suspension and some in solution. The main drains which carry the liquid and feculent refuse from one or more houses are termed *sewers.* The small drains about the several parts of a building, and connecting them with the sewers, are termed *house drains.*

The terms "communicating sewers" and "common sewers" are sometimes used to designate house drains and main sewers respectively.

General Principles.—Having selected the system on which the drainage of any particular locality is to be carried out, the plans should be carefully prepared, so as to secure uniformity throughout.

The position to which the sewage is to be delivered by the drains requires careful arrangement, especially where pumping has to be resorted to, so as to minimize the lift, and the consequent cost; in the latter case the minimum gradients consistent with efficiency would be given to the drains.

Intercepting sewers at different levels may also be arranged so as to reduce the cost as far as possible.

A town which is completely and properly sewered will have a system of underground sewage-conduits, formed with even lines and gradients, true in cross-sectional form, and capable of transmitting sewage at rates of from one mile per hour, to six or seven miles per hour by flushing. If the town stands upon a site such as Brighton, Bristol, or Liverpool, care should be taken to so plan and execute the main sewers that the area shall be sub-divided by intercepting sewers, or by "*ramps*" and double ventilation, as in *Fig.* 3, *Plate* V*a.*, so as to prevent the lower parts from being flooded with the downward flow of storm-water sewage, and the upper parts of the town being injured by the upward flow of sewage-gases. This system of sub-dividing and intercepting the sewage, and specially ventilating the main sewers, will be found to be of the utmost importance; as if sewers are not so dealt with, suburban houses, however superior in construction and accommodation, may be poisoned by the transmission of sewer-gases from the lower parts of the town to the higher parts.

Sewers with steep gradients, if the flow of sewage is unbroken, produce a velocity in the sewage which is liable to be very injurious in its wearing action on the sewers, and during heavy rains it acquires such a velocity as not only to wear out the invert and blow the joints, but also to burst the sewers. Stone-ware pipes under such circumstances should be bedded in concrete; preferably, iron pipes should be used. It is necessary in such sewers to provide means for regulating the flow. This is best done by means of sluice-valves, or pen-stocks (*Figs.* 1 to 4, *Plate* V*a.*).

Storage Tank.—When sewers deliver in such a position as to be liable to be covered by a rise of water, the pressure being insufficient to overcome the obstruction, or when it would be objectionable to discharge the sewage with a rising tide, the lower end of the drain must be made large enough to store the sewage whilst the outlet is closed (*vide Plate* VI.). An overflow outlet should also be provided for flood water.

Valves.—When the outfall of a sewer is subject to a rise of tide, it may be protected by a self-closing flap, or tankard valve, to prevent the sewage from being forced back into the system. All the working parts of a tankard valve should be bushed with gun-metal, to prevent the valve from sticking (see *Fig.* 13; also *Figs.* 5, 6, and 7, *Plate* Va.).

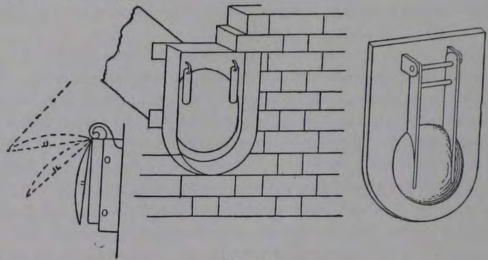


Fig. 13.

A properly constructed tide valve (see *Figs.* 5 to 7, *Plate* Va.) should be entirely self-acting, and should regulate the discharge of the sewers at the outfall of which it is fixed.

Depth of Sewers, etc.—The depth of the sewers and drains below ground must be regulated so as to enable them to drain the basements of the houses.

Manholes.—There should, if possible, be manholes at all junctions and bends.

Straight Lines between Manholes.—Unless there is some practical difficulty in the way, each sewer should be laid in straight lines, and with even gradients between man and lampholes (*vide Plate* XXV.).

Levels.—In arranging the levels for the various portions of the sewers, it must be remembered that they are all converging to one point, consequently their intersections must be carefully considered.

Sewers and drains at junctions and curves should have extra fall to compensate for friction.

In order to connect a high level pipe sewer with one at a low level, such as between M and D, P, in *Fig.* 3, *Plate* XIII., a *ramp* is most desirable to prevent the evils of a direct fall, such as that shown in *Fig.* 11, *Plate* XXVI. The exit at the high level should be made with a very full throat, to check the tendency of storm water to leap the opening, and run straight on through the inspection arm, which is only provided for inspection and clearing purposes. The necessity for an inspection arm may be entirely obviated by the introduction of an inspection pit, as shown dotted in *Plate* XXVI.

Where culverts are used, a similar system should be adopted, and in this case, iron pipes of smaller sectional area than that of the upper sewer, should be employed for forming the ramp.

Inverted Syphons.—Where it is found necessary that a sewer should cross a river, stream, or valley in its passage towards the outfall, and it is inconvenient to bridge the stream at the level at which the sewer must be constructed, inverted syphons are generally adopted.

To effect this the pipes, which should be of strong wrought-iron, are laid, in the case of rivers and streams, in three ways, viz., by means of barges or lighters, by forming cofferdams, or by tunnelling the bed of the channel.

In the construction of these syphons ventilation must be provided, more particularly in the descending leg, otherwise an accumulation of air or gas would interfere with its discharging power.

For this purpose it is customary to provide manholes on both banks of the channel to be crossed, which also serve as convenient places for the removal of any obstruction that may occur.

There is a considerable difference of opinion as to the form inverted syphons should take, and the method to be adopted in their construction.

In some cases pipes are made to follow the sectional outline of the river or channel, by which arrangement there are usually two sloping lengths and one flat length of pipe. If such a syphon be used for crude sewage, and the volume is intermittent and uncertain, there is a liability of chokage, owing to heavy matter carried by the sewage being deposited in the flat length.

It is usual, therefore, during construction to pass a chain through the pipes and secure the ends in the manholes on the adjoining banks, so that it may be drawn backwards and forwards, and thus stir up and set in motion any sedimentary substances that may have been deposited.

For the purpose of calculating the discharge of such syphons they may be treated as ordinary pipes; but if there are any bends, the resistance offered by them must also be calculated. The head necessary to overcome friction of the bends being ascertained, and deducted from the actual head of water on the syphons, will give the head under which the discharge will take place.

It is usual to relieve such syphons from having to carry storm water, by providing suitable overflows into the river.

Pumping or Lifting.—Owing to local circumstances, such as the low-lying portions of a town in relation to its outfall, it may be necessary to lift, or raise, the sewage by artificial means in order to dispose of it. This may be done either by pumping or by the use of Shone's hydro-pneumatic ejectors (*Plate* VI*a*.), which are placed at various points in the districts of a town, and are worked by compressed air from one central station, whereby the whole drainage area is divided into a number of compact districts, each with its separate outfall and discharging station, the discharge from all the stations converging into one common main leading to the ultimate common outfall.

The advantages claimed for such a system are as follow, comprising :—

(1). "The interception of the bulk of the sewage at higher levels, and consequent saving of power as compared with a single pumping station, in which the whole bulk has to flow down to the lowest point merely to be pumped back again, the fall to the pumping station being so much absolute waste of power.

(2). "The obtaining of short, good, and self-cleansing gradients from the houses to the district outfalls or ejector stations, with small sewer-pipes in which there is no room for the accumulation of sewage-gas.

(3). "The entire severance of each district from the main sewer and the rest of the drainage area. Thus, in the event of any epidemic disease breaking out in one district it cannot be conveyed by the sewers into healthy districts, as is often the case when the whole area is connected by a network of drains leading to one common outfall.

(4). "The avoidance of deep cuttings and of large sewers, whereby great economy is effected in first cost.

(5). "The ready extension of the system in proportion as the population and occupied area increases, thus avoiding the heavy outlay in providing for probable future requirements, and relieving the ratepayers of the present day of the heavy burden of providing prematurely for the want of a possible future population.

"But the disadvantage of distributed sewage pumping stations of the ordinary kind would obviously be in the multiplication of establishment expenses by the maintenance of a separate staff of superintendents, assistants, and workmen at each such station. To overcome this difficulty, Mr. Shone devised his patent sewage ejector, which can be placed under the street and worked by compressed air. Any number of these can be worked from one central air-compressing station. The ejector is simply a large iron pot or vessel placed under the roadway, into which the sewage of the district flows until it is full, when compressed air is automatically admitted on top of the sewage, ejecting it in a few seconds into the main outfall sewer—the process repeating itself automatically as long as there is sewage to flow. It is the invention of this apparatus which has rendered the distributed station system practically attainable.

"*Plate* VI*a*., *Fig*. 1, gives a sectional view of a Shone pneumatic ejector of ordinary construction, suitable for raising water, sewage, sludge, chemicals, and hot fluids of all kinds. Ejectors are made of any size or shape convenient for the special circumstances for which they are required. For sewage, sludge, pail contents, preference is given to those having the lower portion of hemispherical shape.

"The motive power employed is compressed air, and the action of the apparatus is as follows :—

"The sewage gravitates from the sewers through the inlet pipe A into the ejector, and gradually rises therein until it reaches the underside of the bell D. The air at atmospheric pressure inside this bell is then enclosed, and the sewage continuing to rise outside and above the rim of the bell compresses the enclosed air sufficiently to lift the bell, spindle, etc., which opens the compressed air admission valve E. The compressed air thus automatically admitted into the ejector presses on the surface of the sewage, driving the whole of the contents before it through the bell-mouthed opening at the bottom, and through the outlet pipe B into the iron sewage rising main or high level gravitating sewer, as the case may be. The sewage can only escape from the ejector by the outlet pipe, as the instant the air pressure is admitted on to the surface of the fluid the valve on the inlet pipe A falls on its seat and prevents the fluid escaping in that direction. The fluid passes out of the ejector until its level therein reaches the cup C, and still continuing to lower, leaves the cup full until the weight of the liquid in the portion of cup thus exposed and unsupported by the surrounding water is sufficient to pull down the bell and spindle, thereby reversing the compressed air admission valve, which first cuts off the supply of compressed air to the ejector and then allows the air within the ejector to exhaust down to atmospheric pressure. The outlet valve then falls on its seat, retaining the liquid in the sewage rising main; the sewage then flows into the ejector through the inlet once more, driving the free air before it through the air-valve as the sewage rises, and so the action goes on as long as there is sewage to flow.

"The position of the cup and bell-floats is so adjusted that the compressed air is not admitted to the ejector until it is full of sewage, and the air is not allowed to exhaust until the ejector is emptied down to the discharge level.

"The compressed air for actuating the ejector is produced at some central station, and conveyed in cast or wrought-iron pipes laid under the streets to the several ejector stations."

The advantages of this apparatus, it is stated, may be summed up as follows:—

(1). "The working parts are reduced to a minimum, and those of a kind not likely to get out of order.

(2). "The parts into which the sewage enters contain no tooled surfaces, such as are unavoidable in pumps, and get rapidly destroyed by the action of the sewage sludge and grit from road detritus, etc. In the ejector there is nothing but the hard skin of the castings, coated with Dr. Angus Smith's composition, upon which the sewage can produce no detrimental effect.

(3). "The friction of a pump piston and other working parts is avoided, the compressed air itself acting direct upon the fluid, without the intervention of any machinery, and forming an almost absolutely frictionless and perfect *air piston*, past which there can be no slip or leakage whatever.

(4). "The cup and bell-float arrangement is one that cannot possibly get out of order, as an ordinary rising and falling float would be liable to do.

(5). "The *only* tooled parts are those in connection with the small automatic air-valve, which makes only one movement, of two or three inches, for each discharge of the ejector of from 50 to 1,000 gallons (according to the size of the ejector), and is only in contact with the compressed air, and out of reach of the sewage.

(6). "The sewage inlet and outlet valves are so arranged as to give a passage-way of the full area of the pipe, allowing a free passage to all the solids that the pipe itself can carry.

(7). "The outlet is from the bottom of the ejector, so that the whole of the sewage, including solids, sludge, grit, and everything brought down the sewer, is discharged out of the ejector.

(8). "For these reasons, no screening or straining of the sewage is necessary, as is the case with pumps, and the great nuisance caused by the cleaning of pump gratings and sump wells is avoided.

(9). "The sudden rush of the whole contents of the ejector, when the discharge is into a main gravitating sewer, forms a most effective flush.

(10). "The ejector forms an absolute severance of the house drains of each district from the main sewer.

"The use of compressed air in mining, tunnelling, and for driving domestic and other motors, as in the case of the Paris Compressed Air Power Company and the Birmingham Compressed Air Power Company, furnishes abundant proof that with properly jointed and correctly proportioned pipes, the losses by leakage and friction, through even miles of pipes, is insignificant."

The ejectors are in successful use at Warrington for the transmission of pail contents from central depôts in the town, through $2\frac{1}{2}$ miles of cast-iron main, to the works at Longford, saving the Corporation over £1,200 per annum in cartage alone; and at Southampton for transmission of sludge through a length of 1,500 yards 4-inch cast-iron main. They are also in use for the same purpose at Plymouth, Shirley, and Freemantle.

In towns where the solid refuse—ashes from private house bins, etc.—is destroyed by fire in specially constructed furnaces, the resulting heat may be utilized for generating steam to work air compressors, and the site of the refuse destructors may be used for the compressing station, as has been done at Southampton and other places; or the compressors may be placed at the gas or waterworks, or other site where steam or water power is available.

Shone's hydro-pneumatic ejectors have also been applied recently at Rangoon, and the following is a description of the system as there carried out (*Plate* VI*b.*) :—

"A gravitation system of sewerage *per se* for a perfectly flat and tide-locked city like Rangoon was naturally found impracticable, and could not, under any circumstances, be recommended on sanitary grounds. After considerable inquiry by the municipality, it was decided, with the approval of the Government of India, to adopt the Shone system as being the only known system by which the city could be properly drained on sound sanitary principles.

"The works were commenced in February, 1888, and completed by March, 1890.

"The city proper is divided into 22 sub-sections, or ejector districts, and within each of these districts is placed, in as convenient and suitable a position as possible, an ejector station, in which are placed two ejectors, each of 200 gallons capacity; one ejector in each station being capable of doing the maximum work, the other being in reserve in case of accident.

"All gravitating sewers converging and discharging to the several ejectors are of six inches diameter, cast-iron spigot and socket connections, and are laid throughout with steep gradients, none being flatter than 1 in 200; the total length of gravitating sewers being about 22 miles.

"The junctions for connection to the houses are five inches diameter, and have been carried in all cases above the water level in the sub-soil.

"*Night Soil Depôts and Flushing Tanks.*—For the purpose of temporarily disposing of the excreta from the houses not yet connected with the gravitating sewers, 130 night soil depôts have been erected and connected with the sewers in the back drainage spaces, to which depôts the excreta is carried in ordinary pails by the conservancy, and there discharged into a large trough, from whence it flows into the sewers and gravitates to the ejector stations.

"At the head of each length of gravitating sewer is placed a 200-gallon flushing tank, regulated to discharge automatically once or twice a day, or as often as experience shows it to be necessary, to keep the sewers perfectly clean and free from deposit.

"The sewage is discharged to the outfall at a level of three feet below the lowest tide through cast-iron sewage mains of various sizes, commencing at six inches diameter at No. 1 ejector station, and gradually increasing in size until they are finally 21 inches diameter from No. 20 ejector station to the outfall.

"The total length of sewage rising main is nearly six miles.

"*The Supplementary High-pressure Water Supply* forms a portion of the combined scheme carried out in Rangoon. The water gravitates from the Royal Lake into twelve of Shone's 500-gallon ejectors, from whence it is ejected by pneumatic pressure of 27lbs. per square inch into the 27-inch water main, thus giving an additional head of 62 feet to the water delivered in the city.

"The whole of the sewage and water ejectors are worked by compressed air, produced at the compressing station, situated in Dalhousie Street, nearly opposite the New Government Offices. The compressing machinery consists of—

"Three complete sets of triple expansion steam engines, each engine having three air compressing cylinders 16 inches diameter, 24 inches stroke. The steam cylinders of each engine are of the following dimensions:—

High-pressure cylinder	...	12in. diameter,	24in. stroke.
Middle " "	...	$16\frac{1}{2}$ "	24 "
Low " "	...	$21\frac{1}{2}$ "	24 "

and are arranged in front of the compressing cylinders, so that each steam cylinder drives a compressing cylinder direct.

"Each engine is able to work up to 150 indicated horse-power.

"Five Lancashire steam boilers, each 22 feet 6 inches long, 6 feet 6 inches diameter, with two internal flues 2 feet 6 inches diameter, fitted with three Galloway tubes in each boiler, and stand a working pressure of 150lbs. per square inch.

"Two air receivers, 24 feet long by 8 feet diameter.

"Two Atkinson's feed water heaters.

"Two donkey feed pumps.

"The cast-iron air mains for sewage and water ejectors commence at 10 inches at the compressing station, and are ultimately reduced to three inches diameter, with a total length of about six miles."

Junctions not to be at Right Angles.—The house drains must not join the sewers at right angles; in fact, such junctions should always be avoided.

If a manhole is used for the junction, the bottom can always be constructed so as to give the required curve in the direction of the flow of the current, as shown in *Fig.* 18 and *Plate* VII.; by this means as little disturbance as possible is caused to the proper flow of the liquids along their respective channels.

Sewers of unequal sectional diameters should not join with level inverts, but the lesser, or tributary sewer, should have a fall into the main at least equal to the difference in the sectional diameter.

Cross Sections.—When the ordinary flow of sewage is sufficient to keep a sewer of circular section half full, that form is the best, being the strongest and cheapest.

When the flow is variable, and at times very small, the egg-shaped section should be adopted, as it gives greater depth for small flows than could be obtained with the circular section, the capacity for the maximum flows being the same in each.

Thus, with a variable discharge, the hydraulic mean depth is a maximum for each section of liquid flowing through the sewer.

Area of.—The area of the cross section of sewers must be governed by the amount of sewage which they have to convey, their fall, and whether periodically flushed. Sewage, when fresh, causes no nuisance, but after about 24 hours, according to the weather, decomposition sets in, and it becomes putrefactive, producing deleterious gases. Their capacity should thus be sufficient to carry off in 24 hours the maximum quantity that may pass into them. In a town, the flow of sewage is at its maximum at midday and minimum at midnight. The maximum flow in an hour has been found, in the case of Wimbledon, to amount to upwards of 7 per cent. of the total daily discharge, so that a possible maximum flow of 8 per cent. in an hour must be kept in view when arranging the capacity of the drains; if, on the other hand, the drains are too large there will not be a sufficient flow through them to clear away any sediment and prevent deposit; consequently, care must be taken not to impair the efficacy of the sewer by using pipes of too large a bore. Under ordinary circumstances, they should run about two-thirds full to allow for rainfall. Main sewers should not be less than six inches internal diameter, as house drains in this country are never less than four inches in diameter; the main sewer should, of course, be larger than its tributaries. Drains for liquids only may, in some cases, be as small as three inches, but no drain receiving the contents of a soil-pipe should be less than four inches, which is a suitable size.

Amount of Sewage.—The next point to be considered is the amount of sewage to be dealt with, as on this depends, to a great extent, the size and shape of the cross section, and also the current necessary for the sewer or house drain. A careful survey must be made of the whole locality to be drained, including any neighbouring districts whose sewage may have to be included.

Estimate of.—It is customary to base the estimate of the quantity of sewage to be dealt with at so much per head of population for the discharge in 24 hours.

The records of other places are good guides, and as a general rule five cubic feet of sewage per day per head of population, half flowing off in six hours, should be provided for *in addition* to the quantity of surface water proposed to be admitted to the sewers.

Water Supply as Guide.—The water supply of the district may be considered as affording a constant daily supply of sewage of equal amount.

An allowance must also be made for the prospective increase of population; in the case of a town, its present rate of increase would be considered a guide.

Surface Water of Towns.—The surface water of towns is for the most part so impure as to necessitate its being treated as foul water; there is no occasion for this, as a rule, in the case of a barrack, except in certain localities (*e.g.*, vicinity of stables, cook-houses, etc.).

Admission of Rainfall.—The admission of the rainfall to the drains complicates the question of their proper size, as it is difficult to calculate the exact amount of rainfall to be allowed for, even when the amount to be admitted to the drains is limited, as a considerable proportion finds some other outlet.

The nature of the surface drained, and its inclination, must be considered in connection with the question of admission of surface water.

One inch rainfall in an hour only occurs in very severe storms, such as happen only at distant intervals of time in any part of England, so that an allowance of that amount to be carried off in an hour should be ample; and even when greater rainfalls have been recorded, it would not be advisable on that account to further increase the size of the sewers, as the large section would injure their efficiency under ordinary circumstances, and any excessive rain, being of short duration, would pass off in a few hours.

For house drains taking surface water from roofs, a rainfall of two inches per hour is sometimes provided, on account of the suddenness with which it will pass into the drains.

The surface water from rural or uncovered areas only arrives at the sewers by slow degrees, and a great deal passes off as sub-soil water.

Estimate of Sewage and Rainfall Combined.—It has been found by observation that it is only in exceptional cases that the average discharge exceeds 50 gallons per head per day, and it is usually taken at 40 gallons per head, or 250 gallons per house of six inhabitants and under, including rainfall.

The amount will, of course, vary considerably with the rainfall of the district and the proportion admitted to the sewers.

Gradient and Velocity of Flow.—Small sewers require a greater inclination than large ones; pipe sewers require less inclination than brick drains. The gradients must not be excessive, so as to avoid damage to the sewer.

Minimum Fall.—Latham says that in order to prevent deposit in small sewers or drains, from six inches to nine inches in diameter, a velocity of not less than three feet per second should exist; for sewers 12 inches to 24 inches, the velocity should not be less than $2\frac{1}{2}$ feet; and for larger sewers, two feet per second.

These velocities would require a fall of from 1 in 140 to 1 in 200 for pipes from six inches to nine inches in diameter, and from 1 in 400 to 1 in 800 for pipes from 12 inches to 24 inches in diameter, and less than 1 in 800 for larger sewers.

Where possible, however, main sewers should not have a less inclination than 1 in 600, although a considerably smaller gradient is admissible with egg-shaped sewers.

Maximum Fall.—Rankine states that the velocity of the flow in a sewer should never exceed 4½ feet per second, and Rawlinson gives it as his opinion that four feet is a proper limit of velocity, which, if increased to six feet, would destroy any sewer; this latter velocity is, therefore, often taken as the limit for stoneware drains. The following maximum falls may thus be considered safe for circular pipes:—For 4-inch pipe, $\frac{1}{36}$; for 6-inch pipe, $\frac{1}{60}$; for 9-inch pipe, $\frac{1}{90}$.

House drains should, when possible, be laid with falls not less than these for the several sized pipes, but not exceeding $\frac{1}{10}$. Where a fall of $\frac{1}{10}$ or more is necessary, on account of the circumstances of the site, iron pipes should be used.

Table of Discharge of Pipes.—The following table (taken from Bailey Denton's *Sanitary Engineering*) gives the discharge of different sized pipes, *running full*, at different velocities, and the fall required to produce these velocities:—

Diameter of Pipe.	180ft. per minute. 3ft. per second.		270ft. per minute. 4½ft. per second.		300ft. per minute. 6ft. per second.		540ft. per minute. 9ft. per second.	
Inches.	Fall.	Gallons per minute.	Fall.	Gallons per minute.	Fall.	Gallons per minute.	Fall.	Gallons per minute.
3	1 in 60	54	1 in 30·4	81	1 in 17·2	108	1 in 7·6	162
4	1 in 92	96	1 in 40·8	144	1 in 23	192	1 in 10·2	288
6	1 in 138	216	1 in 61·2	324	1 in 34·5	432	1 in 15·3	648
9	1 in 207	495	1 in 92	742·5	1 in 51·7	990	1 in 23	1485

The same velocity is produced when the pipes are running *half full*, and to produce these several velocities, half the quantities shown must pass through the pipes. Therefore, in house drains, as they are usually less than half full, the pipes, in order to be self-cleansing, should have a greater inclination than that for three feet velocity.

Flushing.—In cases where the available fall from the head of the drain to the junction with the main sewer is less than that required to produce the minimum velocity of three feet per second, it becomes necessary to cleanse the drain occasionally by flushing. Under these circumstances, special apparatus and appliances would have to be used to suit the particular case, *vide* page 174.

Table of Sizes of Sewers: Combined System.—The following table of zes of sewers at different inclinations for various urban areas is ken from p. 67 of the *Minutes of the General Board of Health*, July, 352. It was compiled by Mr. Roe, from results of reliable obser-tions extending over a period of twenty years.

It is, of course, only applicable to the combined system, in which e whole of the rainfall is admitted to the sewers.

ble showing the quantity of paved or covered surface from which Circular Sewers (with junctions properly connected) will convey away the water coming from a fall of rain of one inch in one hour, with house drainage, as ascertained in the Holborn and Finsbury Divisions.

	Diameter of Pipes and Sewers in inches.											
	24	**30**	**63**	**48**	**60**	**72**	**84**	**96**	**108**	**120**	**132**	**144**
	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres
vel	38¾	67¼	120	277	570	1,020	1,725	2,850	4,125	5,825	7,800	10,100
in 10′ 1 in 480	43	75	135	308	630	1,117	1,925	3,025	4,425	6,250	8,300	10,750
in 10′ 1 in 240	50	83		355	735	1,318	2,225	3,500	5,100	7,175	9,550	12,400
in 10′ 1 in 160	63	113	203	460	950	1,692	2,875	4,500	6,575	9,250	12,300	15,950
in 10′ 1 in 120	78	·43	257	590	1,200	2,180	3,700	5,825	7,850	11,050	14,700	19,085
in 10′ 1 in 80	80	165	295	670	1,385	2,486	4,225	6,625				
in 10′ 1 in 60	115	182	318	730	1,500	2,675	4,550	7,125				

This table will be a useful guide under most circumstances, but fixed rule can be given.

Combined System.

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 two inches in the hour, as ascertained in the Holborn and Finsbury Divisions.

Surface occupied.		Number of Houses of either rate, either of which may be respectively drained.				Diameter and Inclination of Tubes.									
Acres.	Squares of 100 feet.	1st-rate House. Sinks & water on one floor, and water-closets on two floors.	2nd-rate House. Sinks & water on one floor, and water-closets on two floors.	3rd-rate House. Sinks & water on one floor, and water-closet in yard at back.	4th-rate House. Sink & water on one floor, and water-closet in yard at back.	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 sizes of the pipes in this table, as in the preceding one, are smaller than those given by calculation, as many circumstances, such as those already mentioned with regard to the dimensions of *sewers*, materially affect the quantities discharged in the several cases.

Formulæ for the Flow of Liquid in Sewers.—Many of the formulæ found in most engineering handbooks for the flow of liquids in an open channel, or in pipes running full, are based on the assumption that the resistance to the flow of liquids varies with the square of the velocity, but results of experiment tend to show that this is not quite the case. To overcome this difficulty, Neville's formula was introduced, and from it the table in Hurst's handbook is calculated.

If Ω = sectional area of stream in feet,

d = diameter of pipe in feet,

h = head of water in feet,

l = length of pipe or channel in feet,

s = sine of fall $= \frac{h}{l}$,

v = velocity in feet per second,

Q = discharge in cubic feet per second,

r = hydraulic mean depth or radius.

NOTE.—*The hydraulic mean depth or radius is the sectional area of stream, divided by the wetted perimeter.*

Thus in Fig. 14 :—

Area of stream $= 2' \times 6' = 12$ *square feet.*

Wetted perimeter $= 2' + 6' + 2' = 10'$.

Hydraulic mean depth $= \frac{12}{10} = 1{\cdot}2'$.

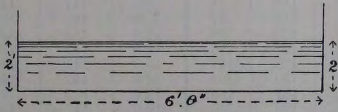


Fig. 14.

For pipes running full the hydraulic mean radius $= \frac{d}{4}$.

Neville's Formulæ :—For open channels.

$$v = 140\sqrt{rs} - 11\sqrt[3]{rs},$$
$$Q = \Omega v.$$

For pipes running full, these become

$$v = 140\sqrt{\frac{d}{4}s} - 11\sqrt[3]{\frac{d}{4}s},$$

$$Q = 0{\cdot}7854d^2v.$$

Darcy.—The above formulæ are, however, somewhat cumbersome, and the following, due to the careful researches of M. Darcy in Paris, will be found simpler to use, and are accurate for velocities exceeding four inches per second.

For Open Channels :—

$$v = \sqrt{\frac{2g}{\mu}}\sqrt{rs} = c\sqrt{rs},$$

$$Q = \Omega v,$$

where $\mu = \alpha\left(1 + \frac{\beta}{r}\right)$, and where for cement or planed timber, $\alpha = 0{\cdot}00316$, $\beta = 0{\cdot}1$; for ashlar or brickwork $\alpha = 0{\cdot}00401$, $\beta = 0{\cdot}23$; for rubble masonry $\alpha = 0{\cdot}00507$, $\beta = 0{\cdot}82$.

Table for values of c in

$$v = c\sqrt{rs} :—$$

Hydraulic mean depth=r.	Values of c.			Hydraulic mean depth=r.	Values of c.		
	Cement or planed timber channels.	Ashlar or brickwork channels.	Rubble masonry channels.		Cement or planed timber channels.	Ashlar or brickwork channels.	Rubble masonry channels.
·25	125	95	57	8·5	147	130	112
·5	135	110	72	9·0	147	130	112
·75	139	116	81	9·5	147	130	112
1·0	141	119	87	10·0	147	130	112
1·5	143	122	94	11·0	147	130	113
2·0	144	124	98	12·0	147	130	113
2·5	145	126	101	13·0	147	130	113
3·0	146	126	104	14·0	147	130	113
3·5	146	127	105	15·0	147	130	114
4·0	146	128	106	16·0	147	130	114
4·5	146	128	107	17·0	147	130	114
5·0	146	128	108	18·0	147	130	114
5·5	146	129	109	20·0	147	131	114
6·0	147	129	110	25·0	148	131	115
6·5	147	129	110	30·0	148	131	115
7·0	147	129	110	40·0	148	131	116
7·5	147	129	111	50·0	148	131	1'6
8·0	147	130	111	∞	148	131	117

For rough calculations, c may be taken as 93.

Another expression often convenient for rough calculation is :—

$$v = \frac{11}{12}\sqrt{2\,r\,f},$$

where f = fall in feet per mile.

For Pipes Running Full.—

$$v = \sqrt{\frac{2g}{\zeta}}\sqrt{r\,s} = k\sqrt{r\,s},$$

$$Q = \Omega v.$$

Where for new pipes,

$$\zeta = 0{\cdot}005\left(1 + \frac{1}{12d}\right).$$

For old pipes,

$$\zeta = 0{\cdot}01\left(1 + \frac{1}{12d}\right).$$

Since $r = \frac{d}{4}$ we may express the above equations thus :—

$$v = \frac{k}{2}\sqrt{d\,s},$$

$$Q = \frac{\pi\,d^2}{4}\,v.$$

The following table shows the values of k for different sizes of pipe, obtained from the equation—

$$k = \sqrt{\frac{2g}{\zeta}}.$$

Diameter of Pipe.	Values of k.	
	New Pipes.	Old Pipes.
$\frac{1}{2}$-inch ($d = {\cdot}\frac{1}{24}$)	65	46
1-inch ($d = {\cdot}\frac{1}{12}$)	80	56
3-inch ($d = \frac{1}{4}$)	98	70
6-inch ($d = \frac{1}{2}$)	105	74
12-inch ($d = 1$)	109	77
24-inch ($d = 2$)	111	78
36-inch ($d = 3$)	112	79

For rough calculations k may be taken as 78.

If Q and *s* only are known, *d* must first be determined approximately from the formula

$$d = 0{\cdot}2545 \sqrt[5]{\frac{Q}{s}}.$$

d, thus found, will furnish a sufficiently near value for ζ from either of the formulæ

$$\zeta = 0{\cdot}005 \left(1 + \frac{1}{12d}\right);$$

or

$$\zeta = 0{\cdot}01 \left(1 + \frac{1}{12d}\right),$$

according to circumstance.

Having thus determined ζ, *d* may be accurately determined by the formula

$$d = \sqrt[5]{\frac{Q^2\zeta}{\pi^2\zeta}}.$$

The above formulæ, which are intended, in the first place, for calculating the size of open channels and pipes for water, apply also to sewers, except that the latter are usually taken as flowing from $\frac{1}{2}$ to $\frac{2}{3}$ full, in which case the value of *r* must be found in the manner already described.

Cylindrical.—In cylindrical pipes, flowing $\frac{1}{2}$ full, $r = \frac{1}{4}\ d$, the same as for pipes entirely filled; when the sectional area of the sewage is $\frac{2}{3}$ the depth of the pipe, $r = {\cdot}292\ d$; and when $\frac{3}{4}$ the depth, $r = {\cdot}296\ d$.

Egg-shaped.—For egg-shaped sewers, of which the conjugate diameter is $1\frac{1}{2}$ times the transverse diameter, and the radius of the invert is $\frac{1}{4}$ transverse diameter, as in *Fig.* 15.

d being the transverse diameter in inches,

Perimeter $= 3{\cdot}9649 \times d$.	Area of sewer $= 1{\cdot}1487\ d^2$.
Arc A D G $= 2{\cdot}39415 \times d$.	„ below A G $= {\cdot}756\ d^2$.
„ A F G $= 1{\cdot}57079 \times d$.	„ above A G $= {\cdot}3927\ d^2$.

The more modern proportions for an egg-shaped sewer are those shown in *Fig.* 32.

In a sewer of these proportions—

Perimeter $= 3{\cdot}9206d$.	Total area $= 1{\cdot}10612d^2$.
Arc ACB $= 1{\cdot}5708d$.	Area below AB $= {\cdot}71342d^2$.
Arc ADB $= 2{\cdot}3498d$.	Area above AB $= {\cdot}3927d^2$.

Other forms of sewers may be calculated from the formulæ for open channels.

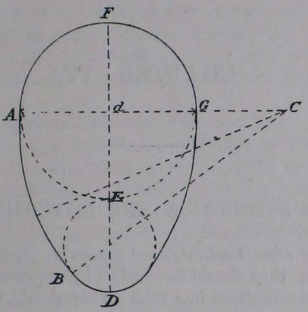


Fig. 15.

Method of Applying.—Neville's formula is more readily used by the system of trial and error, an approximation to either of the unknown quantities being obtained by either of the simpler formulæ already given, or it might be taken from various hydraulic tables.

For ordinary purposes, all calculations may be avoided by the use of such tables as are given in Hurst's *Architectural Surveyor's Handbook*, which have been calculated from Neville's formula.

CHAPTER IV.

CONSTRUCTION AND MATERIALS.

Description of Pipes Used.—Glazed stoneware pipes are, in general, use for drains; they should be made of a superior description of clay, burnt and salt-glazed in a kiln. They should be highly glazed so as to be impervious to moisture; perfectly smooth, and free from defects, especially on the inside; accurate in form; and regular in shape.

Method of Laying.—"Sight-rails" should be put up for each line of pipes, etc., before the ground is opened out, showing the centre line of each sewer and depth to the invert. The proper use of sight-rails in sewer and drain construction will enable the foreman to set out and excavate the trench truly. These sight-rails should be strong, and should also be securely fixed on firm ground, that is, beyond the influence of the excavation to be made; and if the sub-stratum is peaty, or such as will shrink under pumping, so as to lower the sub-soil water, care must be taken that the sight-rail, or bench-mark to be worked to, is in such position as to remain unaffected, or the result will be a crippled sewer, that is, the grade and line will not be true. They must always be laid with the socket facing up against the direction of the current; they should, therefore, be laid starting from the lower end of the drain and working upwards.

The ground under each socket should be hollowed out so as to allow the body of the pipe to have a firm bearing, and to give space for the hand to form the lower part of the joint.

Pipes should be laid by means of a mason's line to ensure their direction being kept perfectly true and uniform throughout their whole length. The inclination or current to be given to the pipe having been arranged, the intermediate levels are obtained with boning rods.

The individual lengths of pipe are then laid and jointed one after the other. The mason is provided with a straight-edge and spirit-level to correct the levels of the sockets of each pipe as it is laid, a small piece of wood being provided corresponding in thickness to the current to be allowed in each length of pipe, and to be placed under the straight-edge and resting on the socket of the length of pipe last laid.

In re-filling the trench it is most important that only the smallest of the stuff previously excavated be thrown in first, so that the spaces between the sides of the trench and the pipes may be well filled up, and thus prevent sinking by leaving hollows under the sides of the pipes. This should be done up to the level of the middle of the pipes, the remainder of the filling being carried out in layers six inches in depth; each layer should be well rammed before another is deposited. Large clods of earth should never be thrown in, as the shock occasioned by their fall tends to injure the joints, dislodge the bricks in culverts, etc. Ramming need not be carried out with either sand or clean gravel. The best means of consolidating the former is to wet it, whereas the latter will settle of itself into its own position. Clayey gravel, or gravelly clay, should always be rammed.

Adjustable Gradient Indicator.—An adjustable gradient indicator, with spirit level and arc graduated to different inclinations (*Fig.* 16), has been brought out by Mr. T. J. Moss Flower, Sanitary Engineer, which would be very useful to an engineer, surveyor, or foreman of works when superintending drainage works.

FLOWER'S IMPROVED GRADIENT INDICATOR.

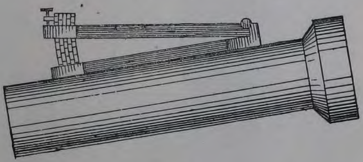


Fig. 16.

Pipes Not to be Laid under Buildings.—Drains should not be laid under buildings, but where it is absolutely unavoidable the pipes should be cast-iron, with leaded joints, and buried in cement concrete. Means of access and inspection should be provided at each end; it should have a free current of air passing through it from end to end, and a flushing tank should be placed at the upper end. At the lower end the inspection pit should be disconnected from the sewer by a syphon trap outside the walls. *Plate* VIc. is an illustration of a method suggested for carrying out this recommendation.

Manholes.—In a large system of sewerage, it is usual to place manholes, or inspection pits, about 100 yards apart, or 18 to the mile, and, even on a small scale, inspection pits, or manholes, are necessary, with lampholes at bends between two pits.

The manholes are intended for examining and clearing the drains. Lampholes are intended for letting a lamp down into the sewer at bends or changes of direction, which would obstruct the line of sight from one manhole to another; if the light is shut out from view it shows the presence of some obstruction in the drain.

It is most desirable, in order to admit of periodical inspections of the drains, to have manholes and inspection pits at all junctions and bends.

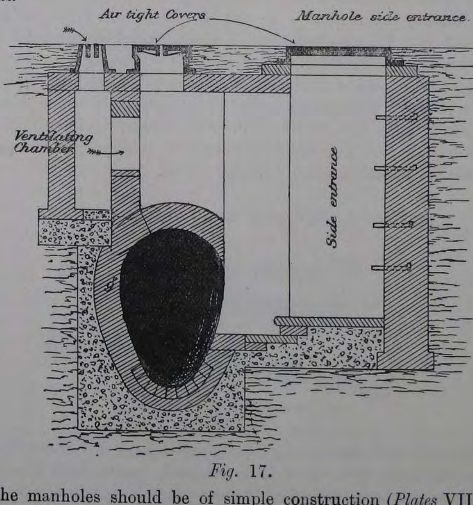


Fig. 17.

The manholes should be of simple construction (*Plates* VII. and

XXVI.), and may be made to serve the additional purpose of ventilating openings, side entrances to large sewers (*Fig.* 17), and flushing chambers as occasion may require.

Plate VII. shows a manhole used in the Metropolitan Sewerage system, and fitted with a sluice-valve. The latter would not be used in connection with the drainage of a group of buildings such as a barrack, as it would interfere with thorough ventilation.

The method of effecting the junction of the pipes at the bottom of the manhole is, however, of universal application.

The rock-concrete manhole, shown in *Plate* XXVI., is formed of rings made in sections, and thus manholes of any depth can be constructed cheaply and quickly. They are especially suitable for use in water-logged ground. They are absolutely water-tight; no internal cement rendering is necessary; a perfectly smooth and clean interior is preserved.

The substance of the rings is easily cut, with a sharp diamond pointed chisel, for ventilating holes or high-level side inlets.

This principle would appear to be equally applicable to the construction of rain-water tanks, cesspools, and wells. The top pieces may be used alone for small manholes.

White Enamelled Channels.—White enamelled channels (*Fig.* 18) have been advocated recently for use in connection with manholes.

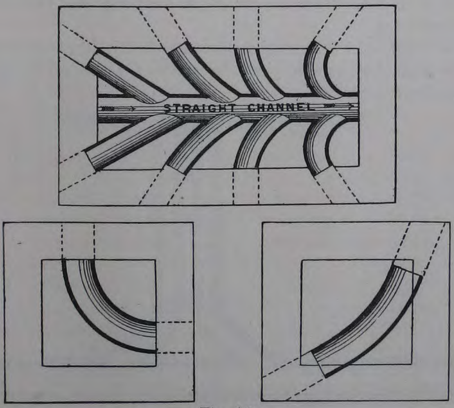


Fig. 18.

Air-tight Covers.—Unless used as a ventilating shaft, the mouth of a manhole should be closed with an air-tight cover.

Fig. 19 shows a cast-iron air-tight cover, with socket-joint, for fixing over manhole, inspection, or disconnecting chambers.

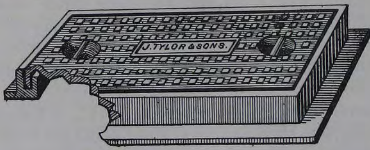


Fig. 19.

The socket should be filled with fine sand.

These covers are so constructed as to form a joint secure against the passage of gas or impure air of any kind. They can be easily opened without the aid of a key, so liable to get lost, or hinges likely to rust and to break. They can be removed and replaced in a few seconds by anyone, no cement being needed, a little scouring sand is all that is required to make the joint thoroughly effective. The cover and frame are never in such close contact as to cause the joint to set fast with rust.

There is no indiarubber to corrode, or anything that can possibly get out of order.

Guide Pipes.—At intermediate points, when it is not convenient to provide manholes, guide pipes for scrapers, as shown in *Fig.* 20, are sometimes used.

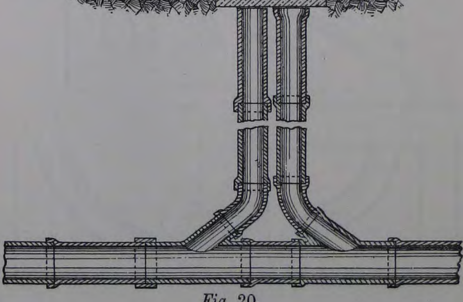


Fig. 20.

Vertical Soil-pipes.—Vertical soil-pipes should be formed of cast-iron, four inches in diameter at least, as, if of smaller size, they are liable to get choked. Ordinary rain-water down-pipes should not be used for this purpose, as they are much too thin, and, being liable to pinholes, will neither stand the hydraulic test nor caulking with lead. Pipes of the circular pattern on *Plate* XXII., with lugs, are suitable; they should not be less than $\frac{5}{16}$ths of an inch thick, with 4-inch sockets. The lead joint should be $\frac{5}{16}$ths of an inch thick, two inches deep, and weigh four and five pounds for four and five-inch pipes respectively. A six-inch pipe should have a $4\frac{1}{4}$-inch socket, the lead joint being as usual, $\frac{5}{16}$ths of an inch thick, by $2\frac{1}{4}$ inches deep, and containing about $6\frac{1}{2}$lbs. of lead. In many instances lead soil-pipes are also used; they should be patent lead drawn pipes of uniform thickness, weighing from 8lbs. to 10lbs. per foot super. Such pipes have fewer joints (*Plate* VII*a.*), but they are expensive and more liable to injury by accident than iron pipes. They should be supported in their length by pieces of lead, called ears or tacks, either double (*Fig.* 1) or single (*Fig.* 2). The method of attaching them to the pipe is seen in *Fig.* 4. Nails are driven through the ears into the joints of the masonry (*Figs.* 3 and 4), and in some cases, for the sake of appearance, the end of the ear is turned back to hide the heads of the nails. When double ears are used, there should be two to every 10 feet (*Fig.* 1); three or four single ears (*Fig.* 2) should occupy the same length. As regards the size of the ears, for pipes from two to six inches in diameter the length should be double the diameter of the pipe, and the width one and a-half the diameter of the pipe, so as to allow sufficient space for nailing without injury. Some authorities recommend the use of an increased size of pipe in proportion to the number of closets discharging into it; thus a 5-inch soil pipe would be required for two closets, with the object of preventing the suction set up by their simultaneous discharge, from untrapping the closet.

In consequence of the weight of the soil-pipe, and the damage to the joints which must ensue on any settlement at the attachments, it is advisable to support the pipe at the base by means of an iron standard, as shown in *Plate* VII*a.*, at the foot of the soil-pipe. The methods recommended for making the joint between it and an iron or lead soil-pipe respectively are shown in *Figs.* 1 and 2. The brass ferrule in the latter case admits of the joint between the iron and lead pipe being caulked.

Position of.—All such pipes should be fixed outside the building, and continued up above the level of the eaves and left open at the top.

Joints in Iron Pipes (*Fig.* 21).—The joints should be caulked with yarn and run with lead.

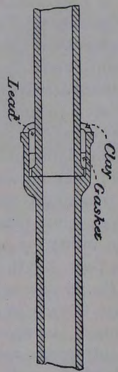


Fig. 21

Rust Joint.—Instead of a lead joint, a rust joint is sometimes made. The following is the composition of the rust cement, which is also useful for other purposes.

Iron cement, or rust joint cement, is made of sal-ammoniac, sulphur, and iron turnings or borings.

If required to be quick-setting, it is made up of 1 powdered sal-ammoniac (by weight), 2 flower of sulphur, and 80 iron turnings or borings, brought to a paste with water.

If required to be slow-setting, mix up 9 sal-ammoniac, 1 flower of sulphur, and 200 iron borings or turnings.

The latter makes a better joint than the former (see Seddon's *Builders' Work*, page 214).

No Traps or Syphons at Foot of Soil-pipes.—There should not be any trap or syphon at the foot of a soil-pipe, so as not to check the flow of effluent water, except in the instance dealt with at page 106, under the head of ventilation.

Stables: How Drained.—Stables should be drained by surface channels only, carried beyond the building to a distance of 12 feet, and terminated by a gully.

Surface channels should be formed of a hard impervious material, in long lengths, with shallow cross section.

In the case of concrete paving, the channels can be formed in the concrete itself.

Surface Channels not Adapted for Waste Water from Sinks.—Waste water from sinks should not, however, be conveyed to gullies by long surface channels, as the liquid would collect a quantity of silt on the road, and traps could not be made suitable for both silt and sewage.

Lead Safes or Trays.—All w.c.'s, slop-sinks, cisterns, and baths should be provided with lead trays. An efficient waste, discharging into the open air, in a prominent position, is necessary in each case (see *Fig.* 128).

Maximum Diameter 18 Inches.—Stoneware pipes should not be used of greater diameter than 18 inches, and if laid at an unusual depth, say 15 to 20 feet, in soft clay or any unstable ground, an extra thickness of pipe will be necessary to withstand the pressure.

Depth.—Where there is any chance of wheeled traffic over the drain-pipes, they should be laid at a depth of at least two feet below the surface, and covered with well-rammed earth; when carried under paving a less depth may be used, the minimum being twice the diameter of the pipe.

Thickness of Glazed Stoneware Pipes.—The ordinary thickness of stoneware pipes is as follows:—

Internal diameter.			Thickness of Material.
3 inches	...	...	$\frac{1}{2}$ inch.
4 "	...	...	$\frac{5}{8}$ "
6 "	...	...	$\frac{3}{4}$ "
9 "	...	...	1 "
12 "	...	...	$1\frac{1}{8}$ "
15 "	...	...	$1\frac{1}{4}$ "
18 "	...	...	$1\frac{3}{8}$ "

They are made in 2-feet 3-inch lengths over all up to a diameter of nine inches, beyond which the lengths are two feet nine inches, the sockets taking up three inches at one end.

Forms.—Junctions, bends, taper pieces, and syphons (*Fig.* 22) are made for each description of stoneware pipe.

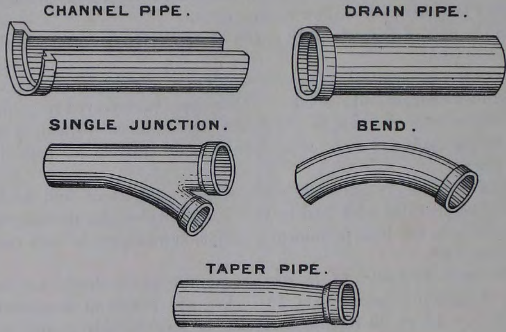


Fig. 22.

Concrete Pipes.—When larger sewers than 18 inches diameter are required, concrete pipes may be used up to 36 inches diameter.

Messrs. Henry Sharp, Jones & Co., of Poole, Dorset, make most excellent rock-concrete pipes (*Fig.* 23) which can be advantageously used in many instances, and are gaining ground in popularity with engineers. Messrs. Bowes, Scott & Western, of Broadway Chambers, Wesminster, are the London agents.

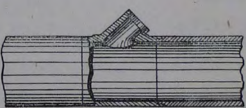


Fig. 23.

The manufacturers state that these tubes are made of a very dense and heavy concrete, the result of careful selection and combination of the most suitable materials, manipulated by processes best calculated to secure the utmost value, both of the matrix and the aggregates employed.

The cement used, and the concrete made, are subject to stringent and constant tests, constituting such safeguards that it is impossible for any but the most reliable material to be manufactured.

They are silicated by the Victoria Stone Company's patent process. The following advantages are claimed for them.

By using rock-concrete tubes, sewers can be constructed with economy and rapidity.

They are imperishable.

They bed well in a trench, having no projecting socket.

They form a perfectly true barrel.

They permit of a water-tight joint being easily made.

They consequently make a water-tight sewer.

They are especially adapted for sewer work, inasmuch as their great strength, hardness, and durability are enhanced by the action of water and sewage.

Junctions with sockets for stoneware pipes are kept in stock.

Half tubes can be supplied for irrigation purposes, and have been so used.

Sizes.—The following sizes are kept in stock :—

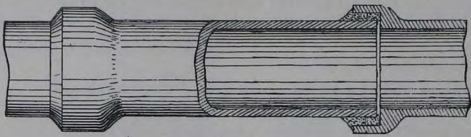
Size.	Thickness.	Price per Foot Run. s. d.	Size.	Thickness.	Price per Foot Run. s. d.
12 inches.	1⅛ inch.	1 6	24 inches.	1⅞ inch.	4 3
15 ,,	1¼ ,,	1 10	,, ,,	2 ,,	5 3
18 ,,	1½ ,,	2 9	27 ,,	2¼ ,,	6 3
21 ,,	1⅝ ,,	3 9	30 ,,	2¼ ,,	8 0
			36 ,,	2½ ,,	10 0

Egg-shaped in Segments for Linings.

3ft. 3ins. by 2ft. 2ins. thick.

Joints : How Made.—Pipes for conveying sewage should have their joints set in pure cement to prevent leakage ; with ordinary socket joints, as shown in *Fig.* 24, tarred gasket should be used to prevent the cement from entering the pipe ; each joint should be carefully examined on the inside, and any cement that may have come through, should be smoothed off before the next length of pipe is laid, so as not to have any obstruction to the flow of sewage.

JOINTS IN EARTHENWARE PIPES.



Gasket and Cement.

Fig. 24.

The joints of pipes set in cement cannot be readily opened for examination without clearing a considerable length of the drain, and breaking, at any rate, one of the pipes.

Saddle-joints.—To obviate this, pipes with saddle-joints were, at one time, much used, but they are objectionable, as it is very difficult to make the joints of the saddles water-tight without using cement, and then, of course, the advantage of their use is lost, for the pipe would have to be broken, as is ordinarily the case. The saddles are also found to give way under pressure.

When a drain is carried under a wall, an opening should be left clear of the pipe, so that the settlement (which takes place to some extent in all buildings) may not produce any pressure on the pipe tending to break it.

Doulton's Self-adjusting.—Another form of joint is that known as Doulton's patent self-adjusting joint (*Fig.* 25); no cement is required, and it is supposed not to be injured by any settlement.

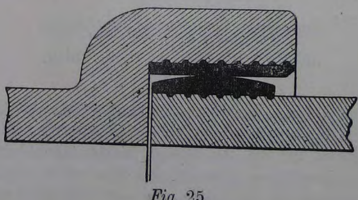


Fig. 25.

Stanford's Patent.—Stanford's patent joint in stoneware pipes (*Fig.* 26), also supplied by Messrs. Doulton & Co., is said to be water-tight without liability to become defective by slight settlement of the ground. It is similar to turned spigot and faucet joints of cast-iron pipes, being formed of turned rings of a hard material adhering firmly to the pipe inside the sockets and around the spigot end of the pipe. These rings, which are spherical in shape, fit exactly to each other, being counterparts, and in order to allow of a little play of the pipes, the sockets are formed slightly concave, and the spigot ends convex to a similar extent. The rings are made of a composition of ground earthenware pipes, sulphur, and tar. The joint is formed by either painting, tarring, or greasing the surfaces, and by giving a twist to the pipe to fit them closely together. The joints can be taken asunder without breaking the pipe.

STONEWARE DRAIN PIPE AND FITTINGS,
with Stanfords patent joint

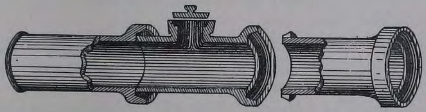


Fig. 26.

It is essential that a good foundation should be made for these pipes.

It is very doubtful whether any joints depending on mechanical fit for their security are permanently reliable; some of the following forms are, therefore, to be preferred :—

The Double Seal.—These pipes, which have been introduced by Mr. Tyndale, Sanitary Engineer to War Department, are similar to the Stanford jointed pipes, but have in addition a deeper and undercut socket, so that after the pipes have been laid and tested, a fillet of cement may be placed all round for the better securing of the joint.

Fig. 27 illustrates two pipes jointed in the manner described, and *Fig.* 28 shows an enlarged section of the socket and spigot, when jointed.

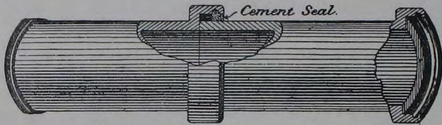


Fig. 27.

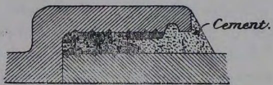


Fig. 28.

The advantages secured by the use of the double seal jointed pipes are :—

1. A rigidity equal to that of the ordinary cemented joint is obtained in addition to the concentric fitting of the pipes, and capability of being quickly laid, tested, and covered in, as secured by the Stanford joint.

2. Obstructions caused by cement being squeezed up inside the pipe are avoided.

They are made by Messrs. J. Cliff & Sons.

The Hassall.—The "Hassall" joint (*Fig.* 29) has many advantages in ensuring a water-tight joint, and avoidance of any irregularity

THE "HASSALL."

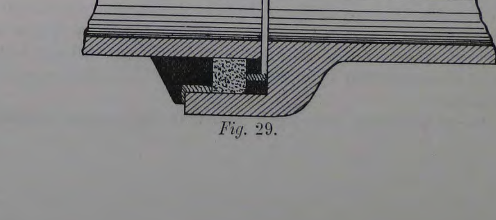


Fig. 29.

of surface on the interior of the pipes at their junction. It is practically a combination of the Stanford and Archer joints. It is supplied by J. Stone & Co. A more recent form has a second ring of composition at the mouth of the socket.

Archer's.—Archer's patent air and water-tight sewer and drain pipes are very simple in construction and application. A luting of clay is placed round the shoulder of the spigot. The spigot of one pipe is then pressed into the socket of the other, and liquid cement poured into one of the holes in the socket, shown in top view of the pipe in *Fig.* 30, the air escaping through the other hole. Sometimes there is a difficulty in expelling the air, and it is necessary to assist the operation with a small piece of stick.

ARCHER'S PATENT AIR AND WATER TIGHT JOINT

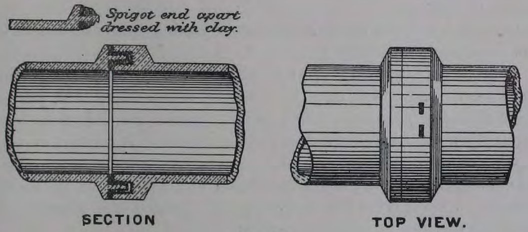


Fig. 30.

Causes of Breakage of Stoneware Pipes.—Drains formed of stoneware pipes get broken through attention not having been paid in their construction to the following points :—

Pipes should not be laid on a rigid foundation without making a recess to take the sockets, so as to ensure an even bearing.

Pipes should not be laid on a foundation which is liable afterwards to yield, or settle, without taking special precautions.

Pipes should not be laid at too great a depth without protecting them by concrete, or in other ways, to resist the pressure of the material resting on them; a sudden settlement will often crack, or crush a pipe, if the filling in over and around it has not been properly done.

Drain-pipes are also sometimes found to be broken in consequence of accidental or wilful injuries, so that careful inspection and testing should be applied before the trench is filled in.

When pipes are laid at a lower depth than usual they should be protected, especially when subjected to heavy traffic; a weight falling on the surface will otherwise often crack, or crush a pipe.

If the joints are weak or defective in any way, the pressure may fracture the pipe, consequently care in selection is very necessary.

Causes of Chokage.—Drain-pipes are also liable to fail by getting choked, and this will, as a rule, be found to be due to some of the following causes:—

The pipe not being properly currented, and consequently not having a sufficient flush to prevent deposit.

Failure of the joints to retain the liquid, which thus escapes, leaving the solids behind.

Badly designed bends and junctions leading to deposit, as they check the current.

Improper articles being introduced into the drain are a fruitful source of chokage.

It may also be the result of the sewer having been crushed in by the superincumbent weight.

Temporary Obstruction: How Removed.—A temporary obstruction in a small-sized sewer may be speedily removed by the use of drain-cleansing apparatus (*Plate* VIII.), which can be most conveniently worked in connection with manholes. It consists of rods capable of being screwed together, and is very similar to that used by a sweep, but is provided with suitable attachments for the special purpose. By its use the necessity for opening the ground and breaking the pipe is, to a great extent, avoided.

The drain can in this manner be cleared on either side to 200 feet, or further.

A small wheel is screwed on to the end to enable the rod to be forced over obstructions, and if the obstruction cannot then be removed, its position can be ascertained, and the ground opened at the right spot.

In the case of syphon traps, a temporary obstruction may be cleared by plunging, *i.e.*, by using a tool called a plunger, which consists of a wooden handle about $1\frac{1}{2}$ inches in diameter, to which is fixed at one end a disc of stout leather ($\frac{3}{8}$-inch thick) of slightly larger diameter than the bore of the syphon. The trap should be first filled with water, and the tool applied and worked up and down like a piston. A mop may be used in a similar manner, as a temporary expedient.

Drains of Larger Capacity.—When drains of larger capacity than can be readily provided by pipes are required, culverts have to be built.

Brickwork.—They are usually built in brickwork, in cement, and sometimes in concrete ; some engineers prefer the latter, as Portland cement resists the action of the sewage better than brickwork.

Rendered in Pure Portland Cement.—The surface should be rendered in pure Portland cement to a perfectly smooth face, and, in the case of brick culverts, the rendering should be carried up to at least one-half their depth.

Bricks for Sewers.—The best bricks for sewers are those that are hard, well-burnt, and absorb the least moisture.

The following classification shows degrees of suitability of different varieties, viz. :—

(1). The best and most suitable are blue Staffordshire, Shropshire, and those from Buckley (North Wales).

(2). Those made from fire-brick and terra cotta clays—more especially when glazed on the surface exposed to the erosion of sewage.

(3). Gault bricks.

(4). Any tough and well-burnt brick, moderately absorbent. On no account should under-burnt, or perforated, brick be used. Bricks should not be rejected for mere roughness of face, provided they be otherwise uniform in size and shape, they may be used in the sides and crown of the sewer. They should, however, never be set in the invert, as considerable friction would occur with sand, stones, and other materials that are generally rolled or carried along with the flow of sewage.

All bricks for use in sewers should be specially made to a given radius, for if ordinary shaped bricks be used, wide open joints will occur in the outer periphery and admit of the percolation of sewage, etc., unless a quick setting cement is used. The ordinary tests applied to such bricks are for ascertaining their hardness, absorption, and power to resist crushing.

Doubtful bricks may be tested by soaking them in water, and afterwards exposing them to frost ; or where the temperature will not admit of this, they may be first weighed dry, then steeped in a strong solution of sulphuric acid for seven days, and afterwards, when dry, re-weighed.

If no loss of weight occurs, and the brick is otherwise unaffected by the sulphuric acid, it may be safely used.

Egg-shaped Sewer.—The form of an egg-shaped sewer may be obtained from *Fig.* 31, where D H $= \frac{2}{3}$ D G and G H $= \frac{1}{3}$ D G; F A = F C = D G.

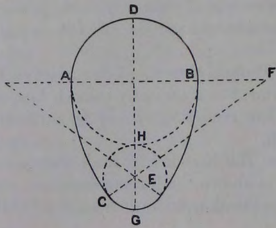


Fig. 31.

Alternative Shape.—The additional form given in *Fig.* 32 has been adopted when the ordinary flow is exceedingly small, and is coming into general use for all purposes.

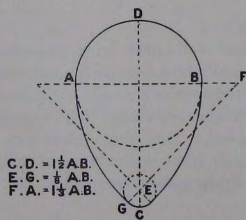


Fig. 32.

In order to ascertain the thickness of the brickwork required, let d = depth of the excavation in feet, and r = the external radius of the sewer in feet; then the thickness of the brickwork in feet $= \frac{d\,r}{100}$.

As a general rule, the thickness of brickwork in circular or oval sewers, in cuttings not exceeding 20 feet in depth, and in good ground, the greatest internal dimension not exceeding three feet, should be $4\frac{1}{2}$ inches; between three feet and six feet the thickness should be nine inches; and above six feet, and under nine feet, the brickwork should be 14 inches thick.

When the ring is only $4\frac{1}{2}$ inches thick, a hood of concrete, as shown in *Fig.* 33, should be laid over it for its protection.

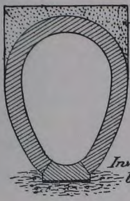


Fig. 33.

Some Methods of Construction.—The shape of the culvert is generally formed by means of centering, composed of ribs and lagging, and made in two halves, corresponding to the invert and arch. After the excavation of the trench, if invert blocks are employed, the centering is placed in position resting on them; but where no invert blocks are used, as is generally the case with concrete culverts, pickets are driven and left projecting above the bottom of the trench, a distance equal to the proposed thickness for the concrete below the invert. The centres rest on the heads of the pickets. The sewer is built in short lengths, and the centering moved forward as the work progresses. Where pickets are used as above, they would be driven down, and the holes made good with pure Portland cement after the concrete has set. *Figs.* 34, 35, and 36 show a variety of methods of construction.

Invert blocks of glazed stoneware, as in *Fig.* 35, may be used with advantage for the bottom of egg-shaped sewers in brick or concrete, as they ensure an even and uniform surface where it is most required. They are generally made hollow, to prevent warping in burning. This hollow is, however, objectionable, as they have to take the weight of the sewer, its contents, and the superincumbent earth, and, consequently, are often found split in the work. The hollow also admits of sub-soil drainage, which causes shrinkage of the foundation and settlement of the sewer, especially in sandy soils.

This hollow should, therefore, be filled in with concrete before laying. Hollow invert blocks are made with butt and lipped joints;

the latter are preferable, as less liable to settle in the work than plain butt-joints.

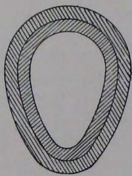


Fig. 34.

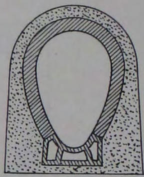


Fig. 35.

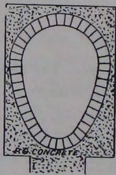


Fig. 36.

Similar blocks (*Fig.* 37) are also made for insertion in the side

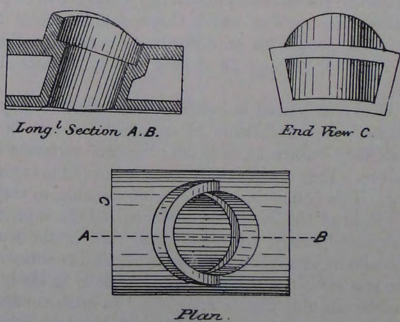


Fig. 37.

walls of sewers, to enable a proper junction to be made with drain pipes at any angle.

Concrete.—When sewers are entirely made of concrete, the least thickness need not exceed what would be allowed in brickwork, but the concrete must be carefully made, and evenly laid.

The concrete for sewers may be composed of :—Portland cement ; wo sand ; and three broken stone, passed through a $\frac{3}{4}$-inch sieve.

Adequate Foundation Required.—It is necessary to be careful to provide an adequate foundation for a culvert ; if the ground is at all soft, the bottom should be built with a rectangular base, as in *Fig.* 38. Where the ground is of a treacherous nature, the concrete is sometimes laid on closely-wattled hurdles, or planks, resting on three longitudinal sleepers $5\frac{1}{2}$ inches die square.

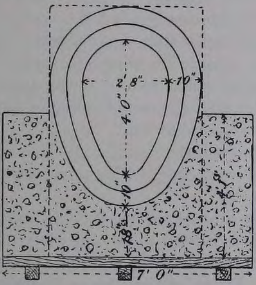


Fig. 38.

The dotted lines on *Fig.* 38 represent the size and method of construction adopted in the case of the sewers for the Thames Embankment. They were for the most part made entirely of concrete, 10 inches thick at their thinnest part, the outside being square. Some were lined with $4\frac{1}{2}$-inch brick, the concrete being $4\frac{1}{2}$ inches.

Plate IX. shows a method of forming a culvert in sand when a spring is met with, and also some arrangements for laying drain-pipes on bad foundations.

The former method was adopted by Mr. Baldwin Latham in carrying out the sewerage works at Redhill, and is described in his excellent work on sanitary engineering as follows :—

"Owing to the large amount of water present when excavating these works, it was found that, if only for a short time, the operation of pumping was discontinued, the sub-soil water would rise and force its way through the newly-laid concrete or brickwork of the sewer; consequently it became necessary to make provision for admitting this water into the sewers during the progress of the works in such a way as to allow the materials a fair chance of consolidation before finally excluding the water. This was done as shown on *Plate* IX., which represents a sewer constructed on an artificial plank and concrete foundation. At suitable intervals along the sewer ordinary sewer-pipes were placed upon the planks socket downwards, and afterwards filled with clean gravel, a communication being made by means of a land drain communicating with the bottom of the sewer. The water passed up through the planked floor and gravel, discharging itself free of sand into the sewer; so that the water, having a free escape, did not injuriously affect the work, and pumping could therefore be dispensed with after the completion of the lower portion of the sewer; and, owing to the small apertures left for the purpose of admitting the spring water into the sewer, at any time that might be thought desirable after the consolidation of the work, the spring water could be effectually shut out."

Where planks are used, the pipes should bear uniformly on them, to allow which it is necessary to lay upon the planks a sufficient depth of good material.

Where stoneware drain-pipes are used in soft ground, a cement concrete bed should be formed to suit the invert, and laid to the fall, its width being 12 inches greater than the bore, and depth varying with the diameter. The following sizes are recommended as suitable, viz.:—

Internal Diameter of Pipe in Inches.	Thickness in Inches.	
	Under Pipe.	At side of Pipe.
4	3	5
6	3½	6
9	4	7
12	4½	8½
15	5½	10½
18	6	11

In cases where the outfall pipes are laid on a foreshore, the action of the sea is liable to uncover and also undermine them.

If the pipes are to be laid in sand, which is liable to shift with the tide and wind, care should be taken to prevent the lateral movement by piling, and also to afford them efficient support in a similar manner. Arrangements for carrying pipes, embedded in sand, and also above the level of the foreshore, so as to obtain a uniform gradient, are shown on *Plate* VI.

Cast-iron Drain-pipes are also used in many instances on account of the greater security they afford against any possible escape of sewer-gas in such a case as when it is necessary to carry a drain under a house. Then, again, advantage would be taken of their extra strength in crossing open spaces, where ordinary glazed pipes would be liable to be damaged by traffic or other causes. Cast-iron pipes may be used for main sewers with economy and advantage, as where the trench contains quick-sand, or where the strata is full of water; also in narrow streets, where deep trenches have to be excavated. A cast-iron sewer may be two-thirds the diameter of an earthenware pipe or a brick sewer, as the cast-iron pipe may work full and even under pressure. They have great advantages over stoneware pipes, but the cost stands in the way of their general introduction; there is less labour in laying them, as they have fewer joints, being made in 6, 9, and 12-foot lengths, in place of two feet three inches; they are more accurate in form, and have less defects on the inner surface than stoneware pipes, as, with every care, the latter twist and crack slightly in the baking.

Iron pipes, if of proper weight, never break; they can be made of any size, and so might take the place of culverts.

A 5-inch iron pipe might sometimes, with advantage, be used in place of a 6-inch glazed pipe, as it would clear itself better.

Except under unusual circumstances, iron drain-pipes need not be made as heavy as water mains; a thickness of $\frac{5}{16}$-inch is sufficient for a 5 or 6-inch pipe. The sockets, however, must be sufficiently strong to stand the leading and caulking. Six feet lengths of 4, 5, and 6-inch pipe would thus weigh about 85, 100, and 125lbs. respectively. The joints for these pipes would be made in a similar manner to those described under the heading of vertical soil-pipes.

For a 12-inch pipe the thickness would be about $\frac{1}{2}$ inch.

In all cases the joints would be run with lead and caulked, just in the same way as obtains with gas and water mains.

The inside of all iron pipes should be coated with Dr. Angus

Smith's process, or with magnetic oxide, by the Bower-Barff process. Experienced persons are required to apply these coatings, consequently they should be obtained from the manufacturers ready for use.

Joints.—Cast-iron pipes are made both with sockets and also with flanges, according to the purpose for which they are to be used.

Socket pipes, as shown in *Fig.* 21, are substituted for stoneware pipes in positions where great strength and few joints are an object.

Turned and Bored Sockets.—Are similar to socket joints, but the head is longer, and is turned cylindrically. The inside of the socket is also turned for about one-half its length, so that the spigot and socket fit mechanically; the remainder of the joint should be caulked with lead in the usual manner.

Flexible Joint.—*Fig.* 41 shows a joint which is easily put together, and admits of a certain amount of play, so that the pipes are not so likely to suffer from any small settlement.

FLEXIBLE JOINT.

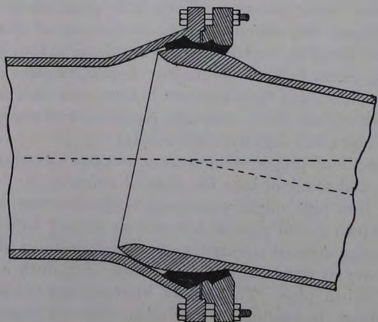


Fig. 39.

Flanged Pipes.—Flanged pipes would be used for large syphons under rivers, and where the pipes are under considerable pressure.

Fig. 40. illustrates a special form of this joint.

Iron pipes are also used for sewer outfalls.

Steel.—An outfall, 800 feet in length, was recently laid in the Lake of Geneva by means of a steel pipe. The pipe was boomed out from the shore as the lengths were bolted together, and thus the whole pipe to form the outfall was floated into position, advantage being taken of its buoyancy for the purpose by plugging the extremity to prevent the entrance of water. When the operation of putting the entire length together was completed, and the pipe was in its correct position over its intended resting place, the water was gradually admitted, and the pipe allowed to take its bearing. Steel was chosen as the material on account of its relative lightness and strength, so that it might be capable of standing any unavoidable stress in landing and settling on its bed.

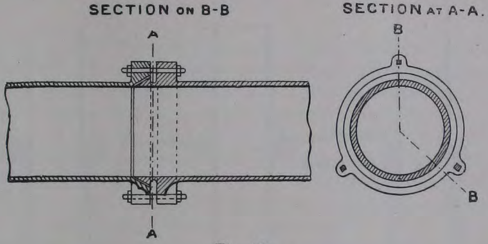


Fig. 40.

Lead Pipes.—Soil-pipes, until recently, have been made of lead, and carried up inside the house; but although lead in such a position may be more reliable than iron, yet all sanitary engineers condemn the practice of placing a soil-pipe in such a position; all such soil-pipes, where met with, should be removed, and replaced by iron soil-pipes on the outside of the building. Lead pipes are often used to connect w.c.'s with soil-pipes, and also as waste pipes from baths, sinks, etc., as the special form required by the particular case is more easily made locally in lead than it could be in cast or wrought-iron.

Drawn Pipes.—Lead pipes over $2\frac{1}{2}$ inches in diameter have hitherto been made of sheet-lead with a longitudinal soldered joint, and only smaller pipes were drawn without a longitudinal joint. Hydraulic drawn pipes, of the larger diameter, are now procurable from most makers, and should always be used in preference to seamed pipes for sanitary purposes.

Waste Pipes.—Waste pipes from small sinks and baths are often made of light lead piping, 6lbs. per foot run.

Connection with Stoneware Pipe.—The connection between a lead pipe and a stoneware or iron soil-pipe should never be formed within or underneath a building, as such a joint cannot be depended on; the syphon should, therefore, if possible, be continued through the wall, and the connection be made outside.

Variety of Joints.—*Fig.* 41 shows a few of the joints which have been recommended for this purpose.

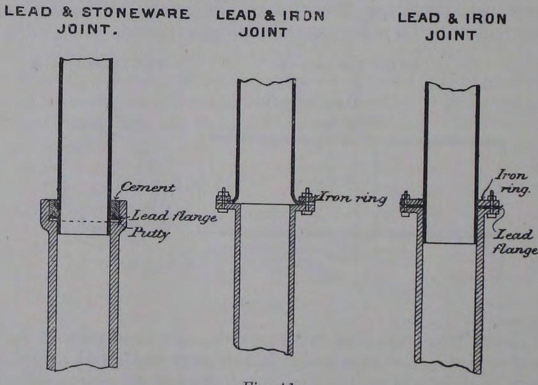


Fig. 41.

At first sight it would seem a very simple matter to make an efficient joint between pipes of different materials, but the question is complicated by the variable expansion of the different substances.

Wrought-iron Piping.—Wrought-iron piping is also much used for wastes from sinks, but is neither so suitable nor so durable as lead.

CHAPTER V.

VENTILATION.

Sewers.—One of the most important subjects which we have now to consider is the sewer-gas generated in the foul-water drains. Sewer-gas proper is described as a "fœtid organic vapour," and has for its companions in a sewer sulphuretted hydrogen, a most poisonous, as well as unpleasant smelling gas; carburetted hydrogen, due very often to leaky gas-mains or services, or to decomposing vegetable matters; carbonic acid gas, or carbonic anhydride (choke damp); and some ammoniacal compounds. The actual component parts vary considerably according to circumstances.

Decomposing Sewage Dangerous.—Sewage which has begun to decompose is more dangerous than when fresh; it should, therefore, as already stated, never be more than 24 hours in finding its way to the outfall; there is even then an accumulation of slime on the inner periphery of the sewers, owing to the rise and fall of the sewage line, which is constantly giving off gases, the result of decomposition.

A quick velocity of discharge, and ample flushing arrangements, are, therefore, very desirable.

There is little doubt that this foul air contains organic matters floating about in it as solids, and that it is excessively injurious, and even dangerous to breathe. These germs should, therefore, be caught and destroyed, or rendered innocuous, and thus be prevented from contaminating and poisoning the air we breathe.

Ventilation and Traps.—Attempts are generally made to control this dangerous product by means of ventilation and proper traps, so as to prevent its passage where it might prove injurious.

Some engineers are of opinion that the foul air invariably finds its way to the upper portions of a sewage system; but this is not always the case, for with quick velocities of discharge the gases are carried by friction in the direction of the flow of sewage.

Duty of Local Authority to Ventilate.—The necessity of dealing in some way with the noxious vapours given off from sewage, and so preventing it from finding its way into dwelling-houses, has led to its being made the duty of every local authority to cause their sewers to be ventilated, so as not to be a nuisance and a danger to health.

Points to be Observed in Sewer Ventilation:—

1. The system adopted should be as simple as possible, and independent of mechanical aid.

2. Efficient expulsion of sewer-gas, and the admission of fresh air at all times to every part of the system.

3. All gases thus expelled from the sewer to be diluted with fresh air, so as either to be rendered harmless, or they should be arrested and destroyed.

4. Natural ventilation must not be impeded by the system adopted.

5. The cost of construction and maintenance must be kept within moderate limits.

It is evident that the configuration of the ground on which a town is situated must affect the disposal of the sewer-gas in the sewerage system adopted.

The position of the outfall, relatively to its exposure to the prevailing winds, materially influences the direction of the flow of sewer-gas in a sewer. Under such circumstances it may be necessary to control the current of air entering by the sewer by means of a hinged flap, so as to prevent undue pressure at any point.

The fluctuation of the flow level in a sewer is also an important factor, as it tends to convert inlets for fresh air into outlets for foul air, and *vice versa*. An increase of the flow level compresses the air in the sewer, and unless means are provided for its escape, it would augment the pressure in the sewer to such an extent as to force the traps intended to exclude it.

The pressure of gas in sewers is ordinarily relieved by shafts constructed along the lines of sewers, some of which are also intended for the admission of fresh air.

These ventilators are generally placed at intervals of about 100 yards, and should never be at a greater distance apart than 200 yards, being placed somewhat closer together at the lower levels, and the intervals increased at the higher parts of the town.

Sewers with steep gradients require more care bestowed on the means for their ventilation than those in flat districts, so as to prevent dangerous accumulation of sewer-gases in the higher and lower portions of the system, and thus it is necessary to ensure the discharge and dilution of this gas as fast as it is generated.

The usual system is to break the line of sewer into short lengths between manholes, with a step, or ramp, and flap at each manhole (*Plate* V*a.*), so that the gas formed in each length of sewer is allowed to escape by the outlets for each section, instead of travelling the whole length of the sewer.

The steps are usually curved and of moderate depth, so that the fall from the upper district shall not tend to the further discharge of foul gas from the sewage.

Simple Ventilation.—Many authorities advocate open ventilation, contending that all that is necessary is to dilute sufficiently the sewer-gas with atmospheric air, so as to be able to disseminate it with safety, and at the same time not to cause any nuisance.

This system is thus free ventilation, which, in its simplest form, would consist of an open channel, or a sewer covered with a continuous grating. The flow in such a channel would be liable to be retarded by detritus, etc., falling into it, and thus the openings are restricted to shafts carried up to the centre of the road at intervals, all road gullies being left untrapped, and, in addition, inlets (*Plate* XII.) may be provided in the footpaths and kerbs.

Such openings are affected by fluctuations in the flow of sewage, and also by barometric changes in the atmosphere. Wind blowing over the surface of the ground interferes with the efficient action of these shafts, and tends to drive the foul air generated in the sewer into the branch, or house drains. Objection has also been taken to these ventilating openings on account of the sewer-gas escaping into the public thoroughfares at points not easily observed.

To obviate this disadvantage, pipes not less than six inches in diameter are recommended to be led from the manholes, or shafts, to the gable of adjoining buildings, or to ventilating lamp posts, so as to deliver the foul-air at such levels that it may become diluted before it can be breathed.

There is sometimes a difficulty in placing these pipes in positions where they would prove most useful. They are mostly made of iron, which, however, being a good conductor of heat, act very well during summer or temperate weather, but in cold weather they tend to check the upward flow. Glazed pipes set in cement, and encased in masonry, might with advantage be substituted.

Separate inlets at a lower level are also provided for the admission of fresh air, so as to obtain a constant circulation of air. They should also be carried up to some height, as, although designed as inlets, the draught may sometimes be in the opposite direction, and thus they will act as outlets.

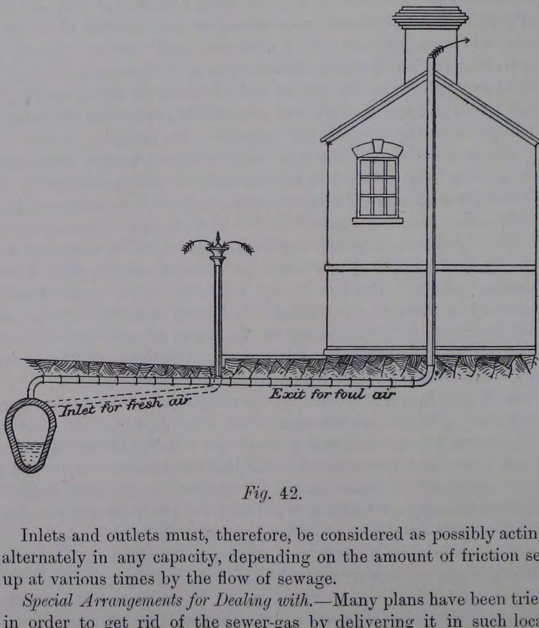


Fig. 42.

Inlets and outlets must, therefore, be considered as possibly acting alternately in any capacity, depending on the amount of friction set up at various times by the flow of sewage.

Special Arrangements for Dealing with.—Many plans have been tried in order to get rid of the sewer-gas by delivering it in such localities that its dangerous qualities may not be felt, such as lofty shafts, built sometimes in connection with furnaces to increase the up-draught. Such a system promises well for long outfall sewers with no connections, as in the case of the large furnace shaft erected on the Brighton outfall sewer; the effect, however, on a general system of sewerage, in displacing the foul gas, is small.

High Shafts.—A further attempt in this direction is made by supplying a number of high shafts at different points; by this means a partial clearance is effected.

Keeling's System.—Keeling's patent sewer-gas exhauster and destructor (*Fig.* 43) is in operation in many towns (Richmond, Ealing, etc.). It consists of a gas jet kept burning in the outlet shaft. The sewer-gas by this means is subjected to great heat, and it is stated to be an effective apparatus for the entire destruction of noxious gases and fever germs. A consumption of one cubic foot of coal-gas effects the extraction of 500 cubic feet of sewer-air from the sewers.

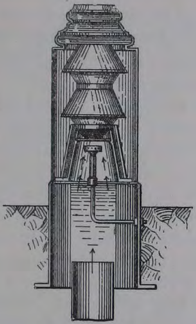


Fig. 43.

It has been estimated that 50 such destructors would efficiently ventilate the whole system at Ealing, consisting of about 30 miles of sewers.

Adams' System.—Within a suitable frame and cover, and surrounding the impure air exit, a receptacle is provided for a liquid disinfectant. A wire hood, upon which loosely twisted asbestos strands are interlaced, covers this opening, and dipping on all sides into the liquid disinfectant, becomes saturated throughout, forming a wet disinfecting screen, through the meshes of which the gases freely rise, in their passage being purified and rendered innocuous.

The usual disinfectant employed is carbolic acid, which requires replenishing every three months.

Water Injected.—In some cases water has been injected into the extracting shafts so as to absorb the gas.

Fans to Extract.—Fans driven by machinery have also been used to extract the foul air.

Other Methods.—Again efforts have been made to prevent the formation of sewer-gas in the sewers; and then again either to neutralize or destroy them. For this purpose absorbent materials, such as charcoal, dry earth, and chemical agents, as well as deodorants and disinfectants, have been placed in the sewers themselves, so as to modify or destroy the noxious properties of the gas.

The latter classes of materials have also been applied before the sewage has been allowed to enter the sewer.

Chlorine has even been laid on to the sewers by means of special pipes provided for the purpose; and galvanic action has also been tried in the sewers, so as to produce ozone from the sewer-gas.

House Drains, Size of.—Ventilating shafts and pipes should be of the same sectional area as the drains they are intended to ventilate, and should have as few bends as possible.

Disconnection of.—In the case of a town, all house drains should be cut off from the sewer by means of a disconnecting trap or syphon, care being taken to provide independent ventilation for them (*Plate* VI*c*.). There are a great variety of these traps (see *Plate* XV., and *Figs.* 55 to 57, also Ingham's method, *Fig.* 58). In order to disconnect the combined drainage of any group of houses from a main sewer, a disconnecting pit is necessary, such as that shown in *Plate* XI., or *Fig.* 45. Any number of drains may be collected into this pit, as shown in *Fig.* 18. It should be covered with perforated grating, or fresh air may be admitted to the pit by a special inlet shaft. Rogers Field's, and Crapper's improved Kenon (*Fig.* 44) have some advantages, and are intended to be used in connection with a manhole, so that they may be readily cleared of any obstruction.

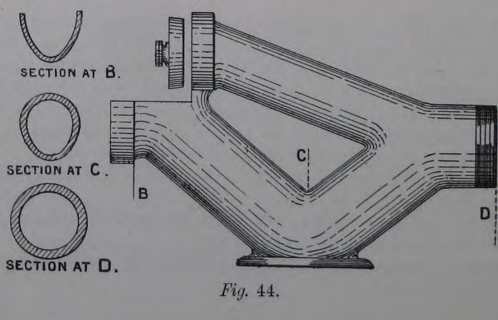


Fig. 44.

In *Fig.* 45 the application of this trap in an improved manhole is given. The small chamber on the upper level is intended to intercept road detritus, and thus prevent the drain from getting choked.

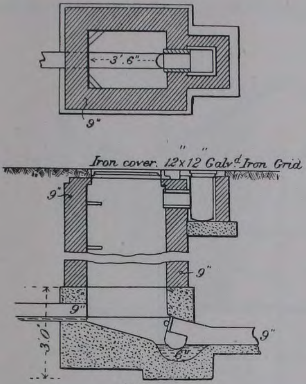


Fig. 45.

Care must be exercised in locating such pits, as for the reason already stated sewer-gas may be emitted from them when liquid is being discharged through the drain.

The pit in *Plate* X. is used for disconnecting barrack drains from town sewers. It would be much improved by providing a cleaning eye to the syphon for clearing the drain beyond.

In addition to this there should be as few connections between the house and the drains as possible, being practically limited to that necessary for the w.c. apparatus, and with this single exception, all wastes from cisterns and safes should discharge into the open air, and those from baths, ablution ranges, and sinks should deliver over traps, and on no account be directly connected with the drains in any way whatever (see *Plate* XI.).

In the case of a single house, instead of a disconnecting pit, a syphon and fresh air inlet would be used, as shown in *Fig*. 46.

Outside Gullies.—Outside gullies for receiving slop water from sinks should be ventilated, and for this purpose, from the drain side of these gullies, a ventilating pipe, 4-inch diameter, should run up above the eaves of the roof, as shown in *Plate* XI. The joints of such pipes should be air-tight.

Yard and parade gullies for surface drainage cannot well be ventilated, and for this reason the separate system should, if possible, be adopted, such gullies being thus kept distinct from the sewage system.

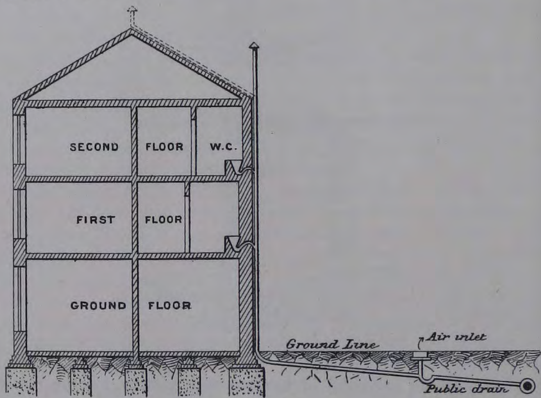


Fig. 46.

Alternative Method of Ventilating House Drain.—When, however, the extremity of the extracting shaft thus carried up from the soil-pipe would be situated dangerously near windows, flues, etc., and the length of drain to be ventilated is considerable, it becomes necessary to place a syphon at the foot of the soil-pipe, a false drain being led to a convenient position for the extracting shaft, as shown in *Plate* XIII.

Under such circumstances the soil-pipe itself still requires ventilation, and with this object a fresh air inlet must be provided on the house side of the trap, by using one of the ventilating traps shown on *Plate* XV. Hellyer's combination traps, *Figs.* 4 to 12 of this plate, are well adapted for the purpose.

Fresh Air Inlet to Soil-pipes.—The inlet for fresh air thus provided at the foot of a soil-pipe is liable to emit foul air, especially when a discharge of liquid takes place in the pipe. In many places it would be dangerous to run the risk of this foul air, generated in the vertical soil-pipe, being given off in such a locality. The inlet may then be carried up a few feet above the ground and protected by a mica flap inlet ventilator, as shown in *Fig.* 47, or a false drain may be led some distance away, and provided with a suitable inlet.

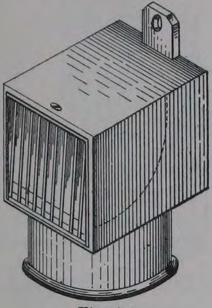


Fig. 47.

The flap closes with the slightest up-draught.

Wastes from Sinks.—In some cases pipes discharging from sinks have been known to become untrapped, and then, even if disconnected from the drain, an unpleasant smell from the pipe itself will enter the house. If, however, the method of ventilation shown in *Fig.* 48 be adopted, this danger will be avoided.

Ventilation of Drains of a Barrack Enclosure.—*Fig.* 3, *Plate* XIII., represents blocks of buildings in a barrack enclosure, and the drainage therefrom. Such a system should be considered as one of house drainage, the ventilation being provided at the end of each branch (as shown at A, *Fig.* 3). A disconnecting pit might be placed at point D P, through which air could be admitted by an open grating covering the pit, or by means of a large pipe led up, or a chamber cut in, the brick wall. All changes of direction should be made in the small inspection pits (marked I P). The drainage of the stable at B should be led by means of surface channels to a trap of the form shown in *Fig.* 66, 12 feet clear of the building. M is a manhole on the town sewer Z, into which should be led the drain-pipe from the barracks, and if proper means of ventilation were provided at this point (M), there would not be, when the flow of sewage was at a minimum, sufficient pressure of sewer-gas to force the disconnecting trap of the barrack drain.

Cowls.—These appliances are intended to control the direction of the current, and ensure the air in the drain flowing in one direction. They may be of use in special cases, but the W.D. advocates the ends of inlet and extracting shafts being left open without a cover of any sort.

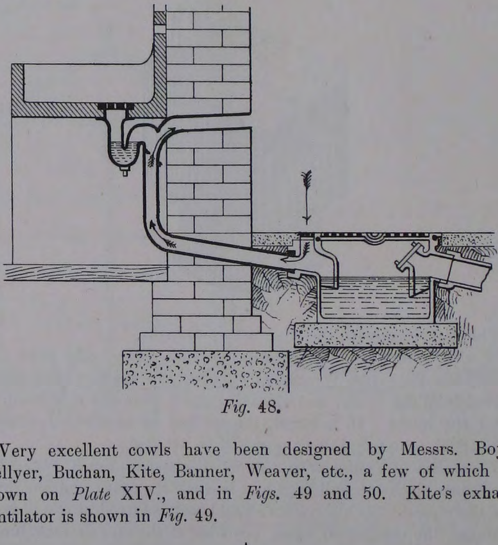


Fig. 48.

Very excellent cowls have been designed by Messrs. Boyle, Hellyer, Buchan, Kite, Banner, Weaver, etc., a few of which are shown on *Plate* XIV., and in *Figs.* 49 and 50. Kite's exhaust ventilator is shown in *Fig.* 49.

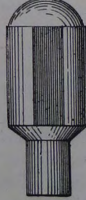


Fig. 49.

A down-cast ventilator by the same maker is shown in *Fig.* 50.

Fig. 50.

The "Empress" revolving cowl is set in motion by the wind. Its action is explained by reference to *Fig.* 51. It requires to be lubricated periodically.

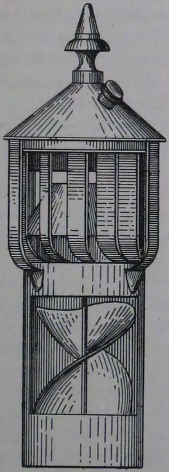


Fig. 51.

CHAPTER VI.

TRAPS.

Traps: Object of.—Traps are used in connection with foul water drains, to prevent the passage of sewer-gas in a particular direction through a pipe, or through the apparatus of a w.c. or latrine, or where it would be obnoxious or injurious.

They should be, like the sewers, self-cleansing, *i.e.*, they should be made so as to allow the free passage of the liquid sewage as well as the more solid portions contained in it. Consequently the traps should not be rectangular either in longitudinal or transverse sections, as any sudden changes of shape tend to produce deposit, which is most objectionable and insanitary.

Water-lock.—Traps are constructed so as to establish a water-lock, through which water, even though carrying solid matter, can pass freely.

The depth of water-lock or seal should vary from half-an-inch to $3\frac{1}{2}$ inches, depending on the frequency of use.

Failure of.—The water-lock of any form of traps, however, cannot be relied on, as it may fail in many ways :—

1. By pressure of gases forcing the foul air through the water.
2. By a partial vacuum being caused by the pipes being emptied suddenly, and so drawing off the water by suction from the trap.
3. By the evaporation of the water, lowering its level below the tongue of the trap.
4. By syphonage, such as may be caused by a piece of rag lying partly in the trap with its end hanging down through the outlet.
5. By sewer-gases being absorbed at the surface of the water at one side of the trap, and being given off on the other side.

Traps: Necessary Evils.—Consequently, traps should be regarded as necessary evils, and their use should be avoided as much as possible by reducing their number to a minimum, and for this reason the only connection with a foul water drain admissable within a building is the one necessary for a water-closet; in no other case should the drain be allowed to enter the house.

By the absolutely separate system, the only gully traps required are in connection with sinks, and thus the danger of any of them running dry is minimized, and constant supervision to obviate it is rendered unnecessary.

Position of.—In arranging for the position of the traps, care must be taken not to interfere in any way with the ventilation of the sewer or drains.

Good Flush Necessary.—A good flush of water should always be provided in connection with all traps.

Form of.—The form of the traps, or gully, should always be adapted to the purpose for which it is intended.

Traps are made in a great variety of forms; as already mentioned, those which are self-cleansing, such as syphons, which allow all solids to be carried into them, and to be swept through them easily by the flow of water, should alone be used for sewage.

As the sectional area of a syphon trap, even of the smallest size made in stoneware (four inches), is large in proportion to the amount of the liquid discharged from a sink, there is a tendency for filth to accumulate in it, so that everything should be done to increase the velocity of discharge through it as much as possible. In order to effect this in the case of a rectangular connection, a drop should invariably be given of at least three inches from the invert of the pipe to the surface of the standing water in the trap, as shown at D in *Plate* XV., *Fig.* 1. In this way a cascade action is insured, which helps to overcome the resistance in the trap. The drop in *Fig.* 57 is six inches. In addition to the foregoing, in order to still further increase the self-cleansing action of the trap, it is recommended to use one of smaller sectional area than the pipe discharging into it; thus for 6, 9, and 12-inch pipes, 4, 6, and 9-inch traps might advantageously be used.

Mason's Traps.—Sometimes Mason's traps (*Fig.* 52) are found in old sewers. A deposit takes place in them, which is stirred up with each discharge, the cure being thus worse than the disease; sewage retained in this manner and allowed to putrify being infinitely more dangerous than fresh sewage. Traps which retain solids are of use for special purposes, such as preventing road detritus, etc., from entering a foul water drain; comparatively few would be required with the partially separate system, and none with the separate system. They will be treated of under the head of surface drainage.

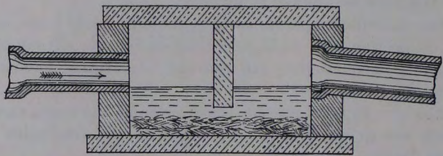


Fig. 52.

Self-cleansing.—Self-cleansing traps should be of the simplest form, such as the ordinary syphon (*Fig.* 53).

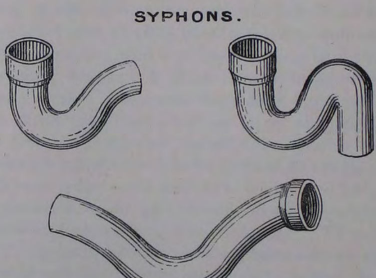


Fig. 53.

Examining Eyes are desirable for clearing traps or the drain beyond when required; the latter are also available for ventilating purposes.

An examination eye over a bend in a syphon is objectionable, as it checks the flow.

Ventilating, for Soil Pipes.—Cregan's patent air-inlet (*Fig.* 54) seems to have some special advantages. The grating is made solid immediately over the opening to the shaft, and can readily be removed. It is supplied by Messrs. Doulton & Co.

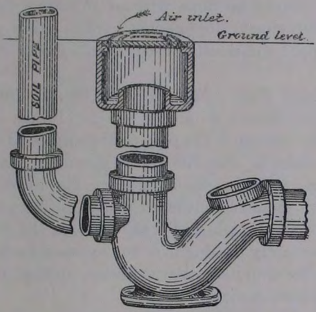


Fig. 54.

Special Forms.—Several other special forms of traps for this purpose, by Weaver, Buchan, and Hellyer, are shown in *Plate* XV., and also special connections for soil-pipes, fresh air inlets, etc., for Hellyer's trap, which can thus be adapted to any particular case.

Doulton's Improved Sewer-gas Interceptor.—*Fig.* 55 is Doulton &

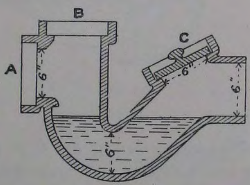


Fig. 55.

Co.'s "Improved Sewer-gas Interceptor." The inlet socket A, as drawn, is intended to receive a drain-pipe, six inches internal diameter, the air inlet B being of the same diameter. It should be larger, and the manufacturers can easily make it so. In this case it should be enlarged to twelve inches, or at least to nine inches diameter in the clear. The air outlet C is six inches diameter, as it ought to be for a six-inch drain. It is closed with an earthenware stopper, put in with common mortar, not cement, so that when it is necessary to remove it, it can be done without breaking the socket of the pipe, as common mortar does not set hard in damp ground, while it keeps the stopper sufficiently air-tight as long as it is required to remain there.

Buchan's Patent Trap.—Fig. 56 is Mr. W. P. Buchan's "Patent Trap," made by Messrs. J. & W. Craig. It has a drop of three inches from the bottom of the pipe to the surface of the water in the trap. Its air inlet is only six inches diameter, same as Doulton's, but the makers are willing to enlarge it. The outlet C is four inches diameter. This should be made six inches for a six-inch drain. The dip, or water seal, of $1\frac{1}{2}$ inches is too little, as the current of air for ventilation constantly passing over the exposed surface of the water in the well of the trap induces evaporation, so that, if not frequently used, the trap soon becomes unsealed.

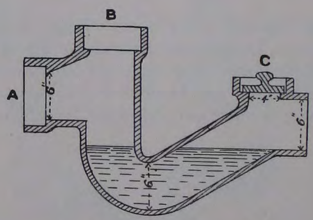


Fig. 56.

Hellyer's.—Fig. 57 is another trap by Mr. S. S. Hellyer, which he calls a "Ventilating Drain Syphon and Sewer Interceptor." Its air inlet is of considerable dimensions in one direction—that shown in the section—but cross-wise it is reduced to the width of the pipe. The trap in the part marked D is of smaller size than the drain itself, being, for a six-inch drain, four inches diameter, thus preventing any sediment forming in the trap, and also ensuring the entire renewal of the water in the trap more frequently than it is in traps which are of the same size in the throat as elsewhere.

There is a vertical drop of six inches from the bottom of the house drain to the level of the standing water in the trap.

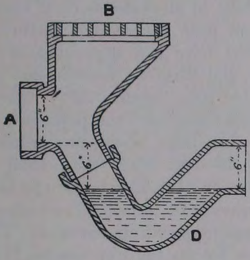


Fig. 57.

Ingham & Sons'.—*Fig.* 58 is Messrs. William Ingham & Sons' quick-motion trap, which is intended for use in connection with a small masonry pit. It is claimed for this trap that the obstruction

DISCONNECTING TRAPS &C.

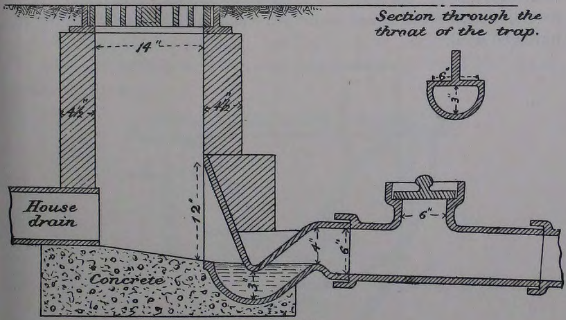


Fig. 58.

to the flow of sewage through it is less than in other traps, inasmuch as there is no unnecessary and useless sinking of the sides of the orifice below the water-level. The top of the trap, cross-wise, is straight and horizontal, parallel with the surface of the water in the trap. Its dip is, therefore, fully effective the whole width of the drain-pipe, whilst in all-round sections both sides dip uselessly into the water and offer unnecessary obstruction to the flow of sewage. Those who have had experience of these traps regard them with favour, and when we examine the principles on which they are constructed there appears every reason why that should be so. The trap effectually bars the passage of air; its dip is the same as that of other traps, about two inches or $2\frac{1}{2}$ inches, and this is effectively disposed, while the bottom of the trap is not sunk more than five or $5\frac{1}{2}$ inches below the bottom of the drain, instead of eight inches or $8\frac{1}{2}$ inches. The body of water in the trap being small, is frequently entirely renewed. The outlet is on the next adjoining pipe, not on the trap itself. It is one of the points of this trap that when the sewage leaves it, it falls immediately and freely over the lip into the pipe, and acquires motion thereby to start with, and a free outlet in the trap is maintained.

The circular bore is, however, by some considered the best for syphons intended to be self-cleansing, and their internal diameter should certainly not exceed that of the pipe running into them, and might be less, as already mentioned.

D Trap.—The old pattern D trap is shown in *Fig.* 59; it is rectangular in section, and is not self-cleansing; it should, therefore, never be used.

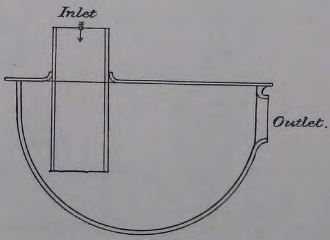


Fig. 59.

Traps for Sinks.—All sinks, even now that they are invariably cut off from direct communication with the drain, should always be provided with a trap immediately below the basin, or trough, to prevent the smell emitted by the matter deposited in the interior of the pipe entering the house.

Bell Trap.—The old-fashioned bell trap (*Fig.* 60), though constantly met with in use in sinks, and sometimes for gullies, etc., is a very defective trap, because, 1st, it is unsealed whenever the perforated bell cover is removed; 2nd, the water soon evaporates from the shallow cup, and the trap is unsealed; 3rd, the bell being only attached to the perforated plate at the apex, is easily broken off and lost, especially when only rivetted on. The loss is not apparent when the plate is in its place, and thus the sewer-gases are allowed to pass unhindered.

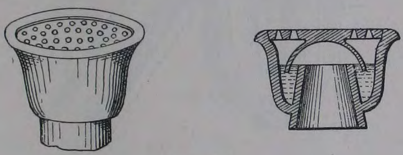


Fig. 60.

Jennings' Bell Trap.—A better form of bell trap is shown in *Fig.* 61, as made by Jennings and other makers. The shallowness of the cup in all these traps renders them liable to become untrapped by evaporation, and the trap itself soon gets clogged with grease. It is very difficult to cleanse it, so that this description of trap should never be used.

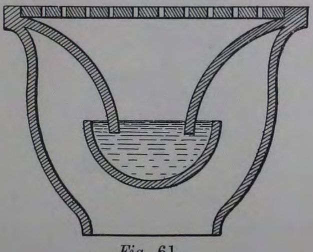


Fig. 61.

Syphon.—A much better construction is to provide a syphon with cleaning eye immediately under the sink (*Fig.* 62), so that the grease may be readily removed.

WITH CAP AND SCREW.

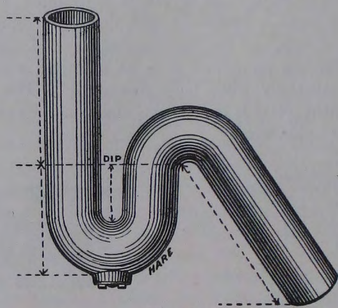


Fig. 62.

A special trap of this kind, by Tye & Andrew, is shown in *Fig.* 63. It is a very good sink trap, and is extensively used. It is made of galvanized iron, with brass grating and screw eye. The galvanizing is liable to destruction from acids passing through the waste, consequently it would be much better to make it entirely of brass or gun-metal.

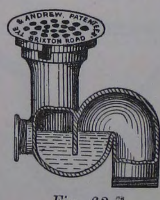


Fig. 63.

Double Seal.—Jennings'.—Jennings' trap (*Fig.* 64) is also sometimes used for this purpose. The water-way is closed by a light ball, which falls back into its place after the passage of the liquid. It has thus a double seal, and was designed to obviate the defect due to evaporation, but the accumulation of grease on the grating makes it uncertain in action.

There is a cleaning eye at the side for the removal of grease, etc.

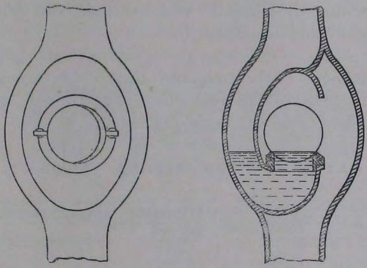


Fig. 64.

The Bower Trap.—*Fig.* 65 shows this trap. The chamber at bottom is readily removed by unscrewing for cleansing. It also has

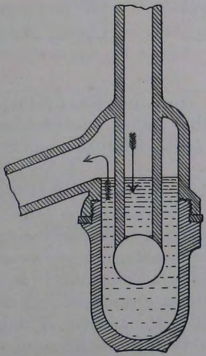


Fig. 65.

a double seal, and the valve is likely to be more effective than in the former case, as a considerable amount of evaporation would be required to unseal it, and in the meantime the pressure on the grating is greater than in Jennings' trap.

It should be here remarked that it is best to use the simplest forms of traps for this purpose, especially now that the discharge pipe is never directly connected with the drain, and thus no advantage is gained by double sealing.

Gullies for Stables.—Gullies for stable drains should have a grating attached to the inlet to the drain, and turned downwards, as shown in *Fig.* 66, in order to prevent floating straw, etc., getting into the drain. They require to be frequently cleared out.

CATCH PIT FOR STABLE YARDS.

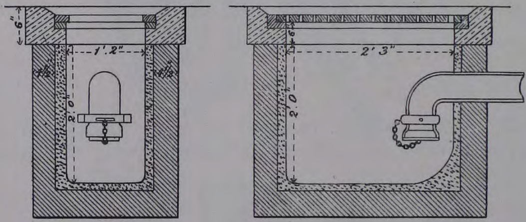


Fig. 66.

Grease Traps.—The pipes from sinks should discharge in the open over the gratings of the gullies, but sometimes when the refuse on the surface would be too unsightly the connection is made below the surface.

Grease traps are intended to arrest fatty matter from scullery sinks, and thus prevent its choking the drain.

Grease, when in solution with hot water, escapes through the finest grating of the sink waste, and gets away into the drain, where it congeals, and becomes a nuisance. It is, therefore, essential to have special traps, with a grease-collecting chamber of considerable capacity, proportional to the amount of sink water to be passed through it, so as to prevent the displacement of the body of water in the trap too rapidly, in order to ensure the grease being chilled and deposited in it. The trap should be easily accessible, for periodical cleaning. A non-conducting material is preferable for the construction of these traps.

Hellyer's.—Hellyer's patent grease intercepting tank or trap (*Fig.* 67) has been widely adopted. There is plenty of room for cleaning purposes, and a tray is provided to remove the fat. There is no ventilation for the grease-collecting chamber, and it would apparently be advantageous to add a contrivance for this purpose, in connection with the recommended drain ventilation.

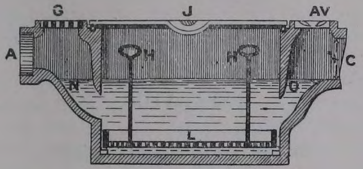


Fig. 67.

Self-closing Traps.—In some cases, as an extra precaution, drains are closed against sewer-gas by means of self-closing traps, or valves, which are opened by the flow of sewage. They are often necessary in connection with outfalls, to prevent gases being forced up the drain by a rising tide. Sometimes, instead of a hinged flap, a ball is used, as in the figure. Means of examination should always be provided. The one shown in *Fig.* 68 is made by G. Jennings.

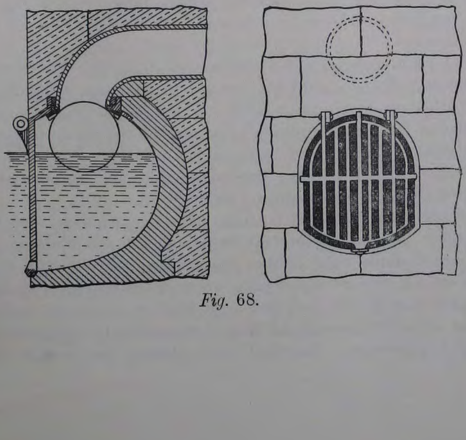


Fig. 68.

CHAPTER VII.

APPARATUS.

Latrines, W.C.'s, Urinals, Etc.

Position of.—Latrines and urinals should be placed at a distance from an inhabited building, and, with this object in view, they are often built against walls with a lean-to roof.

Messrs. Doulton & Co., and Messrs. Jennings & Co., have supplied, in London, very excellent public urinals and w.c.'s in underground chambers built for the purpose. The walls are covered with white glazed bricks to improve the light.

A place like this requires an attendant to see that the closets are not improperly used, and to keep them clean. This is not practicable with ordinary latrines, which have consequently to be of a rougher description, and situated where they will not create a nuisance.

W.C.'s for houses are, for convenience, built in connection with the houses. They should be confined to one part, and built over each other as much as possible. They should project out from the house, for both simplicity in arranging the water service and ventilation. They should also be cut off from the main house by well-ventilated lobbies; free ventilation and ample light are essentials to a properly arranged water-closet.

Water-closets should, if possible, have two windows, one facing the other. Where only one can be provided, it should be so placed as to cast ample light on the seat. The usual rule for sizes of windows in proportion to cubic contents of the room should be departed from in this case, and they should approximate to the size of the other windows in the house, extending to the ceiling, and being double hung. Servants' w.c.'s, which are mostly on the ground floor, should be placed outside, as a rule; the minor inconvenience of having at times to approach it through the rain is more than counterbalanced by the decided advantage of atmospheric connection between it and the kitchen being effectually cut off.

In town houses they are preferably situated in the area, in a front or back yard, entered from the open air, and ventilated into it.

Slop-sinks which approximate so closely to w.c.'s should be placed in similar situations.

Interior urinals are only admissible in large buildings, and should be placed in much the same positions as w.c.'s.

Apparatus: Great Variety of.—There is a great variety of apparatus in use throughout the country, and improvements are constantly being effected in the patterns with the object of securing greater efficiency in operation, and in the exclusion of sewer-gas.

Latrines.—Latrines consist of an assemblage of two or more w.c.'s under one roof, and in consequence of their juxtaposition, the pattern is susceptible of considerable modification from any description of single closet.

There are a great many kinds of latrines, amongst which I might mention one, in which the trough is made in compartments of stoneware, by Messrs. Doulton & Co., and in a continuous length in cast-iron by Messrs. Bowes, Scott, and Western, Mr. G. Jennings, and other makers, in connection with which an automatic flushing tank is used (*vide Plate* XV*a.*). It would be better to have a separate compartment for it, in which cleaning utensils might be stored.

Macfarlane's latrine (*Fig.* 69) was at one time much used. It consists of an iron trough, corresponding in length to the number of seats in the row. It has an extra small compartment at either end, as shown in the figure, the one to take a ball-cock to regulate the supply of water, which is thus kept at a certain level in the trough, the other contains the valve to close the mouth of the soil-pipe. It is flushed daily by filling with water, and lifting the handle which raises the plug. The trough can be cleaned out with a broom as the water runs in.

Jennings' latrines have also been used for many years. The pans are separate for each seat, as shown in *Plate* XVI.

They are connected by a continuous pipe underneath, and the water is supplied by an iron pipe at the back of the seat, with a branch to each pan. Nozzles are provided for each of these branches, to spread the water over the sides of the pan to cleanse it; but this plan does not answer, and it would be much better to have a flushing rim to the basin, and I believe Mr. G. Jennings is making some on this principle.

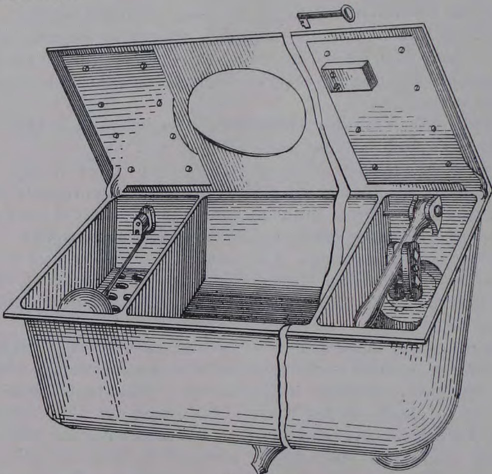


Fig. 69.

The supply of water is controlled by a stop-cock, and the latrine is flushed by raising a valve in the end compartment. This valve has an overflow in it, so as to prevent the pans from being filled too full. Owing to the necessity for using a broom, occasioned by the insufficient flush to each pan, they very often get broken; it would, therefore, be desirable, in setting them, to fill in round each with cement concrete, so as to support and strengthen them.

Fig. 70 is a form of Jennings' latrine pan originally introduced for use in cavalry barracks (where hay, straw, and other improper material used and thrown down by the soldiers is liable to choke the drain). They are also very suitable for any latrines exposed to rough usage; the peculiar shape of the pan, and the fact of all pipes being above the floor, and fitted with inspection-caps at the ends, allows of free access and removal in case of stoppage. This form of pan is largely used for shipment, as great saving in freight, and almost half the ordinary boxing is effected by the *upper* half (when reversed) *nesting in the lower*, with the short pieces of pipe inside, when packed.

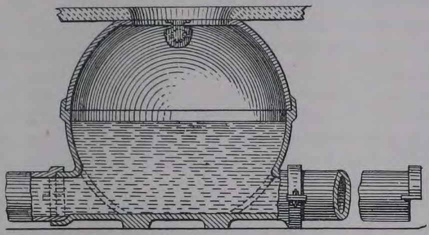


Fig. 70.

Jennings' Patent Automatic Latrine.—This latrine consists of a number of pans, somewhat similiar to that shown in *Fig.* 70, ranged side by side, as seen in his ordinary latrine (*Plate* XVI.)

The automatic tank of the description shown in *Fig.* 114 is placed above the centre of the range, the discharge pipe from which is led down to the level of the latrine seats, where it branches off to the right and left, and passes along behind and immediately below the seats to the extreme ends of the range, where the water is admitted to the pans and tends to start the syphon action. The outlet consists of an S-shaped syphon at or about the centre of the range. At the highest part of this syphon a pipe is fixed, which pipe is attached to and receives a portion of the escaping water from the flushing tank, when the discharge takes place, thus forcing the air out of the discharging leg, and further inducing a syphon action. The syphon action is thus maintained until the whole contents of the range of pans are completely exhausted. The necessary after-flush then enters and refills the pans to a fixed depth.

Water-closets.—The essentials of a good water-closet apparatus are :—

1. The construction should admit of the trap being placed above the floor line, and as close to the basin as possible.
2. The material should be incorrodible.
3. The form should be such as to render the apparatus self-cleansing, and admit of ready access to every part.
4. There should be as few working parts as possible.
5. The flush should be so arranged as to deliver the water as

rapidly as possible, and, at the same time, thoroughly scour the interior of the basin by one discharge.

In order to test a water-closet apparatus, the following simple method is recommended, viz :—

First cover the inside of the basin with lamp-black, then place a few pieces of paper (size about seven or eight inches square) on the covered surface.

Next throw into the basin two or three apples and a cork or bung, the latter is best. Discharge the flushing apparatus used in connection with the water closet. In good types the apples and bung will be forced out of the basin and trap beneath ; the lamp-black and the paper will also be removed.

The apples used for the above purpose should not be overlarge. They are considered to have the same specific gravity as fæces.

Great care should always be taken in setting w.c. apparatus, so as to ensure good gas-tight joints, or the consequences, even with the best apparatus, may be serious. The floor should be sufficiently stable, or the joints may work open. There should be no step up to the seat.

There are a great variety of w.c. apparatus to be found in buildings, some of which are objectionable, for instance :—

Pan Closet.—The old pan closet (*Fig.* 71), in which a copper pan or

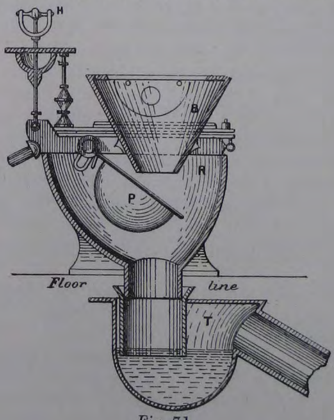


Fig. 71.

cup retains a little water in the bottom of the basin, is still being employed in many places. It is a very objectionable form, and delivers the contents into an iron container, on which the basin stands. The soil is splashed against the rusty interior of this enclosed receptacle, causing, after a time, the most offensive gases to be generated, which pass upwards into the house at each discharge from the basin. The arrangement is usually made still more foul by a D trap placed beneath the container, as shown in the figure.

Valve Closets.—In this description of closet the lower movement of the handle should not allow the passage of sewer-gas into the house. The traps for these closets have often to be placed below the floor line, and they are difficult of access.

Jennings' Valve Closet and Trap.—Jennings' w.c.'s have also been much used. They were a great advance on the pan closet, but have too many valves. Sewer-gas is also admitted when the valve is opened. They should be replaced by the simpler and more efficient apparatus to be mentioned later on. The following diagrams explain sufficiently the different descriptions which are to be met with, as well as their method of working.

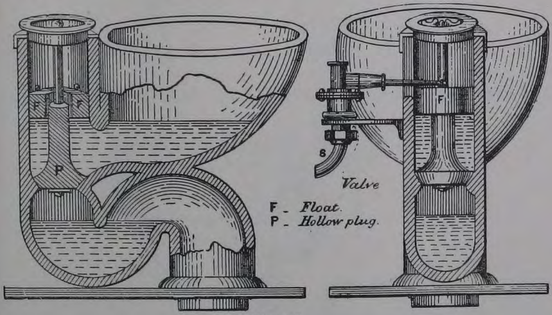


Fig. 72.

Underhay's Valve Closet.—Underhay's valve closet has been much used during the last five years, both Nos. 1 and 2 patterns, which only differ in finish. *Fig.* 73 explains its action.

The water is retained in the basin by means of the valve under the pan, acted on by the weighted lever. The supply of water is regulated by means of a regulator, the supply pipe being $1\frac{1}{4}$-inch diameter; a good flush is obtained.

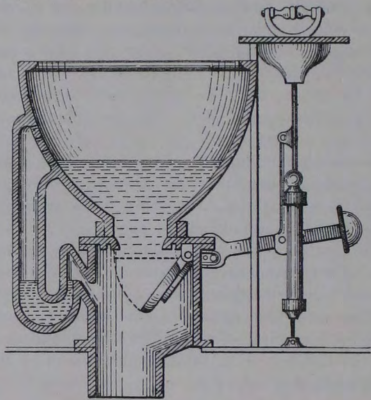


Fig. 73.

In some of the more modern patterns, special flushing cisterns are also provided.

Tyler's valve closet is shown in *Fig.* 74. It is very similar to that

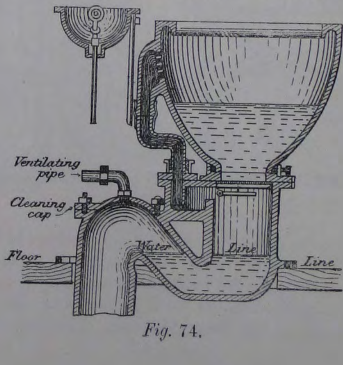


Fig. 74.

of Underhay, except that the flap is hinged, so as to cover the outlet of the overflow pipe, and thus prevent it from getting choked. The syphon trap is above the floor line, and is provided with a cleaning cap. The ventilating pipe shown in the drawing is far too small.

Valveless Closets.—The Hopper Closet.—The Hopper basin, conical shaped (*Fig.* 75), with a syphon, is in general use for servants' w.c.'s out-of-doors. It has a spiral flush, but no flushing rim. It is a very objectionable form, owing to the great length of the basin above the water level. The sides of the pan are dry, and soon get fouled. The flushing arrangements are always defective, and the small amount of water that dribbles down the sides is not sufficient to cleanse the basin properly. Closets of this nature should never be fixed, especially as, where applied for servants' use, they receive less attention than those used by the other occupants of the house.

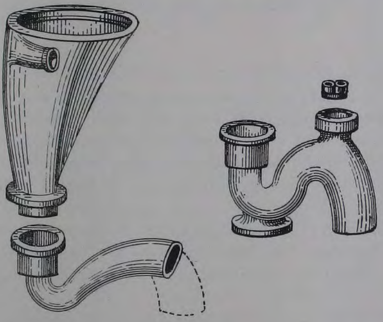


Fig. 75.

Attempts have been made to improve these closets by reducing the length of the basin and increasing the flush, but even then they are unsatisfactory.

Flush-down Closets.—These are represented in *Fig.* 76. In these closets the force of the flush is exerted directly on the water in the trap. There is no cup to break up the current, as in the flush-out type (*vide Fig.* 77), neither is there any part of the basin which is not subjected to the direct action of the flushing water.

Closets of this nature are made by many manufacturers, such as Tyler & Sons, and Doulton.

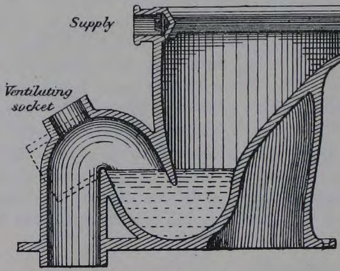


Fig. 76.

Flush-out Closets.—Flush-out closets without valves are in great demand. The basin of the flush-out closet retains a small quantity of water after each discharge, but a good flush is necessary.

These closets have a sentimental advantage over the flush-down in having the mouth of the syphon more or less out of sight, but the inside of the syphon and flushing arm get coated with a deposit, and it is then very unsanitary unless occasionally cleaned.

Doulton's.—*Fig.* 77 shows Doulton's flush-out closet, with its syphon connected. The service pipe to the basin is $1\frac{1}{2}$ inches in diameter, unless there be 10 feet of head, when a $1\frac{1}{4}$-inch pipe may be used.

Twyford's Water-closet Basin, with After-flush Chamber.—Twyford's special water-closet basins, with "after-flush chamber," seem also to be specially advantageous, *vide Plate* XVII. The after-flush chamber always secures a full quantity of water in the bottom of the basin.

Closets of this type are made in great variety.

Both the flush-down and the flush-out patterns are also made as pedestals (*Fig.* 76, and *Plate* XVII.), and again with the basin separate from the trap portion, similar to the closet represented in *Fig.* 77. The latter is made in this way so as to be capable of being adapted to any position of the soil-pipe. The junction between the basin and trap being above the water level in the latter, there is no danger from any defect in this joint.

Connection with Soil-pipe.—The connection between the closet and the soil-pipe is a matter that requires the greatest care and attention, in consequence of its being situated on the drain side of the trap ; any defect in it admits sewer-gas into the house. Foul water may also exude at this joint if it is defective, and produce contamination of the walls and ceilings at and below the floor line. *Plate* XVII*a.*, *Figs.* 1 and 4, show the ordinary method of making this joint, though it is not entirely satisfactory, owing to the unequal expansion and contraction of the various materials employed, and possible want of skill on the part of the plumber.

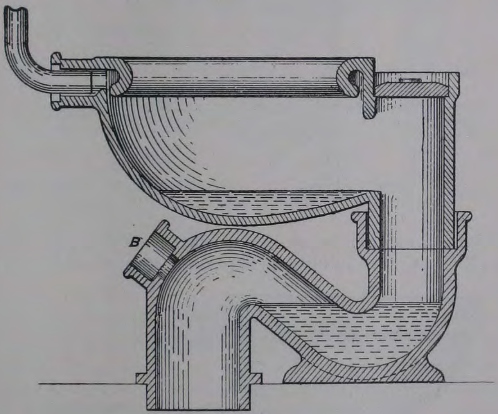


Fig. 77.

It is, therefore, better to make the trap of the same material as the soil-pipe, viz., stout cast-iron, or lead (*vide Figs.* 78 and 79). This enables the joint to be lead caulked in the case of iron pipes, or a wiped joint to be made if the connection is with a lead soil-pipe. The crown pan, if fitted to a special syphon of sufficient length to effect the junction with the soil-pipe outside the building, as shown in *Figs.* 2 and 3, *Plate* XVII*a.*, would have the great advantage of avoiding this joint inside the house on the drain side of the seal in the trap. It will be observed that this necessitates an extra bend at A, reducing the velocity of discharge at this point, but, on the other hand, a thoroughly good joint can be made, which

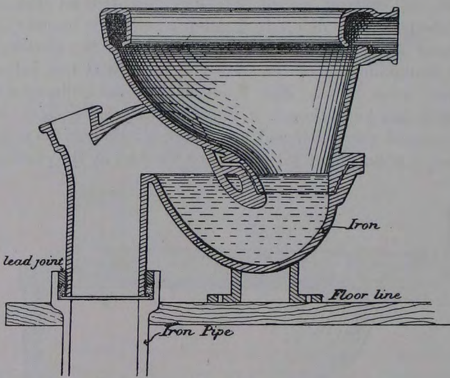


Fig. 78.

is a difficult operation, when situated in the wall as at C (*Fig.* 1, *Plate* XVII*a*.). To still further improve the connection between the

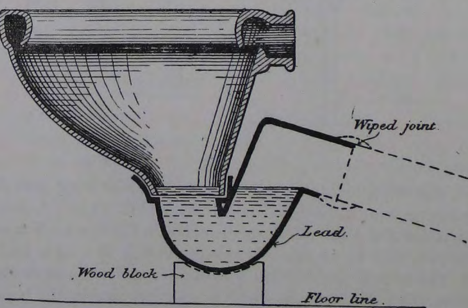


Fig. 79.

basin and soil-pipe it would be better, in the case of the flush-out closet, to adopt the method shown in *Fig.* 80. The water in the trap would certainly be liable to freeze in frosty weather, but as the trap would be made of iron, and be very accessible, it would not be liable to fracture, and it could easily be thawed by pouring hot water into it, as has often to be done at present with traps as ordinarily situated.

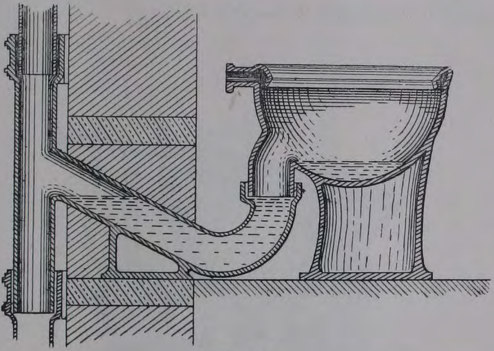


Fig. 80.

Ventilating openings are provided in many patterns of w.c. apparatus, as shown at B (*Fig.* 77). They are intended to provide against syphon action being set up in the w.c. trap when closets at a higher level are discharged into the same soil-pipe, by admitting air to the highest part of the branch from the soil-pipe.

The extra joint thus required within the house is most objectionable, and it is better to meet the difficulty by increasing the size of soil pipe in proportion to the number of closets discharging into it, as already mentioned.

It is desirable to diminish the accumulation of sewer-gas in the branch between the trap and the soil-pipe by reducing its length and gradient as far as possible consistent with an efficient discharge.

A disinfecting apparatus (*Fig.* 81) to be used in connection with w.c.'s has been introduced by the London Patent Automatic Disinfector Company.

The apparatus is applicable to any kind of closet or urinal. It is fixed out of sight, and contains sufficient disinfectant for 10,000 gallons of water, which is supposed, under ordinary circumstances, to last for one year without re-charging. Carbolic acid, or any disinfectant which might be desired, can be used, and a small quantity is discharged each time the closet handle is raised.

It is doubtful, however, whether it can be regarded as a desirable appendage to a closet. It is an addition to the apparatus, and requires to be replenished at intervals.

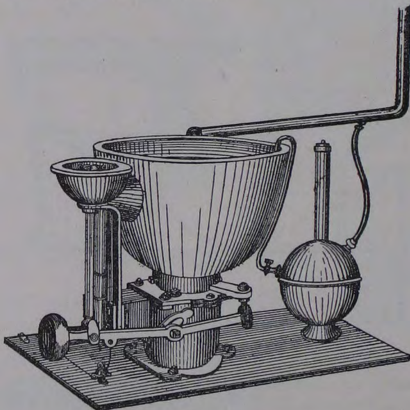


Fig. 81.

Its use recognizes an improper condition of apparatus without effecting a remedy, as it merely acts as a palliative. The more satisfactory way of preventing the atmosphere of a w.c. from becoming offensive is to adopt a good and simple apparatus, and take care that it is kept perfectly clean, not only in the basin and trap, but outside and beneath the basin, and on the seat.

With the best kind of apparatus constant personal attention is necessary in order to secure perfect cleanliness, and even if the closet be properly used, the basin will still need cleansing beyond what it receives from the regular flush of water. In fact, wherever there is a w.c., it should be somebody's special duty to periodically rinse out the basin thoroughly with a brush kept for the purpose.

The brush should be worked into the trap as far as possible, and likewise all round the upper part of the basin, the water being allowed to run while the brush is being used.

Fig. 82 is a description of brush suitable for this purpose.

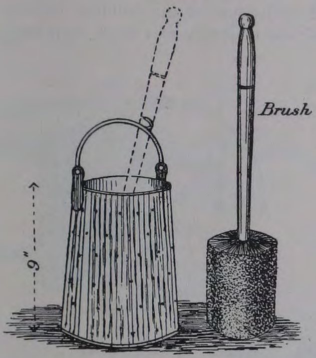


Fig. 82.

If the basin be very much furred, a little dilute acid will expedite the cleansing.

Water Supply to Closets, Slop Sinks.—This should be obtained from cisterns specially provided for the purpose, and not direct from the water main, nor yet from the cisterns in which the water for other domestic uses, *e.g.*, cooking and drinking, is stored.

The best material for such cisterns is galvanized wrought-iron of 14 S.W.G. in thickness, rivetted at the angles, etc., though slate, and wood, lead lined, may be used.

To govern the supply to these cisterns, a high pressure ball-cock, with horizontal action (*Fig.* 83), should be fixed.

A standing waste is necessary, and it should discharge into the open air, where it can be easily seen.

They should be properly covered in at the top, similarly to those for drinking water, in order to prevent dirt, etc., falling in, and eventually interfering with the *water waste prevention valves*, which should be fixed at some point on the supply system.

Further, a lead safe, with waste pipe, delivering into the open air, should be placed beneath the cistern to prevent injury to internal house fitments through leakage or overflow of water in the cistern.

The position of such cisterns will mainly depend upon the nature of the water-closets they are required to flush, but, as a general rule, should be fixed in the roof of the building, between the ceiling of the highest floor and underside of rafters, with ready access.

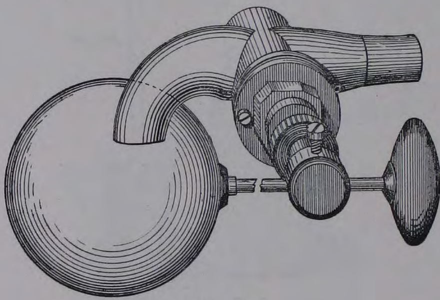


Fig. 83.

At one time the water supply to a w.c. basin was obtained by placing a simple plug over the outlet pipe in a cistern, which was raised by means of a crank, and wire passing down to the handle in the chamber where the w.c. was fixed. The seating for this plug was very liable to get out of order, and the wire to stretch and break, and was a constant source of trouble.

A tap in its simplest form, as shown in *Fig.* 84, was introduced to get over this difficulty, and prevent waste of water.

The sudden closing of the tap, however, produced a shock to the supply pipe—which was generally of lead—sometimes causing it to burst.

Both of these systems are found to be very wasteful of water, for as long as the plug in the cistern is kept raised, or the cock turned on, the water would flow, and possibly empty the cistern.

Where such flushing arrangements are found, the w.c. pan and trap are also generally defective, and if the main water supply to the house be "intermittent," then the w.c. supply pipe is liable to conduct sewer-gas from the basin to the cistern, and thus permeate the building.

A great advance on the preceding systems was the introduction of valves under the seat, as shown in *Fig.* 72.

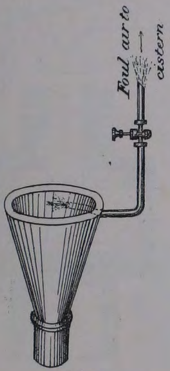


Fig. 84.

Some of the earlier patterns of these valves are those shown in *Figs.* 85 and 86. They are often found in water-closet apparatus and are known as stool valves, and also as cottage valves.

They are divided into two classes, viz. :—

1. Those with stuffing boxes.
2. Those with flexible diaphragms.

Fig. 85 shows a detail of that with the stuffing box arrangement, which may be defined as the stool valve proper.

Fig. 86 is an illustration of a valve with a flexible diaphragm, which in the trade is called the cottage valve.

Neither of these valves have proved satisfactory in obtaining a good flush for the basin and trap, owing to the obstruction they offer to the flow of water, so that their capacity for flushing is not developed unless they are opened to the full extent, and, owing to the suspended weight, the valve is often shut down too quickly to admit of water being left in the basin.

Figs. 87 and 88 show external views of these valves, with handles, levers, and weights attached.

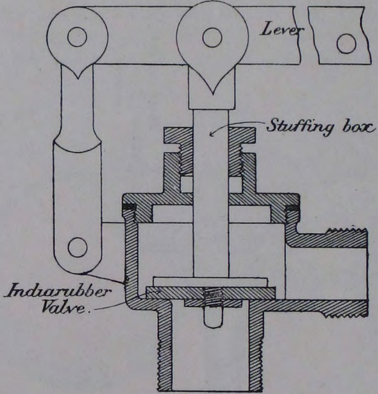


Fig. 85.

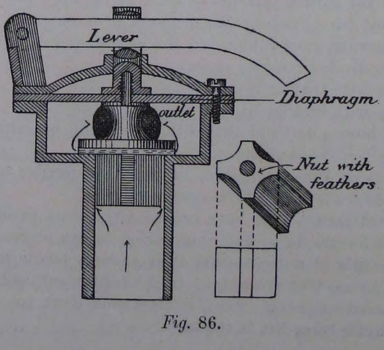


Fig. 86.

A "Bellows Regulator" has been introduced, together with many others of a similar nature, to govern the water discharge in w.c.'s.

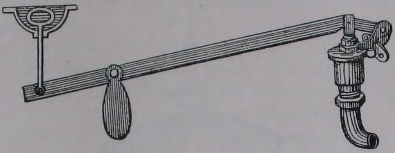


Fig. 87.

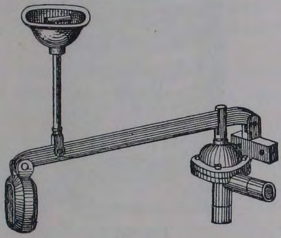


Fig. 88.

Fig. 89 gives an external view of the bellows regulator in position.

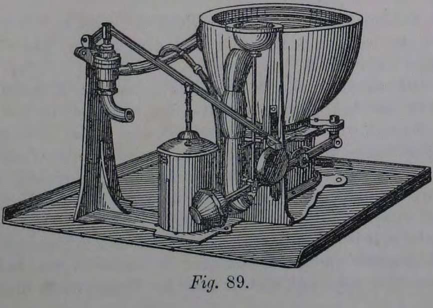


Fig. 89.

Fig. 90 shows the interior construction.

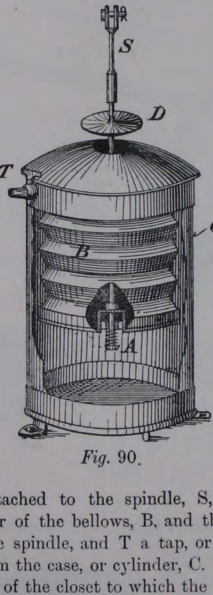


Fig. 90.

A is a valve attached to the spindle, S, and communicating between the interior of the bellows, B, and the casing, C. D is a disc, or stop, on the spindle, and T a tap, or cock, to regulate the discharge of air from the case, or cylinder, C.

When the handle of the closet to which the spindle, S, is attached is raised, the bellows, B, is compressed, air escaping into the case, C, through the valve, A.

When the closet handle is released the bellows, B, descends till stopped by the disc, D, the descent being regulated by the tap, or cock, T, through which the air in the case, or cylinder, C, is expelled.

In large houses, where several closets exist one above another, it may not be advisable to have a separate cistern for each, though, under any circumstances, the quantity of water consumed should be regulated so as not to waste the supply.

In practice, it is found that a flush of from two to three gallons of water, if properly applied, is sufficient to cleanse a w.c. basin and scour out the trap, and that it acts far better when discharged suddenly, and with a good head, than double the quantity would if allowed to run quietly through the closet.

Waste Preventers and Regulators have been designed with the foregoing objects in view, and the different kinds of apparatus will be briefly described.

Care must always be taken in adopting any of these appliances to select those only which are constructed on sound principles, otherwise their employment may be attended with inconvenience.

Waste preventers may be divided into three classes :—

(1). Those that are fixed in a general cistern, and which discharge a fixed quantity of water into each closet which such cistern is intended to serve.

(2). Those which set free the contents of a small cistern, say two gallons, or of a compartment in a larger one holding a fixed quantity, and

(3). Those that effect the same purpose less directly, by means of a regulator placed under the seat of the closet, allowing only a fixed quantity to pass through it.

All these contrivances, when used for valve closets, should have a means of securing the trapping of the basin by admitting sufficient water for that purpose after the valve has resumed its closed position.

(1). *Waste Preventing Valves fixed in Cisterns.*—These valves are an improvement on the ordinary cistern plug arrangement previously mentioned, as they actually prevent a waste of water, due to the handle in the closet being kept raised too long, and ensure the use of a certain quantity of water, *and no more*, each time the closet handle is raised.

Such valves are always liable to derangement, and they therefore should never be put in places where it is not easy to get at them to rectify any defect.

Fig. 91 is Messrs. Tylor's "Waste not" cistern valve. It regulates the supply automatically, preventing an excess of water over that intended to pass to the closet, independently of whatever position the closet handle may be left in after opening it.

In this regulator the plunger, or follower, C, is fitted with a washer valve at bottom, and moves loosely up and down in a fixed cylinder, or case, F. E is a metal actuating carrier. When the ball lever of closet apparatus, which is attached to the spindle, A, is pulled up, it raises the metal actuating carrier, E, which takes up with it by capillary attraction, adhesion, or suction, the plunger, or follower, C, and opens the passage of water through valve.

When the spindle, A, is dropped, the metal actuating carrier, E, descends immediately, and assists in forcing the plunger, or follower,

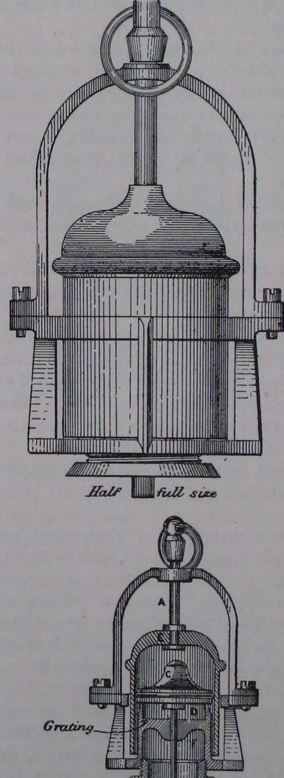


Fig. 91.

C, on to the seating, D, and the passage of water is closed. When the ball lever attached to spindle, A, is held, or propped, up, the plunger, or follower, C, after being held up a short time by capillary attraction, adhesion, or suction, descends on to the seating, D, and closes of itself with the stream, having allowed the intended quantity of water to pass (usually regulated to two gallons).

The adhesion, or capillary attraction, ceases, and the plunger, or follower, C, begins to fall when the pressure within and without the metal actuating socket, E, is equilibrated or made equal.

Fig. 92 gives an illustration of this valve fixed in a cistern.

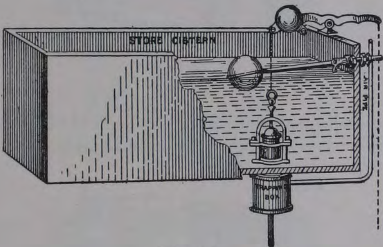


Fig. 92.

There are several other forms of valves of this nature, made by Messrs. Lambert, Messrs. Wallace & Connell, etc.

(2). *Separate Waste Preventing Cisterns fixed in each Water-closet.*—This method appears to be the most efficacious in accomplishing the object in view, but care must be taken in fixing the cisterns to place them in an accessible position directly over the basin, but not too close to it.

The size of the delivery pipe varies with the description of cistern employed.

This class of apparatus is divided into two divisions, viz. :—

(*a*). Those with valves.

(*b*). Those with syphons.

(*a*). *Valves.*—*Fig.* 93 represents a single valve, and *Fig.* 94 a double valve. The latter is more efficient in preventing any possibility of leakage, due to a defect in the valve. The feed-pipe to these cisterns, being very small, it takes a comparatively long time for them to re-fill. To obviate this inconvenience, another pattern (*Fig.* 95) is made, in which the cistern, supplied by the ball-cock, and containing from five to eight flushes, is divided into two compartments. The

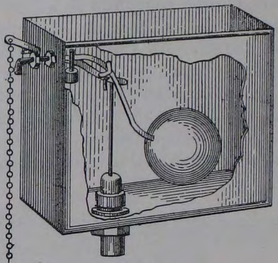


Fig. 93.

upper one contains the ball-cock, and the bulk of the water, and the lower one as much as is required for one flush only.

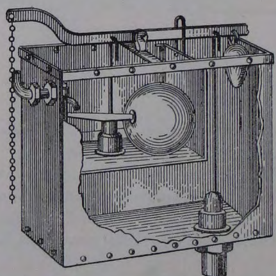


Fig. 94.

The valves in the lower sides of each of these compartments are so arranged on the lever that when at rest the top of one is open (*Fig.* 95), and there is a free communication between them; but as soon as the handle is pulled in the closet, this communication is closed, and afterwards the lower one opened, to allow the flush-box to discharge itself into the closet basin, no more water than one flush being allowed to pass until the handle is again released.

Another description of cistern, but suited to valve and flush-out

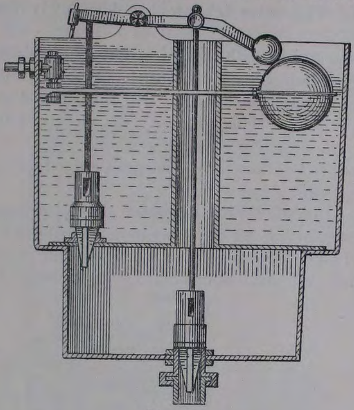


Fig. 95.

closets, where a certain quantity is required as an after-flow to the basin, is that known as the "After-flush" (*Fig.* 96).

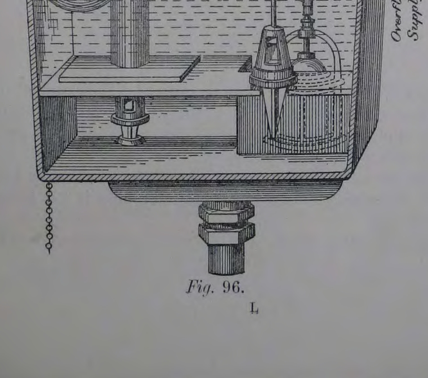


Fig. 96.

This is effected by a small compartment, in which sufficient water is contained. This water is allowed to flow slowly down through a small orifice.

It should be noticed with these descriptions of valves that in order to empty the cistern, the handle must be restrained till the whole of the contents has been discharged, and thus, if too much hurried, the desired flush, which is necessary for sanitary purposes, is not obtained.

(*b*). *Syphons.*—To effect the discharge of a fixed quantity of water, syphons are used.

Doulton's.—Doulton's vacuum water waste preventer, which is specially designed for use with his closet, is shown in *Fig.* 97. It requires a $1\frac{1}{2}$-inch discharge pipe when the fall is under 10 feet, and $1\frac{1}{4}$-inch if over that amount, but is very noisy in its action.

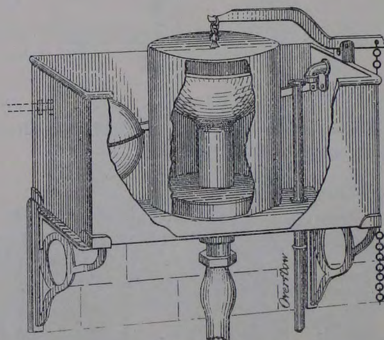


Fig. 97.

Winn's Patent "Acme" Syphon Cistern.—The manner in which this water waste preventer acts is that the inverted cup being raised fills the syphon. To ensure its return to its original position, the lever arm is weighted (*Fig.* 98).

T. Crapper & Co. (*Fig.* 99).—The syphon action in this case is started by raising a valve, and the inlet pipe is led to bottom to prevent noise.

Twyford's National.—In *Fig.* 100 the syphon is shown raised off its seating ; a rush of water is immediately established through the hole at the foot; when the handle is raised the syphon action proper is started. The seating is made of vulcanized indiarubber. The bent tube dipping under the water from the supply pipe is intended to prevent noise when the water is being replenished.

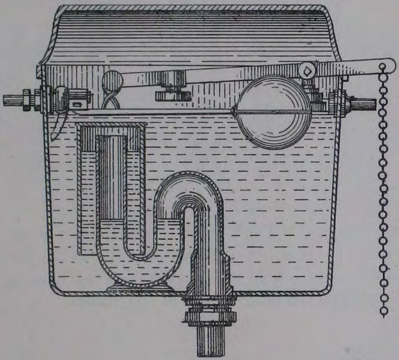


Fig. 98.

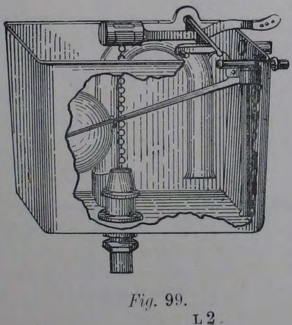


Fig. 99.

There is a chance of the valves shown in *Figs.* 99 and 100 leaking, as previously mentioned.

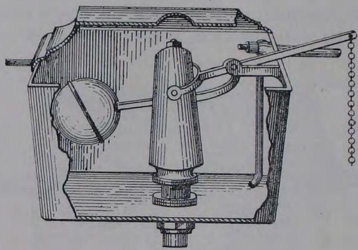


Fig. 100.

The "Westminster."—The "Westminster" water waste preventer (*Fig.* 101) can be obtained from Messrs. T. & W. Farmiloe, and seems simple in its action, which is started by moving the "displacer" D, without the intervention of any valves.

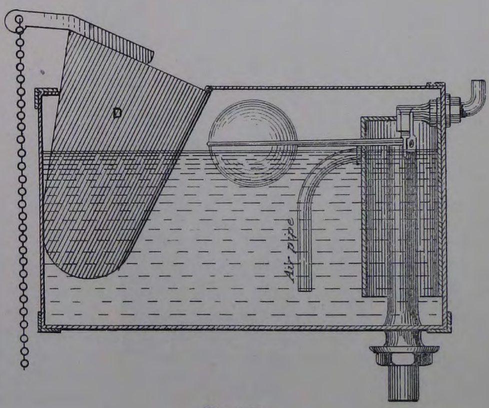


Fig. 101.

Shank's.—Shank's patent "reliable improved" valveless syphon waste-preventing cistern (*Fig.* 102) is made in two varieties. The makers claim that the working parts are few and simple.

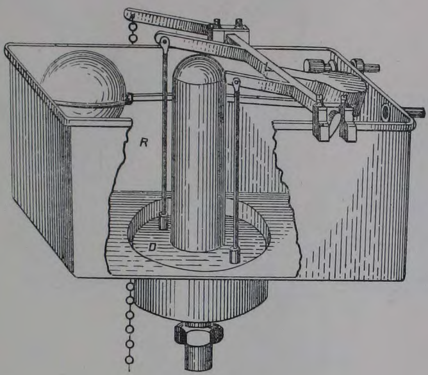


Fig. 102.

It is made with a well, or dip, in which an annular disc, D, works, and through the centre of this disc stands the syphon pipe. This disc is depressed by the lever rods, R, and immediately starts the syphon, emptying the cistern. It acts noiselessly.

Fig. 103 is a section to explain the action.

Fig. 104 is the second pattern, known as "No. 16A Reliable Improved." A section of it is given in *Fig.* 105.

The action in this case is different from No. 16. The disc, or plate, D, is made heavy, and, at rest, lies at bottom of cistern. When the handle is pulled this plate is raised, and upon the handle being let go, the plate falls by its own weight and starts the syphon. It is cheaper in construction than No. 16, but equally durable and satisfactory in action.

(3). *Waste Preventing Regulators Fixed Under Seats.*—The advantages claimed for this class are that they occupy less space in the closet, and a number of closets can be supplied by the same service pipe from the cistern above. The disadvantages are that less force is obtained in flushing out the basin, which is an important defect, and the apparatus is not so durable, owing to the number of working parts.

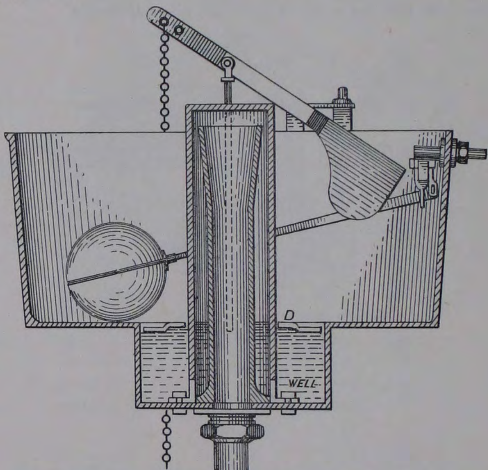


Fig. 103.

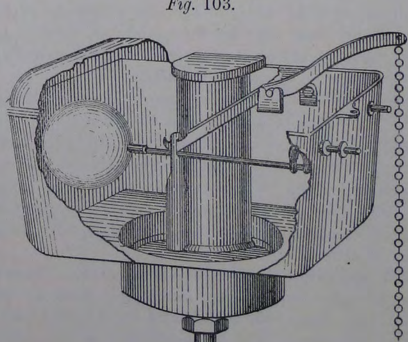


Fig. 104.

Fig. 106 represents Tylor's waste preventer, which consists of a plunger, C, fitted with washer valve, H, at the bottom, and moving

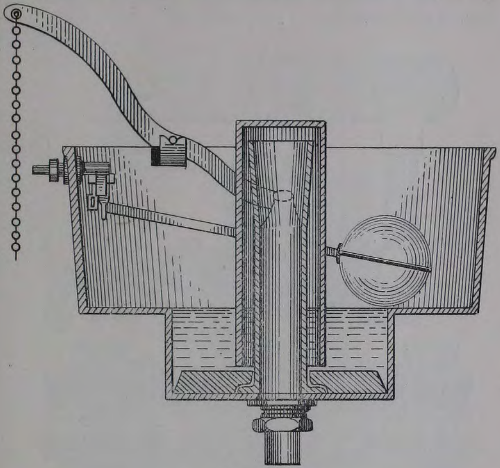


Fig. 105.

up and down in a metal, or elastic socket, E, which forms a carrier, and is fixed to a spindle connected to the lifting lever, F. This valve is made, when preferred, with a flat elastic washer or diaphragm, instead of the metal socket, E. K is a ring valve for the purpose of controlling the descent of the metal or elastic socket, E. On the right is a passage-way by which the water flows from under to above the ring valve, K, and is partially opened or shut by turning the tap, A. When the handle of the closet is pulled up, the lever, F, raises the metal or elastic socket, E, which lifts by suction the ring valve, K, and the plunger, C, and thus opens the passage for water through D. When the handle is dropped the lever, F, commences to fall, the speed of its descent being regulated by the quantity of water which is allowed to pass through the passage-way, L. If the closet lever, F, is held up, the metal or elastic socket, E, and ring valve, K, will be kept up too, but the plunger, C, will be taken down on its seat, D, partly by its gravity, but principally by the pressure of the water. The adhesion, or attraction, should cease, and the plunger, C, begins to fall, when their pressure is made equal inside and outside the socket.

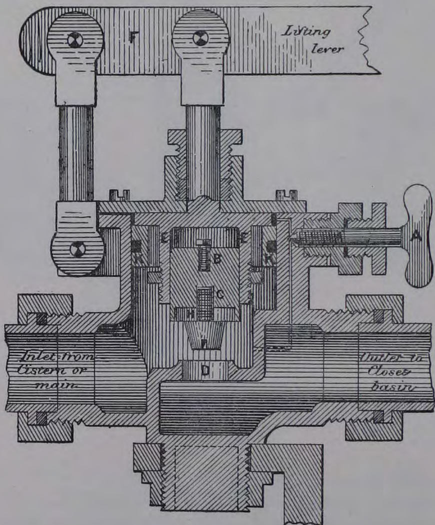


Fig. 106.

Underhay's.—Underhay's water waste preventer (*Fig.* 107) is of a somewhat different class to the flushing apparatus made by Doulton, Jennings, etc. It is fitted to the ordinary supply pipe of the closet, and consists of one cylinder within another. When the plug is pulled the water is turned on by the ordinary valve, enters the "preventer" at A, and commences to flow out into the closet basin at B. But a certain quantity also rushes through C into the cylinder D, raising the float or hollow cylinder E, and lever F. The valve G is thus closed (by the cam-shaped end of lever F), and the water is in a few seconds automatically shut off. Then the water which has entered

D also flows off through H, E and F fall, G is re-opened, and the apparatus is ready for another discharge. The effect is practically to prevent more than a certain necessary quantity of water to be used at each flush. The apparatus is usually placed beneath the seat of the closet.

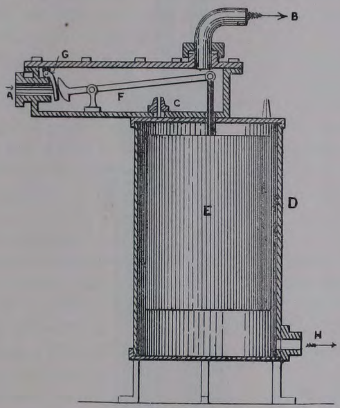


Fig. 107.

In connection with these closets, *Oil Brass Closet Regulators* (*Fig.* 108) are used.

Such regulators consist of a piston, P, in the shape of a hollow cylinder working within a cylindrical case, C. There is a leather cup, L, at the lower extremity of the piston cylinder, which dips, when at rest, into some lubricating fluid at the bottom of the casing.

When the handle is raised air enters through the annular space, S, at the top of the outer casing, and passes by the cup leather, L.

When the reverse movement takes place, the air inside the cylinders is retained by the cup leather, and can only escape by the tap, T, at the top, so that the descent can be regulated by tightening or releasing the tap, thus partly closing or opening the air passage, A.

The efficiency of these regulators depends thus very much on the cup leather and lubricant; the latter is liable to get clogged, and then the regulator ceases to act properly.

Urinals.—When designing urinals, care should be taken to make them as light and open to the air as possible, as the frequent use of such places by many persons will soon make them offensive, unless they are properly constructed and ventilated.

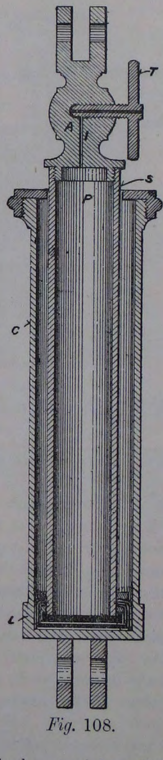


Fig. 108.

If they are to be used also at night, efficient gas lighting should be provided.

As regards the fitments, the areas of the parts liable to be fouled should be restricted to the utmost, and at the same time ample provision is necessary for thoroughly flushing all such parts of the apparatus, as well as facilities for cleansing the surroundings.

Urinal stalls are made with backs and divisions going down to the floor line, and with aprons either of slate, enamelled slate, or painted cast-iron, *vide Plate* XVIII.

The lower part of the apron and sides of the divisions get fouled without a chance of the urine being washed off them, as the perforated supply pipe only sends little channels of water down the backs, and the aprons and divisions are seldom touched, except by the attendant, perhaps once a day. In some instances, to obviate this, the divisions are discontinued at a height of about 18 inches above the floor line (see *Plate* XVIII.), and the aprons also are omitted; this has the additional advantage of facilitating the cleansing of the urinal.

Water is kept constantly flowing over the backs of the stalls, either by a perforated pipe, or spreader. The floor has a fall toward the slate back of half-an-inch to the foot, and a gutter is formed along the whole length of the stalls at the foot of the wall. The liquid discharges along this channel through a brass or gun-metal grating into a syphon trap.

The perforated pipe, also called a sparge pipe, should be of brass, copper, or zinc to prevent corrosion.

A great improvement on this plan is to replace the gutter by a trough at the same level, which should be kept constantly full of water and occasionally flushed.

Urine, after a short exposure, exhales a most fœtid and unpleasant odour, from the decomposition of its nitrogenous matter. It is also of such a nature that in order to prevent its furring over the surfaces with which it is brought into contact, it should be well diluted with water as soon as possible before passing into the waste or drain-pipes.

Carbolic acid, chloride of lime, sanitas, or other disinfectants should also be used, especially in warm weather.

A very good composition with which to treat urinals is a mixture of common coal tar and naphtha. It gives a clean and polished appearance to the place, and is at the same time a good deodorant; the dark colour is the only objection to its use.

Arrangements should be made to thoroughly wash urinals out once or twice a day, so as to keep every part scrupulously clean.

From what has been said it would appear that urinals constructed with basins or troughs to contain water, and through which a constant flow is maintained, are preferable to the flush-down systems.

The usual allowance of water for each stall in a public urinal is half-a-gallon per minute ; the quantity of water to be thus dealt with is small.

The diameter of the waste pipes from urinals should, therefore, not be greater than can be well flushed with the ordinary discharge, that is: for stalls, $1\frac{1}{2}$ to 2 inches, and for ranges, 3 or 4 inches, depending on the extent of the accommodation.

Urinals erected in streets are either circular or rectangular in plan, and are preferably made of iron.

A common type of urinal, as used in barracks, and made by Messrs. Jennings, is shown in *Plate* XVIII*a*. It is flushed by means of a sparge pipe, and regulated by a stop cock. The water is kept constantly flowing.

Doulton's Flush-down.—*Plate* XIX. is based on this principle, and is used in many towns. It is given to show a type of public urinal which has much to commend it, and is known as the Lambeth "flush-down" urinal. It is fitted with Doulton's patent automatic flush tank, on Rogers Field's principle.

This urinal appears to be particularly adapted for public use, as it requires but little attention. The trough, capping, and gutter are made of strong, salt-glazed stoneware, so that a perfectly smooth and impervious material is obtained, and thus the common defects in existing urinals of coating and corrosion, which are the chief causes of the offensive smell, are entirely obviated.

At the outlet a weir is formed for the purpose of retaining sufficient water to dilute the urine, and at stated periods (regulated according to the probable number using the urinal) the whole is swept out by the discharge of the automatic flush tank.

The stoneware gutter is formed with a fall to the front, and may be kept clean by means of a branch from the pipe from automatic tank. The backs and apron pieces are made of slate (plain or enamelled), and the latter are sloped inwards to allow room for the feet, and to permit of any drip falling direct into the gutter. The divisions are also of slate, and are raised 18 inches above the floor level, giving free passage for the atmosphere and great facilities for cleansing. Copper flushing pipes, as shown, can be fixed if desired. Prices—

In plain slate (without weeping pipes), per person ...	£5	0	0
In enamelled slate ditto (any colour), per person	7	7	0

Twyford's flush-out trough urinal (*Plate* XIX*a.*) is much on the same principle as that of Messrs. Doulton's, but omitting the sparge pipe.

Automatic flushing is also effected in urinals by Field's flushing tank. The great advantage of such an accessory is that it obviates to a great extent the necessity for an attendant. On the other hand, they are liable to get out of order, unless properly covered and protected.

Interior Urinals.—Urinals inside buildings are very objectionable from a sanitary point of view, as it is difficult to prevent their becoming offensive and giving a great deal of trouble. A great variety of urinal basins, made of white, glazed earthenware, are used inside buildings. They are made by Messrs. Beck & Co., Messrs. Doulton & Co., Mr. G. Jennings, and others.

It is advisable to use small urinal basins so constructed that the whole of the interior may be washed over with water every time they are used. The front edge should be as narrow as possible, and bevelled so that droppings, instead of lodging on it, may drain readily into the basin.

Conflicting opinions exist as to the form the front of a urinal basin should take, hence the variety of shapes.

In the *Jennings'* pattern the front is generally lipped, as shown in *Fig.* 109.

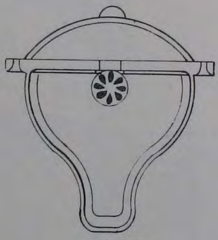


Fig. 109.

Hellyer's.—In the Hellyer pattern it is "wide fronted" (*Fig.* 110). Each is designed to prevent any droppings which may fall on the outside of the basin from running down on its outer side. The front of the basins are undercut, or throated, to cause them to drop on to the floor, which should, of course, be constructed of tiles, or other impervious substance.

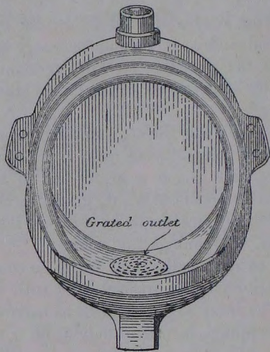


Fig. 110.

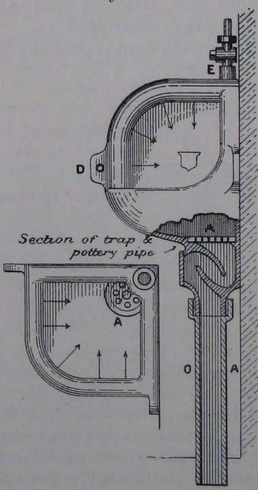


Fig. 111.

The "Holborn" Trapped Urinal.—The "Holborn" trapped urinal (*Fig*. 111) combines a urinal and trap in one piece of white, glazed earthenware.

In order to render the trap easily accessible, the grating, A, is made to lock down by means of a key, which also unlocks the inspection door in front of the trap.

This urinal is secured by screws through lugs in the wall. The water enters by the boss, E, at the top, and flushes the entire surface of the pan, as shown by the arrows in illustration.

Tylor's Patent Urinal Basin (*Fig*. 113).—The part through which the discharge takes place is at a higher level than the bottom of the basin, thus retaining sufficient water in the basin to cover the bottom—about two inches in depth. When water is discharged into the urinal the syphon comes into operation and completely empties the basin, and the contents of the sealing chamber covers and seals the outlet orifice, and prevents the escape of foul air or gases through the same.

It is best, however, in all urinals, to discharge through a proper grating and trap at the floor level, so that the urinal waste may be entirely disconnected from the drain, and at the same time easily

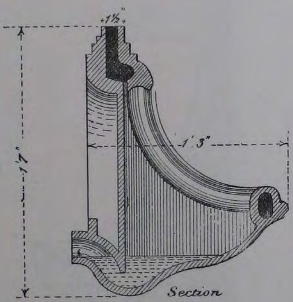


Fig. 112.

accessible for examination and cleansing. This rather points to the use of a straight delivery, as shown in *Figs*. 110 and 113, with a constant flow ; but as the quantity of water allowed by most water com-

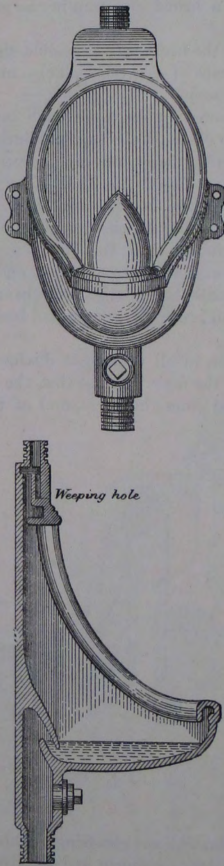


Fig. 113.

panies is very small, it is better economized by flushing automatically at intervals, and then the basin should hold a small amount of water, as shown in *Figs.* 112 and 113. *Plate* XIX*b*. shows a range of Twyford's urinals suitable for a large establishment, with various forms of channel blocks.

There is a great variety of automatic flushing apparatus in the market, such as :—

Jennings' Automatic Urinal Flushing Tank.—By the arrangement illustrated (*Figs.* 114 and 115), consisting of a ball valve and syphon,

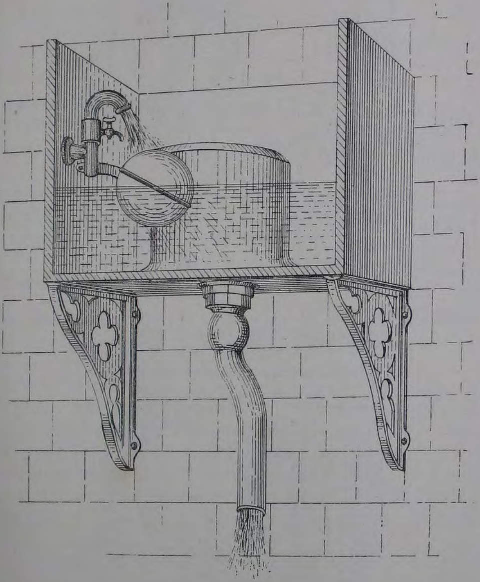


Fig. 114.

the contents of the cistern, when full, are discharged with considerable force and velocity, thoroughly flushing any fittings or the line of drain with which it may be connected. The action of the ball valve is the reverse of that which obtains within the ordinary ball-cock, so that the flow is greatest when the ball is at its highest level.

The small-bib cock in the above figure admits of a bye pass for the water when the ball-cock has fallen, and thus gradually restores its action.

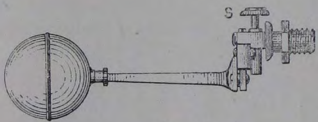


Fig. 115.

The time occupied in filling the tank is effectively controlled by the regulating key, S, on the improved inlet supply valve (*Fig.* 115), and the periodic discharge of the contents can thereby be determined at will.

The cistern in which the syphon is placed is supplied by means of a ball valve, made to open as the water rises in the cistern, the reverse way of the usual action. Thus the water is brought into the cistern with sufficient force to start the syphon.

Crapper's Automatic Cistern is illustrated in *Fig.* 116. It is based on Rogers Field's principle.

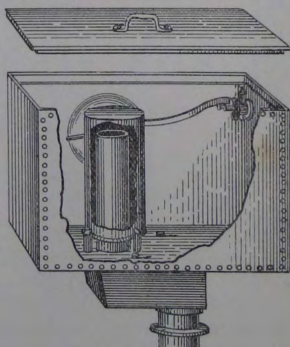


Fig. 116

Twyford's Automatic Syphon Cistern (*Fig.* 117) is very similar to the last, but the supply pipe is carried to the bottom. It is used in connection with his trough, urinals, etc.

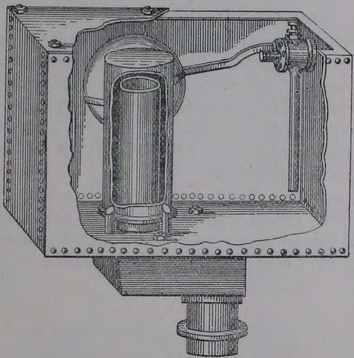


Fig. 117.

Slop Sinks.—Slop sinks have been constructed to prevent as much as possible the carriage of foul water about a house, and to thus economize labour.

For this purpose they are generally placed on an upper, or bedroom floor, but should be fixed in a chamber cut off from the bedrooms by means of a corridor or passage in the same way as recommended for water-closets.

It is most essential that every portion of a slop sink within a house should admit of easy access and inspection, and also that the flushing should be good, otherwise these so-called conveniences become a nuisance of the worst type.

The conditions of a good slop sink should be chiefly those for a good *flush-down* water-closet, including outside soil-pipes, ventilation and trapping; the shape should be such as to prevent splashing. There should neither be valves nor other working parts, but simply a basin with self-cleansing trap above the floor line. A moveable screener or grating, of some non-absorbent material, should be fixed in the basin to arrest the passage of flannels, brushes, etc., that might be accidentally thrown in with the slops.

It is best to have the slop sink trap of cast-iron or lead, in order that a perfect joint may be made with the soil-pipe.

Therefore, in ordinary houses, it is better not to provide slop sinks, but to use the water-closets for this purpose.

In recommending this arrangement, however, great care should be observed in the description of the w.c. apparatus used. A valve closet is not suited to this purpose, as when slops are thrown into it the level of the liquid in the basin is raised, and the water passes off by the overflow before the handle is lifted to empty the contents, resulting in the overflow trap being filled with foul liquid, which gives off very offensive odours.

Fig. 118 is a slop sink known as the "water shoot." It is Messrs. Dent & Hellyer's design, and is made of cast-iron, enamelled on the inside, and fitted with a strong, white, glazed stoneware screener. The configuration is such that there is no place of lodgment in any part.

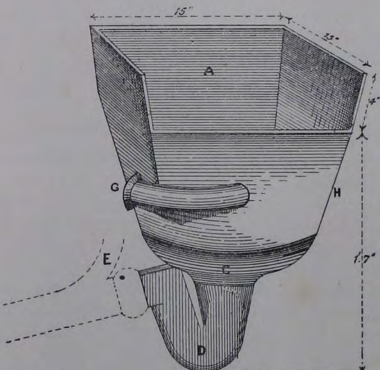


Fig. 118.

The next figure, 119, represents an angular slop sink by Messrs. Doulton & Co. It consists of a glazed stoneware top with slate skirtings. The basin and syphon are of iron, and it is provided with a flushing valve by which the basin is cleansed after use.

A slop sink, by Messrs. Tylor & Sons, is shown in *Fig.* 120. It is

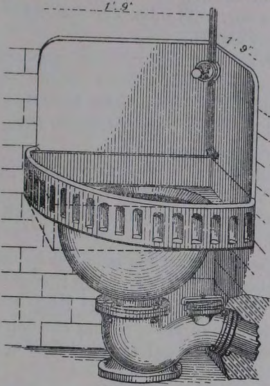


Fig. 119.

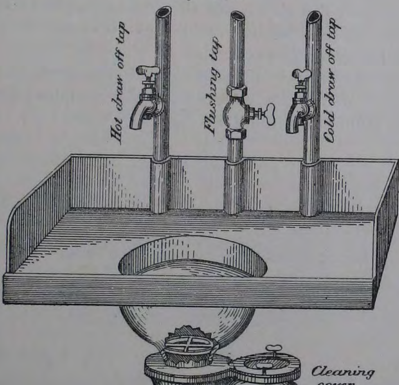


Fig 120.

made the same as the last, both as regards material and design, but has, in addition, hot and cold water draw-off taps, which of course might be fixed to any slop sink.

On *Plate* XIX*c*. is shown a description of slop sink recommended for use in connection with the dry earth system.

Such sinks should not be constructed in a house, but may with advantage be fixed in a yard, at a distance from the dwelling, to admit of atmospheric disconnection.

The flap, although shown in the plate as made of timber, would be better if of wrought iron. When timber flaps are fixed only hard-wood, such as oak or elm, should be used, and the whole surface well tarred.

It will be seen that a small tap is provided immediately alongside the sink, so as to allow of pails, etc., being rinsed.

To reduce the chance of the rinsings being thrown on the surrounding ground, instead of again raising the flap a surface channel is formed, and along it the water which falls or is thrown down runs.

The exit into the sink is protected by a small gun-metal grating.

Scullery Sinks.—The position of these sinks should be against an external wall, so as to easily provide light by means of a window, and reduce the length of waste pipe.

Scullery sinks are best made of glazed stoneware, as shown in *Figs.* 1 and 2, *Plate* XIX*c*., but where liable to injury from rough usage, they should be of iron (*vide Fig.* 121).

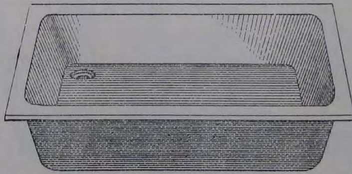


Fig. 121.

Stone should never be used, as the description employed for this purpose, known as "freestone," is very absorbent, and in time becomes foul.

A trap of the class shown in *Figs.* 62 and 63 should be fixed immediately below the sink, and trap ventilation provided, as illustrated in *Fig.* 48, so as to prevent any possibility of sewer-gas entering the house.

The waste pipe for ordinary sinks should be formed as previously recommended, of (1½ inches to 2 inches) lead delivering over a trap (*Plate* XI.) or effective water seal (*Fig.* 48).

All such sinks should have good deep skirtings fixed around their upper edges, to protect the face of the wall from splashing, and consequent absorption of foul matter.

Pantry sinks are intended for washing more delicate articles than scullery sinks.

They should be fixed in the butler's pantry or room, and are generally made of wood, lead lined, as that material is not so liable to damage glass, china, and silver, as stone, stoneware, or iron. Such sinks should not be less than 15 or 16 inches deep, in order to admit of a decanter being placed under the draw-off tap (*Plate* XIX*d.*).

The junction between the sides and bottom of lead lined sinks should have the angle filled in with a wooden fillet, triangular in section (*Plate* XIX*c.*), to prevent the accumulation of dirt and facilitate cleaning. A good fall should be given towards the outlet, which should be placed in one of the back angles or corners nearest the wall.

The lead for lining these sinks should weigh 7 or 8lbs. for the sides, and 10 or 12lbs. per foot superficial for the bottom.

The opening in the bottom of the sink should be fitted with a counter-sunk wash, with washer and plug (*Fig.* 5, *Plate* XIX*e.*).

The waste of pantry sinks should conform in all other conditions to those recommended for scullery sinks, and a trap, illustrated in *Fig.* 62, should be selected for convenience of jointing.

It will be found that a piece of indiarubber tube, a few inches long, fixed to the draw-off tap of a pantry sink, will save much chipping and breakage of glass and china.

Baths.—Fixed baths with hot and cold water laid on tend so much to economize domestic labour, and are so very convenient, that they are looked upon as a necessity in all modern houses.

Special bath rooms are also erected in connection with large public buildings, such as barracks, etc.

They are made of a great variety of materials, viz., copper, zinc, iron, slate, glazed fire-clay, or porcelain, etc.

Copper baths are the most expensive, but, at the same time, are the most durable. They are generally enamelled, and when this wears off the enamelling can be renewed. They should be supported on a wooden framework, to prevent alteration of shape.

Zinc baths are made of thin sheet-zinc, and require to be supported in the same way as copper baths, but are not so durable. They may be either painted or enamelled.

Iron baths are made either of cast or of sheet-iron. They are generally painted, or enamelled in imitation of marble, but this covering material is very liable to damage and come off. With cast-iron this is especially likely, partly owing to the metal being less elastic than other metals, and partly owing to the fact that iron is so readily oxidized when in contact with moisture. Iron baths are comparatively inexpensive, but they change colour after a time, and do not look as clean and nice as is usually desired. Cast-iron baths have the advantage, in consequence of their strength, of being able to dispense with any wooden framing for their protection.

Slate Baths are sometimes enamelled, but the enamel is liable to be chipped off. The disadvantage of the use of these baths when not enamelled is that, being of a dark colour, it is difficult to see if they are clean.

Slate baths being formed of slabs, the joints of which are made with red lead, are liable to leak, and the corners harbour dirt.

Porcelain baths are very durable, and the glaze with which they are covered is not easily damaged; they are made in one piece, and have rounded angles and corners, in which dirt cannot collect. The colour is generally white, which also gives them a clean appearance. They are very cumbersome and heavy, and have the property of absorbing heat and not readily parting with it; consequently, when warm water is used, its temperature is soon lowered. Heat being retained in this way would be an advantage if the bath was used by several people consecutively. To prevent risk of fracture from boiling water suddenly impinging on a part of it, especially in cold weather, care should be taken in filling the bath to admit some cold water first, and then gradually add hot water till the required temperature is reached.

For occasional use a copper, zinc, or block tin bath is preferable.

The floor on which baths rest should be composed of some non-absorbent material, such as tiles, concrete, etc., and if of wood, it should be protected with sheet lead, turned up a few inches all round so as to form a safe.

Wastes from Baths.—Whatever kind of bath is adopted, it is important to have means of rapidly emptying it.

All bath wastes should discharge with an open end outside the walls of the house into a self-cleansing drain trap, such as are represented in *Figs.* 55 to 57. The main waste pipe should be carried up full size above the ridge of the house for ventilation, so as to be clear of all windows, etc. (*Plate* VIc.).

As a bath contains from 30 to 50 gallons of water, it should be made a means of flushing out the house drains. The size of the waste should not be less than from $1\frac{1}{2}$ to 2 inches in diameter, so as to discharge the contents at the rate of about 30 gallons per minute.

A form of valve made by Mr. G. Jennings is shown in *Fig.* 122, in which an overflow and trap are provided.

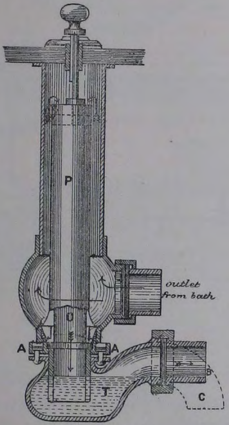


Fig. 122.

Fig. 123 is a form of flap-valve, made by Hellyer, for emptying

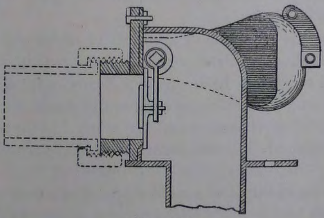


Fig. 123.

baths rapidly ; it, however, requires a separate trap and arrangement for overflow.

In some cases the orifice for the waste is also utilized for the admission of fresh water to the bath ; this is, however, an objectionable system.

The discharge of so large a body of water through such small pipes is liable to unseal the trap at the bath, consequently trap ventilation, as shown in *Fig.* 124, is very necessary.

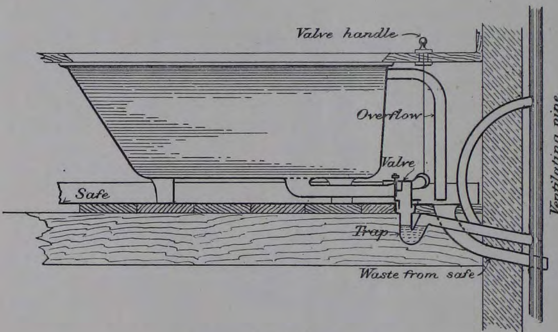


Fig. 124.

Lavatory Basins.—The best position for a lavatory basin or range is against an external wall, in order to afford easy means of providing light and convenience of drainage. Lavatory basins should not be fitted up in a bedroom. They are a great convenience on the ground floor, and when hot and cold water are laid on, they save a great deal of domestic labour.

Lavatory basins are made of a variety of materials, such as iron—either enamelled, galvanized, or tinned—porcelain, and stoneware. Porcelain and stoneware basins have a cleaner appearance, and wear better than iron. The basins are generally made in one piece, and fixed in a slab of marble or slate. In many instances the basin and slab are combined in one piece, and have recesses for soap, brushes, etc.

Fig. 125 is an example of an oblong lavatory basin, with skirting, soap and brush tray.

The water supply in this case would be by bib or push taps.

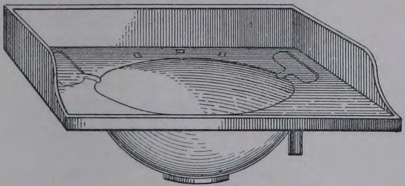


Fig. 125.

The basin in *Fig.* 126 is provided with a flushing rim, the object of which is to assist in cleansing the sides of the basin.

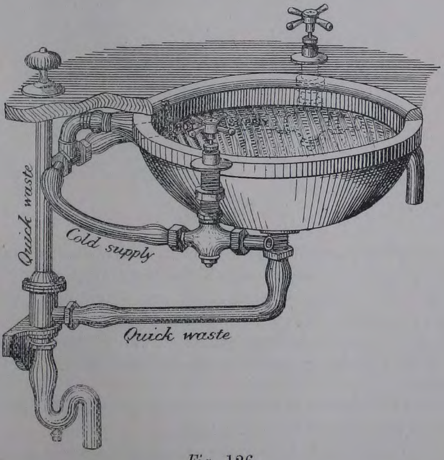


Fig. 126.

The tip-up basin has lately been introduced; this basin is hung on pivots at the sides inside a funnel-shaped receptacle, into which the water is discharged by tipping. This description of apparatus is a doubtful improvement, for the surface of the receiver becomes coated with soap, etc., and being out of sight it is frequently omitted to be cleansed, and therefore becomes offensive.

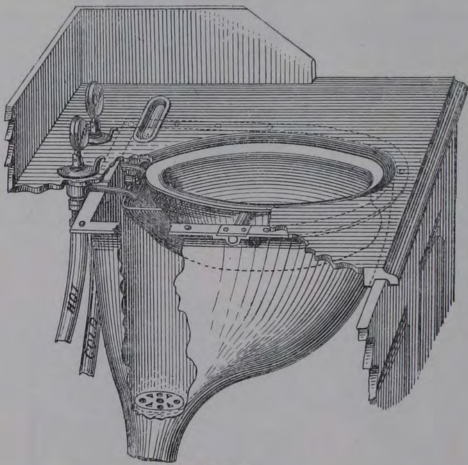


Fig. 127.

The unsightly stain often noticed on stoneware basins, caused by constant dripping of water, may be removed very readily by the application of a little powdered chalk and a few drops of dilute ammonia by means of an old tooth-brush.

The waste from a lavatory basin should be large enough to admit of rapid discharge, and it is usually from one inch to $1\frac{1}{4}$ inches in diameter.

It should be trapped in the same way as recommended for wastes from baths immediately below the basin.

The discharge should be into the open air, and into a proper self-cleansing trap outside the house.

If fixed on an upper floor, the top of the vertical waste pipe should be carried up beyond the eaves, clear of all windows, etc., for ventilation.

In ranges, *each* basin should be trapped before passing into the common waste. Provision should also be made to prevent syphonage, as in the case of a single basin, or bath (*Fig.* 124).

Wastes from baths and lavatories may be combined.

Lead Safes, or Trays.—To obviate the unsanitary condition produced in wooden floors, ceilings, etc., by splashing of slops and leakage of water, lead safes are used.

They are generally placed under baths, cisterns, w.c.'s, etc., on an upstair floor, and should be made of 5 or 6lbs. lead, turned up at the edges for a few inches, viz., six inches for baths and cisterns, and four inches for closets, etc. The angles should be formed either by piglugs, or by soldering (*Fig.* 128).

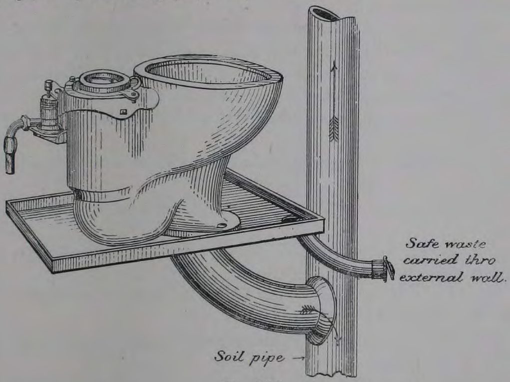


Fig. 128.

To prevent overflow from the safe, a lead pipe should be carried from it through the wall, the end being left open to the atmosphere, so as to discharge into the open air. Hinged flaps, *vide Fig.* 129, are sometimes soldered at the end of the pipe to exclude draught.

Fig. 129.

Washers, Plugs, and Wastes.—On *Plate* XIX*e*. is shown a number of washers, plugs, and wastes, suitable for cisterns, sinks, and baths.

Fig. 1 is a waste and washer that may be used for a lead-lined cistern.

Fig. 2 is suitable for an iron or slate cistern. The union is for attaching to a lead overflow pipe.

Fig. 3 is one that may be used for similar cisterns to those mentioned for *Fig.* 2. It is a patent of Mr. Geo. Jennings. The three above-mentioned should be used in connection with standing wastes.

Fig. 4 illustrates a plug and washer for a lead-lined sink.

Fig. 5 a plug and washer, with perforated bottom, that might be used for a pantry sink.

Fig. 6 a plug and washer suitable for a stoneware, iron, or slate sink, and a union for connection with a lead waste pipe.

Fig. 7 is a plug and washer that could be used for a bath, the bent union shown being supplied for connection to the lead pipe.

Fig. 8 is a grated washer and union for iron, slate, or stoneware sinks.

Fig. 9 a grated washer and union for fixing as an overflow from a bath.

Fig. 10 is a plug, waste, and stench trap, and union combined, for a bath.

Figs. 11, 12, 13 are lead drawn traps, with cleansing eyes, that may be used under sinks or in similar situations.

Fig. 14 is a cap and screw that is used for fixing to the traps shown in *Figs.* 11, 12, 13 as a cleansing eye.

Where plugs are used, vulcanite is very frequently substituted for brass or gun-metal.

Flushing Drains.—*Method.*—Flushing is effected by accumulating water in a flushing chamber at the head of the drain or sewer, and suddenly liberating a sufficient quantity of it to carry away all sediment, and clean the invert by its sudden rush.

Brick, or stone drains, may be injured by too much flushing.

Iron drain pipes have a great advantage in this respect.

Water from reservoirs, streams, or other special sources, may sometimes be available, but it is usually more economical to store bath and ablution-room water, and some surface water, for this purpose.

Fig. 130 shows a flushing tank for utilizing surface water. It consists of two chambers, in the first of which silt is collected; the water overflows from it into the second chamber, and from thence it is discharged when full by means of a syphon connected with the drain. The passage of sewer-gas is prevented by a trap at the junction of the syphon arm with the drain.

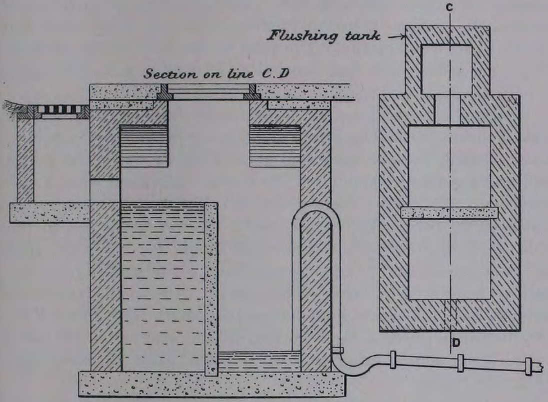


Fig. 130.

Fig. 131 shows a method of flushing closets with sink water, and

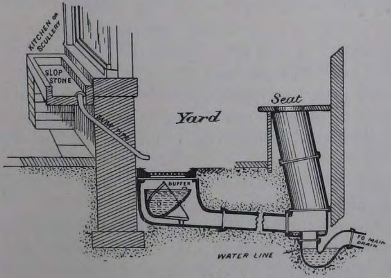


Fig. 131.

known as Duckett's closet. The tumbler gradually fills, and upsets when full, thus cleansing the closet and trap. A flushing tank on Rogers Field's syphon principle is substituted for the tumbler in some instances; the syphon is, however, liable to get choked with grease. At Crewe, the L. & N.W. Railway Company provide their workmen's cottages with the tumbler slop-water closet, and they appear to act satisfactorily. The sides of the long hopper are liable to become fouled, and such closets should only be used when there is extreme scarcity of water.

Manholes are sometimes used in towns for flushing purposes, and special chambers can be made in connection with them, with flushing doors, similar to those shown in *Plate* VII., in which the sewage and storm water can be retained by a sluice valve, and when a sufficient accumulation has taken place, it is liberated by opening the sluice, either automatically or by hand. In the latter case, to provide against inattention, the sluice gate should not cover the whole orifice of the sewer. A good proportion for the gate is from one-half to two-thirds the area of the sewer. The method indicated tends to raise the water lines temporarily above its ordinary limit, the discharge leaves a large surface of the interior of the sewer fouled, from which, owing to decomposition, gases are continually being given off.

It is, therefore, better to use clean water for flushing purposes, as it is necessary not only to remove the deposit, but also to cleanse the whole of the interior of the sewer from any matter adhering to it.

Field's Automatic Flushing Tank.—Field's automatic flushing tank (*Plate* XX.), with annular syphon, is most effective. The discharge of the tank is effected by gradually causing the syphon action to be started; the water runs in till it attains the right level.

Moveable Tanks.—In some towns, tanks with a capacity of 2,000 to 3,000 gallons, placed on wheels, previously filled from a hydrant, are brought into position near openings in the sewers. They are discharged through a 12-inch or 15-inch outlet for flushing the sewers.

Fire Engine.—Fire engines may also be used advantageously for drains up to nine inches diameter.

Order of Flushing Drains.—When a system of flushing is established, the lower parts of the sewers should first be flushed, and then the upper parts in succession. The flushing of a drain has a tendency to cause a backing-up in the branch drains running into it, especially when the fall is small, and for this reason it may be necessary to flush all the branches separately, and even to clear them with rods.

CHAPTER VIII.

SURFACE WATER COLLECTION.

Surface Water.—Surface water includes all water collected from roofs of buildings, paved and other surfaces.

How Collected.—Roof water is collected by gutters and down pipes.

Eaves' Gutters.—Eaves' gutters should be attached at a slope of 1 in 60, unless of a sufficiently large section to retain the water, when, for the sake of appearance, they are fixed horizontally.

The sections vary much in shape; the ordinary pattern is half-round (*vide Plate* XXI.), but more ornamental forms are often used.

Down Pipes.—Down pipes (*Plate* XXII.) are made of cast-iron, with hopper heads to receive the water from the guttering; also swan necks, off-sets, bends, and shoes.

The form of their section also varies from circular to square, and they are made more or less ornamental.

Joints.—The joints should be stanched with tow, and then filled with red or white lead.

Not to be Led into a Drain for Foul Water.—Rain-water pipes should never be led into a drain for sewage or foul water, but should discharge over outside gullies.

Along Surface Channel.—It is also sometimes economical to lead the water from a down pipe along a surface channel to the nearest surface-water gully, instead of providing a special gully immediately under it.

From Roads.—Surface-water from roads, parades, and pavements is collected by giving a fall or current to the surface, and by forming surface channels in paving, concrete, asphalte, etc.; tar paving is also much used for this purpose in many towns.

Surface Gutters, Fall of.—Surface gutters should have a fall of 1½ inches in 10 feet, or 1 in 80, though the fall is sometimes as little as 1 in 125.

Surface of Road.—The surface of a road should have a fall towards the side channels of from 1 in 20 to 1 in 40.

Drains.—As the water thus collected would at times accumulate into a considerable stream, besides being liable to get dammed up and overflow the channels, if kept on the surface, it passes at intervals of about 100 feet to 200 feet, or even more where the ground is very steep, through gratings into underground drains, which carry it off to some outlet.

Catch-pits.—As a good deal of sand and dirt is washed off roads and open spaces by the surface-water, a catch-pit should be formed underneath the grating, in which the silt may be deposited, and from which it can be readily removed on raising the grating or other cover, which should be hinged for this purpose.

The following are the requirements which should be kept in view in selecting the kind of catch pit, or gully, to be used to suit any system of drainage :—

(1). They should have sufficient area to carry off all the water led to them.

(2). They should not be easily choked on the surface by leaves or other *débris.*

(3). The pit should be sufficiently large to retain all sand or road detritus, and prevent it being washed into the drain-pipe.

(4). The grating should be amply strong to resist any traffic that may come upon it.

(5). They should give the least possible obstruction to traffic.

(6). They should be made in such a manner as to be readily cleaned out.

(7). The drain from it should be easily freed from any obstruction.

(8). If used in connection with a sewer, they should be trapped, the water seal being four inches deep, to prevent escape of sewer-gas.

The catch-pit may be built of brickwork in cement $4\frac{1}{2}$ or 9 inches thick, or formed in stoneware, and vary in size according to the requirements of the situation.

If made of brickwork, it should be rendered in cement on the inner faces ; a stoneware junction pipe set on end will often answer the purpose.

The bottom should be formed of concrete, or a 2-inch York flag, extending underneath the sides. From this catch-pit the water is carried off by stoneware drain-pipes, the outlet being from six inches to three feet above the bottom.

(*a*). *Separate System.*—Under this system, traps for surface water are not required, and it is only necessary to collect the silt, leaves, etc., in a catch-pit, so as to prevent them from entering and choking the drain.

The catch-pit in *Fig.* 132 is intended to arrest the passage into the drain of leaves and dirt from the roof.

The slab of stone protects the drain from being improperly used by slops being poured into it, which might be the case if the stone was replaced by an iron grating.

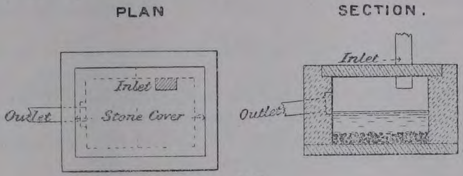


Fig. 132.

The cover should be capable of being readily removed for the purpose of clearing out the accumulation in the catch-pit.

The catch-pit shown in *Fig.* 133 is intended for use on a line of

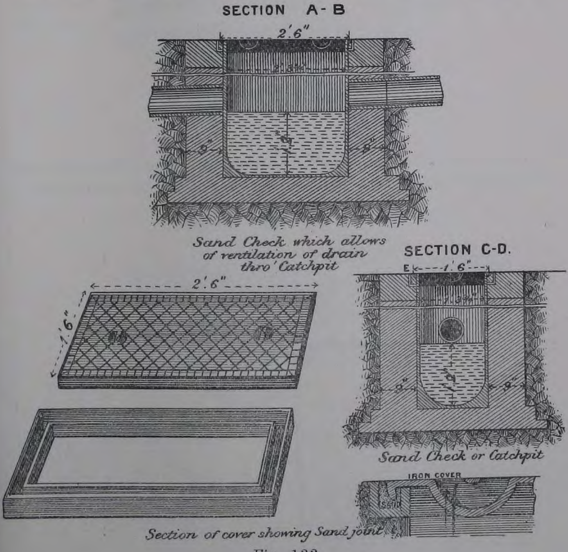


Fig. 133.

drain to intercept road detritus, etc., during a freshet. Sewage should never be allowed to flow through such catch-pits.

Mason's, or dip traps, are sometimes used for surface drainage in connection with this system, but are of no value, as the tongue is not required.

(*b*). *Combined System.*—The following traps are used as silt collectors on this system.

Mason's, or Dip Traps.—Mason's, or dip traps (*Fig.* 134), are sometimes used for this purpose, if connected with foul drains, but they are objectionable, as the point at the joint of the tongue is seldom sound, so that sewer-gas is emitted.

MASONS OR DIP TRAP

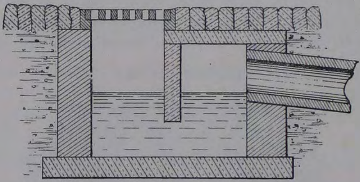


Fig. 134.

Newton's Street Gully.—Newton's street gully (*Fig.* 135) is intended to be used in connection with a sewer, and has some advantages.

NEWTON'S STREET GULLY.

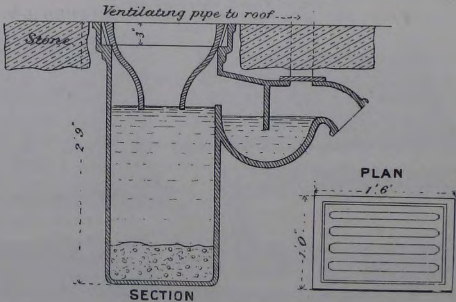


Fig. 135.

Hagen's Patent Duplex Cesspool Trap and Cleanser.—The following pattern (*Fig.* 136) has the advantage of having a bucket to retain the sand, etc., for cleaning out.

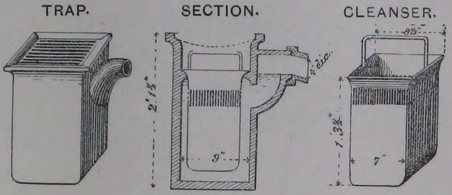


Fig. 136.

Doulton's.—Doulton's street gully (*Fig.* 137) is intended for the same purpose, but is of simpler construction.

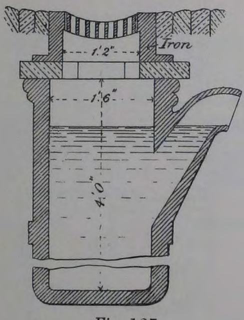


Fig. 137.

Dean's Trap (*Fig.* 138).—This trap is provided with a moveable bucket; it is simple in construction.

Lowe's.—Lowe's patent trap has been extensively used by the War Department. It is strongly made, and has a hinged grating, so that it can readily be opened and cleared out. The seal, however, rarely exceeds ¾ inch, even with the largest size, whilst it very often has practically no seal at all, and it would therefore be advisable to use this trap only in connection with the separate system.

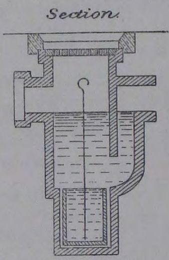


Fig. 138.

Fig. 139 shows Begg's improved Lowe's traps, but even in this description the seal is defective.

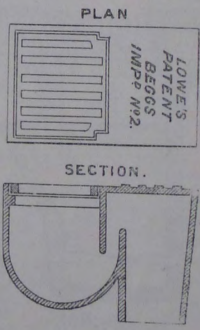


Fig. 139.

Another form of trap is manufactured by Messrs. Oates & Gunn, of Halifax (*Fig.* 140). The plug is intended to prevent the passage of sewer-gas through the examining eye.

Cartwright's Stench Trap.—Cartwright's self-cleansing stench trap (*Fig.* 141) is provided with a moveable pan, and is constructed to collect all dirt and mud passing through the lid.

The trap is strongly made of cast-iron, with hinged lid, and is specially designed for flushing from a water-cart or hose.

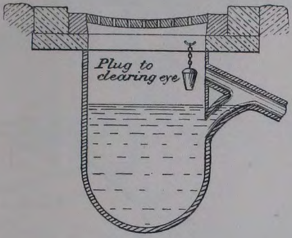


Fig. 140.

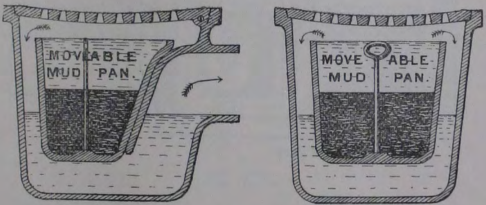


Fig. 141.

Stokes' Gully Trap (*Fig.* 142).—This trap has been designed to provide a ready means of access (A) to the outer side of the trap, so as to clear the drain beyond. It is made by Messrs. Bailey & Co.

The following patterns are also in use; they are provided with flaps to prevent the return of sewer-gas when the trap runs dry, but they are not likely to remain permanently efficient, as the flap may be kept open by any obstruction in the shape of straw, leaves, etc.

Fig. 143 is Lovegrove's patent. It is very liable to get choked, and is difficult to clear owing to the lip.

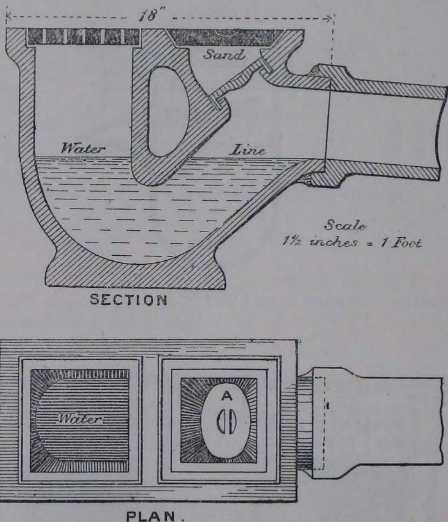


Fig. 142.

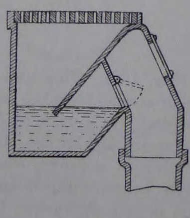


Fig. 143.

The next trap (*Fig.* 144) is more accessible for cleansing.

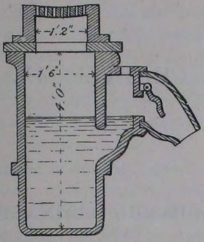


Fig. 144.

Buddle Hole.—A "buddle hole" (*Fig.* 145) is an opening under a kerb, and is advantageous, as it gives a free and undisturbed waterway, and avoids the necessity for a grating in the street itself.

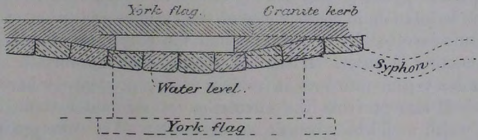


Fig. 145.

CHAPTER IX.

SUB-SOIL DRAINAGE.

Source of Moisture.—The principal source of moisture in the soil is rain, and it is only when in excess, so as to become stagnant by retention within a foot or two of the surface, that it becomes injurious. Rain is in itself a source of fertility, but the stagnant water is prejudicial, and its removal to a greater depth is desirable.

Injurious Effects of Wet Soils.—Wet soils which retain moisture injure vegetation, in consequence of the extreme reduction of temperature involved by evaporation, and the roots also are damaged by standing in water. If the soil is saturated the warmth of the air cannot penetrate into it, as heat does not descend in water. Wet soil also prevents the circulation of rain-water through the soil, which would be a benefit to vegetation. Wet soils produce a considerable reduction in the temperature of the atmosphere, and are very often the cause of fogs, and such land, when used as the site for habitations, is injurious to health.

Peat and heavy clay shrink about one-fifth their bulk in drying, and swell again in wet weather, so that a building resting on such a foundation is liable to serious injury if not carried below the reach of atmospheric changes.

Sub-soil drainage is thus often required to improve the value of land and to secure the stability of a building; in many places also it is a matter of importance on sanitary grounds.

The General Report of the Commission on Improving the Sanitary Condition of Barracks and Hospitals lays down, at p. 58, the following principles with reference to sites for barracks :—

" Having selected the site, the whole area within the barrack enclosure should be thoroughly under-drained to the depth of four feet at least, by tile drains placed at distances differing according to the nature of the sub-soil and the fall of the ground. The lines of drainage should be closer to each other, or more distant, according as the sub-soil is more or less retentive of moisture. In some positions, with a very porous sub-soil, in which water never remains, tile drainage may be unnecessary, but such instances are rare exceptions. The drainage should be, in all cases, sufficient to keep the parade ground firm and dry." And with reference to sites for barrack huts, at p. 171, it is stated that "A dry sub-soil is, in fact, absolutely necessary to health."

The necessity for artificial drainage does not so much depend on the rainfall, or the power of the sun to carry the moisture off by evaporation, as upon the character of the sub-soil.

If the sub-soil is composed of sand or gravel, or of other porous earth, the greater part passes off by natural drainage below the surface. If, however, the sub-soil be of clay, rock, or other impervious substances, the downward flow of the water is arrested, and it sometimes shows its presence in the form of springs. All wet soils may be divided into three classes. 1st. Free soils, from which the water is gradually discharged by percolation through itself, by evaporation on the surface, and absorption by vegetation. 2nd. Peaty soils, which allow the water to percolate, but not so readily as free soils. They have great powers of capillary action, so that a large proportion of water, after being absorbed, is given off by evaporation. 3rd. Clay soils, which are retentive of all the water they absorb until it is relieved by evaporation or vegetation.

Other descriptions of land vary between these classes in proportion to the amount of clay in their composition and their capacity for natural drainage. Each variety requires special treatment for removing the sub-soil water, and this is especially the case with retentive clay soils, which are so powerfully acted on by the atmosphere.

The first of these two classes owe, from their nature, their wetness simply to position, and all that is required is to afford an outlet for the water, so as to set it in motion, and thus lower the sub-soil water-levels. In the case of high and dry lands, it sinks beyond the reach of evaporation, but it still remains within the reach of atmospheric influence in the case of drained lands, even though it thus stands at a lower level than it otherwise would.

Clays require very careful treatment, on account of their retentive character and capabilities of expansion and absorption. Sub-soil drainage makes them permeable, though when the surface is not properly and deeply cultivated their capabilities of absorption are limited, and those of retention and expansion cause them to resist the admission of the rainfall.

Clays readily discharge the excess of water, after a heavy downfall, after their own capacity for retention is satisfied; on other occasions they give it out gradually.

The retentive nature of clay soils can only be restrained by complete aëration. The drains should exert a powerful influence on the intermediate mass of soil, so as to secure a quick and uniform passage through it for the superabundant water.

Clay is capable of absorbing from 40 to 70 per cent. of its own weight of water.

It should be remembered that drainage of clay soils only alters their condition, and not their constitution. The constant expansion and contraction, as water is absorbed and given off, as well as the retentive power of clay soils, form a marked distinction between them and free soils.

Clay cracks as it dries. It also contains fissures of sand and gravel, and where deep cultivation breaks up the surface, the water finds its way into the clay by these various channels, and thence into the sub-soil drains. Atmospheric air follows the water, and as the sides of the cracks are gradually coated with soil carried down by the water, the sides are prevented from sticking together again. The disintegration of the clay soil and the multiplicity of these fissures become greater every year, and consequently the sub-soil drainage more effective, as well as capillary attraction to the surface. There is thus evidently a depth suited to each soil to which it is desirable to reduce the sub-soil water-level, and beyond which it would not be safe to go in the case of cultivated lands without unduly testing its power of supplying moisture to the plants by capillary action.

Depth of Drains.—There has been a tendency of late years, on account of expense, to reduce the depth of the drains to three feet, but the most eminent authorities concur in considering that the drains should not be less than four feet deep, when the outfall will admit of it. They should be properly executed and so arranged as to secure complete aëration of the sub-soil between them, so that although the individual particles of the soil may be moist, it will not retain water.

Many authorities recommend deeper drainage than this, and it is an established fact that the deepest drains flow first and longest.

It may be remarked here that in the case of cultivated land, as the surface is never uniform, drains four feet in depth may approach in some places within three feet of the surface, and thus the sub-soil water is not kept sufficiently low, and in addition to this, if only 3-foot drains are used in the first instance, they may for the same reason come dangerously near the surface, and be disturbed in the operations of cultivation. This would not apply with the same force in the case of sub-soil drainage for sites of buildings. Under the latter circumstances it may in some instances be necessary, in order to obtain a fall for the drains, to make them only two feet deep in places. They should then be placed at only about half the intervals at which 4-foot drains would be laid.

The contention for shallow drains is really maintained by the question of expense, as the extra foot in depth involves an additional foot of excavation at the top, and is not a mere prolongation of the thin end. The earth also gets harder the deeper we go.

Mains should be placed from three to six inches lower than the minor drains discharging into them, so as to avoid any obstruction which might cause the water to head up into them.

Arrangement of Drains.—It is necessary, in the first place, to ascertain the source of the injurious water, so as to secure a permanent and effective discharge. To do this, the geological formation and dip of the strata should be considered. In some cases, the moisture is due to pervious strata cropping out just over an impervious one, and even underlying it, in which cases, by the judicious use of the augur, or boring tool, to tap the water-bearing strata, in connection with other drainage operations, large tracts of land have been cheaply and effectively drained, with beneficial results extending to some distance around. This is known as Elkington's system. Numerous test-holes should, under any circumstances, be made to ascertain at what depth below the surface the water will lie in wet seasons. The natural drainage by hollows and valleys should be studied and retained as the proper course of drainage, though the future conduit is to be below the surface. Close attention must also be paid to the variation in the inclination of the surface, as well as in the nature of the soil. Relief drains should be applied at all changes of planes to those of smaller inclination, so as to avoid the impediment caused by the slower flow of the flatter drains.

It is thus seldom that the drains can be laid uniformly parallel to each other, but they must be arranged to suit each portion of the ground. The minor drains must be of sufficient size to carry the total maximum amount of water that may flow through them without pressure, as otherwise it would wet the land through which it passes without draining it.

The size of the mains should be calculated to carry away readily the water to be collected from the minor drains. In each case proper allowance should be made for the inclination of the pipes.

Fall.—When the general surface of the ground is nearly level, very little fall need be given to the drains. When practicable, it is well to have a fall of not less than 1 in 100; more is preferable, but as little as 1 in 400 is sufficient if the drains be very carefully formed. It will, however, be usually found less expensive to make a fall of 1 in 200 rather than 1 in 400, as the latter requires extra care in forming it. A very steep slope is objectionable, as the flow of water tends to injure or obstruct the drains. With steep slopes it is desirable to place the drains at less intervals than with ordinary slopes. Stone drains require a greater fall than tile drains, as the water does not pass through them so easily.

The fall should be uniform, or of increasing descent, towards the outfall, to avoid deposit of silt, as particles which would be carried along the pipes at a good fall might be deposited when the flow of water is lessened owing to the reduction of the fall in the drain. Where an alteration of fall to a decreasing rate of fall must be made, a silt basin should be placed to catch the deposit.

Distance between Drains.—Under similar conditions the distance apart should be in inverse proportion to the rainfall, so that the maximum amount may be freely absorbed and discharged at all times. It may be made to depend upon the depth of the drains in free soils, but clay soils must be considered independently, the maximum distance in the latter case being 27 feet, and in some cases they may have to be placed from 21 to 24 feet apart. In strong loam they may be placed as far as 30 feet apart, in light soils, 40 feet apart; the intervening ground will then be effectively drained, the level of the water in the ground between being somewhat as indicated in *Fig.* 146. In gravelly soils, drains may be laid at greater intervals than 40 feet, but they should then be deeper than four feet. In good clean gravel the drains may be dispensed with. In every case, however, due regard must be paid to the continuance of humidity of the atmosphere, and to the character of the soil.

In the case of a steep slope terminating in a flatter one, with soil of the same character, the soakage from the hill will necessitate a greater number of drains on the lower land than on the higher.

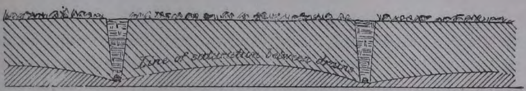


Fig. 146.

Direction.—The minor drains should follow the line of greatest descent, and it is evident that when laid at right angles to the mains, and so parallel to each other, that the shortest possible drains are obtained in land that admits of uniform drainage. They thus share the work done uniformly. In ploughed land they very often follow the furrows when straight, or nearly so, instead of crossing the ridges, as they should do if the plan of parallel equidistant arrangement were strictly adhered to, and this plan should always be adopted in grass land, unless there is a probability of its being broken up, flattened, and laid down again. Where drains are laid across the fall of the land, water escapes from them in its passage. If the work stops on a slope, a cross drain, called a header, should be introduced, connecting the tops of all the minor drains, so as to cut off the water passing down the slope in the sub-soil between the pipes.

An open drain is useful on a gentle slope to cut off the surface water flowing from the upper portions, and would be more effective than an under drain. Sometimes it is necessary to use both the header and the ditch. The direction of the mains may have to be modified, so as to increase their discharging power if, from motives of economy, it is undesirable to use a larger pipe. With this object in view, two separate mains are laid on each side of the hollow, and the inclination increased by running the head of each upwards into the rising ground.

It is objectionable to use long main drains, especially with a low gradient, as they check rapid action in the system. When they cannot be avoided, wells, or sumpts, with overflow pipes into some convenient ditch, should be introduced into the line of drain to relieve the pressure.

Outlets.—The outlets should be carefully chosen, and should be as few as possible, consistent with a proper allotment of the lengths of the mains. An average of about 14 acres to one outlet appears to be the usual practice. The outlets should be composed of iron pipes, set in masonry, and discharge with a drop of a few inches into a watercourse. Care must be taken that the outlets do not get stopped up, and that they are at such a level that there is no probability of water being forced back through them during floods. A flap is sometimes used for this purpose, as shown in *Plate* XXIII., which gives the details of the work required in connection with outfalls for either a small or large system of drainage. An iron plate, with the date and number on it, should be let into the masonry, and entered on the drainage plan. The site of all the drains should be correctly shown on the plan.

Silt Basin.—Silt basins should be formed on mains at junctions where there is likely to be a great flow of water, or at the foot of an incline in the drain, where there is a change of the fall to one less steep. They may be formed of brickwork, or with a large pipe on end, or with a wooden barrel. They will last many years without being filled up, and then they can be cleared out. *Figs.* 147 and 148 show ordinary forms of silt basins.

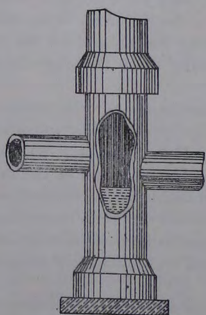


Fig. 147.

Wells, or silt basins, at proper intervals, are very useful for observing the flow of water in the drains, and thus it may be readily ascertained whether the drains are free from obstruction and are acting properly.

Sumpts: Use of.—Where it is necessary to drain below natural outlets, such as on sites only a little above high water level, the water may be carried into sumpts or wells, from which it can be passed off by pumping, or by valves, to let it run out at low water.

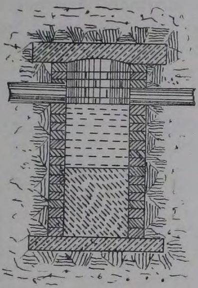


Fig. 148.

To prevent the sub-soil water forcing its way into sewers, drains should be laid to carry it off. *Figs.* 149 and 150, which are taken from *Colonel Slacke's Drains and Drainage*, show the method adopted in the Main Drainage Works of London to drain the sub-soil water from the exterior of the sewers.

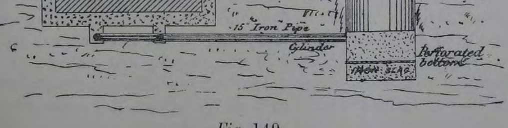


Fig. 149.

Flushing.—It may be advantageous in some cases to provide for flushing the mains from a stream, or by retaining water from drainage by means of a supply pipe and well with a water-tight flap.

Air Drains.—An increased rapidity of discharge from a long main drain, or one of slight inclination, is obtained if air is admitted directly to it, and an air drain connecting the upper ends of the minor drains has also been advocated. Such contrivances would apparently be advantageously employed in the case of the denser clays, but this would not obtain with porous soils.

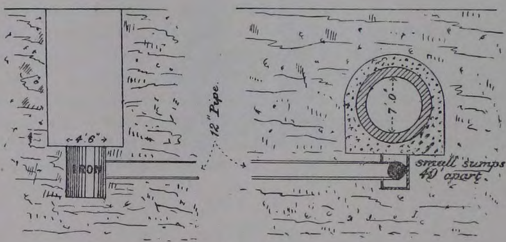


Fig. 150.

Clay Soil.—The worst ground for a site is a clay soil, or a clay sub-soil, coming near the surface; but the disadvantages will be reduced to a minimum, if not entirely removed, by efficient sub-soil drainage.

It is desirable that the sub-soil drains should be below the level of the footings of the walls of a building, and that they should lead away from it without passing under it.

Drainage under Foundations.—It may be necessary in some cases to lay drains under foundations, in addition to the ordinary sub-soil drainage, to guard against *water from below rising* into them. Such drains should be laid with a considerable fall into the adjacent sub-soil drains, or the water from them should be carried away from the site by an independent drain; they should not form any part of the main system of drainage of the site, so that in case of any stoppage of a drain underneath the foundations, no water could find its way under the building from the surrounding drainage.

Buildings.—*Magazines.*—This becomes of importance in the case of a building on the side of a hill, as in *Fig.* 151, and for magazines placed below the ordinary surface level, as in *Fig.* 152, where floors and walls must be kept perfectly free from damp."

DRAINAGE UNDERNEATH A BUILDING.

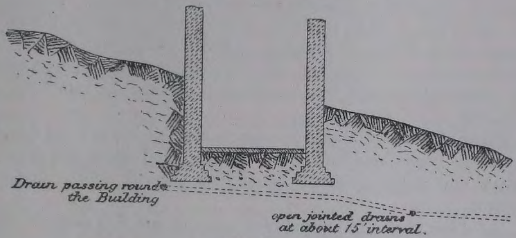


Fig. 151.

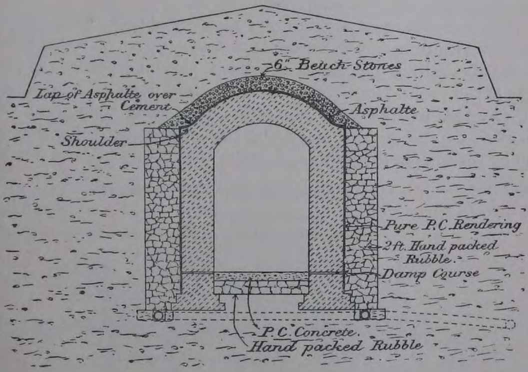


Fig. 152.

Surrounding Site.—It will be found a great advantage to put in sub-soil drains surrounding the immediate site, if possible, to a depth below the footings of a building, before making excavations for the foundations, as the water will thus be prevented running into the trenches.

Special for Footings.—If the excavations are carried below the depth of the sub-soil drains, it will be desirable to drain them separately by carrying off the water to a lower level. In special cases this may not be possible, and it may be necessary to leave the site undrained, building in below ground with hydraulic mortar or cement, and afterwards draining in the ordinary way around the building. In such a position the sub-soil water may be kept out of the trenches by sheeting and puddling, if it cannot be kept under by pumping.

Where the sub-soil drains are not below the level of the foundations, the whole area under the building, and above the level to which the drainage is laid, should be covered with a layer of concrete.

For Peaty Soil.—In ground of a peaty nature it is essential that, if it be drained at all, the drains should be laid before the work is commenced, as such a site is seriously affected by the drainage, and the substratum becomes easily compressible.

Railway Embankment.—When any great weight of earth, such as a railway embankment or a parapet, is to be placed on a site which is already drained, the drainage should be made independent on each side of the site and lead outwards from it and clear of it, as shown in *Fig.* 153, to ensure the proper drainage being maintained, and to avoid the risk of the drains under the embankment being stopped up by the compression of the soil under the superincumbent weight.

SECTION THRO' RAILWAY EMBANKMENT.

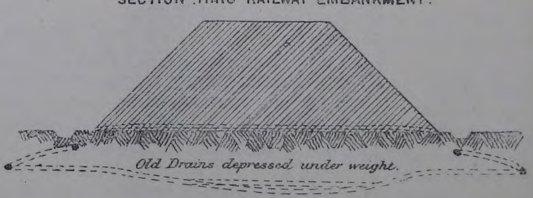


Fig. 153.

Drains through Foot.—It is often advisable to lay open-jointed drains at intervals through the foot of an embankment near the natural surface of the ground to carry off the water which may sink into the made earth, and might cause it to slip or settle; and with retentive soil, it may be necessary to insert drains on the top and down the faces of the embankment to prevent its slipping. When it is required to carry any part of the drainage underneath the embankment, a small culvert should be formed, or a pipe drain jointed in cement carefully laid should be provided, in order to avoid the risk of any accumulation of water underneath.

Execution.—All works of drainage must be laid out with great care, and executed completely and efficiently. Any defects are likely to be of serious consequence, and are usually difficult to remedy. The laying out of the work should be prepared upon a plan and then marked upon the ground. It will be necessary to decide upon the whole extent of the work to be done, including the position of the outlet, the direction of the mains and branch drains (or laterals), the depth, intervals apart, and the sizes of the pipes. On a proper adjustment of all these, economy and efficiency will depend. The consideration of the means of getting rid of sub-soil water before putting weight upon the ground is very frequently neglected, the result being damp walls, unequal settlements, as shown by cracks in a building, and sometimes sliding of embankments.

Trenches, Depth of.—The trench for a sub-soil drain is usually from three to six feet deep, and is cut as narrow as possible for the depth.

The amount of excavation for the required depth will depend a good deal upon the skill of the excavator, and upon the nature of the soil. The bottom need only be sufficiently wide to take the pipes, provided the excavation can be laid without the workmen having to stand in the trench. The tops will be from one to two feet wide, and the sides sloping, as shown in *Fig.* 154.

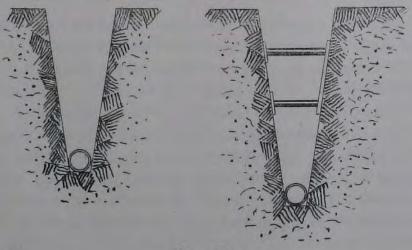


Fig. 154.

Ordinary Tools.—Machines.—It will generally be found more economical to let the workmen make the trench of the width he can conveniently manage, rather than insist, in every case, upon a very narrow trench. Many special forms of spades and scoops are made and recommended to be used in digging trenches, but workmen will rarely be found to use with advantage tools to which they are unaccustomed. But narrow spades and scoops, as *Fig.* 155, and *Plate* XXIV., should, if possible, be used for excavating and finishing off the bottom of the trenches to the required fall. Special excavating machines, worked by steam power, are used to cut the trenches for draining extensive areas.

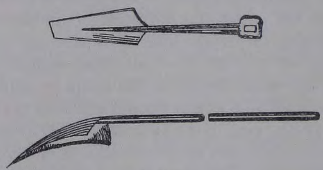


Fig. 155.

Bottom to be Currented Accurately.—The bottom must be currented with great accuracy (*vide Plate* XXIII.), every part being tested with boning rods. Where the soil is very loose or formed in running sand, the bed for the pipes should be formed with a layer of stiff soil or clay. This will not, as might be supposed, stop water rising into the pipes, as after a short time it becomes quite porous.

Pipes.—Material and Size.—The pipes in general use for sub-soil drains are circular, though several other shapes used to be manufactured. They are made of clay similar to that used for ordinary bricks, and are burnt in the same way as bricks. Those from one to two inches diameter are usually made in lengths of 12 to 15 inches. The 1-inch pipes are not reliable, and are now seldom used. The 2-inch pipes are generally used for minor or lateral drains, up to 16 chains in length. For larger drains, $2\frac{1}{2}$-inch or 3-inch pipes should be used at the lower parts. Collars are sometimes made to encircle the joints of pipes, but they are seldom used on account of the increased expense. They are valuable in preserving the continuation of the drain, but in the case where pipes of smaller bore than two inches would be used, the increased difficulty of preserving the continuity is got over by not using any pipes under two inches diameter of bore. Their use would be advisable in sandy soil, to check the tendency of the pipes to become choked with silt. It has been found by experiment that by far the larger part of the water enters the pipes through the joints, and only a small percentage percolates through the pores of the pipes. The pipe and collar are shown in *Fig.* 156. Larger sizes of pipes are used for main and cross drains, into which a number of the smaller drains run, or for draining places where a large accumulation of water may, at times, have to be passed off. Sizes over 2-inch diameter are generally made in 2-foot 6-inch lengths.

ROUND TILE AND COLLAR.

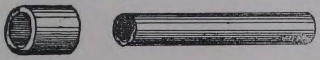


Fig. 156.

From the conditions already given for mains, they should apparently consist of the ordinary glazed stoneware socket pipes with joints set in cement.

Quality.—The pipes should be hard burned, and give a clear ring when struck. They must not be warped or out of shape by over-burning. Exactitude of form is even of more importance than smoothness of surface. One bad pipe may destroy a long length of drain. It is well to order all pipes to be delivered by the contractor who is to supply them, so that he may have the risk of carriage; all broken and inferior pipes to be rejected. Badly burned pipes are very brittle, so that the cost of carriage of broken ones would be considerable if an inferior lot are supplied. Only round pipes should be used; other shapes are still sometimes made, but they have been proved to be much inferior to the round pipe. However, any kind of pipes are better than stone-packed drains.

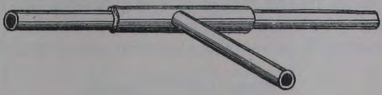
The following table shows the number of rods in length and the net number of pipes required per acre, with drains at various distances apart:—

Distance between the Drains.	Rods ($5\frac{1}{2}$ yards) per Acre.	Number of Pipes in Lengths of			
		12 inches.	13 inches.	14 inches.	15 inches.
Feet. 15	176	2,904	2,680	2,489	2,323
18	146	2,420	2,234	2,074	1,936
21	125	2,074	1,915	1,778	1,659
24	110	1,815	1,676	1,555	1,452
27	97	1,613	1,489	1,383	1,290
30	88	1,452	1,340	1,244	1,161
33	80	1,320	1,219	1,131	1,056
36	72	1,210	1,117	1,037	968
39	67	1,117	1,031	957	893
42	62	1,037	958	888	829

Junctions.—Where a drain is joined on to the main drain or cross drain, it should be laid with an oblique junction and a special Y junction used. These junctions can be obtained of the same make as the pipes, but if there should be a difficulty in procuring them, junctions for socket pipes might be used, but they are much more expensive. However, they are more frequently laid without the special junctions ; in such a case an interval somewhat greater than the external diameter of the side drain-pipes should be left between two pipes of the main drain, a length of pipe of a diameter sufficient to act as a long collar to the adjacent lengths being inserted on the main. The connection should be made by cutting out a hole on the upper side of this collar, with a pointed hammer, to receive the end of the tributary drain-pipe, which must be trimmed off to correspond with the inside surface of the larger pipe to which it is to be joined, as shown in *Fig.* 157, so as to cause no obstruction.

Laying.—The pipes are butt-jointed, and are laid dry in the bottom of the trench ; the adjoining ends should be placed close together, and in all cases it will be found that the uneven faces of the butt ends leave the joints sufficiently open, so that any water coming into the trench can find its way into the pipes.

Method of.—*Fig.* 158 shows the ordinary forms of the pipes and collars laid, though, as before mentioned, the collars may be generally safely dispensed with.



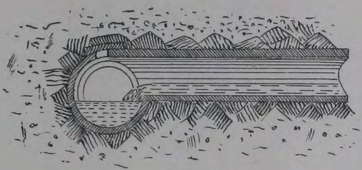


Fig. 157.

The bottom of the trench having been carefully finished to the suitable slope, the pipes should be laid by a bricklayer, or some man specially trained to the work, as it cannot be properly done by an ordinary labourer. Work of this nature should never be done on piece-work.

Fig. 158.

It will be found an advantage to lay the pipes as soon as possible after the trench is formed, as water running into it will injure the surface of the bottom on which the pipes are to be laid.

All pipes should be laid resting firmly on the bottom of the trench, so that the filling in of the earth may not disturb the joint. It is well to wedge them against the sides of the trench, or a few stones may be packed around and above the pipes to steady them.

Filling in Trench.—The trench should be filled in soon after the pipes are laid, so that they may be protected from the risk of being disturbed by earth falling on them. The filling in, or "blinding," over the pipe with the first covering, to a depth of three or four inches, should be done by the skilled workman who lays the pipes ;

this will avoid the risk of displacement of the pipes by the hasty filling in of the trench, which can be done by ordinary labourers.

Stones.—There is a difference of opinion amongst men of great experience as to the best method of filling in over the pipes. One way, and that which at first sight appears to afford the best means of drainage, is to fill in over the pipes with stones, as in *Fig.* 159.

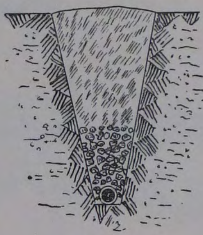


Fig. 159.

Fine Earth.—The packing in must be done with great care, and no stone should exceed four inches in diameter. The object of the stones is to give the water free access through the interstices between them to the pipes. But the crevices being so large and so numerous, a flow of water in small streams is set up, carrying down the fine particles of the earth into the pipes, in which, as the flow is lessened, they are deposited. For this reason the method of filling in around the pipe with fine earth, or even with clay, has been found successful, and is recommended. This is shown in *Fig.* 160.

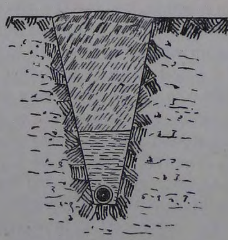


Fig. 160.

The fine earth should be filled in lightly for a depth of about 15 inches; over this the ordinary soil is laid, being at first trodden down and finally well rammed as it comes to the surface level.

Another method is to cover in the pipe with a few inches of gravel or fine earth, and then place over this a layer of compact clay.

Object of.—The object of the fine earth or clay in the first instances is to act as a filter, and to prevent the water flowing in *streams* into the joints, carrying in silt along with it. The clay soon becomes aërated and porous by the water being drawn away from it, and after a time the water will percolate freely through it to the pipes. The layer of compact clay is intended to divert the water from flowing vertically down the trench, so that it may only enter the tiles from the underside, and thus avoid the deposit of silt in them. Drains in which the pipes are surrounded by a stone packing may apparently act more effectively for the first year, as they will carry away the water more quickly at first, but where the compact earth or clay is used, the drains will more thoroughly aërate the soil by the gradual percolation of the water through all parts of it, instead of its trickling down in small streams. Many instances have occurred where pipes surrounded by stones have been silted up in a few years to such an extent as to leave the soil almost entirely undrained. The filtration of water, by means of the surrounding layer of fine earth, is the best safeguard against an accumulation of deposit in the pipes. All roots or fibrous matter liable to decay should be carefully excluded from the earth packed round the pipes.

Stone or French Drain.—In some cases the use of pipes is dispensed with, and instead of them the trench is filled in for about a foot in depth, or sometimes nearly to the surface, with stones from two to four inches in diameter, as in *Fig.* 161. The water finds its

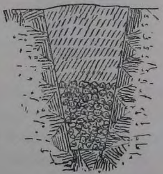


Fig. 161.

way along the trench between the stones. This arrangement is called a *Stone Drain*, or *French Drain*. Rounded pebbles are better for this purpose than angular stones. Where a number of flat spalls are available, a drain may be formed along the bottom of the trench by laying them as in *Figs.* 162 or 163, but if the flow of water washes away the bottom of the trench, the stones are liable to fall inwards and close the ducts.

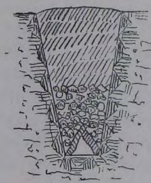


Fig. 162.

When stones are used without drain-pipes, the trench should be larger in section ; the packing in must be very carefully done ; and they must be covered with smaller stones to prevent loose earth passing down amongst them. Over the stones a sod may be laid, grass downwards, to keep out silt. In consequence of the amount of labour required, these drains are more expensive than those with properly laid pipes, and are, moreover, very liable to become obstructed.

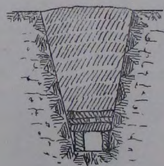


Fig. 163.

Hand Packing.—A dry packing of stones in embankments, at the back of revetment walls, or in the foundation of roads, is frequently used with advantage to facilitate drainage.

Brushwood.—Drains are sometimes formed with bushes, pieces of wood, or sods, as a means of getting rid of soakage water. In exceptional cases, when tile pipes are not available, these substitutes may be advantageously applied. All such drains must be regarded as *make-shifts,* very inferior to tile drains.

Boggy Land.—Wet, boggy land is very troublesome to drain properly. It is not often used as a site for buildings, but it may lie near to dwelling houses, and, therefore, require draining. The ordinary tile draining has, in many instances, proved useless in such cases, because the drains have been laid before the ground was in a fit state to receive them. The drying out of such land is a gradual process, which must be carefully developed. One or more deep, open ditches should be dug along the lines on which the main drains will eventually run. They should not be less than five feet deep, and the sides must be at such a slope that they will not be liable to fall in.

Trenches about a foot in depth will then be cut across the surface of the ground at intervals of 10 to 15 feet, with a good fall to the open ditches. As the soil dries and consolidates, these trenches are gradually deepened, the bottom being frequently cleared out to allow an uninterrupted flow of water through them. When they have been made to a depth of about two feet, if the ground is drying well, it may be possible to dispense with each alternate drain, deepening the others by degrees to a depth of four feet, and keeping them open till they have been proved to work satisfactorily, and the ground has become fairly firm, then, but not till then, pipes may be laid. It will be as well to use collars for the pipes, as the bottom of the trench will probably be rather soft, and 2-inch pipes should be used.

Failure of Drains.—Every precaution should be taken to prevent obstructions occurring in drains. If properly constructed, they should last for 50 years without requiring to be re-laid. In low land, however, when the soil is composed of fine materials, it frequently happens that the pipes have to be taken up and re-laid after about 10 years, and in peaty soils this may be necessary after three or four years.

The chief causes of obstructions are *silt*, *vermin*, and *roots.*

Silt.—Silt will be deposited wherever there is slack water, owing to a defect in laying, or to an irregularity in the shape of a pipe, or to a decrease of the fall in the drain.

The entrance of silt into the pipe may be to a great extent prevented by having collars on the pipes, or by covering them with a few inches of gravel or other porous soil, and placing over this a layer of compact clay, so that the water may enter *at the bottom* of the tiles instead of at the top, as already mentioned. The deposit of silt in the pipes may be guarded against by the provision of silt basins.

Vermin.—Vermin, such as mice, obstruct the pipes by making nests in them, and dying in them. To obviate this difficulty, keep them out of the pipes by covering the outlet openings with a grating or wire guard, or by packing broken glass bottles around the outlets. The outlets shown in *Plate* XXIII. have been used for this purpose.

Roots of Trees.—Roots of many trees, especially willows, will enter pipes, and extend within till they sometimes completely stop up the pipes. However, this difficulty does not occur very frequently. Where it has occurred it has been necessary to take up the pipes and relay them. In such cases, when relaying the pipes, it may be well to provide a double row of them, so that if one gets stopped up the other may escape.

Sometimes it may be necessary to remove the trees for the sake of the drains. Or the difficulty may be got over by making the drains with socket joints in cement through the ground where the roots are likely to extend, say within about 50 yards of the trees.

Roads.—Sub-soil drains ought to be constructed under all roads, at intervals of 10 to 15 feet, unless the soil is open gravel, or the foundations have been made up with packed stone. They will keep the road dry, and prevent the surface remaining muddy after rain. It will be less liable to be cut up by the traffic over it, so the expense of draining will be saved by the reduction of the expense of maintenance.

In all cases drainage will be promoted by a judicious formation of the surface, which should be currented so as to prevent any accumulation of water after rain.

Plan of Drains.—The positions of the several drains, outfalls, sumpts, and examining holes, should be shown upon the plan of the drainage area. The depths, sizes of pipes, and inclinations at the several places should also be marked upon it. It must be expected that the drains will have to be opened at some time or other, so a proper record of them will save much expense in searching for them, and enable an intelligent supervision of every part of the drainage system to be readily maintained, and consequently prompt remedial measures to be taken should any defect be discovered.

Special Measures for Underground Buildings.—When magazines are built underground, or, as in the case of casemates, they are covered with earth, special precautions, in addition to effective sub-soil drainage, have to be resorted to in order to exclude damp. With this object in view, the roof of the magazine, or casemate, is usually covered with asphalte, the external shape being arranged so as to facilitate drainage; the slopes, however, should not be excessive, or the settlement of the superincumbent mass may drag the asphalte down with it, and thus produce cracks. The slopes on which the asphalte is to be laid should be limited to about 30°, and the portion to be so covered should terminate in shoulders, as represented in *Fig.* 152.

It is best to render all vertical walls and slopes greater than 30° in pure Portland cement, floated with a steel float to a glassy surface; in fact, the whole of the magazine might be so treated, for, being protected from the action of the sun, the cement would not be liable to crack.

Care should be taken at the junction of the cement and asphalte coverings to provide an efficient lap.

To still further assist in the escape of water, two feet of hand-packed rubble should be built against the external vertical portions of the buildings, and, if procurable, a layer of six inches of gravel is advantageous immediately over the roof—although even here carefully hand-packed spawls are admissible, as asphalte will bear considerable pressure without cracking. Sharp corners resting on the asphalte are, of course, most objectionable, and tipping on to it from a height should never be allowed.

Should water find its way into an underground building, it may be excluded by the process referred to at page 175 of *Permanent Fortification for English Engineers*, by Major J. F. Lewis, R.E.

The following is an account of the process, as issued with I.G.F. Circular, No. 553 :—

Major Moore's Process for Curing Damp Walls.—Portland cement is used as the basis of the system, and is applied to the inside of the building, as a rule in two coats, which are afterwards covered over with a third coating of common hair mortar in the ordinary manner, or the third coating may be formed with either Parian or Keen's cement.

The first coating of pure cement is intended to exclude the damp and prevent any wet, no matter how porous the wall may be, from working through; but as pure cement induces condensation on its surface, it is necessary to cover it up with a substance which would not promote it; the third coating is designed with this object in view; the second coat forms a non-conductor and a connecting link between the first and third coats.

1. *Process.*—Rake out the joints of the masonry carefully and render half-inch thick in pure Portland cement, leaving a key on its surface.

2. Whilst still green, render the first coat over again with Portland cement and washed sand $\frac{3}{4}$-inch thick, in the proportion of one to three, also leaving a good key on its surface.

3. The last coating of hair mortar, brought up to a surface with putty and plaster in the usual way, should now be applied.

As an alternative, when it is required to paper or paint the wall at once, instead of using hair mortar, the last coating may be hand floated, and set with either Parian or Keen's cement.

N.B.—If it is of importance to finish the work still more rapidly, rendering, floating and setting the walls with Parian or Keen's cement $\frac{1}{2}$-inch thick may be substituted for the second and third coats already detailed, but it would be more expensive.

1. *General Remarks.—Rules for Guidance in Application.*—The result of experience in the use of this process is that the best results are obtained with hair mortar for the final coating, and that it should always be used when it is intended to whitewash, distemper, or colour the walls afterwards.

2. Parian or Keen's cement may be used with advantage for the final coat if it is intended to paint or paper over it, and the work is of an urgent nature.

3. Parian cement is preferable to Keen's cement for this purpose, as there is always a certain amount of efflorescence with the latter when first applied, which lasts for several days and delays the work.

4. If there be no objection to a rough, gritty surface for the finished work, as in passages, walls of casemates, magazines, etc., the third coating may be entirely omitted; the second coating being finished with a wooden float, so as to leave the grit exposed; this gives excellent results.

5. *Advantages.*—There is no difficulty in application.

6. Houses, etc., may be built on this principle, using it in place of hollow walls, thus effecting a saving in the cost of construction, and at the same time affording a much more complete protection from damp than is obtainable by the system of hollow walls, for the damp-proof lining can be brought close up to the door and window frames and tucked in round them, so as to effectually exclude the damp at

all points, the only care required being to set all the masonry at the junction of the cross walls with the outer walls in cement, so as to preserve the cement envelope intact.

7. When building a house on this system, compared with one built with hollow walls, there is either a small saving of roofing and a corresponding reduction in the width of the outer walls, or an increase in the area of the rooms is effected without additional cost.

8. The process is capable of being used for the purpose of curing buildings which are damp under every circumstance, as the application is to the inside surface of the walls; consequently walls of buildings which act partly as retaining walls, casemates which are covered with earth, etc., may be made quite dry by its means, without the expense of having to uncover them in order to stop the leaks.

9. Its application will even make the soffit of an arch quite dry, through which previously the water was running like a shower bath.

10. This process for curing damp walls is certain in its action, and for this reason, and others already given, its application is most economical, the cost of any other method being in some instances almost prohibitive.

11. It is much easier of execution, and it affords a far superior and a cheaper means for the construction of really dry buildings than can possibly be obtained by any other system.

Fig. 164 shows an extreme case in which the water is finding its

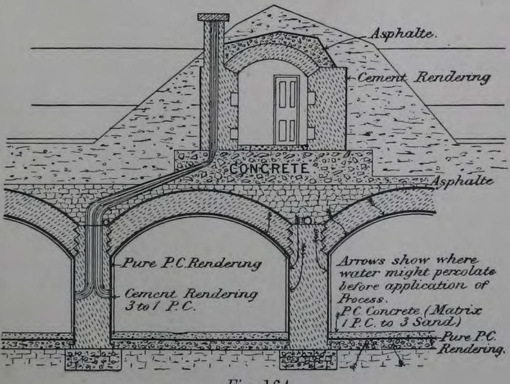


Fig. 164.

way into the building, not only from the crown of the arch, but also through the floor. It will be noticed that the pure cement envelope is carried over the soffit of the arch, down the side walls, and through the concrete floor, thus effectually excluding the water. It must be intact throughout.

The proportion for the matrix of the upper bed of concrete for the floor must not exceed the proportions of one pure cement to three of sand.

This system has been employed both at home and abroad with uniform success, having been found in many instances to be cheaper than to uncover and make good defects in drainage and asphalte on the outside, and it must be remembered that time is even of more importance sometimes to a military engineer than cost.

CHAPTER X.

SANITARY NOTES.

Sub-soil Drainage, Etc.—Suitable sub-soil drainage should always be provided, and in all cases care should be taken to ensure its remaining efficient as far as practicable, and free from contamination by sewage. All buildings should have a carefully-constructed damp-proof course, either of asphalte or pure Portland cement.

A layer of Portland cement concrete, from four to six inches thick, should be laid on the ground under all wooden floors to prevent damp from rising, and the growth of fungus.

Ample through ventilation should be provided under all floors.

When floors are re-laid, the space beneath should be disinfected.

Sites of Infectious Diseases to be Recorded.—A plan should be kept showing, in selected colours, the location and date of each reported case of infectious disease.

Periodical Examination of Drains.—The drains should be periodically examined from the manholes, and the clearing rods passed through them to ascertain that there is no obstruction.

"Sanitary engineers consider that an unusual smell is generally the first evidence of something wrong, and that, traced to its source, the evil is half cured. They inspect first the drainage arrangements. If the basement generally smells offensively, they search for a leaking drain-pipe, *i.e.*, a pipe badly jointed or broken by settlement, and these will often show themselves by a dampness of the paving around. If, upon enquiry, it turns out that rats are often seen, they come to the conclusion that the house drain is in direct communication with the sewer, or some old brick barrel-drain, and therefore examine the traps and lead bends which join the drain-pipes to see if they are gnawed or faulty. If the smell arises from any particular sink or trap, it is plain to them that there is no ventilation of the drain, and more especially no disconnection between the house and the sewer, or no flap-trap at the house-drain delivery into the sewer.

"If a country house be under examination, a smell at the sink will, in nearly every case, be traced to an unventilated cesspool; and, in opening up the drain under the sink, in such a state of things, they will take care that a candle is not brought near, so as to cause an explosion. If the trap is full of foul, black water, impregnated with sewer-air, they partly account for the smell by the neglect of flushing. If the sink, kitchen, and scullery wastes are in good order, and the smell is still observable, they search the other cellar rooms, and frequently find an old floor-trap without water, broken and open to the drain. If the smell be ammoniacal in character, they trace the stable-drains and see if they lead into the same pit, and if so, argue a weak pipe on the route, especially if, as in some London mansions, the stable-drains run from the mews at the back, through the house, to the front street sewer.

"Should a bad, persistent smell be complained of mostly in the bedroom floor, they seek for an untrapped or defective closet, a burst soil-pipe, a bad junction between the lead and the cast-iron portion of the soil-pipe behind the casings, etc., or an improper connection with the drain below. They will examine how the soil-pipe is jointed there, and, if the joint be inside the house, will carefully attend to it. They will also remove the closet framing, and ascertain if any filth has overflowed and saturated the flooring, or if the safe underneath the apparatus be full of any liquid. If the smell be only occasional, they conclude that it has arisen when the closet-handle has been lifted in ordinary use, or to empty slops, and satisfy themselves that the soil-pipe is unventilated. They, moreover, examine the bath and lavatory waste-pipes, if they are untrapped, and, if trapped by a sigmoidal bend, whether the trapping water is not always withdrawn owing to the syphon action in a full-running pipe. They will trace all these water-pipes down to the sewer, ascertain if they wrongly enter the soil-pipe, the closet-trap, or a rain-water-pipe in connection with the sewer.

"If the smell be perceived for the most part in the attics, and, as they consider, scarcely attributable to any of the foregoing evils, they will see whether or not the rain-water-pipes which terminate in the gutters are solely acting as drain ventilators, and blowing into the dormer windows. They will also examine the cisterns of rain-water, if there be any in the other portions of the attics, as very often they are full of putridity.

"A slight escape of impure air from the drains may be difficult to detect, and the smell may be attributed to want of ventilation, or a complication of matters may arise from a slight escape of gas.

"Neither are all dangerous smells of a foul nature, as there is a close, sweet smell which is even worse. Should the drains and doubtful places have been previously treated by the inmates to strongly-smelling disinfectants, or the vermin killed by poison, the inspectors of nuisances will find it difficult to separate the smells. In such a case, however, they will examine the state of the ground under the basement flooring, and feel certain that there are no disused cesspools or any sewage saturation of any sort. They will also ascertain if there be any stoppage in the drain-pipes by taking up a yard-trap in the line of the drain, and noting the re-appearance of the lime-water which they had thrown down the sink. And invariably, after effecting a cure for any evil which has been discovered, they will have the traps cleaned out and the drains well flushed.

"A thoroughly-drained house has always a disconnection chamber placed between the house-drain and the sewer, or other outfall. This chamber is formed of a raking syphon and about two feet of open channel-pipe, built around by brickwork, and covered by an iron manhole. Fresh air is taken into this chamber by an open grating in the manhole, or by an underground pipe, and the air thus constantly taken into the chamber courses along inside the drain, and is as continuously discharged at the ventilated continuations of the soil-pipes, which are left untrapped at the foot, or at special ventilating pipes at each end of the drain. This air current in the drain prevents all stagnation and smell.

"When a house is undergoing examination, it is wise to test for lighting-gas leakages, and there is only one scientific method of doing so, which is as follows:—Every burner is plugged up save one, and to that is attached a tube in connection with an air force-pump and gauge—the meter having been previously disconnected. Air is then pumped into the whole system of pipes, and the stop-cock turned, and if, after working the pump for some time, and stopping it, the gauge shows no signs of sinking, the pipes may be taken as in safe condition; but if the mercury in the gauge falls, owing to the escape of air from the gas-tubes, there is a leak in them, which is discoverable by pouring a little ether into the pipe close by the gauge, and re-commencing pumping. Very minute holes can be detected by lathering the pipes with soap and water, and making use of the pump to create soap bubbles.

"Besides the drainage, they will, especially if they detect a bad and dank smell, see if it arises from the want of a damp-proof course, or of a dry area, see if there be a wet soil under the basement floor, a faulty pipe inside the wall, an unsound leaden gutter on the top of the wall, or an overflowing box-gutter in the roof, a leaky slatage, a porous wall, a wall too thin, and so on.

"They will also keep an eye upon the condition of the ventilating arrangement, and whether the evils complained of are not mainly due to defects there. The immediate surroundings of the house will also be noted, and any nuisances estimated.

"Sanitary inspectors, whilst examining into the condition of the drains, always examine the water cisterns at the same time, and discover whether the cistern which yields the drinking water supplies as well the flushing water of the closets. They will also ascertain if the overflow pipe of the cistern, or of a separate drinking-water cistern, passes directly into the drain. If the overflow pipe be syphon-trapped, and the water rarely changed in the trap, or only when the ball-cock is out of order, they will point out the fallacy of such trapping, and, speaking of traps generally, they will look suspiciously on every one of them, endeavour to render them supererogatory by a thorough ventilation and disconnection of the drains."*

Smoke and Peppermint Tests.—If there is a suspicion that there is anything defective in the traps, apparatus, or joints of pipes, resulting in the emission of sewer-gas at improper places, the drains should be tested by either the peppermint or smoke tests.

The following are the instructions issued by the W.O. for the conduct of these tests:—

Instructions for.—1st. Carefully close all ventilating pipes from soil-pipes or drains; ventilating shafts from drains; inlets for fresh air to drains, or soil-pipes, etc.

2nd. Place about a table-spoonful of the crude oil of peppermint in the pan of the topmost w.c., and gradually pour in about a gallon of hot water. If the peppermint makes itself felt inside the house, or in the drain outside, it indicates a defect in the soil-pipes or drains. Care must be taken to tightly close the door of the w.c.,

* Parkes *Hygiene*.

and the person putting the peppermint down must not emerge until the test has been finished, as he, of course, would taint the air in his vicinity, consequently two persons must be employed in applying the tests. (Petroleum, terebene, oil of rosemary, ether, or other strong-smelling essential oil may also be used, but peppermint is considered the best for the purpose).

3rd. This should be repeated in the topmost w.c. in each house throughout the barracks, and also, if considered necessary, in the lower w.c.'s in each house; also in the sinks, baths, yard gullies, or any other outlet for water connected with the drains.

4th. The smoke test should be applied by using one of the smoke testing machines used for this purpose. "The Eclipse Smoke Generator" is a very good one, and can be obtained from Messrs. Burns & Baillie, 14, Newcastle Street, Farringdon Street, E.C., as shown below.

This should be applied by opening the drains outside of each house that contains closets, baths, sinks, or other fittings directly connected with the drains, or where the drains run under any portion of a building and forcing the smoke up the drain towards the house. If any smoke is visible in the house, or any smell of the same can be detected, it also indicates defects in the drains or pipes sufficient to admit sewage-gas into the house.

5th. The outside drains should also be tested in sections between the various traps and gullies; probably they are old brick or stone drains, and may leak and contaminate the earth, or there may be old disused drains from some buildings connected with them.

The Eclipse Smoke Generator, as mentioned above, is shown in *Fig.* 165.

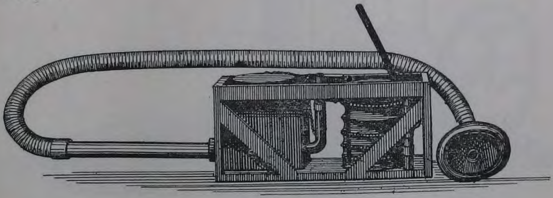


Fig. 165.

Messrs. Burns & Baillie claim that this is the only smoke generator, of any description whatsoever, which applies a positive test to drains. It consists of a double-action bellows covered with specially prepared leather, and a copper cylinder, which, in applying the smoke test, is used as the fire-box. The cylinder is surrounded by a square copper tank, which is filled with water, so as to keep the fire-box as cool as possible. A deep copper cover or float is placed over the cylinder, and, with the water, forms an air-tight joint between them. An indiarubber tube of special composition, to withstand considerable heat, is connected to the outlet of the machine and the drain to be tested, both ends being made perfectly tight, and all openings, such as ventilation pipes, plugged.

The float rises, unless the drain leaks badly, with the action of the bellows, and indicates correctly the condition of the drain. If it is tight, the float remains stationary; if it leaks, the float falls at a rate in proportion to the extent of the leak. The machine will, of course, prove the drain without smoke, but should a leak exist smoke is applied to find it.

With all other contrivances for applying the smoke test to drains, if smoke is not perceived it is assumed that the drain is tight, but it is impossible with their use to prove that it is so.

The price is £4 4s.; deal painted case fitted for machine and tube, and space for fumigating material, 10s. extra.

The Watts' Asphyxiator.—The asphyxiator (*Fig.* 166) is also a

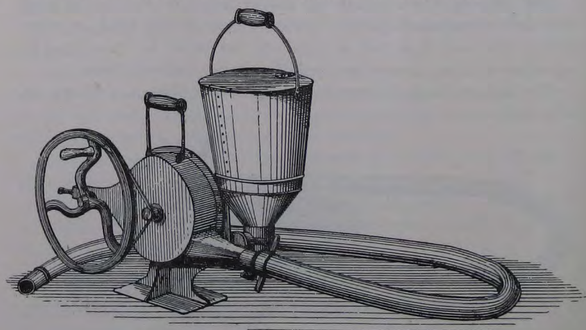


Fig. 166.

very good smoke generator, and has been much used by W.D. It has fewer working parts, and is much more convenient for use than the eclipse smoke generator. The patentees and sole manufacturers are Messrs. John Watts & Co., Broad Weir Works, Bristol. The cost, inclusive of extras, is about £5.

The Tyndale Asphyxiator.—This machine (*Fig.* 167), whilst possessing the good qualities of the last-named apparatus, is much more compact and convenient for transport. There are no small parts liable to be lost. The patentee is Mr. W. C. Tyndale, Sanitary Engineer to the W.D., and is manufactured by Mr. O. D. Ward.

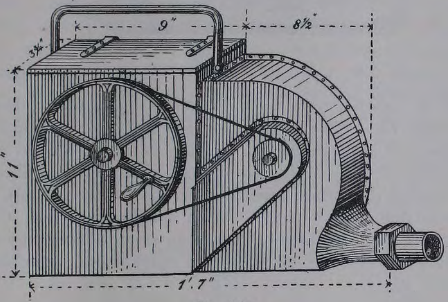


Fig. 167.

The Champion Fumigator.—The Champion fumigator (*Fig.* 168) is on a smaller scale, and is consequently not so well adapted for large drains.

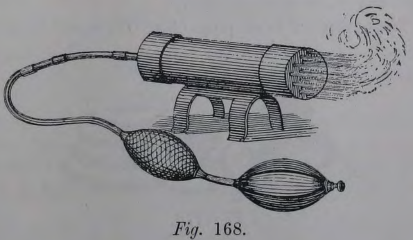


Fig. 168.

Drain Grenades.—The Banner patent drain grenade, or drain ferret

(*Fig.* 169), is very useful in connection with the scent test. It is made of thin glass, and is charged with very powerful pungent and volatile chemicals. When one of the "grenades" is dropped into a pipe, it breaks, and the effect produced by its contents is distributed only as intended, thus avoiding the mistakes which sometimes result from such tests, due to mismanagement or the careless handling of the necessary chemicals.

Fig. 169.

There is a grenade by Mr. Pain, which is similar to the above.

Hydraulic Test.—This is most conveniently done by stopping up the lowest end of the drain with a plug. If there is a disconnecting pit the drain should be plugged at that point, and then filled with water through the surface gratings. At the lowest gratings a few lengths of drain-pipe might be set on end in the gulley, and the joints made water-tight with cement, so as to equalize the levels. Any subsidence of the water after a few hours would indicate leakage.

If no such convenience as a disconnecting pit exists, the drain-pipe would have to be opened and stopped as above described.

Soil-pipes should be similarly tested, as a small accumulation on the inside of the pipe might be sufficient to prevent the passage of smoke, or peppermint, through a defect in the pipe, which, however, would give way under water pressure.

Drain Plugs.—Special drain plugs (*Fig.* 170) would be most useful

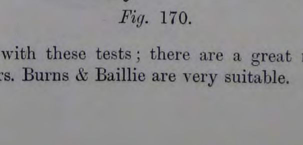


Fig. 170.

in connection with these tests; there are a great many varieties; those by Messrs. Burns & Baillie are very suitable.

Instead of having a bolt and nut by which to draw up the flanges, a brass tube and nut are used, to which an indiarubber supply tube can be very readily connected for use, either with water, smoke, or other tests.

They are supplied in sets comprising two sizes of brass flanges and six moulded indiarubber rings (with which any sized pipe from three inches to $6\frac{1}{2}$ inches diameter may be plugged), and one test cock. Price, per set, 34s. 9-inch expanding plug with test cock, 20s.

Another patent drain-pipe stopper (*Fig.* 171), for applying the water test to drains, or arresting the flow when they are under repair, etc., consists of a bag of indiarubber, or some such material, to which is attached a flexible tube with a tap at the end connected to a small hand-pump. The bag is placed in the drain before inflation, and by working the pump it is quickly filled with air under sufficient pressure to dam up the drain or prevent any escape of gas. Turning off the tap causes the bag to collapse, when it can be removed. These bags are made in different sizes to suit various diameters, and have secured the approbation of most leading sanitary scientists.

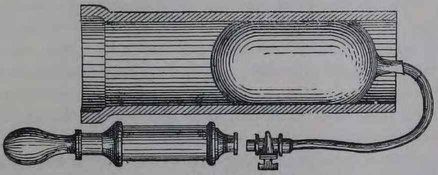


Fig. 171.

By Flushing.—The drains may be flushed separately, noting the speed at which the water travels, and whether or not accompanied by a deposit.

Analysis of Sub-soil Water.—In some cases it may be desirable to analyse the sub-soil water.

Old Culverts to be Destroyed.—Old culverts, if discovered, should be destroyed, as they harbour rats, and may prove to be sources of contagion.

Water Supply Pipes Disconnected from Sewer.—Direct communication between water mains and urinals, w.c.'s, or latrines should be cut off, special cisterns being provided for their supply, and the water in them should never be used either for cooking or drinking purposes, but reserved entirely for flushing the apparatus.

Underground Tanks.—The overflow from such tanks should invariably deliver on the surface, and never into an underground drain, manhole, or inspection pit, as trapping under such circumstances is sure to fail, and sewer-gas will be absorbed.

Water Mains Periodically Tested.—Water mains should be periodically tested, say once in six months, to ascertain that they do not leak, as leaky water mains may lead to in-suction of sub-soil pollution, in addition to entailing a waste of water. Deacon's water meter is well adapted for this purpose, on account of its extreme sensitiveness.

Disinfectants.—The term "disinfectant," which is now in general use, is employed in several senses. By some it is applied to every agent that can remove impurity from the air; by others, to any substance which, besides acting as an air purifier, can also modify chemical action or restrain putrefaction in any substance, the effluvia from which may contaminate air; while by others again it is used to designate the substances which can prevent infectious disease from spreading by destroying their specific poisons.

Experiments have been recently conducted to determine the action of various disinfectants, in a greater or less state of concentration, upon definite microbes, and it has been found possible to define the degree of concentration necessary to constitute some of the chemical substances so employed as germicides. Many powerful deodorizers are not germicides, unless highly concentrated, although they may for a time render organisms inert by preventing their growth without actually destroying them.

The following list, it is thought, may be useful, and is, therefore, appended:—

Disinfectants, Powerful or Germicides.—Capable of destroying the most resistant microbes, under certain stated conditions of strength, temperature, and time.—Fire, boiling water, steam, hot dry air, perchloride of mercury, carbolic acid, cressol, iodine, trichloride, osmic acid, permanganate of potash, iodine water, chlorine water, bromine water.

Disinfectants, Weak.—Capable of destroying microbes which are not in the state of spore.—The powerful disinfectants more diluted, chloride of lime, hydrochloric acid, sulphurous acid, salicylic acid, chromic acid, creosote, caustic lime, soda, and potash.

Antiseptics.—Capable of impeding or arresting the growth of microbes, but without necessarily destroying them.—Sulphate zinc, chloride lime, sulphate copper, sulphate iron, perchloride iron, boracic acid, borax, carbolic oil,* thymol,* oil of turpentine,* eucalyptus oil.

Aërial Deodorants.—For fumigation. Chlorine gas, sulphurous acid, nitrous fumes, ozone, euchlorine.

Powders for Disinfecting Purposes.—Manufactured and sold by the various makers whose names are given in brackets. Sanitary powder (Jeyes'), sanitas (Sanitas Co.'s), eucalyptol (Mackey, Mackey & Co.), chloride lime (Greenbank Alkaline Co.), surgical and tooth powder (Jeyes'), carbolic acid (Mackey & Co.), pinewood and eucalyptus (Mackey & Co.), boro phenol (Calvert's), kanphorkalk (A. Hornby's).

Liquids for Disinfecting Purposes.—Manufactured and sold by the various makers whose names are given in the brackets. Phenol (Bobemf's), perfect purifier (Jeyes'), terebene (Cleaver's), eucalyptol, camphorine, sulphenic acid, oxychlorogene, cresylic acid, carbolic acid (Mackey, Mackey & Co.), emulsion (Sanitas Co.), kresyline (Mackey's), pixine (J. Wheeler).

Use of Disinfectants.—In any district where an epidemic prevails or is threatening, disinfection of all water-closets, etc., should be carried on systematically, either with solutions of chloralum, cupralum, carbolic acid, Burnett's fluid, or perchloride of mercury.

Any manure heaps, or other accumulations of filth that might exist, which it is inexpedient to disturb or impossible to remove, should be covered with powdered vegetable charcoal to the depth of two or three inches, or with a layer of fresh dry earth, or with freshly-burnt lime, if charcoal cannot be obtained.

Cesspits and midden heaps may be disinfected with solutions of copperas (3lbs. to the gallon of water), or with cupralum or chloralum (1lb. to the gallon of water).

Cooper's salts might be used for the streets, lanes, and open courts. It need hardly be said, however, that in a town or district well looked after by the sanitary authorities no such filth accumulations as above mentioned would be allowed to take place at any time. (See *Handbook of Hygiene* (Wilson), page 385).

Condy's Fluid.—Condy's fluid, red and green, consists of a solution of potassium permanganate. It is essentially an oxidizing agent. It is odourless, and very useful for pouring down drains and w.c.'s. It arrests putrefaction for a short time, and prevents smell.

* Chiefly used as deodorants for concealing odours.

Chloride of Lime.—Chloride of lime is most powerful as a deodorant, and also as a sterilizer, especially at a high temperature.

Calvert's carbolated creosote is stated to be very effective for use in drains should any disease be known to be in the locality. The nett cost per gallon for not less than 40 gallons is 1s. 6d., the cask being 6d. extra. About $\frac{1}{4}$ pint would be added to an ordinary bucketful of water. It is readily applied to the drains by supporting the cask over a small water tank connnected by an overflow pipe and syphon with the drain.

Water can be turned on to the tank at any speed desired, and the proportional supply of carbolated creosote can similarly be regulated by a tap in the cask for drawing it off.

This plan has been adopted by Mr. C. Jones, C.E., Borough Engineer at Ealing.

The application of disinfectants for purifying houses, rooms, etc., after cases of infectious disease have occurred therein, is not, in the army, an R.E. Service; it is dealt with by the medical staff, so that the consideration of the methods of disinfection does not properly come within the scope of these notes.

As, however, I believe that R.E. officers in India have sometimes to perform this duty, I may mention that the ordinary plan is to close all openings or apertures in a house or room, and employ the fumes of sulphurous acid, chlorine, nitrous acid, or other gases, with the object of destroying the germs of disease. But as these gases are truly aërial deodorants, the object in view is not effected.

It is, therefore, thought best to give an extract from the report of a process recommended by Drs. Dupré and Klein, which has, in some cases, been applied by workmen employed by the R.E., in conjunction with the medical authorities.

Extract from a Report by Drs. Dupré, F.R.S., and Klein, F.R.S., on the Best Method of Disinfecting the Room where Enteric Fever has occurred.

"Recent investigations have shown that gaseous substances, such as sulphurous acid gas and chlorine gas, which have been often used for the purpose of disinfecting rooms and similar localities, cannot be relied on, and that the only disinfectant that can be depended upon to kill micro-organisms, particularly those capable of producing the infectious diseases, is a free application of a solution of perchloride of mercury. It is well to have this solution slightly acid, coloured also in such a way that it shall not readily be confused with drinks or medicines, and proper caution should be given to prevent accidents in its use.

"The solution is made by dissolving half-an-ounce of corrosive sublimate and one fluid ounce of hydrochloric acid in three gallons of common water, with five grains of commercial aniline blue, or ordinary violet ink, to give the fluid a conspicuously distinguishing character. Proper caution should be given to avoid accidents, as the solution is a deadly poison.

"The solution is easily made, keeps well, is very inexpensive, and should not be further diluted, and is easily applied. The use of non-metallic vessels (wooden or earthenware house tubs or buckets) should be enjoined on those who use it.

"The method of applying the disinfectant will, no doubt, vary under different conditions, but the following may be taken as an outline of the procedure that should be usually adopted :—

"The walls should be thoroughly stripped of all paper or other covering and scraped. All skirting should be removed. The floor boards should be taken up, and all rubbish and dust found in the space under the joists should be removed, care being taken that the scrapings, rubbish and dust are not thrown away, but are burnt, as they may contain infectious germs.

"After a thorough clearance has been made, as described above, the whole of the ceilings, walls, joists, architraves and window linings, and any other fixed woodwork in the rooms, together with the spaces below the floors, should be carefully washed with the solution of perchloride, prepared as above directed. The solution should be applied with a whitewasher's brush.

"A syringe should be used to squirt the solution into any nooks or interstices which the whitewasher's brush will not properly reach. Whenever used, the solution should be liberally applied, and should be allowed to remain overnight.

"Any dilapidated flooring or woodwork should be burnt, and only the thoroughly sound portions should be refixed, and these, before being fixed, should be thoroughly washed with the solution, allowed to remain over night, and afterwards washed with warm water, in order to remove the mercury.

"Ceilings and walls should be limewashed, and all fixed woodwork should also be washed with warm water, in order to remove the mercury." (See *Report on the Sanitary Condition of the Richmond Barracks, Dublin*, by Mr. Rogers Field, C.E.).

In executing the above recommendations, the workmen should be provided with special clothing, *e.g.*, white duck to fit over their ordinary apparel, respirators, goggles and gloves, and, further, they should be made to wash their faces before leaving work, at meal time, etc.

Sanitary Maxims.*

1. It is the duty of every householder to ascertain for himself whether his own house be free or not from well-known dangers to health.

2. This duty, imperative at all times, is of surpassing urgency in a house where a confinement is expected, or a surgical operation to be performed.

3. As a rule, the soundness of the sanitary arrangements of a house is taken for granted, and never questioned until "drain-begotten" illness has broken out. In other words, we employ illness and death as our drain detectives.

4. Whenever gas from sewers, or the emanations from a leaking drain, a cesspool, or a fouled well, make their way into a house, the inmates are in imminent danger of an outbreak of typhoid fever, diphtheria, or other febrile ailment, classed together under the term "zymotic," not to speak of minor illness and depressed vitality, the connection of which with sewer-gas is now fully established. Sewer-gas enters a house most rapidly at night when the outer doors and windows are shut, and is then perhaps most potent in contaminating the meat, the milk, and the drinking water, and in poisoning the inmates.

5. The more complete and air-tight the public sewers of a town, the greater the danger to every house connected with such sewers, if the internal drain-pipes of the house be unsound and not *disconnected.* In houses so badly connected, sewer-air is "laid on" as certainly for the detriment of health as coal-gas for illumination; and you can turn off coal-gas at the meter.

6. Every hotel throughout the kingdom and in our watering places, every house let as lodgings, ought to have its sanitary arrangements periodically inspected and duly licensed.

7. A house in which children and servants are often ailing with sore throat, headache, or diarrhœa, is probably wrong in its drainage.

* T. Pridgin Teale, M.A., as published by the "National Health Society," Berner's Street, London.

8. Scamped drain work is one of the most dangerous of the sanitary flaws of new buildings; it is also one of the most common and one of the most difficult to detect, and is rarely found out except by means of the illness it produces.

9. If you are about to buy or to rent a house, be it new or be it old, *take care, before you complete your bargain*, to ascertain the soundness of its sanitary arrangements with no less care and anxiety than you would exercise in testing the soundness of a horse before you purchase it.

10. If you are building a house, or if you can achieve it in an old one, let no drain be under any part of your house, *disconnect* all waste pipes and overflow pipes from the drains, and place the soil pipe of the w.c. *outside* the house, and ventilate it.

11. If there is a smell of drains in your house, or a damp place in a wall near which a waste pipe or a soil-pipe runs, or a damp place in the cellar or kitchen floor near a drain or a tank, let no time be lost in laying bare the pipes or drains until the cause be detected.

12. If a rat appears through the floor of your kitchen or cellar, and a strong current of air blows from the rathole when chimneys are acting and the windows and doors of the house are shut, feel sure that something is wrong with a drain.

13. If you are tenants and your landlord refuses to remedy the evil, do it at your own cost rather than allow your family to be ill.

14. Many a man who would be aghast at the idea of putting small quantities of arsenic into every sack of flour, and so by degrees killing himself and family, does not hesitate to allow sewer-gas to poison the inmates of his house, even in the face of the strongest remonstrances of his medical adviser.

15. A landlord may reasonably look for interest on money which he spends for the benefit of his tenant; but he is committing little short of manslaughter if, by refusing to rectify sanitary defects in his property, *he saves his own pocket at the expense of the health and lives of his tenants.*

16. If you be a landlord, don't intimidate your tenants or threaten to give them notice to quit if they complain of defective drainage or sewer-gas in the house.

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