Practical Sewerage and Sewage Disposal.

BY
H. C. H. SHENTON,
F.S.E., M.I.Mun.E., M.R.San.I.

Price 3/6 Nett.

S. EDGECUMBE ROGERS,
27A, FARRINGDON STREET, LONDON, E.C.

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PREFACE.

THE subject of Sewerage and Sewage Disposal is one upon which many books have already been written, but, generally speaking, they contain a considerable amount of matter which is more or less theoretical, and much information, of methods good and bad, from which the reader is left to draw his own conclusions.

The present work is intended to be more in the nature of a practical handbook, giving definite advice, as far as possible, to those who have actually to carry out work, omitting descriptions of unsatisfactory methods, and leaving the theoretical side of the question alone.

The work is divided into numbered paragraphs, each of which is indexed alphabetically to enable the reader to refer readily to any matter dealt with in the book. The author has also endeavoured to deal with as many points as possible in as small a space as is consistent with clearness. Thus the ordinary minimum gradients for sewers of circular or elliptical section are given, but elaborate tables and methods of calculation are omitted for the simple reason that in nine cases out of ten all that the engineer wants to know is the flattest gradient he can use and the velocity of the flow. For fuller information many admirable text-books exist to which reference should be made.

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LIST OF ADVERTISERS.

PRACTICAL SEWERAGE
AND
SEWAGE DISPOSAL.

CHAPTER I.

Preliminary Remarks.—Notes on the Design of Sewerage Systems.—Physical and Geological Character of the Ground.—Rainfall Drainage.—Foul Sewage Drainage.

(1) Mr. John C. Trautwine, in the preface to the first edition of his world-famous "Civil Engineers' Pocket-Book," alluded to certain eminent men, authors of standard works on engineering subjects, in the following scathing terms. He said: "although their books are the productions of master minds and exhibit a profundity of knowledge beyond the reach of ordinary men, yet their language is also so profound that very few engineers can read them. The writer himself, having long since forgotten the little higher mathematics he once knew, cannot. To him they are but little more than striking instances of how completely the most simple facts may be buried out of sight under heaps of mathematical rubbish."

It is the present author's object, above all things, to avoid coming under such a condemnation, and in writing a series of articles on sewerage and sewage disposal to do so in a simple and straightforward manner, avoiding as far as possible all difficult technicalities and obscure scientific expressions, and carefully explaining the meaning of all such words and expressions where their use cannot be avoided.

A man may be a very good sanitary engineer without knowledge of higher mathematics, chemistry, or bacteriology, each of which subjects can only be properly dealt with respectively by our friends the mathematician, the chemist, and the bacteriologist, who give the results of their labours to the engineer, but who, with all respect, must not poach on the engineer's preserves any more than he may poach on theirs. To quote again from Mr. Trautwine, "Let them work out the results and give them to the engineer *in intelligible language*. We could afford to take their words for it, because such things are their speciality; and because we know that they are best qualified to investigate them. On the same principle we entrust our lives to our physician, or to the captain of the vessel at sea. Medicine and seamanship are their respective specialities."

The author, as an engineer, therefore proposes to speak in detail of the practical design and construction of sewerage and sewage disposal works, taking the conclusions of mathematicians and scientists as a basis, but without attempting to take up the position of either.

Moreover, it is not proposed to give any description of historical matters, or to deal with obsolete methods, or to describe discredited systems, or to treat of anything beyond what will be of immediate practical use to those interested in the design and construction of new work or the setting right of old and defective work. It will be the endeavour of the author to do this in a form that will be equally useful and comprehensible not only to engineers and surveyors, but also to students of sanitary engineering and to those responsible for the welfare of municipalities as members of governing bodies, by enabling them to judge of the possibilities for the sewerage of new places, or to detect serious defects and see the possibilities for improvement in existing systems. It is also hoped to provide such authorities with some data which may be the means of enabling them to see that the money spent for works of sewerage is not wasted on imperfect work, which may fail in the future, or become an absolute danger to health and prove to be an utter waste of money.

Sewerage and sewage disposal are vital subjects, needing expert knowledge and careful separate attention and treatment for each case; nevertheless, certain points are so obvious that any man of common sense can grasp them and their importance, and, having done so, will not readily allow money to be spent upon work unless such points receive proper attention. It is for lack of attention to the principles of common sense, and not to any abstruse matters, that many failures are due. Thus, whilst the following articles are intended to form a practical handbook for engineers and surveyors, and a textbook for students, it is also hoped that they will be of a nature to be comprehensible and useful to any public-spirited person who may have the welfare of his district at heart.

(2) In preparing a sewerage scheme before deciding upon any system to be adopted, the first consideration must be the physical and geological conformation of the ground in the district to be drained. It must be borne in mind, first, that the whole of the rainfall over the district has to be accounted for in one way or another, either by evaporation or by soakage into the ground to an extent which will not leave the ground water-logged, or by running it off in water courses. This rain water must be diverted into natural channels which will carry it to streams, rivers, the sea, etc., or it can be carried to new sewers laid for that purpose. The excessive moisture in the ground itself can be carried away by subsoil drains.

To a great extent the physical and geological conformation of the ground determine what work is necessary. For instance, a district with a pervious stratum on the surface might appear to need very little drainage at all, as far as subsoil water was concerned. It would seem that surface water soaking into it would rapidly descend to a depth where it would be harmless. If, however, it were found that the pervious stratum was only a few feet thick, and that it rested on an impervious stratum, and that whatever water fell was retained, the case would be very different, and a large system of subsoil drains might be needed to keep the district from being unhealthily damp. Again, if a stream ran through the district it might drain it very effectually or enable the engineer to drain off the subsoil water with very little trouble or expense. A clay country, with an impervious surface, would, if it were flat, hold an immense quantity of water on its surface, which would have to be carried to drains of some sort. If the country were not flat, however, there would be natural water courses, and the surface drainage might very likely consist for the greater part of small drains to these courses, and subsoil drainage might be altogether unnecessary and impracticable.

The geological character of the ground at the outfall may often be of the greatest importance. If, for instance, the choice lies between a clay surface or sandy ground, it may be best to choose the sandy site, for the reason that the effluent could be treated much better on sand than on clay. Or, by choosing a site where an abundance of clean gravel exists, the cost of concrete walls and foundations may be materially reduced; or the gravel itself may form a natural filter.

(3) In preparing a new sewerage scheme it is essential that the engineers' preliminary observations should include not only the particular district under consideration, but as much of the ground outside its limits as may form part of the same natural drainage area. Surface or subsoil water from the outside country may come into the district under consideration and have to be drained away. It may also be possible for two or more districts to combine their sewerage systems so as to run to a common outfall. Future possibilities of this kind must receive consideration as well as the probable and possible growth of the town to be drained. Due allowance must be made for the increase of population, each town needing careful consideration on its own merits. In some cases it will not be sufficient to base calculations upon the increase during past years, as it may be altogether misleading.

(4) The importance of having subsoil drains has been demonstrated many times. The unhealthiness of a saturated soil is well known, and it has been found that a reduction in the death-rate from phthisis has followed the drainage of the subsoil in towns, and that the death-rate from this cause is greater on a retentive formation than on an impervious one, except in the case of sea-water saturation, which does not appear to be unhealthy. Moreover, the difficulty of laying sewers in wet ground may be so great that subsoil drainage may actually save expense in constructing and maintaining the sewerage system. They may also improve the value of land for building purposes.

It is a most important fact, and one to be clearly understood, that the subsoil drains must never be combined with the foul sewerage system. Where they occur with the combined system they must be quite distinct from it. In the separate system they may be separate from the clean surface water sewer or combined with it. The reason for keeping subsoil drains distinct from foul sewers is that they would be likely to conduct sewer gas to unsuitable places, and sewage might flow back into the open-jointed subsoil drains and saturate the soil under houses or elsewhere. And when the springs were high enormous quantities of land-water might get into the sewers and increase the flow out of all proportion to the works.

The next thing to be considered with reference to the rainfall drainage is whether any old sewers, culverts, drains, etc., exist which can in any way be utilised. Such old sewers, though very likely quite unsuitable for foul sewage, may do excellently for clean surface water or for subsoil water.

(5) Having considered the question of the water due to the rainfall, and ascertained the possibilities as to whether there will be much or little to be dealt with in the sewerage scheme, the second thing to be borne in mind is the question of the disposal of the whole of the water supply of the district, which, whether used for drinking, washing, sewer flushing, or other purposes, can be reckoned as the amount of the foul sewage. In doing this care must be taken not to overlook the fact that some of the rainfall must of necessity reach the foul water sewers from surface water gullies in places such as crowded streets, where the water would be too impure to allow it to run to any clean water drain or natural channel; also in the most perfect separate system it would probably be impossible to exclude all rain water from roofs. These matters will be dealt with later

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CHAPTER II.

Ordinary Method of Procedure for Local Authorities—Local Government Board Loans, Regulations, and Requirements—Preparation of Schemes for Presentation to the Local Government Board.

(6) When a local authority decides upon carrying out a sewerage scheme, and the expense of the works proposed is likely to prove too serious a burden to the ratepayers of the district to be benefited, it is customary to borrow the money under the sanction of the Local Government Board. Local authorities are allowed by the Public Health Act of 1875 to borrow money for carrying out works of sewerage, etc., but this money may only be borrowed with the sanction of the Local Government Board. The money is borrowed on the security of the rates, and is not allowed to exceed in amount the assessable value of the district for two years. This sum must include all outstanding loans, if any have been previously contracted.

If the loan required exceeds the assessable value for one year, the Local Government Board are not allowed to sanction the loan until one of their inspectors has held a local inquiry. Money may not be borrowed for a longer time than sixty years, and has to be paid off within that time. It may, however, be borrowed for such shorter time as the local authority, with the sanction of the Local Government Board, determine. The local authority have either to pay off the money borrowed by equal annual instalments, or they may in every year set apart a certain sum as a sinking fund, and invest it. This sum must be such that, with compound interest, it will be sufficient to pay off the money within the period sanctioned.

(6a) Before the Local Government Board will sanction a loan they require to see plans and sections of the scheme proposed, together with detail drawings and an estimate, and, unless the scheme submitted is of a character of which they approve, they will not sanction the loan. The estimates submitted to the Local Government Board have to be prepared upon forms supplied for the purpose by the Board. The engineer should prepare (a) a 6-inch ordnance map of the district, showing the boundary of the particular parish or ratable area by a single red line; (b) a 25-inch plan showing the lines of the sewers and the positions of all works; (c) sections of the sewers to the same scale showing sizes of sewers, depths, levels, and gradients, etc.; (d) detail drawings of sewers, manholes, disposal works, and of any other works for which the loan is required. No drawings should exceed double elephant size.

(7) On the estimate forms there are certain directions and suggestions, referring to the general design and details of the work.

(8) The requirements of the Local Government Board with regard to sewerage works are not officially published, but are fairly well known to engineers who have had much to do with the preparation of schemes for the approval of the Local Government Board.

The Board relies upon the judgment of its officials and inspectors in deciding as to whether a scheme is fit for approval or not. There are certain fixed requirements for sewers, such as that a manhole or lamp-hole shall occur at every change of gradient or direction; but each scheme is considered on its own merits, and the engineer who presents a properly designed system of sewers need not fear criticism.

In preparing a scheme for presentation to the Local Government Board, the engineer should make no statement which he is not able to verify at once—e.g., he should have ready to hand detail estimates of each piece of work for which a lump sum has to be given on the L.G.B. form. He may be asked for them at the inquiry. If he shows a retaining wall of a certain thickness he should have his calculations ready to hand. If he states that land can be purchased at a certain figure, he should hold a provisional agreement with the landowner showing willingness to sell at that figure.

(9) If the estimate for the work is exceeded after the sanction of the Local Government Board has been obtained to the loan, a supplementary estimate must be prepared and submitted and approved before any further loan can be sanctioned. The estimates have to be signed by the engineer.

The Local Government Board have no liking for supplementary loans. Such loans should not be required for extensions of the works, and are only necessary when the cost of the work, as originally designed, has exceeded the estimate. Extensions require separate loans, which should be asked for before the work is put in hand.

CHAPTER III.

Notes on the Design of Sewerage Systems (Continued).—Outfalls—Their Position, Number, Size, etc., discussed—Data Needed by Engineer in Designing New Systems—Manufactory Refuse.

(10) The position of the outfall or outfalls must be decided upon before the actual course for the sewers of a district can be properly planned. The lines of the natural drainage of the land will be the best guide, but it will sometimes be found worth while to follow other courses for the sewers in order to secure good outfalls. There are many cases where it has been found worth while to carry sewers under rivers or through hills or across valleys or aqueducts, or through syphons. It is a good principle, however, to keep the main sewers at a low level. A sewer is sometimes laid half-way up a hill when it should be laid along the bottom of the valley. A sewer at the bottom of a valley will

drain everything above, whereas if a sewer is constructed at a higher level than is necessary it leaves areas below it undrained, and this may cause trouble in the future when new houses are built.

(11) The natural watercourses of a district should not be covered or converted into sewers. If this is done, the sizes of the sewers will probably have to be larger than would otherwise be necessary, the natural channels for surface water being covered up. Wherever possible, it is, of course, cheaper and better to leave the natural channels to do their work of surface drainage.

(12) The engineer will require data showing approximately the quantity of sewage to be expected from various sources in the district or town, and the total volume of sewage that may be expected at the outfall. Such data are needed by the engineer before he can prepare a proper scheme, and they must be collected carefully.

Calculations as to the amount of sewage to be dealt with will be based on the rainfall, water supply, and population. The flow of sewage from houses varies in volume considerably, according to the habits of the people, while that from manufactories is generally discharged at all hours of the day or night. Provision has to be made for this irregular flow of foul sewage, both in the design of the sewers and in that of the disposal works. It has been estimated that for a safe allowance the discharge into a foul sewerage system may be as much as 70 per cent. of the daily flow in twelve hours and 8 per cent. of the daily flow in one hour. Following this rule, if a district had a flow of 500,000 gallons a day, the outfall sewer would have to be of a size to accommodate 40,000 gallons per hour. The flow of sewage in flat districts, or in places where houses are far apart, will not fluctuate to anything like the same extent as it will in districts where the houses are close together or the sewers laid at a steep gradient. The foregoing remarks refer to foul sewage. The surface drainage from the backs of houses and yards, and from gullies in crowded streets, has to be carried, as a rule, to the foul sewers for reasons already mentioned. The amount of the rain water to be expected from these sources can be calculated. It should be remembered, in doing so, that the sewers must be of a size to take all the water during the greatest storm or rainfall.

(13) The fact that the discharge from water-closets does, or does not, form part of the sewage in a system

makes practically no difference in the quality of the sewage. Of course, the drainage from water-closets always should go to sewers, but there is still an ignorant belief among some people that something is to be gained by excluding it from the sewage of a town. Analysis has shown that there is very little difference in the chemical composition of the two kinds of sewage mentioned—viz., that from water-closets and that from sink gullies, etc. That this is so may be the more easily grasped if one realises what ordinary sewage from gullies or "slop water" is. To quote from a modern book, "It contains the liquid excretions of the inhabitants, the foul waters from the kitchens, containing vegetable and animal matters, bits of fat and other refuse, the suds from the washing of dirty linen, cooking utensils, and the people themselves, holding in solution and suspension soap, fatty acids, and the exudations from the human skin. Such soapy slops, as everyone is aware, if allowed to stand for twenty-four hours, become most foul and offensive. Then there is the dirty water from the washing of floors, the swilling of yards, the solid and liquid excretions of animals in the streets, the drainage from stables and pig-styes, the blood and other animal matters from slaughter-houses, silt from road sweepings, etc." (Barwise, "Sewage Purification.") Thus one may readily see the fallacy of taking trouble, as was formerly done, in some obsolete systems, to exclude water-closet drainage from town sewers with the idea of keeping the sewage purer and free from disease germs.

(14) Careful note should be taken of any drains or sewers existing in a place which has to be newly sewered; also the number of houses containing water-closets, baths, or other sanitary appliances, should be noted.

(15) Careful attention should be given to the volume and character of the discharges from any manufactories, breweries, etc. In the case of breweries it should be the object of the engineer and of the local authorities to make arrangements that the refuse may be filtered or otherwise treated before it leaves the works. It may also be found well to adopt some such course with other manufacturing refuse. Although it is possible to treat brewery refuse with the other sewage at the purification works, it will greatly assist if the brewers will filter it and strain off the hops before discharging into the sewers. This method has been adopted with success by the author, by using a coke filter near the brewery.

CHAPTER IV.

Position of Outfall—Test for Effluent—Gravitation Sewers—Lifting sewage.

(16) Under no circumstances should foul sewage be taken into a stream or river without careful purification. It is even questionable whether in these days it should be taken into the sea in its crude state. Certainly there is no excuse for taking sewage into the sea at any place where it will become a nuisance without purification.

Frequently it will be found possible and desirable not to conduct foul sewage towards any stream or river at all, but, on the contrary, that it should have its outfall as far from the river as possible. The reason is clear. In these days it is quite inadmissible that foul sewage should be allowed to run into a river; it must always be purified first. Prevention is better than cure, and therefore the further the works are from any river the better. If the effluent is allowed to run into a long ditch or small stream for some distance before it reaches the river any neglect or mismanagement will soon be apparent by the fouling of the channel. With proper treatment the effluent should be so pure that the channel is kept clean. If this ditch or channel is about half a mile long there could be no better test for the effluent.

(17) A gravitation scheme is, no doubt, the simplest and cheapest where practicable, both as regards first cost and maintenance; but it may often happen that there are small districts or groups of houses situated at such a low level as to prevent their being connected directly to the main sewers, or, if connected, it may involve making the depth of the main sewers very great, so as to add considerably to their cost. There are several methods by which a small quantity of sewage may be raised by automatic apparatus at a comparatively low cost, such as by a small water motor, or other special machinery, which can be obtained for the purpose from well-known manufacturers. Such appliances are at the present time in successful operation in many places, and will be referred to later on. Again, such small districts may be treated separately by means of small local sewage purification works, which can be made to act automatically. Such works properly constructed need very little attention, and are quite efficient.

(18) In cases where the sewage has to be raised by artificial means, before choosing the outfall it is necessary to consider how the sewage is to be raised. It may sometimes be well to consider the advisability of making use of existing machinery or power, to enter into an arrangement, for instance, to use the steam from the boilers of an existing water works, or the current from an electric power-station, etc., by which means much expense may be saved both in erection of machinery and in running it.

(19) That nothing is impossible in engineering is a maxim which should be kept in mind with regard to sewage works, and especially with regard to obtaining a proper outfall. Without doubt the fewer outfalls the better, and if possible there should be only one. A multiplication of such places, especially when sewage has to be purified, will be likely not only to add considerably to the cost of construction, but yet more seriously to that of maintenance. The cost of the maintenance of outfall works is sometimes a very much more important point than the cost of construction.

(20) If possible a spot should be chosen for the outfall to which the whole of the sewage may gravitate. The outfall to a large town should be kept as far from houses as possible, but there should be no necessity to carry it to a great distance in putting in a new system. It is possible if the outfall works are properly designed, constructed, and attended, that there should be no noticeable smell outside their area. Of course, where crude sewage is discharged in great bulk it must smell at the mouth of the sewer, however perfect the system. In the case of a small town or village it is actually an advantage not to have the disposal works too far away or out of sight. They should be in a place where they will be under continual public observation, and then if any smell should arise its cause will be investigated and the matter set right, and there will be no chance of neglect, which has often been the only cause of the failure of works. It cannot be too clearly understood that sewage disposal works of proper design do not smell unless they are neglected.

The best way of proceeding is first to select a site for the outfall, and then to see how the sewage can be conducted to the place. As already stated, it does not always follow that sewers are best laid along the natural fall of the ground. Great saving in expense may sometimes be effected by crossing a valley or river, or by tunnelling through a hill, or by carrying a sewer for some distance falling the reverse way to the ground level, or by carrying the sewer as a syphon under a river, etc.

A really good site for an outfall that will enable an economical scheme to be carried out should not be abandoned because a small section of the district or a particular building or group of buildings cannot be drained to it by gravitation. It will be found in such cases best either to resort to lifting the sewage of the small district or to make a second outfall for it elsewhere.

(21) In the case of an absolutely flat district of large extent, where a gravitation outfall is impossible, it will generally be found best to divide it into sections and let the sewers of each section gravitate to a separate lifting station. At each station the sewage can be lifted from the level of the deepest sewer to the highest point of the next section, or to a separate intercepting sewer running to the main outfall. The number of these lifting stations will be a matter for careful judgment. In the one case it must be remembered that the greater the number of lifting stations the greater will be the cost for construction and maintenance, and in the other case that the fewer number of such stations the more sewage will have to be lifted at each, and the deeper will be the sewers, meaning increase cost for their construction and maintenance. Probably in most cases it will be found that the fewer the lifting stations the better.

No sewage should be allowed to run to a lifting station if it can reach a convenient outfall by gravitation. By carefully arranged intercepting sewers and by excluding the rainfall as much as possible the lifting may often be reduced to a minimum.

(22) It will be well to avoid placing the outfall and the sewage disposal works near to gas works or other places producing noticeable smells. With regard to sea outfalls, or outfalls near tidal estuaries, it will be well wherever possible to avoid places where large flats of smelling mud exist at low water, or where seaweed accumulates. There are many places where a strong smell exists from natural or artificial causes, and the engineer who constructs an outfall sewer near them will for ever after be held responsible for the smell, notwithstanding the fact that his work may have nothing to do with it. The engineer would also do well to have samples of the river water analysed, whenever it is proposed to discharge effluent or storm water into a river, in order to be able to compare them with any analysis made after the works are constructed. It is possible that the new works

may be regarded as causing a contamination or chemical change in the river water which is due to other and older causes. At some places the sewage effluent will be found to be considerably purer than the river into which it is discharged.

CHAPTER V.

Notes on the Design of Sewerage Systems (Continued).—Systems of Sewerage—Intercepting Sewers—Preliminary Survey—Best Courses for Sewers.

(23) Although there are in theory several systems for town sewerage, practically speaking there are only two—(1) the combined system, (2) the separate system.

In the combined system the surface water and the foul sewage are carried in one sewer. In the separate system they are carried in separate sewers.

With regard to the majority of cases it may even be said that there is only one system, viz., the partially combined or partially separate system, for it is obvious that the cases in which all rain-water can be absolutely excluded from the sewers must be very rare, if not impossible.

(24) It will be seen at a glance that it would be wrong to adhere rigorously to any particular system for all cases, or even for any particular case. The best system will probably always be a modification of the two already mentioned. At the same time, speaking broadly, it is generally admitted that the separate system is not only the most perfect, but the most economical. Though we cannot exclude all the rain water, the bulk of it may be kept out.

(25) In the case of separate sewers for clean and foul water, fewer traps will be needed, and the chances of foul gases escaping at wrong places are reduced. There will be no chance, for instance, of sewer gas escaping from unsealed surface gullies in hot weather if they form part of the clean water system. Another great advantage in the separate system is that the quality of the foul sewage will be more uniform, and its flow more regular—facts which help greatly in the process of purification, as will be demonstrated later on. Also, the amount of sewage likely to flow through the foul sewers can be ascertained

with such accuracy that it will not be difficult to construct them of a size suitable to the amount that must flow through them. If such sewers have to be made of a size to take the rainfall of the district during a storm, as may be the case in the combined system, they must obviously be a great deal too large ever to flow sufficiently full to be properly self-cleansing without very considerable flushing arrangements. It will be seen that if flushing arrangements are needed in the case of a small separate sewer they will be very small by comparison. This is an important matter in the saving of expense in a new scheme. It also must be remembered that in large sewers considerable volumes of sewer gas may be accumulated. They are also difficult to ventilate efficiently. The clean water sewers in the separate system will be altogether a cheaper matter, then, to construct and maintain than foul sewers of the same size ; there should be no need for flushing arrangements, and the construction need not be so elaborate as for foul sewers. As already stated, old sewers and culverts may be utilised for clean water drains. It may often happen that short sewers with outfalls into existing watercourses may be constructed for surface water, so that only a small separate sewer for foul sewage is needed, where in the combined system a large sewer for all purposes would have been required, which would have been expensive to build and to maintain.

(26) It may be argued in favour of the combined system that the rain water itself would be of use in flushing the sewers. The mistake of relying upon any such arrangement will at once be seen when it is remembered that during the dryest weather, when there is the most need for sewer flushing, there can be no flush.

With regard to the combined system, it is sometimes possible by the use of storm overflows to keep the sewers of a moderate size. It is, however, objectionable to allow even dilute sewage to flow into rivers or the sea, for though the water in the sewers may be clean rain water, it may yet carry with it paper and solid matter at any moment.

(27) It is no doubt a disadvantage in the separate system that foul drains may through carelessness be connected to the clean water drains, and vice versa. But on the other hand, it may be argued that such mistakes should not occur where there is intelligent supervision of work.

It would, in a perfect system, be an excellent thing if each house in a new town had a separate system of drains for rain water and for foul sewage where the town is sewered on the separate system. It must be owned at once, however, that there is a very serious drawback to the arrangement—viz., that bath and sink wastes would in time without doubt be carried to rain water heads, and through this and other causes foul sewage would get into the clean water drains, and it would be very difficult to discover where it came from. The extra cost of two systems of drains would also be a serious outlay to private owners.

(28) Where subsoil drainage is required with the combined system it is customary to lay the pervious open jointed or perforated pipes by the side of the sewer in the streets. They are sometimes laid below the level of the sewer. But care must be taken that this does not ultimately cause a disturbance or settlement of the ground near the new sewers or cause the sewers themselves to sink.

(29) Sewers in either system are laid so as to slope to their outfall, and where this is impossible they are made to fall to a lifting station, or, if necessary, to several lifting stations, where the sewage is raised so that it may gravitate to its outfall. There are instances where the sewage of a town is pumped through miles of main to reach the disposal works. There are various methods of lifting sewage, which will be referred to later.

(30) It is often advantageous to divide a town into districts, with a sewer to intercept the sewage of each particular district, and carry it to the outfall. Thus it may be possible to do without any very large sewer, to avoid the possibility of the lower parts of a town becoming flooded, and to let the sewage from the upper parts gravitate to the outfall, and also to lift only the sewage of the district which lies too low for its sewers to descend to the outfall. These sewers, which take or intercept the sewage from a particular district, and carry it to the outfall, are called "intercepting sewers," and, naturally, they generally run more or less along contour lines.

Intercepting sewers may often be laid to carry off the sewage of the greater part of a district to a gravitation outfall, while the sewage of the lowest parts is raised artificially to the same outfall.

It is often much more economical to divide a town into a number of districts, each having its own intercepting sewer, as already described, than to let all the sewers form one large system. In the former case no very large sewers will be needed. Large sewers will be found very expensive to construct, and a long length of sewer of small size will probably be found cheaper than the sewer of larger diameter thereby avoided. If the sewage from the higher districts does not have to be carried to the sewers serving the lower districts, there will not be the same chance of floods in times of heavy rainfall that must exist where all the sewers are connected. The use of intercepting sewers serving the high districts is doubly advantageous in the case of a tide-locked outfall, as will be explained later. Again, in the event of a town extending, a new district can with advantage be served by a separate intercepting sewer when it might be impossible to make the original outfall sewer take so great a quantity of sewage, in addition to the flow for which it was designed.

(31) If the country to be sewered is of such a character that it is difficult to judge, from inspection and from the ordnance plans of the district, in what directions the sewers may be most advantageously laid, it will be necessary for the engineer to have contour surveys made of those parts presenting difficulties as to the disposal of the sewage. It is necessary that he should have a thorough grasp of the lay of the land. For instance, a town on the side of a hill with a good site for a sewage outfall at its base would probably need very few levels to be taken in order to ascertain the best position for sewers, it being clear from inspection that good falls could be easily obtained. On the other hand, if the town were situated on flat or slightly undulating ground, where a fall would be difficult to obtain, and where a matter of a foot or two might mean having to pump the sewage or not, very careful levels would probably have to be taken before the engineer could come to a right decision in planning the courses of the sewers.

(32) When the courses of the proposed sewers are chosen, levels should be taken along their lines at every pronounced change in the surface of the ground, and also at the inter-sections of roads. Care should be taken to ascertain the levels and positions of existing water, gas, or electric mains, tramrails, etc. Any watercourse, such as a stream or ditch, which has to be crossed, should have the water level and profile at the bottom recorded.

(33) It may also be very necessary in cases where the foundations are treacherous to have trial hole borings made along the courses of sewers, particularly so in the case of the outfall sewer. A bad foundation may cause one route to be more expensive than another.

(34) It will be found best to lay sewers in public roads in preference to private property. It is essential that a certain number of inspection manholes should be made along the course of each sewer, and if these are made on private ground it will be practically impossible to inspect and clean the drains properly when required without serious inconvenience to the owners of property. Sewers on private ground will probably be expensive in the first instance, owing to claims for compensation. Local opposition may also be aroused by laying them in such positions.

(35) Sewers should be laid in the roads below the levels of the floors of all basements and cellars, and it is essential also that they should be constructed at such levels that all yards behind houses can be drained into them. For this, and for other reasons easily seen, it is necessary before designing any new scheme of sewerage that careful levels should be taken over the district intelligently by a competent surveyor.

CHAPTER VI.

Notes on Design of Sewerage Systems (continued).—Methods of Crossing Rivers, Valleys, etc.—Syphons, Lifting Arrangements, Pumps, the Shone System, the Adams Lift, the Liernur Improved Pneumatic System, Electric Pumping, Various Motors.

(36) When a river has to be crossed and a bridge is not available, the sewer may be carried under it in the form of an inverted syphon. Such syphons are used also for crossing valleys, or passing under some otherwise impassable obstruction in the street (a thing which should, however, be avoided if possible). They are constructed with a vertical or sloping drop on either side. Cast-iron pipes are generally used for the purpose, and, as they will always be under pressure and flowing full, they should be of circular section. In the case of large sewers they are sometimes lined. The pipes may be laid by lowering them into position from the surface from barges, etc., or it may be found better to fix caissons or coffer dams in the river bed, and, having pumped the water out, proceed to construct the sewers at the bottom of the river. The syphon must be weighted and held down to prevent its floating when empty. It should have foundations sufficient to protect it from undermining

currents. One method of making such foundations is to drive two rows of sheet piling across the river, and, having excavated the material between them, to fill concrete in. It is well, if possible, to make the syphons in duplicate, so that, in the event of one becoming stopped up, the sewage can be diverted into the other, and the stopped-up syphon can be pumped and cleaned out. Manholes should be provided on both sides of the river, so arranged that any stoppage can be removed from the syphon. Generally there is a catch pit at the bottom of one or both of these manholes to catch grit. Also there should be penstock chambers at each end of the syphon, so that the flow of sewage may be stopped while it is being cleaned. Thus the cleaning manholes descend to the level of the lowest part of the syphon, and the penstock chambers are level with the sewer at the top of the syphon. The descending arm should be ventilated at the bend to prevent an air lock.

(37) Syphons should be constructed of such a diameter that the flow of sewage through them may have the same velocity as it should have in sewers of equal size. The difference in level of the two ends should be equal to the fall required for an ordinary sewer, flowing full, of the same diameter and of the same length as the syphon—*i.e.*, the exact length of the pipes forming the syphon, not the horizontal distance between its ends. The required velocity of flow may be obtained by reducing the diameter of the pipes if the fall available is insufficient to produce it. As a rule, sewers run about half-full, but the syphon always runs full bore. If the size and the hydraulic gradient of both are the same it will be clear that the velocity of the liquid passing through the syphon will be less than that in the sewer, and if the velocity of the flow is reduced matter held in suspension will have time to be deposited. It is a good thing when constructing a small single syphon to insert a loose chain or wire which can be moved backwards or forwards from either end of the syphon to clear stoppages when they occur. Sewers may also be laid under a river by tunnelling, or carried across a valley by an aqueduct, or on an embankment, or trussed between piers.

(38) With regard to lifting arrangements, pumps of several kinds are used. An ordinary plunger or lift pump may be used, or a centrifugal pump, and for small installations where plenty of power is available a chain pump may be used with advantage. The centrifugal pump is very suitable for sewage lifting, and is likely to

be more economical for low lifts than other kinds. The wear from grit is not so harmful to centrifugai pumps as to piston pumps, and they can be driven direct from electric motors or engines without gearing.

(39) Where a number of lifting stations are needed, Shone's compressed air system is used in a great many places. In this system the sewage gravitates into a receiver, and in filling the receiver it opens a valve which admits compressed air. The compressed air forces all the contents of the receiver into a sewage rising main or high-level gravitating sewer. The compressed air for actuating this ejector is produced at a central station and carried in iron pipes to the several lifting stations.

(40) Where the sewage from a low district has to be raised while that from higher ground above it gravitates to an outfall, it is possible to use the energy of this descending liquid to lift the sewage from the low-lying district. This may be done with Adams's sewage lift, in which the drainage from the lower district runs to a receiver, and is raised to level of the gravitating high-level sewer by air compressed by the fall of the sewage from the high district. Some of the high-level sewage runs to a tank which, when full, discharges its contents automatically into a down pipe running to an air compression chamber. In this manner the air is compressed and the sewage in the low-level sewage receiver is expelled and lifted to a higher level by the entrance of air from the compressed air chamber, to which it is connected by a pipe. With this lift, water is more generally used for compressing the air than sewage. In places where the water supply is abundant it may be used for lifting the sewage of flat districts with advantage, the lifts being entirely automatic. (*See also* Addendum, p. 148.)

(41) The Liernur improved pneumatic system is also well deserving of attention. As in the case of the Shone System, the town to be sewered is divided up into a number of districts or sections. Each section is sewered upon the separate system by means of cast iron pipes of small diameter. These pipes are made to gravitate to an underground retainer called a district cylinder, or if gravitation is impossible they are laid flat, or in some cases even uphill. Sewage is made to flow through these pipes at intervals by the creation of a vacuum in the district cylinder. The flow thus induced is very rapid, so that the pipes are well flushed out at every discharge. The district cylinders are each connected to a reservoir at a central station, to which the sewage flows when the

air is exhausted. The whole is worked by means of a vacuum pump at the central station. With a carefully designed system, in which full advantage is taken of the natural fall available and an artificial flow or acceleration is induced by means of the vacuum pump only to the extent that is absolutely necessary, it is probable that a very great saving could be effected by the use of this system.

The Liernur System has been in operation at Trouville-sur-Mer for over ten years, and in this country it has been working for some years at Stansted, in Essex.

(42) It is also possible to divide the town and district into sections, as in the Shone system, and to instal electric motors and pumps instead of ejectors in each section to raise the sewage. At the first glance one might reasonably suppose that such a system would be more economical than one worked by means of compressed air, but it must be admitted that hitherto results have been in favour of the ejector. This is due to several reasons, among them being (1) The great difficulty of keeping electrical plant in proper condition in damp situations, and the consequent heavy maintenance expenses both for skilled labour and for renewals. (2) The greater wear and tear of the working parts of electrically driven pumps as compared with the ejector, in which the moving parts are reduced to a minimum. However, each case must be judged on its own merits, and the system of lifting sewage in this manner from several stations by electric motor pumps may have special advantages under certain conditions.

43. Steam, gas, produce gas, and oil engines, electric motors, or turbines may be used advantageously for driving sewage pumps, also windmills. It will always be necessary in the case of windmills to provide for the time when the wind fails. Also water raised to a small reservoir by a hydraulic ram or other means may be used to drive a motor or work a lift.

CHAPTER VII.

The Arrangement of Sewers.—General Principles of Design of Sewerage Systems—Positions of Sewers—Flushing—Levels—Gradients—Velocity of Flow in Sewers.

44. After, and not until, the site for the outfall has been chosen, the courses for the main sewers and their

branches can be decided upon. They should be laid out on a plan of the district, and for this purpose, if necessary, a contour plan should be prepared. The 6 in. ordnance maps give contour lines at every 50 ft., besides spot levels; the 25 in. ordnance maps also have many useful spot levels. The engineer should supplement these by levels taken along the valleys and elsewhere before he fixes on the courses of his sewers.

45. To give a few general principles, all sewers should be laid along the shortest and most direct courses. Long branches or mains should, if possible, be avoided. Sewers should be carried near to all houses or other places in the district needing drainage. They should be laid in such positions that the drains from houses, etc., discharging into them may not be of greater length than can be helped, and that the house connections may have a fall of, say, about 1 in 40. Dead ends in sewers should be avoided wherever possible. Sewers laid with dead ends and those with flat gradients will not keep clean without flushing, and may therefore be expensive to maintain in an efficient condition. If they are not flushed they may become blocked up, and certainly will smell badly. It is best to fix upon the positions of the road gullies before laying down the lines of storm water or combined sewers. They are generally fixed not more than 200 ft. apart in busy streets, and not more than 600 ft. apart in suburban streets. They often have to be fixed much closer together. Sewers should be laid in perfectly straight lines between the inspection "manholes." These places for inspection should occur at every junction, change of direction, or change of gradient, and also at stated intervals along straight lengths. On sewers of 6 in. or 9 in. diameter the manholes should not be more than 300 ft. apart. On larger sewers the distance may be a little greater. What is called a "lamphole" is sometimes used instead of a manhole on straight lengths and at points where a change of gradient occurs. The use of manholes and lampholes is for inspecting and cleaning the sewers. They will be described in detail later on.

46. The sizes and diameters of the various sewers and the gradients to which they are laid must be, if possible, such that they will be self-cleansing. Wherever this is not the case flushing arrangements must be provided, as it is obviously wrong to lay sewers in which solid matter will remain and cause the emanation of foul gases and the ultimate blocking up of the sewer. The gradients of the sewers must be sufficient to produce such a velocity

in their flow that no deposit may remain behind. It has been found that this velocity should be about 3 ft. per second when the sewer is flowing full or half-full. Neither is it sufficient to lay sewers at gradients which will give this velocity unless the volume of the sewage flowing through them is sufficient to make the sewer run at least half-full. If the flow is insufficient to do this the velocity will be reduced, and solid matters will be deposited. It can thus be seen that it is almost as bad to have the diameter of a sewer too large as to have it too small, and that care must be taken to make sewers of the right size. They should be two-thirds full when taking their greatest flow, including rainfall.

47. As a safe general statement, it may be said that in sewers of 6 in. or 9 in. diameter the velocity should be about 3 ft. per second, in larger sewers up to about 24 in. diameter 2 ft. 6 in. per second, and in sewers above this size not less than 2 ft. per second. This is the mean velocity when the pipes are running full or half-full. The velocity at the invert will be about 25 per cent. less. These are statements of generally accepted facts, the result of experience and experiment. Thus, speaking broadly, circular sewers may be laid to the following gradients, at which, if they are flowing full or half-full, they will be self-cleansing. Unfortunately it is frequently impossible to lay sewers at such good gradients; flatter gradients are in general use, the minimum falls being 1 in 200 for 6-in. sewers, 1 in 300 for 9-in. sewers, and 1 in 400 for 12-in., etc.; but they should not be taken as standard by the student, though the experienced engineer may use them if compelled by the flatness of the ground, provided that proper flushing can be guaranteed.

Diameter of Sewer in Inches.	Gradient.	
6	1 in 137	Velocity of flow, 3 feet per second.
8	1 ,, 183	
9	1 ,, 206	
10	1 ,, 322	Velocity of flow, 2 ft. 6 in. per second.
12	1 ,, 386	
14	1 ,, 450	
15	1 ,, 482	
16	1 ,, 515	
18	1 ,, 579	
20	1 ,, 643	
21	1 ,, 676	
22	1 ,, 708	
24	1 ,, 772	

These figures give a slightly slower velocity than that stated, according to some formulæ, viz., 2.75 ft. per second for sewers up to 9-in. diameter, and 2.3 ft. per second for larger sewers; they are merely meant as a rough guide. There are many excellent tables published giving the velocity of flow in sewers of various sections to which reference can be made, and which it is not the author's present purpose to reproduce or add to. As practical figures the above may be of use in dealing with some cases where highly theoretical calculations are not, from the circumstances of the case, required.

48. As the depth of the liquid in a sewer diminishes below half the full bore, its velocity decreases. It may often happen that when the flow is least the sewage is foulest and most likely to leave a deposit behind. If possible, therefore, the sewers in the upper portions of a district should have a greater slope, comparatively, than the larger sewers below. That is to say, they should be so arranged that the velocity of the flow in them may be greater than that required to make them self-cleansing, when properly charged, as a safeguard against the possibility of the flow of sewage through them being frequently very small.

49. Very steep gradients, however, should be avoided, because the flow in them is generally very shallow, owing to the rapidity of the current due to their steep fall, and this insufficient depth of water causes solid matters to get left behind and form a deposit in very steep sewers. After the flow of 5 ft. per second has been reached, it is well, if possible, not to increase the gradient. This gradient for a 6-in. sewer would be 1 in 43, for an 8-in. 1 in 57, for a 9-in. 1 in 65, for a 10-in. 1 in 72, for a 12-in. 1 in 86, and so on. These figures are only intended to give a rough idea of the steepest falls at which sewers will work well

50. Sewers which receive domestic sewage only are less likely to retain deposit than those which take storm water. The heavy grit, etc., from road gullies needs a greater velocity to carry it along than that required by the house sewage.

CHAPTER VIII.

The Arrangement of Sewers.—Minimum Size for Sewers—Different Forms—Changes of Direction—Water for Flushing Purposes—Branches—Connections.

51. It has been found by experience that it is unwise to make a public sewer less than 6 in. in diameter—some

authorities say 9 in.—to prevent the likelihood of stoppages occurring frequently.

52. Sewers which will always flow at least half-full should be circular, as that is the most economical form, and gives the greatest velocity when flowing full or half-full. Circular pipes should be used for all sewers up to 18-in. diameter, or even up to 24-in. diameter, according to circumstances. Egg-shaped pipes would be as good or better than those of circular section were it not for the fact that no satisfactory egg-shaped pipe is to be got. Stoneware egg-shaped pipes are untrue and difficult to joint. After 24-in. diameter, brick, stone, or concrete sewers must be constructed. In the case of large sewers, where the current is variable, an egg-shaped section is better than a circular section, because it will give a better rate of flow for shallow currents, the velocity being proportional to the square root of section when divided by the wetted perimeter.

53. With regard to changes in the direction in the line of a sewer, it is well to have no turn sharper than a right angle. For sewers larger than 12-in. diameter it is better to make two manholes near together, with a flat curve in each, and a length of straight sewer between them, than to make an awkward sharp turn in one small manhole. If a sewer is of such a size that it can be entered for cleaning it can be constructed on the curve where necessary, as, obviously, a sewer of, say, 6-ft. diameter could not change its direction with a very sharp curve at one small manhole.

54. In laying a separate system of sewers, the storm water drains are generally laid at the roadside, while the house drainage sewer is laid at a deeper level in the centre of the road. Care must be taken that the storm water sewers do not prevent the connecting drains from the houses having a proper fall into their sewer.

55. At the top end of each branch the discharge into it will probably be quite insufficient to give the proper rate of flow. It will very likely be too large for its work even if laid in 6-in. pipe, and so will need flushing. It will be necessary to calculate also how soon the volume of sewage reaching this sewer will be great enough to need the pipe to be enlarged. Such enlargements must take place at manholes only.

56. When for any reason it becomes absolutely necessary to lay a sewer on a curve, instead of letting the

curve occur at a manhole, a manhole should be built at each end of the springing of the curve.

57. The position of existing streams, springs, or other sources of water, natural or artificial, useful for flushing purposes, should be taken into consideration when planning the position of a dead end or flat gradient sewer needing flushing. Much expense in maintenance may very likely be saved by doing so.

58. When the positions of the sewers have been plotted on the plan, careful sections should be made of the profiles of the streets down which the sewers run. The levels of the lowest cellars, basements, areas, etc., should be shown by a dotted line on the sections. The line of the sewers should be then plotted on. There should be a minimum depth of about 3 ft. of earth over the tops of the sewers, which should be below the level of any gas, water, or electric mains. The maximum depth for a cutting must depend entirely upon the character of the ground. A cutting, say, 16 ft. deep is generally about as deep as it will be found convenient to make in an ordinary street. However, there are many examples of sewers laid in much deeper open cuttings. It will often be well to tunnel for deep sewers.

59. Where a branch joins a main sewer its centre line should never be below that of the sewer into which it discharges. All drains, whether storm water, sewage, or sub-soil, should be kept well below the level of cellars.

60. It is absolutely essential that sewers in a town should be watertight. They can be made so, and, although it is by no means an easy matter to ensure them, they are to be had if the work receives proper supervision. They should be capable of standing a carefully made water test, which should always be applied before the trench is filled in. The lower end of the sewer should be plugged, and the sewer itself filled with water. The engineer will probably have to overcome very considerable opposition in order to get the sewers quite watertight, but there can be no doubt as to the absolute need that they should be so. Obviously it is wrong to allow sewage to saturate the ground and find its way under the houses along the road where sewers are situated, or to permit land water to enter the system.

61. House connections should always join the sewers wherever possible at manholes. If, however, they have to come at points in between they should join by Y junc-

tions or by curved T junctions in the case of small sewers, and by T junctions in the case of large sewers. Junction pipes may be built into a pipe sewer if the connection to a house is to be laid forthwith, otherwise it is best not to put in any provisional junction piece, which will be probably forgotten or lost. House connections are generally made after the sewers are laid, and in that case, if they cannot be made at a manhole, it is best to use what is generally called a "saddle junction." For this a hole has to be carefully cut in the pipe sewer of the size of the inlet with a cold-chisel and hammer. The saddle junction is a stoneware pipe with a saddle, which fits against the main pipe, so that a sound cement joint can be made. There is no great difficulty or risk of cracking the pipe if the work is properly done. The advantage is that the sewer remains undisturbed. The practice of inserting a Y pipe and disturbing the sewer is not to be recommended. Saddle junctions similar to those described are regularly used for making private connections to sewers in some of our most important towns, and have been used by the author in his ordinary practice.

Where for any reason it is absolutely necessary to leave a junction pipe in the sewer not connected with a house drain, the socket of the junction pipe should be carefully sealed off with a piece of slate fastened in place with a fillet of cement. This can easily be cut out when the connection is made later on.

62. When house connections join a brick sewer, what is called a "drain block" is generally used. This is a stoneware block for building into the sewer wall, having a hole through it of the diameter of the house drain and a socket to receive the last pipe of that drain.

Iron pipes should be used for sewers wherever they are likely to be under pressure or where the foundations are untrustworthy. They should be coated to prevent rust, and may, in the case of a large sewer, be lined.

If a long length of sewer is laid at a great depth it may sometimes be well to make one connection to it from an auxiliary branch, laid at a higher level, to which the house drains may be connected to save the trouble of making a number of very deep and difficult trenches.

Wherever it is possible to do so, house connections should run to manholes. Hidden junctions of any kind should always be avoided as far as possible.

CHAPTER IX.

The Construction of Sewers.—Details of Construction—Methods—Materials—Forms.

63. To pass on to the actual construction of sewers. In the first place it is essential that all sewers should have good foundations. They should be so constructed that there is no chance of a settlement, for, as will readily be understood, the least settlement will be likely to produce a leak. The sewers must be strong enough to support any weight which may come upon them from above, which, in the case of a shallow sewer, may mean the full impact due to a heavily-loaded wheel of a traction engine dropping several inches into a hole in the road surface; or, in the case of a very deep sewer of large diameter, may be due to a live load plus the great weight of the earth above the sewer, and may be very considerable. The necessity for a good foundation exists with regard to small pipe sewers quite as much as for the larger kinds. A dip in a sewer is most undesirable.

64. In constructing sewers their centre lines should be pegged out on the ground, and the levels for their gradients set up in the following way.

Horizontal sighting rails should be set up at each end of a trench at such levels that the line of sight between the two rails may be parallel to the gradient of the sewer. Thus, if a sewer had to be laid at a fall of 1 in 500, and its trench were 250 ft. long, the sight rail at the top end would have to be fixed at a level six inches higher than the sight rail at the bottom end of the same trench, giving a fall of 1 in 500 to the line of sight between the two rails. By standing at either end of the trench it will be easy to see whether the top of a rod, cut to the proper length, and held on the bottom of the trench at any point, or on the pipe itself, is projecting above or comes below this line of sight. In this way the bottom of the trench can be formed, the concrete foundation laid, and the sewer itself put in to a perfect gradient. This is the simplest and surest way of laying pipes at proper gradients.

The levels thus set up must be frequently checked. In such positions the rails may easily sink or get shifted.

65. Pipe sewers, even of the smallest sizes, should always be laid on concrete. If the earth is soft they need support, and if the ground is hard rock they need

bedding on to it. The pipes must not be laid so as to rest on their sockets only. If a sewer passes near trees the concrete will be needed as an additional protection against the roots, which, if they once find an entrance, will soon fill any pipe.

66. It may not be out of place to describe one method of laying pipe sewers. There may be variations to the method described which would not alter the soundness of the work. The following is a description of the general practice in laying pipe sewers in the author's experience.

The trench is excavated carefully to the exact gradient of the sewer, and, if the ground is firm, a layer of at least 3 ins. of concrete is put in also to the exact gradient. If the ground is treacherous, stronger foundations must be constructed as required. Bricks should then be laid on this concrete (one brick laid flat or on edge coming behind each socket) to raise the pipes to a height at which a man can easily reach the under-side of each joint. It is very important that there should be plenty of room for the pipe jointer to make the underside of each joint. The pipes should be laid with their sockets uphill, beginning at the lower end. They can be supported temporarily with small props of concrete to prevent rolling. The first pipe should be bedded and tested for position and level, then the next pipe should be put into position and tested in the same way, and a joint of neat cement made. Any cement projecting on the inside of the joint should be carefully removed with a scraper or mop. One good method for doing this is to have a disc of heavy indiarubber, slightly larger than the sewer, bolted between two smaller wooden discs; it can be drawn through each pipe as a joint is made. It is well to have two such discs, one following behind the other. The process, as described above, is repeated for each pipe as it is laid. The cement should be mixed, not too wet, in small quantities, and none should be used which has once begun to set. The very greatest care must be taken not to disturb or shake any joint after it is once made. The slightest movement will mean a crack in the cement. Each joint should be finished off with a trowel to a smooth face, the joint should be the same all round, with no projecting piece of cement on the underside and no roughness. It is at such places that leakages occur. The joints should be protected from the sun or frost while setting. After the joints have set for three days the sewer should be plugged at its lower end and filled with water. Each joint should be carefully examined, and the level of the water at the top end should remain constant. It is as well to make sure that it does remain constant, because it sometimes happens that a pipe leaks through a crack on the under-side, and the water does not show at once in the trench. Defective joints should be made good by cutting away the cement as far as possible and re-making the joint. If a broken pipe is discovered it must be, of course, taken out; to do this it will be necessary to remove at least three pipes. Joints should be quite sound, and should not sweat. Such joints can be easily made by any man used to the work, and those interested in sewer laying should not be satisfied till they get them.

67. The cement used for joints should be exposed to the air in a 6-in. layer on the floor of a dry shed for a week or so before being laid. If this is done there will be no difficulty in making the neat cement joints. If it is not done, the cement will be apt to crack, or otherwise to give trouble by bursting the pipe sockets. When a length of sewer has been laid it should be possible to see through it from end to end, and to see the full circular section throughout. Sometimes as many as three pipes may be jointed in cement outside the trench, and after they have set for a week or more may be lowered into place. This is perhaps rather too risky a method to recommend, but it has been done with success. When the sewer has been tested and found to be quite watertight, concrete should be filled in round the pipes up to the middle all along the trench. This should under no circumstances be done till the work has been passed. Great care should be taken in filling the trench with earth that no damage is done to the sewer.

68. There are very many kinds of joints used for stoneware pipes, some of which will be mentioned in detail later. They may be described as the ready-made composition joint, the same with a cement joint added, and the bitumen joint. Asphalt joints are used extensively in Germany and elsewhere, and are generally well spoken of. The ready-made bitumenous joint may sometimes be used with advantage, but there can be no doubt that when it has once been made there is nothing to beat the cement joint for stoneware pipes. Composition joints are apt to perish in time.

The author has used socket joints into which hot bitumen was poured, and butt-jointed stoneware pipes having a joint made with a steel clip and hot bitumen with good results in wet ground.

Some people like to mix sand with the cement for pipe joints. If this is done at all, the sand should be added in a very small proportion—say one part of sand to three parts of cement. If the sand used for joints is in too large a proportion or too coarse, the joints will be porous. Tarred yarn is sometimes caulked into a socket before making a cement joint. It serves the purpose of keeping the pipes concentric and of preventing cement from getting into the sewer. There is, however, the chance of an end of yarn projecting inside, which is more difficult to get rid of than cement. Such ends, when they occur, have to be burnt or cut off. In very wet positions a cement joint may sometimes be made by wrapping a piece of light canvas or muslin tightly round the joint while it is setting.

It will be found convenient to use stoneware pipes made in 3-ft. lengths instead of 2-ft. lengths as the number of joints is then reduced.

CHAPTER X.

The Construction of Sewers (continued).—Iron Pipe Sewers—Patent Joints—Danger of Water in Trenches —Foundations—Larger Sewers — Ferro Concrete— Elliptical Sewers and their Gradients—Inverts— Special Joints for Pipes.

69. Where iron pipes are used they generally have spigots and sockets with caulked blue lead and yarn joints, or else turned and bored joints are used, which consist of a close-fitting spigot and socket with machined faces; these faces are smeared with red lead and the pipe is driven into the socket either with a mallet or, in the case of large pipes, by using one pipe to drive the other home, a wood buffer being used between the two. The more expensive flange joint is also used under exceptional circumstances. With regard to yarn in joints, it has been pointed out that in the event of a serious epidemic, disease germs might find a home in the yarn after the rest of the sewer has been cleansed. A more serious objection, perhaps, is that in time the yarn will probably decay and leave a space to be filled with foul matter. As it is quite easy to do without the yarn by substituting a cold lead packing before pouring in the hot lead in the case of

iron pipes, and by leaving the yarn out in stoneware pipe joints it is best not to use yarn in new work. Concrete pipes for large sizes are made and used with success; the joints are made with cement, or with a steel clip and bitumen. Ferro concrete pipes are also made; these and Ferro concrete sewers generally are largely used in America and elsewhere.

70. Pipes may be lowered into a trench conveniently with a rope and hook. The rope is passed through the pipe and the hook is caught into the rope so as to hold the pipe in a horizontal position.

71. It is desirable, for several reasons, that water should be kept out of the trenches during the construction of sewers. This is effected by means of subsoil drains or by making temporary inlets so that the new sewer may carry off any water accumulating in the trench (these holes are afterwards stopped up), or by pumping from sumps made to take the water, or by cutting the trench through to some point where the water may find a natural outlet. In some cases turned and bored iron pipes have been laid actually in the water.

72. Care must be taken that trenches do not fill with rain water during a storm or through the land water rising in them. If a trench containing a pipe sewer fills with water, the pipes, being water-tight and full of air, will float, and so break their joints. Whenever water mains cross a trench they should be very carefully supported with chains or struts, not with ropes. If a water main should break over a sewer trench, the greatest harm will probably be caused.

73. If the ground upon which sewers are constructed is very unstable, more extensive foundations must be provided. The width of the concrete bedding can be increased, and sometimes, for pipe sewers, longitudinal planks or longitudinal bearers supporting cross boards are laid to take the concrete.

74. With regard to large sewers, whether of brick or concrete, it may be readily understood that a circular or egg-shaped sewer needs a solid foundation, with a level base. In ordinary firm ground a plain concrete bedding may be made of a width generally greater than that of the sewer. If the ground is very unstable, this width can be increased. If the ground is marshy, or of running sand, it is customary to lay planks or hurdles on the top of heavy timbers, placed longitudinally, so as to break

joint, as a foundation for the concrete. If necessary, a close boarded raft is made, and it is a generally accepted fact that, with sufficient width and depth given to the foundations so put in, a heavy sewer may be carried over the worst ground. Pile foundations are also frequently used for large sewers. Another method is to construct concrete piers, carried down to a firm stratum, and having bridged between them, to build the sewer on this foundation. When constructing a brick sewer it is often found useful to have what is called a cradle upon which to build it. The cradle is generally made of timber, sometimes with wrought iron ribs. The cradle is made of the size and shape of the outside lower part of the sewer.

75. In the matter of timbering the sides of trenches it will be found cheapest in the end to err on the safe side, and to take no great risks.

76. Large sewers are constructed of brick, concrete, stone, iron, and ferro-concrete, even large timber sewers made on the barrel principle are sometimes constructed abroad, also sewers have been cut in the solid rock and used without lining in this country. They are of various sections. The circular form is used for a large constant flow, and the egg-shaped sewer for a variable flow. In very large sewers it is sometimes necessary to make the shape altogether different, the width may have to be greater than the height, because the depth is limited, owing to there being very little fall in the sewer. Sewers with vertical sides and flat roofs are sometimes constructed of necessity for storm water for this reason. There is no reason why the roof of a sewer should not be made flat in many cases where arches are used, and where the construction of a steel and concrete roof would be cheaper, and would allow a better fall to be obtained in the sewer. For this purpose sewers of an egg-shaped section, but without the top semi-circular arch, are sometimes used. A flat roof is substituted for the arch.

77. Another form worthy of notice is that in which there is a footway above the invert level on one side of an otherwise egg-shaped sewer. The object of this is to make the inspection work easier.

Small brick sewers are constructed in cement mortar, and rely upon their jointing, and on the imperviousness of the bricks themselves, for keeping watertight. When they are constructed of two ring work or more, a 1in. space filled with cement can be made all round between the rings. This is called a "collar joint," and is for the purpose of making them quite water-tight. As it is well known how difficult, or even impossible, it is to make brickwork watertight, owing to the fact that bricks themselves are likely to be porous, it is clear that sewers which are for foul sewage must be constructed with some such provision for making them watertight.

78. Circular stoneware pipes are made up to very large sizes, and it may be found well to use them for large sewers if they are regarded as a lining only and enclosed in a protecting mass of concrete. Large iron sewers are generally lined. A good example of a modern sewer was one laid in Edinburgh, near Leith Docks. It was egg-shaped, and its dimensions were 9 ft. 3 ins. by 7 ft. 2 ins., and it was made in segments. The lower part of it was lined with concrete, the flanges of the joints being inside. The upper part of it had the flanges on the outside, and was not lined. An iron sewer such as the one described has many advantages; it can be laid with rapidity through the worst ground, and will be quite watertight and of great strength.

79. Elliptical sewers are generally made of one or two sections, for which the ordinary tables of velocity of flow in sewers have been calculated. These sections are called respectively the "old form" and the "new form." The invert of the sewer of "new form" is of smaller diameter than that of the "old form." The velocity of flow in such sewers should not be less than 2 ft. per second. The following gradients will be safe for sewers of either form:—

Size of Sewer.	Gradient.	
2 ft. by 1 ft. 4 in............	1 in 540	(Velocity of flow about 2·25 ft. per second.)
2 ft. 3 in. by 1 ft. 6 in. ...	1 ,, 640	
2 ft. 6 in. by 1 ft. 8 in. ...	1 ,, 750	
2 ft. 9 in. by 1 ft. 10 in....	1 ,, 850	
3 ft. by 2 ft.	1 ,, 975	

80. It is impossible in a short article to deal at all fully with the subject of large sewers. One point needing careful attention is that of the invert of a sewer. It has been found that the scour will very often wear through ordinary brickwork, and for this reason inverts in sewers are generally constructed of some hard material, such as Staffordshire blue brick, granite, or vitrified stoneware. The glazed stoneware invert is apt to be slippery to walk upon, and some difficulty has been experienced in keep-

ing the joints watertight. A simple method of forming a good invert is to use a half-channel pipe bedded on concrete.

Where sewers have to be laid at very steep gradients it is well that they should be of iron, to withstand the scour, and to resist the great pressure which may at times come upon them.

CHAPTER XI.

Access to Sewers for Inspection and Cleaning.—Junctions Manholes—Various Forms and Details of Construction.

81. Sewers should be arranged in such a way that the whole system may be clear and easy to understand. The less complicated it is the better. The object of the engineer should be to construct straight lengths of sewer between inspection manholes, so that access may be possible to every part by means of rods or other cleaning apparatus. There should be no sewer junctions except at manholes. Wherever possible, the drains from houses, surface water gullies, etc., should be connected to manholes in preference to the sewer. No doubt a hidden junction of any kind is an unsatisfactory thing, but unfortunately in the case of house connections they cannot be avoided very often without considerable expense, and it is the general practice at the present time to take house drains into the sewers by junctions made in the sewer itself, except where a manhole is close at hand. It must be seen that it is very unsatisfactory to have to disturb the main sewer every time a new house has to be drained, and in designing a new scheme, an effort should be made to prevent this where possible. The practice of laying new sewers with junction pipes provided, for connections which are not going to be laid at once, is not to be recommended for two reasons—viz., as soon as the sewer is finished and the trench refilled, the position of the provisional junction will, without doubt, be lost, and very soon its existence will be forgotten, and, even if it is remembered, it is not possible to make an extensive excavation whenever a new house connection

is made, in order to find the junction provided. Again, dead junctions along a sewer will be apt to retain filth, and cause the sewers to smell badly, however well they may be flushed or cleaned. It is as well to state, before leaving the subject of drain junctions with sewers, that, in the case of pipe sewers, the Y junction pipe or saddle junction pipe should be set to rise sharply from the sewer, and in the case of brick sewers the junction should be kept above the ordinary water level in the sewer.

fig. 1.

fig. 2.

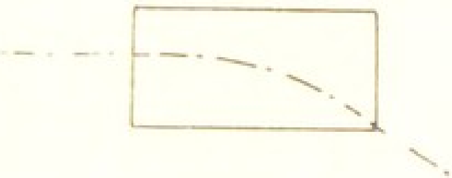


fig. 3.

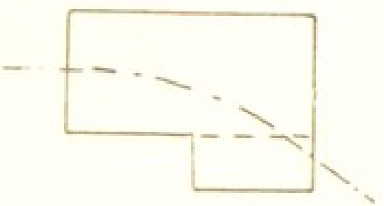
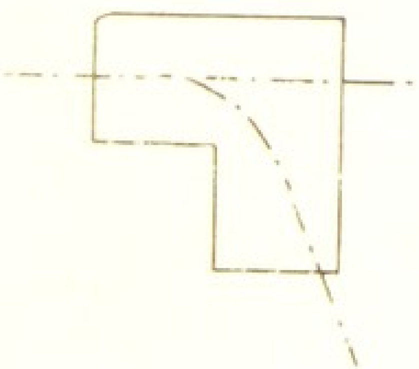


fig. 4.



82. It is necessary that the whole sewerage system should be under perfect control for cleaning or testing. It should be so designed that the engineer can at any time tell without trouble whether any part is quite clean or sound. For this reason inspection manholes have to be made at all places where the flow of the sewage is likely to be checked—viz., at changes of gradient, changes of direction, and places where sewer junctions occur. Special open channels, with a fall greater than that of the sewer, to make up for the extra friction, due to the bends, etc., are constructed in the manholes. Manholes are also placed at such distances apart on straight lengths that cleaning apparatus may be passed through from one to another. Before going further, it will be well to describe the construction of manholes and lampholes.

83. Manholes may be built of brick, stone, concrete, or other suitable

Fig. 5.

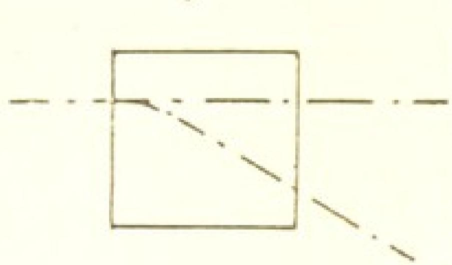
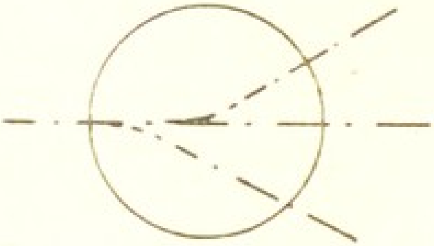
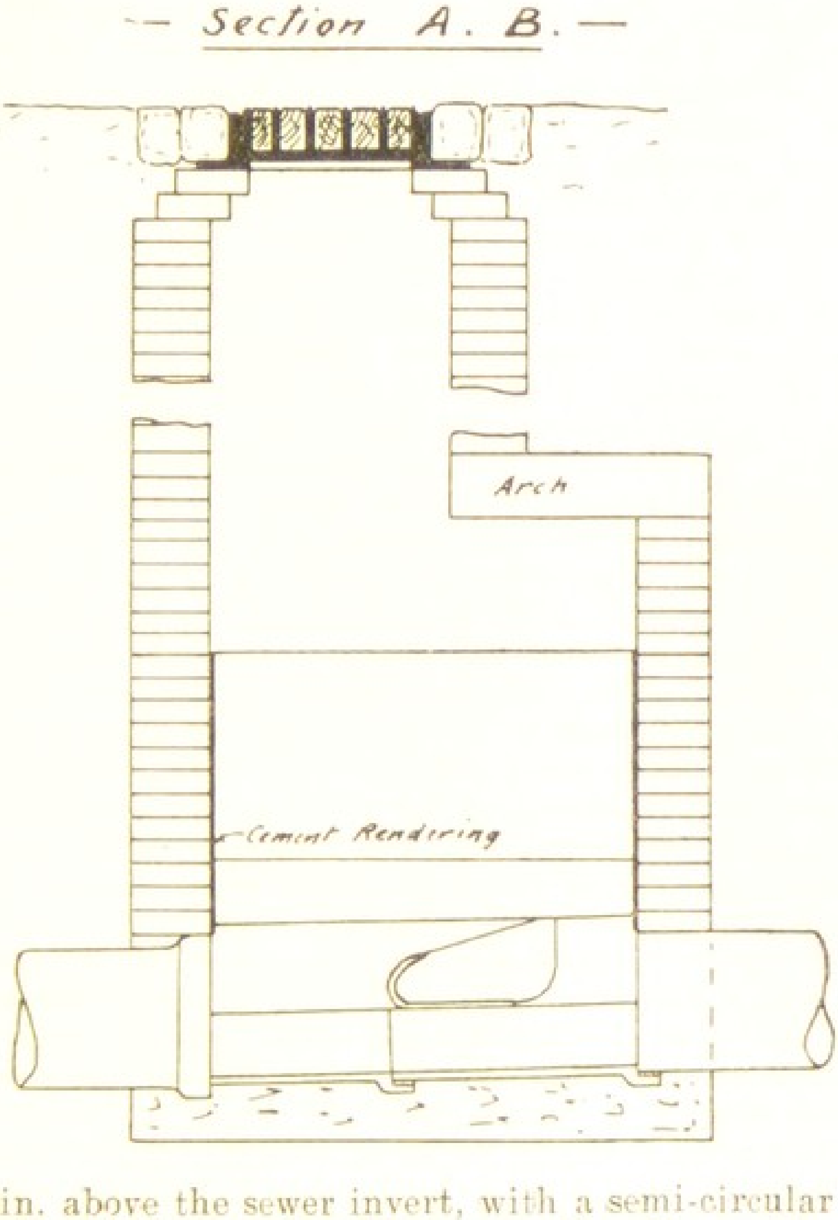


Fig. 6.



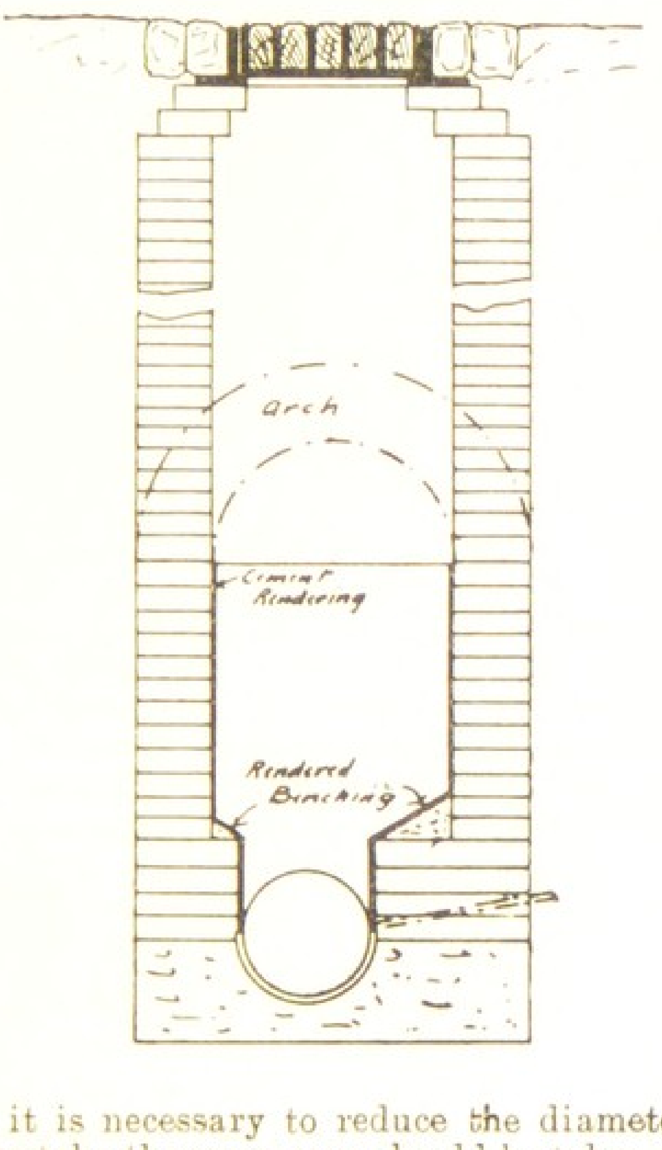
material, and they must be of such a size that a man can descend and work comfortably at the bottom. The shape should depend upon the number and positions and sizes of the sewers running into and from it. The accompanying diagrams will explain this. The inside line of the walls is shown in plan in each case, and the centre lines of the sewers are shown by dashes and dots. In Fig. 1 the oblong form of manhole is shown. This shape is most suitable for manholes on a straight length of sewer. Length is needed rather than width in such a case. Any work which has to be done in it will be along the line of the sewer, such as pushing a cleaning rod down and screwing fresh lengths to the rod as it is pushed into the sewer. For small sewers a length of 4 ft. and a width of 2 ft. is quite the minimum size it will be found possible for a man to work in. In Fig. 2 a manhole of the same shape is shown, with a slight bend in the channel. It would be well in such a case to increase the width a little. If the manhole were constructed as in Fig. 3 the work of cleaning would be easier. If the manhole were deep the extension might take the form of a pocket—that is to say, the extra bay need not be carried up to the ground level. A height of 3 ft. or so would be enough for it. The same shape, with a longer bay or pocket, is suitable where sharp bends or junctions occur, as in Fig. 4. In Figs. 5 and 6 manholes square and circular in plan are shown. These shapes may be used for deep manholes of all kinds, and have the advantage that movement in all directions is possible to the same extent. There are important existing examples of manholes only 3 ft. square. The square and circular forms are more suitable for manholes where changes of direction or junctions occur than the oblong shape. It is a matter of opinion entirely which of these shapes shown in Figs. 1 to 6 is the best. Local conditions, the material available, depth, etc., may decide the point. The oblong form, with pockets made at the bottom of a size to make access to all sewers easy, is perhaps as satisfactory as any. If necessary, it can be lengthened to any extent where many junctions occur.

84. In the accompanying detail drawing of an oblong manhole on a pipe sewer, the manhole is shown constructed for its full length and width for a height of



4ft. 6in. above the sewer invert, with a semi-circular arch above that (a flat roof would do as well). The main sewer runs into a half-pipe channel, which is bedded in the manhole. It is equally good if this channel is formed of cement worked to a polished face, but unless the engineer is quite sure of obtaining men capable of making such channels properly it is best to put in glazed stoneware channels in manholes. These channels can be procured from makers. In the case of large sewers the inverts in the manholes can be made of blue brickwork bedded in cement. It is as necessary that the manhole should be watertight as that the sewer should be so. For this reason the channels should be bedded in cement, and the pipes passing through the walls of the manhole should also be carefully bedded in cement. The weight of the manhole wall should not be allowed to come upon the pipes. An arch turned over them, or a stone bedded above to take the weight will overcome the difficulty. What is called a drain "chute" is sometimes used at manholes, on the sewer at the outgo end. This is a pipe with an enlarged mouth, and it is useful on small sewers to facilitate the working of rods, and also to prevent the checking of a flush at the manhole. In the accompanying drawing it will be seen that the side junction drain discharges over the side of the main channel through a curved channel. This arrangement is to assist the flow of the sewage and to prevent any back-flow up the branch. Sewers of equal size may, if necessary, join on the same level, but smaller sizes should always come above the main sewer. Vertical walls are built above each channel to a level of 3 ins. above the top of the main sewer, and the top of the benching is sloped at an angle of 30 degrees up to the manhole walls. The vertical walls of the channel and the sloping tops are rendered with cement worked to a polished, trowelled face. The rendering is carried up the manhole walls to a height well above any possible sewage level. This rendering is a matter deserving the most careful attention. By means of it the bottom of each manhole should be made so that there are no rough places or projections to which sewage can adhere. There should not be any small ledge left at the top of each channel pipe, or where a pipe projects into a manhole. The rendering should be made flush with all such projections, so that there is absolutely no place where sewage can be held. By careful attention to such matters a cause of smell in sewers will be avoided The benching is sloped at an agle of 30 degrees to ensure all water falling rapidly back from it into the channel. and also in order that it may afford no resting-place for rats to nest upon. If the slope is made greater than 30 degrees it is difficult for a man to obtain a footing at the bottom of the manhole. It is not necessary to build the manhole up to the surface of the ground for its full size In the accompanying drawing a square shaft equal to the width of the manhole is shown. It is, however, essential that plenty of space should be left for a man to work at the bottom, and, therefore, in all cases it is well not to begin diminishing the size of the manhole till a height of about 5 ft. above the benching is reached. After this height, in the case of circular manholes, it is customary to begin reducing the diameter, giving them a conical form in the case of deep manholes, and a domed form

— Section C. D —



where it is necessary to reduce the diameter quickly. In order to take the cover care should be taken that the form of the dome is not such as to make it difficult for a man to enter and climb down the manhole on the step irons. The curve of the dome should, therefore, be flat, and if the shallow depth of the manhole renders this impossible, a manhole of rectangular form should be used.

85. Where manholes have to be constructed in wet ground it is very important that they should be made watertight above the highest possible water-level in the ground. This will sometimes mean making them watertight by means of rendering up to the ground level. In such cases it is well to lay first sail-cloths, tarpaulin, or linoleum on the bottom. On this should be placed a good concrete platform of at least 6 to 1 strength, with no interstices through which water can enter. This platform should then be rendered with cement mortar worked to a polished face. On the platform thus made the brick walls should be built, and two or more iron weeping-pipes should be built in the bottom courses. These pipes will relieve the water pressure behind the brickwork, while the rest of the work is setting. It will then be quite easy to build up the brick walls and to render them down to the floor rendering. When this cement work has had time to set hard—say in a week or a fortnight's time—the iron pipes should be carefully plugged, first with wooden stoppers driven well in, and then with neat cement. After this the benching and channels can be finished. If by any chance water should leak in at any crack or bad place in the cement, it is quite useless to try to patch it with cement in the ordinary way. In such a case a hole should be made and an iron weeping-pipe inserted well below the leak to relieve the water pressure. After this pipe has been set in cement so that no leakage can take place round it, and after the water has been lowered to a level below the leak which has to be repaired, the bad place can easily be made good, after which the weeping-pipe can be plugged as already described.

This simpler method should be noted by contractors, who often incur great loss in their attempts to make good leaking manholes, ejector chambers, and tanks. The author has seen much money wasted in such attempts, and has used the method described many times with invariable success.

86. In places where the ground is very bad, the Stilfgoe patent cast-iron manhole base, made by Messrs. Ham, Baker, and Co., may be used with advantage. This is the lower part of a manhole made of cast iron, which can, of course, be fixed in the worst ground, and cannot possibly leak.

87. The circular concrete manhole is also worthy of notice, and may be found economical in construction. It consists of a concrete base on to which complete concrete cylinders with cement joints are lowered. The concrete cylinders are of great strength, and will probably be used more extensively in the future.

88. Iron covers of various shapes are used for manholes. They are square, oval, and circular. Of these the circular is probably the best shape for most cases where manholes occur in the road, because there is no trouble in placing it, as is the case with others, which if placed askew as regards the line of the road look bad. The circular cover also cannot through carelessness be dropped into the manhole through its frame, as is the case with the oval or square patterns. It has also been found that the oval cover has a greater tendency to "rock" that the circular. Covers should fit closely into their frames; a loose fitting cover will often rise in its frame through stones getting in, and a rocking action will be caused when wheels pass over it. For manholes on the footpath hinged square covers are generally used, and a grating is provided under the cover, which can be kept shut when the other is open, to prevent passers-by falling in.

89. Entrances to manholes should be kept on side walks wherever possible, so as to be out of the way of the wheels of vehicles, and also in narrow streets to avoid obstructing the traffic. In the case of large or deep sewers it is generally possible to do this by having side entrances to the sewers connected with a descending shaft on the footway. In the case of small, shallow sewers, the same thing can be often arranged by keeping the pipes on one side of the road. It is not safe to fix iron manhole covers in the roadway on steep hills, where skids are used, which will be likely to get caught in the cover and damage it, or even lift it out of place. Covers in the roadway should be strong and heavy, to resist the weight of heavy loads, such as steam rollers or traction engines. Light covers on roads are very likely to break. They should be heavy also that they may not be easily lifted by jars or by unauthorised persons.

90. Covers may be either perforated with holes for ventilation or closed, according to their position and the requirements of the case, a subject which will be dealt with later, under the heading of "Ventilation." Road covers should present a sure foothold for horses. This

may be accomplished by having a specially rough iron surface, or by inserting blocks of wood into the covers made to receive them, or by filling the spaces with other suitable material. One good way is to fill them with broken granite and cement. This will, however, add to the weight of a cover, which may, in the case of one already heavy enough, be a drawback. The covers should be fixed a quarter of an inch below the road surface, and should be surrounded with granite pitchers or other suitable material. Great care should be taken to give these granite pitchers a firm foundation, otherwise they will fall away from the cover and give considerable trouble. They should be bedded on concrete, which should take its bearing on the solid earth or on the manhole roof or walls.

91. In the case of perforated covers it is customary to fix dirt boxes to catch the road material which may fall through. It is questionable, however, with a large sewer, having a good gradient and flow, whether this is quite necessary, as the dirt falling through would soon be carried away. Also it is very probable that the dirt box will be neglected in some places. Covers must have openings large enough to admit a man and buckets, etc.

92. Lampholes are of very little use. The object of a lamphole is that a lamp may be lowered through it into the sewer, so that by looking through the sewer from the nearest manhole it may be seen whether the sewer is blocked up or not. Also, if the sewer is blocked beyond a lamphole, the liquid can be seen standing in the sewer from the top. It is obviously no good putting in the ordinary kind of lamphole anywhere where a real place of inspection and access is needed. Sometimes places may exist where there is a very slight change of direction or gradient in the sewer, and where, owing to the fact that manholes are close at hand, there is no necessity for another. The Local Government Board's regulations demand a manhole or lamphole at such a place. It is generally best to put in manholes instead of lampholes.

The lamphole is generally a vertical pipe taken out of the sewer with a Tee junction. The weight of such a pipe would be liable to break the sewer and its own sockets if it were not supported. Some authorities, therefore, prefer a small vertical brick shaft, constructed just like a small manhole. The vertical pipe can, however, be supported, with, say, a 6 ins. ring of concrete round it and a mass of concrete at the base. It is generally made about

9 ins. in diameter. The vertical pipe should stop in a pit below the level of the ground, and the lamphole cover should rest on the walls of this pit, so that loads coming upon the cover are not transmitted to the pipe or sewer, with which the pit walls should have no connection. The remarks made about manhole covers apply generally to lamphole covers, with the exception that lamphole covers are smaller.

93. Manholes for sewers large enough for a man to walk through take the form of an inlet shaft only, or inlet shaft and tunnel, the bends or junctions being carefully constructed in the sewer itself. Step irons are built into the walls of manholes to allow a man to climb down. They are generally spaced 15 ins. apart vertically by 12 ins. horizontally from their centre lines.

It is wrong to bury a cover. If this is done the manhole it belongs to will most probably be forgotten, and will then be a cause of obstruction rather than a means of access to the sewer.

94. Where house connections or drains from surface water gullies run to a manhole they should be made to discharge into properly constructed curved channels. No junctions should be made so as to discharge sewage with a vertical drop into the manhole, as this will produce splashing. If necessary, a vertical pipe with a bend at the bottom may be carried down to the right level outside the manhole, and the drain itself continued in a straight line above into the manhole for cleaning purposes.

Junctions made with sewers should never be carried through so as to project within the sewer, as they will cause an obstruction, and filth will be always liable to adhere to such projections and cause the sewers to smell ; also great care should be taken to make good all such junction places inside the sewer.

If proper means of access to sewers is provided it will never be necessary to break them at any point for cleaning

CHAPTER XII.

SPECIAL PIPES AND JOINTS.

95. Speaking generally, it will be found best to use the plain stoneware spigot and socket joints wherever possible, as they are cheaper and cannot be beaten as to

lasting qualities and general trustworthiness when properly laid. There are, however, many occasions when, owing to a variety of circumstances, it is desirable to use pipes which can be laid more quickly and with less labour than the ordinary stoneware, cement-jointed pipe.

Iron spigot and socket pipes with blue lead joints and turned and bored pipes, and, in special cases, flanged pipes, should be used where the circumstances make it worth while to incur the extra expense—*i.e.*, where the cost of the labour in laying other pipes makes the total cost of the work greater than it would be if iron pipes were used, or where great strength is required, as in crossing a stream or passing through a treacherous bank.

96. The most common form of patent joint is that in which the outside of the spigot and the inside of the socket of the ordinary stoneware pipe is coated with a composition which generally consists of tar, sulphur, and sand. This is generally known by the name the Stanford joint, and has been largely used. There are many composition joints of this kind.

97. Owing to the fact that the patents have elapsed, there is a danger of the Stanford joint, the Hassall's joint, and others which come under the heading of "composition joints," being made of inferior composition which will perish. It is therefore very important that the engineer should satisfy himself not only as to the design

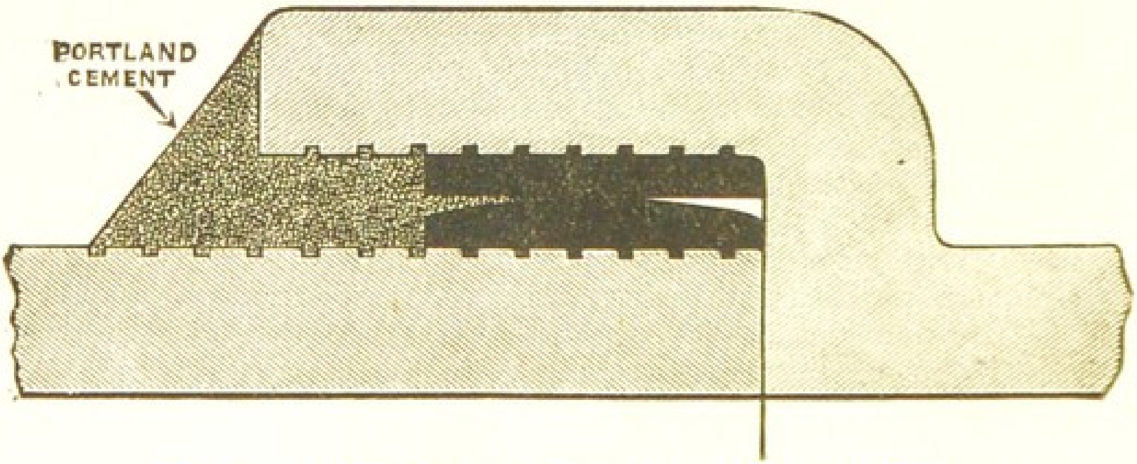


Fig. 9.—SECTION OF COMPOSITE JOINT.

of the joint, but as to the quality of the composition used in making it. With the ordinary Stanford joint the direct advantage lies in the fact that the pipes require very little labour in jointing. If, however, the composition perishes, it is clear that there is nothing to prevent the joint leaking badly. The author has on various occasions discovered joints which have so perished. Fig. 9 shows the improved Stanford joint, in which the composition forms the first part of the joint at the bottom of the socket, and a cement joint is made beyond this. It is no doubt safer with the cement, but it seems hardly worth while to make half a cement joint in this way. If it is possible to work the cement in the trench and form a good cement joint outside the composition, it certainly would be quite possible to make a good cement joint throughout, which would be far more trustworthy than the composition joint. Fig. No. 10 shows the ordinary form of Hassall's joint. This joint is used perhaps more than any other for sewers in wet trenches, and, owing to the fact that a ring of cement is formed, or supposed to be formed,

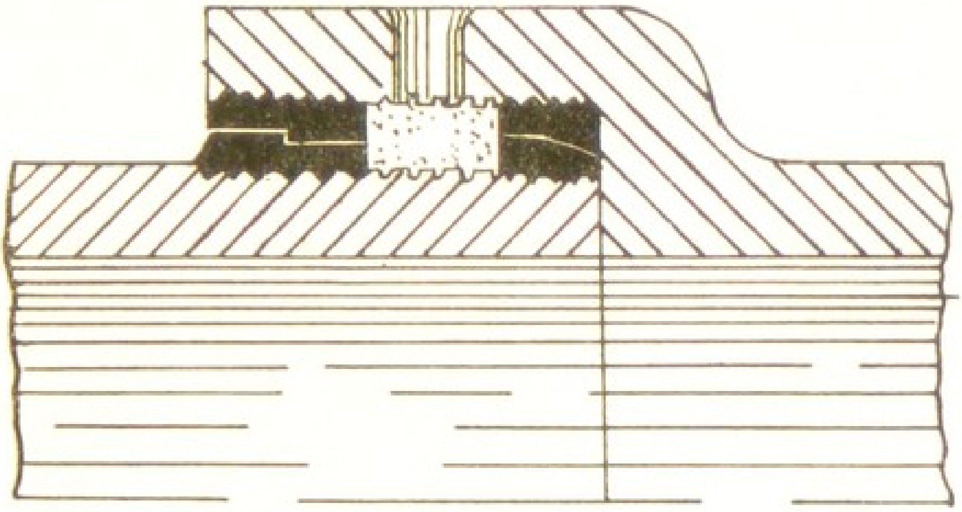


Fig. 10.

between two rings of composition, great confidence is placed in its watertightness. When the joint is properly made the cement grout is poured in at one hole at the top of the socket, and finds its way round, filling up the whole of the space and driving the air before it, until the cement appears at the other hole at the top of the socket, thus proving that the entire ring is full of cement. There can be no doubt that this is a very good joint, provided the composition is right, and provided the work is properly looked after. But there is always a possibility of a careless workman pouring cement into both holes at once, in which case the joint would appear to be quite sound, and would stand a water test, owing to the two composition joints; but the cement ring, which is trusted as a third line of defence, is not there. It is therefore necessary to guard against a false sense of security when using joints of this description. The supervision of the work should not be relaxed because patent pipes are being used.

98. As an improvement of this joint, the Doulton's grouted composite joint is especially designed for use in

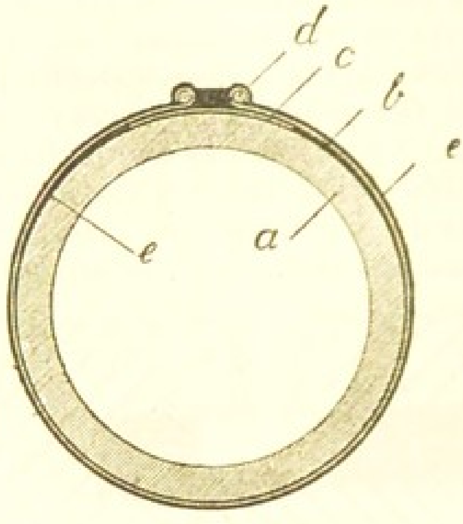


Fig. 11.

wet trenches. To quote from the catalogue :—" In earlier joints of this class the grout has been poured into a closed cavity in the socket, of small dimensions, and having no adequate provision for the escape of air or superfluous

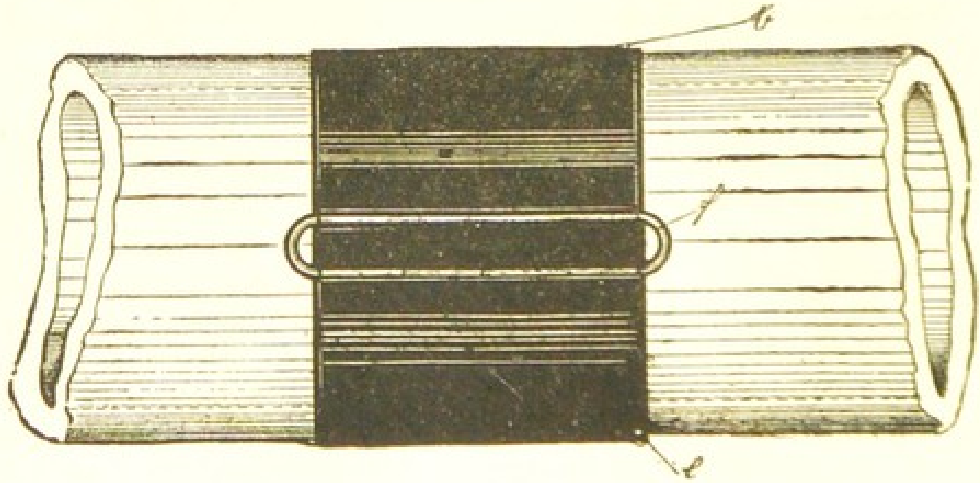


Fig. 12.

water, the operation therefore invariably having been attended with risk of imperfect joints. In the 'grouted composite' joint the sealing chamber is of ample dimensions, offering no hindrance to the flow of the grout. The chamber is closed by a band of *porous fabric of a texture such as to retain solid particles of cement while it allows the escape of air and superfluous water.* It is this feature of the joint which makes it unique. Risk of faulty joints through confinement of air or water is entirely absent, since both air and water filter away through the pores in

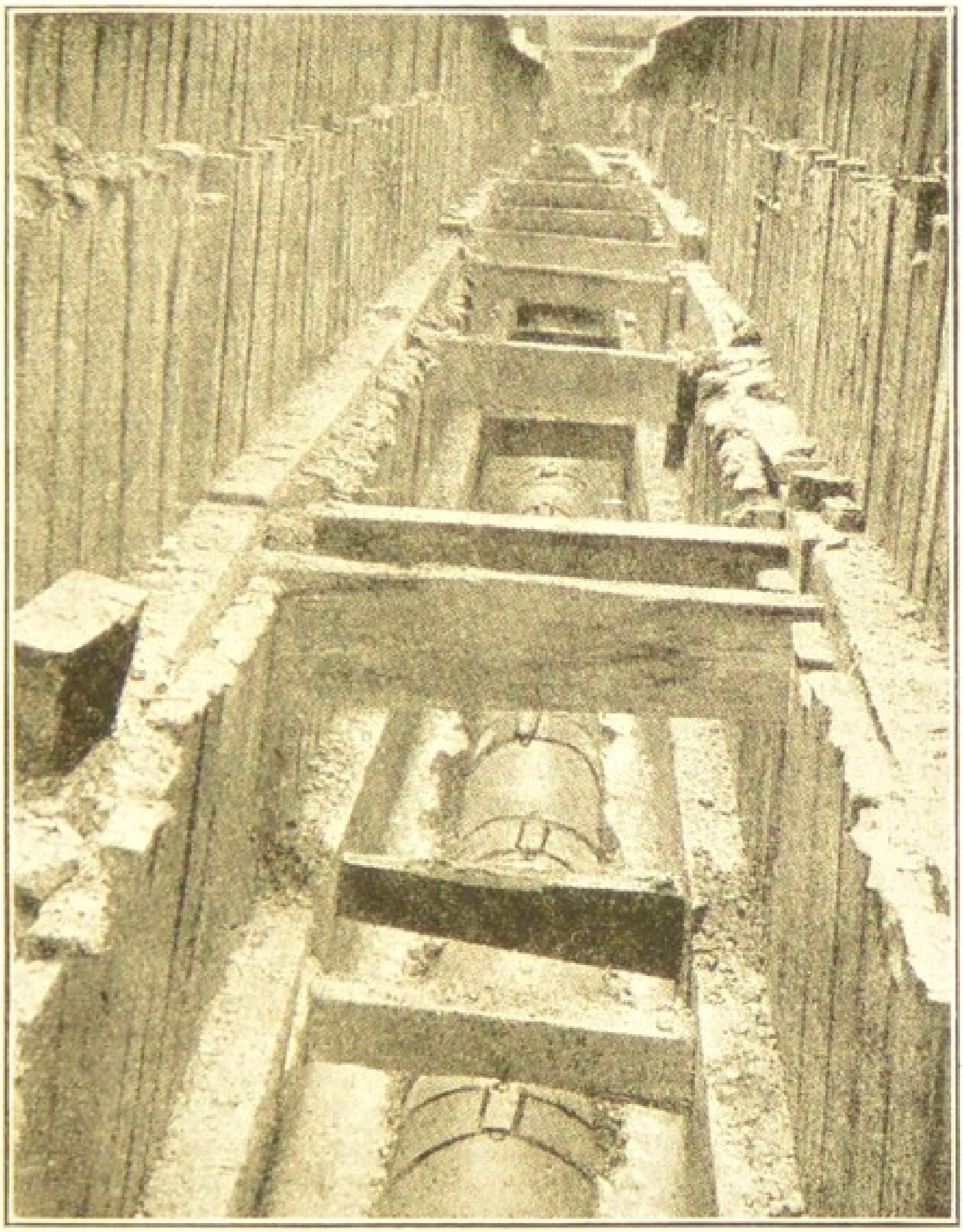


Fig. 13.

the canvas. An absolutely solid and continuous ring of cement around each joint can thus be relied upon; and, moreover, its presence is actually visible from the *outside* of the completed joint, an advantage not possessed by any joint used hitherto." This joint should be very useful, but the porous fabric must be of a quality to allow air to pass through it easily even when wet.

In the Brandram joint (shown in Figs. 11 and 12) the pipes employed are plain butt-jointed stoneware pipes, or sometimes pipes with a rebated joint contained in the thickness of the pipe, are used. A wide steel band (b), nearly equal in length to the circumference of the pipes to be jointed, coated with Dr. Angus Smith's composition, with each end curling over to form an eye (e), is dipped into hot bitumen. The pipes to be jointed are generally wrapped round with a piece of special bitumenised paper or canvas, and the wide steel band is drawn closely round the joint, as shown by means of wire handles, while a small covering plate (c) bedded in bitumen is placed under its ends to complete the metallic circle. Hot bitumen (b) is poured over the joint while this is taking place. A screw-cramp is then applied and the band tightened until the bitumen begins to exude at the edge of the band all round the pipe. Staples (f) are then inserted in the eyes of the band from each side, and further bitumen is poured on, covering the staples, and the joint is complete. Fig. No. 13 is from a photograph taken in a trench showing some Brandram jointed pipes laid under the author's supervision in very wet ground, the foundation being running sand. Among the advantages of this joint are that it can be made quickly and tested at once. Pure bitumen being imperishable, the joints should be altogether superior to the composition joints already mentioned, which composition generally consists of a mixture of tar, sulphur, and sand. A pipe can be readily removed to insert a junction, or for any other reason, when Brandram joints have been used. This joint is very useful for large concrete tube sewers, and has been used by the Portsmouth Corporation for jointing 42 ins. concrete tubes in running sand.

99. Messrs. Thos. Wragg and Sons, of Burton-on-Trent, are makers of what is known as the "Jennings joinder." It is an ordinary junction pipe with a capped socket, designed for use in the construction of stoneware pipe sewers, where it is required to leave junctions for future connections of branch drains. The general feature in these "joinders" or capped sockets lies in the cap and socket being in one piece, with a groove formed outside the socket immediately behind the cap, so that the cap may be easily cut off with a chisel when it is required to make a junction, leaving the socket ready for the inser-

tion of the spigot of the drain pipe. By using these cap sockets or "joinders" in new sewers laid in wet ground, leakage of subsoil water into them through the junction pipes is rendered impossible. The extra expense of the joinder is a very small matter, whereas the saving of money in using them may be very great.

Messrs. Doulton also supply a similar junction cap. The cap fits over the outside of the socket, and is secured with an ordinary cement joint, and, like the "Jennings joinder," the cap is grooved on the outside; it is also grooved on the inside, so that the outer disc can be readily cut off with a chisel, leaving the interior of the socket ready to take the branch pipe.

There are other methods adopted by pipe makers whereby the junction pipes may be securely sealed, and it will always be well for the engineer to specify some such method of insuring that the dead junctions do not give trouble when laying the sewers in wet ground. The junction pipes are frequently a fruitful source of trouble, and great expense is sometimes incurred in finding and making good leaks which take place through them.

CHAPTER XIII.

Gullies.—Surface Gutters—Gullies Trapped and Untrapped—Retainers Often Useless—Gulley Tanks.

100. GULLIES should be fixed at all places where surface water is likely to accumulate; thus it is necessary to place them along the sides of roads to take the water from the surface gutters. These gutters have necessarily to follow the profile of the roads to a certain extent, and the gullies have to be spaced accordingly. The surface gutters are constructed always with a fall towards the gullies. The fall should, if possible, not be less than 1 in 100. On porous ground it is often possible to keep the gullies further apart than in paved streets. They should be fixed at the bottom of every depression, and should be so arranged that there may be no open gutters crossing roads. It is well to avoid placing a gully at the corner of a street, where the wheels of vehicles taking a sharp turn will come over it, or at any other inconvenient place.

101. The grids of gullies should be of such a shape and size that all the water from the gutters may be easily

received, and that they may not be easily choked with leaves or rubbish. This is particularly the case where they are situated on steep hills, where the water has a tendency to overshoot the gully. In such a place it is essential that the grid should be long enough, and for this purpose two grids are often fixed together. Grids with diagonal bars are often fixed at such positions.

A gully is an inlet to the sewer covered by a grating or other arrangement for protection and for straining the water passing into it. Such a gully may be trapped, and may have a pit beneath its outlet for intercepting detritus, according to the needs of the case. It is essential that the gully should be of a simple form, so that it may be easily cleaned, and also that the drain from it may be accessible for cleaning.

102. Gullies are made of stoneware and iron, and they may also be built of brick, stone, or concrete. They should always be watertight. As an example of a small economical gully, with a retainer for detritus, it may be of use to mention that a stoneware T pipe is sometimes used. The bottom of the pipe is made watertight with concrete and cement, and a grid is bedded over the top, while the branch acts as the outlet.

103. The simplest form for a gully would be one for a separate storm-water sewer. All that is necessary in such a case is a small basin with a curved bottom, having an outlet pipe running to the sewer. If the gully were connected to a foul sewer in a place where ventilation was inadmissable a trap, and a cleaning eye for access to the outlet drains would have to be added. If, again, the gully were in a place where a great deal of sand would be washed into the drain, a large and deep basin, well below the outlet pipe, would have to be added. It is well that the outlet from a gully should be larger, if possible, than the drain to which it runs, so that this drain may run full bore, and that there may be no check to the flow from the gully.

104. Where there is a separate sewer for surface water there is no need for a trap, and where surface water gullies discharge into a sewer which is not likely to smell, and are in positions where such ventilation would be unobjectionable, there is no need for a trap. Retainers for detritus are very often fixed at places where they are quite unnecessary. There is no object in fixing a retainer to a gully unless it is in some place in which there will

be a considerable amount of sand or gravel washed into it. On paved roads they are not needed where the sewers are well laid. It is also questionable whether it is not better to allow silt to go into the sewers. If they are well laid to proper gradients silt will probably be carried away with the sewage. As an instance, it may be mentioned that at every storm many tons of sand are washed through the London sewers and deposited at the outfall works at Barking, where vast quantities of it may be seen. It will probably be cheaper to remove the sand remaining in the sewers than to have to clean out all the gullies after every storm. It is sometimes well to have catch pits for sand at the manholes on the course of a storm-water sewer. Another point to be remembered is that after a gully retainer has been filled beyond a certain point all the detritus brought in will be carried into the sewer as if no retainer existed. Two more points with regard to gullies should also receive careful attention, first, that the trap is very likely to become unsealed through evaporation in dry weather when it is most needed; and next, that the matter retained in gullies, particularly in those situated in paved streets, becomes very foul in the hot weather, and is likely to smell badly; as gully retainers are often insufficiently cleaned they are likely to smell, whether full or not. For these reasons it seems well to omit the retainer wherever possible, which will be in most cases, and also to avoid putting in traps where they will be useless.

105. There are positions, such as at the foot of a steep gravelly hill, where a retainer is essential. In such places the retainer should be of ample size to take all the material likely to come into it during the greatest storm. It should be remembered that a great rush of water will disturb all the sand to a depth of, say, 1ft. 6in. below the outlet, so depth will be essential. What is called a gully tank is suitable for such positions. For this a watertight underground tank is built of brick or concrete, rendered, with a grid over it and an outlet drain to the sewer.

106. Gullies can generally be arranged to discharge into manholes on small sewers.

Where a small amount of detritus only is expected, an iron gully with a retainer which can be lifted out may be used with advantage. The gully is then more likely to be properly cleaned out, and is less likely to smell.

107. Gullies are sometimes placed under the footway, with an inlet opening under the kerb and an iron cover over the gully. It is well to put a vertical grid at such a place if the opening is of a size to admit small animals.

CHAPTER XIV.

Sewer Flushing.—Hand Flushing—Flushing by Natural Streams—Flushing Tanks—Portable Flushing Valves—Flushing with Sea Water.

108. With regard to flushing arrangements, it must be remembered that at the commencement of a sewer there is, as a rule, practically no flow of sewage, and also that sewers may exist which have self-cleansing gradients when running half-full, but which generally have a much smaller flow, and are, therefore, not self-cleansing. Dead ends of sewers are sure to need flushing, except under exceptional circumstances, also sewers with insufficient flow, and those with gradients too flat to make the sewers self-cleansing. It will be seen that small branch sewers are more likely to need flushing than main sewers laid at proper gradients.

109. Sewers may be flushed by several methods. It is sometimes possible to use a natural stream for the purpose. A small stream may be dammed off and diverted into a sewer for a certain time every day, or it may be made to fill an underground tank, the water from which is discharged suddenly into the sewer. The water from the mains of the district may be used to supply such a tank. Also water from carts or bath waste water may be stored, and used for flushing. Some of the sewage itself may be held back, and allowed to discharge at a head into the lower sewers. Under some circumstances the subsoil water may be also used for flushing purposes.

110. In flushing sewers less than, say, 24in. diameter, or even larger, it is well that water should, if possible, completely fill them from invert to soffit. The value of a flush depends more upon its sudden discharge than upon the quantity of water used. That is to say, the quantity of water which suddenly discharged will make a pipe flow full bore will be more useful for cleaning the sewer than ten times that quantity discharged at such a rate that the sewer will only run quarter full.

Thus, it is clear that it will be better to store water in a tank and let it off suddenly into the sewer than to let it run in through a hose, or by any slow process.

111. Flushing tanks are built underground of brick or concrete rendered, or of iron. They are made, if possible, so that water in them may be a few feet above the level of the sewer, so that the head of water may make the velocity of the flow at the start rapid. The head should be as great as possible, but it must be limited by the amount of pressure the sewer will stand. In the case of small, well-laid pipe sewers a head of 6ft. or 8ft. may be given with safety, but in the case of large sewers greater care must be taken. The effect of a too rapid flush may be to burst the sewer, in the same way that an excessive rain storm will sometimes burst a large brick sewer.

112. Flushing tanks are often made in conjunction with manholes, and sometimes the manhole itself is used for a flushing tank. A flushing tank may be a simple rendered pit with an outgo at the bottom connected with a manhole. A plug is inserted in the outgo, and the tank filled. Upon removing the plug the contents will be discharged into the sewer. A syphon trap is fixed on the outgo pipe to prevent the sewer being ventilated into the tank when it is empty. A sluice valve or penstock is used instead of the plug if that is more convenient. The outgo from the flushing tank should be at least as big as the sewer into which it discharges. It will probably be found a more convenient arrangement if this tank is made as part of the manhole, so that the water may be discharged more directly.

113. Speaking, generally, the flushing tank as described is unnecessary, except where special discharging apparatus is used. The simplest method for sewer flushing by hand is, generally, to fill a manhole with water and discharge that into the sewer. It is well to proceed by stopping all inlets and outlets to the manhole, but this is not absolutely necessary. It will be enough sometimes to stop up the outlet only. The following things must be borne in mind, however:—(1) The water will have to fill all branches that are not plugged off, and this may mean using a great deal of water. (2) It is necessary, in order to get the required quantity and pressure, to let water stand at a depth of some feet in the manhole. (3) The water must not be allowed to rise to such a level that it will be above any inlets on the branch drains running to the manhole, otherwise, instead of

filling the manhole, the water may be finding an exit in the areas of houses, etc.

114. Penstocks are frequently fixed in manholes for stopping off drains for flushing purposes. There are many kinds, and they are very generally used. It does not, however, appear that they are altogether satisfactory for the purpose, for the reason that they afford places where foul matter may accumulate, and it is inconsistent to fix valves of a kind which will tend to collect dirt in manholes, after taking elaborate measures to avoid such accumulations of filth. As a rule, it is not difficult to insert a plain plug of some kind into a sewer which has to be stopped for flushing. A conical piece of wood covered with india-rubber and with a chain attached will answer the purpose, or, better still, a portable flushing valve, *e.g.*, Bosley's patent flushing block. If the sewer is very large it may be partly dammed off to allow water to accumulate to a certain height, which is then released for flushing. Where sewers are situated near great tidal rivers it is sometimes possible to build large underground tanks, which are filled by the rise of the tide, after which the valves are shut and the water stored for flushing purposes.

115. To do away with the difficulty and expense of flushing sewers by hand, as already described, various automatic apparatus have been invented, and are largely used, being found, as a rule, more economical than other methods. The more common form is the syphon. The automatic syphon is fixed in a flushing chamber near, or built in conjunction with, a manhole. As soon as the tank is full of water the syphon discharges its contents. By regulating the supply the tank can be made to discharge at any interval required.

116. The method of flushing sewers by means of water carts is important. It is possible to carry a large quantity of water in a cart, which should be discharged into the sewer through an outlet as large as the diameter of the sewer itself, if it is to be used as a direct flush.

117. Messrs. Merryweather's patent hydraulic apparatus for cleansing sewers is one in which a number of small jets of water are used on a hose which is put into the sewer to be cleansed. It is said that a great saving in water is effected by this apparatus—viz., that it takes only one-tenth of the water needed to flush sewers by ordinary methods. This, in the case of a scarcity of

water, or where an increase in the flow is of serious consequence at the outfall, is very important; also for flushing large sewers through which a man can walk its advantages are obvious.

118. The quantity of water needed for flushing a sewer will depend upon the size of the sewer, its gradient, and its length, and also upon the head of the water in the tank. It is a matter which will need careful consideration in each case. Bath waste water, rain water, etc., is sometimes stored in a gully tank, which discharges by means of an automatic syphon for flushing.

119. Sewers will need flushing probably at least once in twenty-four hours. A large flush once a day or once in two days will probably clear the sewers better than two or three smaller flushes given during the same period. Sewers regularly flushed will not need anything like the same amount of water as those which are not cleansed in this manner till they show signs of becoming foul or clogged.

120. Sea water is used for flushing low lying sewers by allowing them to fill with water at high tide, and letting it discharge at low tide. The objection to sea water for flushing is that it corrodes ironwork. It is also said to cause solids to deposit and to produce putrefaction in the sewage, which renders it poisonous to fish when discharged into the sea, whereas fresh sewage would not be so harmful.

CHAPTER XV.

Sewer Flushing (Continued).—Hand Flushing—Flushing by Automatic Syphons—Length of Sewer Flushed by Discharge.

121. There can be very little doubt, speaking generally, that where a sewer needs systematic flushing, an automatic apparatus which discharges a flush regularly at stated intervals is better than any hand flushing arrangement can be. The quantity of water used can be regulated to a nicety, and whatever water is so discharged into a sewer does useful work. It must always be a difficult matter where sewers are flushed by hand to prevent a great deal of water being wasted. The valves are very likely to leak and allow a quantity of water to run into the sewer uselessly.

122. The following sketches show some of the various methods for flushing sewers. In Fig. 14 a hand flushing arrangement is shown. A hydrant pit is made next to a flushing pit, which has a trapped drain running to a manhole. An earthenware bend, carried up nearly to the ground level and covered with an iron cover, will do instead of the pit. When the sewer has to be flushed all sewers are stopped by plugs or penstocks at the manhole, and a bent copper pipe is connected to the hydrant by a union, and the manhole is allowed to fill. When full, the water is discharged into the sewer to be flushed by opening the valve or removing the plug. It will be seen that great care is taken that there may be no possible connection between the sewer and the water main.

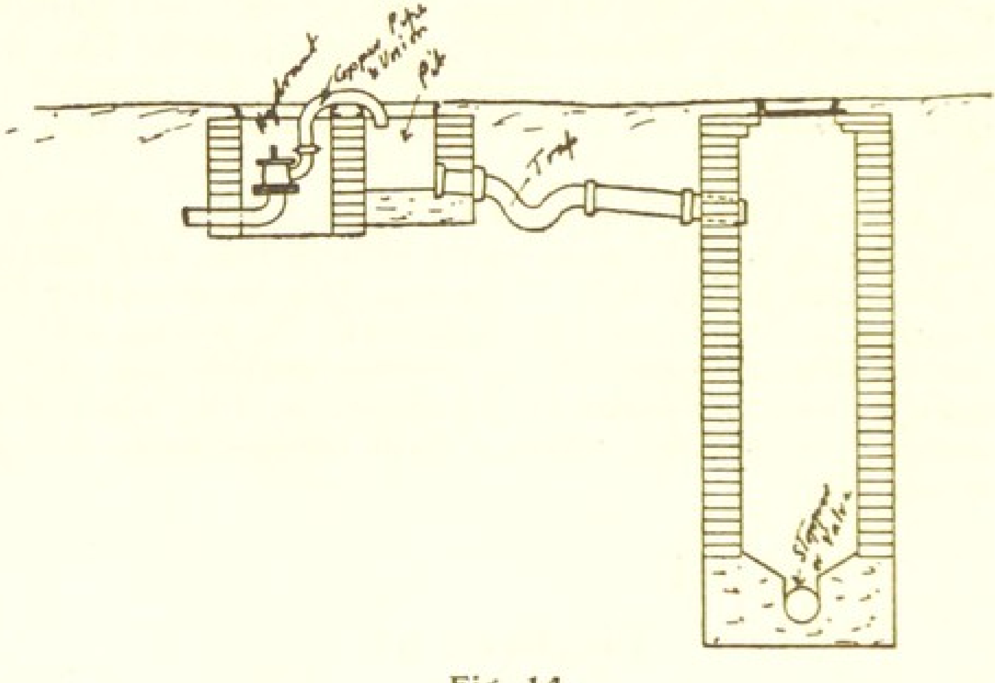


Fig. 14.

Of course, the bent copper pipe is only attached to the hydrant when the filling is going on. In Fig. 15 an arrangement is shown which is used in a case where the supply of water for flushing purposes has to be measured by a meter. A small main runs to an *open* gully, into which it discharges. There is a meter and stop cock in a small pit on the course of this main. It is very necessary that the water main should be disconnected from the sewer *in the open air*, and not in a closed gully, or as is sometimes done, by dipping it into a pit of water which has an outgo to the sewer. Such careless arrangements cannot be sufficiently condemned. It is by no means uncommon to find water mains running directly into flushing manholes, owing to the ignorance or carelessness of those who designed and carried out the work. It is almost needless to say that it is the duty of all those responsible to see that such arrangements are altered. It is possible that sewer gas, disease germs, and even sewage may find their way into water mains connected to a sewer manhole. If a water main should prove to be empty when the valve is opened, it will readily allow sewer gas to enter the main, and in the case of a bad stoppage in the sewer it will allow sewage to enter. It may be said that such a case is not likely to occur,

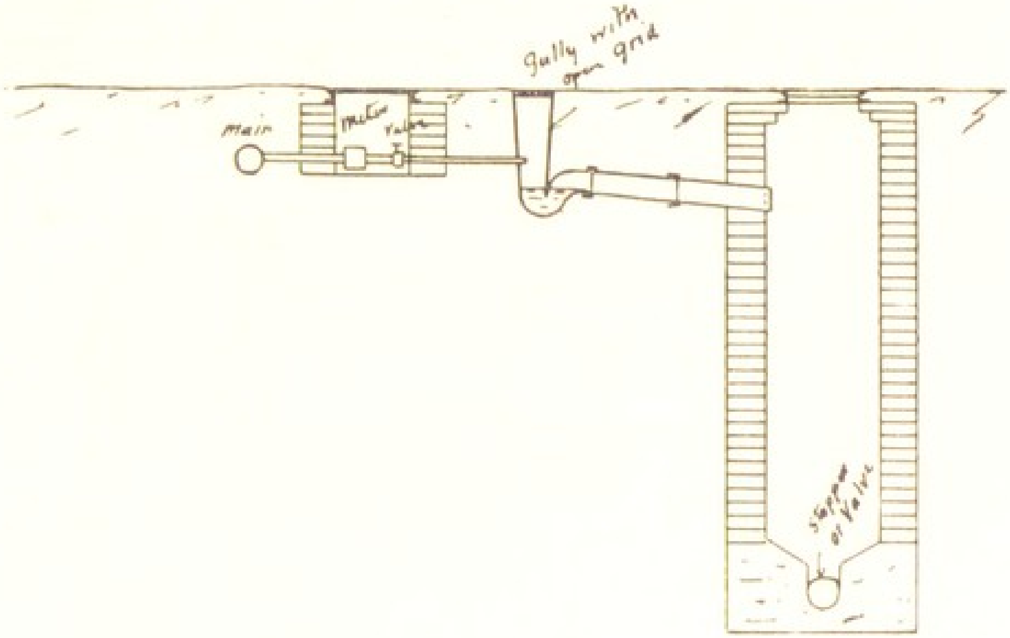


Fig. 15.

but it ought not to be even remotely possible, and any engineer or other person who is connected with the management of an old or unknown sewerage system should look out carefully for such defects, and also see that they do not occur in new work.

123. For practically the same reasons water mains should not be connected to flushing chambers. These chambers, though forming no part of the sewer, have a direct connection with it, and this connection is often not trapped, but is kept closed with a valve. If it is trapped there can be no guarantee that for various reasons the trap may not at some time become unsealed. Therefore water mains should never be carried direct to the flushing chamber unless the water in them is not

used for drinking purposes. It is quite easy to disconnect them in the open air by some such arrangement as is shown in Fig. 15.

124. Flushing chambers are sometimes constructed above the ground at suitable places.

125. The advantages of automatic flushing for sewers are so great that it will be well to give a few examples of some of the syphons most generally in use. The regularity of the flushing, perfect control, economy of water, and saving of all labour make the use of automatic apparatus very desirable in most places.

126. Fig. 16 shows the working and fixing of one of the Adams syphons. It consists of a central syphon

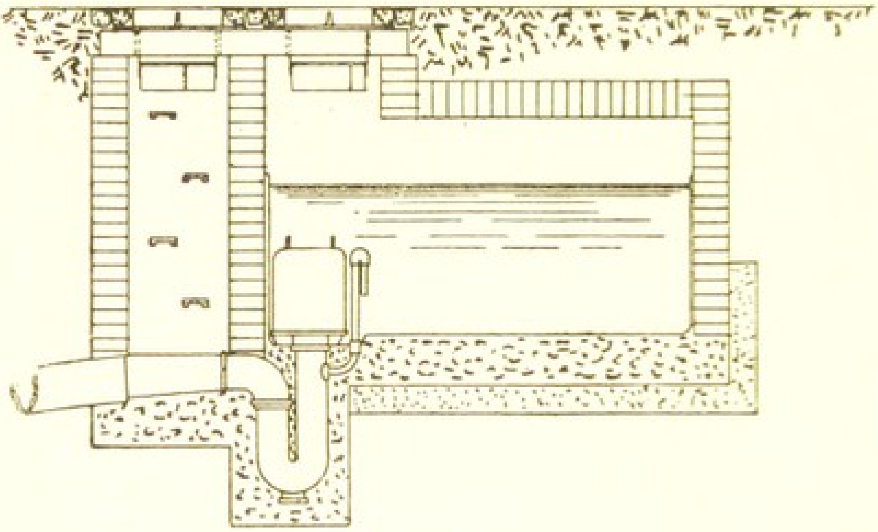


Fig. 16.

with a deep water seal, which is surmounted by a dome. The apparatus is fixed in a flushing chamber, as shown in Fig. 16. As water rises in the chamber it locks a quantity of air in the dome between the water in the deep trap of the syphon and the water in the dome. This air is gradually compressed by the water rising higher and higher in the flushing chamber, till at last a pressure is produced sufficient to expel the water from the syphon trap into the sewer, and to set the apparatus discharging the whole of the contents of the chamber. It will be seen that no discharge can take place till the water has risen to the proper level, after which the whole of the water will be discharged rapidly.

These syphons are generally placed at dead ends of sewers, and may discharge directly into a manhole, as shown in Fig. 16.

127. Sometimes a flush may continue to be useful for a great distance along a sewer. At first it may be sufficient in volume to clean the sewer for its full diameter, and later it would decrease in depth to such an extent as to be useless, were it not for the fact that the ordinary flow of sewage increases in volume the further the flush travels, so that the flush water and the flow of sewage together may produce something like the volume and velocity of the flush at its start.

128. In cases where a sewer is flushed by hand and the supply of water is small, balls of various sizes are sometimes floated through the sewer, behind which the water backs up whenever the ball is stopped by any substance, till the pressure is sufficient to remove it. If the sewer is very much fouled a small-sized ball is floated through first, and then one a size larger, and so on till a ball of a diameter say 1in. less than the size of the sewer is floated through. Whenever the ball stops the water passes all round it, and so scours the sewer. As the ball floats the greatest scour will be along the sewer invert.

CHAPTER XVI.

The Ventilation of Sewers.—Objects of Ventilation of Sewers—Steep Sewers—Influence of Atmospheric Changes—Prevention of Pressure or Vacuum, Essential.

129. The objects to be attained in ventilating a system of sewers are, first, that no pressure of air or gas may occur in any place; next, that fresh air may be freely admitted to all parts of the system; and lastly, that all foul air may find a ready outlet at places where it will at once be diluted by plenty of fresh air, and where there will be no risk of its being a danger to health, and where also there can be no objectionable odour, harmless or otherwise, experienced by anyone. The subject is a difficult one, owing to the fact that the most densely crowded districts, where houses are close together and streets narrow, will naturally have the largest sewers and greatest flow of foul sewage, needing a great deal of ventilation, and will possess the fewest places where foul air can safely be given off.

130. The great difficulty of ventilating sewers in such places, and the undoubted objections, scientific and practical, which can be justly made to any of the methods at present used for ventilating such sewers, has led to great differences of opinion upon the subject of sewer ventilation. Such objections, if examined, will often prove to be not so much objections to the methods of ventilation as to the existence of sewage at all. No doubt it is not an ideal state of things that a large quantity of foul sewage should be carried in a sewer through a crowded district, pipes from which are connected to every dwelling-house. Unfortunately, as nothing better has yet been devised, it is necessary to make the best of a bad job and protect ourselves in every way possible. That this can be done with great success and safety has been conclusively proved.

131. The ventilation of sewers must be always a matter of common sense rather than of rules and methods. It is often urged that a well-laid sewer does not give off harmful sewer gas, because all foul matters are carried away, and do not remain in the sewer long enough to putrefy. This being so, it is then urged that open ventilators can be fixed at all manholes and lampholes along the road or elsewhere, so that an abundance of fresh air may enter the sewer. This system, on the whole, is a good one, but it can only be applied in certain places under certain conditions. It must be remembered that even fresh sewage may smell very badly, and, whether the odour is dangerous to health or not, it may be very objectionable. If fresh sewage flowed down the road, for instance, in an open channel, it would be offensive. Again, it is possible for sewage to accumulate in the best-laid sewer at times when the flow is insufficient, and there is also the probability that a certain amount of foul matter will adhere to the sides of the sewer in time, and this will certainly decompose and form sewer gas. Also, the engineer has to provide against possible neglect, and even damage, to the sewer in the future, when accumulations will be likely to occur and smell badly. For these reasons outlets for sewer air should not be put near houses, in narrow roads, or in confined places. It is well to consider every inlet ventilator as a possible outlet, there being no doubt but that at certain times sewer air will come out there.

132. In order to consider the principles upon which sewers are ventilated, it is well to take the simple case of a long sewer receiving the discharges from a number of house drains. Assuming, first of all, that it is not ven-

tilated at all, it will be seen that any discharge, such as a large flush, running into it suddenly will be likely to compress the air and unseal the traps in the house connections, thereby forcing the sewer to ventilate into the house drains, as it must be remembered that the pressure needed to unseal such traps is probably between one and two ounces on the square inch only. Next, let us consider the same sewer with open grids to manhole covers at frequent intervals. As soon as a large enough flush to compress the air flows down the sewer, air is expelled at the covers. Suppose that the sewer should run full bore, the air will first be expelled, and then drawn in from such places, as the water runs out of the sewer. The same will happen in a less degree for every sort of flow that may pass down the sewer. It is probable that the air in such a sewer is seldom still. The flow of sewage will tend to make a current of air down it. The air inside will often be much hotter than that outside, and it will then rise out of the ventilators. The wind passing over or blowing into the ventilators is likely to produce a current, etc. It is fairly clear, then, that a sewer under these circumstances would be well ventilated and, provided that the ventilating covers could be fixed in places well away from houses, the arrangement would be satisfactory. If this could not be done without objection, it would be necessary to put in ventilating shafts, carried to a height and position where sewer gas could be safely discharged. It might be imagined that such a sewer could be ventilated easily with one inlet point and one outlet point at the far end, where a fan or other apparatus could be used for drawing out the foul air. This is not so, however. A fan extracting the air or forcing air into a long sewer would be likely to force the traps of the house connections and the road gullies ; also, the existence of any unsealed trap, opened cover, the sewer running full bore, etc., would be likely to entirely upset the working. The impossibility of ventilating a large system of sewers with a strong mechanical draught of any kind may therefore be seen at once. The effect would, of course, be that only a very small part would be ventilated at all. The same objections apply to the method of ventilating a system of sewers by a furnace at the bottom of a high brick shaft. These methods of producing ventilation can only be useful in the case of a sewer without branches, such as a long outfall sewer.

133. Sewers should be so arranged that none of the flow takes longer than twenty-four hours to reach the

outfall. After this time sewer gas is produced, as distinguished from the smell which is present with fresh sewage. They should be so well laid, cleaned, and flushed that there may be no accumulations of foul matter. Very steep sewers should be avoided, for the reason that the matter flowing through them is likely to be churned up, when it will smell very badly; also, as already mentioned, such sewers are likely to become foul with solid matter left behind.

134. In steep sewers there is a tendency for the air contained to be carried past any openings for ventilation along the course, with the consequence that there is an undue discharge of sewer air at the highest ventilator on the sewer which may be very objectionable. For these reasons it is customary to break the line of sewer into short lengths on a steep hill. To do this the number of manholes may have to be increased. The sewer is laid in steps or ramps in the following manner. The top manhole is made deep, and the sewer is carried from it at a gradient as steep as can be given without producing bad results to a point where the sewer is as near the surface of the ground as is safe. (The question of the maximum gradient for a sewer was dealt with in Article No. 4.) When the sewer has been carried as far as possible a small manhole is made, and a short, very steep length of sewer is taken to a larger manhole close by. The small manhole referred to may be omitted if the sewer is carried on straight to the deep manhole at the ordinary slope, for cleaning, while the steep branch descends to the invert level in the manhole. The steep sewer should enter the manhole curved at the bottom, so as to avoid splashing. Another method is to carry the sewer to the deep manhole, and allow the fall to take place in it with a carefully formed curved channel. It is not possible to make a great difference in the level of the sewer in this way. In both these methods flaps are fixed, if necessary, on the inlet pipes, and the manholes are ventilated, and also the end of each sewer just above the manhole, so that a number of short lengths of sewer are made with an inlet at the lower end and an outlet at the top end. A modification of this system of steps will prove to be useful in the case of steep sewers, which are more liable to give trouble than sewers at ordinary self-cleansing gradients.

135. In order to arrive at any general conclusions on the subject of sewer ventilation it is necessary to bear in mind that, in addition to the facts already mentioned, sewer gas is generally heavier than air, and that some-

times the atmospheric air is hotter than that in the sewers, and that there are often periods when there is no wind; all these things tend to produce a sewer full of bad air, which has no tendency to move or leave the sewer except from the flow of sewage, which at such times will probably be at its lowest. The fact that a sewer is full of air polluted by fresh sewage is not as satisfactory as might be, but, as has been already pointed out, some smell must exist, and even if the sewer were open along its whole course and a wind blowing through it this could not make foul sewage sweet. When the air from a well-laid sewer which is properly kept is discharged into the open, it is generally believed that there is no risk to health. If, however, there is any risk of sewer gas entering a dwelling house, the danger to health is believed to be very great. This is *the* great danger, and whatever else is done, the ventilation and arrangement of sewers must prevent the possibility of sewer gas finding its way into houses. It is better to have an offensive ventilating manhole in the roadway than to have a slight pressure of sewer gas in the sewer, which, though perhaps unnoticed, will occasionally force the traps on house connecting drains and allow sewer gas to get into house drains, where, perhaps, another step of the same kind will take it straight into the houses. Thus the first thing to do is to arrange that the sewer may have ventilators for inlet or outlet of air at frequent intervals. In practice 600 ft. apart is considered the maximum distance at which ventilators should be placed. It is better to have them much closer together—say, 300 ft. apart. The circumstances of the case must always make a very great difference. If pressure of air inside the sewer at any point is made impossible, the fact that at times there is no current of air along a sewer and that there is no discharge of sewer gas other than an outflow from the top of shafts does not necessarily constitute a danger, and may be necessary in crowded localities, where ventilators at ground level are out of the question.

CHAPTER XVII.

The Ventilation of Sewers (continued)—Positions of ventilators—Ventilators near flushing chambers—Ventilators in crowded localities—The use of shafts.

136. Having decided that frequent openings for ventilation are essential on a system of sewers, and that

these must be sufficient to prevent any pressure of air from taking place, and any vacuum or partial vacuum being formed in the sewers, it is next necessary to consider at what places and in what form they should occur.

137. In the first place, a ventilator must always be provided where any large flush enters the sewer. Thus the manhole which receives the water from a flushing chamber must be ventilated. The same would apply to any other large discharge. This is done to prevent a vacuum which would otherwise be formed. Again, as any sewer may at some time flow full bore, the necessity of frequent ventilators for the same reason is clear.

138. In parts of London it is becoming more and more the custom to avoid ventilators at the ground level, and to fix long shafts to allow the sewer air to escape at points as far removed as possible from buildings and other places where their discharge would be a nuisance or harmful. There can be no doubt that the system is a good one. It has, however, been pointed out that in cold weather the column of air in a long metal shaft will be chilled and heavy, and tend to prevent circulation; also, that when the outside air is still and moderately warm, sewer air does not rise in the shaft, and, in fact, that under certain conditions of the atmosphere the air will not circulate in a sewer ventilated with long shafts. These defects, however, and other theoretical considerations are outweighed by practical results. The alternative of having open ventilators in narrow, crowded streets—a method not only exceedingly unpleasant, but also dangerous to health—and the other alternative of closing any ventilators, and thereby creating a pressure of gas in the sewer, are both of them imposible arrangements.

139. It is, then, clear that in the present state of our knowledge the use of long shafts to convey the bad air from sewers to safe places is often essential. This does not mean that a system of sewers ventilated throughout with shafts is to be recommended, although the objections generally raised to it are more theoretical than practical. It is cheaper and better to ventilate the sewer through an open manhole or lamphole cover wherever possible. It must be noted that, although the long shaft will at times produce a better circulation of air than would take place at an open manhole under the same circumstances, this advantage is outweighed by the fact that a long shaft is just as likely at other times to retard the circulation, as already stated.

140. The modern ventilation of sewers is based on these facts, it being clearly understood that, though a constant circulation of air is desirable, the fact that it does not occur at all times need not be considered a vital objection so long as no pressure occurs in the sewer.

141. In dealing with an ordinary sewer it is best to have a ventilating cover at every manhole or lamphole where possible, and it may often be well worth while to use the road gullies for ventilators; that is to say, to have no trap to these gullies. This can, of course, only be done under circumstances where the engineer can feel confident that the flow of sewage is of a character that will not create an offensive smell at the ventilators, and when the gullies are in such positions that a possible smell from them would not be a nuisance. As an example, it is not unusual to find manholes with ventilating covers at the road side, and sometimes trapped gullies occur close to such ventilators. Such methods are inconsistent. It is well, also, in considering the possibility of using road gullies as ventilators, to notice the many open ventilators situated even in crowded places, which we very likely walk over every day, and from which we experience no nuisance. The fact that in certain places a very great nuisance occurs, owing to open manhole covers, probably points to the fact that the sewer there is defective or badly kept. It is, perhaps, worthy of note, also, that some of the places where the worst smells occur are not the most crowded. Open ventilators, for instance, exist at Westminster in roads which are by no means very wide, from which there is not any very noticeable smell. On the other hand, there are open manholes in certain sewers in more or less open situations in the suburbs which are all the year round a nuisance to those living near them. There is abundant evidence to prove that a well-laid, properly kept sewer does not smell badly at the ventilators.

142. The idea of untrapped gullies as ventilators on a good sewer in an open place is, therefore, well worth taking into account in new work, and may save expense.

143. Storm water overflows generally act as ventilators to the sewers. Care should be taken that their position is suitable for the purpose. There is also likely to be an inlet draught at the outfall, which may need to be controlled.

144. Where sewers cannot be ventilated at the manhole covers an air pipe may be carried from the manhole or

lamphole to a convenient place. This pipe is laid as if it were a sewer, and should take a straight course. If necessary it can be connected to a vertical shaft. It may be possible also to carry a vertical shaft up direct from the sewer.

145. Ventilation shafts for sewers are generally not less than 6 ins. in diameter and circular in section, as that shape gives the least friction, and consequently a better draught. All bends are avoided as far as possible, it being estimated that a square bend will reduce the velocity of the draught by one-half. Such shafts are very generally made of iron, though there is no doubt that if the inner surface of the pipe were of lead or other metal not likely to corrode the result would be better. It is not at all an uncommon thing to discover a ventilation pipe choked at its foot with rust, which has formed on the inside of the pipe and fallen to the bottom, making the shaft useless.

146. Where an iron shaft, therefore, joins an air pipe in connection with the sewer there should be a small pit, with an inspection door, so that if rust should fall it may not block up the pipe, and that it may be possible to clear away any accumulation. Where iron ventilation pipes exist in old work such pits should be added. Galvanised iron pipes should always be used in preference to plain iron pipes, as rust not only tends to block the shaft up at its foot, but also, by making the interior surface rough, retards the flow of air.

147. The tops of shafts should be protected with wire caps, so that birds cannot build in them. Cowls to extract the air are useless in calm weather, when a draught is most needed. Lamp-posts are sometimes used as ventilator shafts.

148. Mechanical apparatus for ventilating an ordinary sewerage system has not proved to be a success, partly for the reasons already given, and partly because the cost of the apparatus and its working is too great. When, however, in the case of the Shone system, compressed air mains are carried to various parts of the system to raise the sewage, it may be found worth while, where necessary, to create an artificial draught in a shaft by means of the compressed air. It goes almost without saying, however, that the method of ventilating sewers should be as simple as possible, and that, except under very exceptional circumstances, mechanical apparatus will be unnecessary.

149. It is necessary to refer to the system of ventilating sewers by allowing all house drains to run untrapped into them, and thus using the vent pipes of the house drains to ventilate the sewers. Of course, there would be no objection to this system if all the house drains and vent pipes were sound, and well arranged with a perfect system of sewers to discharge into, but inasmuch as such perfection is extremely unlikely to exist, or to remain perfect, the method of ventilating sewers through house drainage systems cannot be considered safe. Moreover, this method is, at its best, very unnecessary. If the sewers are fit to be ventilated through the house systems, there can be no reason for not ventilating them at many points in the streets, say at the road gullies, which would be a much better method than allowing them to ventilate near the houses, within a few feet of bedroom windows or chimney tops.

150. The tops of sewer vent shafts should be kept as far as possible from all windows, chimneys, or dwelling-houses. Unfortunately, in the crowded parts of London this is very difficult. It is, however, unpardonable to place them, as is frequently done, close up against houses, within three or four feet of the tops of chimneys, where a down draught can at any time carry the gas emitted into bedrooms. Glaring examples of this exist in London at the present time. It is certainly not only worth the extra expense and possible unsightliness to keep the tops of sewer ventilation pipes at least 20 ft. away from windows or chimneys, but to do so should be absolutely obligatory.

Probably the most serious defect in the ventilation of sewers is the careless way in which vent pipes are placed against buildings.

151. Common sense and a careful study of existing systems can be the only guide in the difficult subject of sewer ventilation, and it is the object of the present article to point out that, speaking generally, new sewers may be safely ventilated in the roads at open manholes and lamphole covers, and sometimes at gullies, and that, where this cannot be done safely, shafts must be connected to the sewers and carried to safe places, and that if such arrangements prove to be a nuisance it points to the fact that there is something very defective in the sewer itself.

152. The practice of building a vent pipe up in a wall and so hiding it is to be condemned if the position is one

in which a leak of sewer gas into the wall would be dangerous. There have been many cases of such shafts which have allowed sewer gas to enter into dwelling-houses, especially where glazed stoneware pipes have been used. Hidden work of any kind is always liable to be a source of danger in the future.

CHAPTER XVIII.

Sea Outfalls.

153. Crude sewage should never be discharged into the sea without purification, unless the existing conditions make it certain that it will be carried by the currents right out to sea, and not taken along the coast to be blown or washed ashore. In choosing a site for an outfall sewer the greatest care must be taken that the position is one from which the currents flow in the right direction. For instance, if the current sets from west to east it would be the greatest folly to place the outfall west of the town, as in that case the sewage would all be carried past the town in front of it, and very likely deposited on the beach. It is obvious that in such a case the outfall should be at the east end of the town.

154. Before deciding upon any position selected, very careful observations should be taken and experiments carried out at all states of the tides and currents to ascertain what will become of sewage discharged at the point chosen. The direction of the currents may be ascertained with floats, which must be of such a character that the wind will not be able to blow them in a direction different from the current; at the same time, the action of the prevailing winds upon floating matters must not be lost sight of. The floats used for such experiments are sometimes made of long strips of wood, weighted at one end, so as to float vertically in the water, the greater portion being submerged; also a small float, from which a bucket is suspended, can be sometimes used with advantage. In either case the float will be very little affected by the wind, and the direction of the current will be made clearer. The currents at different depths should be tested in this manner—those close to the shore, also the currents further out.

155. Under the most favourable conditions the outfall sewer is generally carried out to sea to the lowest low-

water mark, and has sometimes a vertical dip into the water. It is generally necessary that the outlet should be submerged. Where conditions are not so favourable the outfall sewer may have to be carried far out into the water, the work being done by divers. Sewage should not be discharged against the current, or the flow will be interfered with. If possible, the outfall should be parallel with the currents, so that they may aid the flow. It is necessary to arrange that the end of the outfall sewer may not become blocked up with sand or stones, or be undermined by the action of the currents, or sink into the sand, etc. It is also important that the sewage discharged may not settle in front of the sewer, so as to in any way block up the outlet. It may often happen that an outfall sewer has to be constructed at such a level that during a great part of the tide it is full of water, and the pressure of the sewage is insufficient to cause any discharge. Also it may happen that there are objections to discharging the sewage with a rising tide. In such cases the sewer is made of a sufficient size to store all the sewage flowing into it. Such sewers are generally called tank sewers. It is generally very necessary to provide them with efficient storm overflows, to prevent the flooding of the lower parts of the town.

156. It can well be understood that if the tank sewer is at a level below high-water mark the sea water must not be allowed to enter it, or the lower sewers of the town will be likely to overflow. It is customary in such cases to have a flap valve fixed on the sewer to keep back the water, and a penstock to retain the sewage in the tank. The flap valve is fixed as a safeguard in case the penstock is not closed when the tide rises to its level. The penstock should be shut and remain closed till the sewage can be safely discharged without the sea water running into the tank sewer. It is customary to fix a tidal flap on most outfall sewers, unless sea water is intentionally admitted into them for flushing purposes. This flap is not necessarily fixed on the end of the sewer, where it will be likely to become useless for excluding water through getting stuck open, and where it is in an inaccessible position. It is better, if possible, to arrange to have the tidal flap valve fixed in a special manhole, the cover of which is above high-water mark, where it can be attended to and kept in order. The retaining penstock should be fixed in a similar chamber. Another method by which the sea water may be excluded from the tank sewer, and the contents discharged at

low water only is that of the floating arm outlet. This consists of a float in a chamber, fixed to a pipe connected to the sewer, with a movable joint at the sewer. As the tide rises this floating outlet is always kept above water level, and after the liquid level in the tank sewer is reached no discharge can take place till the tide falls.

157. It is said that fresh sewage discharged into the sea is not harmful to fishes, but that, on the other hand, putrifying sewage is very harmful to fish life. Sea water admitted to sewers is said to produce rapid decomposition. This, therefore, is a further reason for excluding sea water from sewers in certain cases.

158. That part of an outfall sewer which is in any way likely to be exposed to the action of the sea is generally constructed in cast iron, or sometimes in steel. Stoneware or brickwork sewers may be used in places where they are at sufficient depth to be well bedded and protected in a mass of concrete, but it is necessary always to bear in mind the fact that a sewer on the foreshore is liable to be uncovered and undermined by the action of the waves. It is, therefore, necessary to protect sewers against this possibility. Thus it is well to support a sewer, laid in sand, not only underneath, but also at the sides, with piles or other suitable protection. This will generally be necessary up to a depth of 3 ft. or so, according to the circumstances. On a rocky shore it is sometimes well to lay the sewer in a trench with a substantial foundation of concrete, and to fill the entire trench with concrete, which should follow the general conformation of the rocks at the surface, so that there may be no unsightly gash in the rocks, as frequently may be seen in works on the foreshore, when exposed at low tide.

159. When an outfall sewer comes above the ground level it should be well protected against vertical or lateral movement. This is generally done with substantial timber piling on both sides of the sewer, the pipes themselves being held by walings above and below them. Flange pipes are generally fixed more easily than spigot and socket pipes for this work, because a bolted joint may be made under water, if necessary. Manholes should be made on the course of the sewer in the tidal water. These generally consist of an inspection hole in the iron pipe, the cover of which is bolted down and made watertight. It is necessary to remember that the outfall sewer should be so constructed that there may be no danger to boats from the submerged piles

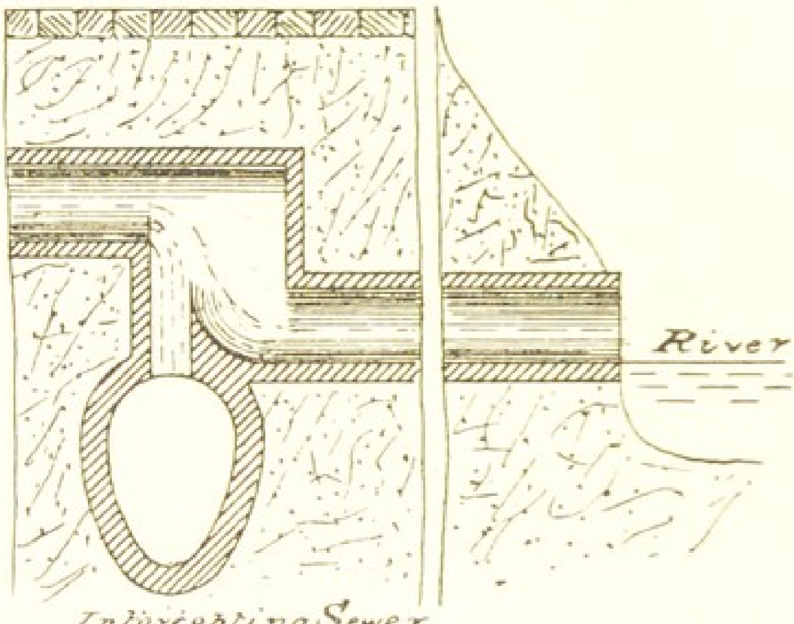
CHAPTER XIX.

160. With regard to storm overflows, their need arises from the fact that it is a great advantage to get rid of the excessive quantity of clean water, which flows into a system of sewers during a storm, which, if carried to the outfall, would make it necessary for sewers to be of very great size, and would very much increase the bulk of the foul sewage to be dealt with in one way or another. A very small sewer may be quite sufficient for the ordinary flow, but if all the storm water is to be carried to the outfall a sewer of vast size may be necessary. There will also be chances of such a sewer bursting and flooding the lower districts. The smaller a sewer can be kept in size the greater chance will there be of it having a rapid flow, and so keeping clean.

161. In designing storm overflows it must be remembered that when a storm occurs after a long drought the first rush of storm water through the sewers washes away any deposit left in them during the dry weather, and thus it may be more foul in character than the ordinary sewage. It is very clear, therefore, that the sewers must be of a size to take this first flush, and that none of it must escape at the storm overflow outlets. As soon as the sewers are clean the flow of storm water following the first flush will be clean enough to discharge into any natural watercourse, or river, lake, or the sea. Storm outlets can be, therefore, carried to any suitable point at hand where the water may be safely discharged, or it may be possible, as stated in an earlier chapter, to discharge the storm water into some older and otherwise disused system of sewers, or into a disused outfall sewer, or it may be discharged into a separate sewer made for the purpose. These storm outlets from sewers must be taken from the main sewer at such levels that storm water only can escape.

162. The arrangement shown in the accompanying sketch (which is copied from Baldwin Latham's Sanitary Engineering) shows how the principle of the leaping weir (by which waterworks engineers manage to intercept the clear water in a storm for use, and let the flood water pass away) may be used for storm water sewers. In this case the liquid which flows with a low velocity in small quantities is the foul sewage, and it is all intercepted by passing through an opening in the bottom of the upper sewer

and falling into the sewer below, which runs to the outfall. When there is a great current of clean storm water in the upper sewer it will leap over this opening and run to the storm outlet shown. In constructing this



interceptor the opening through which the foul sewage drops is generally made smaller than is necessary, and is afterwards enlarged to suit the requirements of the case as ascertained by trials.

163. Great care must be taken that the storm outflows and sewers are of sufficient size to carry off the flow due to the greatest rainfall.

The storm outlets should discharge in places where a possible ventilation of sewer gas will not be dangerous or objectionable. A flap valve may be fixed at the outlet, and this is needed particularly in the case where the storm outlets are below the water level of high tide.

CHAPTER XX.

The Maintenance of Sewers.

164. The proper maintenance of sewers is a matter needing very careful and regular attention, without which the best-designed system is always liable to fail in one

way or another. It is, however, very often neglected, with the result that sewers become a nuisance and a danger, and various troubles arise.

165. If a sewer ventilator should give forth foul gases, the first thought of a great many persons is that it should either be stopped up, or that the foul gas should be conducted elsewhere. It goes without saying that if such a state of things occurred in a properly designed system the remedy would be to *remove the cause of the smell*—viz., the foul matter adhering to the sides of the sewer. If, on the other hand, the sewers are so defective that they are not self-cleansing, it is clear that steps ought to be taken to alter the defect.

166. The maintenance of sewers consists chiefly of keeping them quite clean and well ventilated, seeing that all valves and apparatus are in an efficient state, and that the sewers are sound.

167. The sewerage system should be inspected frequently and regularly, and the more often the work is inspected the less chance will there be of any very considerable work having to be done. If the system can be inspected, say, once a fortnight, it will be found well worth while.

168. The inspection should include looking into all man-holes to see that they are clear, and that no stoppage exists in the sewer to dam the sewage back, and to observe if any particularly foul smell exists due to a deposit of sewage. All flushing chambers should be examined, together with the automatic flushing apparatus. It should be ascertained that the syphons discharge properly, and do not dribble into the sewer continuously instead, in which case they will not flush the sewers. All gully grids should be inspected and cleaned out if stopped up The gully catch basins and retainers should be inspected once a week, and cleaned out whenever necessary; they should also be cleaned out after every severe rainfall. If they do not receive frequent attention they will be useless for intercepting road grit. Gully basins and retainers should be cleaned with a hose and brush, after the material has been removed, and if they smell they should be washed out with a deodoriser.

169. Manhole dirt boxes should be emptied, and the open gratings of manhole and lamphole covers should be cleared wherever necessary at the inspection. If any bad smell other than that caused by fresh sewage is found to exist in opening any manhole or in inspecting

any ventilator the cause should be ascertained and removed.

170. Hand flushing from manholes, lampholes, and gullies will be found advantageous under particular circumstances, in addition to the ordinary flushing arrangements.

171. Iron vent shafts should be inspected occasionally to see that they are not choked, and the rust pits at the foot of each should be periodically inspected, and cleaned out if necessary. No iron pipe with a bend at its foot should be allowed to go untested, as the chances are that the bend will be found to be blocked up with rust from the pipe.

172. If inverted syphons under streams, etc., occur in the system they should be frequently inspected to see that they are working properly. If necessary they can be cleaned by means of a chain passing through them, as described in a previous article. If a catch-pit occurs at the foot of the descending arm of the syphon it can be cleaned by means of a ladle at the end of a long pole without emptying the syphon. If the syphons exist in duplicate, of course, the sewage can be diverted to one syphon while the other is thoroughly cleaned out.

173. Any part of a small sewer found to be broken or cracked should be relaid. Sewers which exist in places where the soil is porous and where a leakage would be dangerous to living houses near, should be periodically tested with water to see that they are quite watertight. It is an excellent thing to test the whole system where practicable.

174. The maintenance of sewage disposal works is a subject in itself, and is a matter of the greatest importance. Space does not allow of a detailed description of the work required being given. Failures are generally, if not always, due more or less to neglect. It is well that the disposal works should be placed in some conspicuous position, such as at the side of a railway or near a public road, so that if they are neglected and a smell should arise the matter may attract notice and the defect be remedied before serious harm is done.

175. The most usual way of cleaning a small sewer much blocked up is by means of rods. These rods are generally made of cane, and are fastened one into another, some-

times with a screw joint and sometimes with a spring clip. They are very like the rods a sweep uses for cleaning a chimney. A number of tools and brushes of various kinds are sold for use with the rods. They may be worked from one manhole and passed through the sewer to the next, so that the sewer can be thoroughly cleaned. Dirt so removed must be collected at the manholes and carted away.

176. A disc with cords attached to each side of it is sometimes pulled through a sewer for cleaning it. A cord is attached to a point near the edge of the disc, and this cord pulls the disc into the sewer edgeways. The other cord is attached near the edge of the disc at three or four places, so that when it is pulled the disc travels so as to fill the sewer and scrape out any deposit. It is generally best to move it backwards and forwards, cleaning a short length of the sewer at a time. To get the cord through the sewer in the first instance it may be floated through, or, when this is impossible, a ferret may be sent through the sewer with a string attached, a rat being let loose in the sewer first.

177. The method of cleaning a sewer by floating balls of various sizes through it has been described in a previous chapter; sometimes, also, an egg-shaped ball, with a cord attached, is used, with a flush of water behind it, for the purpose of cleaning a sewer.

178. Sewers of 2 ft. diameter and upwards can be cleaned by sending a man through them. It should be remembered that prevention is better than cure, and that, therefore, it is better to prevent the accumulation of deposit in sewers by flushing than to have to clean them by hand. No deposit should be allowed to systematically accumulate in the sewers with the knowledge of those in charge.

179. If ashes or other improper substances are found to cause a deposit in the sewers, the source from which they come should be carefully ascertained and the cause removed.

180. No extension of the sewerage system should be made without carefully considering how it will affect the existing work, and all new work should be carried out as well as the old work; generally, it will be necessary to carry it out better.

CHAPTER XXI.

Sewage Disposal.

181. The subject of sewage disposal is one which presents endless and fascinating problems to the scientist. For him there is an endless amount of useful work to do; he is ever seeking to discover better and still better methods, and to give the engineer exact reasons for the results discovered in practical working. To him sewage disposal is a problem.

For the engineer, however, the case is different, and without any disrespect to the scientist, it may safely be said that the engineer can approach his work in a very different spirit, knowing certainly that there is no insuperable difficulty in purifying any ordinary sewage. In fact, where conditions are satisfactory, it is a comparatively simple matter to the experienced engineer.

The scientist very properly seeks to ascertain the exact causes of purification, to find the best and simplest treatment for sewages of various kinds, to tabulate results obtained, and he is continually experimenting with new methods, with the object of finding out such things as how to treat sewage on the smallest possible area, how to eliminate sludge, how to treat the sludge thus extracted so as to get rid of it without nuisance, how to produce an effluent of absolute chemical and bacterial purity, or how to prevent clogging of filters. All the results obtained have their uses, and the engineer avails himself of them, but, owing to the vastness of the work before the scientist, he occasionally becomes extremely pessimistic, and tells the world in general that he has but touched the fringe of the subject, and that the great sewage disposal problem remains unsolved.

Though this may be true from the scientist's point of view, it is, practically speaking, an absurd statement, as the many excellent works constructed of late years prove.

182. Unfortunately, there has been a very strong tendency for individuals to urge the merits of the particular system on which they have been working, to the exclusion of other methods of equal worth upon which they have had little or no experience. The scientist whose life work has been the perfection of the X system does not hesitate to tell us that the Y system is dead and useless; similarly, the eminent inventor or discoverer of the Y

system does not hesitate to condemn the X system with vigour. Not only so, but each has been in the habit of bitterly opposing all other methods of sewage purification, so that the effect on the lay mind has been that the whole subject of sewage purification is an unsatisfactory problem, the proper solution to which has yet to be found. People have even taken sides at municipal elections, calling themselves "bacterialists" and "anti bacterialists." This actually happened at a town in the West Country, and serves to show the foolish way in which people have taken sides over the matter.

By practical men, with knowledge of sewage disposal, these differences among scientific men are looked upon as purely academic discussions, useful, no doubt, but by no means affecting the undoubted fact that ordinary sewage can be purified, and is being purified satisfactorily and economically at all works properly designed, constructed, maintained, and attended to, of which works there are not a few in existence at the present time.

The causes of failure, where they occur, are almost always perfectly obvious to the experienced engineer.

183. To start at the very beginning, it is an undoubted fact that if a bucket full of the foulest sewage were poured out upon the surface of a loamy, ploughed field, it would soon be purified.

The liquid would soak away into the ground, and soon become harmless, and the solids would disappear in a short time. This would happen in the same way that all foul matters lying on the surface of the ground have, since the world began, been resolved into harmless constituents by natural processes.

184. It is clear, then, that, given sufficient area of land and proper distribution and attention, crude sewage can be purified on land. Whether the method is practically possible, economical, unaccompanied by smell and so forth, is a separate matter, which can only be considered when the special conditions of the case are known.

185. It is acknowledged that sewage passing through sand or loam or most earths is thereby filtered and purified to a degree, and the scientist tells us that the purification effected is due largely to the action of certain micro-organisms present in the land and in the sewage.

186. Experience proved that certain land was better than others for the purification of sewage, and efforts

were successfully made to prepare land so that it might possess the characteristics that were found to give the best results. Hence, acres of porous, sandy, or gravelly, under-drained land were prepared also with success, so that the area could be reduced. This, again, led to the construction of filters of various kinds.

187. It is not too much to say that all modern methods of purification in general use consist of filters of one kind or another under many different names, and that after all has been said and done the undisputed fact remains common to all systems that for its final purification sewage must be brought into contact with some medium on which the micro-organisms necessary for sewage purification can exist. How this may best be done is a matter needing very careful consideration in each case. The possibilities are endless. The quantity and quality of the sewage, the available fall, the possibility of smell being a nuisance, the cost of land, and a hundred other considerations will guide the engineer in designing his works. He will need all the assistance that can be obtained from the chemist and bacteriologist, and it may here be demonstrated that the conclusions of the scientist will prove of little worth, and even be apparently falsified by bad engineering. Unless the works are properly designed, constructed, and managed the results confidently expected by the scientist will not be forthcoming, and he will earn discredit. This has happened only too often where apparently the scientist has been his own engineer. It is with the design, construction, and management that the engineer is concerned, and failure is only possible where these matters get into inexperienced or incompetent hands. To condemn any system of sewage purification as altogether worthless is wrong. One might just as well condemn the wheel-barrow because of the automobile, or the steam engine because of the electric motor. The system which may be essential to success under the special conditions of one place may be perfectly unnecessary, useless, or even harmful at another. It is, therefore, necessary for the engineer who wishes to take up the important work of sewage disposal to study every known method so as to be able to apply his knowledge to meet and overcome all difficulties as they arise.

188. With regard to the various cases where sewage treatment must differ the possibilities are endless; but in order to demonstrate how widely different the condi-

tions may be at different places it will be instructive to consider a few typical instances.

(a) A small town or village on the sea coast where it is possible to obtain an outfall at a point where a strong current will carry the sewage discharged right out to sea, where also there is no likelihood of contaminating oyster beds or fisheries, or of otherwise causing a nuisance.

(b) A small town or village the outfall from which must run into a tidal river. In this case the degree of purification required will often depend on the nearness of fisheries and oyster beds. It is clear that in a large river like the Thames the dilution will be great, and that if the outfall were carried out into the main current it would be possible, so far as nuisance was concerned, to discharge an effluent that would not be fit to go into the same river above the locks. An effluent that would, in fact, be only partially purified would certainly cause no annoyance so far as sight or smell were concerned, but, on the other hand, the possibility of contaminating oyster beds might make it necessary to produce an effluent of very high bacterial purity. It might be necessary to take every possible precaution even to the sterilisation of the effluent.

(c) A town situated on a river above locks might in some cases have to discharge an effluent of a very high standard of purity if the river water were used for drinking purposes lower down. This may seem an extreme case, but it is not. The water of the Thames and Lea are used for the supply of London, and an enormous quantity of sewage effluent is discharged into these rivers above the intakes; neither is it possible to avoid doing so, for assuming that it were possible to lay sewers alongside the rivers and all tributaries receiving sewage, or to go elsewhere for a water supply, many years must elapse before such works could be brought to completion. The problem is therefore a very grave one.

(d) A town situated on a river above the locks where water was not used for drinking purposes. Such a case differs from case (c), inasmuch as all the purification that is really required is such as will render the effluent unobjectionable to sight or smell, so that it does not in any way spoil the river or hurt the fish. The enormous dilution and the purification which takes place in the river itself may be taken into consideration if the river authorities will permit.

(e) A small village situated far from any river where the effluent must pass into a ditch with a small flow and travel perhaps for a mile or more before it reaches any larger stream. In such a case the effluent is thereby subjected to a test as severe as can be given, and if it is not quite pure a very serious nuisance may result. Therefore, it will very likely be necessary to treat the sewage in a manner that would be altogether unnecessary for a much larger and more important town situated as in case (d).

189. These instances are typical of many others, and will serve to show how the conditions of each case must be carefully considered before one can come to any conclusion as to the degree of purification required.

190. Then, again, with regard to methods of purification, sewages vary in quality and strength at different places and at different times at the same place, so that the area of a filter which may be quite sufficient to produce an excellent effluent without clogging or exhaustion of the filter at one place, may be altogether inadequate to purify the same volume of sewage of different character at another. Sewage may be affected by large quantities of subsoil water in the case of old sewage systems, causing enormous dilution. Trade waste may give it a peculiar character. Septic action may take place in large systems, or in systems in which lifts, ejectors, or pumps are used, and many other causes may affect the sewage, and till they are all known it will always be impossible to decide the method of treatment exactly. Also at some places the disposal works can be constructed at a site where a certain amount of smell caused by the discharge of the sewage and tank liquor may be of little account. At others it may be a matter of the greatest importance to reduce the smell to a minimum. There may be facilities for dealing with sludge, or, on the other hand, it may be almost impossible to remove sludge, or treat it on the works at all. There may be unlimited area at the engineer's disposal, or space may be absolutely restricted. Likewise the available fall, the character of the subsoil, the materials available, the price of the land, the rights of private owners, and innumerable other conditions, will have to guide the engineer in deciding as to the best method and details of the work.

CHAPTER XXII.

191. The fifth report of the Royal Commission on Sewage Disposal very justly states that sewage may be purified to any degree required, either by land treatment or by artificial filters. This clause, however, would be very misleading if one did not read the other conclusions, among which the Commissioners clearly state that "effluents from soils which are not well adapted for the purification of sewage may often be very impure." In writing on the subject of sewage disposal it would be impossible to omit the extremely important conclusions arrived at by the Commissioners after so many years of work, the report having been published felicitously while the present articles on sewage disposal were in course of preparation. The present work, however, applies more particularly to the sewage disposal of small towns and districts, while the Royal Commissioners deal with the subject generally, and perhaps more particularly with the problems presented by very large towns and cities, where the methods of disposal must differ in detail considerably from those suitable for the vast majority of works, which are, of course, small. A verbatim report of the Summary of the Conclusions and Recommendations of the Commissioners appeared in a recent issue of this journal, so it will be unnecessary to give them again in detail, but reference is made to them and to statements in the body of the report in order to elucidate the subject.

192. It is not the author's intention to describe in detail every known process of sewage disposal. There are a large number of special processes where special chemicals, filtering materials, and apparatus are used which may have their own special merits for special conditions, but, broadly speaking, the methods are as follows:—

(*a*) The treatment of crude sewage on filters, contact beds, or land.

(*b*) The treatment of crude sewage by a preliminary process, whereby grit and suspended matters are more or less removed, the liquid afterwards being treated on filters, contact beds, or land.

The Royal Commissioners are of opinion that such preliminary treatment is generally desirable before attempting to treat sewage on land or filters. It should never be forgotten, however, that the mere removal of suspended matters results in the accumulation of sludge, and that sludge has always been the great difficulty of sewage disposal, and that this sludge has then to be satisfactorily purified at the works, or removed and purified elsewhere. Many reports and interesting papers have been written to describe how best to purify a clear tank effluent, but very little has been said of the sludge. On visiting the works described, it is not at all uncommon to find masses of putrid sludge exposed in a most primitive manner. It is begging the question merely to remove the worst part of the sewage and to purify the rest.

193. The methods (*a*) and (*b*) may again be sub-divided under various headings, and in doing so it will be best to follow the statements made in the Royal Commission Report as far as possible. There are also two other processes which, under special conditions, have their uses when applied in connection with the above, which deserve special attention—viz., the deodorization of tank effluents and the sterilisation of filter effluents, both being possible within limits of reasonable expense, the former being well spoken of by the Royal Commissioners, and the latter by the Board of Agriculture of the United States, in a report issued recently dealing with the subject.

194. The earliest attempts at dealing with the subject of sewage disposal as a whole without any preliminary process for the removal of suspended matters consisted of discharging crude sewage on to land. Such treatment is by no means an impossibility, but the area of land required or the amount of labour involved in producing good results was found to be enormous in most cases. The nuisance caused by the solid matters exposed on the surface of the land, and the unequal character of the sewage at different times, proved the necessity for some other treatment as a preliminary.

195. As a result, tanks in which the sewage could mix and settle were used, and this settlement or precipitation of solids was promoted by the use of chemicals, with the result that a clear effluent, liable, however, to secondary decomposition, was discharged on to the land. This method, at one time considered perfection, of course, resulted in the accumulation of enormous quantities of the most objectionable matter, and this sludge had then to be removed in carts, spread out to dry, buried in the land, hopelessly stored in ever-increasing masses, or pressed into cakes.

UPWARD FILTRATION.

196. A more successful method, and one which undoubtedly got rid of some of the sludge, was that of upward filtration. The crude sewage was passed into the bottom of a tank in which gravel or other filtering material was supported, two or three feet above flow level, on an iron grid or other similar arrangem nt. The liquid passed up through the filter, and the sludge remained below. It was found that some ot the sludge thus intercepted was liquefied and broken up. The bulk of it, however, had to be removed and dealt with as before.

197. Next the septic tank—a tank with submerged inlet and outlet holding about a day's flow—was found to produce liquefaction and breaking-up of the sludge. From the fact that such tanks will often work for years without emptying or removal of sludge, it was argued that the whole of the sludge was liquefied. As a matter of fact fact it has been proved by experiment that a considerable proportion of the sludge is actually liquefied. The remainder, in cases where the sludge is not removed, is broken up before it is discharged, but as this sludgy effluent put sprinklers out of action, and as it also clogged up filters of inadequate size, a storm of condemnation was aroused against this otherwise useful invention.

198. The hydrolytic tank, patented by Dr. Travis, was the outcome of the upward and downward submerged filters and the septic tank. The sewage is passed through various sections of the tank, some being filled with slabs of material. The sludge is thoroughly eliminated by this tank, and a very good effluent is produced suitable for subsequent filtration, but in order to obtain this result, the sludge thus separated has to be withdrawn regularly and dealt with. As in the case of the septic tank, the quantity of sludge was lessened owing to liquefaction in the tank.

199. Every effort has been made, by the use of tanks of various forms, to eliminate the suspended matters—tanks with conical bottoms, with special arrangements for drawing off sludge; tanks in series, upward and downward and vertical; submerged filters in tanks; chemical precipitation tanks; and, in fact, a large number of special devices have been used from time to time in order to remove as much sludge from the sewage as possible, so as to render the subsequent filtration easier.

SEPARATING AND FILTERING.

200. Most of the experiments and research during the last ten years have been in the direction of separating the sludge from the sewage and in filtering the effluent on the smallest possible area. Each exponent has done his best to prove that by his particular method a greater number of gallons per cubic yard of filter can be purified than by any other. They have not failed to tell us that all suspended matter must be first removed. The clearer the tank effluent, the smaller the filter and the better the working of the sprinkler. The arbsurdity of such reasoning scarcely needs demonstration. To carry the argument one step further, one reaches the fact that if one could only extract all impurity by the preliminary process and produce clear water, the filter would take an unlimited quantity of liquid per square yard and the sprinkler would not be needed.

201. Practically nothing by comparison has been done in the direction of finding out how to purify or get rid of the sludge itself. Seeing that by the best processes about 75 per cent. of the impurities present in the crude sludge are removed as a preliminary to filtration, and that these matters remain unpurified, it will be seen that the remarks made above are not without justification. A liquid is discharged from the settling tanks containing only 25 per cent. of the original impurities present in sewage, and this weak liquid can, of course, be easily dealt with on filters. We are asked to forget the remaining 75 per cent. of foul matter remaining on the ground. It is this fact which has caused a general feeling of uneasiness and distrust of every known method of sewage disposal. Local authorities and others who are considering new schemes should ascertain :—(1) how much sludge is likely to be removed by the preliminary process, and (2) how it is proposed to deal with this sludge.

CHAPTER XXIII.

202. It is necessary to consider in detail the methods generally adopted for the removal of suspended matters from sewage before filtration, for the reason that, whether it is possible to do without such treatment or not in the

majority of cases, there will probably always be special cases where such preliminary treatment is the only practical possibility. Before, however, describing these methods, the author wishes to draw special attention to the fact that latterly the object of scientists, and also of many engineers, has been to reduce the area of the filter to a minimum. The reasons for this effort are by no means clear, seeing that filters are not expensive to construct or to maintain, and that if they are of sufficient area they will deal with any sewage in which the solids are broken up, and that, moreover, with filters properly designed and worked, the smell can be reduced to a minimum. On the other hand, the removal of sludge which is an essential preliminary where filters are of inadequate size is very expensive, very objectionable, altogether unscientific, and in most cases would be altogether unnecessary if a larger filter area were provided. Moreover, it is no question of the relative costs of two methods; it is the comparison of the system which purifies the whole of the sewage with the system which purifies part only. In this there should be no confusion of ideas; there can be no doubt as to the comparison between the system which purifies and gets rid of the sludge and that which leaves it unpurified and lying about in heaps.

Surely it is only common sense to start with the assumption that any system of sewage disposal worthy of the name must be one which will purify or at least get rid of the whole of the sewage.

203. It does not necessarily follow that any system which produces sludge is incomplete. Provided that some satisfactory provision can be made for the treatment of such sludge, the system would be complete. For instance, there are some rare cases where all the sludge can be carried out to sea in barges; where there is some some real use for it; or where it can be buried without nuisance or danger. Such cases are the exception, and not the rule.

204. The processes for the removal of suspended matters are generally as follows:—

SETTLING TANKS.

There are two types of settling tanks:—(a) Quiescent sedimentation tanks, or those in which the sewage stands for some time absolutely at rest; and (b) continuous flow sedimentation tanks, or those through which the sewage flows slowly, but continuously. In the first case a tank is filled with sewage, and after it has stood long enough for the solids to settle—probably about two or three hours—the liquid is drawn off, generally through a floating arm outlet. This sort of tank has the disadvantage that the sludge must be removed every time the liquid is drawn off, as fresh liquid entering would otherwise stir it up. It is, therefore, necessary to have duplicate tanks in this system. The cost of so frequently removing the sludge is a drawback.

In the case of a tank with a continuous flow through it, everything is done to retard the flow as much as possible. The sludge is continuously deposited, and is drawn off without emptying the tank. There have been many ingenious settling tanks designed, such as the Kinebühler tank at Dortmund, in which the sewage descends through a tube to distributors fixed low down in a circular tank with a conical bottom. The sewage rises very slowly from the distributors, leaving the solids at the bottom. The sludge is removed by pumping, and the clarified effluent overflows at the top.

The sludge has to be removed from such sedimentation tanks before fermentation is started, which would cause a great deal of solid matter to float, and would render both sludge and sewage very foul. For this reason sedimentation tanks have to be of such a design that sludge may be removed frequently; it is obvious that in the case of quiescent sedimentation tanks the sludge must be removed between each filling if the fresh sewage is not to stir up the old sludge, and that in the case of continuous flow tanks the sludge must be removed at least every two or three days to give the best results.

205. The capacity of a tank or set of tanks must be such that they will take all sewage that requires such treatment without allowing any overflow to take place. The Royal Commissioners advise a period of flow through continuous flow tanks of from ten to fifteen hours where the tank liquor is to be treated in fine filters, and advise also that they should be cleaned out at least once a week.

CHEMICAL PRECIPITATION.

206. The precipitation of solids may be accelerated in sedimentation tanks by the use of chemicals, and this is generally done in the case of very strong sewages or where

it is thought desirable to neutralise an acid sewage. The Royal Commissioners advise an eight-hours rate of flow through tanks in the case of a continuous flow and a two hours' rest in the case of quiescent sedimentation; but they very justly point out that no rule for general application can be given.

Generally the chemicals are mixed with the sewage on its way to the tanks. That no proportion of chemicals will do much more than clarify the sewage has been proved, so it is best to do with the least amount that will produce precipitation. Lime has been found to be an economical substance for this treatment, and it is therefore largely used, generally in conjunction with other chemicals. It is reduced to a milky state before adding to the sewage, and it is sufficient by itself to clarify sewage. It appears, however, that a large quantity is needed, comparatively, to produce the result, and this is very objectionable, for the reason that though an excess of lime produces rapid precipitation and a fairly clear effluent, this effluent, though apparently clear and without much smell, is very likely to become putrid later on, owing to the fact of the lime dissolving a large amount of offensive matters held in suspension in the sewage which will afterwards putrify.

Thus, lime and chloride of lime, lime and sulphate of alumina, lime and phosphoric acid, lime and proto-sulphate of iron, lime and alumino ferric, etc., are used at different places, also strange mixtures of alum, blood, clay, magnesia, manganate of potash, burnt clay, chloride of sodium, animal and vegetable charcoals, and magnesian limestone have been used, also the complicated material ferozone has been found to give good results as a precipitant.

The Royal Commissioners state that for the precipitation of domestic sewage of average strength alumino ferric is by far the most common precipitant, and that the average quantity of the precipitant may be put at about 10 grains per gallon, and that the average cost of the chemical is about £2 5s. per ton.

207. The Royal Commissioners also state that chemicals are most effective when added in the form of a solution, but that in practice it is sometimes more economical at small works to use it in solid form, owing to the fact that it is advisable to vary the quantity of the solution with the varying strength of the sewage. In such cases a solid block of the chemical is placed in the

sewage channel so that the top of it projects above the level of the sewage. In this way the largest quantities of the precipitant are dissolved with the greatest flow. The sewage should be well mixed immediately after the addition of the chemical by means of baffling boards or other mechanical apparatus.

208. Such tanks as those described above have to be emptied of sludge, as a rule, by hand. The nuisance experienced is great, while the labour is of a most unpleasant nature, and no man ought to be expected to do it at ordinary workmen's pay.

209. It is here necessary to state what methods have been devised for getting rid of the vast quantities of sludge remaining behind after the process of precipitation is complete. This sludge, consisting, as it does, of the foulest matters present in sewage, is a very objectionable substance to move. As already stated, it is sometimes pumped into vessels and discharged out at sea. At small works it is sometimes possible to get farmers to buy it to manure their fields with, or they may be induced to take it as a gift. It is more probable, however, that they will have to be paid for taking it. A little reflection will enable anyone to understand that it is impossible to apply manure to fields at all times of the year. It has long been recognised by those who are brought face to face with the practical difficulties in dealing with sludge that it is useless to regard this material as a valuable manure, but that, on the contrary, it is merely a highly offensive substance, which must be got rid of without delay at the least possible expense. Its disposal is often likely to cost as much as 2s. or 3s. a ton in practice, and the process of removal is highly offensive. Sludge is sometimes intercepted by running the sewage through ash refuse heaps. A mixture of sludge and ash is formed, which is carried to the land. It is sometimes mixed with house refuse, and burnt in a destructor. The process of digging sludge into the ground has been found effective at some places. The ground is generally trenched for the purpose. Another method is to compress the sludge into cakes in what is called a filter press. The solid matter is retained, and a large amount of very foul liquid is strained out through canvas when the pressure is applied. The sludge is thus made less in bulk. The cakes produced in the sludge press have then to be got rid of by the best available means, and the foul liquid runs to the ordinary sewage.

210. It may be well understood, therefore, that any system of sewage disposal in which sludge is accumulated presents a very horrible state of things, to be avoided wherever possible.

CHAPTER XXIV.

SEPTIC TANKS.

211. The septic tank receives all the sewage and retains the solids. This is effected by having the inlets and outlets submerged. Solids either sink to the bottom and form sludge or float and form a thick scum on the surface. The object of having the inlet submerged is to prevent disturbance of the scum, and the object of having the outlet submerged is to prevent solid matter escaping with the effluent.

212. In recent work the plan most generally adopted has been to allow the sewage entering the tank to flow over a weir extending for the full width of the tank; a scum plate, or dipping-board, or submerged arch extends in front of this weir for the full width of the tank, and dips two or three feet below the surface of the liquid. There is a similar arrangement of scum-plate and weir at the outlet end. The inlet and outlet weirs are necessarily at the same level. The tank is generally not less than 7 ft. deep, though there does not appear to be any reason why such tanks should not be made (as, indeed, they are sometimes made) considerably deeper; its length is generally at least two or three times as great as its breadth, or more.

213. The Local Government Board generally require that septic tanks shall be made in duplicate, and also that they shall have one or more sludge outlets for cleaning purposes. Such tanks generally hold from one to two days' dry weather flow, and are sometimes covered with a brickwork or concrete arch, or with a lighter roof, and are sometimes open. In the author's opinion septic tanks should always be covered, generally with a light roof; the thick scum which forms on the surface of the tank will otherwise be disturbed by the wind and rain, and a great nuisance will be experienced; also when the scum is thus disturbed it is likely to be given off in large lumps at the outlet end.

THE WORK TO BE DONE BY SEPTIC TANKS DIFFERS.

214. In considering the design of a septic tank it is necessary, first of all, to have a clear idea as to the work one wants it to do. There may be said to be two distinct cases:—(a) If the tank liquor is to be distributed over a percolating filter by means of a sprinkler or over a fine filter it will be necessary first to see that no thick effluent or broken up solid matter likely to clog the sprinkler or filter are discharged; and, secondly, to avoid as far as possible the smell which is generally inseparable from septic tank effluent sprayed or spread out in the open air. The periodical removal of sludge from the tank will be inevitable in such a case. The object to be aimed at will therefore be to construct the tank in such a manner that sludge may be easily withdrawn, and that the liquid may not remain in the tank long enough to become very foul, or, as it is sometimes termed, "over septicised." Up to a certain point there can be no doubt that the longer sewage remains in a septic tank the worse it smells. It is not the author's intention to deal with the purely scientific side of the subject of sewage disposal, which matter must be dealt with by the chemist and bacteriologist, but it seems reasonable to suppose that while the solids require a long period of septic action, a considerable amount of the liquid sewage might well pass on to the filters at once without being subjected to the action of anaerobic organisms. Thus, if the tank is large enough to treat the solids to the extent required, and if sludge is to be removed, it follows that a septic tank of the kind here described may be of a smaller capacity than in a case in which the object is to avoid sludge removal. In such a case as that under consideration the tank might hold, say, half the dry weather daily flow or even less. American practice gives results in favour of such small tanks. They differ from quiescent sedimentation tanks in that sludge is not removed so frequently, and they are therefore better. Good results have been obtained by making such septic tanks in sections capable of being used altogether or with one or more sections cut out. These sections are connected by valves, and the floor of each section has a sharp fall, say, of 45° to a sludge outlet valve. The tank should be, say, 10 ft. deep to allow of a large accumulation of sludge, and the outlet should be, say, 3 ft. or

more below the surface, to avoid the escape of scum or sludge.

By building the tank in this manner it is possible to find, by experiment, the size of tank or duration of flow through the tank which will produce the best result, and it will also be possible to draw off the sludge easily as may be required. The ordinary septic tank with flat floor and perhaps one sludge outlet cannot be cleaned satisfactorily without draining off the liquid; but when the tank is divided up into sections, as described above, the process of sludge removal without emptying the tank becomes possible. In the author's opinion, this is not the most satisfactory method of treating sewage under ordinary conditions, but it is a practicable method of producing a tank liquor fit for distribution by the ordinary sprinkler or fit for treatment in a fine filter.

THE SEPTIC TANK USED TO BREAK UP SLUDGE FOR FURTHER TREATMENT.

215. (b) In the second case we have the septic tank used not to eliminate the sludge, but to break it up so that it may be treated on filters and ultimately purified. That a tank of this kind is quite unsuitable as a preliminary for the treatment of sewage to be afterwards sprayed through sprinklers should be thoroughly understood. Much discredit has been brought upon both the septic tank and the sprinkler by the strenuous efforts of engineers and chemists to force solid matters through small holes in sprinkling apparatus intended for liquid. Also a septic tank which has a capacity sufficient for the breaking up of the solids, and for producing the greatest amount of liquefaction, will undoubtedly under ordinary circumstances produce a most evil-smelling effluent, which when sprayed in the open air will cause an intolerable nuisance. On the other hand, a septic tank in which the solids are broken up and discharged in the effluent is an excellent preliminary to contact-bed treatment or to filtration in filters of large area, over which the sewage is distributed in channels. Filters of the latter kind are not common; those of the Baldwin Latham type are, however, an example where the filter is of large area, with a layer of fine material on the surface, by means of which the sewage is distributed.

Contact beds, on the other hand, are largely used, and if they are of sufficient capacity and not overworked they will certainly purify the sludgy effluent discharged by a septic tank of the second type. The author has not the slightest hesitation in making this statement, having carried out the process and observed it closely during the last six years at several places. Speaking generally, this system, whereby all sludge is purified, has not received a fair trial. Either the septic tank has been emptied, owing to counsels of panic on the part of the authorities, or the capacity of the contact beds has been altogether too small for the work required.

216. Assuming that the filters or contact beds are sufficient, a septic tank may be allowed to discharge a thick effluent, and thus get rid of its broken up sludge without causing trouble. Consequently, it will generally not be necessary to remove any sludge from such a tank. Also, if the liquid is not sprayed in the air there is no great objection to its being foul, as liquid in distributing channels does not smell to the same degree, and such channels can always be covered up if required.

Thus the tank may be made of sufficient size to enable the maximum amount of septic action to take place, and in consequence more sludge will be liquified than in case (a), and what solid matter is not liquified will be broken up by the violent fermentation which takes place in such tanks, and will be delivered with the effluent. The Royal Commissioners appear to have grasped this fact to some extent when they state in Clause 40, page 25, that in the case of works constructed to serve any population up to 10,000 it would be best that septic tanks should be allowed to run, without being cleaned out so long as the suspended matter in the tank liquor showed no signs of affecting the filter detrimentally, provided that the tanks were never allowed to become more than one-third full of sludge. This is a very cautious statement, but it suggests for one thing leaving the tanks alone. Obviously, such advice does not apply to any place where a sprinkler is used.

217. In case (b) the septic tank will be very much more economical than any precipitation tank. There should be no sludge removed at all, because the tank, if left alone, will clean itself. Violent fermentation will take place at times, and the whole of the sludge and most of the scum will come out with the effluent in a broken up form. The filters will be hard worked for a time, but in case of, say, triple contact beds filled only once a day, holding material of the right grade, the-

roughly drained and worked with regularity, the whole of this sludge will certainly be purified under ordinary conditions.

It is objected that in course of time the beds will lose their capacity. This is quite true, and one must honestly face the fact that in such a case the filtering material must be washed or renewed. In the author's experience this has been found to be necessary with a very strong sewage once in five years. Now, it is a fact that the material thus washed away is by no means the same thing as sludge. If the contact beds are in proper order it will not be foul at all, but simply of a black, earthy character.

The removal of sludge matter at long intervals is not a very serious thing, and compared with the cost, trouble, and annoyance of chemical treatment, and the constant removal of sludge, is a trifling matter. Compared with the septic tank of type (a), the advantage is clear, for in the one case the frequent removal of sludge has to be faced, which is an intolerable nuisance; while in the case (b) no sludge is removed, but a more generous allowance of filter area is provided. To compare the relative expense is difficult, but in one case the whole of the sewage is purified and in the other part only.

Septic tanks of class (b) must have a capacity of at least a day's flow or more, and otherwise there is no special difference in the construction except that they need not be divided up into sections, the floor need not have the sharp fall, and a depth of seven feet is generally sufficient. It will do no harm to have sludge-emptying valves, provided they are not opened till the need arises. In the author's experience it has not been found necessary to open one during six years of constant working.

CHAPTER XXV.

FILTRATION OF SEWAGE.

218. Having briefly described the preliminary processes for sewage treatment it is now necessary to consider the methods whereby final purification may be effected.

First of all it can be clearly stated that under ordinary conditions there is only one way in which this final purification can be effected, and that is by filtration. There are, however, many methods of filtration, starting from the simple irrigation of natural land with sewage and ending with the very latest percolating filter or contact bed. Neither is it possible to draw any hard and fast line between what is generally known as natural filtration and the artificial processes. There are many ways of preparing land for the treatment of sewage, which vary according to the conditions of the case and the character of the ground. In one case a few irrigation channels and general preparation of the surface by levelling may produce the required result, while in another special areas of land may have to be carefully prepared for a depth of three feet or more with an elaborate system of sub-drains. It is difficult to see that such a natural filter permits in any way a more natural method of dealing with sewage than a filter which has to be built up artificially. In fact, it seems wrong to call any process natural whereby sewage is conducted through pipes, channels, and other artificial works over a filtering area. As a rule, the ground needs very careful preparation if good results are to be obtained, and more subsequent attention than an artificial filter, or so-called. It would be better to call every method of filtration natural or every method artificial without distinction, since there is no essential difference in the work done by land or by filters, and according to the Royal Commissioners "there is no essential distinction between effluents from land and effluents from artificially constructed filters," and also because "it is practicable to purify the sewage of towns to any degree required, either by land treatment or by artificial filters, and there is no essential difference between the two processes."

219. Thus there can be only one general method for final purification and that is filtration. The problem as to how this filtration may best be accomplished in any case is a matter which can only be decided by the engineer when the exact conditions of that case are laid before him. There are endless possibilities: sometimes one method may be best and sometimes another, frequently a combination of methods will be necessary; there is endless scope for ingenuity, which, if properly applied, will produce works that will not only fulfil their useful purpose to the benefit of a whole community, but will do so in the most economical manner possible.

220. The recommendations of the Royal Commissioners with regard to filters do not leave the reader with any very satisfactory idea of how best to proceed. The first conclusion with regard to filters proper, as dis-

tinguished from contact beds, is as follows: "For practical purposes, and assuming good distribution, the same purification will be obtained from a given quantity of coarse material, whether it is arranged in the form of a deep or of a shallow percolating filter, if the volume of sewage liquor treated per cubic yard be the same in each case.

"With regard to percolating filters of fine material, if the liquid to be purified were absolutely free from suspended or coloidal solids, and if thorough aeration could be maintained, the statement just made for filters of coarse material might possibly hold good for filters of fine material also. In practice, however, these conditions can scarcely be maintained with large rates of flow, and we think that the greatest efficiency can be got out of a given quantity of fine material, arranging it in the form of a shallow filter rather than of a deep filter. But we are not in a position to make an exact quantitative statement as to the difference in efficiency of the two forms."

221. As its name implies, a percolating filter is one through which the sewage percolates, and it is obvious that if such a filter is composed of coarse material the "good distribution" mentioned by the Royal Commissioners is absolutely essential, as otherwise the sewage will run through it in a stream at any point where it may be so delivered on the surface of the filter, and under these circumstances it is desirable at the outset to consider what appliances are available for producing this "good distribution."

SPRINKLERS.

222. The Royal Commissioners offer comments on four types of sprinklers used for this purpose, which may be quoted at length as the matter is of the most serious importance.

"Type No. 1: As regards moving sprinklers we may make the following observations:—

"(a) Unless driven by applied power, which must obviously increase the cost of distribution considerably, they are seriously affected in their distribution by wind, and by severe frost and snow. In the case of light revolving sprinklers, they are not infrequently brought to a standstill by the wind. Where the filter is a small one, this disadvantage may, to a considerable extent, be overcome by building wind screens round the filter or by raising the retaining walls, but on large works we should think that this would be impracticable, and with large filters not very effective."

Whether the Commissioners have quite grasped the true facts is open to question. From the statement quoted above it would certainly seem that the ordinary moving sprinkler is a very unsatisfactory arrangement; but most engineers and sewage works managers must have been surprised to read this sweeping condemnation of an appliance which is in very general use, and in the author's opinion it would be well for any engineer proposing to use a revolving sprinkler to gather facts for himself from the many works where such sprinklers are used. However, assuming that the Royal Commissioners have had an exceptional experience with their sprinklers one cannot altogether lose sight of the fact that with such a method of distribution there is always the possibility of the sprinkler stopping, in which case the sewage will leave a coarse filter absolutely untreated. No such risk is run with filters which are not dependent for their proper working on a sprinkler.

223. Royal Commissioners' Report continues as follows:—"(b) Automatic revolving sprinklers, when used intermittently (i.e., when fed from a flushing tank) are capable of adjusting themselves to large variations of flow, but when used continuously, without a flushing tank, their rates of working can only be varied within somewhat narrow limits."

It would be more exact to say that when used with a storage tank the tank will, if large enough, deal with the varieties of flow. It cannot be said that the sprinkler ever adapts itself to these variations, except within the narrow limits mentioned, and it may be taken that storage sufficient to deal with the inequalities of the sewage flow is generally, if not invariably, necessary.

224. We are next told that "(c) The forms of sprinkler in which tank liquor is delivered to the bed through a number of small holes need a considerable amount of attention. The arms require to be brushed out at least once a day, unless the tank liquor happens to be exceptionally free from suspended matter, or not likely to produce fungoid growths." This is a cautious statement, but indicates the need for cleaning the sprinkler, which is generally admitted.

225. The Commissioners next comment on fixed jet sprinklers as follows:—"Distribution by means of perforated pipes or nozzles laid over a filtering area is almost always rather unequal, and this would be a disadvantage except in the case of fairly deep beds constructed of fine or medium material, or deep beds (say eight feet or more) or coarse material. This method of distribution, moreover, needs a considerable head of liquid for proper working, and also requires constant attention to keep the pipes and distributing holes clean and free.

"At Birmingham, where the nozzle form of distributor is in use on a large scale, for each acre and a half of filter one man is constantly employed night and day in cleaning the nozzles. The constant walking over the surface of a filter is a distinct drawback, but assuming that the occupation is not dangerous to the workman, we think that this method of distribution will, in many cases, be found efficient and cheap."

We are first told that the distribution is "rather unequal," next that the sprinkler needs "constant attention," which involves injury to the surface of the bed by a man "constantly employed night and day" in trampling it down, and finally that this method of distribution will be found "efficient and cheap." If the condemnatory sentences are accurate it follows that the method cannot possibly be efficient or cheap for the majority of works.

TIPPING TROUGHS AND DRIPPING TRAYS.

227. The commissioners deal with tipping troughs and dripping trays under one heading, as follows:—"Tipping troughs and dripping trays are, in our opinion, more suitable for small than for large installations. They can adapt themselves to large variations of flow, and in the case of small or medium-sized works, where constant supervision is not available, this is a great advantage. We may add that these trays are better suited for the distribution of a large volume of weak liquid than a small volume of strong liquid.

"The distribution is seldom perfect by either of these forms of distributor, and, consequently, it is advisable to have deep beds where they are adopted. Further, owing to the fact that the delivery of liquid in both cases is more or less constant, medium-sized or coarse material should be used to prevent ponding.

"A certain amount of supervision is necessary, as a tray may become blocked or a trough may fail to tip. The trays would require to be looked at about once a day, we think, and tipping troughs about twice a day, but beyond this little attention is required. The distribution in both these forms is divided up into a number of units, and it is very unlikely that more than one or two units would get out of order at a time, and that the distribution would be bad over a whole filtering area.

"That tipping troughs are liable to be completely put out of action by severe frost we have seen exemplified at Little Drayton, and, although we have had no experience of the same kind with regard to the trays, we should think that these were also liable to be affected by severe frost, though in their case distribution would never cease altogether."

228. The commissioners do not, however, point out the worst defect of the dripping tray, which is that sewage is discharged drip by drip on to certain fixed points, and these points soon become foul, also the sewage thus discharged passes through the coarse filter along a certain narrow track, which is then overworked. A foul track is formed, and the surrounding material in the bed is not used. The sewage passes quickly down the foul track and is apt to issue in a worse condition than when it left the sprinkler. For this reason alone the moving sprinkler is much to be preferred. Also the fixed trough must have rigid supports; if allowed to merely rest on the surface of the filter it will sink in places, causing unequal distribution and overflowing. This point is of the greatest importance.

229. The concluding remark of the commissioners with regard to sprinklers is that "all forms of distribution or percolating filters are liable to give rise to nuisance from smell, if a strong-smelling liquor has to be dealt with. In the case of trays or tipping troughs the smell is confined, more or less, to the immediate vicinity of the filter, and it may be largely done away with at small works by providing an inexpensive form of cover for the filter. The nozzle form of distributor is, naturally, the most liable to give rise to smell, but moving sprinklers are almost equally bad in this respect."

230. It may be seen, from the above that the commissioners tell us that every form of sprinkler is defective, and if they do not actually advise us not to use them they "damn with faint praise"—praise so exceedingly

faint and so qualified that their remarks must be regarded in the light of a serious warning against "all forms of distribution in percolating filters."

We are told, in the first place, that we must "assume good distribution," but no way of satisfactorily obtaining this is stated. We are later told that "percolating filters are better adapted to variations of flow than contact beds," but this cannot be possible unless the sprinkler will supply the varying quantities. A contact bed or a filter worked without a sprinkler will take sewage in a sudden rush, if required, but no sprinkler will do so.

It does not follow that there is no way out of the difficulty, however, and as the problem of unequal flow has long ago been dealt with by means of a tank used to feed the sprinkler, it is extraordinary that the commissioners should make such a point of the difficulties of unequal flow, and it is not desirable or necessary, within limits, that any sprinkler should distribute liquid at unequal rates on a filter.

The ordinary revolving sprinkler is probably the best for most cases, and the fixed jet has its uses. In the author's opinion the defects of the rotary sprinkler are less serious than the commissioners' report would lead one to suppose.

CHAPTER XXVI.

231. The discussion as to the grade of material to be used in filters has gone on for many years, and will probably continue. Some authorities recommend fine material, and point to results which justify their conclusion, while others obtain good results from filters constructed of large blocks of clinker. There can be no doubt that when very fine material is used the good results could not have been obtained without considerable preliminary treatment, for it is perfectly obvious that a thick sewage would choke a fine filter if discharged upon it in large quantities. Assuming, however, that the sewage can pass through the filter properly, it is clear that a mass of fine material must provide more surface for contact than an equal mass of coarse material, and it is common experience that the finer the material the greater the degree of purification and the greater the tendency to clog; also that the coarser the material the less will be the amount of purification and the less the tendency to clog.

232. It must therefore always remain a matter which can only be settled by the engineer after weighing all considerations whether the filters shall be coarse or fine.

It may be that filtering material is very dear, and that land is very valuable, and that sludge can be extracted from the sewage and removed without nuisance. In such a case, with a clear tank effluent to treat, a very fine filter may treat a very large quantity of sewage per cubic yard most satisfactorily.

In another case where filters can be constructed cheaply and where there is ample area for the works, it may be well to treat a thicker tank effluent on coarser filters, with secondary treatment on finer filters to follow.

At other places it will be desirable to purify the whole of the sewage, including the sludge, and this may be done by the use of the septic tank, followed by contact beds or filters, or by the slate bed, followed by contact beds or filters. In such cases the first filters will probably be best constructed of coarse material, and with secondary filters of a much finer material.

233. There can be no hard and fast rule for the grade of material in filters. It is merely a matter of size and capacity. A very fine filter would treat the thickest sewage if the quantity distributed were only small enough, while the weakest tank effluent may sometimes be treated advantageously in very coarse material, seeing that very little purification is required, and an enormous quantity of liquid per cubic yard may have to be passed through.

234. There is much confusion of ideas with regard to the work that can be done by a filter per cubic yard. One hears of one filter dealing with 500 or 600 gallons of sewage per cubic yard per diem, while another of similar construction can only be worked at the rate of, say, 60 gallons per cubic yard. These statements are valueless unless one knows—(1) the strength of the sewage, (2) the nature of the preliminary treatment, (3) the degree of purification effected, and (4) the life of the filter.

It is quite easy to understand that where sewage is weak at the start and diluted with an enormous quantity of land water, and is then submitted to elaborate tank treatment, and afterwards passed on to a filter with, say, 75 per cent. of the impurities removed, an enormous quantity can be treated per cubic yard because the work required from the filter is, in that case, very small. Also it is possible to make a filter purify for a time a much larger quantity of sewage than it can go on treating indefinitely. This is particularly the case with contact beds, which will often produce a good effluent when much overworked. These results do not show normal working possibilities.

235. Similar errors are due to the results obtained from small experimental installations, which do not reproduce the conditions of ordinary working. The only true guide to the engineer is the result of actual working at sewage disposal works which have existed under normal conditions for some years. Such results are to hand all over the country, and from them can the only true practical data be gathered.

236. The Royal Commissioners say that "For practical purposes, and assuming good distribution, the same purification will be obtained from a given quantity of *coarse* material, whether it is arranged in the form of a deep or of a shallow percolating filter, if the volume of sewage liquor treated per cube yard be the same in each case."

With regard to filters of fine material, owing to practical difficulties due to suspended and colloidal solids and insufficient aeration, the commissioners consider that the greatest efficiency can be obtained from a given quantity of material arranged in the form of a shallow filter rather than of a deep filter.

237. It is not the author's purpose to criticise the Royal Commission's report, but in dealing with the subject of sewage disposal in the order adopted by the Royal Commissioners it is impossible always to agree with them. The Commissioners consider contact beds and filters under one heading, and although it is convenient in many ways to do so there is such a wide difference in the working of the contact beds and in that of the percolating filter that it is unwise to regard them always in this manner. Moreover, it is due to this careless method of regarding the contact bed as a filter that bad results have been obtained at many places.

COMMON ERRORS.

238. Nothing is more common than for a contact bed to be allowed to fill at a very slow rate. This method of filling or of distributing sewage is quite satisfactory

with the filter, but is calculated to put the best contact bed out of working, and neither the Royal Commission nor the Local Government Board appears to have grasped this all-important fact.

Another point which should be clearly grasped is that where sewage is allowed to stream through a coarse contact bed the purification effected is nil, for the reason that in such a case a stream of sewage short circuits down through the bed and into the sub-drains, and is at once discharged, with the result that no purification is effected and the part of the bed through which the sewage runs is altogether overworked and soon becomes exceedingly foul. For instance, one finds such statements as the following :—In the experiments carried out for the United States Board of Agriculture at Marion, Ohio, in the sterilisation of contact bed and filter effluents the result was found to be better in the case of the sand filter effluent than in the case of that from contact beds, but we are told that "during the night the contact beds are operated continuously." This is exactly what is done at many other places, and the practice cannot be sufficiently condemned. If the contact beds are allowed to act as streaming filters during any part of their period of work not only will a bad effluent be the immediate result, but the beds will become clogged and foul, so that they will not work properly at other times, and not only will this take place, but it will be hard to induce the manager to work the beds regularly at all, with the consequence that foul sewage will be allowed to pass through the beds frequently so as to make them absolutely unfit for their work.

Unless a contact bed is so arranged that it cannot be used as a streaming filter in this manner, it will be sure to produce an unsatisfactory result.

RELATIVE CAPACITY OF FILTERS.

239. The Royal Commissioners state that, "taking into account the gradual loss of capacity of contact beds, a cubic yard of material arranged in the form of a percolating filter will generally treat about twice as much tank liquor as a cubic yard of material in a contact bed." This conclusion, however, is based upon experiments which are by no means conclusive. In the first place the Commissioners admit that, "the question of the relative merits is one of some difficulty, as very few

strictly comparative experiments on a large scale have been made." The contact beds and filters used by the Commissioners from which they drew their conclusions were very small indeed, and from evidence contained in the report they appear to have been filled with material liable to disintegration, and to have been insufficiently drained. General experience does not bear out the conclusion that contact beds are only half as efficient as percolating filters, and any engineer who had obtained results from the best type of contact bed would be very unwise in assuming, under ordinary conditions, that he could deal with the same quantity of sewage on a percolating filter of half the size. Until recently the Local Government Board required percolating filters to be of the same cubic capacity as contact beds. If the same care were taken over the construction and the filling and the emptying arrangements of contact beds as is generally taken in the case of the percolating filter, there is no doubt that the old rule would be a very safe one. In the author's opinion the conclusions of the Royal Commission can only be justified by taking into account the fact that contact beds are generally badly constructed and improperly worked. Both the percolating filter and the contact bed have their special uses, and it is a mistake to condemn the contact bed because it is not, as a rule, properly understood.

VARIATIONS OF FLOW.

240 The Commissioners tell us that " percolating filters are better adapted to variations of flow than contact beds." It is impossible to agree with this conclusion. The percolating filter is generally fed by means of a sprinkler, and it is clearly not practicable to increase the rate of flow to any great extent in such a case, seeing that a considerably increased head of liquid would be required to produce the effect, which is generally quite out of the question, and the only means by which great variations of flow can be dealt with is by putting additional sections of filter into use, or by storage in a tank, which is equally possible with either contact beds or filters. On the other hand, it is possible to increase the rate of filling the contact bed to any extent, seeing that, practically speaking, it is simply pouring so much liquid into a tank, and increased rate is of no consequence.

PRACTICAL DETAILS OF CONSTRUCTION—CONTACT BEDS.

241. In the first place, a contact bed must be so arranged that it will fill within a stated time and at any rate, and at works of moderate size this regular filling can only be obtained by the use of a tank the liquid capacity of which is equal to the capacity of the contact bed. Only one such tank will be required, and the ordinary sewage or tank effluent must flow into it until it is sufficiently full to fill one bed. The liquid must then be discharged till the bed is full, when the flow must be shut off. This can be done by hand, but, if so, constant attention will be required, and, practically speaking, automatic apparatus is therefore essential. Unless this dosing tank forms part of the scheme and automatic apparatus can be installed, it is as improbable that good results will be obtained with the contact bed as would be a case if a percolating filter were installed without a preliminary tank in which the liquid could head up and without some form of automatic distributor.

CHAPTER XXVII.

CONTACT BEDS (*Continued*).

AUTOMATIC APPARATUS.

242. The automatic apparatus required for the proper working of contact beds is of such importance that it is necessary to deal with the subject separately as a preliminary matter. The automatic apparatus for filling the first contact beds should be of such a kind as to make it possible for a works manager to set it to discharge the full contents of the storage tank (described in the preceding paragraph) or part of the contents only, as may be required, so that in the first place it may be possible to make the apparatus fill the beds up to a certain level without any fear of over-filling, and in the next place that it may be possible for the manager to alter the quantity discharged from the tank to a nicety, so that as the beds lose their capacity they may not over-fill; absolute control of the discharge is required. The apparatus as a whole must be capable of filling the beds in rotation, and must be such—(a) That all flow into any bed may be absolutely shut off directly the bed

is filled to the required level; (b) that this flow may remain so shut off till the bed is quite empty again—that is, that no liquid may flow into the bed and so through it while the bed is emptying; (c) that there may be absolutely no possibility of liquid rising in the bed above a certain stated water level. In addition to these requirements, it may sometimes be desirable to have the apparatus so arranged that in case of an excessive flow due to an abnormal rush of storm water, when all the first contact beds are standing full, the overflow may cause the opening of the automatic valves so as to produce streaming action throughout each set of beds until the excessive flow ceases. This requirement is more in the nature of a safeguard against accident, such as the bursting of a large water main, than for ordinary working. It, in short, prevents the possibility of the works ever being flooded.

EMPTYING BEDS.

243. The automatic apparatus for emptying contact beds in first, second, or third series, should be capable of holding the liquid in contact in the beds for any time required—say, between five minutes and six hours. When the liquid has stood in contact for the time required, the liquid contents of the bed must be automatically discharged. The time taken for emptying the beds should generally be about one hour, and sometimes longer. It is important that the discharge from the first beds should not be too violent, or the undigested solid matters will be washed out. It is to be remembered that the work of the contact bed is done while it is empty rather than while it is full, and that the matters in suspension should first come to rest on the filling material in the body of the bed, after which the liquid should be drawn off in such a manner as not to disturb them. The solid matters will then be liquefied in the first bed, while it is standing empty. This remark applies particularly to slate beds, which often discharge much undigested matter owing to the quick rate of discharge. The engineer should give this point very careful attention in the design and construction of the bed, and also in his choice of automatic apparatus. When the beds are empty the apparatus should permit them to drain for at least half an hour, and if the beds are clogged a longer period of drainage will be desirable.

It should be possible for the manager to be able easily to adjust the apparatus so that one set of beds, consisting of a first, second, and third bed, if so many are installed, may be set out of use for rest or for cleaning, without in any way upsetting the automatic filling and emptying of the others.

244. The apparatus should be capable of working with the smallest possible flow, or with the main sewer running full bore without over-filling or under-filling the contact beds.

The apparatus in the contact beds should also be capable of being set easily, to discharge when liquid stands at any particular level to be chosen; that is to say, the apparatus should be capable of working with the beds filled up to the top water level, or to any level below it. For it is obvious that if the first beds lose their capacity quicker than the second beds—as may well occur—they will not deliver enough liquid to fill the second beds, and unless the apparatus in the second beds can be set to discharge their contents when water stands at a lower level, it is clear that they will not work properly. In such a case the second beds will not empty, but will stand, say, three-quarters full of liquid till the next discharge occurs, when they will be over-filled. In the meantime, the second beds will have been fouled and temporarily spoiled. This miserable condition of affairs is very common, and largely accounts for the prejudice against the contact bed. Thus it is absolutely essential that the apparatus of the second beds must be capable of being easily adjusted so as to empty them, however low the water level may be. First contact beds will often lose capacity and recover, and it is most uneconomical to clean them whenever they lose capacity.

The same remark also applies to the apparatus in the third beds, which beds very often have a greater liquid capacity than the second beds. The automatic apparatus in the third beds must, therefore, be capable of similar adjustment.

ADJUSTMENT OF AUTOMATIC APPARATUS.

245. It is important that the adjusting of the apparatus should not be a difficult matter, needing special knowledge, seeing that if the works are to be kept in the best possible order and give the best economical results small adjustments will frequently be necessary. Thus

it should be well within the power of an intelligent manager to set the apparatus and adjust it to a nicety, and for this reason simplicity of design should be taken into account. Moreover, it ought not to be a lengthy process making it necessary to put the beds out of use while it is being done. It is well, in addition to the automatic working, to have complete control of the installation by means of hand valves.

246. These requirements may sound exacting, but there is automatic apparatus on the market supplied by more than one firm which will comply with them, and unless such automatic apparatus is installed it will, in the majority of cases, be unwise to have contact beds. On the other hand, if the contact beds are properly designed and constructed so that they fill promptly, stand full without leaking, discharge at a proper rate, and give their proper time of contact, and cannot be used as streaming filters for sewage, they will deal with the whole of the sewage in a manner which has not as yet been equalled by any other type of filter if freedom from nuisance and absence of the sludge difficulty may be taken into account. Unfortunately, the vast majority of existing works do not conform to this standard, and so give indifferent results.

CHAPTER XXVIII.

ARRANGEMENT OF CONTACT BEDS.

247. The author has found that in order to obtain a really good effluent from a strong sewage, such as is discharged from a septic tank which is never emptied, it is necessary to provide a much larger area or filter or contact bed than is generally allowed if the clogging of the beds is to be avoided. Unless the sewage is very strong, double contact is generally sufficient, but it will always be well as a safeguard to provide triple contact beds, or fine filters if the effluent is to be of the highest possible quality.

It is a very common error to assume that contact beds, if filled only once a day by the dry weather flow, will produce a good effluent, taking no account of the grade of the filling material or of whether the beds are arranged for single, double, or triple contact.

Assuming that it is possible to arrange the filtering material in a triple contact system, it is clear that for each cubic yard of material in the first bed about fifty-six gallons of sewage can be treated per day with one filling. This is true, but the sewage will be only partly purified by the process, and it must then pass into a second contact bed of similar capacity. This bed will generally be sufficient, but in the case of a very foul sewage a further step will be required, viz., triple contact. Thus, for the fifty-six gallons of sewage purified, three separate cubic yards of filtering material will have been required, so that the quantity of material required will be roughly one cubic yard for every nineteen gallons treated. This may sound an impossible allowance, but the author has found it to be absolutely necessary in one case, at least, after trials extending over several years. Ordinarily for second contact the allowance for dry weather flow will be about thirty-eight gallons per cubic yard, but not more if the sludge difficulty is to be really overcome.

248. Whether it is more economical to remove the sludge before filtration is a matter for very careful consideration, but the author has found it economical to construct works on the lines suggested above in the case of small flows, of, say from 30,000 to 40,000 gallons per diem. If such an allowance of contact bed or filter cannot be made it is practically impossible, with an ordinary sewage, to avoid having to remove the sludge.

DIBDIN SLATE BEDS.

249. With regard to the sludge difficulty, the engineer has another and probably a better alternative than the septic tank and contact beds to deal with the sludge, viz., the Dibdin slate beds. The Royal Commission are at the present time carrying out a series of careful observations in order to set forth exactly the results which are to be obtained from this bed.

250. The principle of the slate bed is the same as that of the contact bed, but it is filled with horzontal layers of slate. Crude sewage is run into the bed, and is held there, and the solid matters are deposited on the shelves of slate. These shelves of slate become covered with a growth of living creatures, these being not only bacteria, but small worms, and other life visible to the naked eye. As the bed stands empty these organisms feed upon the

solid matters and break them up and tend to resolve them into liquid, and into harmless chemical constituents. The result is that with careful working the liquid discharged contains no solid matters, but only earthy matter more or less inodorous. In the author's opinion, the weak point about the slate bed is that it is generally allowed to discharge with such violence that solid matters, such as pieces of paper, are discharged at times with the effluent. This could be overcome, no doubt, and the only other possible drawback to the slate bed is that it might possibly sludge up. It does not seem at all probable, however, that it would sludge up, and it therefore seems that if more care were given to the emptying arrangements that the slate bed would be the best and least objectionable method of dealing with sludge. The bed has now been working at several places with good results for some years, and is being generally adopted, and it is to be hoped that the report of the Royal Commissioners will confirm the good opinion which many engineers have formed of this process. If it should prove to be successful there can be no doubt that it will form the best preliminary treatment for sewage, whatever the final process may be.

251. Assuming, however, that the slate bed will not deal with all the sludge, it will obviously deal with most of it. If the bed clogs it can easily be cleaned by flushing, and the sludgy matters washed out can be conducted to a sump and dealt with by one of the usual methods of sludge disposal. If the effluent is too thick to be passed through a sprinkler it can be passed through a settling tank from which the humus or solid matters, if any, can be withdrawn. At the worst, the quantity of sludge would have been greatly reduced, and, therefore, facing all these possibilities, engineers have not hesitated to instal the slate bed at a great many places.

252. The engineer must decide whether he is prepared to face the disposal of sludge removed from settling tanks or whether it will be best to deal with the whole of the sewage, sludge and all. If he is prepared to eliminate the sludge by a preliminary process, it is clear that he may fill his contact beds several times a day, and obtain a pure effluent according to the degree of purification effected by the preliminary process, or he may make his percolating filters of correspondingly small area, but if he is not prepared to remove the sludge he must either make his filters or contact beds of ample

size, or be prepared to do a considerable amount of cleaning. If these facts are thoroughly grasped the chief cause of disappointment in sewage disposal works will have been removed.

CHAPTER XXIX.

THE GENERAL PRACTICE AS TO DIMENSIONS OF TANKS, FILTERS, AND CONTACT BEDS.

253. As a result of the report of the Royal Commission, certain generally accepted rules may be said to exist and to have been adopted by the Local Government Board, but it is not to be imagined that such rules have more than a general application, and, although they are helpful, they do not in any way alter the fact that each case has to be dealt with according to its particular conditions.

SCREENS AND GRIT CHAMBERS.

254. The Local Government Board generally require that all sewage should be screened, and two or more detritus tanks are demanded below the screen chamber, the capacity of each tank being about one-hundredth of the dry weather flow.

TANKS.

255. Septic tanks are generally demanded in duplicate, at least, and their total capacity is generally taken as equal to the daily dry weather flow.

Chemical precipitation tanks for quiescent treatment are generally not less than eight in number, each tank having a capacity equal to two hours' dry weather flow.

Chemical precipitation tanks for continuous flow treatment are generally not less than two in number, with a capacity of at least eight hours' dry weather flow. It will be safer as a rule to have more than two tanks.

Settling tanks for quiescent sedimentation are generally at least eight in number, each of which tanks should have a capacity of about two hours' dry weather flow.

Settling tanks for natural precipitation with continuous flow treatment should not be less than two in number, with a total capacity of from ten to fifteen hours' dry weather flow.

RATES OF FILTRATION.

256. With regard to the total cubical contents of filters required for treating sewage, the rates of filtration given by the Royal Commissioners are rates which, according to their conclusions, can be doubled in wet weather. The Commissioners state that where it is necessary to deal with three times the dry weather flow, it would only be necessary to provide one and a-half times the capacity of filters required for the dry weather flow (see par. 293, page 209, Fifth Report). Thus the rates of filtration given by the Commissioners are reduced by one-third to arrive at the basis for calculating the size of filters for three times the dry weather flow. The Commissioners give figures for sewages of various strengths and for filters of different grades, and for sewages which have been treated by various preliminary treatment. Thus, following their conclusions, it is by no means easy to make any short statement as to the capacity of filters.

LOCAL GOVERNMENT BOARD'S REQUIREMENTS.

257. Moore and Silcock, in their book, "Sanitary Engineering," give a table which summarises the requirements of the Local Government Board as based upon the Royal Commissioners' conclusions, and a similar table has also been issued by private publication. Moreover, it is generally accepted that the L.G.B. have certain requirements regarding percolating filters and contact beds, and that these requirements vary according to the strength of the sewage and the preliminary treatment chiefly, though other conditions must also have due weight. These requirements should be carefully studied by the engineer, but should not be too readily accepted as the sole guide in preparing a scheme for submission to the Local Government Board.

STRENGTH OF SEWAGE.

258. In the following remarks as a rough guide the working basis is the figure for oxygen absorbed from

strong permanganate in four hours at 80deg. F. ; thus the strength of sewage may be roughly classified as follows :—

Strong sewage, 17 to 25 parts per 100,000.
Average sewage, 10 to 12 parts per 100,000.
Weak sewage, 7 to 8 parts per 100,000.

It will always be safest to assume that the sewage will be strong unless samples can be properly analysed.

TREATMENT OF CRUDE SEWAGE WHICH HAS PASSED THROUGH DETRITUS TANKS OR GRIT CHAMBERS.

259. One cubic yard of coarse material that will not pass through a one-inch mesh arranged as a percolating filter is considered to be capable of treating not more than fifteen gallons of strong sewage per day. If this sewage is of average strength the allowance may be increased to twenty-five gallons per cubic yard, and if the sewage is weak, one cubic yard is considered as being capable of dealing with forty gallons. If one cubic yard of material is arranged in the form of triple contact beds—that is to say, with one-third of a cubic yard in each bed—it will treat twenty-five gallons of strong sewage per cubic yard per diem. If the cubic yard is arranged in the form of double contact beds, it will treat twenty-five gallons of average sewage per diem, or thirty-eight gallons of weak sewage.

TREATMENT OF SEPTIC TANK EFFLUENT.

260. For the treatment of septic tank effluent it is reckoned that one cubic yard of coarse material, that will not pass through a one-inch mesh, arranged as percolating filters, will treat forty-five gallons of strong sewage per day, but the allowance is reduced to thirty-five gallons if the material is from 1 in. to $\frac{1}{2}$ in. in size. The obvious reason for the reduction is that the small material is more likely to clog.

For sewage of average strength it is reckoned that seventy gallons per cubic yard can be dealt with, the material being over 1 in. in size, while for weak sewage the allowance is 100 gallons per cubic yard, the material being either coarse or fine, the minimum grade being $\frac{1}{2}$ in. With contact beds, however, the allowance is only thirty-three gallons per cubic yard, the material being arranged in triple contact beds. With average sewage the allowance is thirty-eight gallons per cubic yard, arranged for double contact. For weak sewage the allowance is seventy-five gallons per cubic yard, the material being arranged for single contact only, and with weak sewage the allowance is sixty-six gallons per cubic yard, the material being arranged for double contact. It appears to the author that the chief reason why it has been considered necessary by the Commissioners to allow a larger capacity for the contact bed treating tank effluent than for percolating filters treating the same effluent is that in the case of the percolating filter a sprinkler is generally used which will clog up if the effluent is too thick. This is a safeguard as far as the filter is concerned in that there is every reason to suppose that the works manager will take steps to clear the tank, so as to keep the effluent moderately free from sludgy matters. In the case of contact beds, however, the tank is less likely to be cleaned, because, however sludgy the effluent may be, it can flow readily into the bed, and thus there is not much chance of the tank being cleared until the bed becomes clogged. The Commissioners have apparently thought well to allow a larger area for contact beds, so that this tank effluent can be treated, and it is difficult to believe from the results of actual working that the percolating filter will deal with a larger quantity of tank effluent than the contact bed, provided that the effluent in each case is of exactly similar quality and that the drainage arrangements in the contact bed and the grade of the material are equal to those of the percolating filter.

THE TREATMENT OF SEWAGE WHICH HAS PASSED THROUGH SETTLEMENT TANKS WITH A CONTINUOUS FLOW.

261. In this case the allowance for percolating filters and for contact beds is exactly the same as that for septic tank effluent.

262. **For Effluent from Quiescent Settlement Tanks.**—With a strong sewage the allowance for percolating filters is 50 gallons per cubic yard, the material being above 1 in. in grade; 40 gallons per cubic yard, the material being from 1 in. to ½ in. in grade; and 25 gallons per cubic yard if the material is under 1 in. in grade. For sewage of average strength the allowance is 100 gallons

per cubic yard, the filtering material being above 1 in. in grade, and 70 gallons per cubic yard, the material being under ½ in. in grade. For weak sewage the allowance is 130 gallons per cubic yard for coarse, medium, or fine material.

For contact beds the allowance for strong sewage is 44 gallons per cubic yard where the material is arranged for triple contact; for sewage of average strength 50 gallons per cubic yard where the material is arranged for double contact, and with weak sewage 100 gallons per cubic yard where the material is arranged for single contact.

263. Treatment of Sewage from Chemical Precipitation Tanks with Continuous Flow.—For percolating filters the allowance is 65 gallons per cubic yard, the material being over 1 in. in size; 50 gallons per cubic yard, the material being under ½ in. in size. For sewage of average strength the allowance is 100 gallons per cubic yard, the material being 1 in. in size, and 80 gallons per cubic yard for material under 1 in. in size. For weak sewage the allowance is 150 gallons per cubic yard for material over 1 in. in size, and 175 gallons per cubic yard for material under ½ in. in size. For contact beds with strong sewage the allowance is 33 gallons per cubic yard, the material being arranged for double contact; for sewage of average strength 50 gallons per cubic yard for double contact, and for weak sewage 133 gallons per cubic yard for single contact.

264. Treatment of Sewage from Precipitation Tanks with Quiescent Settlement.—For strong sewage the allowance is 100 gallons per cubic yard, the material being over 1 in. in size, and 65 gallons per cubic yard, the material being under ½ in. in size. For sewage of average strength the allowance is 130 gallons per cubic yard for coarse, medium, or fine material, for weak sewage the allowance is 170 gallons per cubic yard for material over ½ in. in size, and 200 gallons per cubic yard for material under ½ in. in size. For contact beds with strong sewage the allowance is 43 gallons per cubic yard for double contact, for average sewage 66 gallons per cubic yard arranged for double contact, and 133 gallons per cubic yard for weak sewage in single contact beds.

It cannot be said that these results appear to be altogether consistent, but the chief point which is quite clear is that filters and contact beds must be made of ample size for the sewage with which they have to deal.

CHAPTER XXX.

THE CONSTRUCTION OF CONTACT BEDS.

265. With regard to the construction of contact beds it is essential to remember that the design of the first beds in particular must depend largely on the local conditions. Thus, if it is desired to treat a strong septic effluent at a site where smell is undesirable, special steps must be taken in order to prevent the liquid being exposed to the air.

PREVENTION OF SMELL.

266. The author has constructed several works where special steps have been taken to prevent smell, and the process that has proved most satisfactory has been to distribute the liquid about 9 ins. below the surface of the contact bed in covered channels; in some cases the author has constructed distributing walls composed of slate layers throughout the bed for the full depth, so that the liquid can be conducted to all parts of the bed without appearing at the surface at all. It will be necessary to take special steps in order that the liquid may never be able to rise above the surface of the bed. This can easily be arranged by putting in an overflow slightly above the level of the liquid, so that in the case of the liquid beginning to rise too high in the bed it may flow into a pit and open the outlet valve automatically. The filling material in the bed is then laid to a level of 9 ins. above the overflow level.

DRAINAGE.

267. It is also, in the author's opinion, essential to good working that the beds should have a false bottom for drainage purposes similar to that of a waterworks filter or percolating sewage filter. This has generally been constructed of dry brickwork, and also in certain cases by means of a layer of slate similar to that used in the "Dibdin" slate beds in the author's practice. The necessity of having automatic apparatus has already been mentioned, and it is difficult to see how contact beds can be satisfactorily worked at small installations by means of hand-valves

FILLING MATERIAL.

268. The first contact beds can be filled with various materials, but it is certainly of importance that the material used shall be unlikely to disintegrate. Clinker, unless it is of very good quality, will disintegrate, and for this reason it is better to use an imperishable material. The author has used gravel, broken stone, and quartzite in preference to clinker where possible. It will generally be necessary in course of time to cleanse the filtering material in the contact beds; it is certainly well to use some material which will not break up during the process. It certainly has not appeared from practical experience in working that there is any special advantage in using coke or clinker. It is often maintained that the structure of these materials affords a better home for bacteria, but seeing that each lump of coke or clinker becomes in time covered with humus and gelatinous growth, each piece of material appears to present a face similar to that of broken stone, and under these circumstances the amount of contact given by each piece of the filtering material cannot depend upon its fine structural formation, seeing that the interstices are generally filled up with matter which does not come in contact with the sewage.

269. A curious result has been noticed in one case where the contact bed was filled with broken flints. In this case the contact bed has cleared itself at intervals and has retained its capacity in a manner quite superior to that of the clinker beds working alongside under precisely similar conditions. The amount of humus and sludgy matter discharged on to the surface of the second beds was greater in the case of the broken flints than in the case of the clinker, but it is obviously better to have to remove this material from the surface of the second bed than to have to wash the material in the first bed. If the effluent discharged on to the second beds is of a quality which is likely to cause a nuisance from smell it will be well to place covers over the distributing channels and also to arrange matters so that the liquid standing in the bed does not rise to the surface of the filtering material. This can be done in the manner described in the case of the first bed The drainage arrangements should be similar to those in the first bed. In the case of the third contact beds, the liquid can be discharged

over the surface without fear of causing smell. The third contact beds should be drained in the same manner as described in the case of the first contact bed.

GRADE OF FILLING MATERIAL.

270. For ordinary domestic sewage it has been the author's practice to fill the first contact beds with material of such a size that it will pass through a $1\frac{1}{4}$ in. mesh and be retained on a $\frac{3}{4}$ in. mesh. For second contact beds the material used has been capable of passing through a $\frac{3}{4}$ in. mesh and of being retained on a $\frac{1}{4}$ in. mesh. On third contact beds the material has been capable of passing through a $\frac{3}{8}$ in. mesh and retained on a $\frac{1}{8}$ in. mesh. It is very important that all dust or fine material should be excluded from the beds. These sizes of material have been used for the treatment of sewage which has passed through a septic tank, and which is of sludgy quality at times. If a preliminary treatment for removing the sludge by sedimentation or by emptying the septic tank were given it would be possible to make the grade of the material in the first and second beds finer. Probably in this case the third beds would not be required.

DEPTH OF BEDS.

271. In general practice contact beds are not as a rule made less than 2 ft. 6 ins. deep or more than 6 ft. in depth. The chief reason why it is undesirable to have beds of less depth than 2 ft. 6 ins. is that frost is apt to put a large portion of the filter out of use at times if the beds are too shallow. If they are more than 6 ft. in depth there is very great difficulty in removing the material for cleaning. As a matter of fact it is generally undesirable to have beds much over 4 ft. 6 ins. in depth.

HUMUS TANK OR FILTER.

272. In the case of double contact effluent or of effluent from percolating filters experience has shown that a sediment tank for humus or a fine straining filter has generally been required before the effluent can be safely discharged into any ordinary stream or river of small volume, and it should be observed that this is particularly the case at certain seasons of the year when the filters discharge large quantities of humus and sometimes foul matter. Where third contact beds or filters

containing fine material are used such tanks are generally unnecessary, as the humus and other matters are intercepted on the surface of the fine material. The different series of contact beds are generally made of equal cubical contents.

CHAPTER XXXI.

PERCOLATING FILTERS.

273. In the remarks made by the Royal Commissioners upon the construction of percolating filters, it is demonstrated that the main consideration in laying out an area of filters is to arrange so that portions can be put out of work without interfering with the general working of the plant. Thus, for instance, at small sewage works, if the whole of the sewage had to be dealt with on one percolating filter fed by one sprinkler, the stoppage of that sprinkler would result in the temporary discharge of a large quantity of unpurified sewage into the watercourse, unless there were some other means of disposal available. This point is extremely important.

DRAINAGE AND AERATION

274. In many cases the most economical form of construction involves open sides, but this arrangement does not appear to have any effect upon the aeration of the filters, especially in those of large size. There does not appear to be any special advantage, therefore, in having open sides. Many persons, however, appear to be of the opinion that there is some special benefit as to aeration in the open-sided filter.

275. In constructing the base of a percolating filter it is necessary to remember that large quantities of suspended matter will work their way down through the filter, and that if this suspended matter is not able to go away with the effluent the bottom layers will be clogged, and this will interfere with the proper working of the filter, both mechanically and also by preventing aeration. Thus, it is necessary to make provision for free passage of suspended matters passing through the material into the effluent drains. This statement refers particularly to coarse filters.

276. In the finer filters a considerable amount of washed out material will be intercepted on the upper part of the filter, and so the need for drainage is not quite so great at first, but ultimately there will be every probability of this material finding its way to the bottom and choking the filter if it cannot get away freely. A bottom layer of large pieces is therefore generally allowed to rest upon the false bottom made of tiles, and these tiles rest upon a sloping platform of concrete. This concrete is sometimes made to fall evenly to the channel at the circumference of the filter, or sometimes it is made to fall to a central sump whence the effluent drain runs, and in other cases the whole floor has a fall to one side. Drainage arrangements are of the utmost importance.

WALLS.

277. The filtering material must be retained by a wall of some kind, and though this wall is frequently constructed of large lumps of clinker or other material of which the bed itself is formed, it is, nevertheless, the retaining wall. The only other alternative is to have a bank sloping at the natural slope of the filter material, but it is obvious that such a slope is not an economical arrangement.

278. In constructing the walls of a percolating filter it is necessary to remember that they have to withstand a certain amount of thrust, and there are instances of the retaining walls cracking and giving trouble, which emphasises the importance of making the walls of sufficient strength.

With regard to the depth of percolating filters, it is suggested by the Commissioners that the minimum depth should be three feet, but no reference is made to the maximum efficient depth. It is generally found, however, that the maximum economical depth is somewhere between six feet and nine feet.

279. Filters may be constructed above or below ground or half in and half out of the ground. They may have a containing wall of brickwork or masonry or dry rubble or clinker. Sometimes they are made with a brick retaining wall surrounding them for part of the height, the remainder being built of the filtering material inside and above the retaining wall proper.

FILLING MATERIALS.

280. The grade and quality of the filling material used must depend upon the particular conditions of the case. The size of the material available, the depth of the filters, the convenient area, the character of the sewage, and the methods of distribution vary so much that it is impossible to lay down any general rules which may be applied to all cases. The Royal Commissioners say that "the size of the filtering material should depend very largely upon the amount and character of the suspended matter in the liquid to be filtered." The decision as to the most suitable size of the material can only be arrived at when all the facts of the case are known. It may be said that materials of all sizes are used at various places. Clinker is the material that has been used most generally and there are advocates of very coarse material and very fine material, but it is clear that a very good tank effluent can be treated very satisfactorily on material of fine grade, whereas a tank effluent containing large quantities of suspended matters will need treatment on a very coarse material. Likewise the primary filters will be of a coarser material than the secondary filters. It is important to have the material throughout a percolating filter of even grade, as otherwise the smaller pieces will tend to fill up the interstices in between the larger pieces and prevent aeration.

WORKING.

281. Percolating filters can be worked continuously, and it will generally be better to work them on the principle of the slow distribution of a given quantity over a particular area than on the principle of the quicker distribution of the same quantity over the same area in intermittent doses with periods of rests between the doses.

282. As a general principle it will be found much less trouble to extract the humus or solid matters from the effluent by means of a humus tank or small fine filter than to attempt to remove it from the surface of a percolating filter.

CHAPTER XXXII.

STORM WATER.

STORM FILTERS ABANDONED.

283. The Commissioners state that as a general rule the difficulty in dealing with the storm water lies not so much in the actual quantity flowing over an area as the result of rain, as in the rate at which it flows off. The old method of treating storm water on rough filters was undoubtedly wrong, and the practice has been abandoned, and the Local Government Board generally refuse now to sanction loans for such work. The Commissioners state that "storm water filters as generally constructed and used do not effect the purification in proportion to their cost." Such filters receive sudden rushes of exceptionally foul sewage which passes through them quickly without receiving any purification other than straining.

STORM WATER TANKS.

284. The Commissioners suggest that one and a-half times the area of filter, which would be necessary for the treatment of the sewage if only the dry weather flow had to be treated, should be provided, and that special stand-by tanks, two or more in number, should be provided at the works and kept empty for the purpose of receiving the excess of storm water which cannot properly be passed through the ordinary tanks. It is assumed that ordinary tanks are capable of dealing with three times the normal dry weather flow. It is recommended that the storm overflow should be so arranged that it would come into operation only when the stand-by tanks were full. The sewage intercepted in the stand-by tanks would then be treated on the ordinary filters, which should be made sufficiently large for the purpose. The Commissioners state that in most cases it would probably suffice to provide stand-by tanks capable of holding one-quarter of the dry weather flow, and it would not be necessary to provide for filtering more than three times the normal dry weather flow. The chief difficulty which presents itself with regard to this arrangement is that in most cases there is not sufficient fall at the works to allow for the emptying of these storm water stand-by tanks on to the filters by gravitation, and it will, therefore, be neces-

sary sometimes to pump the contents on to the filters. In such a case, however, as that in which a dosing tank is provided for filling contact beds it seems that a smaller tank might be provided for taking the storm water, and, moreover, the dosing tank itself would in some cases actually hold one-quarter of the daily dry weather flow, and would, therefore, certainly intercept any sudden rush of the sewage.

Where there is sufficient area of suitable land available the Local Government Board generally allow treatment of storm water in excess of three times the dry weather flow by irrigation provided that detritus tanks are provided.

CHAPTER XXXIII.

LAND TREATMENT.

GENERAL.

285. Under favourable conditions, treatment of sewage on land is a very satisfactory and efficient method. The ground must be of such a quality and of such an area as to form a natural filter for the sewage. Hence clay land or soil which is impervious is unsuitable for sewage farms.

286. It should be noted that ordinary clay, clay mixed with sand or clay mixed with gravel, are used in ordinary practice for the formation of watertight linings and puddle trenches for storage reservoirs, yet this same material, viz., clay, has been used in the past for sewage filtration in broad irrigation schemes, and it is to this cause chiefly that so much trouble has been experienced at sewage farms within the area of the London clay.

287. Sewage farms have failed owing to the unsuitable nature of the ground, but also owing to the neglect of those in charge, and to the fact that the production of good crops from the land has received more attention than the proper disposal of the sewage. Agricultural considerations must always be subservient to the object for which the works are intended, viz., the disposal of sewage.

SEWAGE TREATED ON LAND MAY NEED CONSIDERABLE PREPARATION.

288. Land treatment was used in the past, and is still used for the purification of crude sewage, or tank effluent, but unless the land is very light and gravelly it will generally be necessary to purify the crude sewage by tank treatment as a preliminary, and it will often be economical to treat the sewage also by filtration to a greater or lesser degree before it is applied to the land, using the land, in fact, only as a final filter.

289. If the land is of a really good quality it will deal with an effluent such as one might expect to get from a settling tank under its worst conditions, but if the surface should be impervious owing to clogging there will be a nuisance immediately. It is impossible to avoid a very bad smell wherever a strong septic effluent is discharged in the open, and for this reason alone it will be seen that treatment in sedimentation tanks or slate contact beds will generally be a better preliminary than the septic tank.

290. Where the land is of first-class quality and very light and gravelly, and where the sewage is not too strong, crude sewage can be satisfactorily treated on the land, but it should be clearly understood that this can only be done satisfactorily under the best conditions. To attempt to treat crude sewage on a limited area of land or on land which is anything less than a natural filter, allowing the liquid to soak away rapidly at all times, will be to court disaster. Similarly, to attempt to purify even a sewage of average strength by passing it once only through a few feet of soil will mean an unsatisfactory effluent unless the area is enormous. Sewage farms exist all over the country, where it was at first supposed that the land would deal with crude sewage, and when bad results were obtained it was supposed that removal of the sludge by precipitation would settle the difficulty, and where it has finally been found necessary to use settling tanks and filters before turning the effluent on to the land. This is quite a normal state of affairs, and the moral is that if crude sewage is to be treated on land an area much larger than that generally allowed is required. Hence, speaking generally, land treatment alone is not economical, but as an auxiliary for secondary treatment land is most valuable.

DRAWBACKS TO LAND TREATMENT.

291. The chief drawbacks to land treatment are the large area of the works required, the heavy cost, the amount of attention needed, and the ease with which a short cut to the outfall or stream is made by the sewage. On the other hand, as a set-off against expense, there is the value of the crops produced. There also remains the great difficulty of making the agricultural considerations subservient to sewage disposal. It has sometimes been found that the crops from a sewage farm sell well for a year or two, and then some animal dies, and the local reports say that its death is due to the effects of eating vegetables grown on the sewage farm. The story goes round the country, with the result that the sale of vegetables grown on the farm is seriously injured. Thus those farms which at the beginning show a profit frequently fail to do so afterwards. Sewage farms are sometimes let to farmers, but in such a case the disposal of sewage becomes a secondary consideration, and the chances of failure are largely increased.

METHODS OF LAND TREATMENT.

292. In the very best cases, where circumstances are favourable, the land is sometimes capable of dealing with both sludge and sewage, the liquid soaking away into the ground and the sludge being left on the surface. In this case the sludge generally has to be dug into the ground.

293. Generally speaking, however, there are two methods of land treatment:—(1) Intermittent downward filtration and (2) broad irrigation. In either system the object of the engineer is to make the sewage percolate through the soil. With intermittent downward filtration the sewage filters vertically through the earth to the subsoil drains below; with broad irrigation the sewage is purified by allowing it to flow over the surface of the land so that the top soil is saturated with the sewage, which filters through it laterally to drains or surface channels.

294. There are also cases where, owing to the character of the ground, the sewage will soak straight into the ground and descend to the ordinary water-bearing stratum of the district. Thus sewage farms on the chalk and in

deep sandy districts frequently have no sub-irrigation drains; the sewage is merely discharged into them and allowed to soak away into the ground. This arrangement is very satisfactory as far as getting rid of the sewage is concerned, and the sewage works manager has no trouble as to quality of effluent; but it must always be remembered that where sewage can percolate into the chalk or other water-bearing stratum it is liable to pollute the water supply of the district.

ARRANGEMENT OF IRRIGATION WORKS.

295. Land must always receive the flow of sewage intermittently in either system—that is to say, the land must have frequent intervals of rest. A loamy, porous soil is the most suitable for sewage purification. It is sometimes possible to do with very few sub-drains, as many being put in as will keep the water level in the soil below a certain depth being found sufficient. As a rule, however, the ground will become waterlogged if a regular system of subsoil drains is not provided, and the number of these drains can only be decided when the character of the ground is known.

296. Irrigation is generally adopted where the ground is not very porous. It is often very difficult to adopt such a system because it is difficult to find sufficient land surface suitably situated. The surface must present a gentle slope, so that the sewage may travel forward slowly in a lateral direction, and thus admit of the surface being regularly saturated and of the liquid draining off rapidly and of the ground drying again. Land has to be divided up into sections, and the sewage is discharged on to each section in turn. There must be no hollows in which sewage can be held. Sometimes even clay land has been made to give a good result by preparing a porous stratum about 12 ins. thick on the surface, by mixing the top soil with some light material such as ashes. It should be clearly understood, however, that it is not the clay which does the work. It is useless to mix ashes with stiff clay, and it is only where top soil is available that a good result can be obtained in this manner, the clay itself being quite useless for this purpose. Ashes are laid on the comparatively porous top soil and the ground is ploughed.

297. The gentle slope required for broad irrigation is sometimes obtained by breaking the land up into a series

of ridges and furrows; the carriers from which the sewage is discharged run along the tops of these ridges, which may be 30 ft. or 40 ft. apart. The furrows at the foot of each incline have a slight fall towards the effluent drain or channel. It is not to be supposed, however, that a very high degree of purification can be accomplished in this manner, unless the sewage passes through two or three such systems of ridges and furrows. In the author's experience it has been found that sewage will pass very rapidly through land which has been thus prepared, the made ground being of a loose and porous character at the start. On the other hand, it is necessary to keep the land in a porous state by ploughing it. Crops can be grown on such irrigation land.

298. The most general plan with board irrigation is to allow the sewage to travel forward over the surface of the land from long carriers made at right angles to the slope, the distance which it travels depending upon the character of the land. Within limits, the greater the distance the more thorough the purification. The chief danger of the system is that the sewage is apt to form channels and run across the land without percolating through it. The working, therefore, requires considerable attention. The laying out of the land is a very important matter, and should receive the greatest care. Subsoil drains may be required in the broad irrigation system to prevent the land becoming waterlogged by water or by sewage percolating downwards, but it should be observed that it is worse than useless to put in subsoil drains in the case of clay land, as the clay is sure to crack in dry weather and the sewage will short-circuit into the sub-drains without any proper purification. Drains and surface channels must be provided to take the effluent after it has flowed over the surface of the land. Wherever possible the effluent from one plot of land should be made to pass on to a lower plot before it is discharged into a river. Double or even triple filtration may sometimes be obtained in this way.

WORKING.

299. It is most important that land should not be overworked. It requires long periods of rest, and sewage should never be allowed to pond on the surface or to form a scum, as the ponding will cause a nuisance and the scum will prevent the sewage percolating through the land. Wherever a scum forms the ground should be broken up.

ARRANGEMENT OF LAND FILTRATION WORKS.

300. The process of intermittent downward filtration can only be carried out where the soil is very porous. Great care must be taken in the preparation of the surface. The land is divided up into level sections, and the sewage is discharged on to each in turn. As much use is made of the area of the land as is possible in this system by using the soil as a filter for a depth of about 3 ft., instead of using the top few inches of the soil only, as in the broad irrigation system. The sewage passes vertically downwards to subsoil drains, the effluent from which may be run into a stream. It is, of course, well in this case also to pass the sewage through land a second or even a third time in the same manner.

FURROWS.

301. If the flow of sewage is slow and the ground very porous each section is laid out in furrows, so that the sewage may run equally on to all parts. These furrows are sometimes very close together, say two or three feet apart. If, however, the discharge of sewage is rapid the whole area of the section is covered by it at once, and the furrows are then unnecessary.

CHANNELS.

302. In either system of land treatment it is as well to avoid artificial-built channels as far as possible, as they are expensive, and interfere with the cultivation of the ground. Of course, the main carriers for the sewage will have to be built, and, in fact, as many of the channels as are essential for conveying the sewage to the various sections must be of a permanent nature, but the other channels for distributing the sewage over any particular section can be formed by cutting them in the ground.

CROPS.

303. It is customary to grow crops on the ground in both broad irrigation and intermittent downward filtration systems, but in some cases where the filtration area is limited and hard worked no crops are grown. It must always be remembered that the crops are quite a

secondary consideration, and that they should never be allowed to interfere with the proper use of the land for sewage disposal.

EFFLUENT.

304. It is as well to bear in mind when examining the effluent from sewage farms that the naturally clean subsoil water may form a large part of the effluent coming from the subsoil drain, and thus give a very false idea of the amount of purification effected by the land.

CHOICE OF SYSTEM.

305. The choice of a system depends chiefly upon the character of the ground and the area available. Whether any particular land is fit to deal with sewage and how much preliminary treatment is required before sewage of a given strength can be applied to land is a matter which can only be decided after careful consideration of the circumstances in each case.

SEWAGE PUMPED TO LAND.

306. With regard to land-treatment schemes, it should be remembered that the sewage must be applied regularly and in suitable doses, and where a day's flow is to be pumped up on to the land in two or three hours it will obviously be necessary to have some intermediate tank between the land and the sewage. For instance, under good conditions the Local Government Board would allow 30,000 gallons of sewage to be treated upon one acre of land. Now, irrigation land is generally divided up into sections, and the whole sewage is not distributed over the whole area at one time. Thus, in any ordinary pumping scheme the sewage would be raised more quickly than the land could take it, and at such a rate that it would be practically impossible to distribute it in ordidary channels over the comparatively small area of land in use, and it would quickly flow over it, and would then find its way into the neighbouring ditches or water-courses.

AREA OF LAND REQUIRED.

307. With regard to the area of land required for treatment there can be no absolute rule. The Local Government Board have in the past required one acre of suitable land

for every 150 head of population with broad irrigation, and with intermittent downward filtration one acre for every 1,000 head of population. The Royal Commissioners, in their fifth report, make suggestions for the area of land required under different conditions, and they make the following statements:—

(1) A strong sewage which has passed through chemical precipitation tanks can be treated at the rate of 25,000 to 30,000 gallons per acre per day, i.e., at the rate of from 5 to 6 gallons per square yard.

(2) Strong sewage which has passed through a settlement tank can be treated at the rate of 20,000 gallons per acre or 4 gallons per square yard.

(3) Strong sewage which has passed through a septic tank will be liable to create a nuisance if discharged over land, and no recommendation as to area is given.

(4) Sewage of average strength which has passed through chemical precipitation tanks may be treated at the rate of from 30,000 to 40,000 gallons per acre, or at the rate of from 6 to 8 gallons per square yard.

(5) If it has passed through natural precipitation tanks sewage may be treated at the rate of from 25,000 to 30,000 gallons per acre, or from 5 to 6 gallons per square yard.

(6) With regard to sewage which has passed through a septic tank, the remarks made in the case of strong sewage apply equally in the case of average strength.

(7) For weak sewage which has passed through a chemical tank the area of land required is one acre for from 30,000 to 40,000 gallons, or from 6 to 8 gallons per square yard.

(8) If weak sewage has passed through a natural settlement tank from 30,000 to 40,000 gallons per acre, or from 6 to 8 gallons per square yard, are allowed.

(9) If weak sewage has passed through a septic tank, 30,000 gallons per acre, or 6 gallons per square yard, are allowed.

308. It is fairly clear from these statements that for intermittent downward filtration the old allowance of 1,000 persons per acre is a fair figure to assume, in the case of good land. Where the land is of inferior quality and the sewage is to be filtered on the surface by broad

irrigation, a much larger area is required, which may be anything according to the nature of the ground, but the low figure of 150 persons per acre will be useful as a rough guide. Where sewage has been filtered, of course the allowance of land will depend upon the quantity which can be passed through it, and the amount of purification already effected by filters. It is to be assumed that the Local Government Board follow the advice of the Royal Commission.

309. In considering the large area of land which has to be allowed for the treatment of sewage, one must not overlook the fact that owing to the need for resting the land and for growing crops, it is not possible to treat the sewage over the whole area at once, but that on the contrary a large portion of the land must generally lie unused.

CHAPTER XXXIV.

STERILISATION OF SEWAGE.

EFFLUENTS IMPROVE BACTERIALLY.

310. There can be no doubt that the effluents from ordinary sewage purification works are bacterially impure. Though proper treatment will produce a clear, inodorous effluent which under the best conditions may look like drinking water, and be subject to no after change, yet this effluent is often comparable to crude sewage from a bacterial standpoint.

Dr. Houston, in his report to the Royal Commission on Sewage Disposal, states that effluents from septic tanks, contact beds, and trickling filters contain enormous numbers of bacteria, and that though they may be reduced in number by the treatment, the relative abundance of the different kinds of bacteria are much the same in effluents as in the crude sewage. Furthermore, and this is a very important point, Dr. Houston showed that of undesirable bacteria—such as B. coli, proteus-like germs, spores of B. enteritidis sporogenes, and streptococci—the effluents contained almost as many as the crude sewage.

NEED FOR STERILISATION.

311. The Royal Commissioners have also pointed out that none of the ordinary methods of sewage disposal are sufficient to make it possible to discharge sewage effluents

near to shell fish layings, and recommend that in such cases the sewage should be discharged elsewhere, or the layings closed.

It is perfectly clear, therefore, that if for any sufficient reason it is impossible to keep sewage effluents out of drinking water rivers or shell fish layings, some further treatment is necessary in order to remove the harmful bacteria.

It is often urged that to drink water which is known to be sewage polluted, or to allow sewage-contaminated shell fish laying to exist, ought not to be countenanced, and on the face of it, without exact knowledge of facts, one might readily agree to the contention. But as a matter of fact this is a counsel of perfection not to be attained under existing conditions. For on the one hand we have a shell fish trade of immense value which cannot be done away with, and on the other hand the polluting authorities in some cases have not the funds required to take their sewage elsewhere. We have an ever-growing population which must cause pollution to the sources of supply, to the rivers and springs and wells, and we have an ever-increasing demand for pure water.

312. Of course, in many cases the dilution is so great that no bad results are apparent or are even likely to occur, and it may well be that in most cases natural processes remove the harmful germs after the sewage or sewage effluent has been discharged into the sea or river. It is impossible for the engineer pure and simple to say whether a given effluent under given conditions is dangerous to health when discharged. In this we must look to the bacteriologist and medical officer to tell us whether the danger does or does not exist, whether the shell-fish are contaminated or are likely to be contaminated, and whether the water drawn from the river or spring for drinking purposes is pure or not. But where danger is found to exist there is a possible remedy, and that is sterilisation.

STERILISATION AS A MATTER OF POLICY.

313. There is, however, another case in which the engineer may be called upon to decide whether it may or may not be politic to sterilise the sewage. It is only too well known that a river or an oyster bed may be polluted from causes quite outside the sewage works where the fault is attributed to the sewage, however unlikely sewage pollution may be. There are cases on record where

authorities have been fined for such pollution where the contamination may have been due to other causes. In such a case the engineer will do well to sterilise all effluent passing from his works, and then it will be possible to prove that no effluent containing disease germs issues from his works, and this will be better evidence in a court of law than the pious opinion of the most eminent scientific witness to the effect that the dilution ought to have been sufficient to remove all harmful germs.

Sometimes also it will be necessary to prove to nervous opposing authorities that a new system will be quite safe, and here again sterilisation may be found useful.

METHODS OF STERILISATION.

314. Various methods of sterilisation have been tried, but the method which has hitherto proved to be efficient and economical is that of mixing a solution of hypochlorite with the effluent *after filtration*. Plain chloride of lime mixed with water has been used largely, but it is probable that for large works hypochlorite, prepared by electrolytic methods, will eventually be found to be the most economical and trustworthy method.

315. Early experiments, as well as those of later date, have been made with crude sewage, tank effluent, and poor filter effluent. These have failed for the simple reason that the amount of sterilising agent required was enormous, and then not effective as a rule. The energy of the sterilising agent was used up in dealing with solid matters and organic matters in suspension, and bacteria contained in the solid matters were not affected. Later experiments, both with water and sewage, all point to the fact that sterilisation can only be economically and satisfactorily accomplished under ordinary conditions after the solid matters and organic matters in suspension have been removed as far as may be possible.

316. The process is really so simple that it is surprising that it is not more readily understood. Having filtered the sewage a liquid remains which is clear of matters in suspension, but contains harmful bacteria. If the liquid is really well filtered a very small quantity of hypochlorite will deal with the bacteria, in some cases one part per million of available chlorine has been found to suffice, and where the water is really well filtered, say, through sand, the quantity required is sometimes much

less. If, on the other hand, the effluent contains organic matters in suspension, the quantity of chlorine has to be increased in proportion.

317. It is in the filtration and careful application of the sterilising agent that the engineer's work lies. The experiments hitherto have generally been carried out by chemists and scientists with very crude appliances, but latterly engineers have taken the matter up and are perfecting dosing apparatus, electrolysers, and testing arrangements.

COST OF STERILISATION.

318. Early experiments were made with electrolytic hypochlorite at Guildford and Maidenhead in this country, while in America experiments with chloride of lime solutions made at Boston, New Jersey, and Baltimore have proved after years of careful experimental work that sterilisation of ordinary percolating filter effluents can be effected on a large scale satisfactorily and economically.

319. The following figures were given in a report published by the Massachusetts Institute of Technology. The cost per million gallons, including maintenance and operation of plant, for sterilising sewage or sewage effluent with chloride of lime, based on a capacity of 5,000,000 gallons a day, is estimated as follows:—

ESTIMATES OF THE COST OF MAINTENANCE AND OPERATION OF A PLANT FOR DISINFECTING SEWAGE OR EFFLUENT WITH CHLORIDE OF LIME, BASED ON A CAPACITY OF 5,000,000 GALLONS A DAY.

Available Chlorine in parts per Million.	Time of Contact (in hours).	Cost per Million Gallons.					
		Storage Tanks.	Other Fixed Charges.	Bleaching Powder.	Labour.	Power.	Total.
1	5·0	5d.	1d.	1/3	5d.	—	2/2
2	2·5	2½d.	2d.	2/6	5d.	—	3/3½
3	1·6	2d.	2½d.	3/9	5d.	1d.	4/7½
4	1·2	1½d.	3½d.	5/-	5d.	1d.	5/11
5	0·8	1½d.	4d.	6/3	5d.	1½d.	7/3
10	0·5	1d.	8d.	12/6	7½d.	3d.	14/1½
15	0·5	1d.	1/-	18/9	10d.	4½d.	£1 1 0½

It should be borne in mind that the higher figures do not refer to any ordinary effluent. From the results obtained at Boston and Baltimore, for instance, it was found that three to four parts per million of available chlorine would successfully treat the effluents of percolating filters of a quality which cannot be considered first-rate. A better effluent would need less chlorine.

ELECTROLYTIC HYPOCHLORITE STERILISATION.

320. The success achieved by the American experimenters with plain chloride of lime and probably the difficulty of obtaining the necessary machinery and plant, have, in the author's opinion, caused them to overlook the advantages of electrolytic treatment. By means of an electrolyser it is possible to prepare a sterilising agent which possesses many advantages, the reasons being that electrically produced hypochlorites can be more economically produced under favourable conditions than solutions of chemically produced hypochlorites, such as bleaching powder, and not only is the cost of production and labour less, but the resultant available chlorine is much more efficient than the chlorine of the bleaching powder. This has been carefully demonstrated by the highest authorities. Ledboir, Messrs. Cross and Bevan, the "Lancet" Commission, Dr. Rideal, Dr. Alexander, of Poplar, and others have supported this fact. It should be noted that Messrs. Cross and Bevan determined that the superior efficiency was as great as two to one. Bleaching powder is subject to great fluctuations in price, and though it contains from 33 per cent. to 37 per cent. of available chlorine, this is apt to be very misleading, because the chemical rapidly loses its efficiency when open. Thus, it is often necessary to deduct something like from 15 per cent to 18 per cent. from the efficiency of the available chlorine in the chemical at its best, and when actually used. Of course, loss of efficiency will in a great measure depend upon the care which is exercised. It will be seen also that two-thirds of the bleaching powder added to the water will be useless, and this is apt to accumulate and, in a minor degree, it will become a nuisance.

PRACTICAL STERILISATION.

321. The means adopted for sterilisation are extremely simple. To give an example: Suppose a flow of 100,000 gallons a day has to be treated with two parts of available chlorine per million. If ordinary commercial bleach-

ing powder is used and steps are taken to prevent loss of efficiency by exposing it to the air too soon, it will possess about 33 per cent. of available chlorine. Thus, three times as much bleaching powder will have to be used as the amount of available chlorine required. One hundred thousand gallons equals one million pounds, therefore two pounds of available chlorine will be required and six pounds of bleaching powder. This powder is then dissolved in any quantity of water that may be convenient to facilitate the dosing. Suppose, for example, it is dissolved and mixed with 100 gallons of water, then one gallon of solution must be added to or mixed with every thousand gallons of sewage effluent. Suppose, for instance, the effluent passed through a tank of 10,000 gallons capacity, ten gallons of solution must flow into this tank with the sewage. Short contact is sufficient, but, as will be seen by the table quoted above, a longer period of contact will sometimes reduce the quantity of sterilising agent required. It is in the arrangement of this dosing that the skill of the engineer is required. It will sometimes be best to add the sterilising agent to the effluent as it flows away, at other times it may be best to provide sterilising tanks, and so on.

322. The mixing of the chemical solution is not a difficult matter. It is generally mixed in a small tank, and further diluted and settled in larger tanks. With electrolytic hypochlorite the process is equally simple. An electrolyser, for which electric power is, of course, required, supplies a liquid already diluted. There are several types of electrolyser on the market, but in the simplest form common salt is the only chemical required, and where sea water is available this can be used instead of the sodium chloride solution. In the electrolyser an electric current passes through the solution of salt and water, with the result that the chemical constituents are divided and recombined, so as to form a hypochlorite of greater efficiency than the chemical hypochlorite.

TESTING.

323. In both cases it is a very simple matter, and quite within the power of an intelligent works manager to test the effluent. A simple colour test is employed, whereby all that the manager has to do is to add a chemical to a sample of effluent. If the effluent contains an excess of chlorine the harmful germs will have been destroyed, and

the colour of the sample will be violet. If the violet colour does not appear it shows that a larger dose of sterilising agent is required. If the colour is too deep then the dose may be diminished.

324. While the author does not suggest that sterilisation of sewage effluents is generally desirable or necessary, he does emphasise the fact that the process is available wherever required, and that in some cases it is necessary, and if adopted would save much public money and possibly much disease.

ADDENDUM.

SEWAGE LIFTING.

A difficulty with pneumatic ejectors has been the dealing with the night flow. It has been necessary either to keep the compressors at work all night or to allow the sewage to lie in the sewers. On the Coombs system, however sufficient compressed air can be stored to deal with the night flow without working the air compressor. Such an arrangement has been installed at Hungerford.

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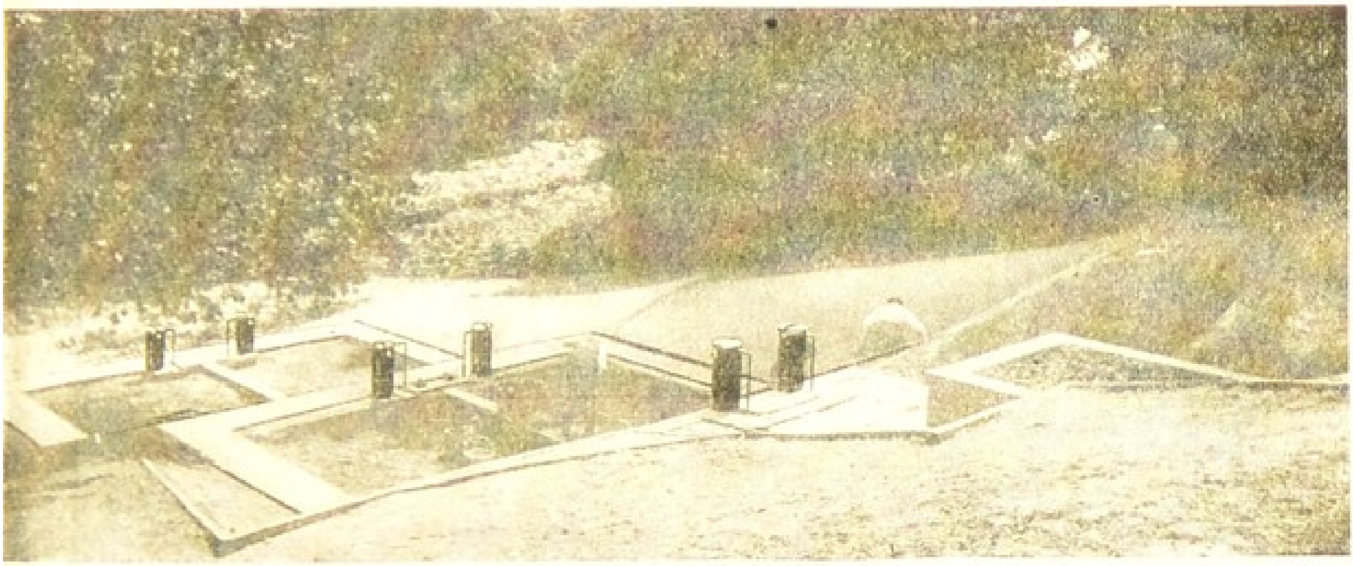

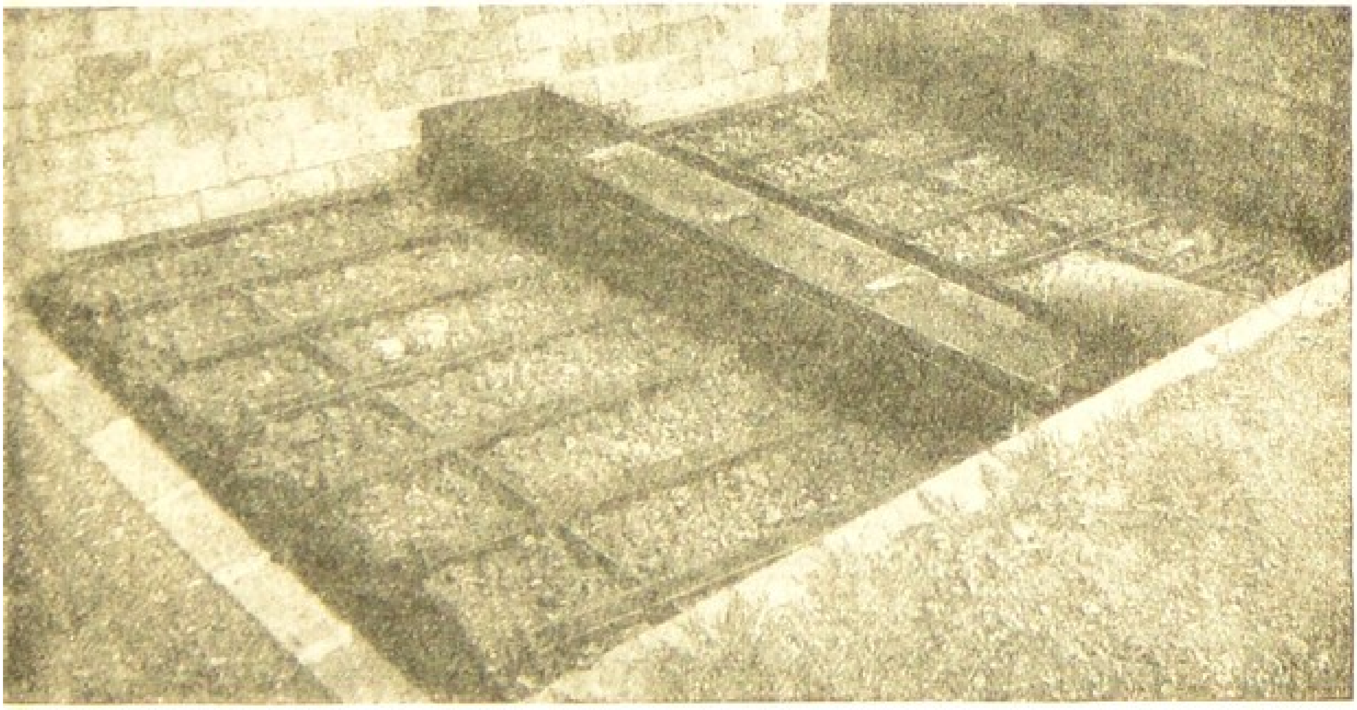

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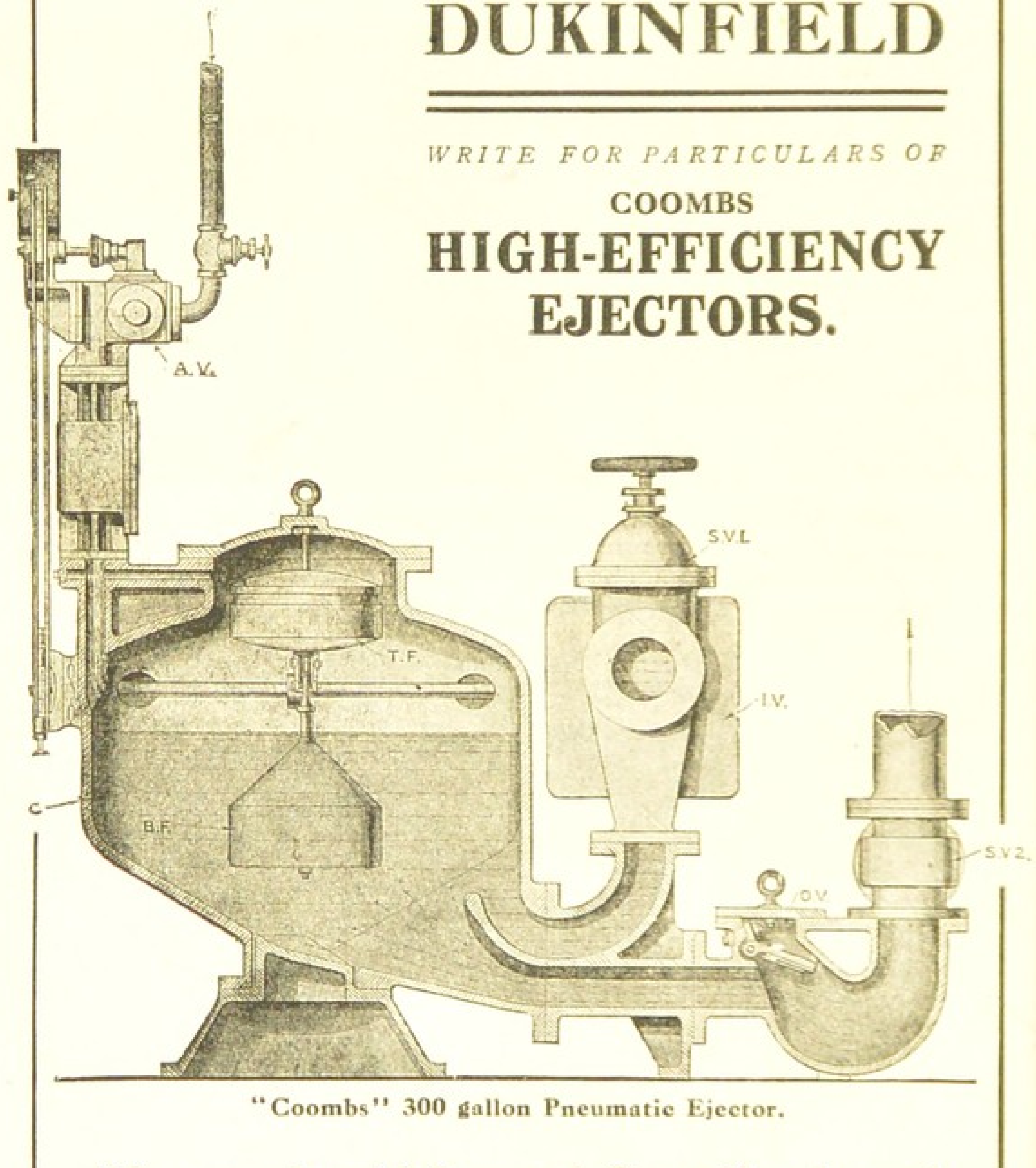

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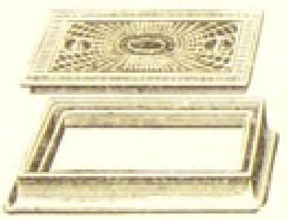

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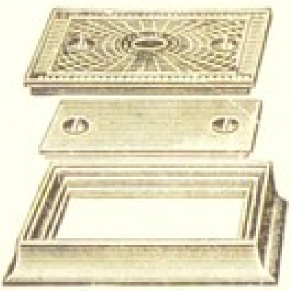

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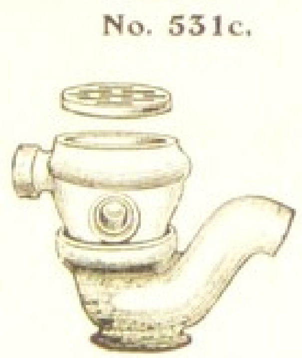

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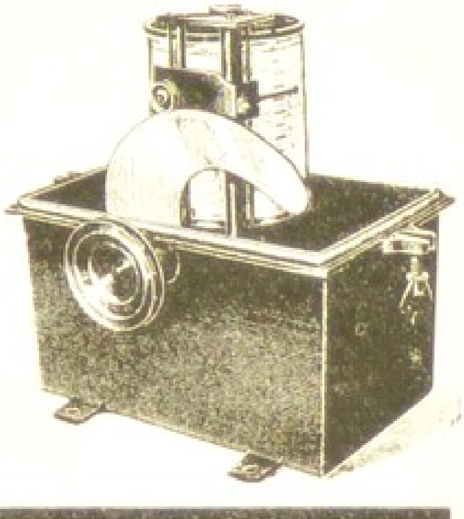

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