
General Reference to Systems in Use.—The removal of the sewage of towns, consisting mainly of excreta, liquid household and trade wastes, is carried out upon either the "conservancy" or "water carriage" systems. The former method, in its various forms of cesspool, midden, dry earth, and pail, having proved itself quite unsuitable for use in large centres of population, has now largely given place to the more effective "water carriage" system, with which the present article is mainly concerned. Another system, which may be described as the "pneumatic method," has been employed to a smaller extent. By this process the sewage is removed by compressed air as in the "ejector system" (see "Ejectors"), or by means of a partial vacuum created in small sized iron mains, as in the "Liernur" method (q. v.).

The "water carriage" method may be again subdivided under two heads—the "combined" system and the "separate" system. In the former, one set of sewers are provided for the conveyance of all sewage matter, slops, rain water from roofs, roads, yards, &c., whilst in towns drained upon the "separate" system duplicate sewers were laid, one for all foul matters and liquids, and another sewer, usually the larger of the two, for the removal of storm-water direct to the nearest natural outlet or watercourse. Very commonly, it will be found in the majority of towns that the older parts are drained upon the "combined" method, whilst the newer portions are provided with separate sewers for sewage and storm-water respectively.

In districts drained upon the separate system the amount of sewage reaching the outfall works will be much less in volume and more uniform both in quality and quantity than in cases where duplicate sewers are provided. It will be stronger and probably more difficult to treat, but much depends upon local conditions. Storm-water troubles at the outfall works will be greatly minimised, but care must be taken that the outlets, or storm-outfalls, are so placed as to avoid nuisance—bearing in mind that the character of the discharge therefrom naturally varies according to the town and locality from which it is drained. In the separate system the soil sewers do not receive the thorough flushing during storms as in the case of combined sewers, but they may be designed in smaller diameters involving a more rapid flow of the sewage during dry weather periods.

In many instances the practice has been followed of converting the old soil sewers into storm-water sewers, and laying in a new system for the receipt of the sewage proper. This may be done where the existing sewers are sufficiently sound, but in many cases leaky storm-water sewers lead to serious blockages.
and subsidences in the roadways, and the policy of continual patching then proves to be of doubtful economy.

The sewerage systems of old towns, or the older parts of a town, usually prove to be much more difficult problems to deal with than is the case with modern systems of drainage. This is especially the case in hilly districts, where often the sewers are laid at shallow depths, at steep gradients, and are subjected to serious wear and tear by the swell of storm-water. The exact courses, depths, and diameters of the sewers are often unknown, there being no reliable record available.

The Design of a System of Sewerage must depend largely upon local conditions and requirements, but there are certain general principles which are applicable to the majority of cases. The question of cost is a leading determining factor. A large item of initial capital outlay may be justifiable if it saves a considerable sum in annual working expenses. The interest and repayment charges on a gravitation scheme, for example, must be considered against the annual working expenses of a pumping scheme of less initial outlay. The former will in a great many cases be the most advantageous—but there are, of course, important exceptions.

In designing a system of sewers for any district some of the principal points to be considered are: the area of the district, its geographical contour, levels, and convenience of division into drainage watersheds, the nature of the subsoil in which the sewers are to be laid, the present and possible future population of the district, the water supply, and the amount of the average annual rainfall.

Other important factors include questions of the site of the outfall works, best course, and possible levels of the outfall sewer, the relative advantages of a wholly gravitation scheme as against part gravitation and part pumping, or as local conditions may determine, and the necessity, or otherwise, of any special works peculiar to the locality.

The population of a district generally equals from five to six times the number of the dwelling-houses, and the quantity of sewage may be reckoned at about 30 to 35 gallons per head per 24 hours, provided there is no infiltration or other water from extraneous sources gaining access to the sewers. The amount of the water supply may often be taken as a rough guide to the amount of sewage to be dealt with. The proper provision to be made in designing the sewage system for future growth of the district drained is not so easily arrived at, but comparisons of the census returns for several periods will give a good guide as to whether the population is increasing, stationary, or declining. (See “Population” and “Vital Statistics.”) The probable development of business areas, new factories, and works and of likely residential areas, must be carefully considered.

The contour and levels of the district must be fully gone into, as this forms an important factor in the selection of the system to be adopted. Where pumping has to be resorted to the gradients of the sewers are minimised as far as permissible in order to reduce the “lift” at the pumping-station. In flat districts the pneumatic or ejector systems might be found advisable.

The amount of rainfall to be admitted to the sewers is an important factor in determining the sizes to be adopted. One inch of rain in an hour should prove an ample allowance, as this amount only occurs in occasional severe storms. Any increased size beyond that necessary to convey this amount would decrease the efficiency of the sewers under ordinary conditions.

In settling the main lines of sewers the site of the proposed outfall works must be constantly kept in view. Such a site should, wherever possible, be situated at a level to which the sewage can flow by gravitation, and be near a river or watercourse into which the effluent may be passed.

Minimum and Maximum Velocities in Sewers.—To prevent deposit taking place a velocity of not less than 3 ft. per second should exist in 6 in. to 9 in. sewers; this may be
reduced to 2\(\frac{2}{3}\) ft. in 12 in. to 24 in. sewers, and to 2 ft. per second in larger diameters. These are the mean velocities: the minimum velocity occurs along the bottom of the channel, and may be taken at about 75% of the mean. A 4 in. drain should have a minimum velocity of 1 in 36, a 6 in. diameter 1 in 70, a 9 in. diameter 1 in 180, and a 12 in. about 1 in 250.

As a maximum velocity the flow should not exceed from 4\(\frac{1}{2}\) to 6 ft. per second for stoneware pipes. For a velocity of 4 ft. per second a 4 in. drain requires a gradient of 1 in 20, a 6 in. diameter 1 in 39, and a 9 in. drain 1 in 75.

General Principles affecting the Design of Sewers.—Sewers should be laid true in line and invert from point to point with access manholes every 500 ft. It is convenient to have intermediate lampholes to facilitate inspection by passing down a light. In setting out the lines and levels every effort should be made to avoid pumping stations or "lifts" of any description, as a purely gravitation scheme will generally be the most economical in the long run. Manholes are also necessary at all changes of gradient or direction, and at all junctions of branch sewers, storm overflows, or other special points. Where a sewer unavoidably passes under a railway, stream, building or other structure there should be a manhole on each side of the crossing point, except where the sewer is large enough for a man to walk through.

Gradients of sewers should be carefully proportioned according to their varying diameters, doing the best possible with the fall available. Excessive fall should be avoided, or damage to the sewers will result. "Drop-pipes" or "ramps" at the manholes and tumbling-bays are employed to consume excessive fall where such exists.

The depth at which sewers should be laid depends upon the description of property to be drained, its distance from the roadway on which it abuts, and the depths of the basements, if any.

Sewers should not be deeper than necessary, not only on account of the increased cost, but also having regard to the greater pressure or weight of earth upon the pipes, and the increased expense of connecting house drains.

Where streets are sewered upon the "separate system," it is customary to lay soil-sewers and storm-water drains side by side in the same trench—the storm-water drain being generally at a higher level. It is important in most soils that the lower or bottom part of the sewer trench should be filled with concrete, or the earth filling stiffened up with lime mixed therewith in the course of the filling. The pipes should be supported with concrete below the centre line, as it is difficult to secure earth filling being put in so as to give adequate support to the lower half of the pipe. Should there be any weakness at this point the weight of superincumbent earth has to be carried by the pipe itself, which, if of stoneware, may very probably be crushed under the load when the newly filled trench settles down upon it. Modern heavy traction-engine traffic may give rise to sudden movement in a sewer trench and cause the pipes to move out of line and give way under the excessive load. As a rule, in most soils, when stoneware pipes are laid deeper than 10 ft. they should be surrounded with concrete, to give increased strength against crushing by superincumbent loads. If possible, junctions for house connections should be provided when the sewer is laid, if the positions can be determined, so as to avoid subsequent disturbance of the sewer.

Branch or tributary sewers should connect with the main sewers at manholes, and the junction should not be at right angles, but at an inclination or sweep leading in the direction of the main flow. Where bends occur extra fall should be given to the pipes to compensate for friction, and the inverts of tributary sewers should have a fall or drop into the main.

When pipes are being laid careful supervision is necessary to see that the inverts of the pipes are true and even, and that the
cement jointing does not protrude inside the pipes. This should be cleared out as the laying proceeds.

Flushing tanks are necessary at the upper ends of sewers having flat gradients. Such tanks are best fitted with automatic flushing apparatus regulated to discharge at fixed intervals.

Manholes on soil and storm-water sewers are commonly built to accommodate and give facilities of inspection to both sewers in order to save the expense of constructing two separate manholes. In the case of combined manholes, provision should be made to prevent sewer gases ventilating through the storm-water drains.

Road gullies, whether entering soil or storm-water drains, should always be trapped at their outlets. They are constructed of brickwork internally rendered in cement, or of stoneware or iron. The intervals between periods of cleansing such gullies depends upon the gradients of the roadways and the amount of rainfall occurring. Large quantities of sand are washed into the gullies in hilly districts, and frequent emptying is necessary.

Execution and Supervision of Sewerage Works.—Upon works of any considerable extent it will be necessary to engage a resident engineer, or representative deputed from the municipal engineer’s staff, to supervise the details of the work regularly as they proceed. He should be provided with a small temporary office at the site of the works, and it will be his duty to, from time to time, set out the works ahead of the contractor’s workmen, to define the centre line of the courses of the proposed sewers by means of iron or wood pegs, and also to give the contractor the correct levels to which he is to work. All levels should be verified by comparison with the nearest ordnance survey bench mark, and all sight rails and sewer inverts or other levels in the work should be referable to ordnance datum. Should there be any deviation from the original plans, either in regard to level or line of work, these must be carefully recorded on the plans by the resident engineer in charge. He should also keep a note-book to record the dates of progress of the work, to insert measurements to any special junctions, crossings of other pipes or work, and generally any matters likely to be of interest and utility after the work has been covered in. It will be the resident engineer’s duty to examine all classes of material brought upon the works, to condemn it, and order its removal from the works when found inferior in quality, or to report to the chief engineer. He must also carefully examine all pipe joints, test the sewers before allowing them to be covered in, and generally, on behalf of the engineer, to keep a close eye on the execution of every detail of the entire contract.

Materials for Sewerage Works.—As all works of sewerage are of a subterranean character, subjected to considerable pressure and wear and tear from the flowing sewage, it is important that all classes of materials used should be of the best obtainable.

Bricks.—Brickwork in sewers, manholes, penstock chambers, and other sewage work should be built of the hardest and most impervious bricks obtainable, and be laid in cement mortar. The “backings” may be of good hard stock bricks, as wire cuts, &c., but the “facings” should be of best blue Staffordshire bricks. The walls of settling-tanks should also be faced with Staffordshire blue bricks.

Concrete is largely used for foundations, bedding, and the backing of brickwork; also for forming the sewer itself in the case of the larger diameters, when it is laid in situ around centres. Such concrete should be of the cleanest of materials, and be mixed under experienced supervision and care. There does not appear to be any serious deleterious action by the sewage upon the concrete. Concrete is greatly used also for settling-tanks and filter beds. When in large areas it is very liable to crack; such defects have to be chased out, grouted up, and pointed in cement.
Concrete-Tube Sewers are now largely employed both for sewage and storm-water purposes, but more especially the latter. The tubes are made of all diameters, from 12 in. upwards, and will be found less costly than stoneware pipe sewers (12 in. to 24 in. diameter), and much cheaper also than brick sewers of larger diameters.

The tubes are made of concrete, consisting of crushed granite and cement, and may be obtained either “armoured” or unarmoured. Provided the concrete is of high class and of a sufficient thickness, it is doubtful if, in the long run, there is any great practical advantage in using “armoured” concrete tubes. There has, as yet, been no very lengthy experience sufficient to prove that the metal placed in the concrete will not in time become more or less oxidised, and so split or weaken the concrete. The latter, it has to be remembered, is practically always wet, and the prevention of such oxidation must depend largely upon the quality of the concrete.

Pipe Sewers are constructed of stoneware earthenware, or fireclay pipes; also of cast-iron pipes in special circumstances. Earthenware and fireclay pipes should never be used for public sewerage work, as the material is weak, porous, and unreliable. Fireclay pipes, purporting to be stoneware, have been placed on the market, but the broken section will appear porous and prove absorbent.

Stoneware pipes are very generally used for the great majority of sewerage and drainage work. The materials from which they are manufactured varies in different localities, but the more refractory clays are employed, and the pipes are thoroughly vitrified. A broken section should appear dense in grain, have a metallic ring, and be non-absorbent. The latter quality may be tested by observing the effect of an ink-line drawn on a fractured section with an ordinary pen; if the ink spreads and rapidly sinks in, the material will be of a porous character. The pipes should be even in thickness, true in bore, and be well “salt-glazed” so as to secure a lining approaching natural glass as near as possible. Soft lead glazes are quite unsuitable. When examining a consignment of stoneware pipes every pipe should be gently tapped with a hammer, and if a clear metallic ring is not produced the pipe will almost certainly contain a crack (though sometimes very difficult to find), and should be rejected.

For drainage and public sewerage work the sizes of stoneware pipes used are generally of 6 in., 9 in., 12 in., 15 in., and 18 in. diameters. Larger diameters than 18 in. are not advisable for stoneware pipes. Beyond this size concrete tubes and brick sewers should be used. The thickness of material in stoneware pipes is commonly as follows:

<table>
<thead>
<tr>
<th>Diameter (in.)</th>
<th>Thickness (in.)</th>
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<tbody>
<tr>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>1 1/4</td>
</tr>
<tr>
<td>15</td>
<td>1 1/2</td>
</tr>
<tr>
<td>18</td>
<td>1 5/8</td>
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</tbody>
</table>

What is known as “tested” stoneware pipes are largely used for public sewerage work. These pipes are specially selected and tested under a considerable head of water, and afterwards stamped with the word “tested” before leaving the maker’s works. They cost from 15% to 25% more than the ordinary pipes.

The “specials” in stoneware pipe goods consist of bends, junctions, saddles, channel pipes, and such like. Bends should not be used in a line of sewer, but all changes of direction of line should be made in the manholes, so that the sewers may be thoroughly accessible. Taper pipes should be used for joining sewers of different diameters and junction pipes for connecting up branch drains. Saddle pieces are used where a drain has to be connected to the main sewer after it has been laid, but the “tapping” weakens the sewer, especially if done upon sewers less than 12 in. diameter. Junction-pipes should be inserted wherever possible.

Joints in Stoneware Sewers.—There are many patented forms of joint aiming at better alignment of the pipes and perfect water-tightness. The many forms now available may be observed from the manufacturers’ catalogues and price-lists. The cost of the
pipes is invariably greater than that of the ordinary spigot and socket type, and it is
doubtful, except possibly under some special
circumstances, if any corresponding advantage
is obtained by their use. For the great
majority of sewerage work the ordinary spigot
and socket joint made with cement, with the
inverts carefully levelled and the insides of
the pipes wiped out at each joint as the work
proceeds, will be found to produce a sound
job.

Concrete and Stoneware Pipes.—Where
the foundation is bad, concrete should be laid
to give a sound bed for the pipes. The con-
crete should be shaped to fit the body of the
pipe and depressions formed to receive the
sockets. The lower half of the pipes should
be well supported by the concrete, and, if laid
in a deep trench, a thickness of 4 in. or 6 in.
should be carried over the top of the pipes to
relieve the pressure. It should be remem-
bered, however, that by so doing the sewers
are rendered less accessible for purposes of
connecting drains thereto.

Cast-Iron Pipes.—Cast-iron pipes are ne-
cessary in certain cases, such as where sew-
ers are laid at shallow depths, at stream or
railway crossings, or through bad ground. The
pipes used are of the usual water-main
strength, viz.:

<table>
<thead>
<tr>
<th>Diameter (in.)</th>
<th>Thickness of Metal (in.)</th>
<th>Weighing 1 cwt. per pipe</th>
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<tbody>
<tr>
<td>8&quot;</td>
<td>3/8</td>
<td>11</td>
</tr>
<tr>
<td>4&quot;</td>
<td>1/8</td>
<td>21</td>
</tr>
<tr>
<td>6&quot;</td>
<td>3/4</td>
<td>4</td>
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<tr>
<td>9&quot;</td>
<td>1/2</td>
<td>8</td>
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<tr>
<td>12&quot;</td>
<td>3/4</td>
<td>11</td>
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<tr>
<td>15&quot;</td>
<td>3/4</td>
<td>14</td>
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All pipes should be tested under a hydraulic
pressure of 600 ft. head of water, and when
under test rapped sharply with a hammer.

Cast-iron pipes should be manufactured
from the best tough grey metal from the
second melting, and the castings should be
free from honeycomb, spongy places, air and
sand holes, and other imperfections.

Before the pipes become rusted on the sur-
face they should be treated whilst hot with
the Angus Smith solution, consisting of a
mixture of coal-tar, pitch, and a small quantity
of linseed oil heated to a temperature of
400° F.

The jointing of cast-iron pipes is usually
done with molten lead, well caulked into the
joint. "Lead wool" has also been used, and
sometimes a "rust cement" joint consisting
of sal-ammoniac, sulphur, and iron-filings or
turnings mixed to a paste with water.

Reinforced Concrete Sewers Laid in
Situ.—Where large concrete sewers are to be
constructed, such as diameters of 4 ft. and
over, it will generally be found more
economical to build them in situ on temporary
centering rather than transmit large diameter
pipes great distances, as the handling of such
is difficult and costly. Local materials for the
concrete aggregate can often be used, but it is
important that these should be perfectly
clean, hard, and durable. A soft aggregate
will result in a porous, weak concrete, and a
leaky job.

The reinforcements used consist, generally
speaking, of a permanent sheet centering,
rolled sections or rods in one or other of the
various forms available, or of a meshwork of
some description. Expanded metal is also
used.

The "Bonna" system of armoured concrete
tubes, or conduits, has been used in France
for over 12 years past, both for sewage and
water carriage, and has given satisfaction.
The system has also more recently been intro-
duced into this country. An 18 in. armoured
cement rising main, 1 mile in length, has
been laid in connection with the Swansea
Corporation Waterworks.

The Laying of Pipe Sewers.—The trenches
are excavated to the necessary widths and
depths, and a shaped or curved bed formed
upon which to lay the sewer-pipes, care being
taken that they are evenly bedded throughout
their length, and not allowed to rest upon the
sockets only. The pipes should be truly laid,
both as regards line and level, invert to invert
in as true a manner as possible. The proper
gradient of the invert is secured by setting up
"sight rails" at convenient intervals (Fig. 1).
The ordinance level of the sewer invert throughout its length being ascertained from the plans, the sight rails are set up at a convenient height of, say, 10 or 12 ft. above the invert, according to the depth of the sewer, and all intermediate points in the invert of the pipe line are sighted in by the aid of "boning rods" over the tops of adjacent sight rails.

The jointing of stoneware pipe sewers is usually done in cement or cement and sand (1 to 1), a piece of gasket or twisted yarn being first coiled round the spigot end to prevent the cement protruding inside the pipes. After the joint has been completed, the inside of the pipes should be wiped out and left perfectly clear.

The filling in of the trenches should be carefully done, and, in order not to disturb the pipes, the finer portions of the excavated material should be packed carefully around the pipes, and over their tops, to the depth of 1 ft. or more and carefully rammed, and the trenches then filled in, in layers of 6 in. to 9 in. thickness, with adequate ramming and watering, if necessary, so that the whole trench may become thoroughly consolidated. The pipes are greatly supported and strengthened by packing fine concrete along the sides, so as to support the lower half of the circumference; but this, of course, considerably adds to the cost.

The jointing of concrete tube is simple. The rebate joints are covered with a thin layer of Portland cement and the pipe forced home. The joint is then pointed up inside and out, and left neat and clean.

Barreled or egg-shaped in cross-section. The circular form is the strongest, simplest, and most economical form, and well adapted to fairly large and continuous flows; but where the volume of sewage is variable, the egg-shaped sewer has advantages, owing to the comparatively small wetted perimeter in the case of small flows. The standard egg-shaped section is shown in Fig. 2, and a new form of this type is given in Fig. 3.

The thickness of brickwork in sewers should not be less than 9 in., and may be determined by the formula

$$\frac{d}{100} = \text{thickness in feet},$$

where $d =$ depth of excavation in feet, and $r =$ external radius in feet.

![Diagram of Section of Trench for Sewer and Storm-water Drain, showing Concrete Support to Pipes, etc.](image)

The inside ring of brickwork should be of the hardest, non-porous, well-burnt bricks, and blue Staffordshire bricks for the invert as shown in Fig. 4 are preferable to the use of hollow invert blocks.

Invert blocks with hollow spaces or chambers as illustrated in Fig. 5 are not recommended, especially where the work is to be executed in tunnel. Unless the chambers are carefully filled up solid with concrete, the sewage leaks into these passages and in time undermines the sewer. Care must also be taken that the cement used in such filling be well
“cooled” by spreading on a floor of a dry shed for a week before being used, otherwise the invert blocks may be burst by the expansion of the concrete in setting, thus producing a leaky sewer invert. Blocks having a rebated, or spigot and socket joint, instead of a plain butt joint are best. Solid blue Staffordshire invert blocks are also advantageously used in egg-shaped sewers. For circular sewers, an invert of the best blue Staffordshire bricks as shown in Fig. 6 makes the best job, and is more conveniently built, especially in tunnel.

Clydebank intercepting sewers at Glasgow were constructed of the ordinary circular section (Fig. 7) varying from 3½ ft. to 8 ft. in diameter. The illustration shows a 6 ft. diameter sewer of 14 in. brickwork with Portland cement concrete foundation and backing.

A sewer of the “new egg-shape” form is shown in Fig. 4, as used in the main sewers at Southampton. The invert is of blue Staffordshire blocks, and the sides adjoining same are of six courses of blue Staffordshire bricks. The whole of the brickwork is built in Portland cement mortar.

The section shown in Fig. 5 is often adopted in waterlogged ground. The subsoil drain is necessary for the removal of ground water whilst the work is being constructed.

Fig. 8 is a section of a branch sewer as adopted in Paris. It is of the egg-shaped form, provision being also made for a flat benching or path along which sewer-men can
walk, whilst the narrow channel below is suitable for small flows.

A section of the main sewer, Rue de Rivoli, Paris, is shown in Fig. 9. A narrow channel for small flows is provided between two walks, and the sewer above is of very ample section. They are also utilised as subways for the underground telegraph and telephone wires, as well as for water-mains, hydraulic and pneumatic-power pipes placed on brackets at the sides in the upper part of the sewer.

The new Clichy collecting and outfall sewer is shown in the section, Fig. 10. Like many of the Paris sewers, it is built of rubble masonry with an inside lining of Portland cement, and an outside layer of cement concrete on the upper part of the exterior. The usual side walks are also provided for inspection and clearance of deposits, &c. A part of this large sewer under the Boulevard National was constructed in tunnel by the use of the shield. The cover was only from 10 ft. down to 2 ft. 4 in. The sewer has a fall of 1 in 2,000, or about 2.67 ft. per mile.

The northern outfall sewer for conveying the London sewage, on the north side of the Thames, from the Abbey Mills Pumping Station to the Metropolitan Outfall Works at Barking is shown in Fig. 11. It consists of three 9 ft. by 9 ft. culverts side by side, laid with a fall of 2 ft. per mile on a bed of concrete. For a distance of about 1.5 mile in the neighbourhood of Barking the structure is carried on brick arches supported on concrete piers, passing down through the peat to the gravel. The culverts are encased in an embankment of earth raised above the low-lying marshes, over which they cross and carry a roadway on the top.

Sewer Accessories and Details.—Manholes should be provided on sewers at all changes of line or gradient, and, in any case, not less frequently than 100 yards apart. They should be built of 9 in. brickwork set...
in cement, and may be rectangular or circular in plan. A good method when adopting the rectangular plan is to give the walls a slight curve concave on the inside, which gives additional strength and also increases the working space within the chamber. Cast or wrought iron foot-irons are built into the walls to facilitate access to the chamber. The invert of the manhole is usually formed in concrete with strong glazed channel pipes. A combined sewer and storm-water manhole is shown in Fig. 12. Where a number of branch sewers at various angles unite at one chamber, manholes of special design to suit the case become necessary. The roofing in of the manhole chamber is also occasionally a matter of some difficulty, especially where the sewer is shallow, and the headroom necessary for the usual manhole arch is not available. A flat or shallow construction, such as obtained by girders and armoured concrete, becomes necessary in order to give adequate room within the manhole, and at the same time sufficient strength to carry the street traffic.

Lampholes are sometimes provided midway between the manholes placed at 100 yard intervals on a pipe-sewer. They are useful for lowering a light to facilitate inspection, but are not often of much service on brick-sewers, these being generally large enough for a man to pass through.

Flushing Chambers and Apparatus. Flushing is frequently necessary in sewerage systems owing to flatness of gradient or limited use of the sewers. Sewers laid on new estates are sometimes not called upon for many years to convey sufficient sewage to keep them thoroughly clean, and frequent flushing
is needed. This is accomplished in various ways: (a) by hose discharging down the manhole; (b) by lowering a penstock in the manholes and thus heading up the sewage flow and flush water to a certain height, and then suddenly discharging the same in order to give the sewer a thorough scour; (c) by providing special flushing chambers at the head of all sewers having flat gradients and fitting the chambers with flushing penstocks, or, better still, with automatic flushing siphons, which can be regulated to discharge at stated intervals according to requirements. Such a flushing chamber is shown in Fig. 13. The requisite capacity of these tanks depends a good deal upon the circumstances of the case, but about 400 gallons will be advisable for 9 in. sewers, 500 to 600 gallons for 12 in. sewers, 700 to 800 gallons for 15 in., and about 1,000 gallons for 18 in. In large intercepting or collecting sewers there is usually a sufficient depth of flow to keep them clear of deposit. Underground flush tanks are constructed of brickwork, backed with concrete or clay puddle according to circumstances, the inside faces of the brickwork being rendered in Portland cement so as to insure a thoroughly water-tight job. Bituminous sheeting, such as Callender’s and others, will also be found a useful means of securing water-tightness.

There are a number of automatic siphons on the market suitable for use in underground flush tanks as above. In some types, the water as it accumulates gradually displaces the air in the siphon, whilst in others the air is confined and compressed by the accumulating water until it blows off, and thus induces siphonic action.

For small flushes not exceeding 100 gallons, metal tipping buckets are occasionally used for flushing in sewer manholes, but are not so satisfactory as the automatic flush siphon above referred to. The tipping buckets are pivoted on bearings fixed in the brickwork of the manhole, and are so arranged that when the water supply has dripped into the buckets to a certain height the centre of gravity is upset, and the contents of the tipper are projected forward down a sloping benching into the sewer. When empty, the bucket or tipper reinstates itself and the refilling proceeds as before.

Sewer Ironwork.—In connection with all sewerage work a considerable amount of ironwork of various kinds is employed, such as in penstocks, valves, sluices, tide and flap or back-flow valves, valve and penstock gearing, step-irons, landings, manhole covers, and so on.

Tank or Storage Sewers become necessary where a free and continuous outlet for the sewage flow cannot be provided, as in the case of a sea outfall or low-lying district, from which the sewage must be pumped. In the case of sea outfalls the sewage cannot usually be discharged at high-tide, nor is it desirable to do so at low-tide when the sewage would probably have to run over a portion of the foreshore and cause a nuisance. It is more commonly necessary to discharge only when the tide is at the ebb, and provision must be made for the accommodation of the sewage accumulating at the outfall until it can be discharged. The size of storage required depends, of course, upon the quantity of sewage and storm water to be dealt with, but, as the ebb occurs twice in the 24 hours, very large tanks will not usually be necessary, unless the volume of liquid is excessive, or other local necessities obtain. Fig. 14 shows a chamber on the junction of a 4 ft. 6 in. by 3 ft. egg-shaped outfall sewer with a tank or reservoir sewer 7 ft. 6 in. in height suitable for a sea outfall.
The tank is of the nature of a widening out or enlargement of the outfall sewer and a valve is provided to prevent a back-flow of sewage and sewer air from the tank into the town outfall sewer.

**Inverted Siphons** are necessary where the line of sewer must cross some obstruction, such as a stream, railway, or subway occurring at such a level as to prevent the sewer following the proper hydraulic gradient. Such siphons are to be avoided, but when necessary should be made as accessible as possible. In the case of a stream or canal the pipes of wrought iron or of boiler plate are commonly laid, from a line of barges arranged across the stream, in a trench dredged in the bed of the stream and afterwards covered over with gravel, &c. Such pipe lines should be laid in duplicate, and communicate on each side of the stream with a roomy penstock chamber to give facility for frequent clearing of the siphons, which is invariably necessary. At the upper chamber a storm overflow should be provided so as to relieve the siphon of excessive pressure at storm times. When sewers necessarily cross canals, railways, and bridges, arrangements must be made, well in advance, with the various authorities owning such works, and their requirements as to terms, conditions, and details of construction at such crossings must invariably be complied with. The work must be done in the most permanent and stable manner, especially in the case of railway crossings.

**Tumbling Bays, Ramps, Drop Pipes.**—These are different methods of overcoming excessive fall in lines of sewers in hilly districts. Tumbling bays are objectionable on account of the direct fall breaking up the sewage and tending to cause nuisance by the discharge of sewage gas. A better method of connecting between a high-level and low-level sewer is by means of a "ramp" constructed in connection with a manhole as shown in Fig. 15. The ramp or "drop pipe" should have a wide mouthed junction, and preferably be of cast-iron.

**Storm or Relief Overflows.**—Provision for relief of internal pressure in sewers in times of heavy rain is very essential, especially in hilly districts, and also in cases where the sewers carry both sewage and storm water. The most favourable position to make such provision is at a point on the system where several sewers
from the higher districts converge. The overflow usually consists of a pipe or brick weir placed at a certain height above the sewer invert, in order that, when a dilution of, say, six times the ordinary flow has been reached, the surplus water passes out or over the storm weir direct to the nearest watercourse. The adjustment of storm overflows in a manner so as to insure a uniform degree of dilution or of strength of sewage water passing over is a matter of some considerable difficulty, seeing that the strength of the dry weather sewage itself is very variable throughout the 24 hours, e.g., the character of the liquid passing over a fixed weir in the middle of the night when the sewage proper is weak would be very different from that escaping over such weir at say 10 to 11 a.m., when the ordinary sewage flow is at its maximum volume and strength.


W. H. M.

Shallow Wells. (See “Wells.”)

Shone’s Ejectors. (See “Ejectors.”)

Shone’s System of Ventilation. (See “Ventilation of Sewers.”)

Sight Rails.—Sight rails are used for the purpose of obtaining true gradients for sewers, drains, &c. Uprights are fixed at the sides of the trench at convenient points and the “sight rails” nailed thereto, with their upper edges (which must be level and perfectly true) at a fixed height above the invert of the work. For convenience in sighting they are often painted in alternate bands of black and white. At least three sight rails should always be in place in each length of the work, so that any displacement of either of them may be at once detected.

The levels of the work are obtained from the sight rails by means of “boning-rods”—each consisting of two pieces of light scantling nailed together in the form of a T, the length of the longer piece being equal to the depth from the top of the sight rail to the bottom of the work. In use a boning-rod is held upright in the trench, and raised or lowered until the top of the cross-piece on it is in exact alignment with the tops of the rails. The bottom of the rod then gives the required level for the work. In laying pipe-sewers two rods will be required—one for the bottom of the trench, and the other for the pipes. The latter should have a short L-shaped foot to rest on the invert of the pipe, and the pipe is raised or lowered until the top of the rod is in correct alignment. (See Fig. 1 under article on “Sewerage.”)

A. J. M.

Sinks.—The classes of sinks in general use, of each of which one or more may have to be provided in large houses, are:

Scullery Sinks, Pantry Sinks, Nursery Sinks, Drip or draw-off Sinks, Larder or Dairy Sinks, Vegetable Sinks, Pickling Troughs, Wash-tubs and Housemaids’ Sinks.

These should all be chosen in accordance with the uses to which they are to be put.

Scullery Sinks must be governed in dimensions by the size of the premises in which they are fixed and the amount of washing-up to be done. They are best made of glazed stoneware—white or cane—and should have a plug and overflow so that they may be filled with water. In large premises they are best provided in pairs—one for the washing of plates, and the other for rinsing them.

PANTRY SINKS, in which glass and silver are washed, may be constructed of lead-lined wood, as this material is less liable to cause damage than fireclay or stoneware. They