sewer of any size may be determined in feet by the formula *dr/*100, where *d =* depth of excavation in feet and *r =* external radius in feet.

An egg-shaped sewer, made with two thicknesses of brick, an invert block, and a concrete setting, is illustrated in fig. 27∙ Concrete is largely used in the construction of sewers, either in combination with brickwork or alone. For this purpose the con­crete consists of from 5 to 7 parts of sand and gravel or broken stone to **I** of Portland cement. It may be used as a cradle for or as a backing to a brick ring, or as the sole material of construc­tion by running it into position round a mould which is removed when the concrete is sufficiently set, the inner surface of the sewer being in this case coated with a thin layer of cement. A development in the construction of concrete sewers, whether laid in sectional pipes or constructed and moulded *in situ,* is the use of iron or steel bars and wires embedded in the material as a rein­forcement. Such conduits can be constructed of any size and designed to withstand high pressures. Fig. 28 is a section of a concrete sewer having a diameter of more than 9 ft. constructed with round rod reinforcement. With regard to the method for calculating the proportions, generally speaking the thickness of the concrete shell should in no place be less than one-twelfth of the greatest in- ternal diameter of the tube, while the steel reinforcement should be designed to resist the whole of the tensile stress. Where the safe tensile stress in the steel is 8 tons per sq. in. P = the pres- sure in pounds per sq. in., and *r=* the internal radius in inches; the weight **of** the reinforcement per sq. ft = *Pr*∕450,

while its area at each side of the pipe per longitudinal foot, when *f* = safe tensile stress in the reinforcement in pounds, is 12 *Pr*∕*f*.

In determining the dimensions of sewers, the amount of sewage proper may be taken as equal to the water supply (generally about 30 gallons per head per diem), and to this must be added (when the “ combined ” system is adopted) an allowance for the surface water due to rainfall. The latter, which is generally by far the larger constituent, is to be estimated from the maximum rate of rainfall for the district and from the area and character of the surface. In the sewerage of Berlin, for example, the maximum rainfall allowed for is ⅞ of an inch per hour, of which one-third is supposed to enter the sewers. In any estimate of the size of sewers based on rainfall account must of course be taken of the relief provided by storm-overflows, and also of the capacity of the sewers to become simply charged with water during the short time to which very heavy showers are invariably limited. Rainfall at the rate of 5 or 6 in. per hour has been known to occur for a few minutes, but it is unnecessary to provide (even above storm-overflows) sewers capable of discharging any such amount as this; the time taken by sewers of more moderate size to fill would of itself prevent the discharge from them from reaching a condition of steady flow; and, apart from this, the risk of damage by such an exceptional fall would not warrant so great an initial expenditure. Engineers differ widely in their estimates of the allowance to be made for the discharge of surface water, and no rule can be laid down which would be of general

application.

In order that sewers should be self-cleansing, the mean velocity of flow should be not less than 2½ ft. per second. The gradient

necessary to secure this is calculated on principles which are stated in the article Hydraulics (*q.v.*). The velocity of flow, V, is V= *c*√*im,*

where *i* is the inclination, or ratio of vertical to horizontal distance; *m* is the “ hydraulic mean depth,” or the ratio of area of section of the stream to the wetted perimeter; and *c* is a coefficient depending on the dimensions and the roughness of the channel and the depth of the stream. A table of values of *c* will be found in § 98 of the article referred to. This velocity multiplied by the area of the stream gives the rate of discharge. Tables to facilitate the determination of velocity and discharge in sewers of various dimensions, forms and gradients will be found in Latham’s and other practical treatises.

Where the contour of the ground does not admit of a sufficient gradient from the gathering ground to the place of destination, the sewage must be pumped to a higher level at one or more

points in its course. To minimize this necessity, and also for other reasons, it is frequently desirable not to gather sewage from the whole area into a single main, but to collect the sewage of higher portions of the town by a separate high- level or interception sewer.

It is undoubtedly necessary to construct overflows for storm water in connexion with combined systems of sewerage. No com­bined sewer of such size as will make it comparatively self-cleansing under normal conditions can hope to carry off the volume of water resulting from heavy rain. It might be thought that the overflow resulting from a storm would consist of nearly pure rain-water, but this is not the case, as the pressure of storm water has the effect of scouring out from the sewers a great deal of foul matter that is deposited when the flow is small. This being the case it is obviously bad policy to take the overflow into a stream, which would thereby suffer con- tamination. A better plan is to direct the discharge into a dry ditch or channel where the liquid may soak into the soil and the solid particles by contact with the air may quickly become oxidized. In agricultural districts it might be possible by arrangement with farmers to run the overflow over grass-land, as it has good manurial properties.

Occasionally when a sewer has to cross a stream or other ob­struction it is found impossible to bridge or carry the pipe across and preserve its proper gradient. In such cases it must he carried under the obstruction by means of an inverted siphon. The exact form that should be given to inverted siphons is disputed, but it is generally agreed that they are ex­pedients to be avoided wherever possible. The majority take roughly the form of the stream section, that is, they have two sloping pieces corresponding with the banks with a flat cross-piece under the bed of the stream. The pipes are invariably of iron and should be laid in duplicate, as they are liable to silt up in the flat length. For this reason it is usual in constructing a siphon to place permanent chains in the pipes, and these are periodically pulled backward and for­ward to stir up the silt. Brushes may also be attached to the chains and pulled through from end to end. At either end of the siphon pipes there are manholes into which the pipes are built. Penstock valves also should be provided at each end so that sewage can be shut out of one or both of the siphons as desired for clearing purposes.

Tumbling bays being prohibited, the usual method of leading a high-level sewer into a low-level sewer is by means of a ramp. This is constructed in connexion with a manhole into which the end of the high-level sewer is taken and finished usually with a flap valve. Some distance back along this sewer a wide-throated junction is put in the invert of the sewer, and from this junction a ramp-pipe is taken down to the invert of the low-level sewer, so that the sewage in the upper sewer instead of having a direct fall runs down the slope of the ramp. The ramp-pipe is usually con­structed of iron and is of smaller section than the high-level sewer because of the greater fall and pressure.

In the low-lying parts of towns storage tanks are often constructed to receive the sewage of such districts. They are periodically emptied of their contents, which are pumped up into the main sewers through which the sewage travels to the outfall. This storing of sewage should be avoided whenever possible. It is much better to provide for raising it as it is produced either by an installation of one or more automatic lifts, such as Adams’s sewage lifts, or, where a large amount of material is to be dealt with, necessitating continual pumping, by a Shone ejector worked by compressed air.

Sewer gas is a term applied to the air, fouled by mixture with gases which are formed by the decomposition of sewage, and by the organic germs which it carries in suspension, that fills the sewer in the variable space above the liquid stream.

It is universally recognized that sewer gas is a medium for the conveyance of disease, and in all well-designed systems of sewerage stringent precautions are taken to keep it out of houses. It is equally certain that the dangerous character of sewer gas is reduced, if not entirely removed, by free admixture with the oxygen of fresh air. Sewers should be liberally ventilated, not