Mr. HOMERSHAM was of opinion, that a loss of evaporative power almost always followed any attempt to introduce air above the fire. In a locomotive boiler, the comparatively restricted surface was required to do as much work as the more extended surface of stationary boilers; therefore it was necessary to adopt the blast pipe, for creating the draught in the chimney; in any attempt further to reduce the dimensions and weight of marine boilers, it would probably be necessary to have recourse to the blast pipe in the chimney, if any attempt was to be made to rival the powers of the locomotive boiler, as it was by the volume of air drawn through the fuel in the fire box, by the action of the blast pipe, that the extraordinary work of the locomotive boiler was due. Stationary boilers were clothed to prevent radiation, but the locomotive attained nearly the same end, by presenting such a restricted radiating surface. The whole question was extremely interesting to practical men, and with such ample means at the command of members, it was to be hoped some accounts of results actually obtained would be laid before the meetings every session.

March 30, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

No. 869. "An Account of the Drainage of the Town of Richmond, Surrey, under the authority of the Metropolitan Commissioners of Sewers, in 1851." By GEORGE DONALDSON, Assoc. Inst. C.E.¹

IN consequence of applications made by the inhabitants of Richmond to the Metropolitan Commissioners of Sewers as to the insufficient drainage of the town, the Author was instructed to examine into, and report upon it. The works consequent upon his report, which was presented to the Commissioners in August 1849, form the basis of this Paper.

Richmond is very favourably circumstanced for drainage, being situated on elevated ground, mostly of a light, or gravelly character, and therefore, naturally dry and salubrious, but owing to the general and long-continued custom of draining the houses into cesspools, the ground had become so saturated with the filtration from them, as

¹ The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

not only to affect the purity of water in the wells, but even sometimes to occasion offensive exhalations from the surface.

In September 1849, the Author received orders from the Commissioners "to prepare a plan for the drainage of the town by means of tubular stoneware pipe sewers." Here a question came under consideration, as to the admission of surface and storm waters into pipe sewers; and seeing, that to make them capable of accommodating all the storm waters was quite impracticable, and knowing their liability to be choked up with the road drift, the Author decided to dispose of the surface waters by other channels. So the pipe sewers were designed, and their several sizes calculated for house drainage only. Finding, however, that there were in most of the streets, brick drains, which had, from time to time, been constructed for draining the roadways, they were retained for carrying away the surface and storm waters into the Thames.

This is probably the largest area on which the separate system has yet been carried into effect, in connexion with the Metropolis, and it involves a principle of some importance, in relation to town drainage, upon which different opinions are held by high authorities. The chief points in the arguments on either side are to the effect, that the combined system¹ is more favourable to economy in works of drainage, while on the other hand, the separate system facilitates the conversion of the sewage into manure, and its application to the purposes of agriculture, from its being more constant in quantity and less diluted, at times, by storm water.

In designing the sizes of the several sewers, consideration was given to the greatest number of houses likely ever to be erected, in addition to those already in existence upon the area to be drained, which comprised about 320 acres. An average was assumed of five persons to each house, and a water supply of 5 cubic feet of water per diem, to each individual; and it was calculated, that about half of the entire quantity of water used, would be discharged into the sewers, between the hours of 7 and 12 (A.M.) each day.

The natural declivity of the ground gave to the new sewers generally, a good fall; for instance, the sewer in Hill street and George street, composed of pipes of 9, 12½, 16, 18, and 20 inches diameter,—altogether 3,608 feet in length,—has a fall of 83½ feet. That in the Vineyard, with pipes of 10 and 12½ inches diameter, 2,007 feet in length, has 55½ feet of fall; that in Dunstable-shot, with pipes of 12½, 14, and 18 inches diameter, 2,829 feet long, has 20 feet of

¹ By combined system is here meant the combination of house drainage, with that for surface and storm waters.

fall; that in Park road, with 1,950 feet of pipes of 9 and 12½ inches diameter, has 45 feet of fall; and that in the Queen's road, 4,456 feet in length, with pipes of 10, 12½, 14, and 15 inches diameter, has a fall of 95 feet. The lowest gradient was 1 in 231, the greater number ranging between 1 in 120 and 1 in 44; and care was taken to avoid sudden changes in the gradients and to make that of each sewer as uniform as possible. The general depths of the sewers were such as to admit of a gradient of at least 1 in 60, in all the house drains.

The plans, when completed, comprised 52,876 feet of pipe sewers, varying in size from 9 inches to 20 inches in diameter, and 13,460 feet of brick sewers, part of which were to be 3 feet 9 inches by 2 feet 6 inches, and part 4 feet by 2 feet 9 inches, constituting, in fact, the main and outfall sewers for which pipes were considered inadequate.

In April 1850, the plans were, by order of the Commissioners, examined and revised by their Engineer-in-chief Mr. Frank Forster, and with some trifling alterations were, upon his recommendation, ordered to be carried into execution, at an estimated cost of £13,904.

In the month of September following, the main sewers, in that part of the town situate south of the railway, were contracted for; those on the north side of the line, together with the principal main sewer, being deferred for a time.

Whilst these sewers were in course of construction, junctions were put in, for connecting the branch sewers and the house drains; and to avoid the necessity of again breaking up the streets, for connecting the house drains with the sewers, these drains were extended to the kerb of the pavement, on each side of the street, and so branched as to make each junction serve for two, or three house drains.

These junctions were formed at an acute angle with the sewer, one, or two straight pipes being placed next to it, followed by curved pipes, to bring the branch into the line of the house drains; and wherever the house drains were not immediately connected, the ends of the branch pipes were stopped up with a piece of board fitted to the socket, to prevent anything from getting into them, and the gradients were so arranged, in the first 6 feet of the branch drains, next to the junction, that its invert should be, at that distance from the junction, on a level with the upper side of the pipes in the main sewer. This was done, in order to prevent the water from backing far up the house drains.

In the construction of pipe sewers, it is important, that the proper

position for all the house drains be previously ascertained, so that the junctions and branches for their reception may be properly placed; and they ought to be marked, so as to be readily found when wanted, and to avoid mistakes in opening the ground at wrong places.

A great part of the pipes for the main sewers, being of unusual sizes, with sockets somewhat longer than usual, were made to order, and no pipes were allowed to be used, until they had been inspected and approved; all distorted, cracked, or otherwise unsound pipes being rejected. On being laid, the joints of the pipes were rammed first, with well-tempered clay, to one-third the depth of the socket, above which the joint was made good with cement, the sockets being purposely made somewhat longer than usual; and great care was taken to pack the earth solidly about the pipes, so as to support them laterally, against the crushing pressure of the superincumbent earth. This is a very important part of the work, in constructing pipe sewers, particularly in closely timbered trenches, where in drawing out the timbers, a void, or vacancy is apt to be left alongside the pipes, which renders them more liable to be crushed by the weight above them.

In cutting the trenches, various qualities of ground were met with; in some parts there was a solid clay, in others a sharp dry sand, in others a sand charged with water, and in some places a slippery clay, intersected by numerous veins of sand, full of water. In part of Hill street the sewer was laid 19 feet under the surface, from 4 to 7 feet of the bottom of the trench being in a sharp running sand, charged with water, and at about 200 feet farther up the hill, the trench was cut through the solid blue London clay.

The estimated cost of the works comprised in this contract was £2,872 17s., and the entire cost of the work when completed, including all extras, was £2,665 17s. being about 7 per cent. within the estimate.

Shortly after their completion, the sewers were washed out by a flush of water sent through them, and the velocity of the flow in each was ascertained and found to agree very nearly with, being somewhat above, what the Author had calculated upon: the greatest being 3.81 feet and the least 1.88 feet per second.

In the construction of the house drains all the inlet pipes were trapped, and being of a size somewhat smaller than the succeeding pipes in the drain, whatever passed through the inlet was enabled to proceed freely onwards. No case of obstruction, or stoppage has yet taken place in either the sewers, or the house drains.¹

¹ Since this Paper was written, obstructions have taken place in the sewers, owing to the admission of surface waters, for which they were not adapted.

In some cases, where several adjoining premises belonged to one proprietor, combined house drainage was adopted, but generally, the several owners objected to that system, as exposing all the houses to every annoyance arising from any obstruction in, or interference with, any portion of such drains.

The several sizes of pipes, adopted for these works, were selected with a view to the introduction, into practice, of a series of sizes better adapted for drainage purposes, than those hitherto in use. For as hydraulic calculations are usually made in cubic feet, so pipes in a series of sizes, whose sectional areas represent decimal parts of a cubic foot, would be preferable; with this view, the Author submits the following seven sizes, believing they would be found sufficient for every purpose and be convenient in practice.

Diameter of pipes . . }	$4\frac{1}{2}$	$6\frac{3}{4}$	$8\frac{1}{2}$	$10\frac{1}{2}$	$12\frac{1}{2}$	$13\frac{3}{8}$	$14\frac{7}{8}$	Inches.
Areas . .	$\frac{1}{100}$	$\frac{2}{100}$	$\frac{3}{100}$	$\frac{5}{100}$	$\frac{7}{100}$	$\frac{8.35}{100}$	$\frac{10}{100}$	Of a cubic foot.
Thickness of substance }	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{2}$	Inches.

As a general rule, the thickness of substance should not be less than one-tenth of the diameter of the pipe.

Pipes of a larger size than the above, are neither safe nor economical.¹

The consideration of this subject naturally led the Author into that of town drainage generally, and though on that topic, there are many conflicting opinions, still open to discussion among Engineers, yet he ventures to hope, that the following remarks, the result of his experience and of a careful consideration of the subject, may not be thought out of place.

If there is any portion of the works in the building of towns, which more than another ought to be imperishable, it is the sewers. Permanent efficiency is the first point to be attended to in their construction,—economy, the next; and with regard to this, the cost of their maintenance should be kept in view, as well as that of their construction in the first instance.

Stoneware pipes may be used for house drains and also for small sewers, in courts and alleys, and in some cases, for short street sewers, where new junctions for house drains are not likely to become

¹ See Advertisement of the Metropolitan Commissioners of Sewers in the 'Builder' of 21 May, 1853, relative to the size and substance of pipes.

necessary. The frequent breaking open of a pipe sewer, for the purpose of connecting additional house drains, very soon occasions its entire destruction, and the constant lifting of the pavement, for such purposes, is a cause of much of the annoyance and expense complained of in the use of pipe sewers. Every common sewer in the streets ought to be of a sufficient size to permit workmen to enter them without difficulty, or danger, whenever it may be necessary to connect additional house drains, or to make any repairs; and this should be done without creating any considerable obstruction within the sewers, or being under the necessity of breaking up the surface of the streets. In the reiterated statements advocating the exclusive use of pipe sewers, their sectional area has been treated entirely as a hydraulic question, and the conveyance and discharge of so much water as their only use and duty.

The proper and most economical sizes for sewers is, however, by no means a merely hydraulic question, though the conveyance of water may be their primary use. As regards economy in their construction, it may be observed, that a pipe sewer of 18 inches, or 24 inches diameter, is more expensive than a brick sewer of similar dimensions, and that the cost of sewers does not increase in proportion to their sectional areas, but as their circumferences. For instance, a circular sewer of 3 feet 6 inches diameter, has a sectional area of $9\frac{1}{2}$ feet, its circumference being 11 feet, while one of 4 feet diameter has an area of $12\frac{1}{2}$ feet, its circumference being also $12\frac{1}{2}$ feet; the difference in sectional area between the two sewers being 3 feet, while their difference in brickwork is only $1\frac{1}{2}$ foot. Again, the difference between a sewer of 4 feet and one of 6 feet diameter is 15 feet of area, for 6 feet of brickwork, and in a circular sewer of 4 feet diameter, there is one foot of brickwork for each foot of sectional area; while in a sewer of 8 feet diameter, there is only half a foot of brickwork for each foot of sectional area and the difference in the cost of excavation is still less. It appears very desirable to prevent, as much as possible, the road drift from entering the sewers, and this might, to a great extent, be effected by the construction of catch-pits of sufficient dimensions, at the gullies; they might be in the shape of a trough, say 6, or 9 feet in length, about 2 feet in width, and 4, or 6 feet deep, placed alongside the kerbstone, under the channel, or gutter, with suitable grates and cast-iron, or stone covers. The sand, &c. would be much more easily removed from these, than from the sewers, and with less offence, as it would be free from any unpleasant feculent matter; and in the absence of such road drift within the sewers, they may be more efficiently cleared by flushing them with water.

With regard to the flushing of sewers, it ought to be borne in mind, that the heavier matters held in suspension in the sewage, or driven along the sewers by the force of its current, never moves with the same velocity as the water, and consequently, with intermitting currents as in house drains, it is often left dry and sometimes becomes indurated, so that it cannot be moved by the succeeding flow of water; hence the necessity of a continuous current of water in all pipe sewers, to prevent the accumulation of matter within them. The sizes of all house drains and pipe sewers should be such, that they should never be more than four-fifths filled with water, or sewage, so as to allow of a free circulation of air through them, at all times, as the air not only facilitates the flowing of the water and promotes ventilation, but it also prevents the accumulation of highly-concentrated gases and their rising through the drains into the houses.

The paper is illustrated by a plan of the sewers of Richmond.

Mr. DONALDSON said, that at present, the drainage was conducted into the Thames, the main and outfall sewers not being yet completed, but it was intended to connect them, ultimately, with the Kennington sewer. The largest pipes he had employed, were 20 inches in diameter, but pipes of that size were rarely made so perfect as those of smaller dimensions, and there was great difficulty in well securing the joints. Where a larger diameter than 18 inches was required, he should prefer, on the score of safety, to construct a brick culvert, of which the cost would be about the same: the Contractors, indeed, finding at the time, some difficulty in obtaining the 20-inch pipes, offered to construct instead, a 30-inch sewer of bricks in cement. If pipe sewers could be made large enough to carry off the surface waters, and strong enough to bear the pressure of the superincumbent earth at great depths, he should prefer them to brick drains, provided the cost were the same; for the damage to drains arose not only from the wear and tear, but also from the rats, who could not attack the pipes, which should be carefully jointed with clay, not with cement. The use of pipes was, however, subject to this inconvenience, that whenever it became necessary to make a new junction, it was difficult to avoid breaking them in opening the ground, and thus a greater expense was often incurred, than would have resulted from the use of brick drains.

Mr. HERTSLET said, the most striking feature of the plan was the employment of the separate system. There was no doubt, that