CHAPTER XVIII.

USE OF FLUSH-TANKS.

The following paper, read by the author before the American Society of Civil Engineers, in May, 1898, offers a discussion on the suitable use of flush-tanks, their proper capacity, frequency of discharge, etc.

The use of flush-tanks in connection with small pipe sewers, which has been made an integral part of the "Separate System," and generally adopted in systems caring only for house-sewage, is attended with much uncertainty. In such systems it is generally specified that a flush-tank be placed at the head of every lateral, each tank being so regulated as to discharge at least once in 24 hours. The relation between the size of the sewer-pipe and the amount of water used in a flush is not given, nor is the influence of grade discussed. The general law is laid down that all laterals, regardless of size, grade, or contributing population, must be supplied with flush-tanks in order to secure a self-cleansing flow in the laterals and to maintain the integrity of the system.

The financial burden of such a requirement is evident. As an example, it may be cited that in the plans for the sewerage system of Ithaca, N. Y., in which plans this requirement of flush-tanks was thoroughly complied with, even for the 12 per cent grades, no less than 131 flush-tanks were required in 25.3 miles of sewers, or one for every 1920 feet. The relative importance of the flush-tanks may also be seen by comparing the actual cost of the sewers with the estimated cost of the tanks. The cost of the sewers, viz., the sum of the amounts of the several contracts, was $81,000, and, estimated at $50 each, the flush-tanks would cost $6550, or more than 8 per cent of the cost of the system. It would seem, then, that the cost of flush-tanks is by no means insignificant, but that their use increases the cost of the separate system by nearly one tenth, besides introducing a permanent charge, both for water used and for intelligent care in maintenance. That these annual charges are no bagatelle will be apparent by again referring to the case of Ithaca. Assuming that the tanks required are of a capacity of 150 gallons, a minimum amount, discharging but once a day, the water required is 19,650 gallons a day. Twenty cents per 1000 gallons (the amount charged in Ithaca*) is a fair average amount, and at that price the daily charge for water is $3.93, or $1434.45 per year. Adding to this $600 per year as the wages of a mechanic, whose constant attention is found by experience to be necessary in examining and readjusting the tanks, the total annual charge is $2034.45. This, capitalized at 6 per cent, gives $33,908, and, added to the $6550, gives $40,458

as the total expenditure on account of flush-tanks in a sewer system costing for pipe laid $81,000. Surely the item of flush-tanks is an important one, and should be carefully examined, so that if the conditions of the sewer-grade, for example, modify the necessity for tanks, or if the amount of water is a function of the time-interval between flushes, or of the size of the pipe, it may be known in order that the large proportionate cost of flushing may be reduced to what has been found by careful investigation to be an absolute minimum.

That the requirement given above is felt by present-day engineers to be largely in excess of necessity is sufficiently evident from a study of the paper by F. S. Odell, M. Am. Soc. C. E., entitled "The Separate Sewer System without Automatic Flush-tanks,"* and the subsequent discussion, in which the author says that at Mt. Vernon, N. Y., no flush-tanks are used, and that, while hand-flushing by means of fire-hose is practised at intervals of six months, even this infrequent flushing does not appear necessary, as examination of the sewers invariably shows a very wholesome and satisfactory condition. In the discussion very little positive evidence is given, but the experiences recorded go chiefly to show that while automatic flush-tanks do not in themselves make the separate system practicable, there is, nevertheless, a need, under certain conditions, for flushing, those conditions being as yet not fully determined.

The questions, answers to which are essential for an intelligent disposal of flush-tanks on a sewer system, are four, viz.:

1. What is the relation, if any, between the grade of the sewer and the necessity for automatic flush-tanks?

2. Assuming a need for automatic tanks, how does the grade of the sewer affect the amount of water required, and what is the proper amount to be used?

3. How often should tanks be discharged?

4. What effect does the substitution of a 6-inch for an 8-inch lateral have on the necessity for tanks and on the amount of water to be used?

Before attempting to answer these questions, it will be well to look at the subject broadly, and consider the hydraulic problem involved. Sewage is water carrying in suspension less than 1 part in 1000 of solid matter, and sewers are supposed to be so laid that the resulting velocity of flow is sufficient to keep this solid matter in suspension. This suspending and scouring power probably depends on the velocity, and on the depth, of the sewage stream, and if either gets below a certain point, sedimentation will follow and a deposit take place. It is generally stated that a velocity of about 2.5 feet per second is required; but the effect of depth is neglected. At the lower end of a 6-inch lateral the depth and velocity are assumed to be sufficient to prevent this sedimentation, but as the contributing population grows less toward the upper end, the depth and velocity decrease and the transporting power of the stream falls so low as to allow the solid matter, brought into the sewer by the house-drains, to become stranded. This deposit increases by

---

gradual accumulation until the sewer is blocked, until
the head from the backed-up sewage is sufficient to
carry away the obstruction, or until the discharge of
the flush-tank (and here is seen its true function) takes
up the obstruction and carries it to a point where the
depth and velocity of the sewage will hold it in sus-
pension. Table XX and the diagram (Fig. 50) are
given to show the requirements in grade to maintain
a velocity of 24 feet per second in a 6-inch lateral,
assuming a constant contributing population of 76
persons per 100 feet of sewer, with a daily flow of 60
gallons per capita, and with the assumption of one
half flowing off in 6 hours.

The diagram (Fig. 50) shows that, taking \( n \) equal
to 0.013, and computing velocities by Kutter’s
formula, a grade of 1 per cent is required for a 6-inch
pipe half full for a velocity of 2.5 feet per second, and
that if the amount of flow constantly decreases, the
depth of flow decreases also, and the grade, in order
to maintain the same velocity, must be increased
according to the diagram. The diagram is given for
two reasons: first, to show that by the accepted laws
governing the transportation of material in flowing
water, lateral sewers could be laid, theoretically, on
such grades that no flushing would be necessary, since,
with grades which continually increase toward the
upper end, the corresponding velocities will always be
equal to that required to transport matter in sus-
ception; second, to show that as the grade of the sewer
increases, the distance from the upper end to the
point where the stream reaches the velocity required
to carry matter in suspension decreases, and so the aid
required from flush-tanks is less. No value can be
placed on the grades given, as the diagram is based
on the assumption of a house with five persons every
66 feet, and this is not always the case; but it is
believed that there is a grade at or beyond which
flush-tanks are not required, and if the distance to
which the flushing power extends is a function of
the amount of water discharged, then this amount
should be less on steep grades.
Referring again to Mr. Odell’s paper, it is first noted that at Mt. Vernon, with grades of from 0.5 to 6 per cent no flush-tanks are used, and a good hand-flushing twice a year answers every purpose.

In the discussion, Mr. Hering says that on light grades flushes of 200 to 300 gallons generally lose their flushing power after passing a few hundred feet through the pipe, and that sometimes after 500 feet he has been unable to detect any difference in the flow due to the discharge of the tank.

Mr. Kiersted writes that in one system designed by him he recommended flush-tanks only on laterals of less than 0.5 per cent grade, and for five years the system has been in operation with but few stoppages.

Mr. Folwell writes that in his experience he has omitted flush-tanks on grades from 6 to 12 per cent, and on the 6 per cent grades no stoppages were discovered, nor were there any odors.

Mr. Le Conte intimates that flush-tanks as built do not answer their purpose, for where grades are light and the flush most needed, they do the poorest work; and the large quantity of water needed to be effective must be obtained by some other means.

Mr. Odell maintains that flushes of 200 gallons or less fail to flush a sewer properly, especially on flat grades where flushing is most needed.

A table by Mr. Allen shows that on grades greater than 0.5 per cent a velocity of more than 2\(\frac{1}{2}\) feet per second is maintained over 1000 feet from the flush-tank, but on lesser grades the velocity drops to 2 feet or less within 600 feet.

In order to obtain an insight into general engineer-

ing practice in the matter, and, at the same time, reap the benefit of any experience which was to be had, the author sent out, on January 17th, 150 reply postals, reading as follows:

"Ithaca, N. Y., January 17, 1898.

"Dear Sir:

"To aid me in deciding as to the necessity for flush-tanks for our sewer system, will you kindly answer the following:

"I. Do you find flush-tanks a necessity, or is periodic hand-flushing sufficient to keep sewers clean?

"II. Does the element of grade affect the question, and within what limits of grade are tanks required?

"III. Does your experience show any relation between the minimum amount of water required for effective flushing and the grade of the sewer?

"Thanking you in advance for your kind assistance in this matter,

"I am, yours very truly,

"H. N. Ogden,

"Engineer, Ithaca Sewer Commission."

These postals were sent to those cities of between 10,000 and 60,000 population, in the New England and Middle Atlantic States especially, which were reported in the "Manual of American Water-works" for 1897 as having separate or sanitary sewers. Eighty answers were received, and the courtesy and good-will expressed in all was much appreciated. It was the same story in nearly all cases. "I would be pleased to answer your questions fully, but this is the best that I can do for you," or
"This is only my idea, while I can readily understand that what you want is the result of actual experience," or "I cannot give you the desired information, but would be thankful to you if you would let me know the result of your inquiry." The results given below in a brief summary show chiefly how uncertain and vague is the knowledge on the subject, and how necessary are some experiments and investigations.

Of the eighty engineers who sent replies to question No. 1, whether flush-tanks are necessary, seventeen had no opinion on the subject; twelve had experience only with combined systems, but had, according to their replies, found no trouble in keeping the ends of their 10- and 12-inch laterals clean with rain or with hand-flushing; twenty-six of the eighty used periodic hand-flushing and found it to answer every purpose, keeping the sewers clean and free from obstructions; twenty-five either used flush-tanks or considered them a necessity for small pipe sewers. It was not possible in these last answers to separate actual experience from personal conjecture on the question, so that this number may include many hearsay opinions.

The evidence is not very clear. The fact that twenty-six used hand-flushing satisfactorily indicates that such flushing is sufficient. That it must be properly and regularly done, however, is made plain by the fact that, out of the twenty-five believing in flush-tanks, nine had tried periodic hand-flushing, found it uncertain and irregular, and had put in flush-tanks, to secure proper attention. On the other hand, of the twenty-six believing in hand-flushing, two came to that opinion after becoming disgusted with the uncertainty of tanks.

On the second question, only twenty-three of the eighty ventured an opinion. Of these, eight thought that the grade did not affect the question, but that flush-tanks were as necessary on steep as on flat grades. One engineer explained his position by saying that while the velocity on the steep grades might be greater, yet as the depth would be less, the transporting power would be less, and therefore tanks were equally necessary. Of the fifteen who thought that tanks are not needed above a certain grade, six merely ventured it as an opinion, and nine fixed the limit at from 0.5 to 3 per cent; four of these gave 1 per cent as the limit; one, 3 per cent; and the other four less than 1 per cent.

Only six replies were given to the last question, whether the amount of water in the flush-tank should be varied with the grade of the sewer. Of these six, two engineers thought that no difference should be made; three thought that less water could be used on the steep grades, but had no definite opinion as to the relative amounts; while one well-known engineer, who has thoroughly studied the workings of the sewer system under his care, writes that he finds one flush daily on a 2 per cent grade as effective as two flushes daily on a 0.5 per cent grade, each flush of 300 gallons.

The general conclusion from the replies is that on low grades, probably below 1 per cent, occasional flushing is needed at the upper ends of laterals; that this may be accomplished, either by hand-flushing or by the use of automatic tanks; that if tanks are
used, less care and vigilance are required in inspection and oversight, but, on the other hand, the periodic examination of the system, which should not be omitted, is apt to be irregular, and if a tank fails to work or if an obstruction occurs below the effect of the flush, a serious nuisance may result; that if hand flushing is used, a constant and regular inspection must be practised, although actual flushing may be required but once a month or even less. The amount of water needed in flush-tanks is not known, nor the relation between amount and grade.

With a view of obtaining more information on this apparently unstudied subject, the author carried on some experiments in the spring of 1897, in which he was assisted by Mr. I. W. McConnell, C.E. The results of the experiments have been recorded by Mr. McConnell in a thesis for the degree of Civil Engineer in Cornell University.

The sewers on which the experiments were made, chosen so as to afford a variety of grade, with as long lines as possible, were all 8-inch pipe, and each had at the upper end a manhole about 4 feet in diameter at the bottom. Flush-tanks of the usual commercial size discharge at a rate of about 1 cubic foot per second, and, by repeated experiment, the opening from the manhole into the sewer was reduced to such a size (about 5 inches) that the rate of discharge varied from 0.89 cubic foot per second for 4 feet head in the manhole to 1.1 cubic feet per second for 6 feet head. These conditions it was thought approximated closely enough to the workings of a flush-tank. A 5-inch opening was cut in a pine board held firmly against the end of the 8-inch pipe; then a flat rubber-faced cover, 6 inches in diameter, was placed over the opening and held there by a light stick braced against the back of the manhole, making an effective plug. The manhole was filled to any desired depth by means of fire-hose attached to neighboring hydrants, and then, by means of a cord fastened to the stick and to the cover, the contents of the manhole were discharged into the sewer. The capacity of the manholes at depths varying by 6 inches was determined by measurement, so that by filling to the proper depth any desired amount of water could be discharged. The effect of the flush-waves was then noted at the successive manholes down the line. No determinations of the velocity of the wave were made, the effect being judged by the depth of the wave, and by the force shown in moving gravel, etc., placed in the different manholes. The wave-depths were read by observers stationed in the manholes, where they recorded as rapidly as possible (usually every seven seconds) the depth as marked on a thin vertical scale placed in the sewer. Figs. 51 to 54 show the wave-forms and the progressive flattening as the wave gets farther and farther from the flush-tank.

To test the transporting power of the wave small brickbats and gravel of various sizes, coated with paint so as to be recognizable, were placed in the invert at the manholes. A considerable growth, apparently of vegetable origin, had become attached to the sides and bottom of the pipe, and the value of the flash in removing this growth was also noted.
The order of procedure was to examine and note the condition of the line, and, after placing the gravel, etc., in the manholes, to make a number of flushes, each of 20 cubic feet, and note the results. Then, increasing the amount discharged to 30, 40, 50, and 60 cubic feet, the respective results were noted. Then either the whole pipe was scraped by a rubber-edged piston-like cleaner, or merely the manhole invert and about 6 feet each way into the pipe, and the flushing repeated. Tables XXI–XXIV give the results on the different lines.

**Table XXI.**

<table>
<thead>
<tr>
<th>Volume of Flush</th>
<th>Manhole No. 1</th>
<th>Manhole No. 2</th>
<th>Manhole No. 3</th>
<th>Manhole No. 4</th>
<th>No. of Flushes</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 cu. ft.</td>
<td>Scoured clean</td>
<td>Scoured clean</td>
<td>No effect</td>
<td>No effect</td>
<td>1</td>
</tr>
<tr>
<td>30 cu. ft.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>40 cu. ft.</td>
<td></td>
<td></td>
<td>Several stones started</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>50 cu. ft.</td>
<td></td>
<td></td>
<td>Small gravel generally scattered</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>60 cu. ft.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>80 cu. ft.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>120 cu. ft.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>
Before commencing the work, the examination of the Green Street pipe showed it to be practically clean, with no ground-water, except between the third and fourth manholes, where there was a stream about one fourth inch deep. No house-connections had been made, but there was a small depth of silt, and bits of cement left from construction, also a slight vegetable growth on the sides and bottom of the pipe. Gravel of all sizes placed in the pipe at the flush-tank was carried through to manhole No. 1 in two flushes of 25 cubic feet each, the first flush alone not being sufficient. The gravel scoured out of the bottom of manhole No. 1 by the first flush was not brought to No. 2 until the 80-cubic-foot flush was put in, and no gravel scoured out of No. 2 was brought to No. 3 by any of the flushes. After the seventeenth flush as above, the pipe was thoroughly scraped and cleaned, and flushes eighteen to twenty-eight were made. Similar results were obtained, except that the flushes carried the gravel about 200 feet farther than before and seemed effective for that distance.

In Cayuga Street there were a few connections and little flow, so that the condition of the pipe was very foul; there was also a heavy vegetable growth in the pipes.

On Linn Street no comparative records could be made. The pipe was clean from the flush-tank to manhole No. 1, and in this length there were no connections. From No. 1 to No. 2 it was slightly foul, and very foul the remainder of the length. There were two house-connections on the line. Five flushes of 20 to 60 cubic feet were made. Each was very effective, one apparently as much so as another. All obstructions introduced were removed at once from manholes Nos. 1 and 2. A steady flow 1 inch deep from the hose carried everything forward at once to a point beyond No. 2 and to the flatter grade.

**Table XXIII.**

<table>
<thead>
<tr>
<th>Volume of Flush</th>
<th>Manhole No. 1</th>
<th>Manhole No. 2</th>
<th>Manhole No. 3</th>
<th>Manhole No. 4</th>
<th>No. of Flushes</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 cu. ft.</td>
<td>Cleaned</td>
<td>Cleaned</td>
<td>No effect</td>
<td>No effect</td>
<td>3</td>
</tr>
<tr>
<td>60 &quot; &quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>No effect</td>
<td>&quot;</td>
<td>7</td>
</tr>
<tr>
<td>80 &quot; &quot;</td>
<td>&quot;</td>
<td>Partly secured</td>
<td>Some vegetable growth passed through</td>
<td>&quot;</td>
<td>2</td>
</tr>
</tbody>
</table>

**Table XXIV.**

<table>
<thead>
<tr>
<th>Volume of Flush</th>
<th>Manhole No. 1</th>
<th>Manhole No. 2</th>
<th>Manhole No. 3</th>
<th>Manhole No. 4</th>
<th>No. of Flushes</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 cu. ft.</td>
<td>Cleaned</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
<td>5</td>
</tr>
<tr>
<td>60 &quot; &quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>3</td>
</tr>
<tr>
<td>80 &quot; &quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>2</td>
</tr>
</tbody>
</table>
On the Aurora Street line the pipe was very foul, chiefly from a hospital connection at the upper end. The vegetable growth was excessive, and the accumulations of organic matter very evident.

On Buffalo Street, where the grade is about 12 per cent, the effect of the flush was amazing. Where any sewage at all flows in the pipe, it is sufficient to remove all obstructions. A flush of any volume rushes down the hill at a high velocity, with piston-like action, and sweeps everything before it.

Table XXV gives the distances and grades between manholes on the lines used in the experiments.

### Table XXV.

**Distances and slopes between manholes.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Green St.</th>
<th>Cayuga St.</th>
<th>Aurora St.</th>
<th>First St.</th>
<th>Loo St.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distance in Feet</td>
<td>Grade Percentage</td>
<td>Distance in Feet</td>
<td>Grade Percentage</td>
<td>Distance in Feet</td>
</tr>
<tr>
<td>Dead end to manhole No. 1</td>
<td>208</td>
<td>1.31</td>
<td>300</td>
<td>0.80</td>
<td>317</td>
</tr>
<tr>
<td>Manhole No. 1 to manhole No. 2</td>
<td>131</td>
<td>0.59</td>
<td>116</td>
<td>0.30</td>
<td>300</td>
</tr>
<tr>
<td>Manhole No. 2 to manhole No. 3</td>
<td>200</td>
<td>0.59</td>
<td>300</td>
<td>0.60</td>
<td>403</td>
</tr>
<tr>
<td>Manhole No. 3 to manhole No. 4</td>
<td>305</td>
<td>0.59</td>
<td>300</td>
<td>0.40</td>
<td>393</td>
</tr>
<tr>
<td>Manhole No. 4 to manhole No. 5</td>
<td>206</td>
<td>0.75</td>
<td>300</td>
<td>0.60</td>
<td>397</td>
</tr>
</tbody>
</table>

The manager of the Van Vranken Flush-tank Company gives his practice in proportioning the sizes of flush-tanks for any particular sewer as follows: The capacity of the reservoir should be equal to one half that of a length of sewer in which the grade produces a rise equal to the diameter of the pipe; so that the

Green Street line, 8 inches diameter and 0.5 per cent grade, should have a discharge of half the volume of the pipe, $\frac{1}{2} \times 100$ in length, or 23 cubic feet; and for a 1 per cent grade one half of that, or 11.5 cubic feet. He says further, and the statement has been confirmed by the author's work, that an 8-inch pipe on a 0.4 per cent grade will flow about one third full at a distance of 300 to 400 feet from the tank discharging the above amount; and that on a 5 per cent grade the water will come down as a solid piston for any discharge greater than 14 cubic feet.

The manager of the Pacific Flush-tank Company writes that as a rule he does not interfere with engineers in their design for tanks, but, in his opinion, a flush of 175 gallons on a 1 per cent grade is sufficient, and on any flatter grade twice that amount of water should be used, or, as he says, "long lines or flat grades require greater capacity of tanks than steep grades or short lines."

**Conclusions.**—The following conclusions are based upon previously published data on this subject; upon the experience of engineers in different parts of the country; upon the flushing diagrams recently published by J. W. Adams, and upon observation and the special experiments made in Ithaca; and it is believed that they are justifiable and a safe guide in the use of flush-tanks.

1. Flushing of some sort is required at the upper ends of laterals, the frequency and amount depending on the number of house-connections, on the carefulness or prodigality in the use of water by the householders, on the grade and size of the sewer, on the
character of its construction, and on a mysterious something which defies definition, but which produces frequent accumulations in one line and does not affect another, apparently like the first.

(2) This variety in the conditions prevents any exact statement of a relation between the quantity of water which should be discharged from a flush-tank and the grade of a sewer, but it plainly indicates that the advantage of automatic flush-tanks lies in a general guarantee or insurance against accumulations in the upper part of the laterals, while periodic hand-flushing must be depended on only when in charge of a responsible, indefatigable, and intelligent caretaker.

(3) Judging by the experience at Ithaca, and despite the statements of other engineers, it seems to the author that on grades of less than 1 per cent automatic flush-tanks are an economic necessity, even where water has to be paid for, the added expense of frequent hand-flushing more than offsetting the possible discharge of flush-tanks when not absolutely necessary.

(4) The volume of water discharged should not be less than 40 cubic feet, and the effect of the flush can hardly be expected to reach more than 600 or 800 feet. Below this point accumulations may occur which must be removed by hand-flushing and carried on to a point where the sewage-flow has the necessary transporting power.

(5) On flat lines and where obstructions occur below the influence of the flush-tank, a second flush-tank, placed about 800 feet from the first, will be more effective than increasing the first tank to a capacity of three times its original discharge.

(6) The frequency of discharge should depend on the local conditions, but it is probable that the maximum interval depends on the practical working of the siphon, so that the usual prescription of once in 24 hours is a safe rule.

(7) If tanks are used on grades greater than 1 per cent, 15 to 20 cubic feet give as good results as larger amounts, with the same rule as to frequency of discharge.

(8) However, economy is best served, on grades above 1 per cent, by omitting flush-tanks, and resorting to periodic hand-flushing at such intervals as experience shows to be necessary on the different lines. In most cases semi-annual or quarterly flushings, with a hose, are sufficient.

(9) On grades greater than 3 per cent flush-tanks are unnecessary, and their installation is a waste of money.

(10) Hand-flushing should be performed and tanks discharged at night, as a flow of even an inch in a sewer offers a large resistance to the flushing action; while with a pipe flowing half full the effect of a flush-tank is scarcely visible.