CHAPTER X.

FLUSHING AND VENTILATING.

In the Combined System.—Any one seeing the volume of warm vapor rising from the man-holes of an ordinary combined sewer on a cold morning will get some idea of the immense quantity of gas which constantly rises from a sewer; and if he once gets a smell of the ascending column he can form some slight conception of its composition.

An examination into the condition of the sewers will, in most cases, at once show the cause of this enormous evolution of gas.

The sewers of the Combined System are designed to carry not only the sewage of the town, but also the storm water from the roofs, yards and streets. Under these circumstances the size of the sewer is determined solely by the amount of storm water to be provided for; the amount of sewage being so small in comparison that it may be disregarded.

In fair weather, and especially in the long continued dry weather in summer, the sewage forms only a very small stream in comparison with the capacity of the sewer. This comparatively small amount of sewage is spread out on the bottom of the large sewer and the stream is shallow and sluggish.

Since the capacity of a stream to carry solid matter depends upon its depth and velocity it is readily seen that the solid particles in the sewage soon get stranded and the sewer becomes foul even where street refuse is rigidly excluded by the catch basin, which is not often the case.
The storm water from the streets usually carries with it a large amount of detritus, straw, leaves and sticks. As the flow in the sewer produced by the storm slackens this solid material is stranded, forming small dams in the sewer. These hold the sewage in pools, where it decomposes and sends off immense volumes of sewer gas.

Sewer gas contains sulphuretted hydrogen, carburetted hydrogen, nitrogen, ammonium sulphide and fetid organic vapor.

Besides these gases, and quite as much to be dreaded, are the disease producing micro-organisms, commonly known by the name of bacteria, which abound in the warm, moist air of the sewers and are carried wherever the sewer gas penetrates. Several diseases are known to be produced by bacteria, and it is highly probable that the list will be increased as our knowledge in this field is extended.

In any place the struggle for life is between the bacteria and the human being. It is a survival of the fittest in any environment. Where sanitary matters are properly attended to and the environment is favorable for man it will be unfavorable for the bacteria, so the man will live and the bacteria will die. But where sanitary laws are disregarded and the environment is unfavorable for man it will be favorable for his enemy, and the bacteria will thrive and the man will die.

The question arises—what remedy can be applied to improve the condition of the sewer, and to prevent or diminish the dangers to health from this source?

Two things are needed in order to accomplish this end: flushing and the ventilation of the sewer. Thorough flushing will carry out the accumulations of solid matter and dispose of the pools of putrefying sewage. Fresh sewage is not very offensive, and if it can be carried rapidly to its outfall before decomposition sets in it will cause very little trouble either by becoming obnoxious or dangerous. It is
the standing pools of decomposing sewage which causes most of the trouble.

Flushing may be accomplished in several ways. One of the simplest of these is to dam up the sewage by gates in the sewers until the sewers are nearly or quite full and then suddenly release it, causing a full strong current in the sewers. Care must be taken not to hold the sewage until it backs up into the cellars and basements along the line. To prevent the possibility of this, gates which only partly fill the sewers are used, so that when the sewage rises to a certain height it flows over the gate. Automatic gates are also used which turn on a horizontal axis placed below the centre of the gate, the top turning outward away from the confined sewage. When the sewer becomes nearly full, the pressure on the part of the valve above the axis being greater than on the smaller section below the axis, the valve opens outwardly and releases the sewage.

The principal objections to the use of gates in the sewers are that there is a tendency to deposit the solid particles on the bottom of the sewer where the sewage is impounded, and that the method cannot be applied to the upper ends of the sewers.

At the upper ends other devices must be resorted to. One is to collect the sewage in tanks, which are discharged automatically when full. Another is to use automatic flushing tanks filled with water, either by collecting rain water from the roofs, or from the public water works. When the water supply of a town is abundant the problem of flushing sewers can usually be easily solved.

In any Combined Sewer there will be a certain amount of organic matter smeared by the floods on its interior surface above the ordinary surface of the sewage, and the decomposition of this is constantly going on, developing a considerable volume of gas. Added to this is the gas generated by the stagnant sewage held in pools by the obstruc-
tions in the sewers. If there are no openings in the sewer the traps in the houses would be forced by the pressure of the gases produced. Openings are absolutely necessary and wherever there is an opening the gas will escape. To dispose of this gas or to mix it with so large a volume of air as to render it harmless is the problem which presents itself.

The ventilation of a system of large sewers is a difficult task, and up to date it has not been satisfactorily done. One of the best authorities after careful investigation gave it as his opinion that the only practicable plan was—to use his own words—"to just let the stink out in the middle of the street."

The use of high chimneys has been strongly recommended, and they have been experimented with to a considerable extent.

It has been quite confidently stated that as some of the gases found in sewers are lighter than air there will always be an upward draught in the chimney without any artificial aid. Unfortunately this is not the case, and to insure a constant current of air from the sewer up the chimney some means must be employed to secure a draught. This may be accomplished either by a fire at the foot of the chimney or a fan or screw in the chimney which is operated by a steam engine or other power. When the fire is used the sewer gas is usually passed through the fire. In this there is an element of danger, as leaks from the gas mains into the sewer are quite common and explosions from this cause have occurred.

Owing to the numerous openings into the sewers each chimney affects only a limited area, so that an extended system of sewers would need many chimneys. The cost of these chimneys and of running the fires in them prohibits their use, except in special cases. This system can be made efficient if we disregard expense, but engineers soon find that the item of expense is one of the most important
considerations in any engineering project, especially if it relates to sanitary matters which are to be decided by the public.

Another plan is to ventilate the sewers by running an untrapped branch up through each house, relying upon the heat in the house to create an up draught in the pipe. This would be an efficient way of ventilating sewers, but it greatly increases the danger from them. A leak in the soil pipes, or the emptying of a trap by evaporation or syphonage (and both of these contingencies are much more common than is usually supposed) makes the house itself a ventilator for the sewer.

The rain water conductors have sometimes been used as sewer ventilators, but this releases the sewer gas in too close proximity to the windows of the upper story of the house and is a dangerous practice.

One of the best plans is to carry up an untrapped pipe on the outside of the house to a sufficient height above the roof. If this plan could be generally adopted on any line of sewers it would afford one of the best solutions to the ventilation problem.

Various chemical processes for treating sewer gas in the sewers have been proposed, such as liberating chlorine gas, or sulphurous acid in the sewers. These methods have been tried on a small scale but the results have not thus far been encouraging.

A more successful plan has been to purify the sewer gas as it comes from the sewers by passing it through loosely packed charcoal. This has been tried on a large scale and has been fairly satisfactory although quite expensive.

A patent was taken out in 1858 for purifying sewer air by passing an electric current through it.

In the Separate System.—We have thus far been dealing with the "Combined System" of sewers. Where the
Separate System is employed the problems of flushing and ventilation are materially simplified.

As has been already stated the amount of sewage is so small in comparison with the storm water as to be neglected entirely in computing the sizes needed in a Combined System. This being the case it is readily seen that the necessary size of separate sewers is small in comparison with those of the Combined System, and hence much less water is needed for flushing.

Again, since the flow of sewage is approximately constant and not fluctuating between the wide limits of the flow of storm water, the sizes of the pipes may be designed so that the flow of the sewage will keep the mains in proper condition, while the upper ends can easily be flushed by means of automatic flushing tanks of small size, compared with those needed on the large sewers of the Combined System.

A tank placed at each dead end and adjusted to discharge once every day will generally keep the sewers well flushed.

To thoroughly flush a sewer requires a volume of water sufficient to fill the sewer for a considerable distance. The best results would be obtained if the sewer could for a time be filled its entire length, so as to flush all of the upper part of the pipe as well as the lower. This would not only cleanse the pipe, but materially aid in its ventilation by securing an entire change of air in the sewer.

When flush tanks are used to flush the sewers, if the discharge from the tank is sufficiently rapid, the flushing will be thorough, for a greater or less distance, depending upon the grade of the sewer. Gradually, however, the water will lose its velocity, and the flushing effect will be less and less until it amounts to but very little.
Roof Water.—The storm water from the roofs may be utilized for flushing by connecting a limited number of rain water conductors with the sewers at the upper ends of the lateral branches.

When roof water is used for flushing a difficulty arises in adjusting the amount of water to be admitted. When the sewers are first completed, much more water will be needed to flush them than will be required after their use has become general, and the flow of sewage has more nearly reached its maximum. But having once permitted the roof water from any building to be turned into the sewers it is difficult to shut it out when the proper time comes.

When the sewers are flushed by connecting the dead ends of the sewers with the water mains, the amount of water can readily be adjusted to suit the requirements in each case. The water from the mains may be admitted to the sewers by a direct pipe connection, provided with a suitable valve, or it may be taken from a hydrant and carried through a hose to a lamp hole at the dead end of the sewer, which in this case should be constructed as shown in Plate I.

As the small sewers are of smooth earthenware pipes they are much easier kept clean than the rough interior surfaces of the large brick sewers and flushing will be more effective.

The ventilation of the separate sewers is a much simpler matter than in the case of the Combined System. When properly designed and constructed there are no pools of decomposing sewage standing along the lines, and as a consequence there is much less evolution of gas and hence much less need of special appliances for ventilation.

The rush of water from the flush tanks changes the air in the upper ends of the sewers, and the fluctuations of flow in the mains is an important factor in changing the air in the sewers by driving out the foul air as the sewage rises at the
time of its maximum daily flow, and refilling the pipes with pure air as the flow falls to its minimum.

Any of the methods of ventilation which can be used on the Combined System are available for the Separate System, and as the amount of air to be moved is much less they will be more effective.

The man-holes, flush-tanks and lamp-holes, when provided with perforated covers, as shown in the plates, will assist in the ventilation for the street sewers of the Separate System. The house drains, however, need some special arrangement for that purpose. An opening from the house drain to the air is necessary, not only for ventilation but to prevent emptying the traps by syphoning when the sewer is flushed.

The simplest method of accomplishing the ventilation of the house drains and at the same time of the sewers themselves, is to extend the main drain upward and out through the roof, unbroken by a trap in any portion. In this case it serves the double purpose of soil and ventilating pipe, and the air which passes into the street sewers at man-holes supplies the draught upward along the street sewers, and out through these and their upward extensions. In this case the isolation of the interior of buildings from sewer air depends solely upon the trap under each fixture. Where street sewers are properly constructed on the Separate System, and properly cared for, this method has proved entirely satisfactory. It certainly has great advantages in simplicity and facility of arrangement.

Where the sewers are built on the combined plan the method of isolation shown in Plates XVIII and XIX is to be preferred. This diverts the foul air currents from the interior pipe and provides a supply of fresh air for the upward current through the soil and ventilating pipe. If the street sewers are not properly ventilated at frequent intervals, either by the upward extension of exterior or
interior unobstructed pipes or otherwise, there may be reasons for believing that an isolated one may draw from too wide a territory and prove offensive. In this case it is advisable to dispense with any vent pipe communicating directly with the sewer.

If we could be perfectly certain that all the drain, waste and soil pipes were perfectly gas tight throughout their whole length, and would remain so, and that no fixture traps would ever be emptied by syphoning, evaporation, capillary attraction, or any other of the many ways by which traps do get emptied, we might safely use untrapped house drains. But taking the conditions as they are, it seems to be taking too great a risk to ventilate the public and private sewers through the dwellings.

S. Stevens Hellyer, the well known sanitary engineer, writes as follows:

"Where the drains (house drains) are carried direct into the sewer, without traps, the houses, through the sewer, are brought into direct communication with each other, i.e., the air in the drain of one house can pass into the drain of another house. Contagious diseases—typhoid or what not—may be infecting a house, and however isolated it may be from other houses above ground, it would not be so under ground with such a system. The untrapped drains branching into the sewer would form a subterraneous passage for the bad air or disease germs—coming from the stools of the infected patients—between house and house. But when each house drain is trapped off before entering the sewer, an all but impassable barrier would be placed between the drains, so that the houses would be as much isolated under as above ground."

If every house could be thus provided with the means of ventilation the whole problem of the ventilation of sewers would be simplified, and the provision for ventilating the house drains would supply the needed ventilation of the sewers.

Man-holes and flush-tanks are liable to be covered with snow or mud at times and their efficiency as ventilators interfered with. If all house connections are made in the way above described—that is, if there is a free communica-
MAIN VENTILATING PIPES AND TRAP.
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tion between an upright ventilating pipe on each premises and the sewer proper—we have substantially a horizontal pipe having at frequent intervals vertical pipes leading from it. These vertical pipes are of varying lengths and their upper ends are at different elevations, covering a range of several hundred feet, perhaps. These vertical pipes are also subjected to different conditions. For instance some of them are within buildings near artificial heat, some of them are at the south side of buildings where the sun will effect them, some on the north side where the temperature is lower, some of them are short and some are long. In short, the conditions are such that there cannot be an equilibrium of pressure throughout the system. Now, if the openings at the mouth of the sewer, at the man-holes and flush-tanks are relatively large enough, and the air space along the sewer toward the higher levels where the house connections are numerous, is relatively large enough, it may happen that there will be an upward current in all the house ventilating pipes, the air being supplied, of course, through the openings along the sewer proper. It is probable, however, that this rarely occurs for the reason that the combined section of the ventilators is many times the section of the air passage in the sewer proper and consequently any difference in pressure that may be induced in the ventilating pipes by the causes above cited, is more easily restored by downward draughts in some of the ventilating pipes. It may thus happen that the short, cool ventilating pipes, particularly at the lower levels have, some of the time at least, a downward draught and that the total volume of air which passes through the system at various points is greater than could be supplied through the outlet, man-holes, etc., at the velocity which would be likely to be induced.
Automatic Flush Tanks.—Flush-tanks are used either to collect the sewage and discharge it rapidly at intervals for the purpose of flushing the sewers, or to collect and discharge clean water for the same purpose. They should be automatic in their action.

This regular and automatic flushing is usually applied to Separate Systems, and the diminished size of the pipes renders it very effective. It sweeps down all deposits and stranded matter from the remotest portion of the system into the mains, and the aggregate of these discharges in the mains from tanks differently timed, continued with the flow of sewage proper, sweeps it on to the outlet. The more regular flow in the Separate System and consequent immunity from variations in air space and pressure reduces the danger of forcing traps. The smaller air space increases the efficiency of all openings in relieving any pressure resulting from such variations, and also increases their efficiency as ventilators.

There are many forms of automatic flush-tanks, most of which may be classed under the four following varieties: 1, Tilting Tanks; 2, Syphon Tanks; 3, Valve Tanks; 4, Collapsing Tanks.

Tilting tanks are so designed that as they fill the centre of gravity is changed, until finally the equilibrium of the tank is destroyed and the tank tilts over and empties itself. The tank is so adjusted that when empty it returns to its proper position. A tilting tank on a small scale is shown attached to the long leg of the syphon in Van Vranken’s flush tank, Plate XXI.

Syphon tanks are discharged by means of a syphon. They differ in the devices for starting the syphon. In places where the sudden rush of a considerable quantity of

*The following descriptions of flush tanks are taken mainly from the manufacturers catalogues.
water can be secured, no device is necessary. Where house sewage is collected in tanks for flushing, the rush of water caused by emptying a bath tub, wash tub, etc., will be sufficient to start the syphon. But where the tank is filled by a stream of water small enough to fill a tank holding but a few hundred gallons only once in twenty-four hours, some special arrangement will be necessary to start the syphon. This can be done by means of a small tilting tank on the long leg of the syphon, as in Van Vranken's tank; by a supplementary tank and syphon, as in Field's; by a ball cock, increasing the flow when the tank is nearly full, as in Vibbard's; by having the long arm of the syphon movable, as in Landon's; by a collapsing disk or tube, as in Chaplin's; by an automatic valve on the long leg of the syphon; by an aspirator; and in various other ways.

Field-Waring Flush-Tank.—The syphon invented and patented by Rogers Field and improved by Col. George E. Waring, Jr., consists (in the form shown) of an annular intaking limb, and a discharging limb at the top of which is an annular lip or mouth piece, the bottom of which is tapered to less diameter. The discharging limb terminates in a weir chamber which when full to its overflow point just seals the limb. Over the crest of the weir is a small syphon whose function is to draw the water from the weir chamber and thus unseal the syphon. At the lower end of the small syphon is a dam or obstruction to prevent its breaking. The main syphon is brought into action (on the tank being filled) by means of a small stream of water flowing over the annular mouth piece and falling free of the sides of the discharging limb. As soon as the lower end of the discharging limb has been sealed by filling the weir chamber the falling stream of water gathers up and carries out with it a portion of the contained air, thus producing a slight rarefaction.
FIELD-WARING FLUSH-TANK.

This rarefaction causes the water to rise in the intaking limb higher than in the basin outside, and hence increases the stream of water flowing over the mouth piece, which in turn increases the rarefaction, and the syphon is soon brought into full play.

On the tank being emptied to the bottom of the intaking limb the flow is checked, and the small syphon over the crest of the weir draws the water from the weir chamber, air enters the discharging limb, and the syphon is vented ready for the tank to again fill.
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Van Vranken's Flush Tank.—This tank consists of an ordinary syphon, to the longer or descending limb of which is applied a small tilting tank. The arrangement of the parts is shown in Plate XXI. The tilting tank is hung directly below the descending limb of the syphon, at such a level as to leave its mouth sealed at all times. The tilting basin is contained in a small cast iron chamber, built into the bottom of the flush-tank chamber proper. The action of the tank is as follows:

The water being admitted to the tank by an ordinary faucet, at whatever rate may be desired, gradually rises in the tank until it overflows from the ascending to the descending leg of the syphon and is collected in the tilting tank. As it accumulates in the tilting tank the center of gravity is thrown beyond the axis of support and the pan tilts, the water level in the basin being lowered about one inch. This produces a corresponding rarefaction in the syphon and brings it promptly into full action. When the tank ceases to discharge the tilting basin resumes its former position.

The Miller Automatic Flush Tank.—This flush tank is shown in Plates XXII and XXIII. Previous syphons have been brought into action by the simple release or rarefaction of the air confined in the syphon, or by the sudden removal of such air by special subsidiary devices, which are entirely absent in the "Miller" syphon. It consists of two simple Castings, a U tube or trap and mouthpiece, cast in one piece, and a cast-iron bell which is placed over the longer leg of the syphon, and is held in place by brackets cast on the trap. The action of the syphon is as follows: As the water entering the tank rises above the lower edge of the bell, it incloses the air within, the lower portion of the trap being, of course, filled with water. As the water level of the tank rises, the confined air
gradually forces the water out of the long leg of the trap, until a point is reached when the air just endeavors to escape around the lower bend. Now, as the difference of water level in the two legs equals the difference of the levels between the water in the tank and the water within the bell, it will be seen that the column of water in the short discharge leg has practically the same depth as the head of water in the tank above the level at which it stands in the bell. The two columns of water, therefore, counterbalance each other at a certain fixed depth in the tank. As soon as this depth is increased by a further supply, however small, a portion of the confined air is forced around the lower bend, and by its upward rush carries with it some of the water in the short leg, thus destroying the equilibrium. But the secret of this invention is the free projection of the overflow edge, which allows of the instantaneous escape or falling away of the heaved-up water. Thus, if the discharge mouth were formed as an ordinary bend, the syphon would not act (although the confined air rushes around the lower bend), for the simple reason that the heaved-up water has no means of instantaneous escape, and, therefore, the equilibrium is not sufficiently disturbed. It will thus be seen that the action of the syphon depends, not on the escape of air, but on the sudden reduction of a counterbalancing column of water.

Repeated trials have shown that a 6-inch syphon will discharge full bore a 500-gallon tank, fed so slowly as only to be filled in fourteen days. There being no internal obstruction, the discharge is extremely rapid.

**Rhoads-Williams Flush-Tank.**—The Rhoads-Williams syphon, as illustrated, consists of an annular intaking limb, and a discharging limb terminating in a deep trap below the level of the sewer. Below the permanent water line in the discharging limb, is connected one end of a small blow-off or relief-trap, having a less depth of seal than the main trap,
THE MILLER AUTOMATIC FLUSH TANK.
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THE MILLER AUTOMATIC FUSH TANK,
Combined with Manhole.
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the other end of which joins the main trap on the opposite side, at its entrance to the sewer and above the water line of the trap. At the same point is connected an upright vent pipe which rises through the tank to a point above the high water line, and is turned down through the top of, and into the intaking limb of the syphon, terminating at a given point above its bottom.

As the tank fills with water (the main and blow-off traps being full) it rises in the intaking limb even with the level of the water in the tank until reaching the end of the vent pipe, a volume of air is confined in the two limbs of the syphon between the water in the intaking limb and the water in the main trap. As the water rises higher in the tank the confined volume of air is compressed and the water is depressed in the main trap and in the blow-off trap. This process goes on until the water in the tank reaches its highest level above the top of the intaking limb at which time the water is depressed in the blow-off trap to the lowest point and the confined air breaks through the seal, carrying the water with it out of the trap, thus releasing the confined air and allowing an inflow from the tank, putting the syphon into operation.

On the tank being discharged to the bottom of the intaking limb, the flow is checked and the syphon is vented by the admission of air to it through the vent pipe.

The Lightning Automatic Flush-Tank.—The operation of this flush-tank is as follows: See Plate XXV.

The water rises in the tank till it reaches the float “F” of the lever, it also rises under the air chamber, but owing to compression of the contained air the water will rise only to within one inch below the top of the inner leg at the time its outer level will have reached the center of the float in the tank. The rising water acting on the float “F” then moves the lever “H” which holds down the hinged chamber “I.”
The instant the lever moves and releases the chamber the latter springs open on its hinges and the inner confined air bodily escapes. Gravity brings the chamber back to its original position immediately that the air has escaped, and full and complete syphonage takes place.

Valve Tanks.—In the valve tanks the valve is usually operated by a float which releases the valve when the water has reached a certain level.
PLATE XXV.

THE LIGHTNING AUTOMATIC FLUSH-TANK.
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Requirements to be Met.—The requisites for an automatic flush-tank are: 1, Certainty of action; 2, rapidity of discharge; 3, simplicity of construction; 4, ease of inspection of all its parts; 5, durability; 6, economy of cost and maintenance.

Strange as it may appear, there are flush-tank syphons, sold in considerable numbers, which cannot possibly be made to work under the usual conditions imposed by the requirements for flushing sewers.

Rapidity of discharge is next in importance to certainty of action. The sewer pipe should be filled for some distance in order to get the proper benefit from the flush.

In simplicity of construction the syphon tanks are superior to the valve tanks, and as durability is likely to depend upon simplicity of construction, the syphon tanks will, in general, be most durable.

Complicated mechanism is undesirable for use in a flush-tank, which must work automatically, and often for a long time without inspection. It is not at all uncommon to find that devices which look well on paper fail utterly when put to the test of actual service.

Quantity of Water Required.—An erroneous idea prevails as to the quantity of water required for flushing sewers by the use of automatic flush tanks. A properly designed system for a city of 10,000 inhabitants ordinarily requires from twenty to fifty flush-tanks, of a capacity of about 150 to 300 gallons, discharging daily, or at most twice a day. The maximum amount of water required is about two per cent. of the water supply. This momentary discharge does not sensibly occupy the capacity of the main sewers further down the line, being, as before stated, but a very small percentage of the ultimate discharge. An equally efficient flushing by a constant stream, applied directly and without the intervention of a flush tank would require an amount of
water materially encroaching upon the capacity of the main sewers, and would be inadmissible under ordinary conditions of water supply, on the score of economy.

Rapidity of Discharge.—Flush-tanks are ordinarily adjusted to discharge automatically once in each twenty-four hours. Their capacity of discharge should equal or exceed that of the pipe into which they empty.

Experiments made by the writer with a flush-tank of 7,000 gallons capacity, having a ten-inch outlet, opening into an eight-inch sewer, demonstrated that with the minimum grades indicated in Table XV, there was no danger of gorging the sewer at a distance of one or two hundred feet from the flush-tank, although the hydraulic head was seven feet and the capacity of the tank was sufficient to fill the sewer for a distance of 2,682 feet. At a distance of 600 feet the flow, as observed in a man-hole, did not fill the sewer.

In the case of flush tanks as ordinarily constructed the tank can hardly discharge too rapidly.

The rate of discharge from the tank should at least equal the capacity of the sewer when the flow has acquired the velocity due to its inclination. A sewer six inches in diameter, laid at a grade of five-tenths per hundred, discharges, when full, at the rate of 215 gallons per minute. The conditions above named would therefore require the tank to discharge at the rate of 100 gallons in 28 seconds or less.

Experimental Data.—Some valuable experiments were made upon the effect of flush tanks in the sewers in Washington, D. C., by Asa E. Phillips, Assistant Engineer, District of Columbia, and the results were presented by him in a paper read before the American Society Municipal Improvements, in October, 1898.
The following extracts are taken from his paper:

"No formula has been proposed for the volume of water required for different grades and sizes, and the only rule known to have been used appears to be of little value. This important detail is determined by individual judgment, generally unsuported by investigation or experience, so that the common practice has varied within a large range of values, while tanks of uniform size usually have been constructed regardless of differences in the size or gradient of the sewers to be flushed. The uncertainty as to the precise effect of the flush and the complex conditions as to contributing population, rate of water consumption, etc., have been justly considered a bar to any precision in this respect. Recent discussion of the subject, however, has tended to establish certain limitations in the use of flushing devices which should lead to improvement in the general practice.

"The work to be accomplished by the flush is the removal at regular and frequent intervals of solid matter flushed into the sewer from house laterals, and there stranded because of the shallow depth of flow and sluggish current and its carriage down the line to a point where the depth and velocity are sufficient to insure removal to the ultimate point of discharge. The efficiency of the flushing device in performing this work is not well understood. But little is known of the effect under the varying conditions encountered, especially for widely different grades and at considerable distance from the dead end. It is generally considered, however, that the effect diminishes very rapidly as the distance increases, and becomes almost imperceptible 500 or 700 feet from the tank, but, so far as can be ascertained, this has been observed only in cases of flush of small volume on flat grades, or where the depth of ordinary flow was considerable. Of the effect of discharge of 500 gallons or more, such as were used in the cases to follow, there appears to be no recorded observations, so that no comparison with those already published can be made. Several grade conditions have been selected for the purpose of illustrating the effect of the flush under such circumstances, and an attempt made to indicate by means of diagrams the different results obtained. For these no special accuracy is claimed, but in the few cases given the differences are sufficiently marked as to suggest certain conclusions therefrom.

"The Park street line is the first of these. This sewer is 12 inches in diameter, about 1,870 feet in length, and has a uniform grade throughout of 9 inches per 100 feet. Preliminary examination discovered slightly unfavorable conditions for experimental work, such as an uneven grade, rough joints, and poor alignment in places, all of which affected the observations and results to some extent. It may now be stated that, with the exception of the Chapin street line, the sewers cited are old and generally possess these irregularities, but, excepting slight silt accumulation at points distant from the basin, they were found to be very clean. The presence of even a small amount of silt in
the invert, particularly at man-holes, undoubtedly affected the flow and was the chief source of error in the observations.

"The tank on Park street was found to have an effective capacity of 84 cubic feet, or about 630 gallons, and discharged through an 8-inch syphon in the mean time of forty-two seconds. No attempt was made to determine the velocity at the point of discharge, but this data would indicate an approximate mean velocity of 6 feet per second. Observations of the flush were simultaneously taken at all of the man-holes, and the depths of flow were recorded at intervals of fifteen seconds or less. These depths were referred to the time of syphon discharge, and the diagrams of the flush have been constructed from this datum.

"The first diagram, (Fig. 1, Plate XXVI), shows the form of the flush wave as taken at five consecutive man-holes within 1000 feet of the tank. The lower four man-holes were not platted because of the confusion of lines that would result, but the data are given in Table XXII. This diagram and tabulation show how well the depth of flow is maintained for very long distances. One thousand feet from the dead end the flush is very efficient, and at a distance of nearly 2,000 feet appears to be quite effective. This large radius of effect is doubtless due to the volume of water used, as published data for smaller discharges indicate that a tank of half this capacity would have a very greatly diminished influence.

**TABLE XXII.—Park Street Sewer.**

CAPACITY OF TANK, 84 CUBIC FEET = 630 GAL.; TIME OF DISCHARGE, 42 SEC.

<table>
<thead>
<tr>
<th>Manhole</th>
<th>Site (Diameter)</th>
<th>Gradient</th>
<th>Distance from dead end</th>
<th>Depth of Flow</th>
<th>Duration of greatest effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inches</td>
<td>Per cent.</td>
<td>Feet</td>
<td>Inches</td>
<td>Inches</td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>0.75</td>
<td>200</td>
<td>3/4</td>
<td>3/4</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>0.75</td>
<td>382</td>
<td>7/8</td>
<td>7/8</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>0.75</td>
<td>572</td>
<td>1 1/2</td>
<td>6 1/2</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>0.75</td>
<td>738</td>
<td>1 1/2</td>
<td>5/4</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>0.75</td>
<td>948</td>
<td>1 1/4</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>0.75</td>
<td>1,132</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>12</td>
<td>0.75</td>
<td>1,332</td>
<td>1 1/4</td>
<td>4 1/2</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>0.75</td>
<td>1,406</td>
<td>1 1/4</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
<td>0.75</td>
<td>1,688</td>
<td>1 1/4</td>
<td>3 1/2</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>0.75</td>
<td>1,869</td>
<td>1 1/4</td>
<td>3 1/2</td>
</tr>
</tbody>
</table>

"The second diagram for this line, (Fig. 2, Plate XXVI), shows the computed velocity curve for the ordinary flow, the assumed velocity to prevent sedimentation and the accelerated velocity due to the flush. These curves are not
supposed to be precise, but they illustrate the purpose of the flushing device, and to some extent the degrees of effectiveness required. The curve of normal flow shows the very low velocity along the upper portion of the line, and its gradual increase approaching the required velocity at the lower end, while the flush curve shows a corresponding high velocity at the upper end and its rate of fall toward the 2½-foot-per-second velocity, where in theory at least it would seem that the two curves meet at a common tangent point. In this sewer, it may be noted, the normal flow does not attain a rate of 2½ feet per second, and probably would not for a distance of 2,000 feet. It is also to be observed, however, that the flush would seem to maintain this velocity for a distance probably as great; so that, so far as these observations go, they indicate that for this very long line and flat grade the flush tank is efficient and of the proper size.

"The second series, taken on one of the Connecticut avenue sewers, is chiefly interesting as showing the effect produced on a varying and decreasing gradient.

**TABLE XXIII.—Connecticut Avenue Sewer.**

**CAPACITY OF TANK, 82 CUBIC FEET—515 GAL.; TIME OF DISCHARGE, 45 SEC.**

<table>
<thead>
<tr>
<th>Manhole</th>
<th>Size (Diameter)</th>
<th>Grade</th>
<th>Distance from dead end</th>
<th>Depth of Flow</th>
<th>Duration of greatest effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inches</td>
<td>Per cent.</td>
<td>Feet</td>
<td>Inches</td>
<td>Inches</td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>1</td>
<td>175</td>
<td>½</td>
<td>5½</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>1</td>
<td>325</td>
<td>1½</td>
<td>5½</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>0.4</td>
<td>473</td>
<td>1</td>
<td>5½</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>1</td>
<td>613</td>
<td>1½</td>
<td>3½</td>
</tr>
</tbody>
</table>

"The diagram, (Fig. 3, Plate XXVI), illustrates the diminished velocity and enlarged area of section of the flush wave, as recorded at man-hole No. 3, showing the marked effect of the diminished rate of grade in the portion of the sewer immediately above. Unfortunately this could not be further observed, owing to a change in gradient from this point. It probably indicates, however, that for a line of varying slope the minimum should be considered in fixing the capacity of the tank.

"The third series was taken on the Chapin street sewer, which has the reversed conditions of a varying but rapidly increasing gradient. The observed effect of the flush is very clearly shown by the diagram, (Fig. 4, Plate XXVI). The rapid run-off and greatly reduced area of section toward the lower end of the sewer indicate the very high velocity which such steep slopes must produce. In this case the minimum grade being 1 per cent., and that for a length of only
190 feet, a flush tank of considerably less capacity would probably be sufficiently effective, if, indeed, for such grade conditions automatic flushing is at all necessary.

**TABLE XXIV.**—Chapin Street Sewer.

**CAPACITY OF TANK 83 CUBIC FEET—620 GAL.; TIME OF DISCHARGE, 48 SEC.**

<table>
<thead>
<tr>
<th>Manhole</th>
<th>Size (Diameter)</th>
<th>Grade</th>
<th>Distance from dead end</th>
<th>Depth of Flow</th>
<th>Duration of greatest effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inches</td>
<td>Per cent</td>
<td>Feet</td>
<td>Inches</td>
<td>Inches</td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>1</td>
<td>190</td>
<td>½</td>
<td>6⅔</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>2</td>
<td>350</td>
<td>¾</td>
<td>4½</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>5.6</td>
<td>490</td>
<td>¾</td>
<td>3½</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>9</td>
<td>795</td>
<td>¾</td>
<td>5</td>
</tr>
</tbody>
</table>

"The fourth series, taken on one of the Thirty-second street sewers, shows the observed effects on a nearly uniform steep grade. The first diagram, [Fig. 5, Plate XXVI], for this line shows the form of the flush wave as observed at each manhole. The quick run-off and nearly uniform area of section maintained indicate the piston-like effect of the discharge. In fact, the flow was so rapid and so quickly past as to render the taking of the observations rather difficult and their relative accuracy to some degree uncertain.

**TABLE XXV.**—Thirty-Second Street Sewer.

**CAPACITY OF TANK 84 CUBIC FEET—630 GAL.; TIME OF DISCHARGE, 48 SEC.**

<table>
<thead>
<tr>
<th>Manhole</th>
<th>Size (Diameter)</th>
<th>Grade</th>
<th>Distance from dead end</th>
<th>Depth of Flow</th>
<th>Duration of greatest effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inches</td>
<td>Per cent</td>
<td>Feet</td>
<td>Inches</td>
<td>Inches</td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>4</td>
<td>75</td>
<td>¼</td>
<td>4½</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>4</td>
<td>265</td>
<td>¾</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>4.1</td>
<td>485</td>
<td>¾</td>
<td>5½</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>5.0</td>
<td>725</td>
<td>⅓</td>
<td>5</td>
</tr>
</tbody>
</table>

"The curves here and there seem to suggest such unavoidable irregularities, but the general effect is very clearly shown. The second diagram, [Fig. 6, Plate XXVI], indicates the approximate velocity attained by the flush in
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connection with the assumed 2½ feet per second constant, as well as the estimated velocity of ordinary flow. This shows in another form the marked effect of the discharge on a steep slope, and also how quickly on such grades the normal flow attains sufficient velocity to prevent deposit. From a study of these diagrams we may conclude that the flush increases rapidly in effectiveness as the grade increases, having a remarkable scouring power on grades of 4 per cent. or more, but at the same time the necessity of automatic flushing decreases correspondingly, there being apparently little need for such a device on slopes approaching 4 per cent."

"As has been seen, no attempt is here made to indicate the results with a variable volume of discharge for the purpose of determining the comparative radius of effect under such circumstances. This and other interesting details are necessarily omitted, an effort having been made only to show the general influence of the slope on the flush, and, in a limited way, the range of effect."

Some valuable data on the effectiveness of flush-tanks has also been secured by Mr. H. N. Ogden from experiments at Ithica, N. Y., a record of which appears in the Transactions of the American Society of Civil Engineers, December, 1898.

Plate XXVII is reproduced from Mr. Fuertes discussion of the data in the Transactions and the following extract is also from his discussion:

"On the diagram, Plate XXVII, is shown the form of the flushing wave discharged into the Green street sewer, drawn from the author's data. A profile of the wave is shown at the end of the 1st, 2nd, 3rd, 4th, 6th, 8th and 10th minutes. In this diagram the shapes of the waves are not claimed to be exact as to profile at all points. They are accurate at the points where they cross the man-holes, and the positions of the toes of the waves were interpolated; the remaining portions of the curves are sketched in.

"The velocities corresponding to the greatest depths of flow were calculated by the Kutter formula, (n=0.01). The velocities marked for the toe of the wave are the components, along the bottom of the sewer, of the velocities of the surface of the water at the given points when the wave reaches those points.

"At the first man-hole the sewer was nearly full, and probably had been running under a head up to within about 60 feet of the man-hole. After passing this point the foot of the descending body of water, under a-free flow by gravity, rushed forward rapidly, the point being 135 ft., 265 ft., 391 ft., 513 ft., 630 ft., 743 ft., 852 ft., and 957 ft. distant from the man-hole in 1, 2, 3, 4, 5, 6,
General Statements.—From the observed facts above quoted, and also from the theory of hydraulics, the following general statements concerning the efficiency of flushing may be made:
The efficiency of flush is proportional to
(1) The velocity of flow;
(2) The depth of flow;
(3) The duration of flow.

The velocity of flow is proportional to the rate of discharge and the inclination of the sewer. (We are now considering sewers of a given diameter.) The inclination being fixed and uniform the velocity is ordinarily less as the distance from the flush tank increases.

The depth of flow is proportional to the rate of discharge and (under the conditions usual in sewers) inversely proportional to the inclination of the sewer. The rate of discharge being fixed and the inclination being fixed and uniform it is usually less as the distance from the flush-tank increases.

The duration of flow is proportional to the quantity and rate of discharge and inversely proportional to the inclination of the sewer. Under the usual conditions of quantity, rate and inclination, the duration of flow is greatest at points farthest from the flush tank. This naturally follows from the fact that the wave crest becomes lower and the velocity less as the distance from the tank increases as illustrated in the diagrams.

The velocity and depth of flow are interdependent. Depth of flow is particularly advantageous as it induces velocity. Depth of flow is desirable, however, independent of its influence on velocity since it increases the cleansing contact at the sides of the sewer, increases the section of stranded matters which are exposed to the current, and, by a greater degree of immersion makes their hold upon the invert of the sewer less stable.