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Methods of Distribution of Sewage in Sewage Filtration Plants

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METHODS OF DISTRIBUTION OF SEWAGE IN SEWAGE FILTRATION PLANTS

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METHODS OF DISTRIBUTION OF SEWAGE IN SEWAGE FILTRATION PLANTS.

INTRODUCTION.

The method of sewage distribution used greatly affects the results obtained in sewage purification plants. Its importance can not be overestimated and a knowledge of this subject is indeed necessary for a Municipal Engineer. Many of the refinements attempting to provide more nearly ideal surface distribution such as rotating and travelling devices or fixed nozzles of perfect distribution of flow, would become unnecessary if the filtering material would distribute the flow.

It is surprising however that there is hardly any available data about the subject or in other words, little has been done along experimental lines on this subject. Probably the best article is that written by W. G. Taylor in the Engineering Record on "Subsurface Distribution in Percolating Sewage Filters."

This thesis has a two-fold object: First; To review the methods of sewage distribution in sewage filtration plants that have been or are in use. Second; To perform some experiments, arrive at certain conclusions as to the nature of distribution thru sand and broken stone, and determine the factors that may affect this distribution.

REVIEW OF THE METHODS OF SEWAGE DISTRIBUTION USED IN SEWAGE FILTRATION PLANTS.

The method of sewage distribution used at a purification plant depends upon the system of purification employed. There are four principal systems of purification, namely:-

(1) by broad irrigation and sewage farming,

(2) by intermittent filtration thru sand,

(3) by the use of contact beds,

(4) by trickling or percolating filters.

The method of distribution for each will be considered separately.

Broad Irrigation and Sewage Farming.

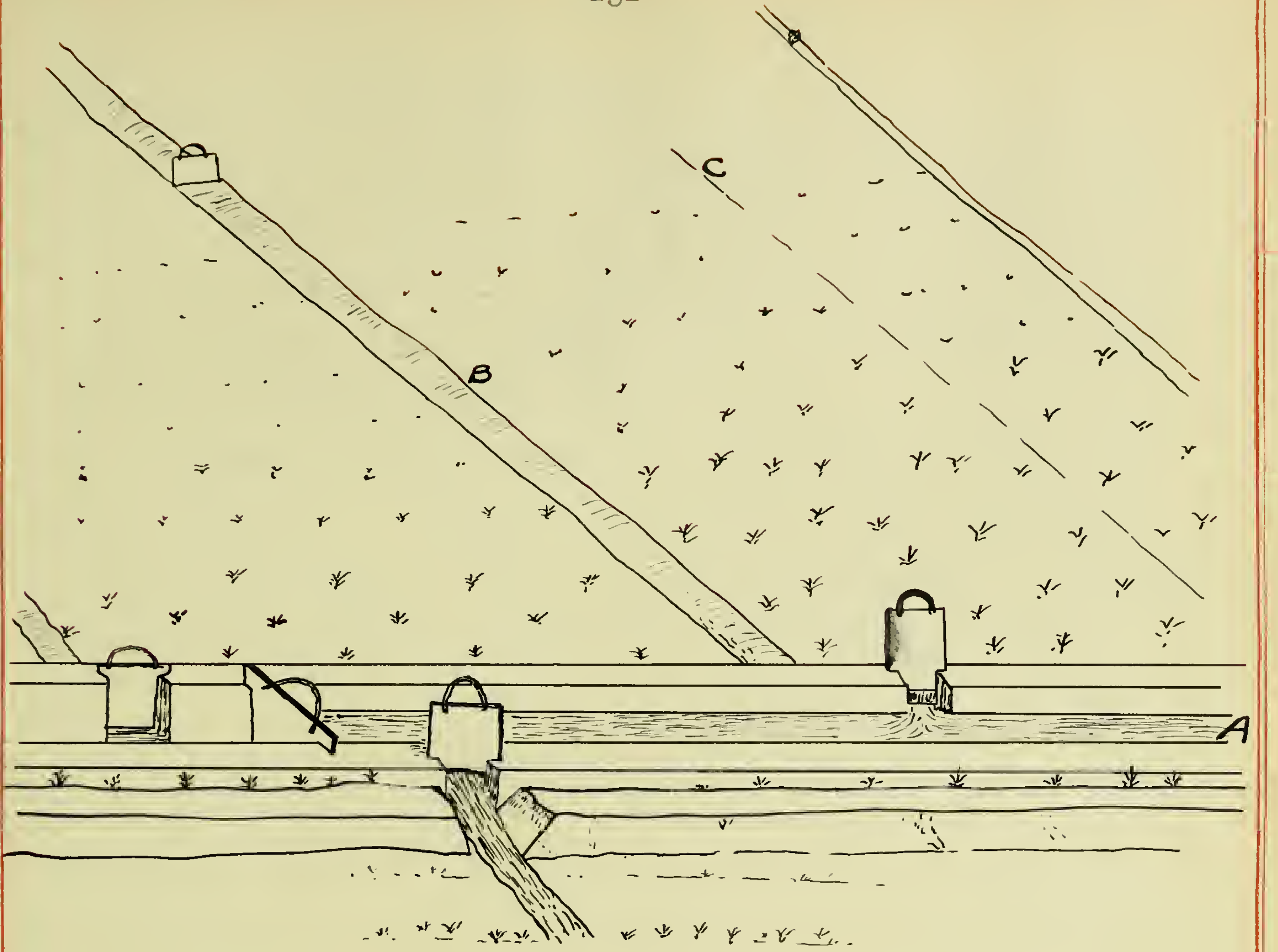
The most natural method of sewage disposal in localities not favored by the location of rivers or lakes, is irrigation. The earth absorbs the liquid and by the aid of bacterial action the constituents are changed to harmless compounds, some of which serve as food for plants. It is well known that China and Japan have disposed of sewage by this method for thousands of years. In Europe the same principle was applied at a very early date. For example Sausanne discharged all its sewage into a small brook which was used for irrigation purposes.

The British Metropolitan Sewage Commission of 1884 defined irrigation as "The distribution of sewage over large surfaces of ordinary agricultural land, having in view a maximum growth of vegetation (consistent with due purification) for the amount of sewage applied." It must not be supposed that all soils are suitable for irrigation. Clay soil as well as peaty soil are unsuitable for irrigation purposes.

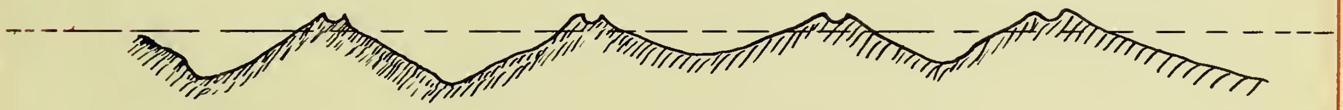
The simplest method of distribution is known as contour irrigation or ridge irrigation. On sloping ground the sewage is first brought to the highest point of the land and allowed to flow over a small plot of land. It is then collected in a channel from which it is evenly distributed over the next lower plots. In very steep ground it is necessary to construct a large number of channels and dams in order to retain the sewage longer and to effect more even distribution. In more or less level land, ridge irrigation is adopted. The following figures on page 5 illustrate this system.

The sewage from the sewers or tanks enters a distributing channel A, which commands the whole of the area, and to which are connected at right angles smaller distributing channels such as B. From the latter, which are blocked at the lower end, the sewage percolates thru the soil and when they are full, overflows the surface of the plots and passes into the lower channels C. These collecting channels communicate with a second distributing channel D, from which the sewage passes along smaller distributing channels as before and is irrigated over another series of plots.

In Germany, whenever possible market gardening is carried on on sewage irrigation plots. The sewage is not allowed to flow off the surface of the land,but is compelled to filter thru the soil. In this broad irrigation the sewage is conveyed to the land along channels as in figure A. The land however is not flooded, and the distributing channels are only partly filled so that the sewage can only enter the beds from



Bird's Eye View.



Cross Section.

FIGURE A.

RIDGE & FURROW
IRRIGATION.

the side and beneath the surface.

Another method used is the so-called flood method, in which a piece of land usually from five to twenty-five acres in extent is surrounded by earthen banks and flooded with sewage to a depth of ten to twenty inches. This method is used only in isolated cases as a winter method.

There is another method and that is the so-called subsoil irrigation. Sewage is applied to the soil intermittently by discharging the fluid in periodical doses into a specially constructed system of distributing tiles buried in earth.

Intermittent Filtration Thru Sand.

The practical development of sewage purification, along intensive lines, and by the application of scientific principles, made little advance before the experiments of Sir Edward Frankland in connection with the first report of the Rivers Pollution Commission of Great Britain. In the year 1881 the report of the Massachussetts State Board of Health on work done at the experiment station at Lawrence awakened further interest along this line.

" Intermittent filtration differs from broad irrigation as a controlled scientific process differs from a merely empirical one." Sewage is not poured over any convenient plot of land, but specially selected areas of sand and gravel of proper fineness and uniformity of size are used.

The beds are carefully under-drained so that the sewage shall filter thru a thickness of four or five feet of aerated sand, instead of allowing the sewage to find its way as best it may. The quantity of sewage applied is so regulated by intermittent closing that the bed may not be waterlogged. As compared with broad irrigation, the volume of sewage treated per unit area by sand filters may be increased tenfold by the regulated intermittent process, that is; the rate may be from 50,000 to 100,000 gallons per acre per day as against 500 to 10,000.

The methods of sewage distribution in intermittent filtration are much like those of broad irrigation. One of the

methods is as used at Brockton and described in "Sewage Disposal" by Kinnicut, Winslow and Pratt. " The sewage is distributed on the surface of the beds by carriers laid across the bed from the center of one side. They are simply flat-bottomed sluiceways reducing from a width of five feet at the inlet to one foot at the extreme end by a series of offsets of six inches on each side. At each offset is an opening controlled by slanting wooden gates."

Figure A, page 9, shows a section of a cheaper type of distributing sluice. This distributor is made entirely of wood. The objection to this type is that if the wood used is soft, the distributors are liable to become saturated with sewage and give rise to objectionable odors. However, the distributor is commendable on account of its cheapness.

It is absolutely necessary for the successful operation of a filter that the application of sewage be intermittent. Sufficent time should also be allowed between doses for the organic matter to be entirely reduced, otherwise the surface of the filter bed will become clogged with organic matter. For an intermittent sand filter, treating average sewage, in moderate climates, it seems best according to Cosgrove, to divide the daily dose into four portions to be applied at equal intervals of six hours. During winter weather in cold climates, it is better to apply larger doses at less frequent intervals to prevent freezing of the beds.

A SECTION of a DISTRIBUTING SLUICE USED in INTERMITTENT FILTRATION.

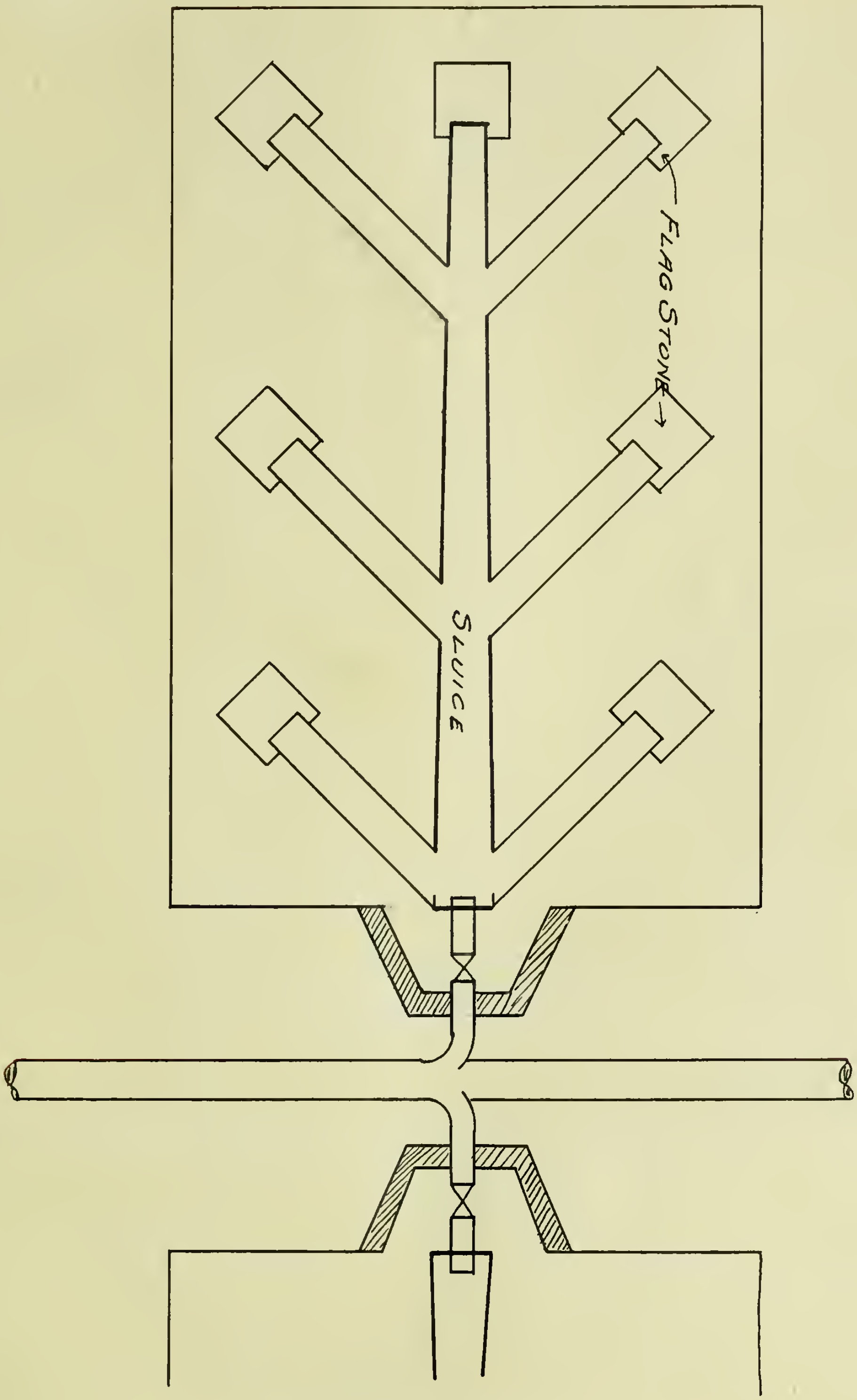


FIGURE A1.

Contact Beds.

The practical development of artificial biological processes will not be followed here, but the first experiments along this line were made in London. The works in Massachusetts, Sutton, and Hamburg are the most notable ones that led to the further developments of Contact beds.

The principle involved in this process is the removal of putrescibility by bacterial purification. The process on the whole is biological and differs from broad irrigation and intermittent filtration in that this process is carried on in artificially constructed filters, instead of being carried out in naturally occurring soils. The process is termed Contact beds because the sewage remains for some time in contact with the filtering material. One of the important factors in this process is the period of aeration. In land filtration the period of aeration extends over the whole period of working. In the contact process, biological action is suspended by keeping the beds full of sewage.

Another factor in this process is the size of material and the area of surface exposed. The finer the material, the greater is the reduction of oxygen absorbed as shown by experiments performed by Dunbar. The most important result in the experiments is the fact that contact beds clog up, even when constructed of material which is very resistent to weathering action.

The methods of distribution used in the contact beds re-

semble those used in intermittent filtration except that the distributors are modified so as to suit the conditions in this process. This is accomplished by having a sluice gate at the outlet to cut off the flow and hold the sewage in contact for the full period.

In the earliest beds constructed, the sewage was intended to flow away thru channels covered with perforated plates; but the holes in these plates soon became stopped, and the beds could not run dry, which interferred with the quantitative and qualitative results produced by the beds. At the present time, it is considered the best practice to lay the drains so that the bed may be emptied in one half hour. To accomplish this, at some places, contact beds have been constructed with what are practically false bottoms made of tiles separated from each other by a space of about a quarter or half an inch. At other places the drains are laid in the cement concrete and covered with perforated tiles so as to prevent the falling of the filling material into the drain. Some times the drains are of pipe laid with open joints. Distributors for contact beds are similar to those used to distribute sewage in intermittent sand filters, although, instead of wooden or concrete sluices, trenches may be made of cinders, which will allow the liquid portion of the influent to seep thru and at the same time act as a strainer to hold back the coarser particles of matter. When cinder sluices are used they are shaped roughly like wooden sluices and likewise have branches to conduct sewage to various parts of the bed. It is not necessary to have

a pavement on the surface of filling material, where water leaves the troughs, because the material of the contact bed is too coarse to be easily disturbed, and even if it were disturb- it is not vitally important to keep the surface of the bed level.

Percolating Filters.

In 1893 the first description of a method for sewage treatment based on the plan of trickling filter over coarse material with natural aeration was published by Stoddart. Stoddart, Corbett, Ducat, Scott-Moncrief and Whittaker are the pioners in the development of the trickling filter.

Described in simplest terms, a trickling filter is a heap of selected filling material. Mr. Rudolf Hering in a summary of the principles of sewage treatment has pointed out that the main engineering factors in the operation of the trickling bed are: (1) the area of the bacterial surface on the stones in the filter, (2) the amount of oxygen available for the oxidation of the organic matter and (3) the time of exposure. Hence the size of the filling material, the amount of air supply and the rate of flow are the essential factors in a percolating filter.

The conditions in a percolating filter are far more favorable for the process of absorption, decomposition and oxidation than in a contact bed, and hence it becomes a question merely as to whether the even DISTRIBUTION necessary for a percolating filter presents greater technical difficulties and costs more than carrying out the contact or some other process. In other words the DISTRIBUTION of the sewage in a fine spray over the filter surface is the chief problem in the construction of a trickling bed and its successful operation.

Early in the history of percolating filters three dis-

tinct types of distributors were used. First; Lowcock and Waring tried to secure distribution by spreading a layer of fine material over the whole surface of the bed forcing air under pressure into the middle layer of the bed. This method is now very rarely attempted. Second; The Tipping bucket and troughs used by Scott-Moncrieff and Ducat, were placed at intervals over the filter, relying on the dash to distribute over intermediate areas. The third type of distributor is the dripping tray, devised by F. Wallis Stoddard. It is practically a series of channels over the sides of which the sewage flows continuously, dripping from a series of points on the underside, 340 to 400 points being allowed to a square yard. Figure B from page 193 of Dunbar's Principles of Sewage Treatment shows the distributor.

The necessary even distribution is only obtained when the distributors are perfectly level and any deviation causes bad results. Theoretically it should give even distribution but the channels are not only liable to buckle but also are subject to serious clogging. The systems that have attained a rather general acceptance include the use of movable sprinklers and systems of stationary sprinklers. Figure C from Dunbar's Principles of Sewage Treatment shows Corbett's Sewage Distributor for intermittent action. The distribution of sewage over the surface of filters is effected by feeding the pipes from a tank in which the sewage collects and from which it is emptied by syphonic action, the sewage is first sprayed to the further portions of the filter, and as the

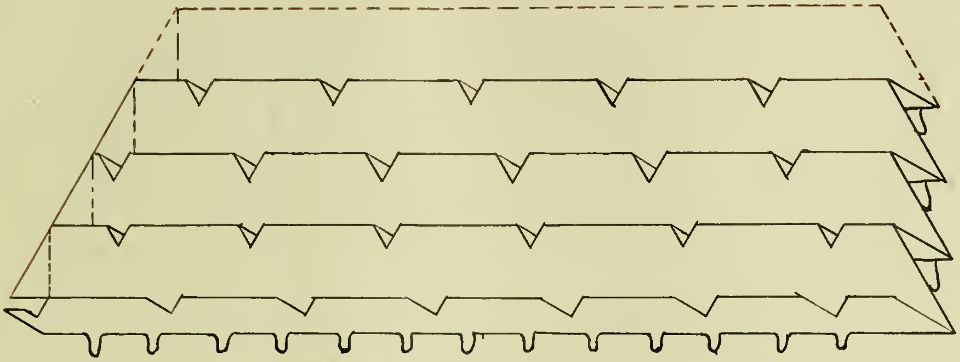


Figure B
Stoddard's Distributor.

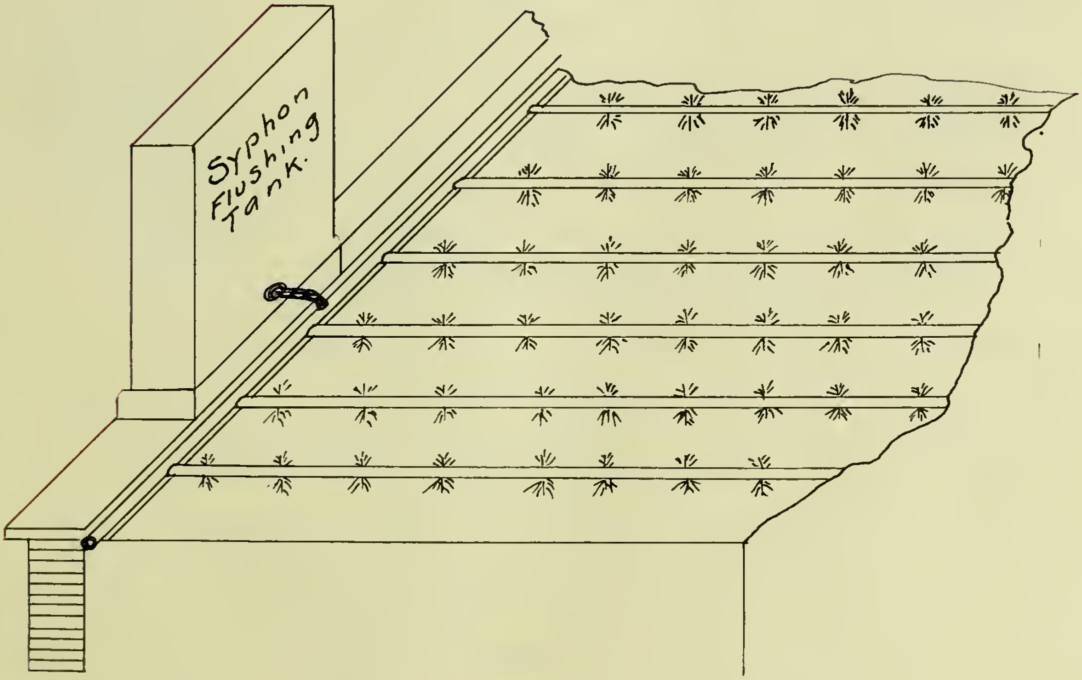


Figure C
Corbett's Sewage Distributor.

water level in the tank sinks, the nearer portions receive their dose. However the distribution of sewage over the surface of filters by means of fixed perforated pipes will never be very even. The movable type has movable sprinklers which rotate or travel back and forth over the surface of the bed.

Movable distributors may be subdivided into two classes, according as they are driven by the head of the sewage itself or actuated by special applications of power.

The first to come into use belong to the first type. The distributing apparatus consisted of a number of perforated iron pipes radiating from a central pillar and revolving about it, receiving sewage from the center and discharging thru holes all on one side of the pipes, so that the reaction of the escaping sewage caused the arms to revolve in the opposite direction. The Candy-Whittaker distributor is a form of this type. In general the arms of the distributors are fed from below. This requires the apparatus to be water tight under pressure.

Another form of revolving sprinkler designed by Mather and Platt is driven by a turbine wheel in the central pillar. Figure E on page 17 from Dunbar's Principles of Sewage Treatment shows the plan of the distributor. Still another entirely different type of automatic distributor depends on power developed by discharging the sewage over a sort of movable water wheel so that the impact of the sewage from the trough revolves the wheel. The Fiddian distributor is an example of this kind.

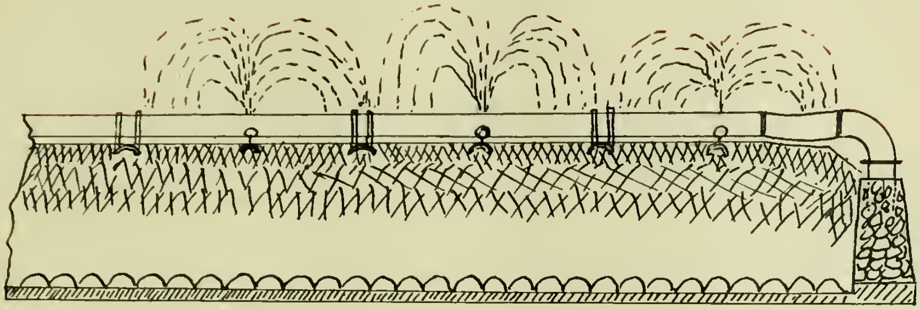


FIGURE D BIRMINGHAM FILTERS
SHOWING DISTRIBUTORS.

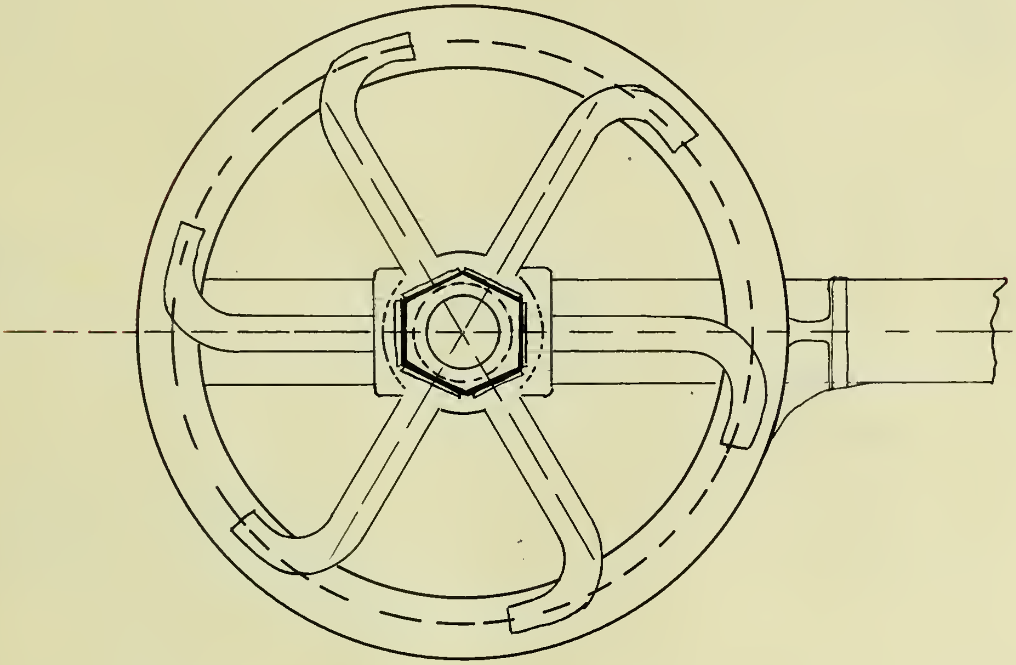


FIGURE E. MATHER and PLATT SPRINKLER
driven by Turbines.

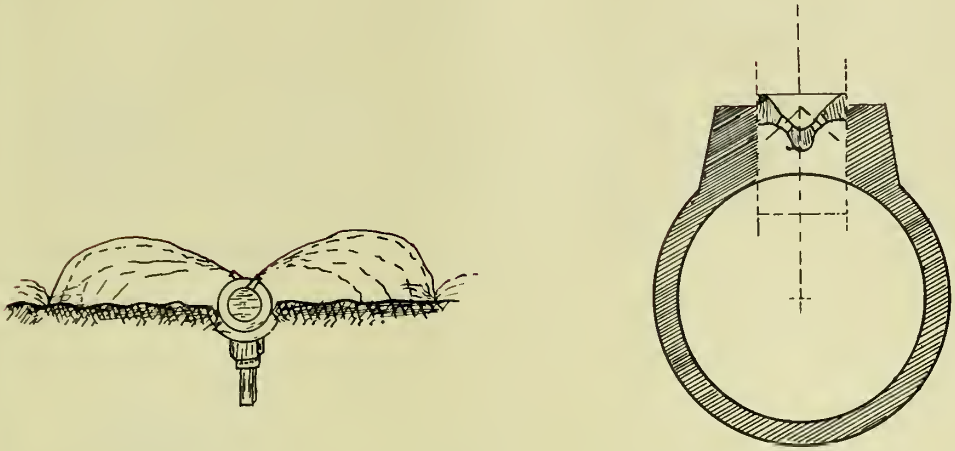
Where there is insufficient head for any of the above mentioned automatic devices, power-driven sprinklers have been introduced in many English towns. Figure D shows a view of the Birmingham filter distributors which are of this type.

All the movable distributors may give excellent results as far as even distribution is concerned but they are costly to install and are liable to be frequently out of order under the best conditions. Moreover they are hard to operate in severe winter conditions without protecting the whole filtering area by a roof. Several methods of dosing trickling beds from fixed sprinkler nozzles have been used.

The latest developments are; to form a spray by the impact of two converging flows and the use of a special form of opening to give a rotating movement to the stream. A noted example of the converging flow of nozzle is the Gjers and Harrison fixed spray jet which is shown in figure F. Corbett used this nozzle at Salford and it has given satisfactory distribution. This type has also been used by Watson at Birmingham on a very large scale. See Figure D page 17.

The Columbus sprinkler is shown in Figure G on page 19. It has a clear aperture of 9/16 of an inch with an inverted cone supported above by lateral arms. This type was designed by Hering and Fuller. To aid in securing uniform distribution attempts have been made to use intermittent dosing, and by designing sprinklers to discharge a square rather than a circular spray. At Chesterfield in England the nozzles were arranged to discharge intermittently, so as to spread the sewage more

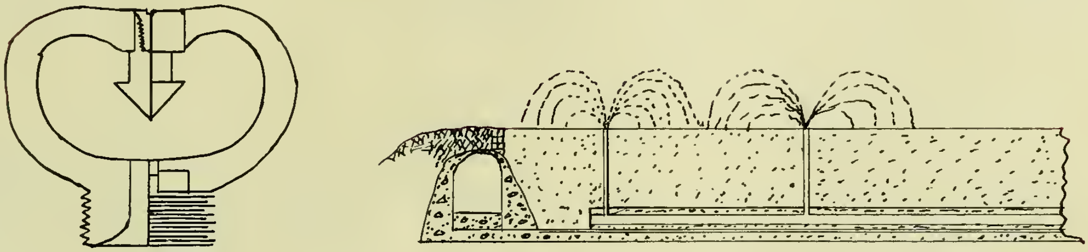
TYPES of NOZZLES for SEWAGE SPRINKLERS.



A Gjers & Harrison Fixed Spray Jet in Action.

Gjers & Harrison Spray Jet. Impact of Converging Flows.

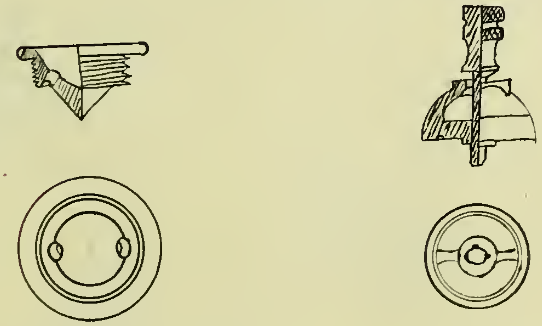
FIGURE F.



COLUMBUS Sprayer

Columbus Sprayer in Action.

FIGURE. G.



Salford - Old Style.

Birmingham

FIGURE G'.

evenly over a wide area. At Columbus intermittent dosing was made a part of the design. It has been found that it is best to discharge sewage on each bed in rotation under three different heads. The net result of this process is to secure excellent distribution, as shown in the table below, compiled by Fuller in 1909.

Distribution of Sewage over the Columbus Filters in Gallons per Foot per Minute.

(Fuller)

Distance from nozzle	Nozzle Head			Average for cycle
Feet	4 feet	7 feet	9 feet	
1.0-1.5	0.012	0.011	0.010	0.011
1.5-2.0	0.03	0.012	0.012	0.018
2.0-2.5	0.070	0.017	0.016	0.034
2.5-3.0	0.014	0.025	0.020	0.061
3.0-3.5	0.230	0.037	0.029	0.098
3.5-4.0	0.22	0.053	0.037	0.103
4.0-4.5	0.200	0.074	0.050	0.108
4.5-5.0	0.110	0.098	0.062	0.090
5.0-5.5	0.053	0.124	0.078	0.085
5.5-6.0	0.024	0.136	0.096	0.085
6.0-6.5	0.011	0.137	0.131	0.091
6.5-7.0	0.005	0.108	0.155	0.089
7.0-7.5	0.002	0.090	0.175	0.089

Recent experiments made by the city of Philadelphia show better results by filters operated continuously rather than intermittently.

EXPERIMENTAL INVESTIGATION.

Tests were made to prove whether or not perfection in aerial distribution is essential; to show the amount of distribution affected by the filtering material; and to determine the factors that govern the distribution.

Description of Apparatus and Operation.

The Apparatus used consisted of a miniature filter having for its bottom screens such as are used in locomotives as spark arresters, supported by blocks of wood. The sides of the filter consist of boxes of varying sizes (depending on the nature of the experiments) having both top and bottom open.

The screen has a mesh of 0.2 inch. It consists of steel rods 0.5 inch in diameter. All rods in one direction are nearly straight while those at right angles to the former are bent. Figure 1 shows the screen.

Figure 2 shows the arrangement of the piping and tanks to which water is run from the pumping station of the University and from which it flows to the filter. The arrangement of the apparatus is shown in figure 3.

The operation is carried on as follows:- Water is led from the pumping station to a tank, A (shown in Figure 2) Then it is conducted thru a pipe, ab, to a regulator as

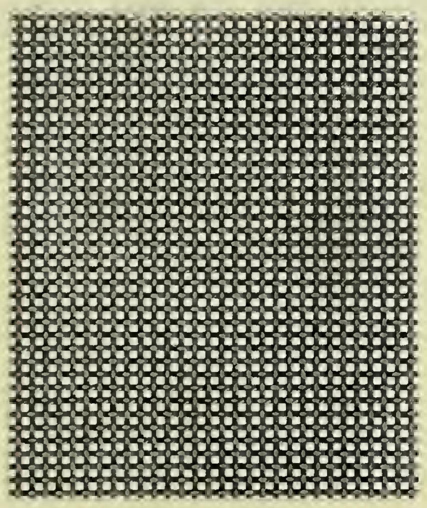


FIGURE 1.

SCREEN for SUPPORTING FILTERING MATERIAL

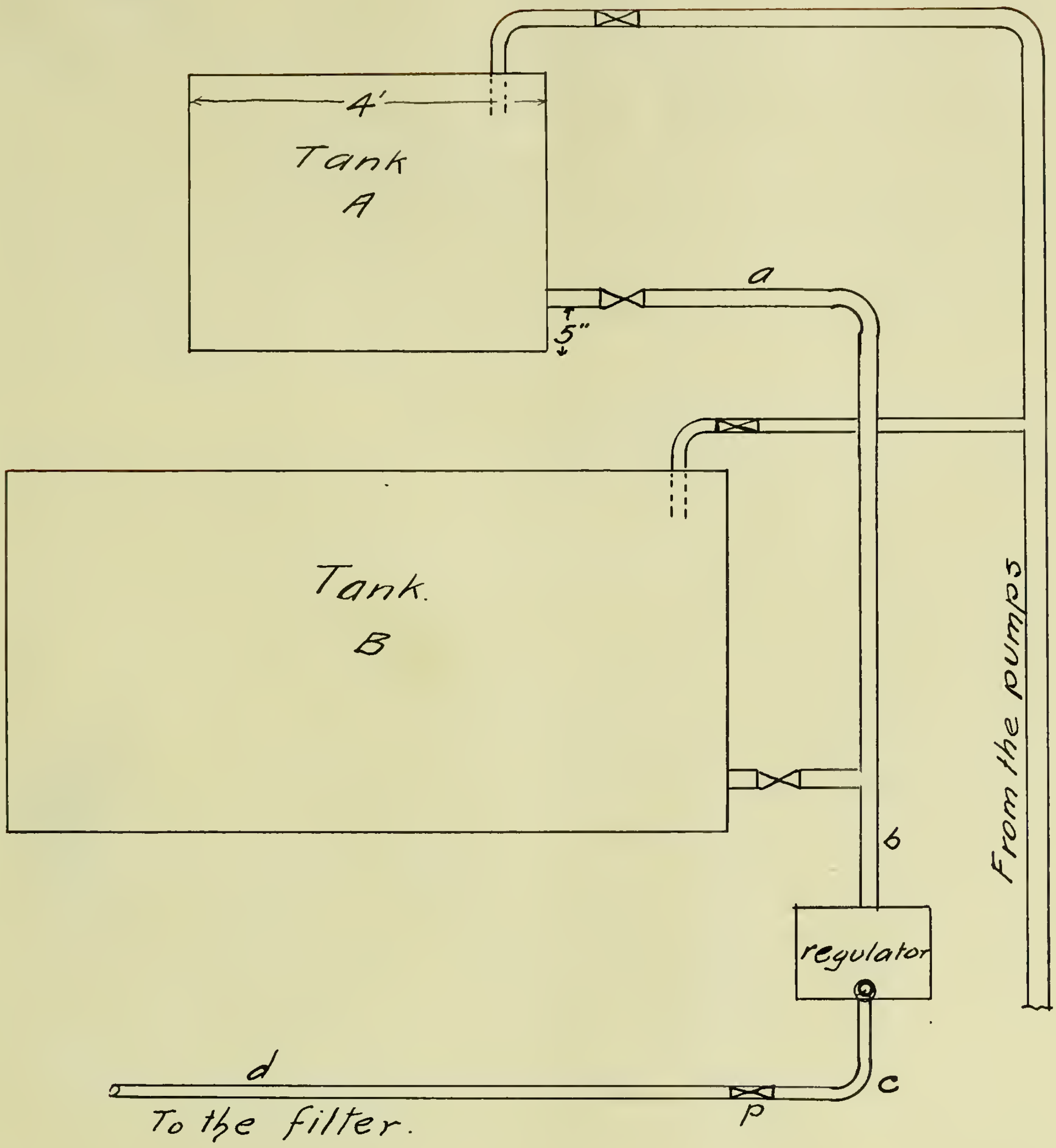


FIGURE 2.

SIDE ELEVATION of TANKS and PIPE CONNECTIONS.

shown. From here it runs thru a pipe, cd, regulated by means of a valve P. The water then flows to the filter. Cups 3 1/2 inches in diameter and 2 1/2 inches deep are placed at various distances from the outlet, in order to measure the amount of water falling after a certain period of time. By varying the depth of sand or broken stone, the size of the filter, and the rate of the water the distribution of the water may be determined as affected by these factors.

Data and Results.

Experiments with Sand:- In the first trial sand 5 1/4 inches deep over about 3/4 of an inch of gravel was placed in a box 24 inches by 21 inches. The results of test no. 1 show that cups no. 1 and 3 receive most of the water in all places tested. There does not seem to have been an even distribution here. Why no. 3 cup should receive more water than any of the others except no. 1 the writer did not at once see. Test no. 2 shows identical results. The water seems to be distributed proportionally from the inlet except towards no. 3 cup. After more tests it was found that iron pipes used as a support were not level and that water ran on the pipe from one end of the filter to another, incidentally falling on no. 3 cup. The pipe was then made level and different tests were made. Test no. 3 shows that the water was distributed unevenly as is shown by depth of water caugh in cups no. 2 and 4 which were expected to have about the same amount. The cause of this was found to be due to slope.

Test no. 4 was performed when the depth of sand was in-

Figures showing Arrangement of Apparatus.

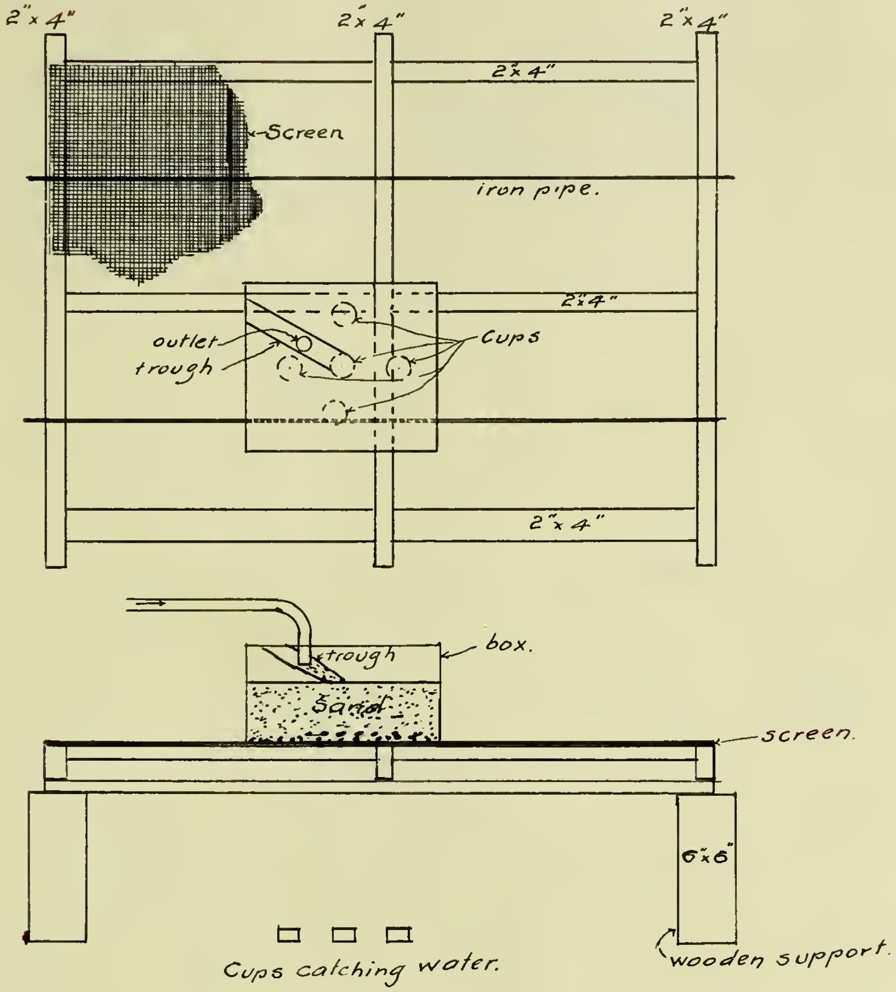


FIGURE 3.

creased 2 inches more, making a total depth of 8 inches for both sand and gravel. Test no. 5 shows that with a high rate most of the water falls in the vicinity of the outlet.

From tests numbers 6 and 7 it is seen that with greater depth a better distribution is attained. That is with a depth of 8 inches instead of 6 inches.

Tests number 6 and 7 were made with a filter 34.8 inches long and 28.5 inches wide. The depth of the gravel was 2 inches and that of the sand 6 inches making a total depth of 8 inches. Figure 8 shows the bottom distribution with a rate of 0.31275 gallons per minute. It is seen that with such a rate the distribution is on only about four square feet. Assuming 4,000,000 gallons per acre per day, about the maximum rate used in filtration with percolating filters, the rate used should be only 0.24 gallons per minute. With such a high rate as 0.87 gallons per minute as used in test no. 7 the area distributed is only about five square feet. Figure 9 shows the bottom and surface distributions. Tests no. 11 and 12 were performed with a depth of 16 inches of sand and gravel.

Table I.

Depth of Filter - 6 Inches.

	Cup No.	Time in Min.	Depth of Water in Cups. Inches	Rate in Gal. per Min.	Remarks
Test No.1	1	5	2.5	0.2835	See Fig. 4 for the arrangements of cups and distribution.
	2	5	0.5		
	3	5	2.5		
	4	5	1.6		
	5	5	1.0		
	6	5	0.6		
Test No.2	1	5	1.60	0.10425	See Fig. 4.
	2	5	0.25		
	3	5	1.90		
	4	5	0.10		
	5	5	0.35		
	6	5	0.20		
Test No.3	1	5	1.4	0.139	See Fig. 5.
	2	5	0.10		
	3	5	0.33		
	4	5	1.0		
	5	5	0.7		

Table II.

Depth of Filter - 8 Inches.

	Cup No.	Time in Min.	Depth of Water in cups. Inches	Rate in Gal. per Min.	Remarks
Test No.4	1	5	1.8	0.2435	See Fig 5 for the arrangement of cups.
	2	5	0.8		
	3	5	1.0		
	4	5	1.0		
	5	5	0.9		
Test No.5	1	5	1.9	0.31275	Cups placed as in Fig. 5.
	2	5	1.3		
	3	5	1.6		
	4	5	1.7		
	5	5	1.3		
Test No.6	1	5	1.6	0.2835	See Fig 6 for arrangement of cups.
	2	5	0.5		
	3	5	1.2		
	4	5	0.5		
	5	5	0.9		

Tablo III

Depth of Filter - 8 Inches.

	Cup No.	Time in Min.	Depth of Water in cup. Inches	Rate in Gal. per Min.	Remarks
Tost No.7	1	5	2.5	0.31275	See Fig. 8.
	2	5	1.8		
	3	5	0.3		
	4	5	1.5		
	5	5	0.05		
	6	5	1.80		
	7	5	0.10		
	8	5	1.8		
	9	5	0.09		
Test No.8	1	5	1.8	0.8689	See Fig. 9.
	2	5	1.4		
	3	5	0.2		
	4	5	0.2		
	5	5	0.0		
	6	5	1.1		
	7	5	0.2		
	8	5	0.4		
	9	5	0.1		

Table IV.

Depth of Filter - 8 Inches.

	Cup No.	Time in Min.	Depth of Water in cup. Inches	Rate in Gal. per Min.	Remarks
Test No.9	1	5	1.1	0.6	See Fig. 10.
	2	5	0.8		
	3	5	0.2		
	4	5	1.1		
	5	5	0.2		
	6	5	0.3		
	7	5	0.05		
	8	5	1.00		
	9	5	0.30		
Test No.10	1	5	1.4	0.44	See Fig. 10.
	2	5	1.1		
	3	5	0.5		
	4	5	1.4		
	5	5	0.1		
	6	5	1.0		
	7	5	0.5		
	8	5	1.4		
	9	5	0.6		

Table V.

Depth of Filter - 10 Inches.

	Cup No.	Time in Min.	Depth of Water in cups. Inches	Rate in Gal. per Min.	Remarks
Test No.11	1	5	1.0	0.11	See Fig. 11.
	2	5	0.6		
	3	5	0.2		
	4	5	1.0		
	5	5	0.1		
	6	5	0.7		
	7	5	0.3		
	8	5	1.0		
	9	5	0.5		
Test No.12	1	5	0.9	0.062	See Fig. 11.
	2	5	0.8		
	3	5	0.1		
	4	5	0.8		
	5	5	0.0		
	6	5	0.7		
	7	5	0.2		
	8	5	0.8		
	9	5	0.3		

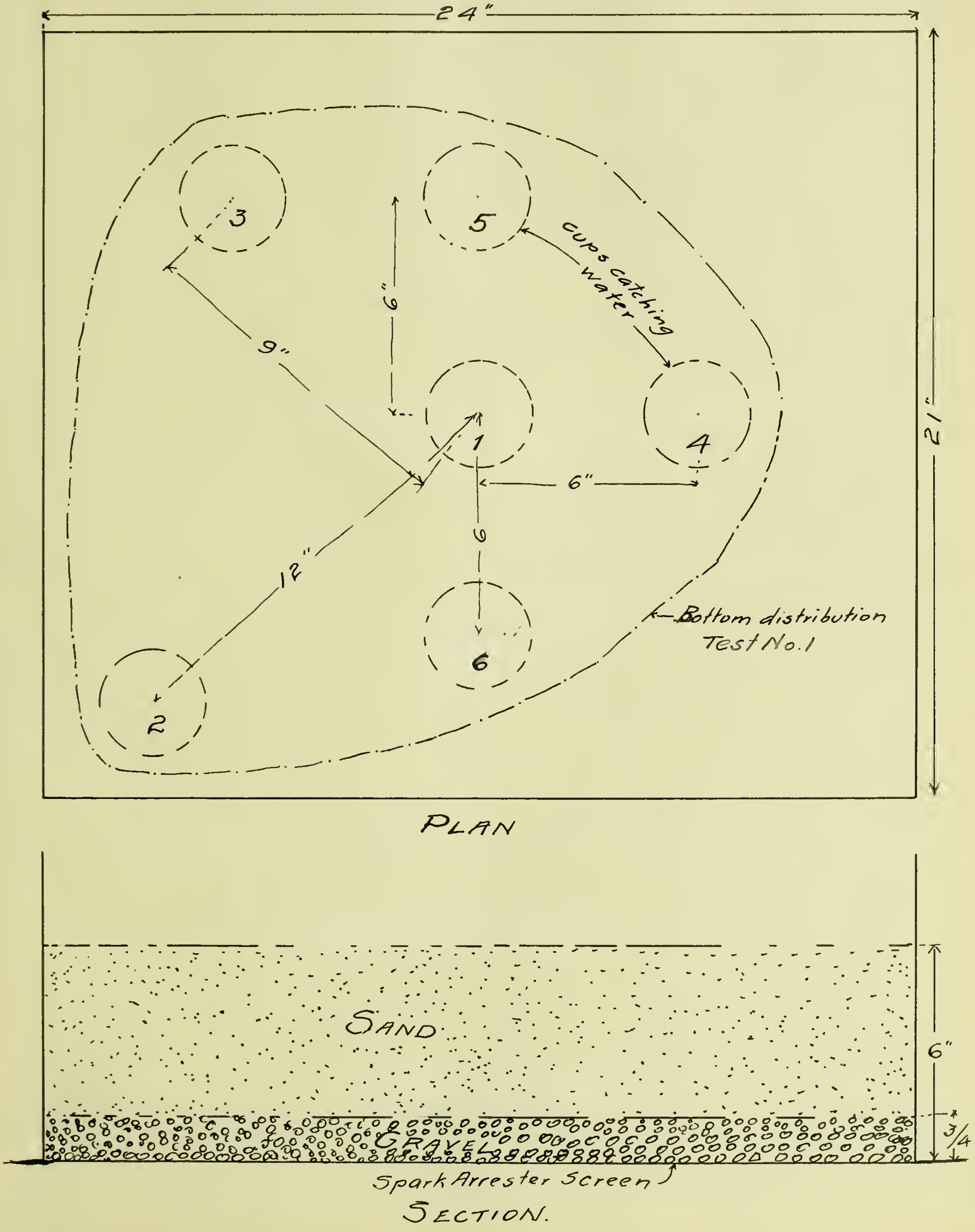
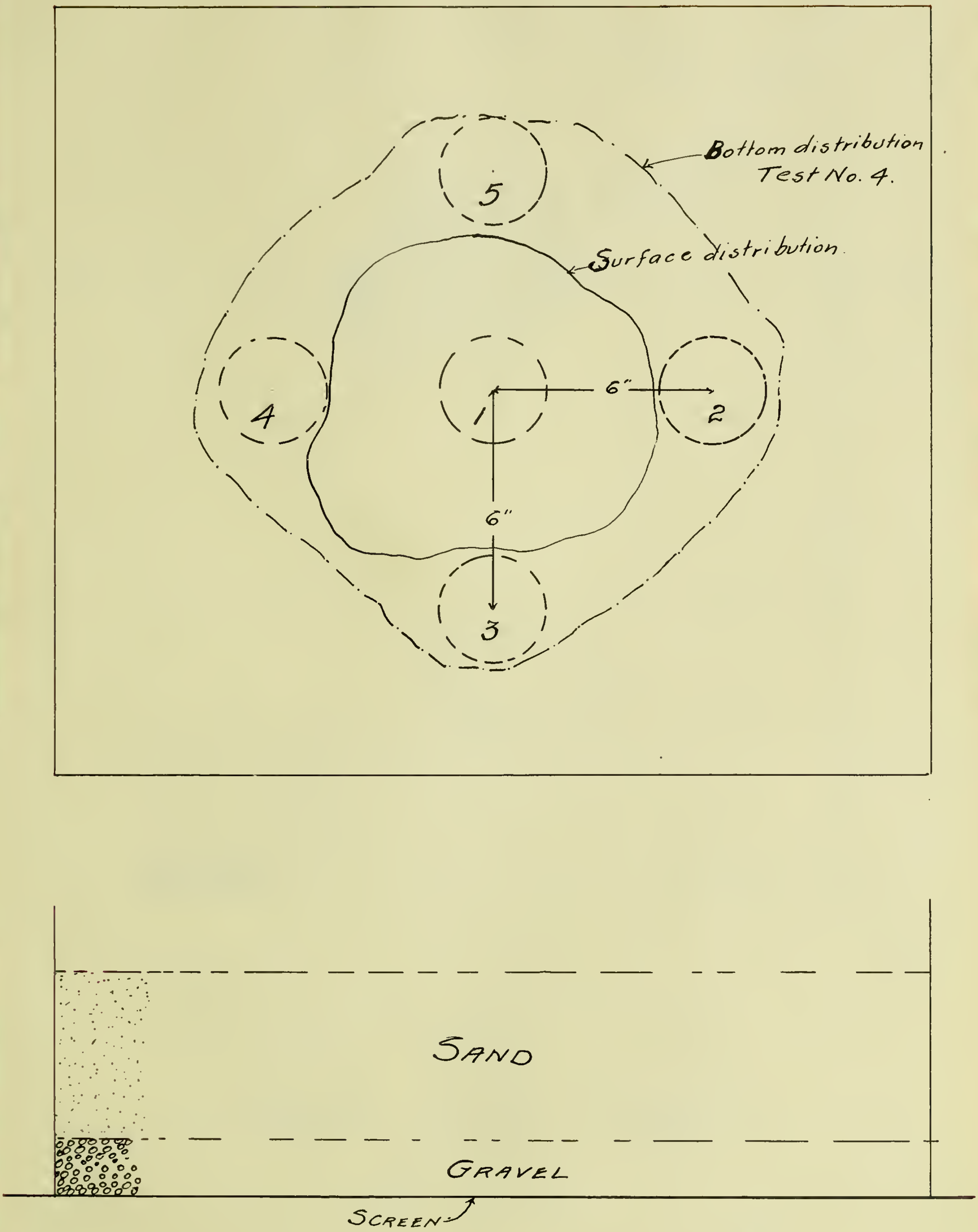


FIGURE 4.

SHOWING POSITION OF CUPS and BOTTOM DISTRIBUTION in TESTS No. 1 and 2.

FIGURE 5

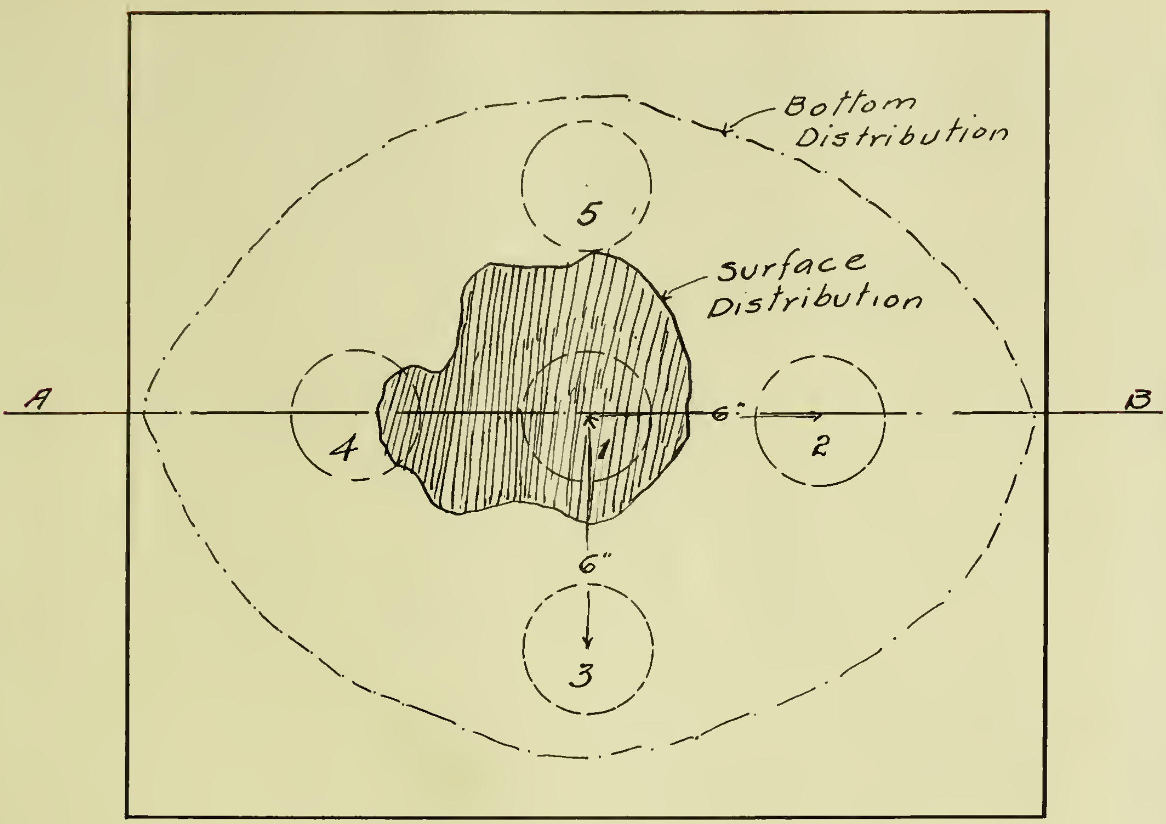
TESTS No. 3, 4, and 5.

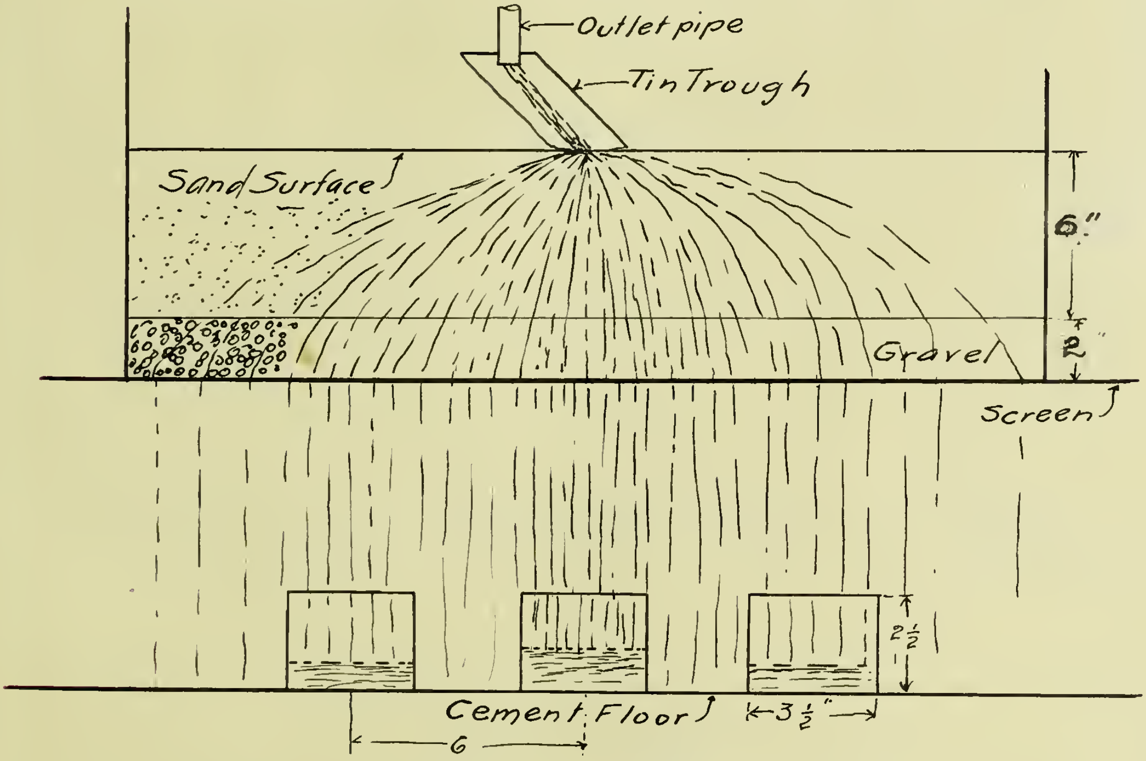


Note:— Dimensions of box are the same as shown in Fig. 4.

FIGURE 6.

SECTIONS SHOWING SURFACE and BOTTOM DISTRIBUTIONS and POSITION of CUPS in TEST No. 6.





SECTION A-B.

FIGURE 8

BOTTOM and SURFACE DISTRIBUTIONS and POSITION of CUPS.

Test No 7.

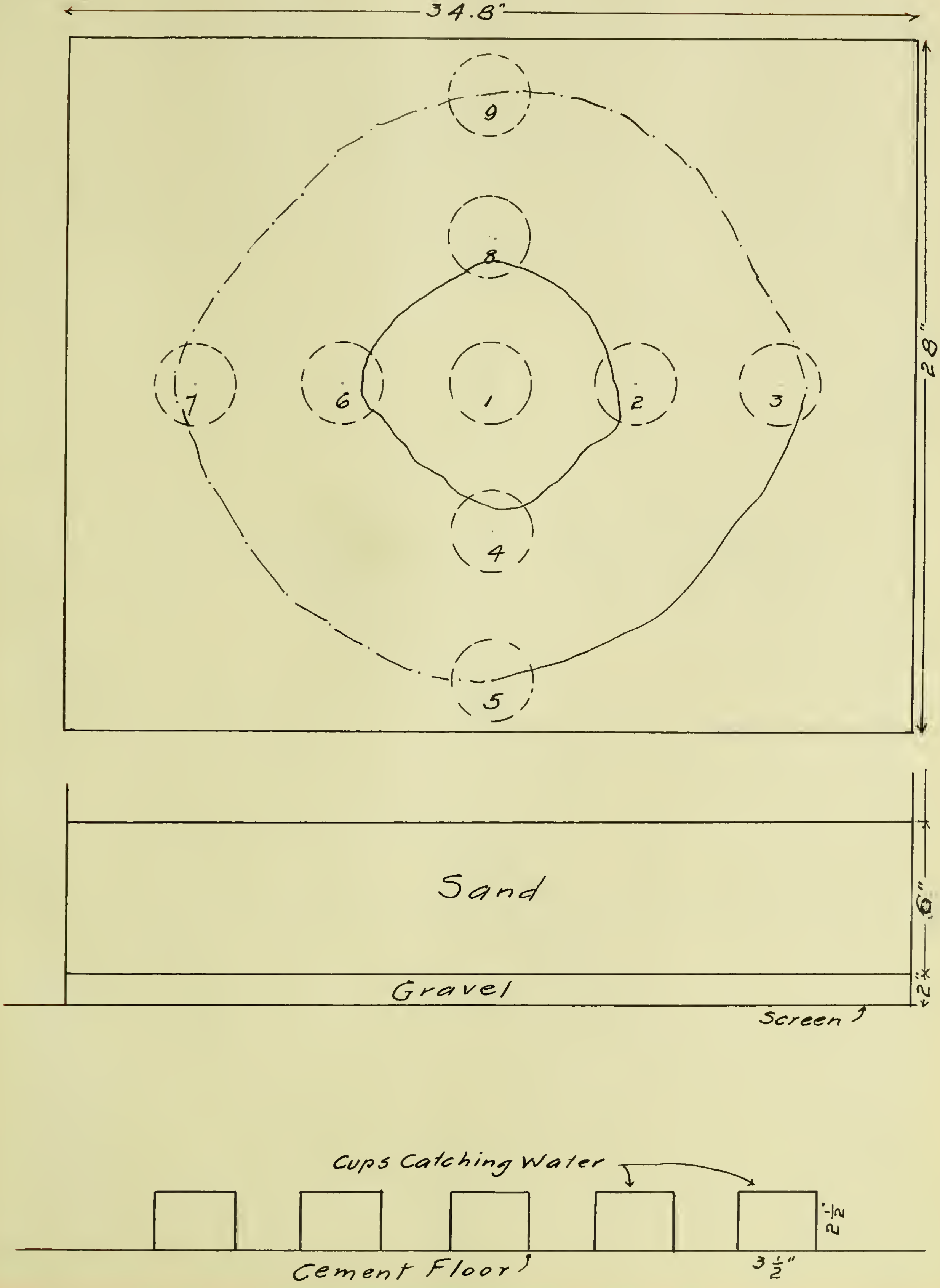


FIGURE 9.

POSITION of CUPS and DISTRIBUTION
TEST No. 8

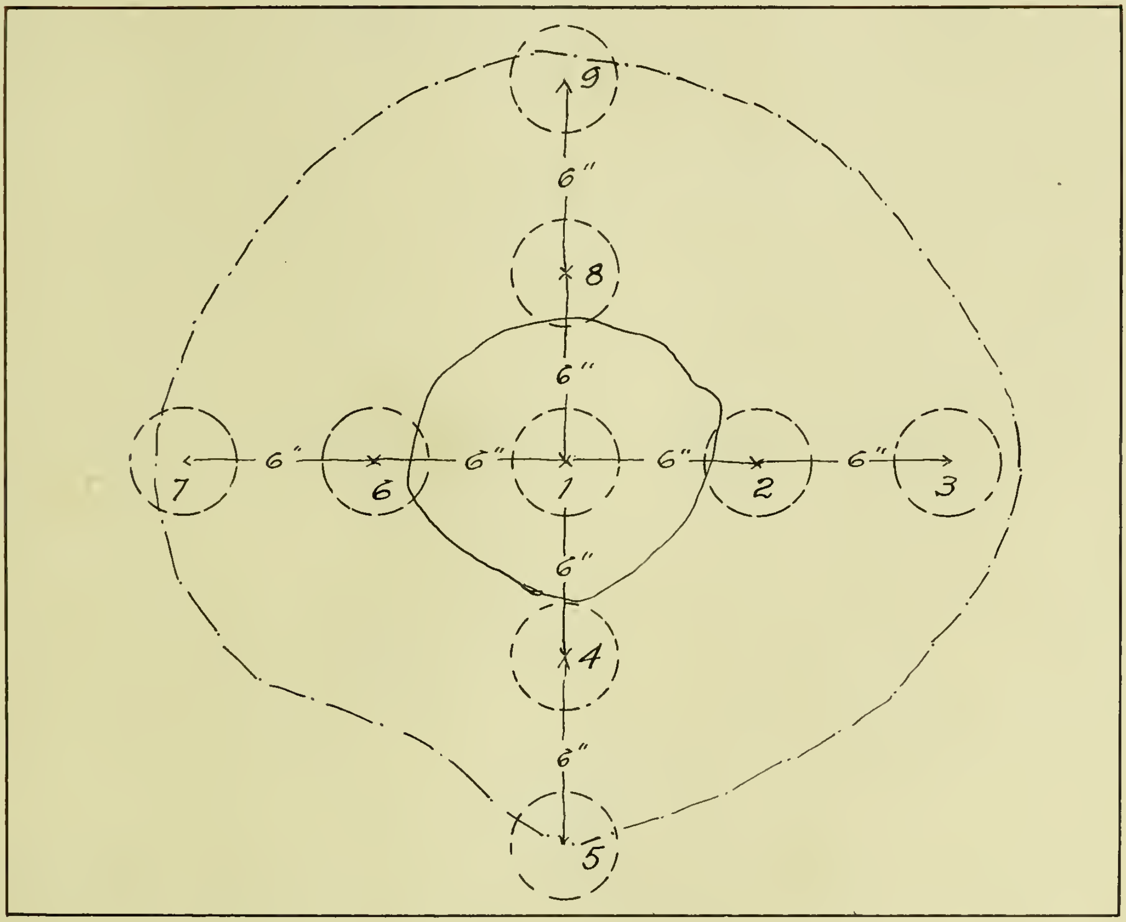


FIGURE 10
POSITION of CUPS and DISTRIBUTION
TEST No. 10

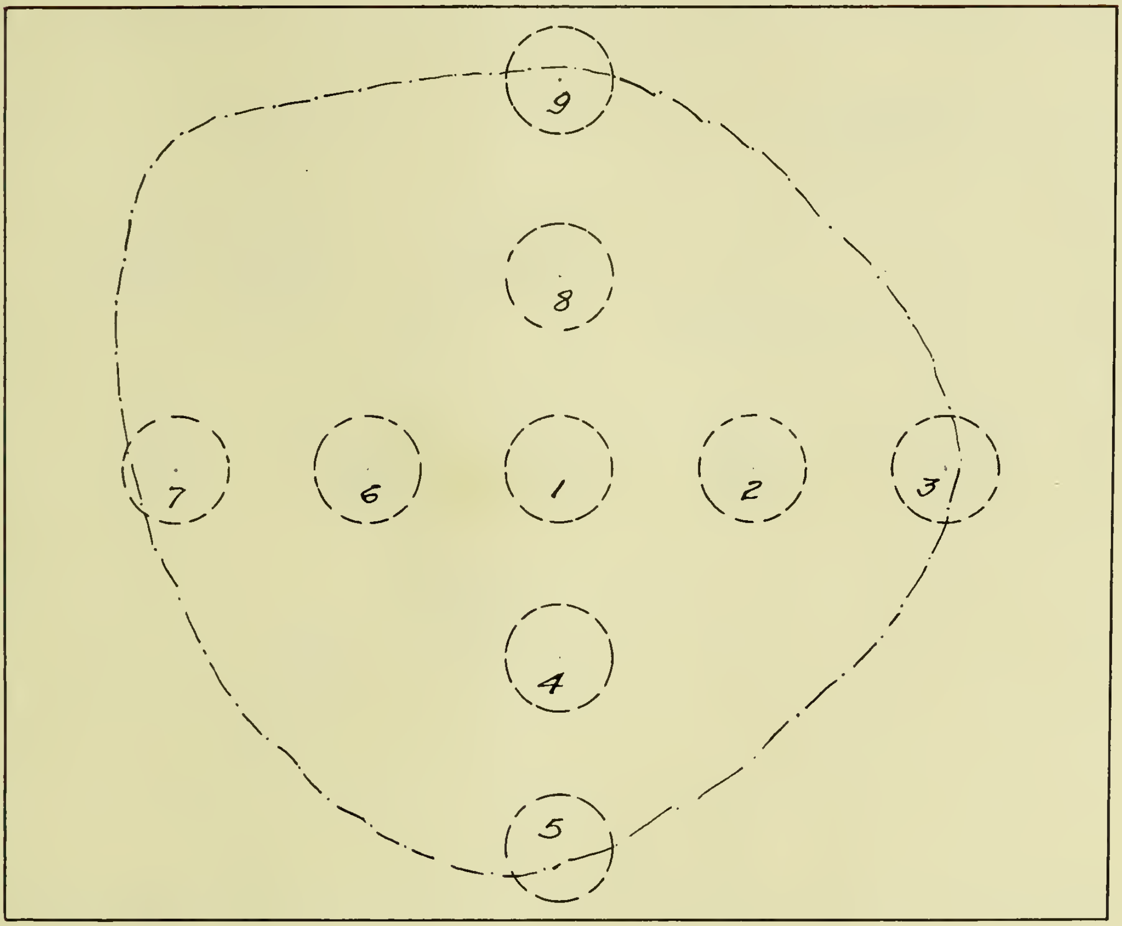
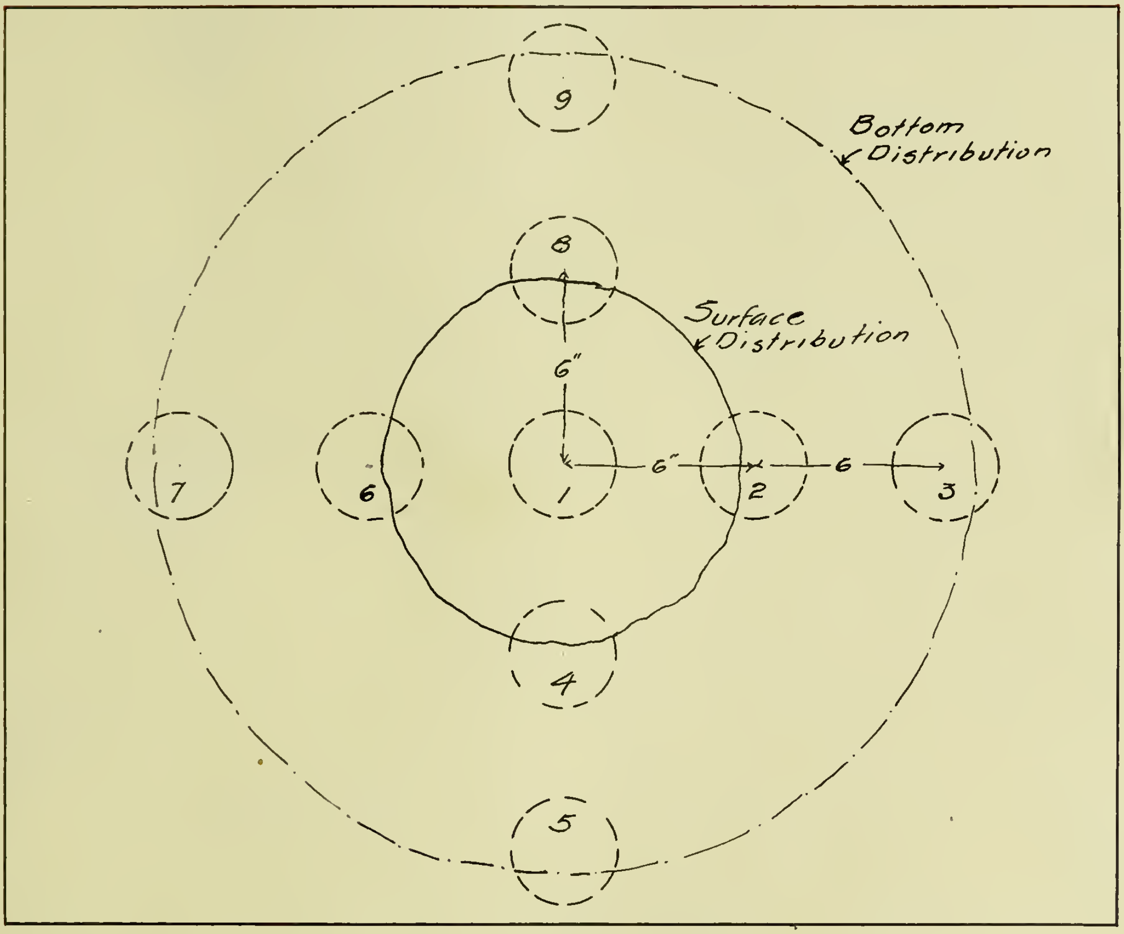


FIGURE 11.



POSITION of CUPS and DISTRIBUTION

TEST No. 12

Experiments With Broken Stone:- The same apparatus was used in these experiments except that broken stone was used instead of sand. For test no. 13 the stone used consisted of particles that passed thru a screen of one inch mesh and nearly all was held on a screen with four meshes to the inch. The material for tests no.14, 15, 16, 17, 18, 19, 20 and 21 was composed of stones that passed thru a screen of two meshes to the inch nearly all being held on screen of four meshes to the inch, and for test no. 22, 23, 24, 25, 26 and 27 the material passed thru one inch mesh sieve and was retained in the half inch mesh sieve. Three rates for each depth of 6, 12 and 18 inches were tried and the results are as follows:-

Table VI.

Broken Stone. Size - One Inch and Fourth Inch.

	Cup No.	Time in Min.	Depth of Water in cup. Inches	Rate in Gal. per Min.	Remarks
Test	1	5	1.6	0.08	Depth of filter 12 inches Distance of cups from center to center 6 inches.
No.13	2	5	0.2		
	3	5	0.2		
	4	5	0.3		
	5	5	0.2		

FIGURE 11a.
BOTTOM DISTRIBUTION and POSITION of CUPS.
TEST No.13.

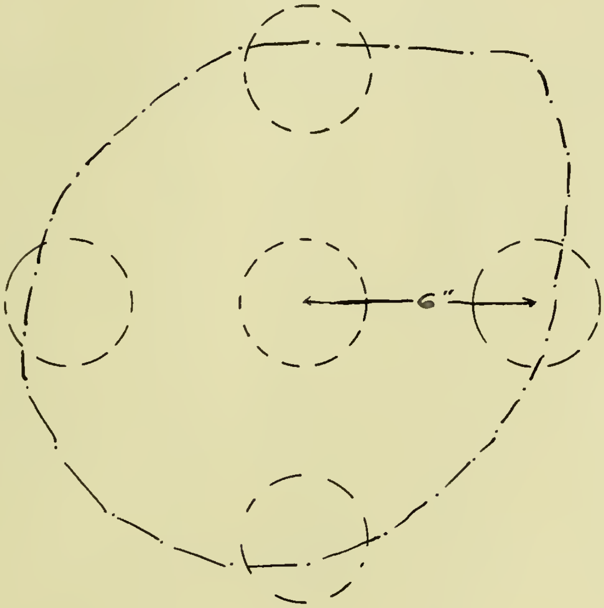


Table VII.

Broken Stone. Size - Half Inch.

	Cup No.	Time in Min.	Depth of Water in cup. Inches	Rate in Gal. per Min.	Remarks
Test No. 14	1	5	2.4	0.204	Depth of filter 6 inches. Distance of cups from center to center 4 inches.
	2		2.0		
	3		1.8		
	4		1.9		
	5		1.7		
Test No. 15	1		1.7	0.212	Not much water at 5 inches from center.
	2		1.6		
	3		1.3		
	4		1.4		
	5		1.2		
Test No. 16	1	5	1.2	0.8	Depth of filter 6 inches.
	2	5	0.6		
	3	5	0.4		
	4	5	0.5		
	5	5	0.3		
Test No. 17	1	5	2.5	0.204	Depth of filter 12 inches.
	2	5	1.2	"	
	3	5	1.0	"	
	4	5	1.0	"	
	5	5	1.2	"	

	Cup No.	Time in Min.	Depth of Water in cup. Inches	Rate in Gal. per Min.	Remarks
Test No. 18	1	5	1.0	0.08	Depth of filter 12 inches.
	2		0.4		
	3		0.5		
	4		0.4		
	5		0.3		
Test No. 19	1	5	2.5	0.204	Depth of filter 18 inches.
	2		1.1		
	3		1.0		
	4		1.3		
	5		1.4		
Test No. 20	1	5	0.8	0.08	Depth of filter 18 inches.
	2		0.5		
	3		0.4		
	4		0.4		
	5		0.5		
Test No. 21	1	5	2.5	0.212	Depth of filter 18 inches.
	2		2.0		
	3		1.8		
	4		1.9		
	5		2.0		

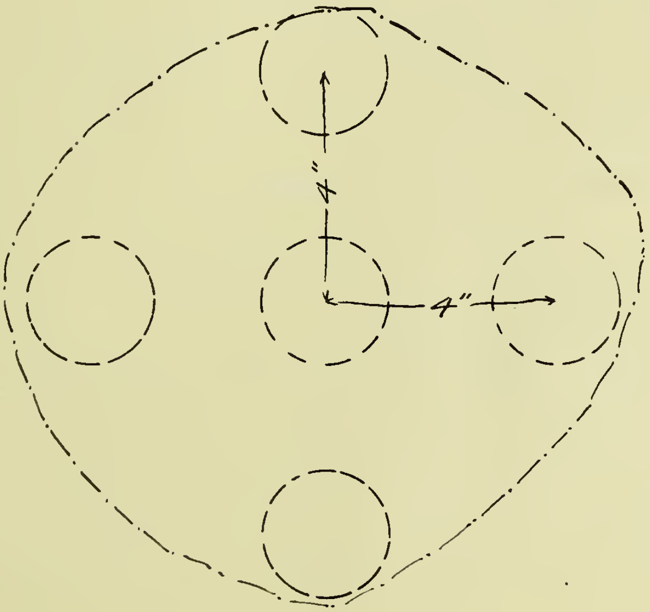
Table VIII.

Broken Stone. Size - One Inch.

	Cup No.	Time in Min.	Depth of Water in cup. Inches	Rate in Gal. per Min.	Remarks
Test No. 22	1	5	1.9	0.08	Depth of filter 6 inches.
	2		0.8		
	3		1.6		
	4		0.3		
	5		0.2		
Test No. 23	1	5	2.1	.204	Depth of filter 6 inches.
	2		1.8		
	3		1.6		
	4		0.5		
	5		0.2		
Test No. 24	1	5	1.5	.212	Depth of filter 6 inches.
	2		2.0		
	3		1.8		
	4		1.0		
	5		0.5		
Test No. 25	1	5	1.3	0.8	Depth of filter 12 inches.
	2		0.5		
	3		0.8		
	4		0.1		
	5		0		

	Cup No.	Time in Min.	Depth of Water in cup. Inches	Rate in Gal. per Min.	Remarks
Test No. 26	1	5	1.5	.204	Depth of filter 12 inches.
	2		1.0		
	3		0.8		
	4		0.5		
	5		0.1		
Test No. 27	1	5	2.0	.212	Depth of filter 12 inches.
	2		1.3		
	3		0.8		
	4		0.6		
	5		0.2		

FIGURE 11b.
Bottom Distribution and Position of Cups.
Test No. 27.



Discussion of Results.

From the results obtained we see that high rates give very uneven distribution, while low rates on the other hand give more even distribution. This may be seen in test number 9 for sand with a rate of 0.69 gallons per minute which gave very uneven distribution as compared with test no. 10 with a rate of 0.440 gallons per minute which gave fairly uniform distribution. The same holds true for broken stone. Test no. 18 shows a very even distribution with a rate of 6.8 gallons per minute while test no. 17 with a rate of .204 gallons per minute shows uneven distribution.

The higher the rates the greater the area thru which water is distributed, but the more uneven the distribution. Figure 12 page 47 shows the relation of total lateral distribution in inches and the rate in gallons per minute, taking the depth of the filter as constant, this being 8 inches for sand and 12 inches for broken stone.

The greater the depth up to a certain limit beyond those used in these experiments, the more even the distribution becomes. This is shown by test no. 6 with an area distributed thru 2.5 square feet as compared with test no. 7 with an area distributed thru 4.5 square feet. The same principle applies with broken stone. Test no. 14 with a depth of 6 inches shows an area distributed thru 64 square inches while test no. 19 with a depth of 12 inches with the same rate as no. 14, gives an area distributed thru of about 100 square inches. The limit of depth effecting lateral distribution as tested by W. G. Taylor

seems to be about 6 feet. Figure 13 on page 48 taken from Vol. 59, page 710 of The Engineering Record shows the relation of lateral distribution to the depth in feet. The curves show that after six feet of depth the direction of flow is nearly vertical.

The finer the material the greater the area of distribution becomes as may be seen by comparing tests made with sand and those made using broken stone. Test no. 12 shows an area thru which the water is distributed thru a sand filter of about 4 square feet, while test no. 18 shows an area of about 3 square feet when the material is composed of broken stone that passed thru a screen of one half inch mesh. Test no. 21 shows an area distributed over about 2 square feet, when the broken stone is made up of one inch and half inch sizes. Figure 14 on page 49 shows the lateral distribution for sand and broken stone. Two sizes of stone were used, in one test half inch size and in the other one inch size. The figure clearly shows that the finer the material the greater the distribution.

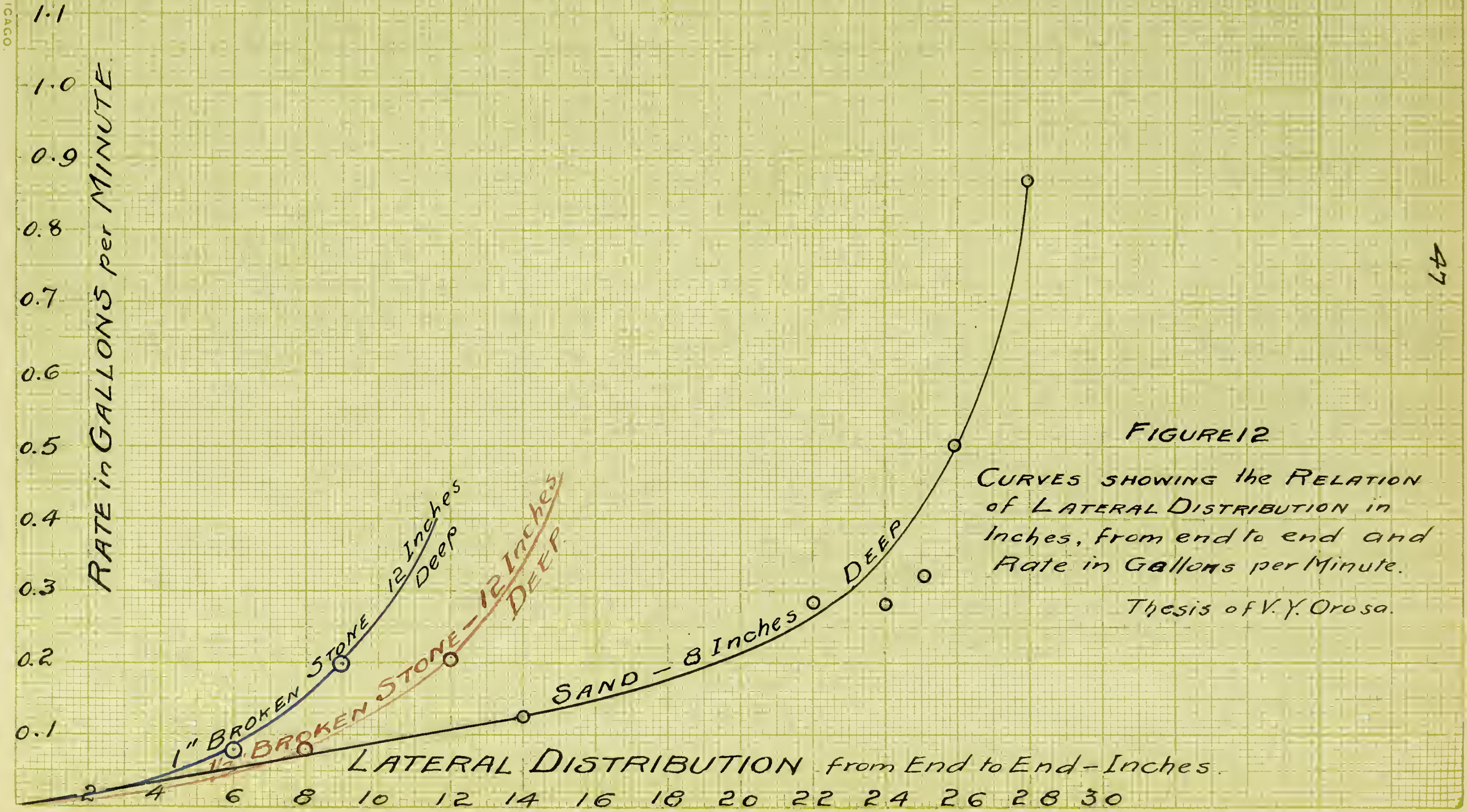


FIGURE 12

CURVES SHOWING the RELATION of LATERAL DISTRIBUTION in Inches, from end to end and Rate in Gallons per Minute.

Thesis of V. Y. Orosa.

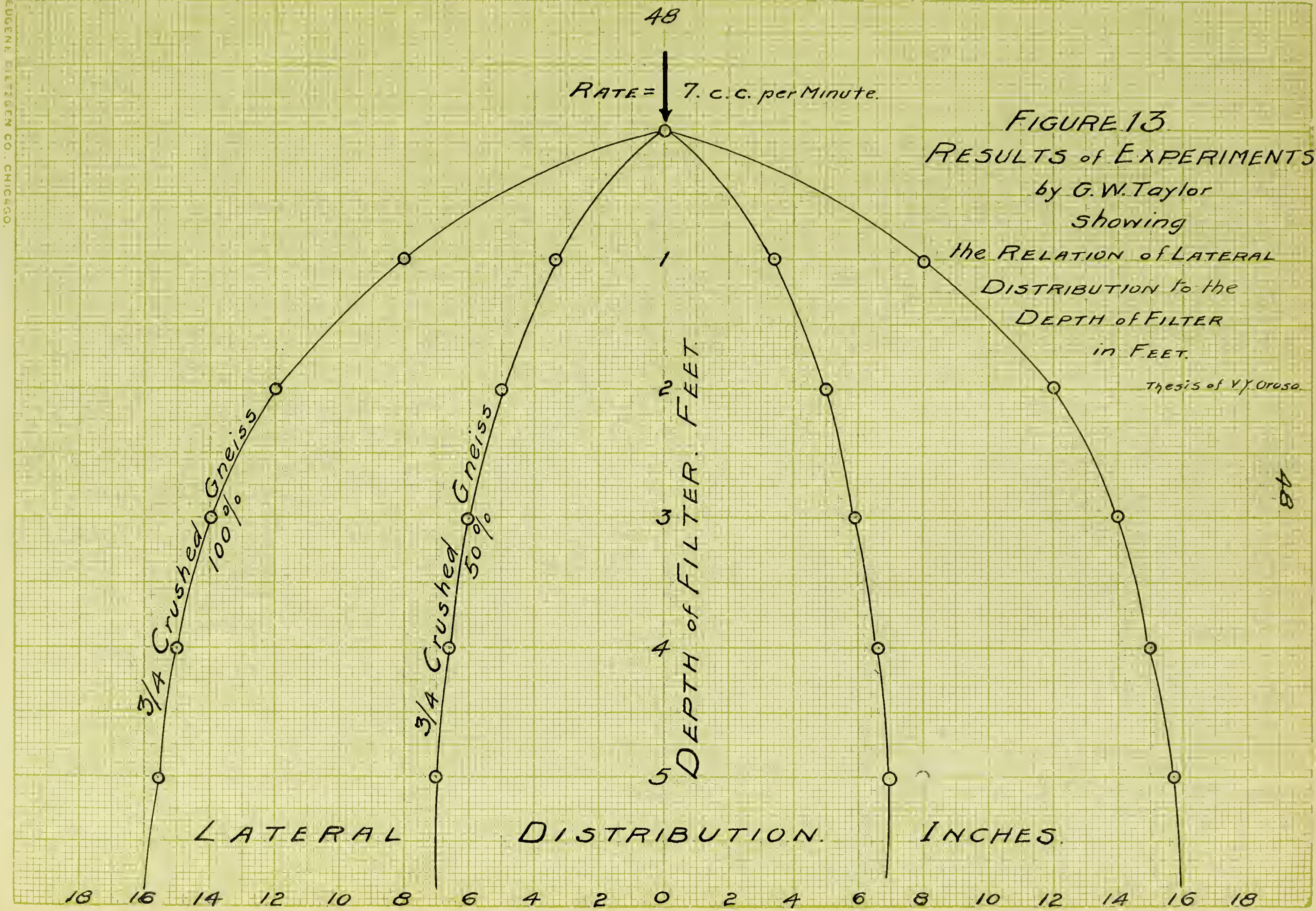


FIGURE 13.
RESULTS of EXPERIMENTS
by G.W. Taylor
showing
the RELATION of LATERAL
DISTRIBUTION to the
DEPTH of FILTER
in FEET.

Thesis of V.Y. Oroso.

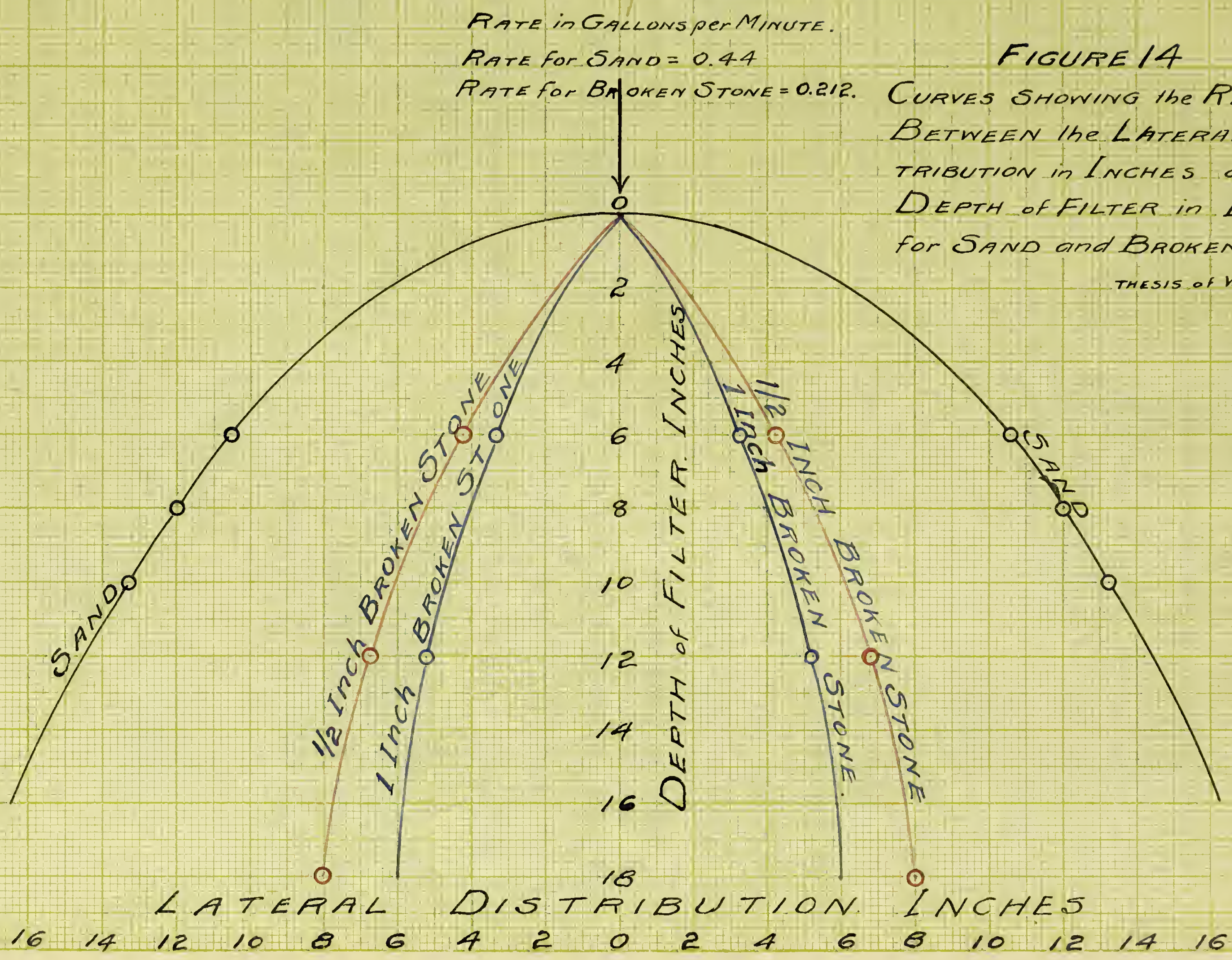


FIGURE 14

Curves Showing the Relation Between the Lateral Distribution in Inches and the Depth of Filter in Inches, for Sand and Broken Stone.

Thesis of V. Y. Orosa

CONCLUSIONS.

The experiments made, show that water would distribute fairly uniformly 12 inches laterally in sand with a depth of filter of 8inches. A rate of 4,000,000 gallons per acre per day which is the highest rate ordinarily used for percolating filters is equal to 0.06 gallons per minute per square foot. Without using any sprinkler nozzles we would have to use about 43,000 outlets per acre. With broken stone fairly uniform distribution, 8 inches laterally may be obtained, when the filter is 8 inches deep. In this case we would have to use still more outlets than for the sand filter. With a fine sand covering over coarse filtering material, the sand may become more or less clogged giving much better distribution, but this will prevent free air circulation which is essential in a percolating filter. However, for very small plants, this might be used to reduce the cost of attendance.

It is very evident then, that for perolating filters, devices such as sprinkler nozzles and the like will have to be used , and that without such devices it is impracticable to secure good distribution.