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UNIVERSITY OF MICHIGAN
ANN ARBOR

FINAL REPORT

USE OF SYNTHETIC ORGANIC CHEMICALS IN SEPTIC TANK ABSORPTION FIELDS

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ORGANIC CHEMICALS DIVISION
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USE OF SYNTHETIC ORGANIC CHEMICALS
IN SEPTIC TANK ABSORPTION FIELDS

FOREWORD

Early in January, 1953, the Civil Engineering Department of the University of Michigan received an inquiry from the Monsanto Chemical Company which requested information as to the available facilities for carrying on an intensive investigation of the use of Krilium soil conditioners in septic tank absorption beds. A series of communications, including a visit to the campus by a representative of the Monsanto Company, culminated in a contract document executed by the Engineering Research Institute of the University of Michigan and the Monsanto Chemical Company.

Engineering Research Institute Project 2141 embraces two related fields of study. Part one was envisioned as a field test in which eight separate absorption beds were to be dosed with equal, metered quantities of septic tank effluent in doses simulating normal home usage. Six of the beds were to be constructed in such a fashion that the soil adjacent to the distribution trench would be treated with Krilium soil conditioners in a variety of fashions. Two trenches were to be built in exactly the same fashion as the treated trenches but were to be left untreated and used as controls.

This portion of the study required a larger than average septic tank installation, an available plot of homogenious clay soil conveniently near the septic tank and large enough to take the proposed installation, appropriate pumping, metering, dosing equipment, and devices to measure the percolation conditions prevalent in each of the absorption beds.

Part two of the study was designed to establish a simple percolation test which would enable a technician to compare the percolation characteristics of any soil to that of the test plots in Ann Arbor. Thus, the effect of Krilium soil conditioners on an unknown soil could be predicted using the results obtained with the Ann Arbor soil as a basis.

The second part of this study would therefore require percolation tubes in which the field treatments would be duplicated and appropriate controls provided. Each type of percolation tube would have to be replicated as often as necessary to obtain statistically significant results.

In addition, if space and time were available the study was to be extended to include certain basic factors not included above which would have a direct bearing on the problem. These would include the determination of durability, rate of percolation under various pH conditions, effect of detergents, temperature, and microbial activity.

SECTION I

THE FIELD INSTALLATION

A study of the metropolitan area of Ann Arbor revealed that there were three possible sites which might be adapted to the installation of such equipment as would be required by the research proposed in the foreword. A consideration of paramount importance was that the site must have a larger than average septic tank lying near a large plot of unoccupied, flat ground, which could be used for absorption-bed studies. Exploration of the possible sites left no doubt that only one of the available sites was acceptable. Borings indicated that the soil at site one consisted of fine sand supported on coarser sand and gravel and both horizons interspersed with boulders of considerable size. Site two was restricted in area and covered with trees. Site three had a great deal of available space. It was accessible in all kinds of weather and according to reports, had been built in clay. The absorption field for the existing septic tank consisted of a bed of washed gravel placed in a hole 15 feet deep and 90 feet square. The hole had been dug through 15 feet of tight top soil to a gravel strata which approached to within 15 feet of the surface near the rear of the property.

An extensive survey of the property indicated that a rather homogenious lens of clay lay directly on the surface of the ground at the front of the property and was surrounded on two sides and at the rear by a soil consisting of sandy clay which accepted water at quite widely varying rates, depending at which point the percolation measurement was taken. Careful borings determined the outline of the clay lens as shown in Fig. I.

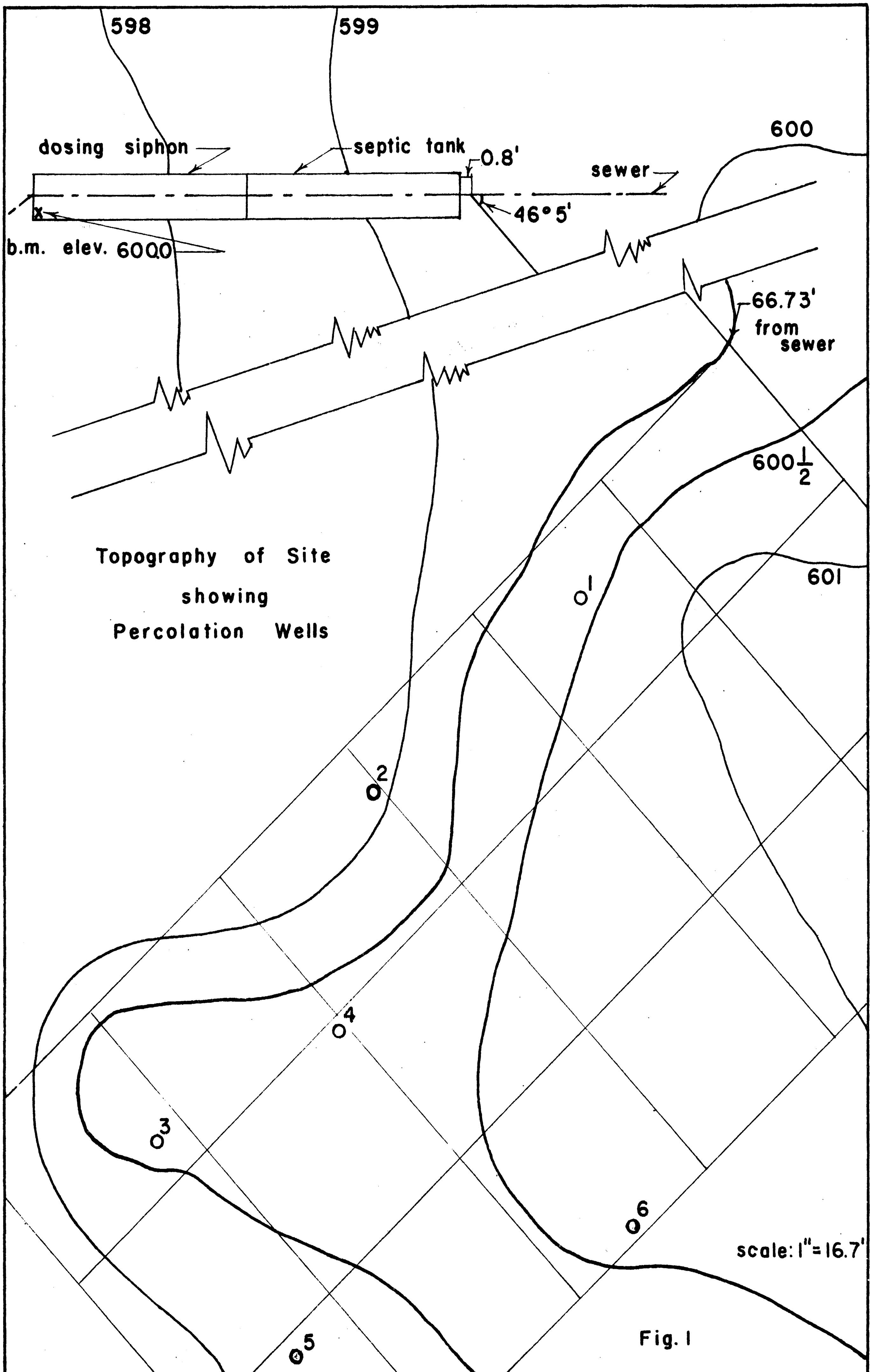
Four-inch auger holes 24 inches deep were placed at intervals over the available space and within the confines of the relatively homogenious clay lens. The locations of these holes were determined by a survey which at the same time recorded elevations and located the existing septic tank with regard to the points in question. With the accumulated information revealed by this survey, a topographic map of the area was prepared and important facilities were located (see Fig. 1).

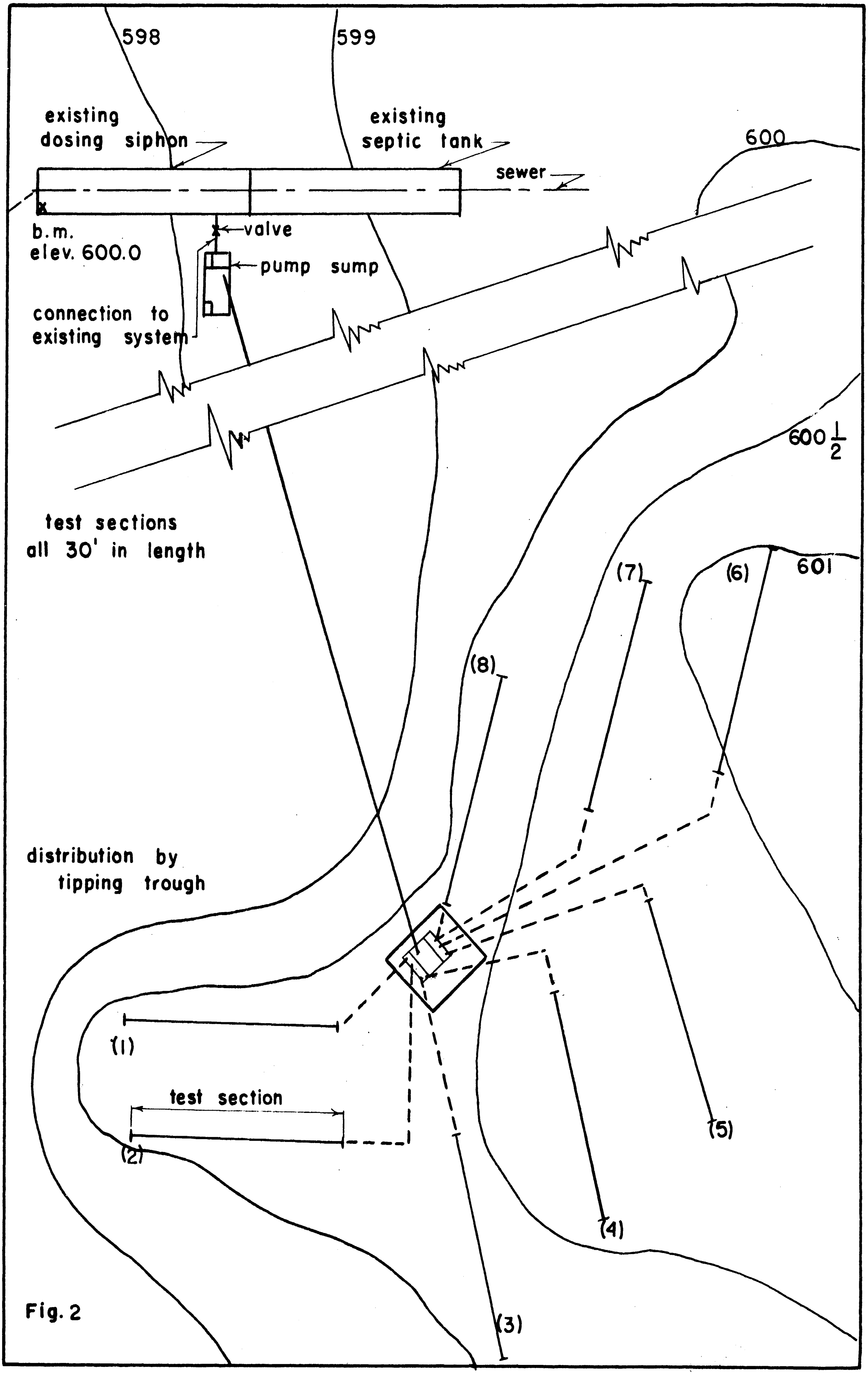
Percolation studies were then made in each of the auger holes to reveal the character of the clay and to provide the necessary information for design of the proposed absorption beds. The auger holes were kept filled with water for a period of two days and at the end of this time the rate of subsidence of the water surface was timed. Results are shown in Table I.

TABLE I

Hole No.	In. Fall per hr	In. Fall per hr	In. Fall per hr
1	1-3/8	1-5/16	1-1/4
2	2-7/8	2-1/8	2-1/8
3	2-1/2	2	1-3/4
4	2-7/16	2-3/16	1-9/16
5	2-5/16	1-7/8	1-1/4
6	2	1-5/8	1-3/16

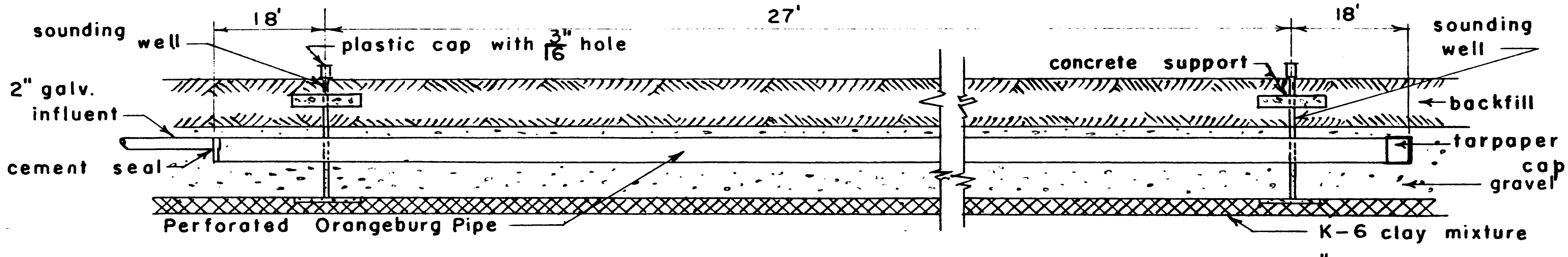
From the evidence indicated in Table I, the proposed absorption beds were designed on a conservative loading factor of 1/2 gallon per square foot per day. The trenching machine to be used in digging the trenches had a bucket width of exactly 18 inches and on the basis of the size of the area available, each experimental absorption bed was made 30 feet long and placed on the topographic map as nearly parallel to the contour lines as possible. A minimum trench spacing of 15 feet was used in order to minimize interference between trenches. Figure 2 shows the resulting plan view and a profile of the proposed installation is shown in Fig. 3.


598
599
600
dosing siphon
septic tank
0.8'
sewer
46° 5'
b.m. elev. 600.0
66.73' from sewer
600 1/2
601
Topography of Site showing Percolation Wells
1
2
3
4
5
6
scale: 1" = 16.7'
Fig. 1



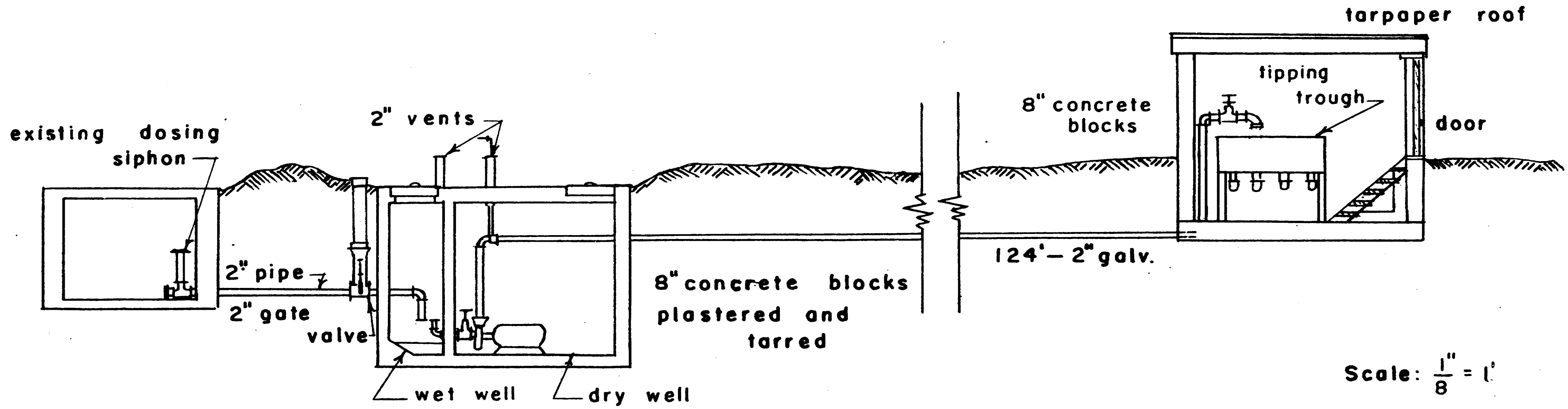
598
599
600
600 1/2
601
existing
dosing siphon
existing
septic tank
sewer
b.m.
elev. 600.0
valve
pump sump
connection to
existing system
test sections
all 30' in length
distribution by
tipping trough
test section
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)

Fig. 2



Scale: $\frac{1''}{2} = 1'$

TYPICAL TRENCH
Profile of Test Section



Scale: $\frac{1''}{8} = 1'$

Fig. 3

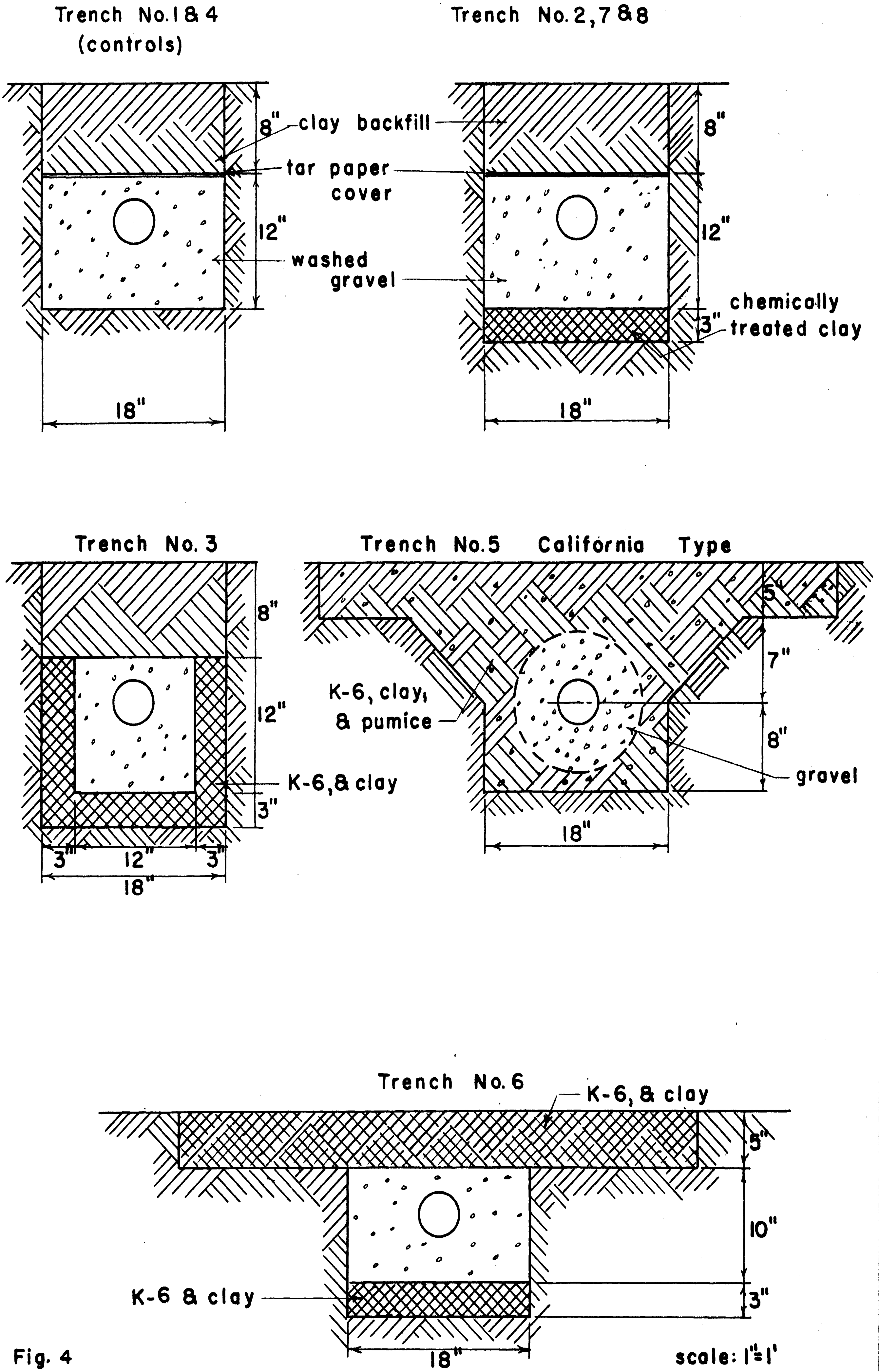
The plan was first approved by the property owners and a contract was signed which gave the University the privilege of renting the space and renewing the rental on a year-to-year basis. The plan was next submitted to the Monsanto Chemical Company and the details were discussed and approved. Several copies of prints had meanwhile been circulated among the contractors in the Ann Arbor-Ypsilanti area. Unfortunately, the project had culminated at a bad time of the year to obtain favorable bids. All contractors were busy; the job was small and as one contractor said, "If we give you a bid at all, it would have to be double what the job is worth." Briefly then, all bids were considerably higher than our estimate. The only alternatives were to raise the allocation, to abandon the project, or to subcontract and build with student help. Monsanto refused to increase the funds allocated for the project, and yet insisted that they were impatient to have the project operating. In this atmosphere, rather than abandon the project, the construction was begun during the first week of August, 1953, using unskilled student help.

Eight trenches were dug in the locations shown in Fig. 2. Though the percolation tests had indicated uniformity of soil at all points in the test area, trenching showed a somewhat different picture. There were, of course, the usual roots and gopher holes, but in addition those trenches near the lower extremities of the clay lobe had veins of a more sandy character appearing and disappearing within the confines of the test sections. Inequalities such as these, it was thought, might produce differences which would be difficult to make compensations for at a later time.

A conference was held with the representative of the Monsanto Company who was visiting the project at the time. It was his hope that treatment of any of the trenches with soil conditioner would so change their percolation characteristics that other more minor inequalities would be unimportant. It was brought out that there was a good chance that this might not be so. In the light of this consideration, the conclusion was reached that this study was primarily interested in major changes in percolation characteristics since any minor improvements would not materially enhance the market for soil conditioners. The decision was made to complete the installation as it was and with all possible speed. At this time it was decided to treat the trenches as follows (sketches shown in Fig. 4):

Trench 1 was to be left untreated as a control.

Trench 2 was to receive a bottom treatment with 0.1% K-6 to a depth of 3 inches.



Trench No. 1 & 4
(controls)
Trench No. 2, 7 & 8
clay backfill
tar paper cover
washed gravel
chemically treated clay
8"
12"
3"
18"
Trench No. 3
K-6, & clay
8"
12"
3"
3"
12"
3"
18"
Trench No. 5 California Type
K-6, clay, & pumice
gravel
5"
7"
8"
18"
Trench No. 6
K-6, & clay
K-6 & clay
5"
10"
3"
18"
scale: 1" = 1'

Fig. 4

Trench 3 was to receive both a bottom and side treatment to a depth of 3 inches with 0.1% K-6.

Trench 4 was to be left untreated as a control.

Trench 5 (originally to receive a coating of dissolved K-6 sprayed on the interior surfaces of the trench) was to be changed to the California type trench. This meant increasing the top width of the trench to 4 feet. The tile was to be surrounded with gravel and the entire trench backfilled in 3-inch layers, each layer to consist of a mixture of soil and pumice treated with 0.1% K-6.

Trench 6 was to be treated as trench 2 except that a 4-foot band of earth, 6 inches deep, at the surface of the trench was to be treated with 0.1% K-6 as well as the bottom 3 inches in the trench.

Trench 7 was to receive a bottom treatment with 0.1% K-6 to a depth of 3 inches.

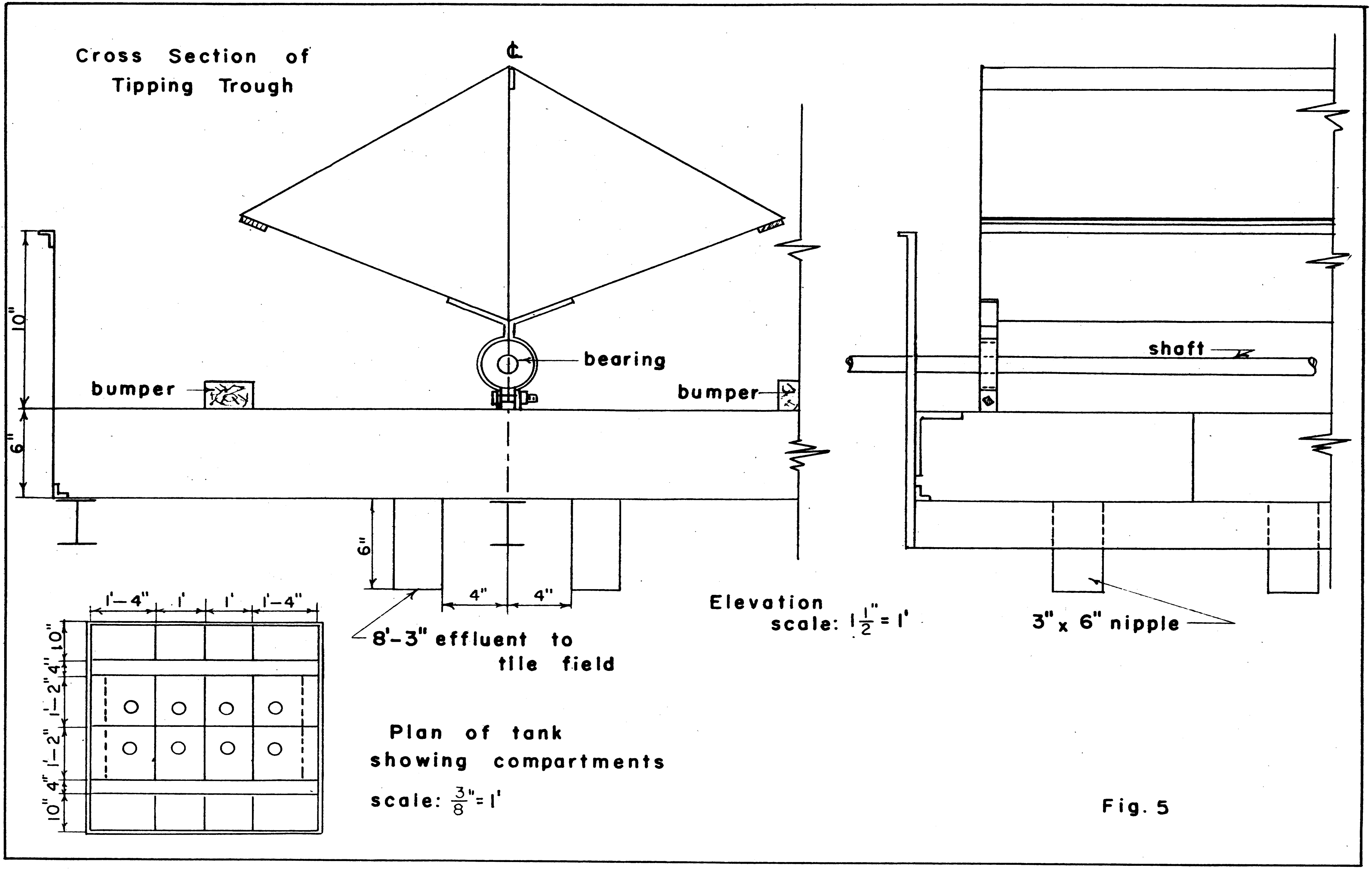
Trench 8 was to receive a bottom treatment with 0.1% K-12 to a depth of 3 inches.

The original intent was to apply the soil conditioners at the trench bottom by passing a roto-tiller through the trench several times. An 18-inch roto-tiller was obtained but working in a trench 18 to 24 inches deep; it stalled so frequently and did such a poor job that the method was abandoned. The trenches were uniformly prepared by excavating them 3 inches deeper than originally intended. The soil was carefully broken up, the proper weight of soil conditioner applied in three increments, and the mixture properly moistened and aggregated outside the trench. It was placed with shovels, raked carefully to grade, and immediately covered with 6 inches of gravel. Eight-foot sections of 4-inch perforated orangeburg pipe were placed so as to provide a grade of 0.1 foot in 30 feet and the gravel backfill continued until the pipe was covered with 2 inches of gravel. The gravel surface was covered with tarred felt and the remainder of the trench backfilled with the original soil taken from the trench.

Sounding wells were located at each end of a trench as a means of determination of the liquid depth within the trench (Fig. 3). Just prior to the placement of the gravel a concrete plate 6 inches square was set level with the bottom of the finished trench. The sounding well, consisting of a 1-inch copper pipe perforated by drilling 1/8-inch concentric holes throughout the bottom 12 inches of the pipe, was placed on the concrete plate and the gravel backfilled around it. As soil was backfilled over the gravel a concrete pad was poured around each sounding well just below the surface; this pad was found necessary after building the first three trenches in which it was omitted. The copper tubes in these instances were promptly removed by vandals and had to be replaced. The tops of the copper tubes were covered by brass caps in which a plastic insert was placed. A 1/8-inch hole in the plastic permitted the insertion of a graduated point gage down through the cap. Contact with the liquid of the trench completed a circuit which caused the deflection of the needle of a voltmeter and indicated the water depth within the trench.

Figure 3 indicates the technique by which the liquid was placed in the trenches. A 3-inch hole was drilled 7-1/2 inches into the 8-inch concrete wall of the dosing siphon of the existing septic tank installation. A 2-inch galvanized iron pipe was caulked into the hole using tarred jute. A 2-inch valve, a short nipple, and a cap were screwed to the end of the pipe and the pipe was driven with a sledge into the tank a distance of 3 inches. Since the interior of the concrete tank was somewhat softened by the action of the sewage, it was possible by this technique to break through the 1/2 inch of remaining concrete quite cleanly, without loosening the caulking. Thus, a connection was made to the dosing siphon while under a head of water and without cutting off service to the tank or pumping its contents.

The 2-inch influent was run into a wet well where the sewage was pumped through 124 feet of 2-inch galvanized iron pipe up to a concrete-block house in which was installed a tipping trough as detailed in Fig. 5. As the trough filled to a critical level of 20.64 gallons, the trough tipped exposing its other half which was then filled and tipped. As the contents of each half of the tipping trough were spilled into the receiving chamber, it was split into four equal portions by metal vanes. Each portion was conducted by a 2-inch galvanized iron pipe to an absorption bed. One complete cycle of the trough dosed each bed with 0.1146 gallons per square foot of bed. The number of doses was controlled by an electrical circuit consisting of a master timer, which controlled an interval timer and thus the pump motor. At the completion of a cycle a limit switch turned off the entire assembly. The master switch could be set for any number of doses per day up through ten. Thus, the absorption-bed dosage could be varied from 0.1146 gallons per square foot per day to 1.146 gallons per square foot per day.



Cross Section of
Tipping Trough
bearing
bumper
bumper
10"
6"
6"
4"
4"
8'-3" effluent to
tile field
Elevation
scale: $1\frac{1}{2}" = 1'$
shaft
3" x 6" nipple
1'-4"
1'
1'
1'-4"
10"
4"
1'-2"
1'-2"
4"
10"
Plan of tank
showing compartments
scale: $\frac{3}{8}" = 1'$

Fig. 5

SECTION II

FIELD RESULTS

Each of the absorption beds requiring bottom treatment with soil conditioner required three man hours of labor over and above those trenches where no soil conditioner was used. This time would vary widely depending on the moisture content of the soil and the experience of the laboring force carrying the job forward. Any wind at all makes the application difficult.

Trench number 3 was constructed with 3 inches of treated soil on the sides as well as the bottom of the trench. To complete this task was doubly difficult. A plywood form 8 feet long was built to fit the trench. Treated soil was mixed in a mortar box and shoveled in place along the trench side while gravel was placed in the center of the form. When the form was lifted, the treated soil and gravel interface was quite perfect. The time required to complete 30 feet of trench was twelve man hours. After one year of use it is quite apparent from the settlement at the surface that the treated soil along the trench sides was not properly compacted. This could have been accomplished probably only by flooding with a hose. There is some evidence from the laboratory studies to date that such a procedure would have broken down the aggregation. From this point of view, if not from the economic aspect, trench number three is not to be recommended.

Trench number 5 was by far the most tedious to build. Twenty-four man hours of added work were required to mix the soil, pumice, and soil conditioner with the proper moisture and thoroughly aggregate the mass. All labor was done by hand using a mortar box. A total of 1300 pounds of pumice was used in the 30-foot trench. Undoubtedly a great deal of time could have been saved by utilizing mechanical equipment for mixing. It was felt, however, that the technique used was the only guarantee that proper control of ingredients would be observed throughout the trench.

It was desired in the trench operation to maintain strictly aerobic conditions within the confines of the trench. It is a well-known fact that under anaerobic conditions, sewage slime can plug the most pervious strata and a very lengthy period of rest would be required to restore the strata to its original condition of perviousness.

Nevertheless, in order to study the rate of percolation, it was necessary to flood the trenches. This was done at the time of a regular dose when instead of the regular dose, eight quick doses were pumped to the trenches. This gave an approximate depth of 6 inches of liquid with which to observe the rate of percolation.

Initially, it was felt that an aerobic flora was not yet built up to destroy the organic matter which was bound to be deposited at the soil interface and so, rather than precipitate an anaerobic condition, one percolation test only was permitted during the first week of operation. This first quantity of sewage was absorbed so quickly that it was impossible to complete a round of all the absorption beds before the liquid had disappeared. It was found that, contrary to the original thought on the matter, an appreciable length of time was required before sewage levels within the absorption beds were stabilized. The liquid surged back and forth in the tile for quite a few minutes before penetrating the gravel and reaching the sounding wells, and about twenty minutes were required for a leveling off of the liquid after a trench was dosed.

Beyond the 20-minute period, as subsequent tests showed, the liquid seemed to subside at a more or less constant rate. Considering the curve as a whole, when plotting depth as ordinate against time as abcissa, the curvature lies concave upward as would be true if the liquid were discharging through one or more orifice openings. After 20 minutes the curve becomes essentially a straight line which would probably best describe conditions within the trench when the loss is due to seepage alone. The first 20 minutes must be considered as a period when percolation through the gravel predominates. Beyond that time the curve shows a true loss in liquid from the trench due to seepage. This in turn probably depends only slightly on the depth of liquid (within the range occurring in the trench) and probably to a much greater extent on capillarity and the general porosity and permeability of the medium. For this reason, the slope of the subsidence curve after 20 minutes was considered to be indicative of the conditions within the trench.

The general procedure after dosing the trenches was to move from trench to trench taking liquid depth readings which were recorded along with the time the reading was taken. These values were plotted as depth against time (Fig. 6). By interpolation the 20-minute value and 40-minute value were obtained from the curve and the difference taken. This difference when divided by 20 minutes represented the rate of percolation from the absorption bed. These values have been plotted for each trench and complete information for the first year of operation is shown in Fig. 7.

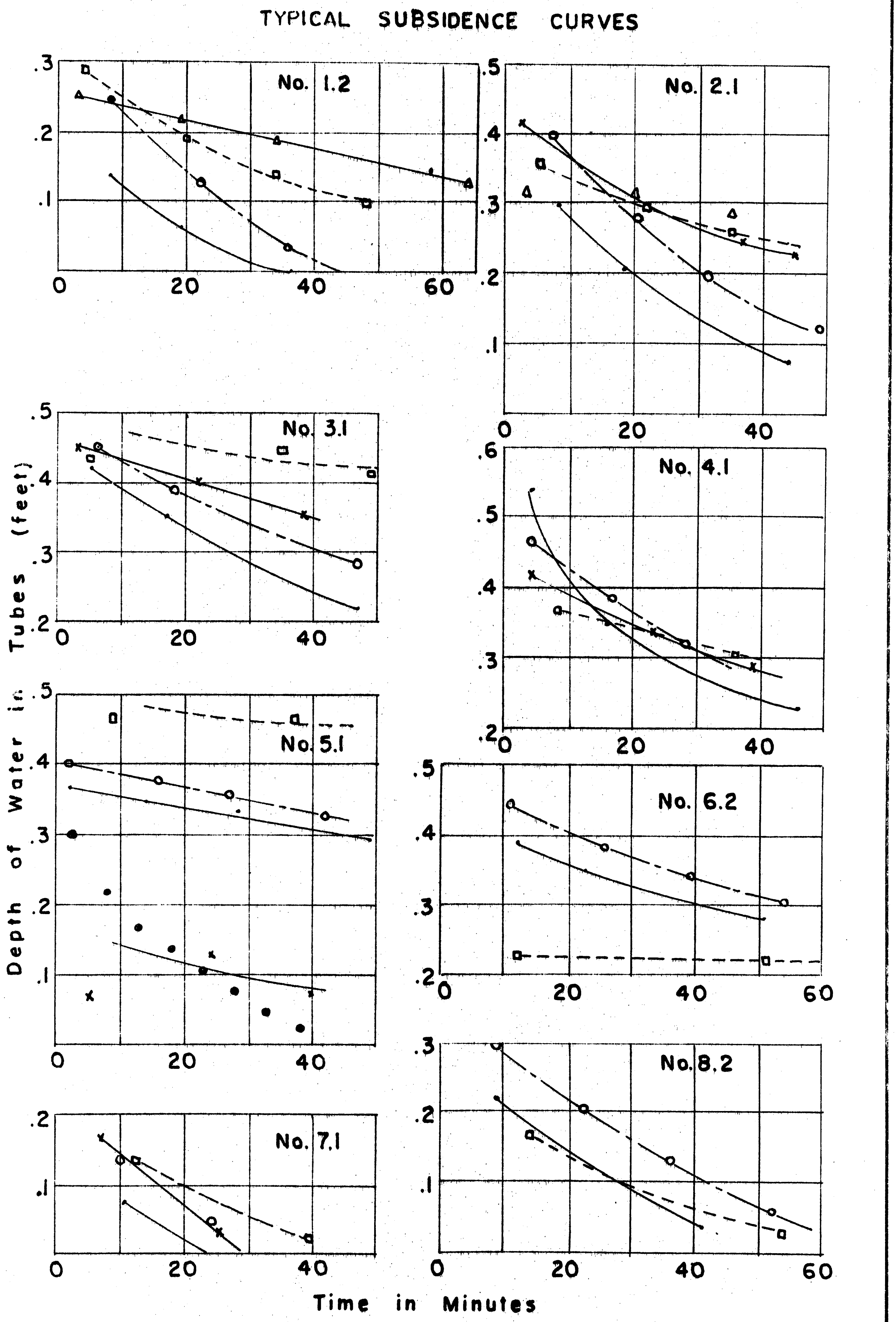

TYPICAL SUBSIDENCE CURVES
No. 1.2
No. 2.1
No. 3.1
No. 4.1
No. 5.1
No. 6.2
No. 7.1
No. 8.2
Depth of Water in Tubes (feet)
Time in Minutes

Fig. 6

SECTION III

LABORATORY PROCEDURE AND RESULTS

The laboratory phase of this study as originally conceived was designed to establish a simple percolation test which would enable a technician to compare the percolation characteristics of any soil to that of the test plots in Ann Arbor. Thus, the effect of polyelectrolyte treatment on an unknown soil could be predicted using the results obtained with the Ann Arbor soil as a basis.

Briefly, the objectives of such a study would be, first to establish a rate of percolation for the untreated Ann Arbor clay, then to establish rates of percolation for chemically treated columns of Ann Arbor clay set up as nearly as possible in the same fashion as the field plots. Any differences in results would have to be modified by a correlating factor to obtain agreement with field results. In order to predict polyelectrolyte effects on clays from other sites, a laboratory percolation test would be run on treated and untreated clay columns of the unknown soil. The difference would be modified by the use of a correlating factor selected on the basis of the experience gained in the Ann Arbor tests. Such predictions could not be assumed to be accurate until validated by field experiences involving other instances of polyelectrolyte treatment on similar types of soil.

The considerations outlined above led to the conclusion that in the proposed laboratory study it would be very desirable to maintain conditions in the tubes comparable to conditions at the field plot in order to keep the correlating factor within useful limits. Scale effects, wall effects, and underdrainage problems were recognized as being of such magnitude in the laboratory tubes that the extension of the results to field conditions would be difficult at best. Optimum moisture concentration, chemical dosage, contact time, and degree of mixing, while of greatest importance in a percolation study, all assumed minor degrees of importance in this case since duplication of field conditions was the ultimate result desired in the laboratory work. Other variables, such as degree of compaction and variations in soil characteristics, of course, would have to be reduced to an absolute minimum in order to obtain comparable results on replicated samples.

Excavation of the field trenches and borings taken before and after construction left no doubt that there were variations in soil characteristics throughout the testing area. To eliminate these variations in the laboratory experiments a large amount of soil was taken from a point near the center of the field installation. This soil was stored in cardboard containers at room temperature and humidity for use on all percolation tests involving Ann Arbor soil. The physical characteristics of this soil are given in Table II.

TABLE II

ANN ARBOR TEST SOIL ANALYSIS

Moisture field conditions	16.95%
Moisture air dried in laboratory	1.243%
Organic content loss on ignition	4.49%
Liquid limit	47.8%
Plastic limit	30.0%

Initially a qualitative test program was designed to reveal what type of equipment and testing methods should be used to produce the best results. Two dozen percolation tubes were prepared as shown in Fig. 8. Each of these tubes was coated with asphaltum since it was expected to be exposed to the corrosive action of a settled sewage. The main problems to be decided by this test were:

a. What type of underdrain and distribution device should be used?

b. How should the waste be placed in the tube?

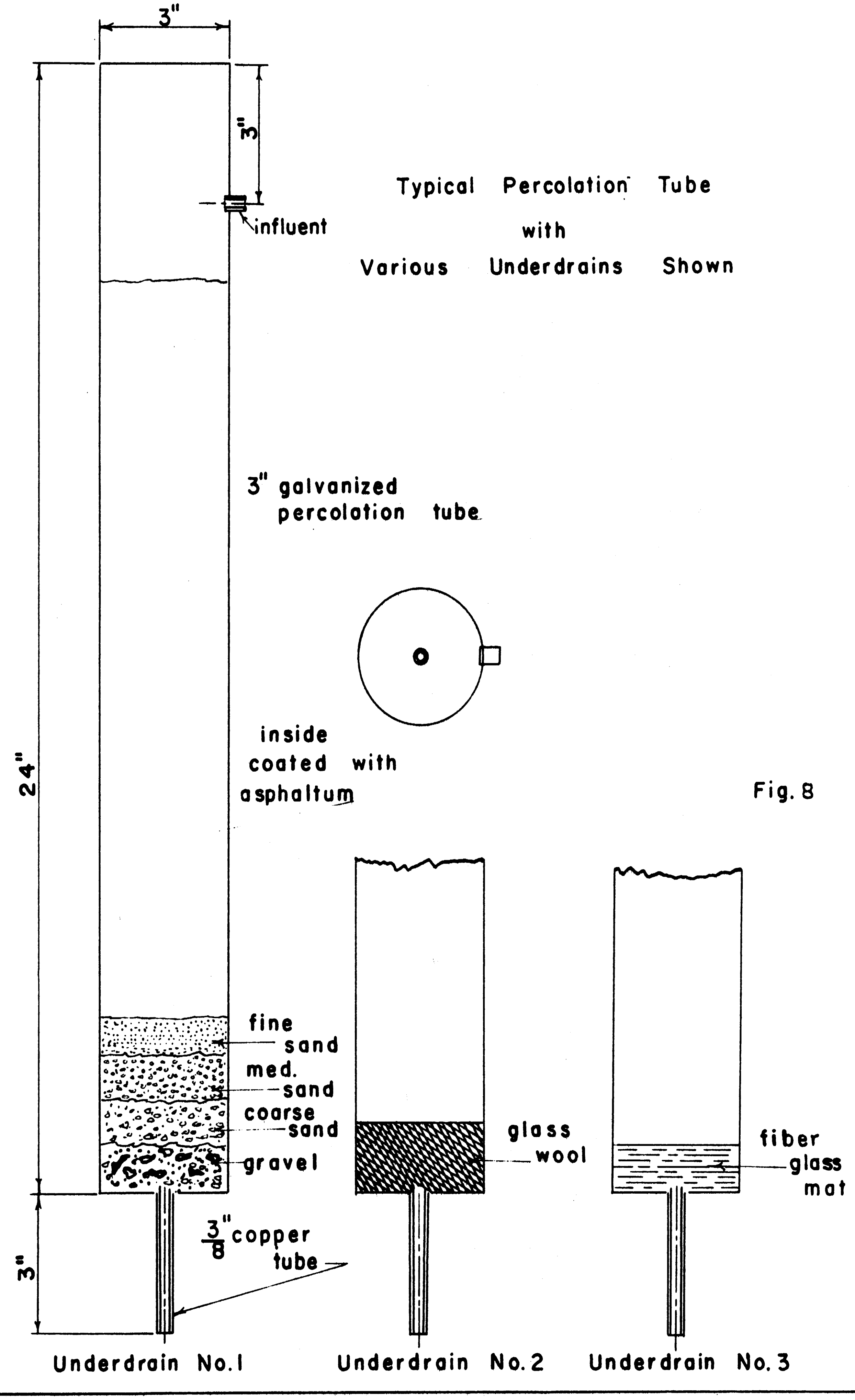
c. How should the rate of percolation be determined?

d. What should be the depth of clay column used?

e. What proportion of this column should be treated clay and what part untreated clay?

f. How should these clay fractions be placed in the tube?

An exploratory test (Series 1) was set up as follows. Enough clay for five tubes, each having a 12-inch clay depth, was air dried, crushed, and sieved through 1/4-inch mesh sieve. That portion passing the 1/4-inch mesh sieve was placed in four 3-inch layers upon a previously prepared underdrain system (see Fig. 8). Each increment was tamped ten times with a blunt wooden rod 1 inch in diameter and 24 inches



Typical Percolation Tube with Various Underdrains Shown

Fig. 8

long. Five hundred cc of clear water were placed on the surface and allowed to saturate the clay column. The tube was then filled with water. No percolation occurred. Clay depths were decreased as indicated below with results as noted.

TABLE III

SERIES 1

Test No.	Underdrain No.	Depth of Untreated Clay in.	Result
1-A	1	12	Negligible flow
1-B	1	9	Negligible flow
1-C	1	6	Negligible flow
1-D	1	3	Slight flow, evaporation a problem
1-E	2	1-3/8	Slight flow
1-F	2	5/8	Slight flow
1-G	2	3/8	High flow, washing along tube sides

In order to observe the action and to determine whether the effect of capillarity in untreated clays could be overcome by inducing a synthetic head, a vacuum was placed on the underdrain systems of three untreated clay columns (Series 2). The clay was processed as in Series 1 and placed in clear plastic tubes.

TABLE IV

SERIES 2

Test No.	Underdrain No.	Depth of Untreated Clay in.	Vacuum in Feet of Water ft.	Result
2-A	1	9	24	Negligible flow
2-B	1	3	24	Small flow, channeling down walls
2-C	1	3	24	Small flow, channeling down walls

A group of tubes (Series 3) was prepared by adding 0.1 percent of K-6 to the dry clay. To this mixture water was added in the proportion of 50 percent by weight of dry soil. The wet mixture was allowed to react, was crumbled, allowed to dry, and then sieved and placed in percolation tubes as in Series 1. It was assumed that percolation would occur and as part of the test it was desired to note consistency of results.

TABLE V

SERIES 3

Test No.	Underdrain No.	Depth of Treated Clay in.	Result
3-A	1	6	Erratic flow, tube sealed after three doses
3-B	1	6	Erratic flow
3-C	1	6	High flow
3-D	1	6	Negligible flow

The erratic results of the previous series of treated clay columns (Series 3) was especially disconcerting. This series was duplicated using underdrain #2 and using two clay layers, each 2 inches thick, of treated clay processed as in Series 2.

TABLE VI

SERIES 4

Test No.	Underdrain No.	Depth of Treated Clay in.	Time in Minutes for Flow of:			
			50 cc	100 cc	150 cc	200 cc
4-A	2	4	23	45	70	110
4-B	2	4	31	62	104	160
4-C	2	4	18	32	48	67
4-D	2	4	43	96	160	260
4-E	2	4	195	412	600	-
4-F	2	4	645	-	-	-

A survey of results to this point indicated that:

(1) Raw Ann Arbor clay placed dry in percolation tubes would swell when wetted and effectively prevent any measurable degree of percolation.

(2) Fairly high heads might be used to overcome capillarity but within the confines of a small diameter percolation tube, inevitably the flow would break through usually at the wall destroying the value of this type of test.

(3) Underdrain type 1 was very time-consuming to prepare and gave comparable results to underdrain type 2. Type 3 is suggested as being probably more reproducible and easier to use than either types 1 or 2.

(4) Moisture content of the percolating soil column must be kept at or near saturation at all times to prevent the development of shrinkage cracks. Intermittent dosing of percolation tubes was used since it most nearly corresponded to field practice. A fiber glass pad is recommended for distribution of the applied water and to prevent evaporation at the surface of the soil if high rates of percolation result in dewatering the tube between dosing cycles.

(5) There was little reproducibility of results in columns of chemically conditioned soils. This suggested that fines and dust, which are possibly unaffected by the chemical treatment, were being washed down through the percolation columns and in some cases were stratifying, causing a major degree of sealing. Visual inspection suggested that either this was the case or that variable degrees of channeling, possibly induced in placement, existed initially. Such channels could be gradually plugged up by washing or erosion.

While elimination of fines is impossible in the field, it was possible to accomplish it quite easily in the laboratory during the preparation of the percolation samples. The elimination of fines would make the extension of resulting test data to field conditions more difficult but it was decided to attempt the sieving of aggregates, since it would at least indicate whether or not the fines were causing trouble. At the same time additional refinements in procedure were adopted in order to improve the reproduction of results.

It was decided that the following procedure would be used at this point: Ann Arbor clay was dried at 103°C for 24 hours. The dried clay was crushed, weighed, and 0.10 percent by weight K-6 applied. Twenty percent by weight of water was added and the mixture was aggregated by cutting the batch a standard number of times. After a 1-hour period for reaction the mixture was fixed by again drying at 103°C for 24 hours. At this point the dried mixture was sieved through a nest of sieves containing 1/2 inch, #8 and #40 sieves. Percolation tubes were prepared using 12 ounces of material measured on a dry weight basis. The material was placed in the tubes in increments of 4 ounces. Each tube was vibrated ten times by dropping it 3 inches to a wooden block. After preparation, the clay column was covered with a fiber glass pad and dosed with 250 cc of water twice, with a 10-minute interval between doses. At this point the tubes were placed in a rack and dosing was continued by hand using a 500-cc quantity six times per day.

The rate of percolation was determined every other day by catching the first 250 cc of a 500-cc dose and recording the time, starting with time zero when the first 10 cc had passed through the soil column. The time was recorded for each 20-cc increment.

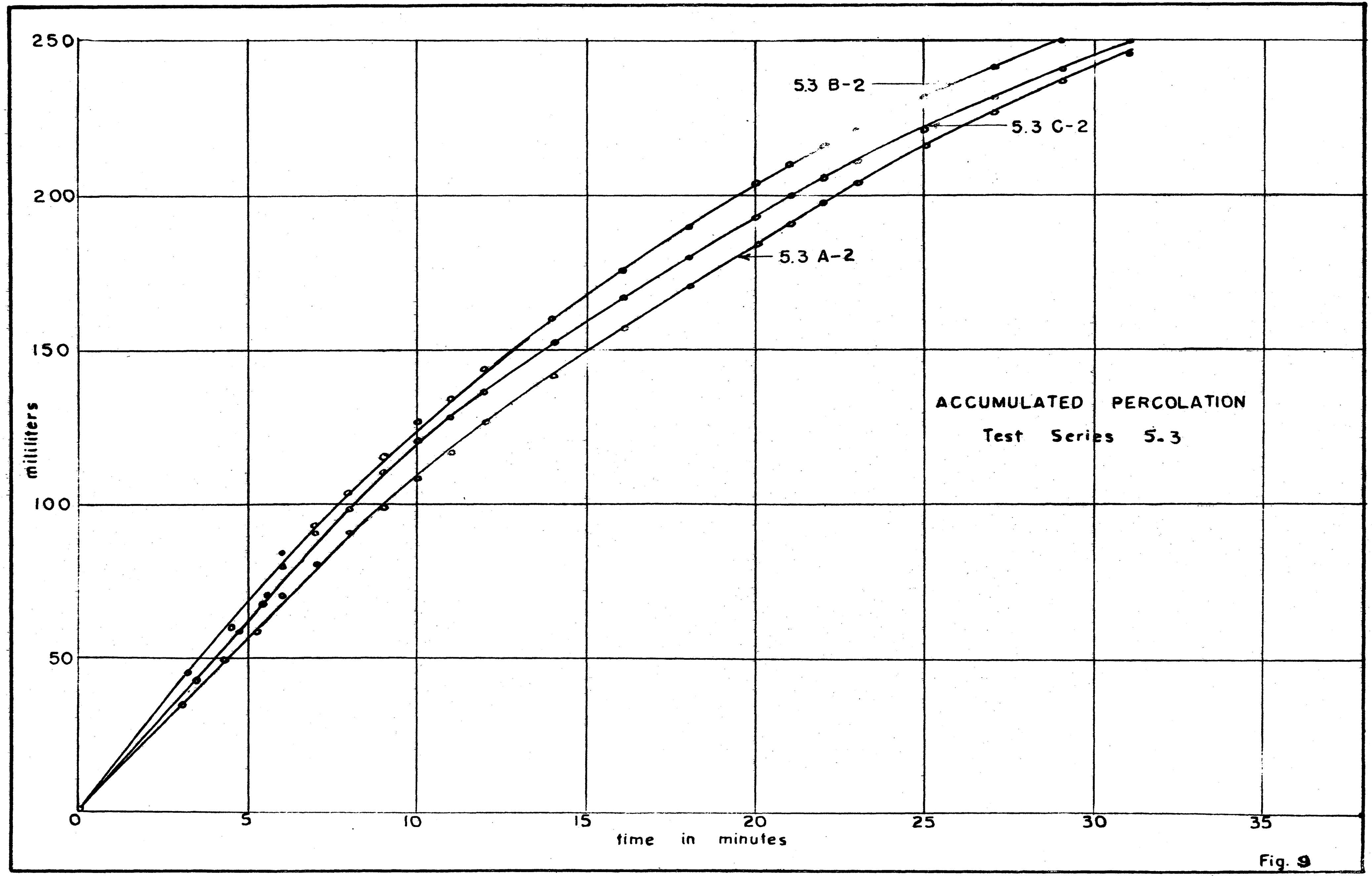
Runs 1 and 2 of Test Series 5 were used in a qualitative sense to determine the desired percentages of sieved sizes in each tube. The following were tried, with results as indicated.

TABLE VII

SERIES 5.1 AND 5.2

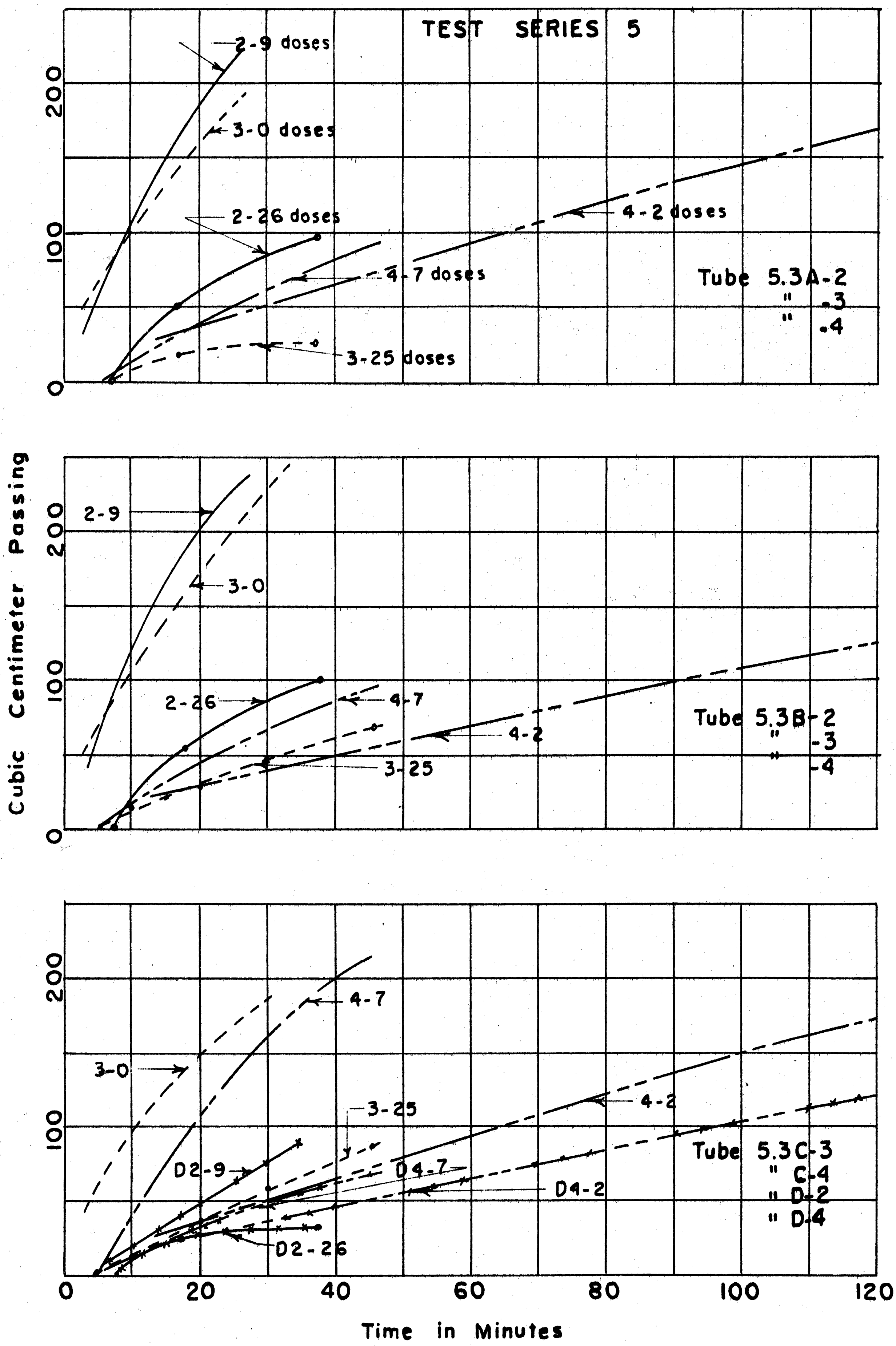
Tube No.	Ret. #8 %	Ret. #40 %	Pass #40 %	Percolation in cc/6 minutes
5.1-A	67	33	-	25
5.1-B	50	50	-	54
5.2-A	44.75	44.75	10.5	Negligible
5.2-B	33	67	-	20

A 50-50 percent mixture, as used in Series 5.1-B, was adopted for the remainder of this test series on the basis of the results above since the highest rate of flow would probably result in the smallest deviation, percentagewise, in replicated samples. Test series 5.3-2, 5.3-3, and 5.3-4 were run primarily to determine the deviations within a batch and between batches. The data from these runs are plotted in Figs. 9, 10, and 11, and it can be noted that there is a great deal of dispersion of results.



250
200
150
100
50
0
5
10
15
20
25
30
35
mililiters
time in minutes
5.3 B-2
5.3 C-2
5.3 A-2
ACCUMULATED PERCOLATION
Test Series 5.3

Fig. 9



TEST SERIES 5
2-9 doses
3-0 doses
2-26 doses
4-2 doses
4-7 doses
3-25 doses
Tube 5.3A-2
" -3
" -4
2-9
3-0
2-26
4-7
4-2
3-25
Tube 5.3B-2
" -3
" -4
4-7
3-0
3-25
4-2
D2-9
D4-7
D4-2
D2-26
Tube 5.3C-3
" C-4
" D-2
" D-4
Cubic Centimeter Passing
0
100
200
0
20
40
60
80
100
120
Time in Minutes

Fig. 10

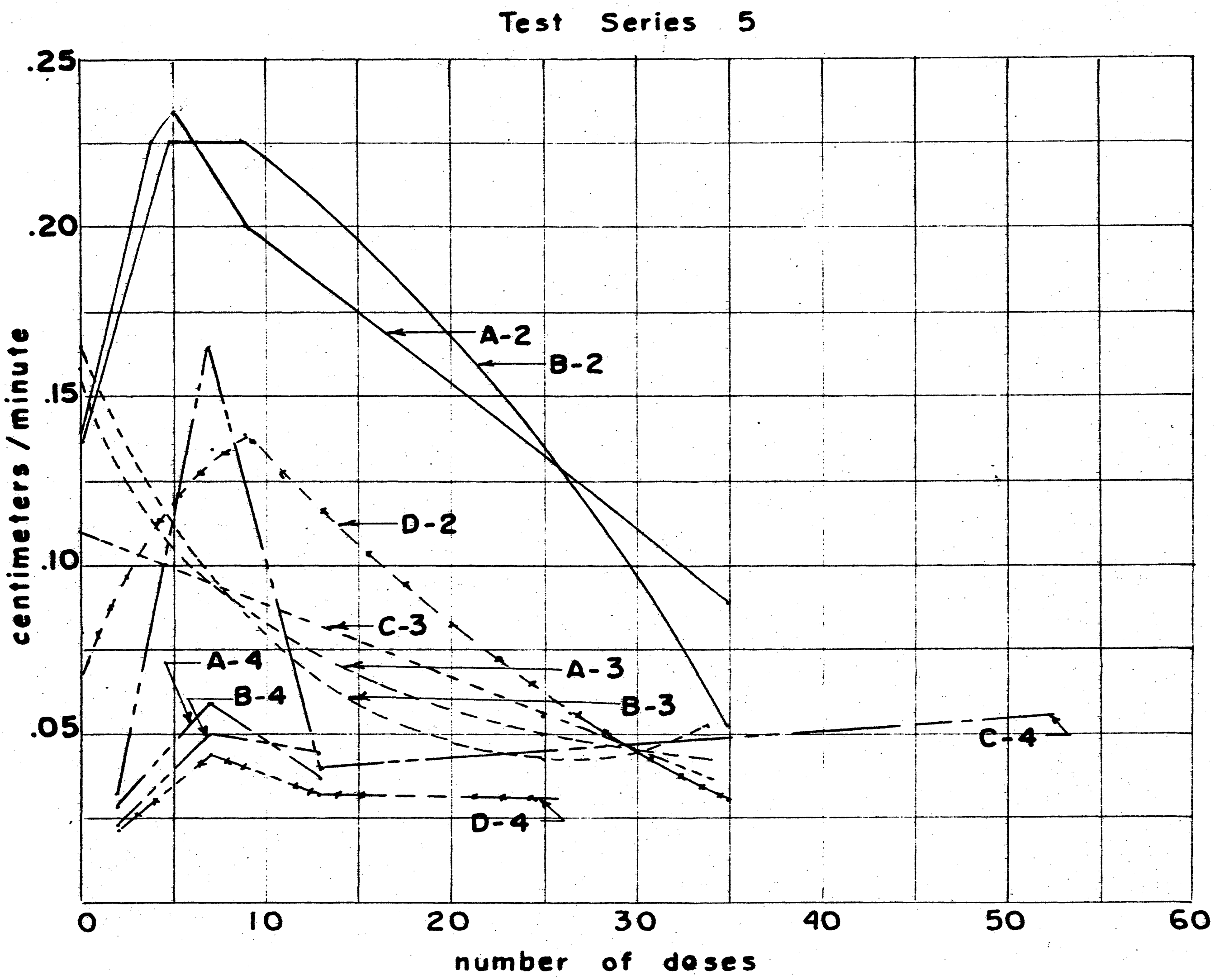

Test Series 5
.25
.20
.15
.10
.05
centimeters / minute
0
10
20
30
40
50
60
number of doses
A-2
B-2
D-2
C-3
A-3
B-3
A-4
B-4
C-4
D-4

Fig. 11

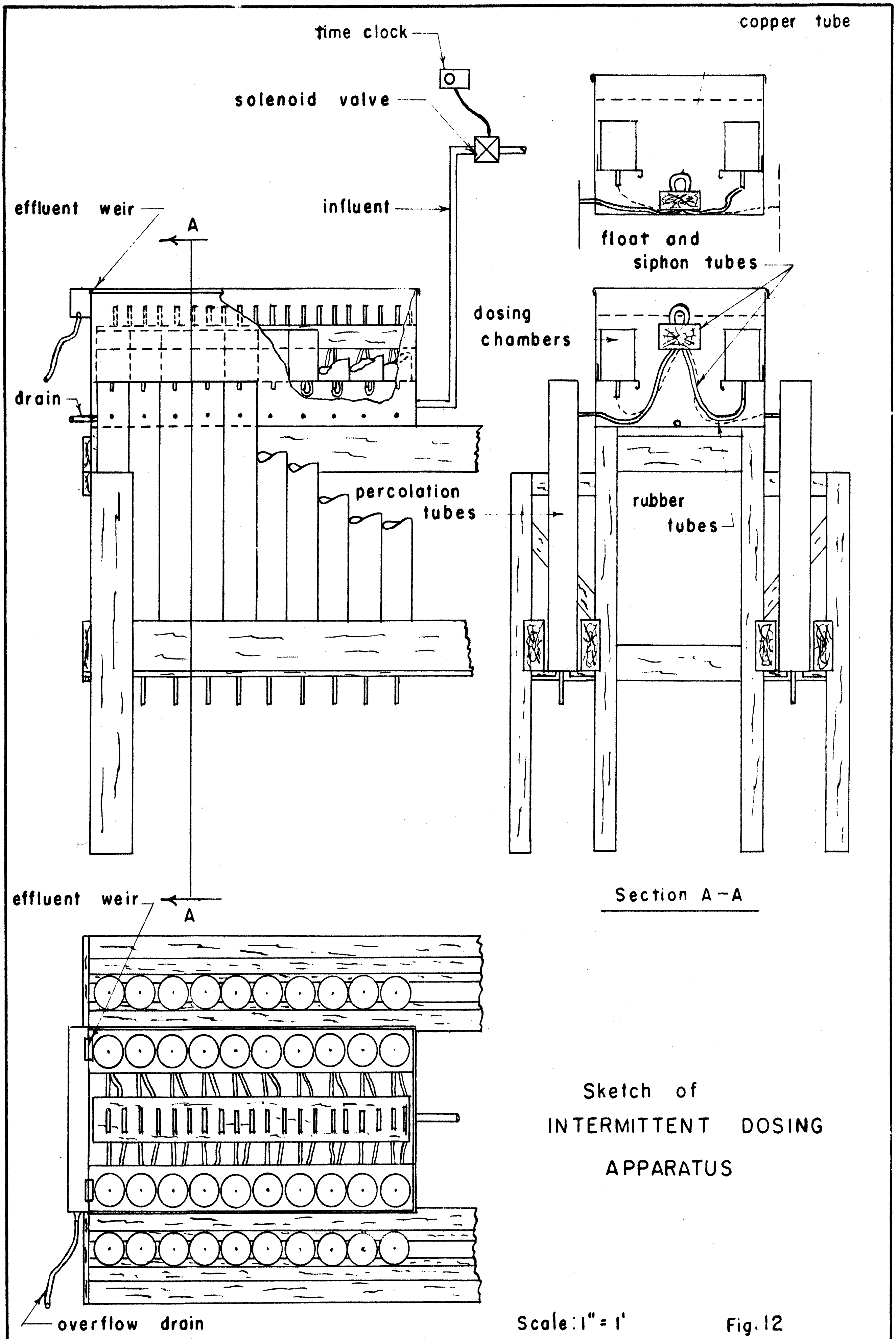
Figure 9 illustrated a typical percolation curve in which accumulated flow was plotted against time. From a curve such as this or those of Fig. 10 a rate of percolation could be determined from the apparent slope of curve. These rates varied considerably as shown in Fig. 11. In general, after a period of wide variation a trend toward a more uniform percolation rate could be discerned.

One variable which was not controlled completely was that of dosing interval. All runs up through 5.3-4 had been dosed by hand at 4-hour intervals. This type of dosing led to difficulties since it was not always possible to dose regularly throughout the evenings. There was some indication that the initial increase in percolation rate was due in part to unequal dosing intervals. It was therefore decided to build a dosing tank which would automatically dose all tubes under test with a definite volume at a definite time interval. The apparatus had to be flexible enough to permit variations in the volume of dose and in the rate of dose. The equipment finally selected was simple and relatively foolproof. As is shown in Fig. 12, a galvanized iron tank was equipped with an inlet, a drain, and a weir overflow. Two shelves supporting a total of twenty volumetric chambers were fastened inside the tank at such an elevation that when the tank was overflowing all chambers were flooded. Each chamber was connected to a percolation tube by a rubber hose which passed up through a float before discharging into the receiving tube. Flow to the tank was controlled through a 3/16-inch solenoid valve actuated by a time clock which could be set to actuate the valve for a given interval of time and for any number of times during a 24-hour day.

A dosing cycle started when the time clock turned on the solenoid valve and the tank began to fill. While filling, the tank was also draining but because of differences in head, the rate of drainage was much lower than the rate of filling. When the tank had filled to overflowing and the volumetric chambers were filled, the solenoid valve was turned off by the time clock. The dosing lines in each case were trapped by the float which held these lines above the lip of the dosing chambers. The discharge on the tank continued to flow, however, and eventually the float fell below the lip of the dosing chambers which permitted all chambers to dose their respective percolation tubes.

The apparatus described above was used to continue the dosing of samples beyond a one-week interval and a decided trend toward a more uniform result was apparent. In addition, a continuous decline in percolation rate was noted with an increasing number of doses (Fig. 13).

Speculation as to the reason for the decline of percolation rates led to a close examination of the dried clay particles which were



Sketch of
INTERMITTENT DOSING
APPARATUS

Fig. 12

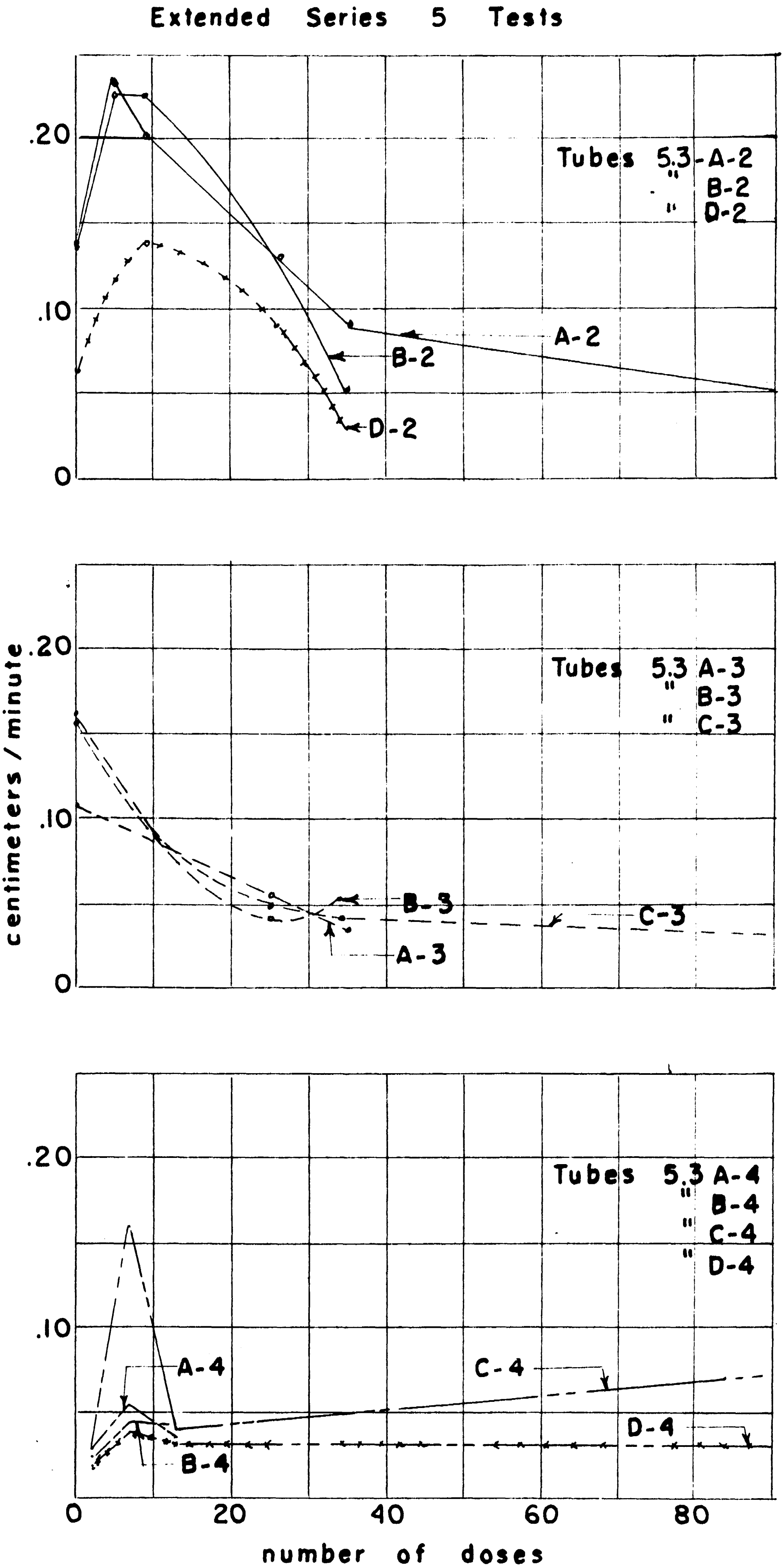

Extended Series 5 Tests
Tubes 5.3-A-2
" B-2
" D-2
A-2
B-2
D-2
Tubes 5.3 A-3
" B-3
" C-3
B-3
C-3
A-3
Tubes 5.3 A-4
" B-4
" C-4
" D-4
A-4
C-4
D-4
B-4
centimeters / minute
.20
.10
0
20
40
60
80
number of doses

Fig. 13

being used. As water was added, the clay aggregate expanded and was seen to break up into fragments. The resulting suspension had none of the properties of porosity or percolation which were possessed by the original aggregate. This tendency was not apparent to the same extent in the aggregates before the final drying step. Two possibilities which could have caused this phenomenon were apparent. A sudden immersion could cause a rapid expansion of the clay; or a high stress could be set up by the air which was being forced from the voids too rapidly.

At this time a conference with Monsanto representatives pointed out the fact that their experiments with wet-sieving techniques utilized an aggregation procedure which made spaghetti of the moistened clay. It was suggested that more uniformity of percolation rates would be obtained by the use of such a technique.

Series 6 was set up to try the spaghetti technique. The clay was ground to dust and K-6 was added. The combination was thoroughly mixed and to it was added 30 percent by weight of water. The change from 50 to 30 percent water was made after 50 percent was found to make the mixture too soupy to respond properly to extrusion. After reacting for 1 hour in a constant humidity box, the sample was extruded through a food mill to give a spaghetti having a 1/8-inch diameter. This material was air dried 24 hours and then dried in a 103°C oven for 18 hours. After cooling the spaghetti was crumbled, weighed, and placed in percolation tubes using underdrain#3. The tubes were wetted initially by flooding the underdrain system and allowing capillary action to draw moisture into the clay column. It was hoped that this would reduce the fragmenting tendency of the clay aggregates. The results are shown in Fig. 14.

A study of the data obtained in test series 6 showed that there was consistency in the results obtained. However, the tests were limited by the number of tubes prepared. Series 7 was designed to increase the number of tubes within a batch and show the relative consistency of results for a number of tubes prepared from the same batch of treated clay. The procedure utilized in the preparation of the clay was identical to series 6 except that the K-6 was mixed with the water and allowed to go into solution before mixing with the dried, crushed clay. The results of this series of tests are shown in Figs. 15, 16, and 17.

In order to show the effect of formation of spaghetti on untreated clay, series 8 was run in which the procedure as outlined for series 6 was followed except that no soil conditioner was used. Percolation results are shown in Fig. 18.

The results of series 7 were so dispersed that it was concluded that the method of placement and moistening the aggregated clay was still faulty. On this assumption a new technique was adopted for series 10,1, Test Series 6.1

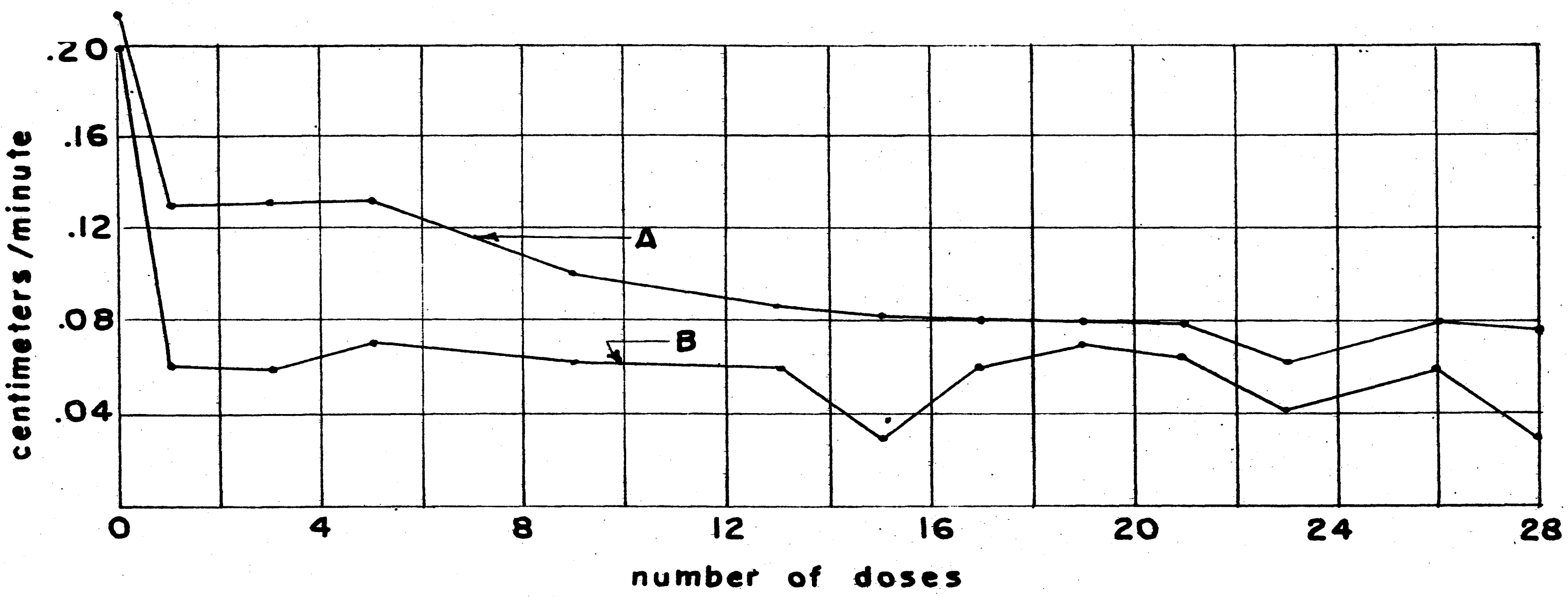


Fig. 14

Test Series 7.1_x

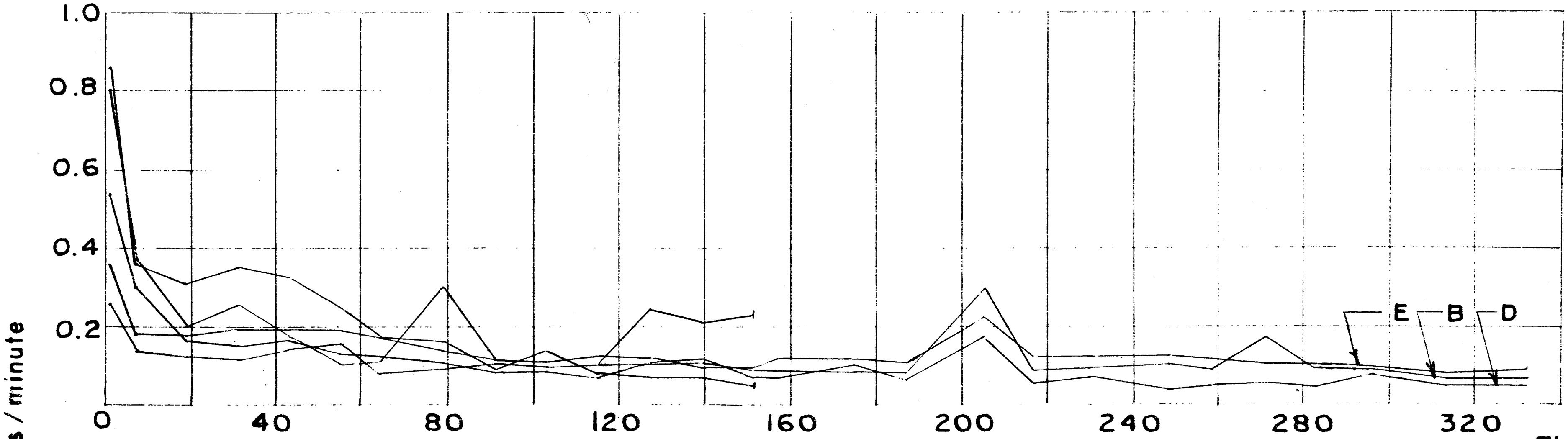


Fig. 15

Test Series 7.1_{x_1}

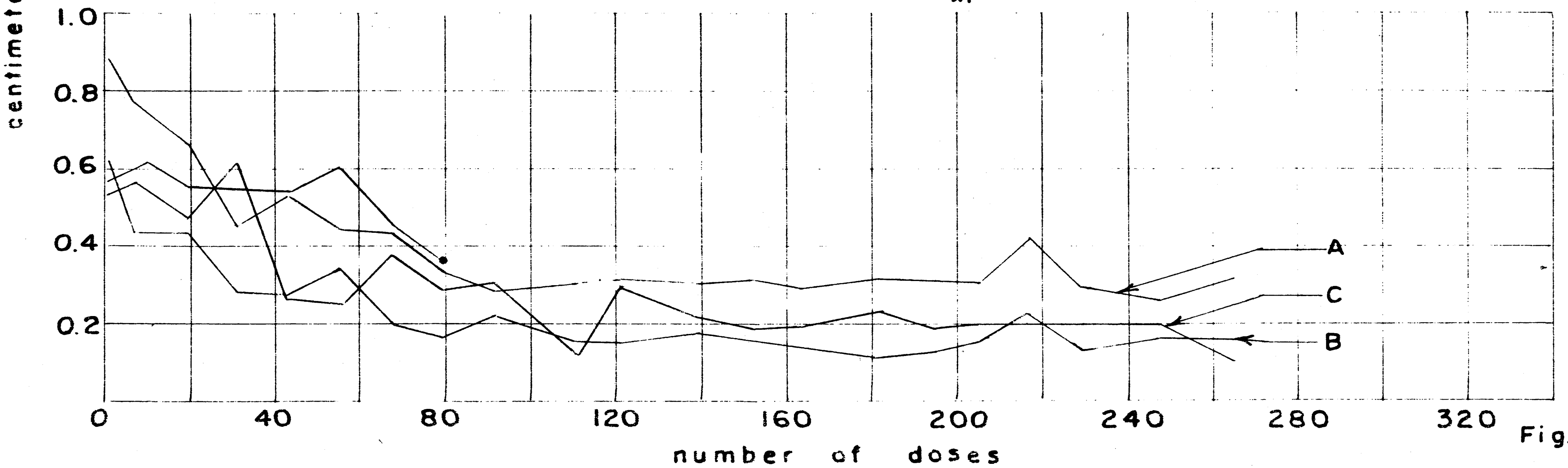


Fig. 16

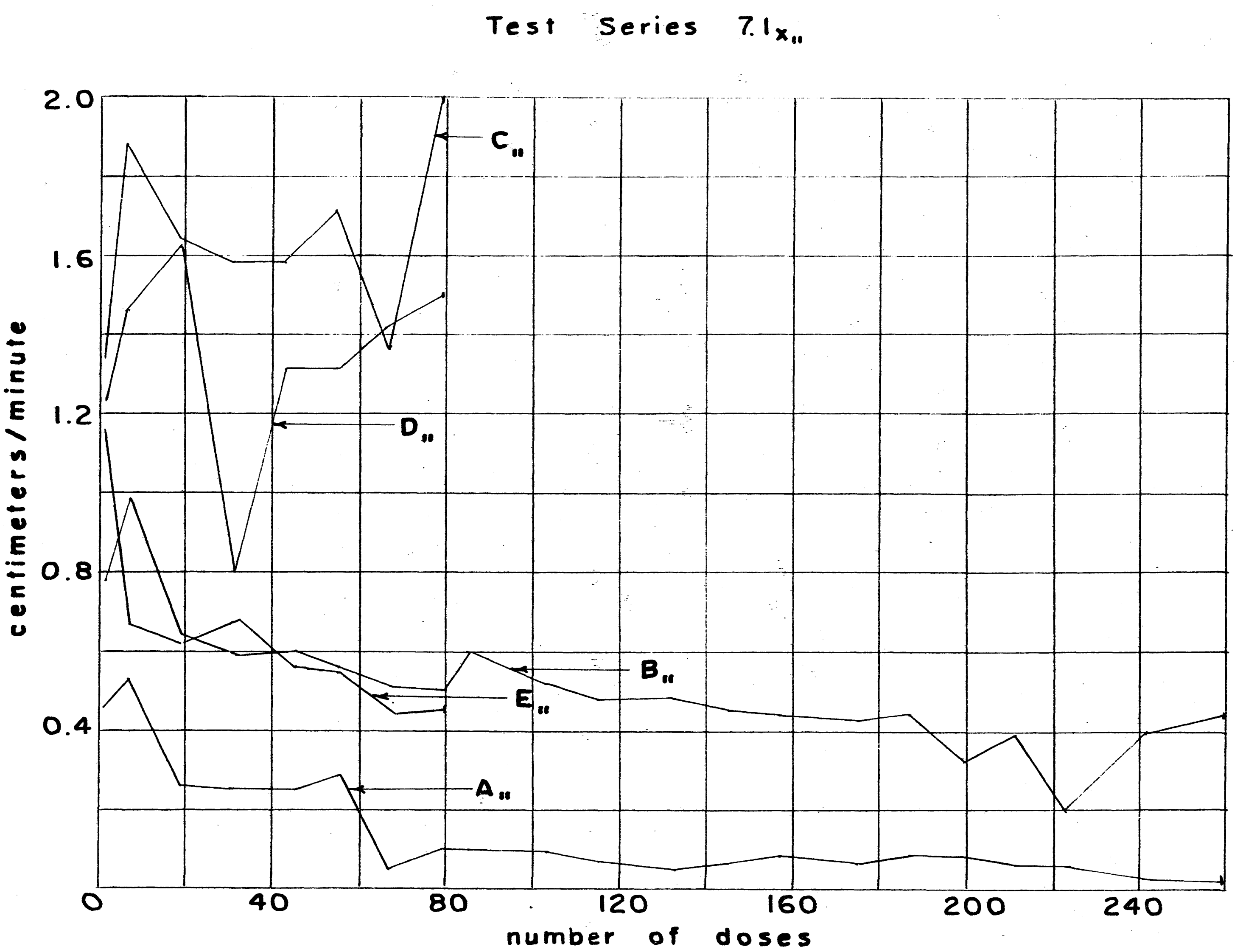

Test Series 7.1x"
2.0
1.6
1.2
0.8
0.4
0
40
80
120
160
200
240
centimeters/minute
number of doses
C"
D"
B"
E"
A"

Fig. 17

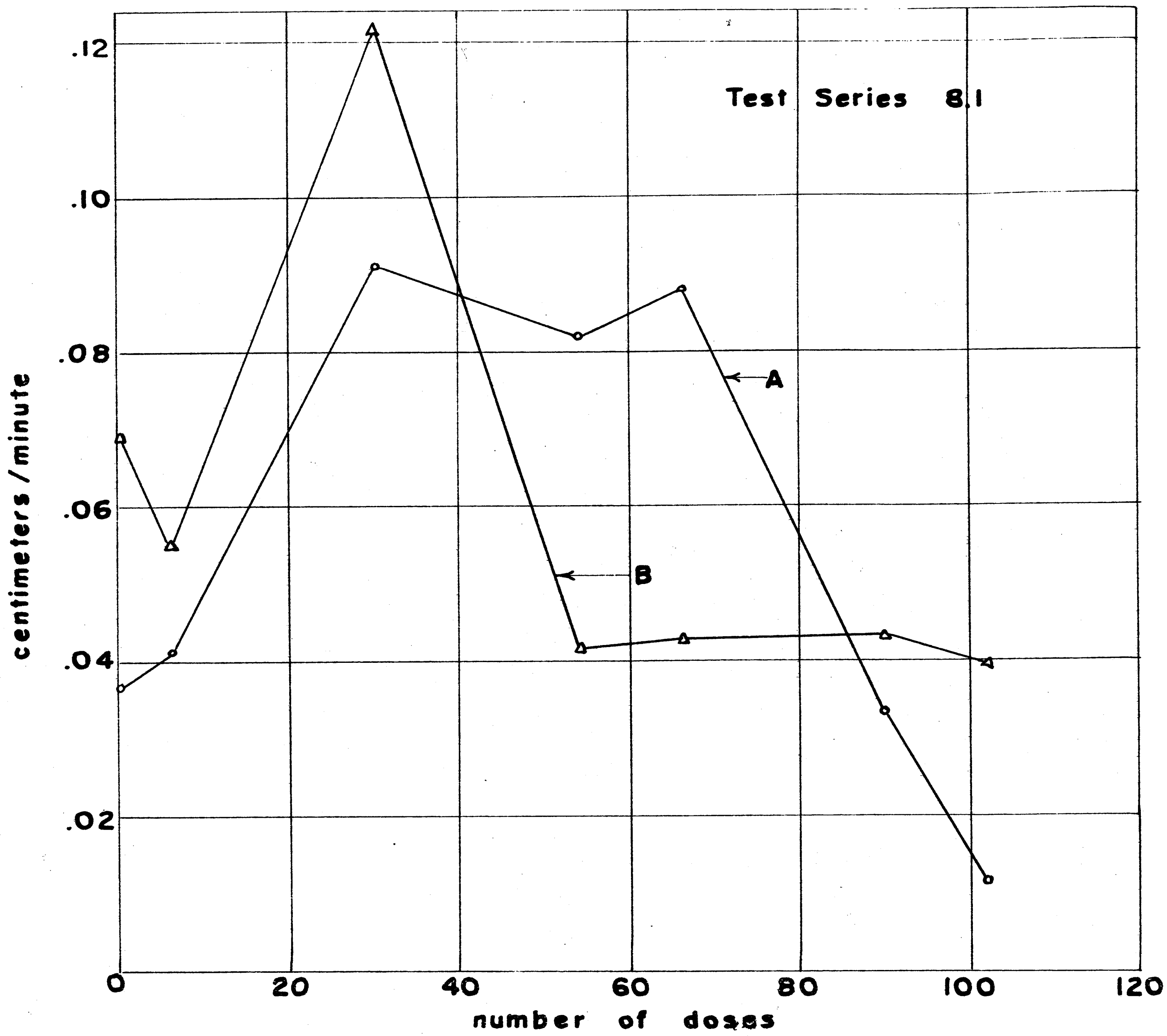

Test Series 8.1
A
B
.12
.10
.08
.06
.04
.02
0
20
40
60
80
100
120
centimeters / minute
number of doses

Fig. 18

namely that of placing the aggregate as it was extruded from the food mill in its wet state into the percolation tubes. The material was dropped into tubes filled with water and allowed to settle into place by gravity. When the water was drained from the tubes a lot of contraction occurred and cracks were observed to open up in the surface and along the sides. Two of these tubes were vibrated slightly to note the effect in closing up the cracks. The cracks closed nicely but on being test run the tubes were found to be completely clogged. The remainder of the tubes in the test was placed in the dosing apparatus and seemed to give fairly consistent results (Fig. 19).

Test series 10.1 was repeated in series 10.1X in order to check uniformity of results. Figure 20 indicated that very little correlation existed initially. After about forty doses, however, a relative agreement seemed to exist with some tubes acting in a peculiar fashion.

The size of the pellets, it was reasoned, would have a direct bearing on the uniformity of placement of the material and for this reason the pellet size was reduced by utilizing a #8 sieve and forming the pellets by pressing the treated clay through the sieve. The clay responded best at a moisture concentration of 20 percent and therefore the original mixture which had been prepared at 50 percent moisture was air dried to the optimum level before processing. Series 10.2 consisted of tubes containing these small pellets placed in flooded tubes while still wet. The contraction of the mass when placed in the dosing apparatus was much less than observed in the case of the 1/8-inch pellets. In addition, the contraction from tube to tube seemed to be more uniform. After draining, cracks were again observed in the surface of the treated clay mass.

Rate of percolation through the tubes was computed in the same fashion as for the previous series of tubes. The resulting curves, as shown in Fig. 21, are very erratic. Tube 10.2-B sealed entirely after 90 doses.

At this point the laboratory was again visited by a Monsanto representative. After consideration of the difficulties his advice was to reduce the amount of water being used to 30 percent by weight of dry ingredients. In addition, it was recommended that the soil conditioner be applied in solution form rather than dry.

The same procedure as previously used in test series 10.2 was utilized for series 10.3 with the exceptions noted above. Percolation rates were obtained as shown in Fig. 22. Initially, it was thought that the tubes would prove to be very consistent but, as shown by the curves, the rates of percolation deviated rapidly with continued dosing.

Test Series 10.1

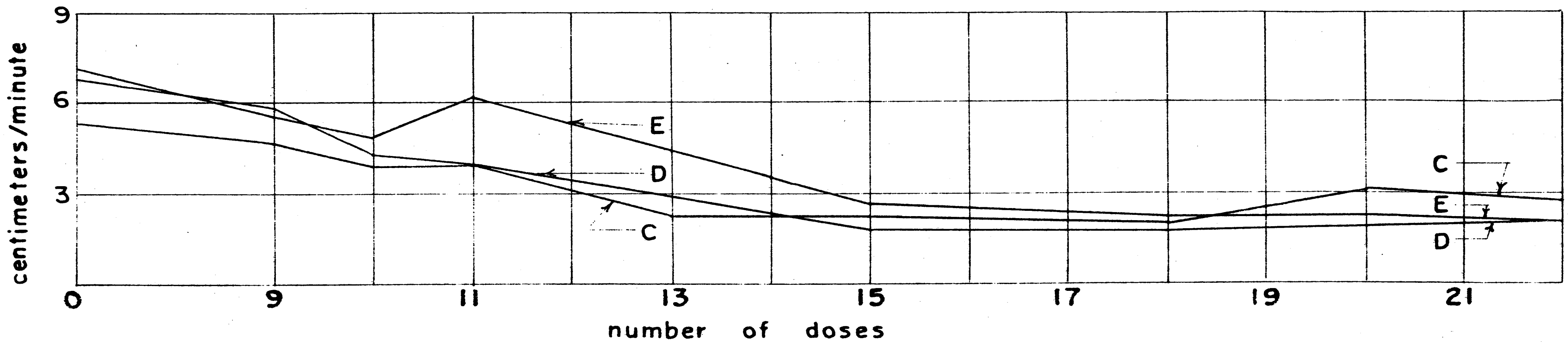


Fig. 19

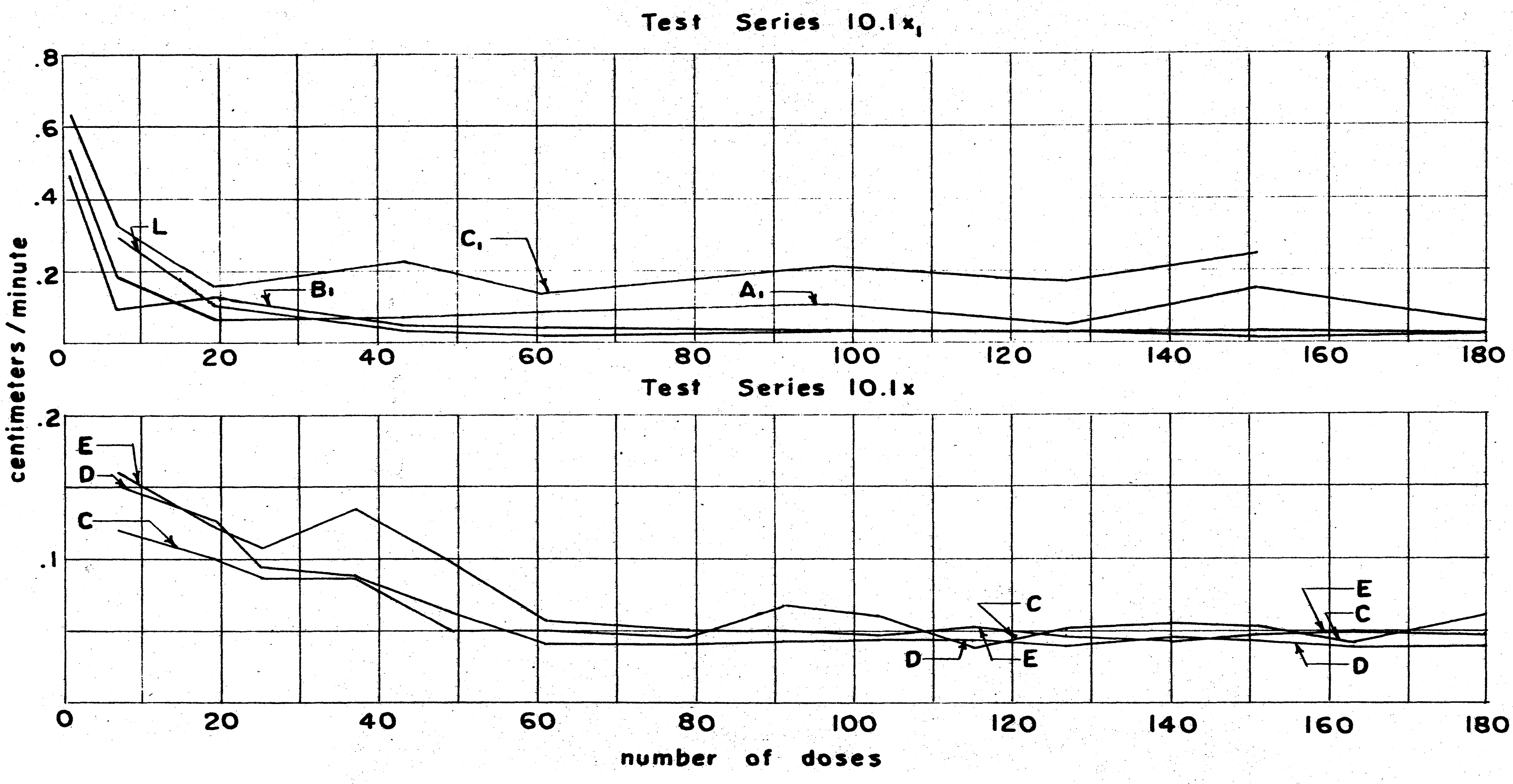
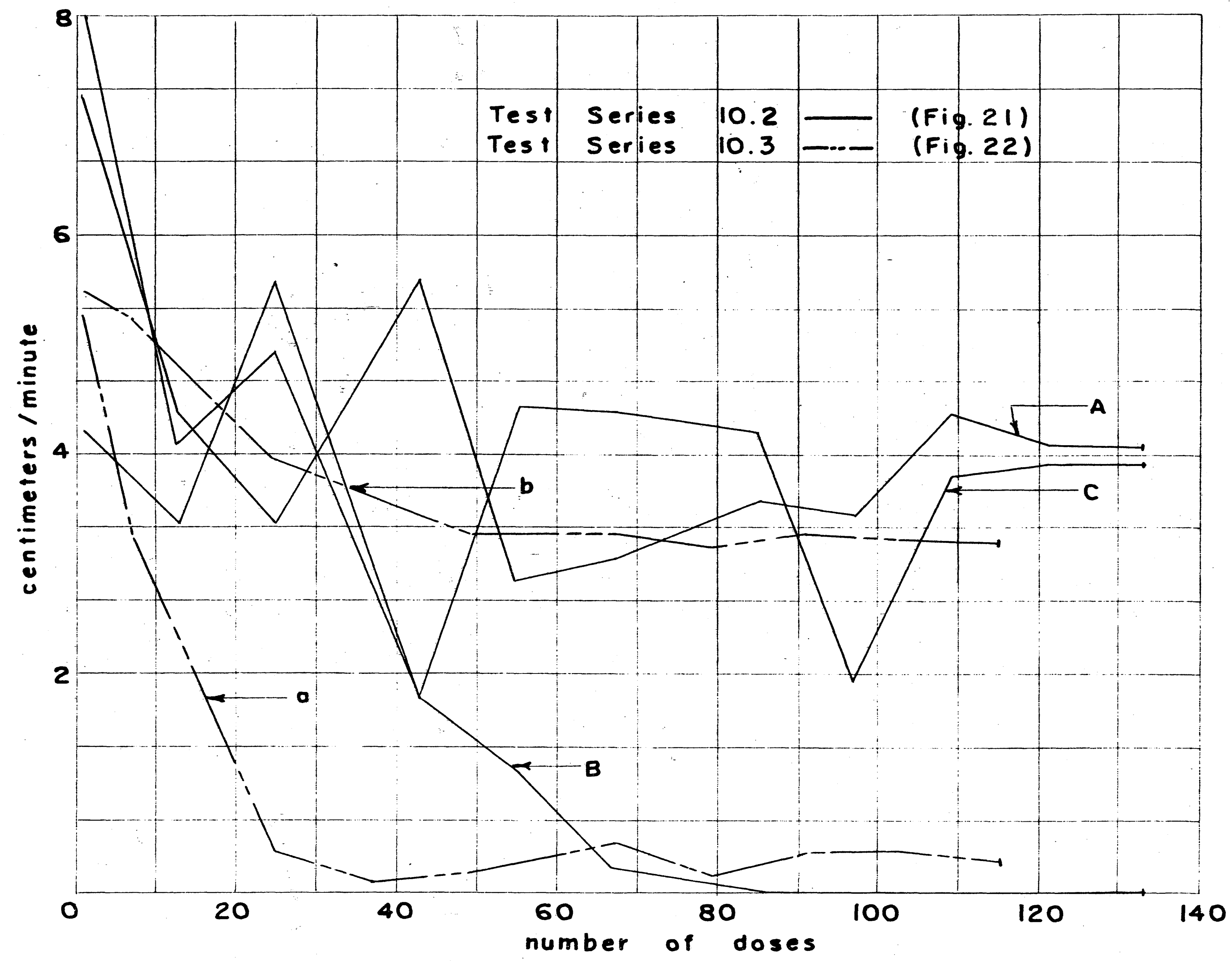

Test Series 10.1x1
.8
.6
.4
.2
0
L
C1
B1
A1
20
40
60
80
100
120
140
160
180
centimeters / minute
Test Series 10.1x
.2
.1
E
D
C
number of doses

Fig. 20


Test Series 10.2 (Fig. 21)
Test Series 10.3 (Fig. 22)
A
B
C
a
b
centimeters / minute
number of doses
0
20
40
60
80
100
120
140
2
4
6
8

Test series 11 was initiated to demonstrate the effects of continuous percolation as opposed to the ebb and flow type of study which had been utilized in all work to this time. Intermittent percolation is, of course, the normal condition found in absorption beds. However, it was felt that with conditions prevalent in the percolation tubes deviating so greatly from conditions in the field installation due to changes arising from findings in the first ten series of studies, the additional factor of continuous percolation would probably not complicate the picture further. In addition, it was reasoned that difficulties to date in the replication of data had stemmed from the presence of cracks and channels opening up during the period when the free liquid had passed out of the tube. Air that had been drawn down into the tube and which was caught there could hamper percolation. Air bubbles breaking out of the aggregation while it was submerged could cause channeling and increase percolation.

While a study of continuous percolation utilizing sewage could never be instituted with any hope of success, the laboratory phase of the study had never gotten that far. As long as clear water was being utilized it was decided to see what would be the effect on chemically treated columns of soil under continuous flow conditions.

A galvanized iron container having two compartments as detailed in Fig. 23 was constructed. This container was connected by a valve to a continuous supply of water. The head was kept constant by a drain connection made to the opposite compartment in the container. Percolation tubes were connected by rubber hoses to the compartment containing the water and set so that a constant depth of 1-inch of water existed above the top surface of the soil column being studied.

Test series 11.1 was a duplication of series 10.1 with the exception of the effect of constant flow. In this series the attempt was made to throttle the effluent so as to maintain a constant flow of 2 cc per minute. The volume of the clay column kept decreasing and the head losses through the column kept increasing which made any control of this nature difficult. After six days the control was abandoned and flow was governed only by the 1 inch of water depth maintained over the top of the soil surface and by the head loss through the column.

Test series 11.1X was a duplication of series 11.1 with the exception that unrestricted flow was permitted from the start of percolation. It should be mentioned that both tests 11.1 and 11.1X were made with a soil which had been obtained by the Monsanto Chemical Company from an absorption field in the St. Louis area.

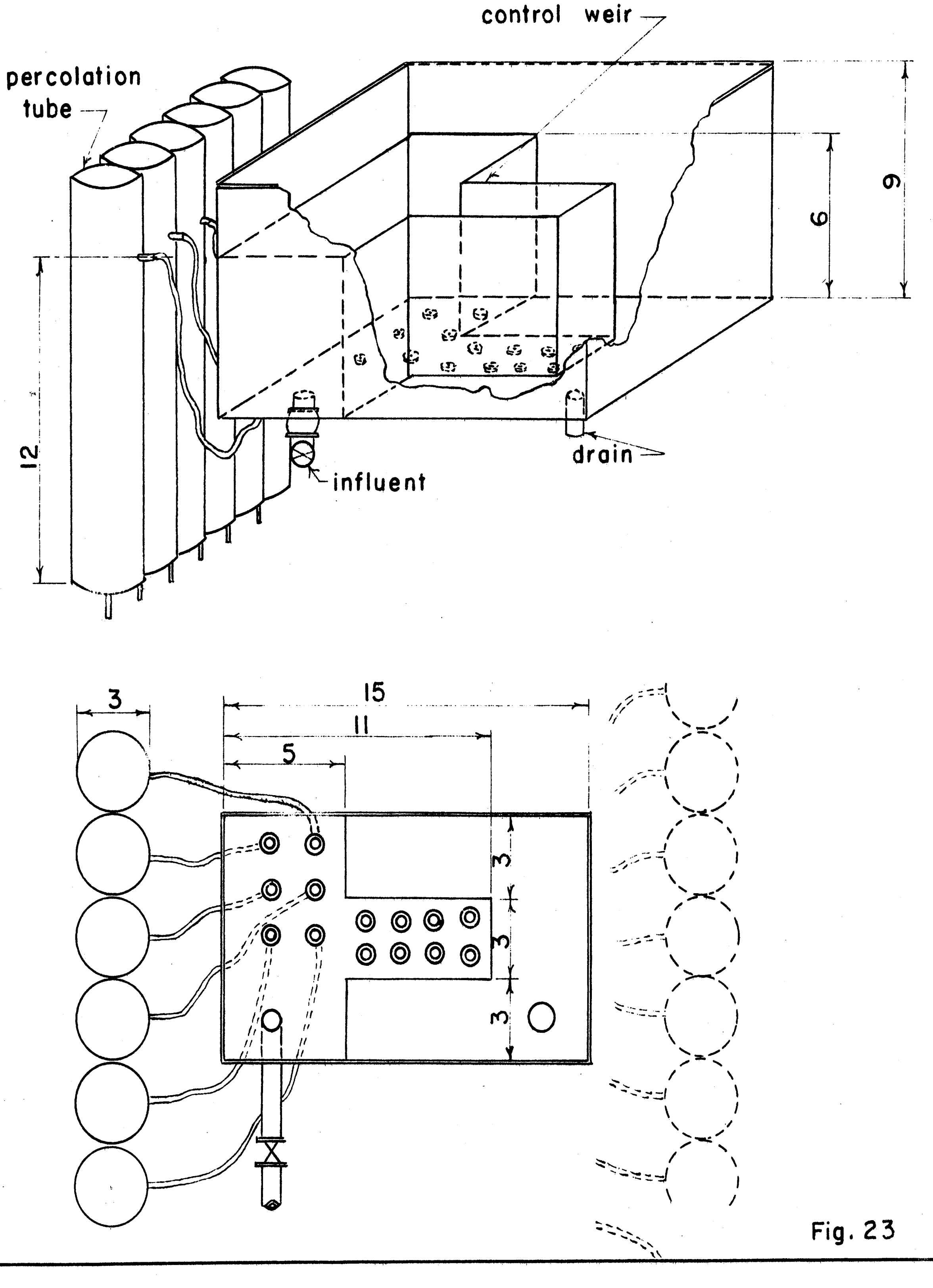

control weir
percolation tube
9
6
12
influent
drain
3
15
11
5
3
3
3

Fig. 23

The results of the percolation tests were plotted (Fig. 24) and were seen to result in a dramatic drop from high initial percolation rates to fairly low rates. In spite of different rates of passage of liquid through the soil columns, eventually all tubes seemed to arrive at a very consistent rate.

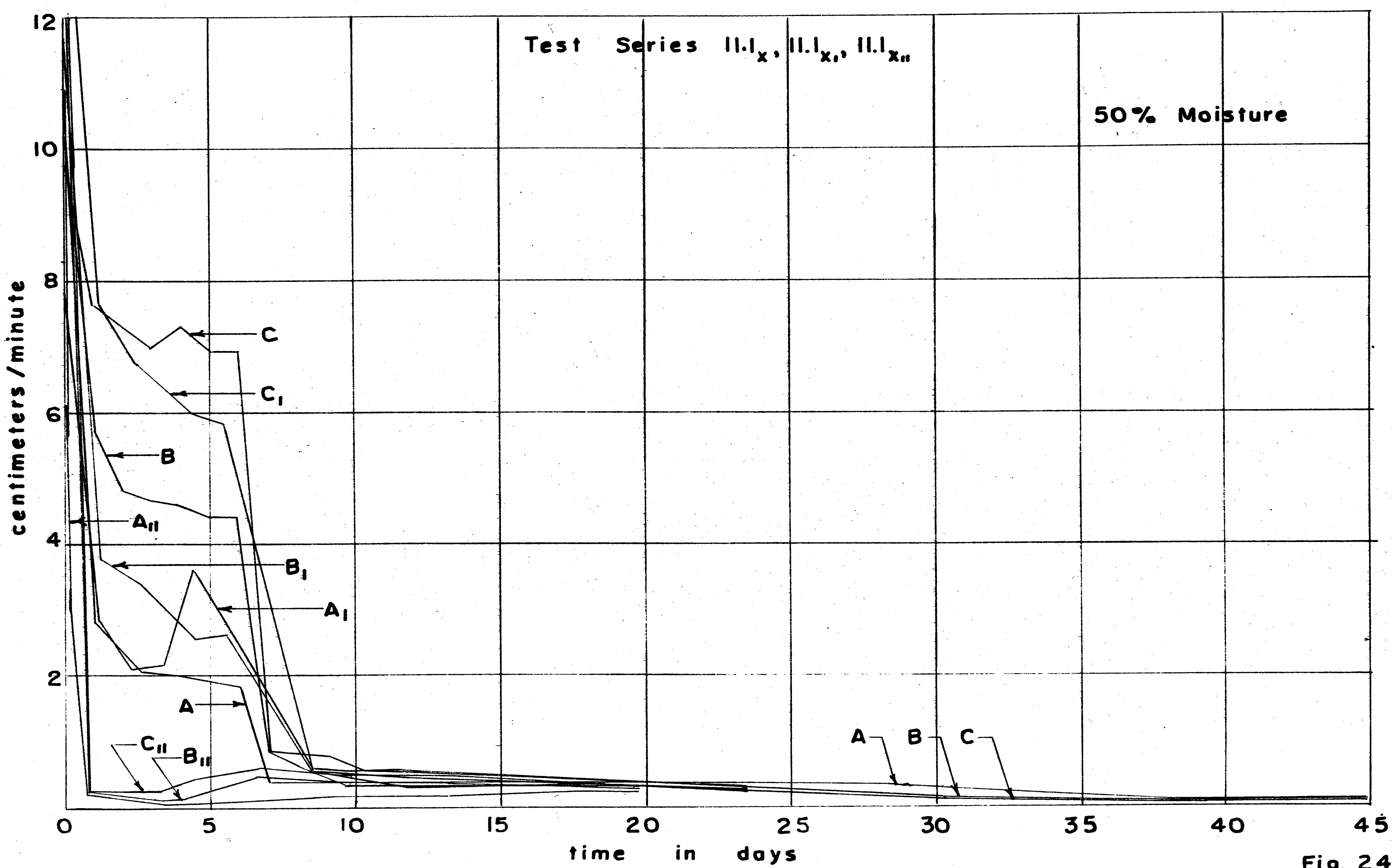
Test series 11.2 was run in an identical fashion to test 11.1X except that Ann Arbor clay was used. The purpose of the test was to note any differences which might be apparent. Figure 25 revealed the same drop in percolation to levels of approximately the same magnitude as revealed in test series 11.1.

SECTION IV

DISCUSSION OF RESULTS

At the present time this report must be considered only as an interim report and not as final conclusion to the study of the effect of soil-conditioning chemicals on the percolation of septic tank effluents from absorption beds. There are many aspects of the problem that can only be answered after a more extended period of study.

Analysis of the rate of percolation from each of the field trenches has resulted in the curves presented in Fig. 7. These curves initially seemed to be without order and appeared to vary considerably with no apparent reason. After a year of operation, certain trends can be deduced from these results. The curves for the two control trenches (numbers 1 and 4) have been separated from the other curves and it can be observed that a great similarity exists between them. Since the two trenches are on opposite sides of the field and include all the variations in soil characteristics which exist within the field, it may be concluded that the rates as indicated by these curves are fairly representative of the untreated soil within the field. Region a-b represents a period of soil saturation in the spring; region b-c represents a dry period in early summer; C-d indicates a brief period when the tile within the absorption field was plugged due to difficulties with the siphon; and region d-e represents an increase in percolation rate after a period of rest and shows a decline with additional use. The overall trend in the untreated trenches is downward and it is paralleled by the average trend in the treated trenches. There is at present no appreciable difference in rates of percolation between the treated and untreated trenches.



Test Series 11.1_x, 11.1_{x_I}, $11.1_{x_{II}}$
50% Moisture
centimeters / minute
time in days
0
2
4
6
8
10
12
5
15
20
25
30
35
40
45
C
C_I
B
A_{II}
B_I
A_I
A
C_{II}
B_{II}
A
B
C

Fig. 24

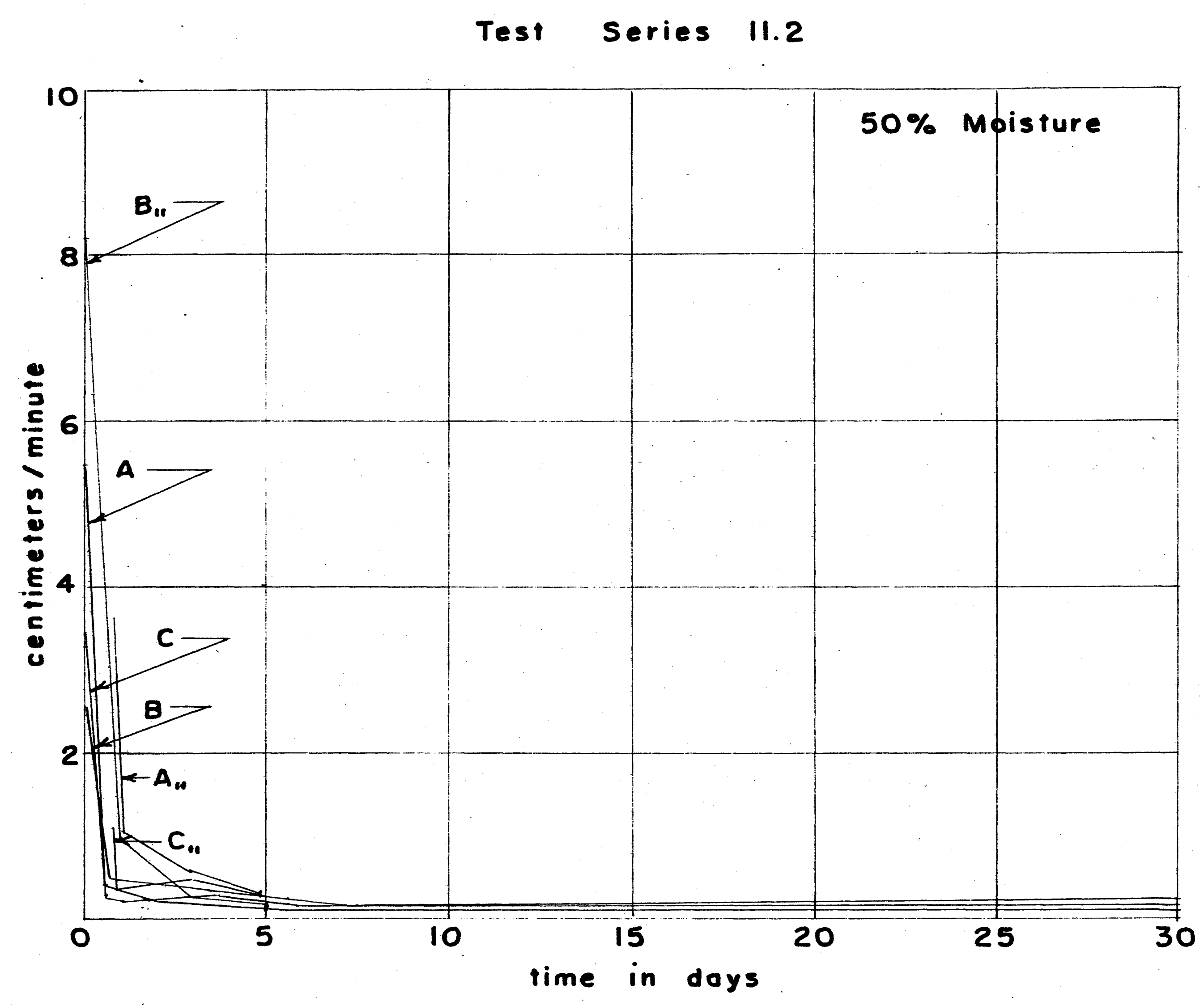

Test Series 11.2
50% Moisture
B"
A
C
B
A"
C"
10
8
6
4
2
0
5
10
15
20
25
30
centimeters / minute
time in days

Fig. 25

It is much too early in the life of this installation to say whether these trenches will continue to absorb liquid at lower and lower rates until the soil is entirely sealed, or whether there will be a leveling off of this trend. It is possible that the presence of soil conditioner might stimulate a more vigorous growth of those organisms which tend to break down the organic products accumulating in the soil. This condition would possibly maintain percolation at higher levels in the treated absorption beds as compared to the untreated beds.

As long as the rate of percolation from the trenches continues to fall it can be concluded that the absorption fields are being overloaded. Once equilibrium is established the rate may fluctuate upward or downward at times but the overall trend as indicated by the curve (Fig. 6) should be a horizontal line. This would indicate that the organic solids or sewage slimes were being oxidized at the same rate that they were being deposited in the absorption fields. Until such equilibrium is obtained in the treated or untreated trenches, or both, any comparison of results should be considered to be only tentative.

Section III of this report outlines fully the original objectives of the laboratory phase of this study. In test series 1, percolation studies with soil samples from the Ann Arbor test plot demonstrated that little, if any, water would pass through an untreated soil column of any appreciable depth. It was immediately realized that the original objectives of the laboratory study would have to be altered. It was concluded that the most fruitful procedure would be to study the percolation characteristics of chemically conditioned soils using a synthetic supporting medium and underdrain. Subsequent laboratory studies, therefore, were directed toward the objective of showing that clay soils would yield characteristic percolation values when chemically conditioned and that such results could be reproduced.

At the present time, within the limitations of the tests performed, only those tests run under continuous flow conditions, namely test series 11, seem to be reproducible. The explanation for the lack of reproducibility of results where samples were dosed by the ebb and flow technique involves many interrelated factors. Probably one of the most important of these factors is that not all of the material in a soil sample responds to treatment by a soil conditioner. Thus, there are some fine materials present which are not aggregated. These fines can be washed downward to collect at the surface of the underdrain system where they act to cut off flow through the sample. Ebb and flow conditions also enhance the cracking of the clay core and induce channeling effects down the tube walls. Air is another factor. It is always drawn into the treated soil as the liquid surface passes down through the soil column.

This air can act to either partially seal off a percolating column, or an air bubble can grow, finally become loosened, and rise upward creating a channel. Either way, air can materially change the percolating characteristics of a soil column.

One of the obvious conclusions of this study is the fact that aggregation and permeability bear no relationship to each other. Many of the tubes which became sealed against further liquid flow showed, upon close examination of the core, almost perfect aggregation. Variations in moisture content or degree of mixing,items known to affect aggregation showed no effect on percolation. Furthermore, a soil perfectly aggregated but wet still maintains its plasticity. Test run 10.1 showed that vibration will cause the particles to slide together and effectively seal the percolation tube even though the texture of the soil has been completely changed by treatment with a chemical soil conditioner.

There was a gradual reduction in percolation rate in almost every instance whether intermittent or continuous dosing was used. Some tubes became sealed very quickly; there were, however, a great many tubes which seemed to be slowly approaching zero flow as a limit. The reduction in percolation rate was paralleled by a reduction in volume of the soil column initially. Further contraction could not be measured, however, after the first week of use and the conclusion must be drawn that other factors have a bearing on the continued decline in percolation rates. The most obvious of these factors is that a gradual breakdown in the aggregated mass of material must be taking place. Visual inspection of a plugged percolation tube will usually show the bulk of the material to be a well-aggregated mass of clay particles. The material is granular and friable even when quite wet. However, at the very bottom of the column there is some evidence of a breakdown in the structure and an accumulation of fines which completely restricts the flow of water through the underdrain system.

The percolation-rate curves from the ebb and flow type of study are usually difficult to interpret. However, in the light of the results of the entire study, it seems logical to conclude that eventually the percolation rates of all tubes tested, whether under intermittent or continuous flow conditions, would reach the same levels. Continuous flow, therefore, may be considered as an accelerated type of test which will give results that can be applied to studies involving intermittent percolation.

From this point of view test series 11 is of great interest. A study of the curves shows that there is no apparent difference in percolation between Ann Arbor clay and St. Louis clay. Reference to test series 8 shows that clay extruded, as in test 11, but untreated by soil conditioners otherwise, gives a similar rate of percolation. This test is not of the same duration as test series 11 but illustrates the fact that very little permanent advantage accrues from the standpoint of percolation as a result of the treatment of the soil with chemical soil conditioners.

The laboratory study reported on in Section III of this report was of necessity more qualitative in nature than quantitative. Little was known regarding the nature of the chemical agent being used or of its effect upon percolation through the soils being tested. The original scope of the laboratory studies was far more comprehensive than the results produced from the actual studies. Nevertheless, the information obtained would have been invaluable in planning a field study.

SECTION V

CONCLUSIONS

(1) There is especially good correlation of percolation rates between the two control trenches of the field installation.

(2) The rate of percolation from all trenches of the field installation is quite dependent on seasonal conditions.

(3) In spite of fluctuations due to external factors a gradual decline in percolation rate can be noted in all absorption beds. This indicates that the beds have not yet matured.

(4) The results of the field-testing program at the present time indicate that no major differences can be discerned between the controls and the treated absorption beds. This observation must not be considered as being a final result as the trenches are still maturing.

(5) The laboratory study has revealed that it is very difficult to duplicate field conditions at the Ann Arbor site on a laboratory scale.

(6) The ebb and flow type of percolation studies on a laboratory scale is particularly difficult because of shrinkage, cracking, and air entrainment.

(7) The continuous flow type of percolation studies in the laboratory creates far more drastic conditions than actually exist in the field. Yet, indications are that the final results of intermittent or continuous percolation studies may not be too different.

(8) Aggregation bears no relationship to permeability. Other factors within a soil will determine the motion of water through it at the higher rates of flow studied.

(9) Aggregation created by treatment of soil with chemical soil conditioners tends to break down to some extent in time.

(10) Two entirely different soils were found to percolate at approximately the same rate, which is not much different from the rate of percolation through aggregated but untreated clay.