

SIPHON PERFORMANCE AND PRESSURE DISTRIBUTION FOR ON-SITE SYSTEMS

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Siphons have been used for many years to dose septic tank effluent into soil absorption systems as long as the discharge point is below the source. This approach distributes the effluent somewhat more uniformly than gravity through the large diameter perforated pipe and has been used primarily for larger systems. With the advent of pressure distribution systems to more evenly distribute the effluent throughout the soil absorption unit, siphons, instead of pumps, have been used to dose pressure distribution networks when the elevations are satisfactory. Siphons have several advantages over pumps as they 1) are non mechanical and 2) can handle larger volumes at less cost. However, the public perception of siphons is that once they are installed, they will perform satisfactory forever.

The objectives of this study were to 1) evaluate the performance of siphons dosing pressure distribution networks in on-site systems under field conditions, and 2) evaluate the ability of siphons to distribute the liquid uniformly throughout the distribution network used in typical on-site systems.

FIELD PERFORMANCE

Procedure

A total of 50 field systems using siphons to pressurize the distribution network were observed. All of the siphons, which were 7.5 and 10 cm (3 and 4") diameter, were of the Miller type and produced by two different manufacturers (Fig. 1). The sites were visited at various intervals from July, 1983 through June, 1986. Water was run into the dose chamber to determine if the siphon was working properly or if it was trickling. If a siphon was found trickling, air was blown under the bell to reset it (Converse, et al., 1985). Various measurements were taken at each site to determine if the installation met manufacturers specifications (Falkowski, et al., 1985). Corrections were applied to siphons which continued to malfunction in an attempt to return them to normal operation.

Results and Discussion

The performance of the siphons are reported in Table 1. Throughout the course of the study 25 of the 50 systems were found in a malfunctioning state at least once. The 4A (10 cm (4") diameter, Make "A") siphon suffered from a design flaw and as such skews the performance data. All nine of these units trickled for the duration of the study. This problem was very difficult to diagnose as the siphon would discharge when water was run into the dose chamber.

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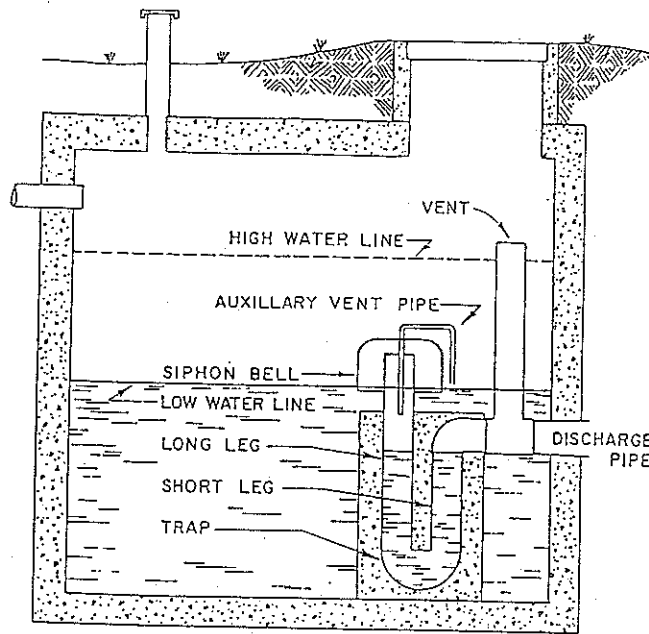


Fig. 1 Cross Section of a Dose Chamber Showing a Miller Type Siphon

Table 1. Field Performance of the Systems Utilizing Siphons

ID	Make	Dia. cm(in)	Number Observed	Percent Of Total	Number Failing	Percent Failure	After Reset or Correction	
							Number Failing	percent Failure
3A	A	7.5(3)	31	62	11	35	1	3
4A	A	10(4)	9	18	9	100	9	100
3B	B	7.5(3)	6	12	4	67	1	17
4B	B	10(4)	4	8	1	25	1	25
TOTAL			50	100	25	50	12	24

However, a stage level recorder clearly showed the siphon would begin to trickle immediately under normal operating conditions. When the dose chamber water level reached the discharge point, a slug of water and air would discharge but the siphon would not achieve full discharge. Enough air and water were discharged from the siphon trap to allow the water level in the dose chamber to rise to the top of the vent (overflow) pipe or the trap entrance and the device would begin to trickle. Running water from a hose into the tank provided enough flow through the siphon at the point of hesitation to activate a flush cycle.

One of the trickling 4A siphons was set up in the lab for evaluation. It operated every time the tank was filled, but at the discharge point the siphon hesitated before going into full discharge. The reason for failure was determined to be an inadequate driving head at the point of discharge. The septic effluent seems to augment this hesitation which causes this siphon to stall. This can be corrected by lengthening the long leg of the trap, or adding a smaller diameter trap in parallel to trigger the larger trap (Ball, 1985).

If the 4A siphons are removed from the study, the initial failure rate is 39%. The failure percentage after simply resetting each siphon was reduced to 17%. This indicates that the number of trickling siphons in this study could be cut in half if they had been monitored periodically and reset when trickling occurred. After corrections were performed on the remaining systems, a failure percentage of 7% remained. Therefore, excluding the 4A model, only 3 out of the 41 systems could not be reset or repaired.

These 3 systems consisted of one of each of the remaining models. These siphons did not trickle at all times, but would work periodically and then begin to trickle until reset. The reason for these failures could not be identified, as all of the measurable specifications were correct and the units were determined to be air tight.

The 4B siphon reacted much the same as the 4A model, in that at the discharge point a hesitation period would occur. Most times this siphon would then activate and go into a full discharge. Other times the same sequence of events described for the 4A model would occur.

This same course of events may also occur in the 7.5 cm (3") models, only much less frequent. Unfortunately, a siphon, once interrupted, will continue to trickle until reset.

The types of corrections which were required by a number of systems consisted of adjusting the siphon vents, overflows and tanks to match design specifications, or to insure an air tight seal at all joints and seams. Insuring that all design criteria are met will aid in the performance of any siphon device.

Another problem encountered was plugged laterals. Laterals were found plugged in both trickling and properly operating systems. Some of the causes of plugging were obvious upon flushing and consisted of large objects such as seeds, and synthetic hand towelettes which had passed through the septic tank to lodge in the network orifices. Many of these items may have been eliminated had the siphon been surrounded by a small sieve screen (Ball, 1985) or filters installed at the outlet end of the septic tank. Other systems however had become plugged by a cellophane like film which covered the lateral holes. This film was also found coating the insides of the tank walls and siphon bell.

DISTRIBUTION PERFORMANCE

Procedure:

A laboratory study was performed using a full size pressure distribution network, siphon and dose chamber (Fig. 2). A 7.5 cm (3") dia. siphon was placed in a 1900 L (500 gal) dose chamber. The 12.2 m (40') force main was interchanged between a 7.5 and 10 cm (3 and a 4") dia. PVC pipe. The 6-3.2 cm (1 1/4") dia. laterals were each 6.1 m (20') long and connected to a 7.5 cm (3") dia. center manifold which was 1.2 m (4') long. The laterals were perforated with 6.4 mm (0.25") dia. orifices spaced 0.76 m (30") apart. All network materials were constructed of schedule 40 PVC pipe. Pressure transducers were placed at the ends of the center two laterals and at the entrance to the manifold. The siphon outlet invert varied from 0.43 to 1.45 m (17 to 57") above the distribution network invert. A stage level recorder was placed in the dose chamber to monitor liquid levels during the discharge phase. The siphon had a 0.33 m (13") draw down depth with an average unrestricted flow rate of 272 Lpm (72 gpm). The transducers and stage level recorder output were connected to an IBM-PC through a Lab Master A to D converter. Water was used as the liquid medium.

This portion of the study consisted of 3 parts: evaluating the system for 1)

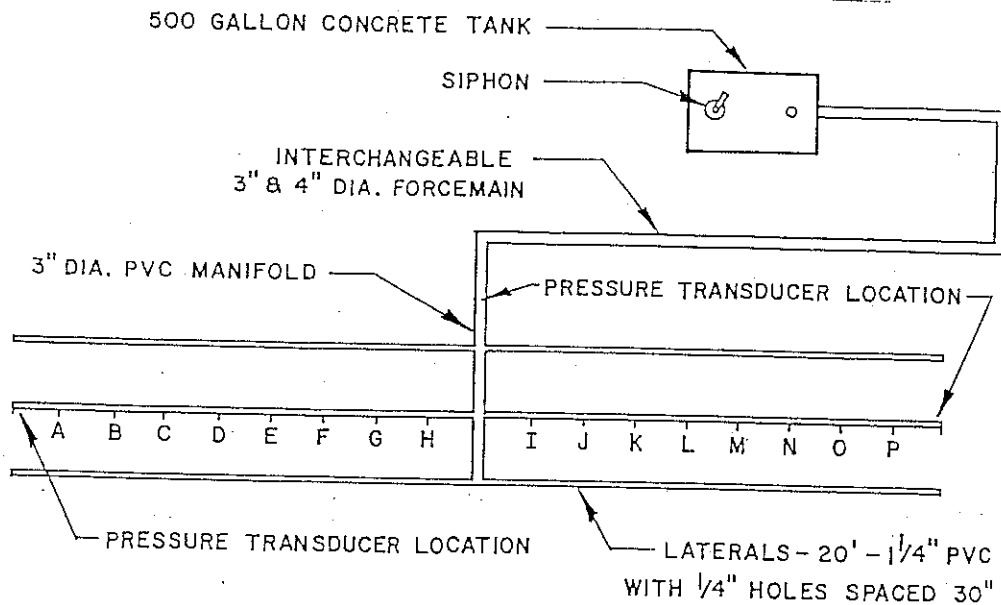


Fig. 2 Plan View of the Laboratory Setup for Evaluating a Siphon Attached to a Pressure Distribution Network

pressure distribution, 2) volume distribution, and 3) pressure distribution related to perforation plugging.

Pressure Distribution: In this portion of the study, the water was collected beneath the perforations in a trough and returned to a sump located directly beneath the center of the distribution network (Fig. 3). A pump conveyed water to the dose chamber. In this manner the siphon could be cycled continuously. Pressure distribution in the network was measured using 7.5 and 10 cm (3 and 4") dia. force mains at elevations of 0.43, 0.64, 0.84, 1.04, 1.24, and 1.45 m (17, 25, 33, 41, 49, and 57") between the siphon outlet invert in the dose chamber and the distribution lateral inverts. Five replications of each combination was performed.

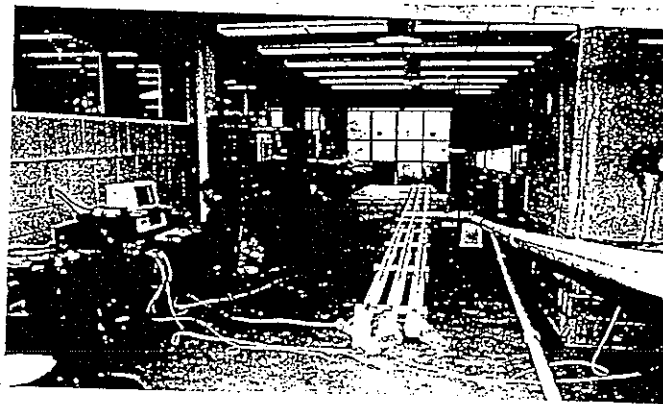


Fig. 3 A View Showing the Laboratory Setup for Studying Pressure Distribution

Volume Distribution: For this portion of the study, the area around each perforation was surrounded by 1) open atmosphere, 2) large diameter aggregate, 3) medium diameter aggregate, or 4) small diameter aggregate. Table 2 gives sieve analysis of the aggregate. The stone was placed in a basket directly beneath the perforation and weight applied to the lateral to insure good

contact with the aggregate. A 19 L (5 gal) tub was placed beneath each perforation to collect the water, each tub was weighed, and the water returned to the sump (Fig. 4). The volume distribution measurements were performed using the 10 cm (4") dia. force main with the elevation difference between the siphon outlet invert and the invert of the distribution network set at 1.45 m (57"). Pressure profiles were also measured for each condition. Five replications of each was done.

Table 2. Sieve Analysis of Aggregate

Aggregate	Sieve Size Range		Average Sieve Size	
	(mm)	(in.)	(mm)	(in.)
Large	25 - 38	1.0 - 1.5	32	1.25
Medium	13 - 25	0.5 - 1.0	19	0.75
Small	6 - 19	0.25 - 0.75	13	0.50

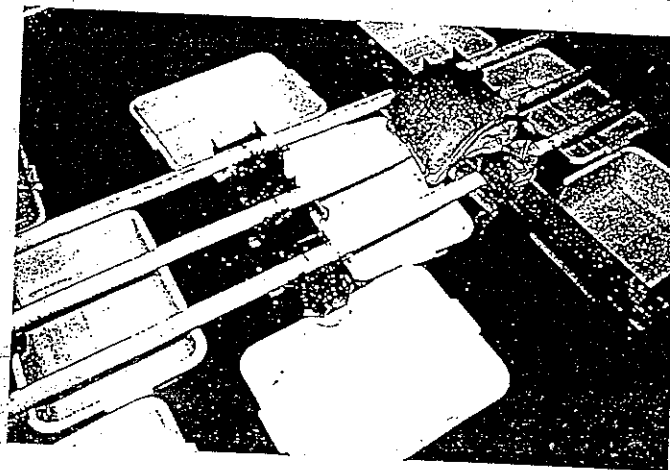


Fig. 4 View Showing the Placement of Aggregate Around the Perforations

Perforation Plugging: The effect of network pressure distribution on perforation plugging was measured by taping shut 25, 50, and 75% of the network perforations. The evaluations were done with elevation differences of 0.43, 1.04, and 1.45 m (17, 41, and 57") between the siphon outlet invert and the lateral inverts. Both force main diameters were used. The water was collected in troughs beneath the laterals and returned to the sump. Three replications with randomly chosen perforations plugged for each run were recorded.

Results and Discussion

Pressure Distribution: Typical design criteria use the distance between the siphon invert and the lateral invert elevation as the minimum head available to the network (Otis, 1981). Pressure profiles were generated for each of the six levels, which compared the pressures observed with both a 7.5 and 10 cm (3 and 4") force main. The minimum, average and maximum pressures observed over the entire discharge event are recorded in table 3.

These values represent the average of three runs, with their respective standard deviations also listed. The standard deviations indicate that the separate runs correlated well within each set. The 7.5 cm (3") main generates higher pressure in the network for all elevations except the 0.43 m (17") level. The pressures developed in the 7.5 cm (3") main show a definite

Table 3. Network Distal Pressure with Perforations Open to the Atmosphere

Elev. (in.)	Minimum				Average				Maximum			
	3 in.		4 in.		3 in.		4 in.		3 in.		4 in.	
	Press	SD	Press	SD	Press	SD	Press	SD	Press	SD	Press	SD
	(in. of water)											
17	16.2	0.09	18.0	0.16	19.7	0.08	18.5	0.14	22.9	0.33	19.4	0.22
25	23.1	0.29	21.0	0.46	26.2	0.21	19.8	0.34	29.1	0.44	21.0	0.46
33	29.0	0.30	21.4	0.26	31.7	0.26	21.3	0.15	34.4	0.34	21.4	0.26
41	34.7	0.28	23.4	0.53	37.4	0.19	23.6	0.38	40.0	0.39	23.7	0.56
49	39.0	1.16	23.8	0.41	42.7	0.67	24.5	0.36	45.3	0.91	25.5	0.38
57	44.9	0.77	22.7	0.34	49.0	0.46	24.3	0.26	51.3	0.60	26.4	0.75

increase at each incremental change in initial elevation. The average pressures indicate the 7.5 cm (3") main is capable of providing pressures near those predicted by design. As the initial elevation increases, the actual pressures to the network becomes farther away from those expected.

The 10 cm (4") main maintains a near constant pressure for all elevations tested. At the 1.45 m (57") level the actual pressure provided by the 10 cm (4") dia. force main is more than 0.76 m (30") below the design minimum. The difference between the 7.5 and 10 cm (3 and 4") main is best represented by the profile curves pictured in Fig. 5.

The only physical difference between these two systems is the volume which the force main contains. The amount of pipe flowing full becomes the controlling factor for the amount of head applied to the system. The majority of systems are probably designed with an initial elevation difference well above the 1.45 m (57") evaluated in this study. This indicates a large discrepancy may exist between predicted head on the network and that which actually exists. Other network configurations (size, perforation spacing and diameter) will give different distal pressures but the relationships between the 7.5 and 10 cm (3 and 4") diameter should remain similar.

Volume: The uniformity of distribution for the siphon in the open conditions was quite good (Fig 6, open condition). The lower volumes discharged from the end perforations was attributed to flow back into the adjacent perforation near the end of an event and a slightly higher elevation. This was due to the placement of the end holes near the top of the end caps as is recommended for air venting. A statistical test performed on the variances between perforations showed no significant difference between the remaining perforations. The same test applied to the three aggregate conditions demonstrated uniformity was effected and some blinding of the holes did occur.

The open condition was thus used as a standard to which the other three conditions were compared. Table 4 shows the results of a Two Sample T Test (Ryan et al., 1982) performed on the variances and on the ranges. The ranges were calculated by subtracting the lowest volume from the largest volume recorded from each hole.

Each condition was compared to the others, each showing a significant difference except that between the medium and the small aggregate. The two separate tests correlated in each case. The P values give an indication of the degree of significance. It is evident that the difference between the open condition and the large aggregate is less significant than the difference between the open condition and the other two. It is also demonstrated that there is a significant difference between the large aggregate and the smaller aggregate sizes. These results are reflected quite clearly in the volume profiles (Fig. 6) where many more open spaces exist in the profile for the

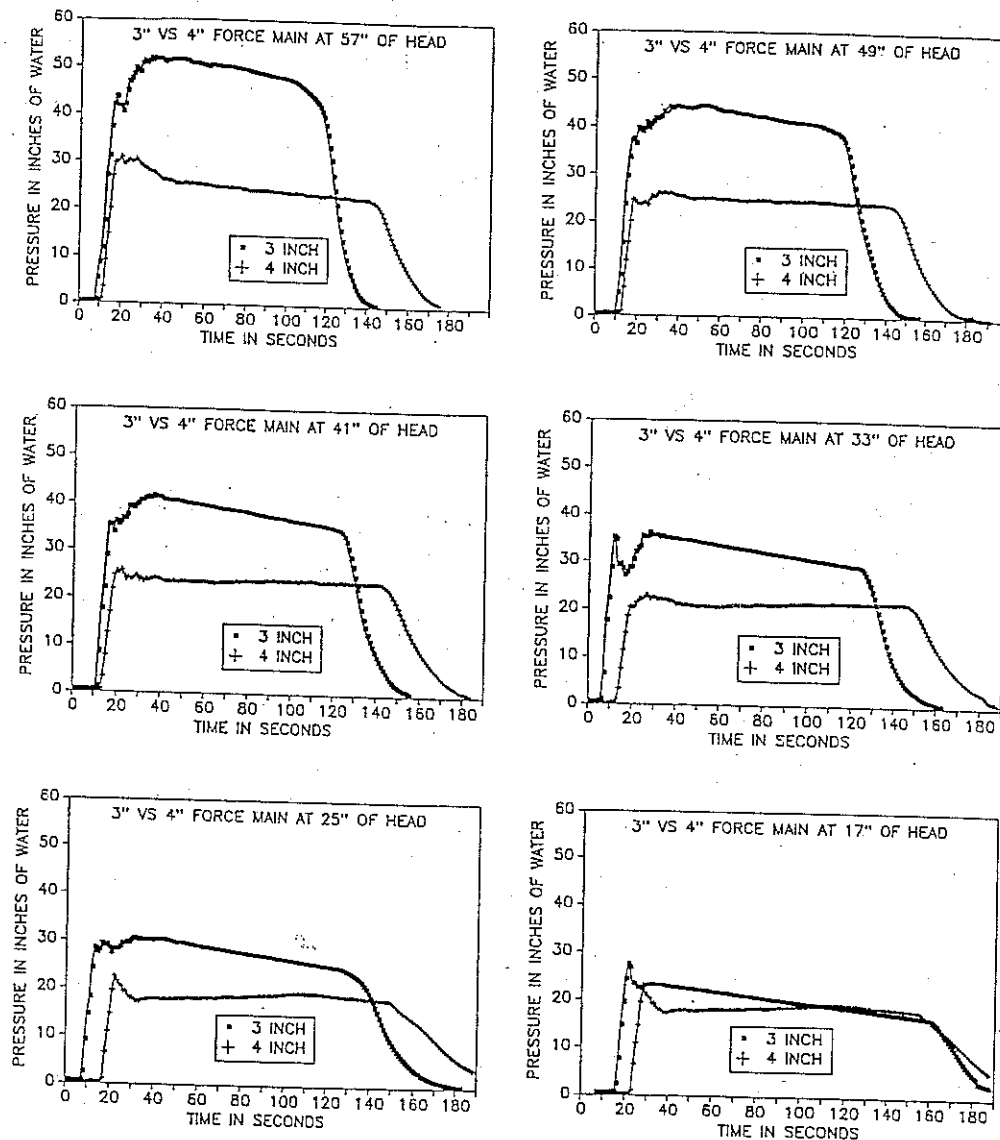


Fig. 5 Distal Pressure Profiles During Discharge for 7.5 and 10 cm (3 and 4") Force Mains for 6 Elevation Differences

small aggregate than the open condition.

The open condition profile demonstrates how evenly the five runs compare at each hole. The largest variation at a particular orifice between runs in the open condition was less than 0.4 L (0.1 gal). Excluding the end orifices for the reasons stated earlier, the largest variation between holes was about 0.8 L (0.3 gal). When the laterals were placed in large aggregate, the variation at each orifice and between orifices becomes evident. Still, the overall distribution with large aggregate averaged around 1.9 L (0.5 gal)

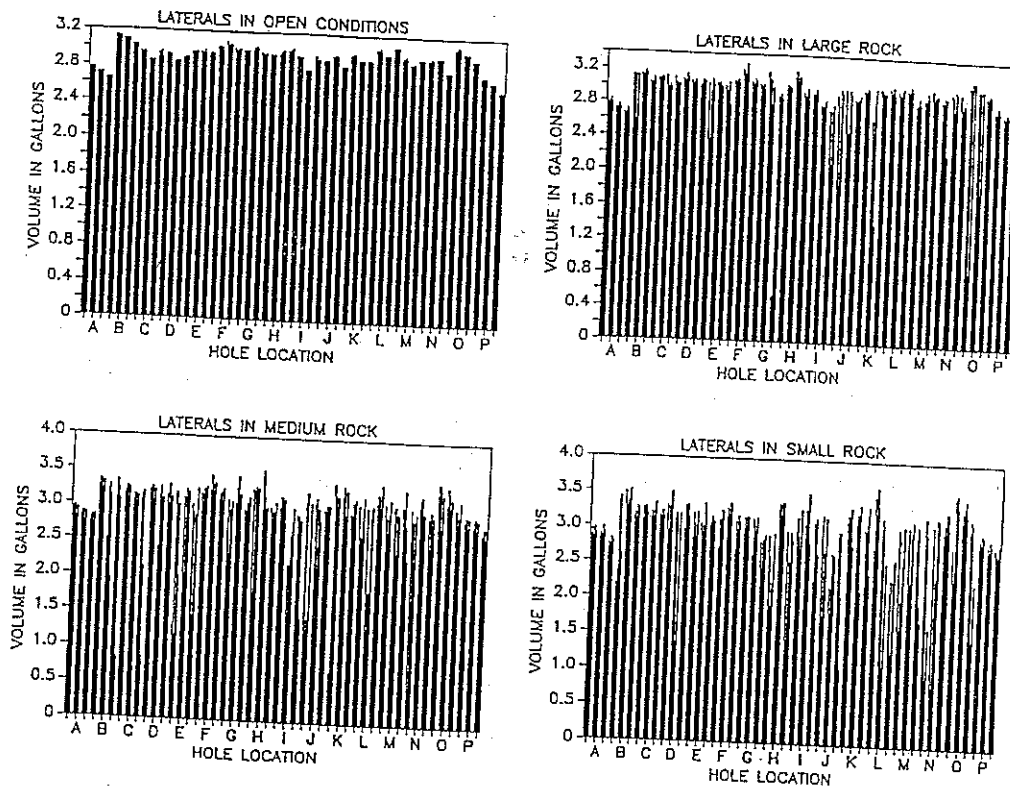


Fig. 6 Volume Profiles of 5 Replicates for 4 Perforation Contact Surfaces

Table 4. Statistical Analysis on Uniformity of Volume Distribution for Open Conditions and 3 Aggregate Sizes

Comparison	VARIANCE TEST(a)		
	P	P/2	Determination
NR vs LR(b)	0.076	0.038	<.05 Significant
NR vs MR	0.0066	0.0033	<.05 Significant
NR vs SR	0.014	0.007	<.05 Significant
LR vs MR	0.014	0.007	<.05 Significant
LR vs SR	0.036	0.018	<.05 Significant
MR vs SR	0.94	0.47	>.05 Not significant
RANGE TEST(c)			
NR vs LR	0.0032	0.0016	<.05 Significant
NR vs MR	0.0	0.0	<.05 Significant
NR vs SR	0.0	0.0	<.05 Significant
LR vs MR	0.0004	0.0002	<.05 Significant
LR vs SR	0.0001	0.00005	<.05 Significant
MR vs SR	0.98	0.49	>.05 Not significant

- (a) Two sample T test: H_0 : No significant difference; H_a : Significant difference; @95% CI if $P/2 < 0.05$ then H_0 is rejected.
- (b) NR - No aggregate; LR - Large aggregate; MR - Medium aggregate; SR; - Small Aggregate (Table 2 gives sizes).
- (c) Ranges were determined by subtracting the lowest volume from the highest volume recorded in the five run set, at each perforation.

between orifices. When the profiles of the medium and small aggregates are observed, the effects become obvious. It is not uncommon to find the volume at an orifice drop by 75%, and the variation at each particular orifice to be quite erratic. The profiles graphically demonstrate the statistical data.

Pressure profiles were also generated for each condition (Fig 7). All the volume tests were run at the same tank elevation of 1.45 m (57") and a 10 cm (4") dia. force main. The pressure profile in the open condition was identical to that which was shown in Fig. 5 (open condition). In each of the remaining profiles the slope of the pressure curve is decreasing with the small aggregate actually showing a slight negative slope. This changing slope is characteristic of a plugged condition as shown in Fig. 8. The pressure profile for the lateral in small aggregate is nearly identical to the curve generated by the 25% plugged network (Fig 8).

Blinding of the orifices does occur when the laterals are placed over aggregate. The occurrence of plugging increases as the size of the aggregate is decreased. The operation of the siphon is not effected, but the pressure and uniformity of the discharge are. Partial blinding of the holes coupled with actual septic effluent could increase the potential for plugged laterals

Perforation Plugging: Table 5 shows how distal pressure is effected when the perforations are plugged. At the low initial elevation of 0.43 m (17"), there is little noticeable effect. The standard deviations are small, signifying good correlation between runs. In each case as plugging was increased, the distal pressure also increased. This is due to the reduction in flow rate out of the laterals allowing the force main to fill to a higher level.

At the 1.04 m (41") elevation, the same holds true when 25% of the holes are plugged, but at 50% both the minimum and average pressures drop. The same

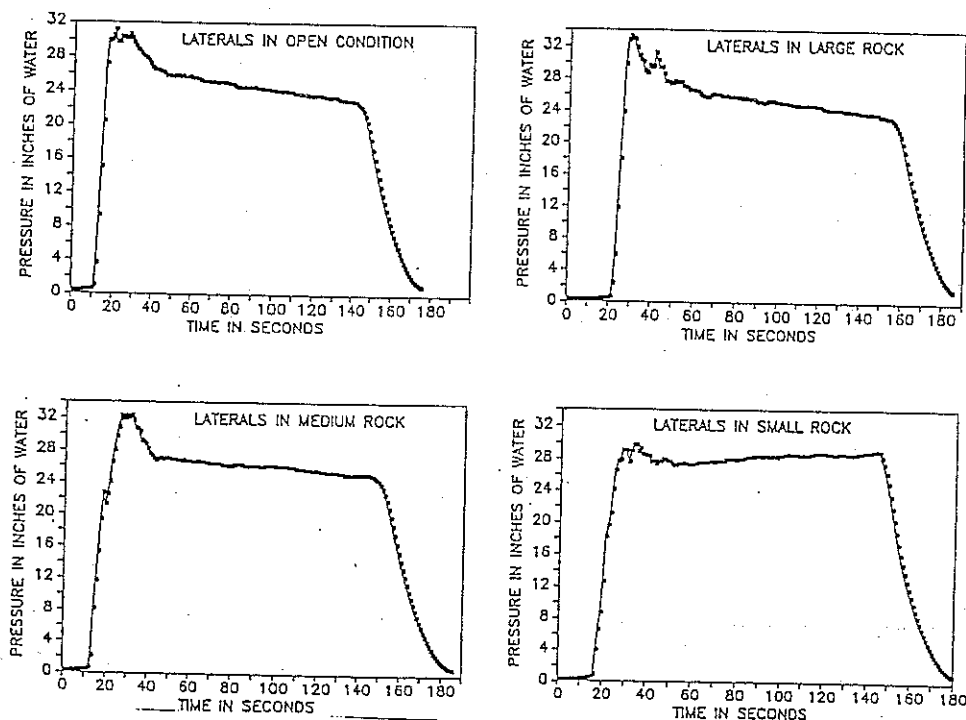


Fig. 7 Distal Pressure Profile for 4 Perforation Contact Surfaces for 10 cm (4") Force Main with Elevation Difference of 1.45 m (57")

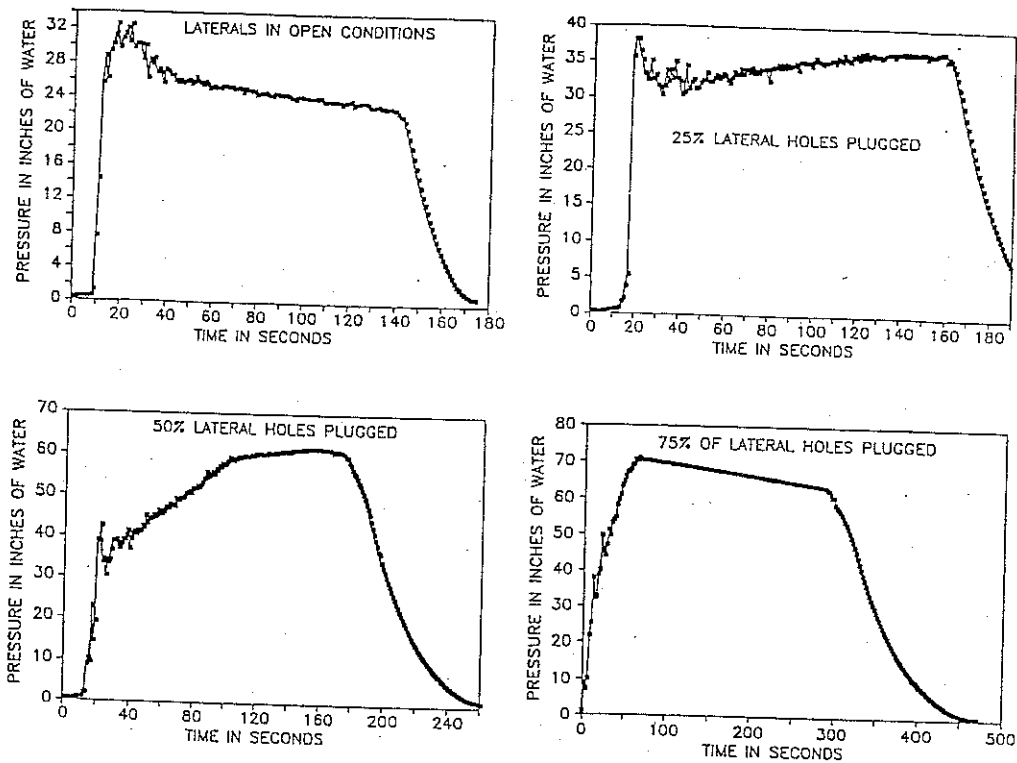


Fig. 8 Distal Pressure Profile for 25, 50, 75, and 100% of the Perforations Open for 10 cm (4") Force Main and 1.45 m (57") Elevation Difference

Table 5. Network Distal Pressure with 25, 50 75 and 100% of the Perforations Open for Two Force Mains Sizes and Three Elevations

El. Hole Open	Minimum				Average				Maximum			
	3 in.		4 in.		3 in.		4 in.		3 in.		4 in.	
	Press		Press		Press		Press		Press		Press	
	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
(in) (%)	--(in. of Water)--											
100	16.2	0.07	18.0	0.11	19.7	0.05	18.5	0.08	22.9	0.11	19.4	0.11
75	18.5	0.08	19.9	0.14	22.4	0.05	23.0	0.18	26.4	0.21	25.5	0.17
50	21.9	0.05	22.7	0.14	25.3	0.08	26.1	0.04	27.4	0.08	29.9	0.05
25	23.8	0.20	24.2	0.26	28.4	0.06	28.3	0.04	32.5	0.29	32.7	0.28
100	34.6	0.14	23.4	0.54	37.4	0.13	23.6	0.40	40.0	0.26	23.7	0.76
75	37.6	0.01	28.2	1.20	40.3	0.09	34.8	0.81	43.3	0.06	38.4	0.35
50	31.6	0.78	31.28	2.26	36.2	0.53	46.2	0.19	44.5	0.86	50.6	0.03
25	41.29	1.00	29.7	0.85	51.5	0.14	51.0	0.18	55.8	0.34	56.0	0.29
100	44.9	0.22	22.7	0.30	49.0	0.22	24.3	0.13	51.3	0.52	26.4	0.75
75	50.9	0.15	31.5	0.23	52.5	0.17	34.6	0.22	53.9	0.21	36.3	0.17
50	39.4	0.91	34.7	2.90	44.7	0.88	53.70	0.27	51.9	1.34	60.6	0.13
25	52.4	3.20	44.1	3.41	63.2	0.28	65.5	0.53	66.0	0.05	70.8	0.10

results are evident for the 1.45 m (57") level. When the entire flow profile is observed (Fig 8), the cause is better understood. When 25% of the holes are blocked, the siphon flow rate slightly exceeds the normal lateral flow discharge. Therefore, a gradual increase in pressure is observed as the force main begins to fill. When half the network is plugged, the force main fills much faster than the laterals can discharge, and thus the pressure begins to increase until the main completely fills. The controlling pressure now becomes the level in the dose chamber, which drops relatively slow until the tank is empty and the level in the pipe again controls. When 75% of the network is plugged, the force main fills very fast in relation to the lateral discharge and the tank level again provides the controlling head. This condition most closely matches that under which the siphon systems were assumed to operate when designed.

Systems with dose chambers elevated well above the laterals and assumed to provide more than enough head on the network may actually be providing much less.

A characteristic of all the siphon pressure profiles is the gradual decline to zero pressure. During this decline, debris has the opportunity to settle into the orifices and possibly block them during the next event. This differs from the situation provided by a pump which actually goes directly from a constant positive pressure to an immediate negative pressure during the back flow event.

SUMMARY AND CONCLUSIONS

An evaluation of siphon performance was conducted on 50 field units over a period of 3 years. Each siphon was dosed to a pressure distribution network for distributing septic tank effluent to soil absorption systems. A full size pressure distribution network dosed by a siphon was evaluated for pressure distribution, volume distribution, and pressure distribution relating to perforation plugging in the laboratory.

Throughout the course of the study, 50% of the siphons were found to be malfunctioning (trickling) at one time or another. After resetting, correcting installation errors, and eliminating 9 units because of a design flaw, 3 out of the 41 units continued to malfunction. Siphons must be monitored to protect the distribution laterals and insure full life of the system. A well designed siphon should have very few joints to seal especially during installation in the field, be simple to install, and should be sized to discharge well above the minimum required driving head. Proper installation and monitoring will insure longevity of a well designed system.

The 7.5 cm (3") force main was much more efficient than the 10 cm (4") at transferring design pressures from the 7.5 cm (3") siphon to the network. The fear of air entrapment in the force main could be eliminated by providing an air gap below the lateral perforations. Even smaller diameter force mains may provide higher pressures, all other factors considered, and should be studied further.

The siphon will distribute the effluent uniformly throughout the network when the perforations are open. Some blinding of the perforations occurs when the laterals are surrounded by large aggregate. Much more plugging occurs when the aggregate size is reduced. A method to allow an air gap below each perforation would eliminate blinding, improve venting of air, and allow the pressurized air at the start of a cycle to clear the perforations.

Trickling siphons will cause the perforations of the distribution network to plug but several systems with properly operating siphons became plugged due to solids carried over from the septic tank. Care must be taken to avoid large solids from getting into the dose chamber.

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