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Field Evaluation of Pressure Distribution Networks

by

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FIELD EVALUATION

of

Pressure Distribution Networks

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Pressure networks for distribution of septic tank effluent in subsurface soil absorption systems were first developed to improve the performance of mound systems. Conventional 10 cm (4 in.) diameter piping was found to provide poor distribution. Portions of the gravel bed became locally overloaded which led to short circuiting of the septic tank effluent out the side of the mound (Bouma et al 1975). Uniform distribution of the liquid through the use of carefully designed pressure networks corrected this problem (Converse, 1974, Converse et al 1974, Otis et al 1977). Since their introduction, pressure distribution has been adopted by a number of states to overcome problems with rapidly permeable soils, shallow water tables, bedrock or other restrictive horizons, steep slopes and large flows (Triangle J Council of Governments, 1979, State of Washington, 1980, State of Wisconsin, 1980, Carlile, 1980).

A pressure distribution network consists of laterals with equally spaced perforations drilled in the inverts. The laterals are connected to a solid wall manifold. The diameters of the laterals and manifold are determined by the perforation diameter and spacing selected such that the rate of flow out each perforation of the network is nearly equal. A pump or siphon is used to pressurize the network.

A simplified design procedure for sizing networks has been developed (Otis, 1982). This procedure permits a variation in discharge rates between any two perforations within a lateral of 10% and any two perforations between any lateral of 15%. It is based on orifice and pipe friction losses only. Junction and fitting losses are ignored. While this procedure has been used widely, very little confirmation of the design assumptions has been made in the field or laboratory. Therefore, the purpose of this study was to determine how well the pressure distribution systems are performing in the field.

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Methods and Procedures

Ten operating networks with treatment capacities ranging in size from 1.7 m^3/d (450 gal/day) to 56.8 m^3/d (15,000 gal/day) were evaluated for uniformity of liquid distribution. Characteristics of these systems are given in Table 1. Since it was not possible to measure outflow rates from each perforation, each network was tested by measuring the pressures with manometers every 15 seconds at various locations during a dosing cycle (Fig.1). The elevations at each manometer connection and the elevation of the liquid surface in the dosing tank at the start, during, and end of the dosing cycle also were recorded. Single runs were usually made because of the time involved to refill the dosing tank. Duplicate runs were made at System C and results of both were very similar.

The networks were evaluated by comparing the measured network losses and estimated average perforation discharge rates to design values. The design procedure used is described by Otis (1982). The network losses were determined by taking the difference between the inlet pressure surface elevation and the average pressure surface elevations at distal ends of the lateral. Maximum network losses permitted by the design procedure were calculated by multiplying 0.31 times the average of the distal pressures measured at the pipe inverts. The average perforation discharge rates were estimated by dividing the measured pump or siphon rate by the number of holes in the network. Using these values and the average network pressure, the actual orifice coefficient could be estimated from the orifice equation and compared to 0.6 value used in design.

Results and Discussion

The design procedure is based upon the simplifying assumption that changes in the perforation discharge rates along the length of the lateral are due to changes in pressure within the pipe as a result of friction losses alone. The results of the field study presented in Table 2 suggest that this may be a reasonably accurate model but that refinements are needed.

The most striking feature of the results is the great variability in network performance. It is difficult to see a pattern to the variability with the limited data collected. Variations in wastewater characteristics and quality of construction could account for much of the variability, but it was not possible to quantify these factors in the field.

The results do indicate, however, that 1) the assumed orifice coefficient in the design procedure is greater than the actual coefficient and 2) lateral lengths that approach the maximum length allowed by the design procedure result in network losses greater than those predicted. These are conflicting results if the model is assumed to be correct. Lower orifice coefficients indicate lower perforation discharge rates which reduce the lateral flow rates and, therefore, the friction losses. In other words, overestimating the orifice coefficient should result in an overestimation in network losses. The fact that results do not indicate this, particularly in networks B and C where the lateral lengths nearly equal the maximum allowed and the orifice coefficients are only slightly less than the assumed value, suggest that the assumed Hazen Williams friction factor is too high and/or the fitting and junction losses cannot be ignored. Unfortunately, the field study was not designed to measure either of these factors. The results from

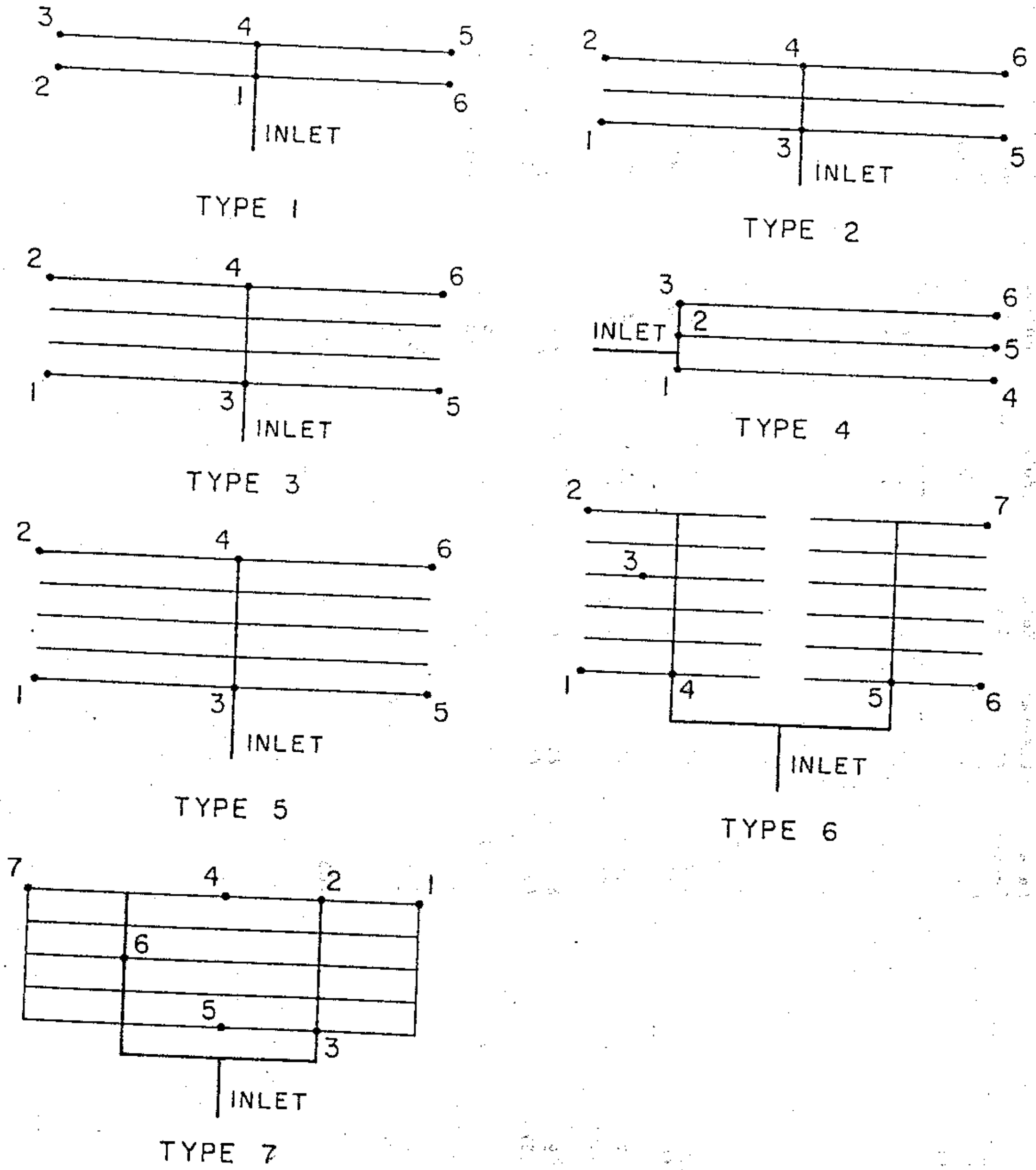

Figure 1. Types of Distribution Networks Evaluated.

Table 1. Characteristics of Field Systems Evaluated

System ident.	Type	System age yr.	Design flow m^3/d (gpd)	Network design type*	Lateral length m (ft)	Lateral dia. mm (in)	Hole dia. mm (in)	Hole spacing cm (ft)	Manifold length m (ft)	Manifold dia. mm (in)	Pressure unit
A	4-bdrm home	<1	2.3 (600)	2	7.47 (24.5)	25 (1)	6.4 (1/4)	76.3 (2-1/2)	1.83 (6)	75 (3)	pump
B	3-bdrm home	1	1.7 (450)	4	15.25 (50)	32 (1-1/4)	6.4 (1/4)	76.3 (2-1/2)	2.44 (8)	75 (3)	pump
C	3-bdrm home	<1	1.7 (450)	2	7.24 (23.8)	25 (1)	6.4 (1/4)	76.3 (2-1/2)	1.63 (5-1/3)	50 (2")	siphon
D	4-bdrm home	2	2.3 (600)	2	9.30 (30.5)	25 (1)	6.4 (1/4)	76.3 (2-1/2)	1.75 (5-3/4)	75 (3)	pump
E	3-bdrm home	<1	1.7 (450)	2	6.86 (22.5)	25 (1)	6.4 (1/4)	91.5 (3)	1.63 (5-1/3)	50 (2)	pump
F	tavern	1	5.9 (1570)	5	8.39 (27.5)	25 (1)	6.4 (1/4)	167.8 (5-1/2)	6.10 (20)	75 (3)	pump
G	rest.	1	21.1 (5570)	6	10.07 (33)	25 (1)	6.4 (1/4)	183.0 (6)	7.93 (26)	100 (4)	pump
H	school	<1	8.8 (2320)	3	11.59 (38)	38 (1-1/2)	6.4 (1/4)	122.0 (4)	5.49 (18)	75 (3)	pump
I	retreat center	3	15.1 (4000)	1	25.93 (85)	50 (2)	6.4 (1/4)	152.5 (5)	3.05 (10)	150 (6)	siphon
J	office bldg.	2	56.8 (15000)	7	18.68 (61.3)	50 (2)	9.5 (3/8)	152.5 (5)	6.10 (20)	150 (6)	pump

*See Figure 1

Table 2. Performance Characteristics of Field Systems

System ident.	Average dosing rate L/sec (gpm)	Average distal pressure m H_2O (ft H_2O)	Lateral length Installed/design max.	Network losses Measured/design	Estimated orifice coefficient	Orifice coefficient Measured/design
A	4.4 (70)	0.48 (1.57)	1.02	1.98	0.67	1.12
B	5.4 (85)	1.13 (3.71)	0.98	1.25	0.55	0.92
C	3.5 (55)	0.35 (1.15)	0.99	1.92	0.58	0.97
D	5.1 (80)	1.37 (4.49)	1.27	1.04	0.36	0.60
E	3.0 (47)	0.91 (2.99)	0.80	0.73	0.47	0.78
F	4.7 (74)	0.30 (0.98)	0.72	0.93	1.17[c]	1.95[c]
G	9.8 (156)	2.47 (8.10)	0.83	_[a]	_[a]	_[a]
H	6.1 (96)	1.07 (3.50)	0.55	0.11	0.52	0.87
I	5.7 (90)	2.13 (7.00)	0.73	_[b]	0.46	0.77
J	32.9 (522)	1.9 (6.43)	0.85	0.22	0.28	0.47

[a]See discussion
[b]Recorded average distal pressures greater than inlet pressure
[c]Perforation size or number may be greater than specified by plans

Systems E through J indicate a change in the friction factor may be sufficient.

In addition to the pressure analysis in each network, the pipe gradients across each network were investigated. Variations in pipe elevation will alter the relative pressures over each perforation resulting in varying discharge rates. The maximum gradients found in each of the networks ranged from 0.07 to 1.86% with a median of 1.06%. Measured distal pressures ranged from 0.30 m (0.98 ft) of water to 2.13 m (7.0 ft) of water. For a 9.2 m (30 ft) lateral, a gradient of 1.06% percent would result in 15% variation in perforation discharge rates at 0.30 m (0.98 ft) of water or a 2% percent variation at 2.13 m (7.0 ft) of water.

The recommended distal pressure of 0.76 m (2.5 ft) of water (Otis, et al 1977) would result in a 6% variation in perforation discharge rate. Thus, it appears that the minimum distal discharge rate should be at least 0.76 m (2.5 ft) of water in order to minimize the effect of elevation difference found in the field. All but 3 of the systems studied meet or exceed that minimum recommended pressure.

System G is a mound system which contains two separate beds which are loaded simultaneously. There were problems encountered with this system and thus it could not be evaluated like the other systems. The proximal pressure at each manifold (points 4 & 5, Fig.1) was greater than 2.0 m (6.6 ft.) of water. Incorrect readings occurred in all but one of the distal manometers. Manometers 1 and 7 were partially plugged with solids pushed in from the lateral. Manometer 1 was unplugged before the end of the run and indicated a pressure of 2.45 m (8 ft) of water. Manometer 2 did not receive any effluent indicating that the inlet to the manometer was plugged or a blockage occurred in the lateral. Manometers 3 and 6 were clean and indicated pressures of 2.5 m (8.2 ft) and 1.9 m (6.1 ft) of water respectively.

Each bed had 2 observation tubes that extended to the rock-sand interface. Three of the 4 tubes had standing liquid. The dry tube was near manometer 2, which did not receive any effluent. Upon investigating the depth of water in the observation tubes prior to and after pumping, it appears that the bed containing manometers 5, 6 and 7 is receiving more effluent than the other bed. No reason for this can be given until further investigations are made.

Summary and Conclusions

Ten field installed pressure distribution network systems were evaluated to determine if the design procedures and assumptions were adequate. These systems ranged in size from 1.7 to 56.8 m^3/day (450 - 15000 gal/day).

The field data shows much variability but that the design model appears to be a reasonable design tool if the lateral length is kept to less than 80% of the maximum design length permitted by the model. If greater, it appears that the perforation discharge rate will vary by more than 10% within the lateral and by more than 15% between laterals.

Seven of the 10 systems yielded distal pressures greater than 0.76 m of water which is the minimum recommended pressure, but the proximal pressure was either higher or lower than 1.31 times the distal pressure. The estimated orifice coefficient varied from 0.28 to 0.67 with one unexplained exception while the design coefficient used is 0.6.

Further study is needed to refine the model. Model sensitivity needs to be examined for changes in the Hazen-Williams friction factor, and orfice coefficient. The effects of velocity heads, fitting and junction losses and perforation blinding due to rock contact with the perforations need to be evaluated.

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