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DRIP TUBING HYDRAULICS DURING PRESSURIZATION

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Introduction

The uniformity of application is one of the primary advantages to using drip irrigation technology to disperse effluent into the soil. Uniform application means that the each area within the absorption field receives an equal dose of effluent. With the advent of pressure compensated emitters, drip systems can be easily designed to provide uniform distribution during steady state operation. However, during pressurization and depressurization (non-steady state operation), flow and pressure in the system is dynamic. During pressurization, emitters near the supply will produce water while emitters at the distal end will not have yet received water. This issue is further compounded because drip systems are dosed several times per day, therefore, the non-steady state phase could significantly degrade the overall application uniformity.

It is understood that longer laterals (continuous lengths of tubing) take longer to fully pressurize. Thus it is reasonable to suggest that longer laterals will exhibit a greater non-uniformity. This project seeks to define the significance of the non-steady state emitter discharge relative to lateral length. Understanding the tubing hydraulics during pressurization is a key parameter when designing a system to have a uniform distribution.

Material and Methods

Geoflow and Netafim tubing were examined in this study. The Geoflow tubing was Wasteflow PC with 0.53 gallon per hour (gph) pressure compensated emitters spaced every 24 inches. This tubing has an internal diameter of 0.55 inch. Also studied was Netafim's Bioline with 0.62 gph pressure compensated emitters spaced every 24 inches. The bioline tubing has an internal diameter of 0.57 inch. Water pressure was provided by a 10 gallon per minute (gpm) turbine pump placed in a tank. Excess flow and pressure from this pump was bled-off using a by-pass valve. The tubing was divided into 50-foot segments and then reconnected to form lengths of 100, 200, 300, 400, 500, and 600 feet. In-line ball valves and air/vacuum relief valves were installed at the head and distal end of the tubing. A Master Meter 5/8-inch turbine-style water meter was used to measure the volume of water entering the tubing. A series of pressure transducers were mounted on the pump-side of the ball valve, at the entrance of the tubing, every 50 feet along the tubing, and at the end of the tubing. Each pressure transducer was individually calibrated using an Ametex Dead Weight Pressure Tester. A Campbell Scientific CR-10 datalogger was used to collect the pressure readings at one-second intervals.

Each test began by draining the tubing of any water and then closing the ball valves. The pump was switched on and the by-pass flow was set to provide about 55 pounds per square inch (psi) of pressure at the head ball valve. When the head valve was opened, a stopwatch was started to record the time required for water to close the distal-end air/vacuum relief valve. Likewise, water meter readings were taken before opening the head valve and when the air/vacuum relief valve closed. Each test was replicated three times. The collected data included time to

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pressurize tubing, water volume needed to pressurize tubing, and pressure readings within the tubing during pressurization. Values for pressurization time and pressurization volume were averaged across the three replicates.

Results and Discussion

One of the goals of this project was to determine the dynamic water velocity within the tubing during pressurization. Using the time of pressurization, the tubing length, and water volume required to fill the tube, average flow rates and velocities were calculated for each length of tubing (table 1).

Table 1. Average in-flow rates and water velocities in tubing during pressurization.

Manufacturer	Length (ft)	Mean Pressurization Time (sec)	Mean Flow Rate (gpm)	Average Velocity (fps)
Geoflow	100	13	5.9	8.0
	200	29	5.2	6.9
	300	57	4.3	5.3
	400	93	4.1	4.3
	500	140	3.7	3.6
	600	201	3.7	3.0
Netafim	100	11	7.4	9.4
	200	26	6.5	7.6
	300	47	6.0	6.4
	400	69	5.4	5.8
	500	100	5.2	5.0
	600	141	5.0	4.3

What is not shown in table 1 is the fact that the velocity changes along the tubing length. Because the tubing is narrow and the water velocity is high, surface tension forces the water to fill the tubing as the wave of water travels the tubing length. As demonstrated later in this paper, it was found that in a 200-foot length of Geoflow tubing, the velocity was approximately 9 fps in the first 50 feet, 8 fps in the second 50 feet, 6 fps in the third 50 feet, and 5 fps in the last 50 feet. Overall the average fill time was 29 seconds to move 200 feet or 6.9 fps. It is reasonable to expect the water wave velocity to decrease exponentially with lateral length. The friction head will increase with length and flow from the pump decreases exponentially with an increase in head (pressure). It is interesting to note that these pressurization velocities are greater than 2 fps (a widely recognized scour velocity). It is likely that solids within the tubing will be progressively moved to the distal end with each dosing cycle. This effect should improve the effectiveness of the periodic forward-flush of the drip laterals.

Of primary concern is the volume of water emitted during pressurization. The water volume entering the tubing during the pressurization was compared to the theoretical tubing volume based on internal diameter and length. It is realized that this is not an accurate procedure for estimating the internal tubing volume because the emitters occupy a portion of this volume. However, because this error will be constant – the relative values of pressurization volume generated by this project will still be useful to the system designer. Table 2 lists the comparison results between the tubing volume and pressurization volume.

Table 2. The volume of water required to fill the tubing as compared to the tubing volume is listed for various lengths of tubing.

Manufacturer	Length (ft)	Average Volume Required to Fill Tubing (gal)	Volume of Tubing based on Length and Diameter (gal)	Estimated Volume Emitted during Pressurization (gal)
Netafim	100	1.3	1.33	below detection*
	200	2.9	2.66	0.2
	300	4.7	3.99	0.7
	400	6.1	5.32	0.8
	500	8.7	6.65	2.1
	600	11.7	7.98	3.7
Geoflow	100	1.2	1.23	below detection
	200	2.5	2.46	below detection
	300	4.1	3.69	0.4
	400	6.3	4.92	1.4
	500	8.6	6.15	2.5
	600	12.4	7.38	5.0

* The resolution of the water meter was 0.1 gallon

As shown in table 2, non-steady state water emission is also exponentially related to tubing length. Using the Netafim results as an example, the emitted volume of 200 feet of tubing is only about seven percent of the tubing volume. However, for a 600-foot length, the emitted volume is approximately 46% of the tubing volume.

Pressure transducers were used to provide an estimate of water pressure on the emitters during pressurization. As the water wave passes each emitter, the velocity head and friction head (energy required to move the wave forward) is converted into a static pressure that will force water out of the emitters. This “back pressure effect” increases with the tubing length. Therefore, the near-end emitters will be at operating pressure before the distal emitters receive water. The design minimum operating pressure for Geoflow and Netafim is seven and five pounds per square inch, respectively. As shown in figure 1, the emitters within the first 50-foot segment are already at operating pressure a full 45 seconds before the emitters located in the last 50-foot segment of a 300-foot Netafim tube.

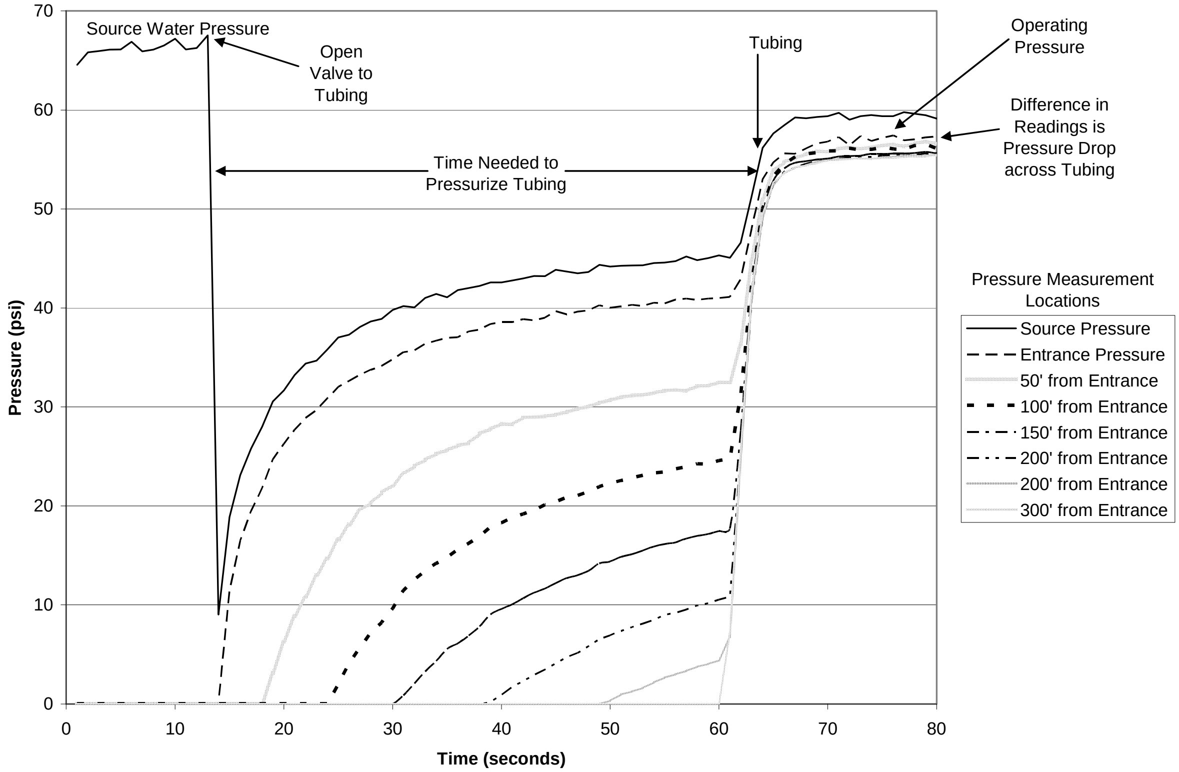

Figure 1. The Dynamic Pressurization of 300 feet of Netafim Tubing.

Recommendations

The data presented in this report indicates that lateral lengths between 300 and 400 feet may be a good compromise of the economy of installing long laterals while minimizing the non-steady state issues. Also, significantly longer run times relative to the pressurization time will also minimize non-steady state effects. While not discussed in this paper, drain down and drain back are also non-steady state problems that must be addressed during system design.