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Increasing Water Use Efficiency Through Improved Orifice Design and Operational Procedures for Subirrigation Systems

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INCREASING WATER USE EFFICIENCY THROUGH IMPROVED ORIFICE DESIGN AND OPERATIONAL PROCEDURES FOR SUBIRRIGATION SYSTEMS

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PREFACE

The aim of the emitter plugging studies reported here was to seek emitter designs that would not plug under extremely adverse conditions. The following companies donated materials for these studies, even though their emitters were to be subjected to conditions not normally encountered:

Submatic, Inc.
Melnor Industries
Controlled Water Emission Systems
Chapin Watermatics, Inc.
Anjac Plastics, Inc.

Flow models were developed on the campus of Texas A&M University. Field and hydraulic studies were conducted at the Texas A&M University Agricultural Research and Extension Center at Lubbock.

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DESCRIPTION OF SYMBOLS

A	cross-sectional area of flow path
a, b	constants
C	orifice coefficient
D	orifice or flow path diameter
d	emitter spacing
g	acceleration of gravity
H	head in lateral
H_o	head at lateral inlet
h	head loss per unit of lateral length
L	lateral length
P	flow path length
Q	flow rate within lateral
Q_o	inflow rate into lateral
q	emitter flow per unit length of lateral
S	land slope
x	distance from lateral inlet
ν	kinematic viscosity

ABSTRACT

Two mathematical models describing one-dimensional flow from buried sources and in unsaturated soils were developed. One considered the consumption of water by roots. For the assumed distribution of the root consumption with time and depth, the 10-cm (4-in.) deep source provided better water distribution than did 20- and 30-cm (8- and 12-in.) deep sources. Irrigation from zero depth, as in the case of trickle irrigation, appeared to be the best system for the given conditions.

Plugging of emitters by particulate materials decreased as the cross-sectional area of the emitter opening was increased. Less than 0.06 atm (1 psig) vacuum had little effect on the flow of emitters tested. Higher vacuum amounts caused the reopening of plugged orifice emitters, but caused plugging of labyrinth emitters. Vacuum-induced plugging of labyrinth emitters resulted from accumulation of silt and fine sand within the flow path. Operation at higher pressures caused limited flow recovery.

A theory was proposed for determining pressure distributions in drip laterals where water is uniformly distributed along the lateral's length. The theory provided acceptable design in two tests. Computer-derived design curves were developed. Because 1000 or more emitters may be required for subirrigation of each acre, emitters need to be both inexpensive and resistant to plugging. Four experimental emitters were designed and constructed. A modification of one microtube emitter is being produced commercially.

Two moveable drip systems were proposed. Drip irrigation lines successfully trailed a center-pivot irrigation system. Also a tractor-mounted implement was developed for moving individual drip irrigation laterals.

CHAPTER 1

INTRODUCTION

The application of irrigation water beneath the soil surface through multi-orificed plastic pipe is a relatively new idea which promises to dramatically increase water-use efficiency. Agronomic data indicate that similar crop yields can be obtained from subirrigation with about half the amount of irrigation water required with conventional sprinkler and gravity systems. Particularly is this true when such systems are automated (7).

When this research was initiated in 1970, the primary problem with subirrigation was the plugging of the orifices or emitters which transmit water from pipe laterals to the soil. Since then, prices for plastic pipe and fittings have doubled and in some cases, tripled. Now, high investment cost also limits the use of subirrigation for field crops.

The original objectives of this project were to investigate the causes and mechanics of emitter plugging, to study the relationships between emitter design and plugging, and to develop and test a mathematical model for use in the design of subirrigation systems.

Some experimental failures caused a delay in the completion of the planned work, and, as a consequence, other important research areas related to subirrigation were expanded. The mathematical model, published as an interim report (2), indicated better water distribution would be obtained from water sources located nearer the soil surface. This fact, coupled with rapidly rising projected costs for subirrigation systems led the authors to investigate alternative systems.

Two mathematical models were developed. Both models describe one-dimensional, vertical flow. Irrigation from zero depth, as in the case of trickle irrigation, appeared to be the best system for the given conditions.

As stated, these models are described in Chapter 2.

In a study of emitter plugging, various emitters were installed in individual soil containers. Lack of consistent results caused this approach to be abandoned. A field experiment was then conducted. Plugging by particulate materials decreased as the cross-sectional area of the emitter opening was increased. These experiments are discussed in Chapter 3.

Large openings plugged less but also produced more flow. Shorter laterals were needed to obtain uniform water distribution and the increased number of headers and main pipelines escalated costs. To alleviate this problem, a theory for varying emitter resistance to obtain uniform water distribution over a wide pressure range was developed and tested. A description of this work is in Chapter 4.

Prototypes of several experimental emitters were produced. The development and characteristics of these prototypes are presented in Chapter 5.

Because better water distribution is expected from zero-depth sources, and because of the lower investment cost of moveable drip systems, two moveable systems were investigated. These systems are discussed in Chapter 6.

CHAPTER 2

A FLOW MODEL FOR SUBIRRIGATION SYSTEMS

An objective of this project was development of a mathematical model describing flow from subirrigation orifices which will be useful in design of subirrigation systems. Research related to this objective was essentially completed in January, 1972. A detailed account is given in Texas Water Resources Institute Technical Report 40, entitled "Dynamic Simulation of Unsteady Flow of Water in Unsaturated Soils and its Application to Subirrigation System Design" as listed in the project publications and in other publications (1, 6). A summary of accomplishments follows.

Unsteady vertical flow of water in unsaturated soils was simulated utilizing S/360 CSMP (Continuous System Modeling Program), a recently developed language speciably designed for digital simulation of transient phenomena that can be represented by differential equations. The principles of conservation of mass and of Darcy's law, which lead to the derivation of the unsaturated flow equation, were directly applied to specify the flow system. The boundary conditions described a no-flow situation across the top surface and an impermeable layer across the bottom of the soil mass considered. The initial condition specified a uniform pressure potential, corresponding to a water content uniform with depth.

Two computer models were developed. One simulated vertical unsteady infiltration through the surface into a homogeneous unsaturated soil. Simulation results were obtained for three different soils--Yolo light clay, Adelanto loam, and Pachappa loam. The results for Yolo light clay compared favorably with the available numerical solutions of Philip for the same soil and for identical boundary and initial conditions. The solutions for the other two soils demonstrated the workability of the model for soils having different hydraulic characteristics.

The other computer model simulated unsteady vertical flow of water in an unsaturated homogeneous soil during infiltration from a buried source and through the following drying period, in a sequence. The consumption of water by plant roots, considered to be a non-linear function of the time of day, was taken into account. The consumption rate at any given time was assumed to be distributed in a linearly decreasing manner with depth of the root zone. The model has the capacity to consider the source at any desired level.

Simulation data for buried sources were obtained for Yolo light clay, using a soil depth as well as a root depth of 60 cm, in two sets. The first set had an initial uniform water content of 0.2375 (cm^3/cm^3), whereas 0.32 (cm^3/cm^3), was the value for the second set. A daily root consumption of 0.635 cm (0.25 in.) was used. In each set, three different depths of the source, i.e., 10, 20, and 30 cm (3.9, 7.9, and 11.8 in.), were used. For each source location, simulation results were obtained for varying durations of the irrigation and drying cycle which were controlled by a chosen water content value at a specified point in the soil mass. The whole system, thus, worked like an automated subirrigation installation.

The water content profiles with time were plotted for each simulation run. The patterns of water distribution with time for each source location were analyzed in light of two important criteria: (1) adequacy of the supply of water with respect to the need at different parts of the root zone, and (2) overall irrigation efficiency. Two new concepts, availability coefficient and proportionality coefficient, which help evaluate the effectiveness of vertical water distribution in a subirrigation system, were defined and illustrated.

For the assumed distribution of the root consumption with time and depth, the 10-cm (3.9-in.) depth source provided better distribution of water with time and space compared to the 20-cm (7.9-in.) and 30-cm (11.8-in.) source locations. Irrigation from zero depth, as in the case of trickle irrigation, appeared to be the best system for the given conditions.

The S/360 CSMP language proved to be efficient in simulating the transient water flow phenomena in unsaturated soils. The principal advantage of the numerical procedure was its complete generality and the ease with which numerical data on the hydraulic characteristics of the soil may be used without arbitrary assumptions and function fitting procedures. The models developed are capable of considering diverse boundary and initial conditions.

CHAPTER 3

FIELD STUDIES OF EMITTER PLUGGING

Initially, several sizes of various orifice and microtube emitters were installed in pipes in individual soil containers. Results were inconsistent and this approach was abandoned.

Next, 100 of each of 7 different emitters were installed in polyethylene pipe laterals. These laterals were buried 25.4 cm (10 in.) deep by chiseling and various tests conducted. The experimental arrangement and results follow.

Emitters

Seven emitters were chosen for this test, including both orifice emitters and labyrinth emitters. Some of the emitters chosen are not recommended for use in buried laterals. Also, all manufacturers recommend filtration of water used. In these tests, surface soil and shredded crop residue were injected directly into laterals. Finally, because of the possibility of experimental error, it is hazardous, and probably unfair, to compare 2 individual emitters. Instead, one can relate emitter opening size to the incidence of plugging. Description of the emitters follows.

1. Anjac Bi-wall. This is a dual-chambered pipe with orifices burned in the wall by a laser. Orifice diameter is about 0.46 mm (0.018 in.) and the cross-sectional area of the orifice is about 0.16 mm (0.00025 in.^{2}).

2. Drip-eze. A spiral labyrinth emitter with approximately a 1.0 mm (0.039 in.) square opening was used. The cross-sectional area of this opening is about 1.0 mm^2 (0.0015 in.^{2}).

3. Melnor-Tirosh. This emitter has a single vortex diode with a

0.9-mm (0.035-in.) diameter orifice inlet and outlet. The cross-sectional area of the inlet is about 0.64 mm^2 (0.001 $in.^2$).

4. Leggo. This is a labyrinth emitter with a series of 180 degree turns. Water entering the labyrinth is screened through 4 slots. The labyrinth opening is roughly 1.6 mm (0.064 in.) square. The cross sectional area of the opening is about 2.6 mm^2 (0.0041 $in.^2$).

5. Screened microtube. This emitter, a project-related prototype, is further described in Chapter 5. The labyrinth is a 1.5-mm (0.060-in.) diameter microtube. The tube is installed inside the pipe lateral. The inlet end of the tube is protected by a 10-hole screen. The outlet end of the tube is protected by a molded outlet. The cross-sectional area of the labyrinth opening is about 1.8 mm^2 (0.0028 $in.^2$).

6. Submatic; 0.76-mm (0.030-in.) diameter. This is an orifice emitter with a hooded outlet. The cross-sectional area of the outlet is about 0.46 mm^2 (0.00071 $in.^2$).

7. Submatic; 0.51-mm (0.020-in.) diameter. Also a hooded orifice, this emitter opening has a cross-sectional area of 0.20 mm^2 (0.00031 $in.^2$).

Lateral Arrangement

Twenty-five emitters of a kind were installed 1.2 m (4 ft) apart in each of 4 30.5 m (100-ft) long laterals. The 4 laterals with that emitter were buried 1.02 m (40 in.) apart and 25.4 cm (10 in.) deep and were connected to a common header. This arrangement was duplicated for all emitters except the Anjac Bi-Wall which has openings spaced 45.7 cm (18 in.) apart. Four 30.5-m (100-ft) long laterals of the Bi-wall tubing were used.

Imposed Conditions

After the emitters were buried, the initial flow rate at 0.68 atm (10 psig) was measured. Then, 8 different tests were conducted. After each test, the flow through each set of emitters was measured. Not all conditions were imposed on all emitters.

After burial, the original flow through the emitters, at .68 atm (10 psig), was measured. Then, the following treatments were imposed.

Test 1. A slight vacuum, 0.03 to 0.06 atm (0.5 to 1 psig) was maintained at the upstream end of the laterals for 30 min. This test was an attempt to simulate a condition which might exist while a subirrigation system is draining following an irrigation.

Test 2. Amarillo loam soil was sieved to obtain particles smaller than 0.33-mm (0.013-in.) diameter. Fifteen grams (0.53 oz) of this material were injected into each 30.5-m (100-ft) long lateral. This sediment was smaller in size than any of the emitter openings. This test was a simulation of the effect of small particles which might pass through filters.

Test 3. Larger sizes of sediment and pieces of crop residue might enter laterals when pipe leaks are repaired or when laterals are carelessly installed. To simulate these conditions, 50 ml (3.0 $in.^3$) of surface Amarillo loam soil containing sorghum residue was mixed with water and poured into each lateral.

Test 5. Because of the relatively good performance of the largest two emitter sizes, an additional 50 ml (3.0 $in.^3$) of soil and crop residue were injected into each lateral with those emitters to determine if additional plugging occurred.

Test 6. To further simulate vacuum conditions which may occur in laterals during drainage, a 0.03- to 0.09-atm (0.5- to 1.5-psig) vacuum was maintained at the upstream end off the laterals for 30 min. Vacuum was not maintained on the Anjac Bi-wall because it collapsed the pipe wall.

Test 7. To determine if greater vacuum would reopen plugged orifice emitters, laterals were maintained at 0.17 to 0.20 atm (2.5 to 3.0 psig) vacuum for 30 min.

Test 8. Laterals were operated at 2.04 atm (30 psig) pressure for 30 min.

Table 1. Flows through 7 groups of emitters at 0.68 atm (10 psig) pressure and following 8 imposed conditions.

Flows, Percent of Original Flow

	Test							
Emitter	1	2	3	4	5	6	7	8
Anjac Bi-wall	117	127	0	64	NA[1]	NA	NA	NA
Drip-eze	89	83	62	60	NA	62	62	65
Melnor-Tirosh	102	113	0	57	NA	74	91	106
Leggo	94	102	81	102	77	83	77	90
Screened Microtube	95	902	81	89	80	NA	62	71
Submatic; 0.76 mm (0.030-in.)	98	108	46	60	NA	94	101	NA
Submatic; 0.51 mm (0.020-in.)	104	156	33	37	NA	67	72	80

[1] NA--Not Applied

After each test, flows at 0.68 atm (10 psig) were measured and compared to original flows at that pressure. Test results are summarized in Table 1 and discussed below.

Test 1. This slight vacuum had very little on flow through the emitters tested. The increase in flow through the Anjac Bi-wall material may have been caused either by continued expansion of the flexible lateral wall or possibly by erosion of orifice walls by water. Slight reductions in flow were observed with the long-flow-path emitters.

Test 2. The introduction of sediments which are smaller than emitter openings generally had little effect on emitter flow. The increase in the flow of the 0.51-mm (0.020-in.) diameter Submatic orifice might be due to erosion of the orifice wall by water, as all orifice emitters continued to show increases in flow during the first two tests.

Test 3. Surface soil containing sorghum residue clogged some of all emitters tested. The reduction in flow caused by plugging was inversely proportional to the cross-sectional area of emitter opening as shown in Fig. 1.

Test 4. Within a particular emitter class, orifice emitters or labyrinth emitters, the percent of original flow recovered by operation at a higher pressure increased with increasing area of emitter opening.

Test 5. Additional of surface soil with sorghum residue caused further plugging of the two emitters tested.

Test 6. Evacuation of laterals by vacuum reopened some of the orifice emitters.

Test 7. Increasing the vacuum to as much as 0.2 atm (7 ft of water head) caused fine sediments to enter and plug some labyrinth emitters.

Test 8. This second increase in pressure again resulted in some recovery of flow.

Conclusions

In summary, evacuation of laterals by vacuum can cause removal of particles which have recently plugged orifice emitters. Limited amounts of sediments which are smaller than emitter openings did not cause a reduction in flows. However, over a period of a month, accumulations of fine sediments might plug emitters. Plugging by particulate matter decreased as the cross-sectional area of the emitter opening increased. Vacuum in excess of 0.06 atm (1.0 psig) inch caused some plugging of labyrinth emitters,

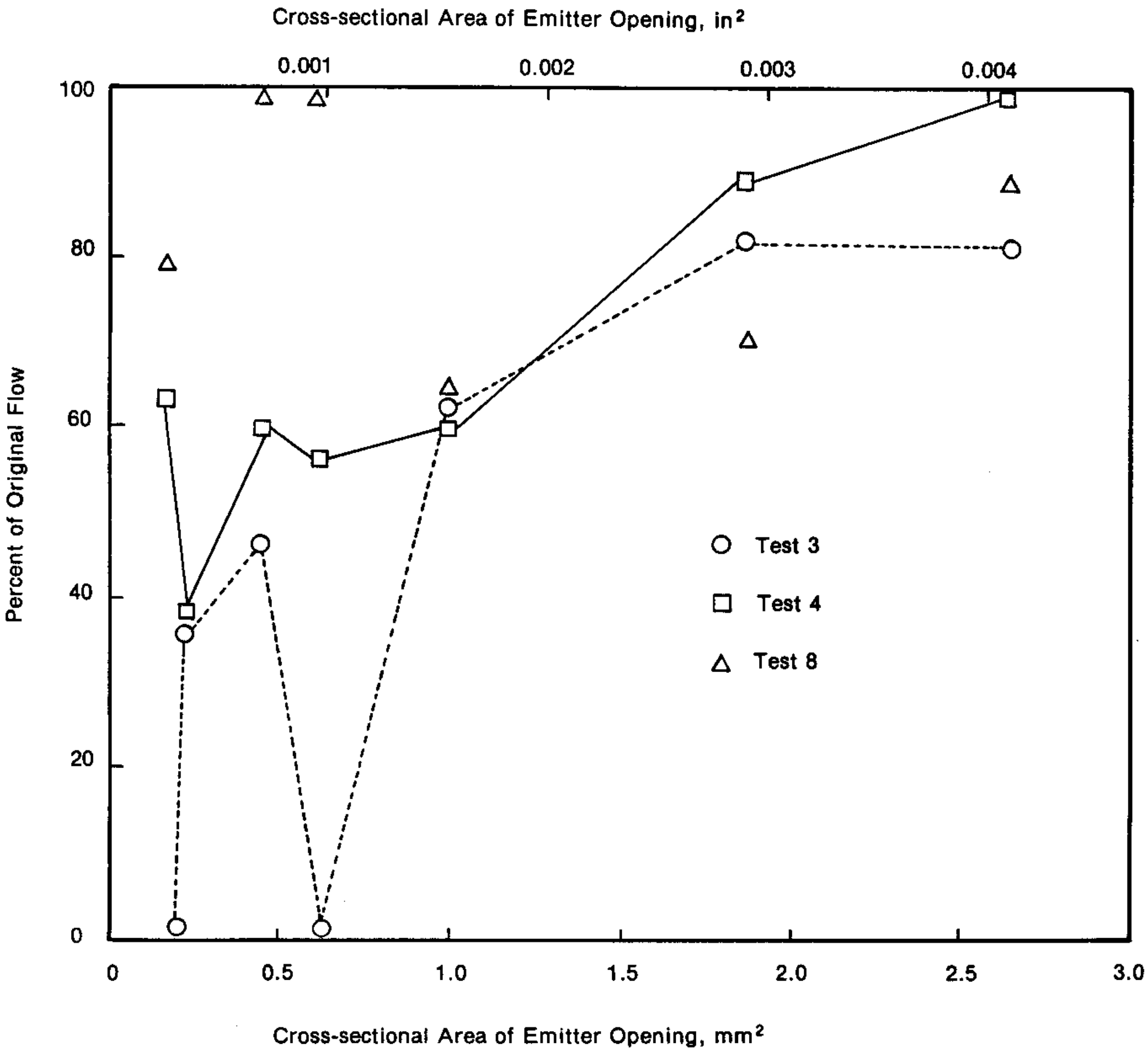


FIGURE 1. Effect of emitter opening size on plugging by injected particles or vacuum.

but did not cause plugging of orifice emitters. Increasing operating pressure caused a limited amount of recovery of flow. Numbers of plugged orifice emitters may be greater than indicated by flow measurements because of erosion of some orifice walls by water.

CHAPTER 4

UNIFORM IRRIGATION ALONG DRIP LATERALS

Introduction

Uniform application of water along laterals of multi-orificed drip laterals can be obtained by varying the size or spacing of orifices or the length of microtubes or through use of an adjustible emitter. It is desirable to maintain emitter opening size as large as practical to reduce plugging by particulate matter.

The procedure proposed by Zetzsche and Newman (12) for computing orifice flows along subirrigation laterals could be used to obtain orifice sizes or spacings or microtube lengths required for uniform water application. However, because of the number of variables and calculations involved, a computer-derived solution for each field design might be a practical necessity. The author proposes an approximate theory for obtaining uniform water application along laterals. This theory permits more rapid design of individual systems and resulted in acceptable designs in two tests.

Theory

If water is uniformly distributed along a trickle or subirrigation lateral, then the flow rate inside the pipe lateral decreases linearly with distance from the upstream end, that is,

$$Q = Q_o \left[1 - \frac{x}{L}\right], \qquad (1)$$

where Q is the flow rate inside the pipe at x distance from the inlet, Q_o is the flow rate entering the pipe, and L is the lateral length.

Assuming that the discrete changes in flow rate and in head loss rate can be treated as continuous changes, the head at any point, x_1, is given by the equation,

$$H_{x_1} = H_o - Sx_1 - \int_o^{x_1} h(x)\ dx, \qquad (2)$$

where H_o is the head at x = 0, S is the land slope along the lateral and h is the head loss per unit length due to friction in the pipe.

When flow is turbulent, the head loss per unit length can be related to pipe flow rate by a power equation,

$$h = aQ^b, \qquad (3)$$

where a and b are constants. Thus

$$h = a \left[Q_o[1 - \frac{x}{L}]\right]^b, \qquad (4)$$

or

$$h = aQ_o^b\ [1 - \frac{x}{L}]^b, \qquad (4b)$$

and at any x

$$H_x = H_o - Sx - \frac{aQ_oL}{b+1} \left[1 - [1 - \frac{x}{L}]^{b+1}\right] \qquad (5)$$

Flow from an individual orifice, q, is proportional to the square root of the head at that point,

$$q = CA\sqrt{2gH}\ , \qquad (6)$$

where C is a constant, A is the orifice area, g is the acceleration of gravity, and H is the head at that point.

The desired orifice spacing d_x at point x is obtained by dividing the orifice flow at that point by the flow per unit length of pipe; that is,

$$d_x = \frac{q_x}{Q_o/L} \qquad (7)$$

or

$$d_x = \frac{CAL\sqrt{2gH_x}}{Q_o}\,, \qquad (7b)$$

where H_x is given by Eq. 5.

Constant flow per unit of lateral length can also be obtained by varying orifice size or by varying the length of microtubes.

With constant orifice spacing d, the desired orifice areas are obtained from the equation,

$$A_x = \frac{q}{C\sqrt{2gH_x}}\,, \qquad (8)$$

or

$$A_x = \frac{Q_o d}{LC\sqrt{2gH_x}} \qquad (8b)$$

As noted by Karmeli (3), the length of microtubes, or other long flow path drippers, is computed by the Darcy-Weisbach equation. For laminar flows, the desired path length, P_x, can be obtained from the equation,

$$P_x = \frac{H_x g D^4 \pi}{128 q \nu}\,, \qquad (9)$$

where D is the diameter of the microtube, ν is the kinematic viscosity, and the other variables were previously defined. Increasing water temperature and resultant viscosity changes need to be considered.

Plots of H_x vs x can be prepared using a few computed values of H_x. Then orifice spacings, orifice sizes, or microtube lengths can also be obtained from plots of these variables vs head as suggested by Myers and Bucks (4). Orifice sizes or spacings or microtube lengths can be computed for several values of x. A plot of the desired variable vs x would also facilitate lateral design.

Verification

Two experiments were conducted to test the proposed theory. In both cases, the values of lateral length L, orifice area A and orifice constant C, upstream head H_o, and flow per unit length of pipe Q_o/L were assumed. Also, the tests were conducted on approximately level ground so that S = 0. Both tests were conducted with pipe lying on the ground surface. The constants in Eq. 3 were obtained from published data (5), which are shown in Fig. 2.

The orifices used in these tests were in molded insert fittings similar to that designed by Whitney and Lo (9).

The first test was conducted with a 3/4-in. nominal diameter pipe 201 m (660 ft) long. Values of other parameters and orifice spacings are shown in Fig. 3 along with calculated and measured flow rates. Measured application rates were slightly greater than design rates.

In 1970, Whitney (8) proposed that two pipes or a two-cavity pipe be used to obtain more uniform flow along subirrigation laterals, with flow being distributed from a high-pressure conveyance pipe to a low-pressure distribution pipe by spaced orifices. His idea was incorporated into a second test of the orifice-spacing theory presented above. A 402-m (1320-ft)

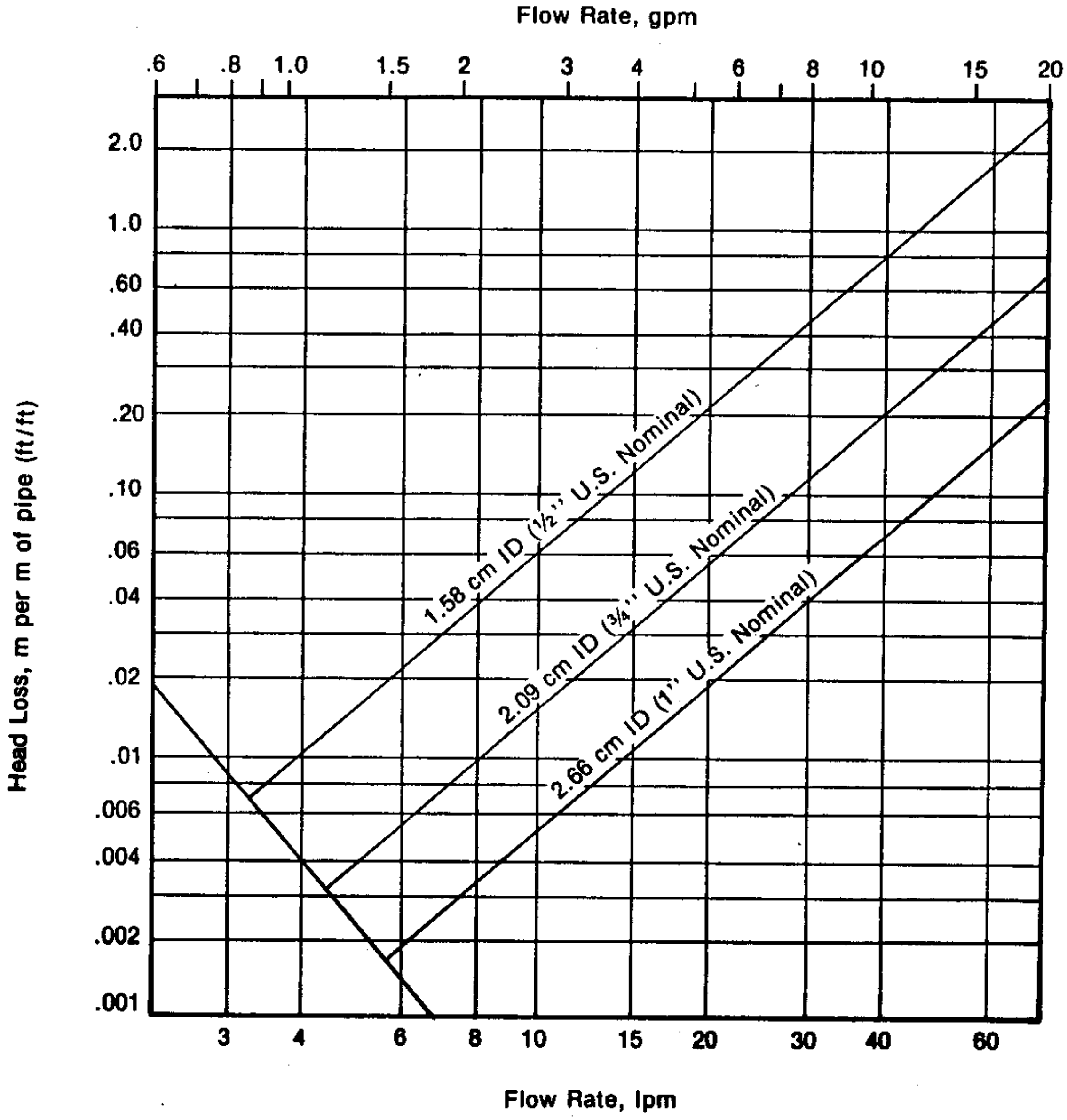


FIGURE 2. Friction loss in polyethylene pipe.

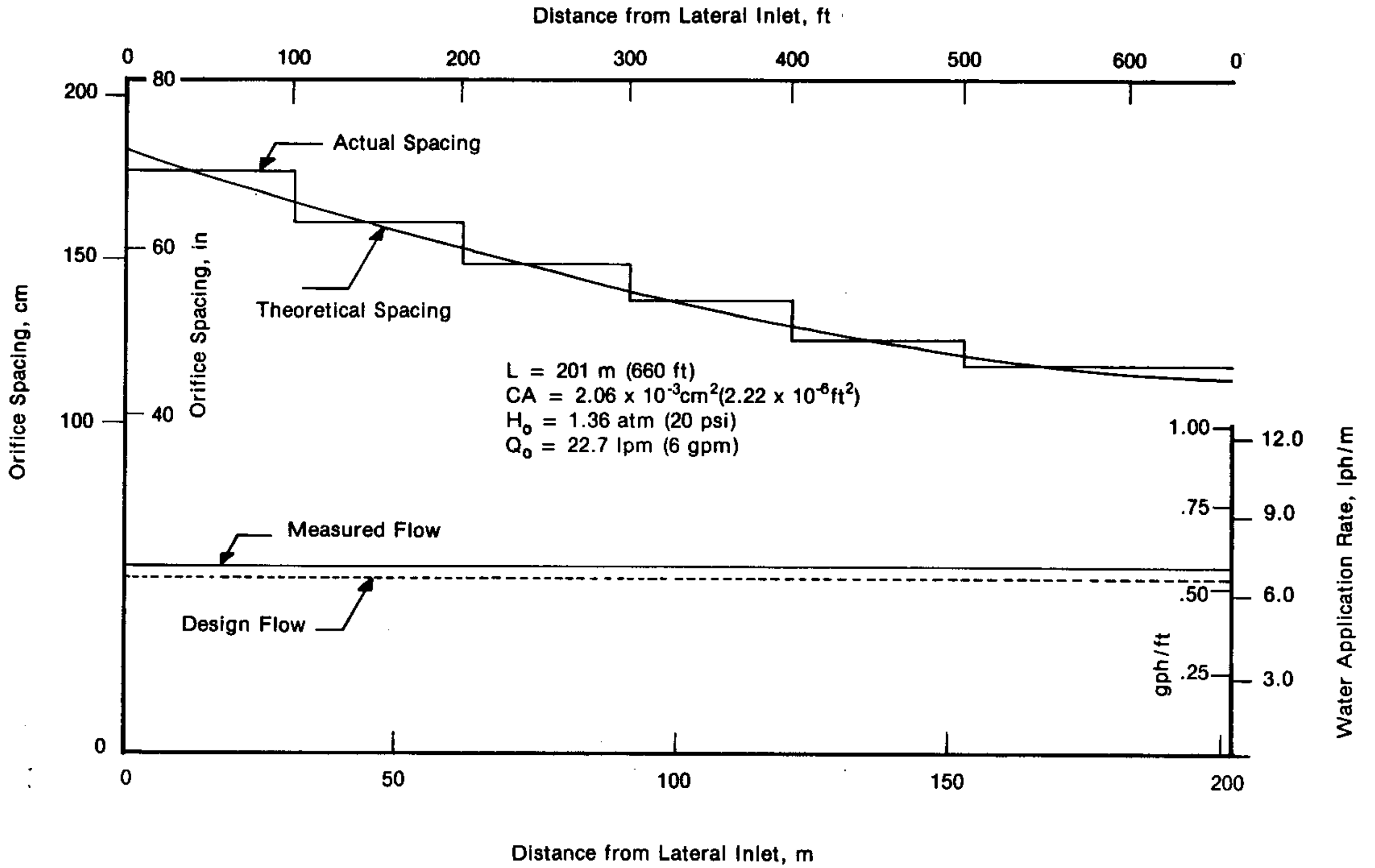


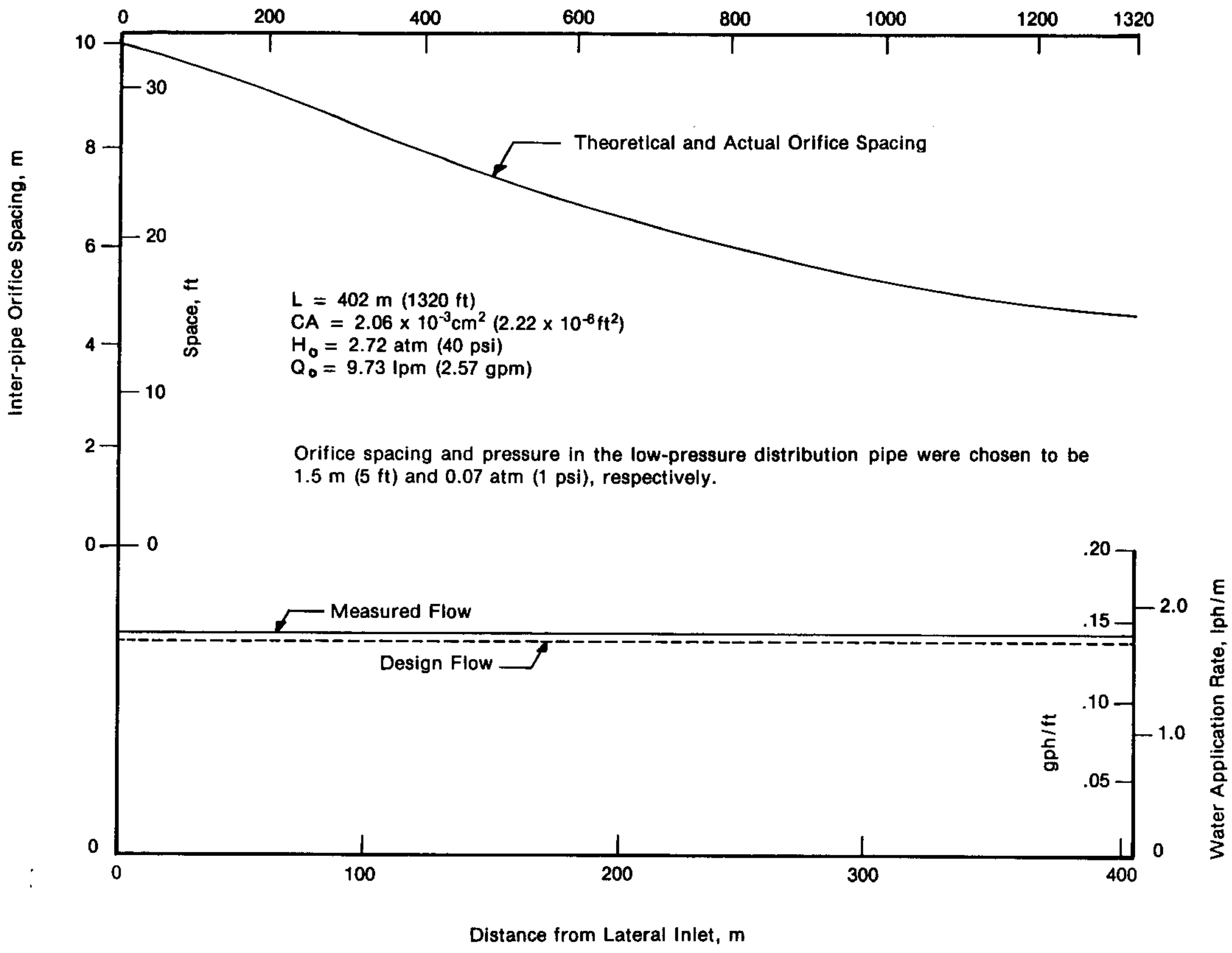
FIGURE 3. Design and performance characteristics of a trickle or subirrigation lateral with a variable orifice spacing.

long trickle or subirrigation lateral was constructed from two ½-in. nominal diameter polyethylene pipes. The pipes were connected by orifices at the spacings shown in Fig. 4. Orifices were installed 1.5 m (5 ft) apart in the low-pressure pipe to distribute water to the soil. Values of the various design parameters are shown in Fig. 4 along with predicted and measured flow rates.

Design Curves

The theory just presented was used to develop a set of design curves for rapidly determining pressure distribution in drip irrigation laterals with uniform distribution of water. Head gain with distance from a lateral's downstream end is given in Fig. 5b for various lateral flow rates expressed in gallons per hour per foot of lateral length. Head gain values in Fig. 5b are for ½-in. nominal diameter polyethylene pipe which has an actual ID of 1.59 cm (0.625-in.). Using a grease pencil, form a cross on the overlay (Fig. 5a) where the upstream pressure and lateral length intercept. An example is given on the overlay. Then, keeping the vertical axes of Figs. 5a and 5b aligned, slide the overlay down until the cross intersects the proper flow curve on the overlay. The head valves on the overlay ordinate represent actual head valves (pressures) at points along the lateral. The curve on the overlay can be adjusted to incorporate the effect of elevation changes.

Once the head at any point along the lateral is known, microtube lengths or emitter settings can be chosen to obtain the desired uniform water distribution. For example, lengths of 0.91-mm (0.036-in.) diameter microtubing for various heads and flows can be obtained from Fig. 6. Head losses for other sizes of microtubing are shown in Fig. 7.



$L = 402$ m (1320 ft)
$CA = 2.06 \times 10^{-3} cm^2$ ($2.22 \times 10^{-6} ft^2$)
$H_o = 2.72$ atm (40 psi)
$Q_o = 9.73$ lpm (2.57 gpm)

Orifice spacing and pressure in the low-pressure distribution pipe were chosen to be 1.5 m (5 ft) and 0.07 atm (1 psi), respectively.

FIGURE 4. Design and performance characteristics of a 1320 foot long, "two-pipe" trickle or subirrigation lateral.

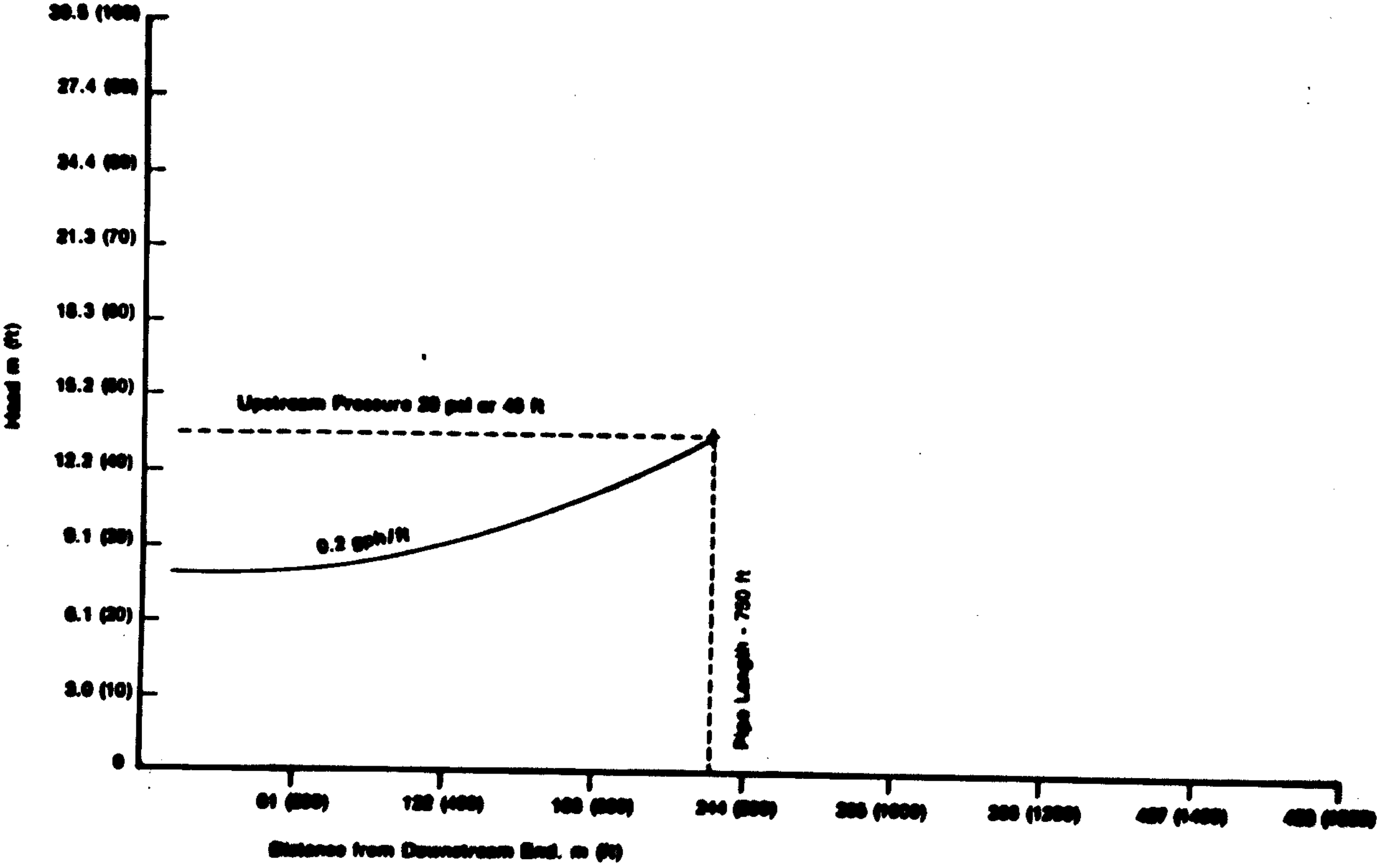


FIGURE 5A. Overlay for Fig. 5B.

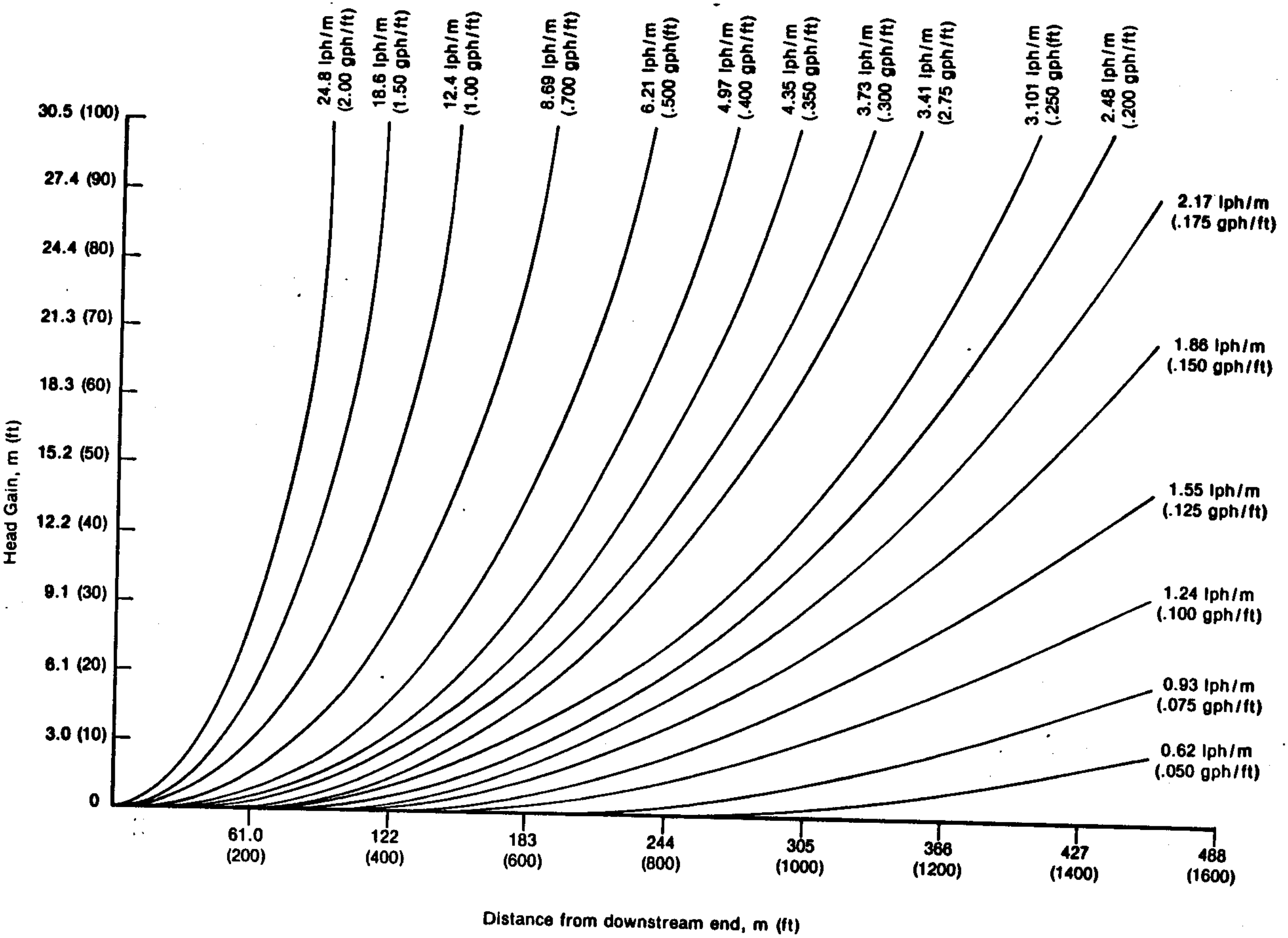


FIGURE 5B. Head gain in drip laterals with various uniform flow rates.

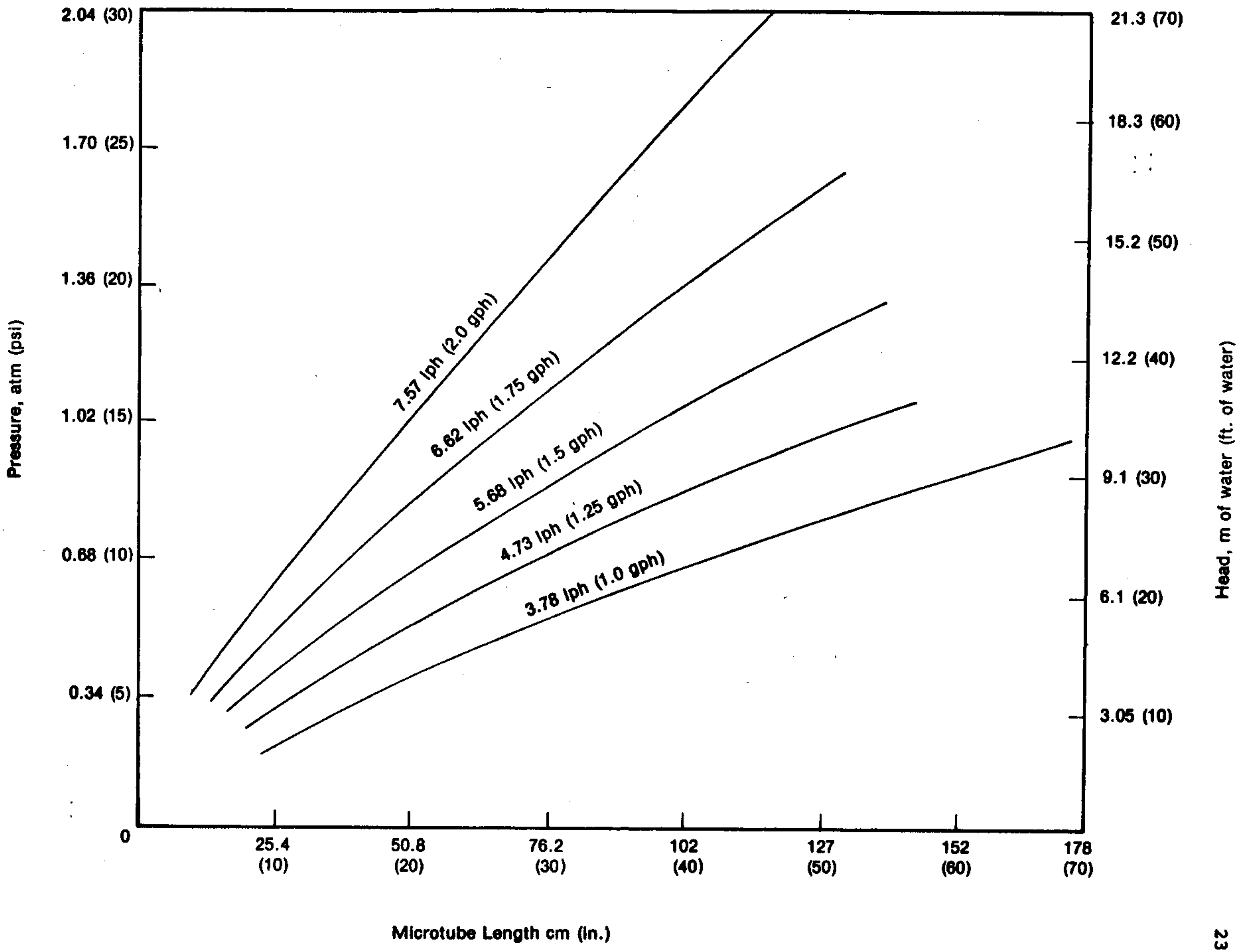


FIGURE 6. Relationships between lengths of 0.036-in. diameter microtube, pressure, and flow rate.

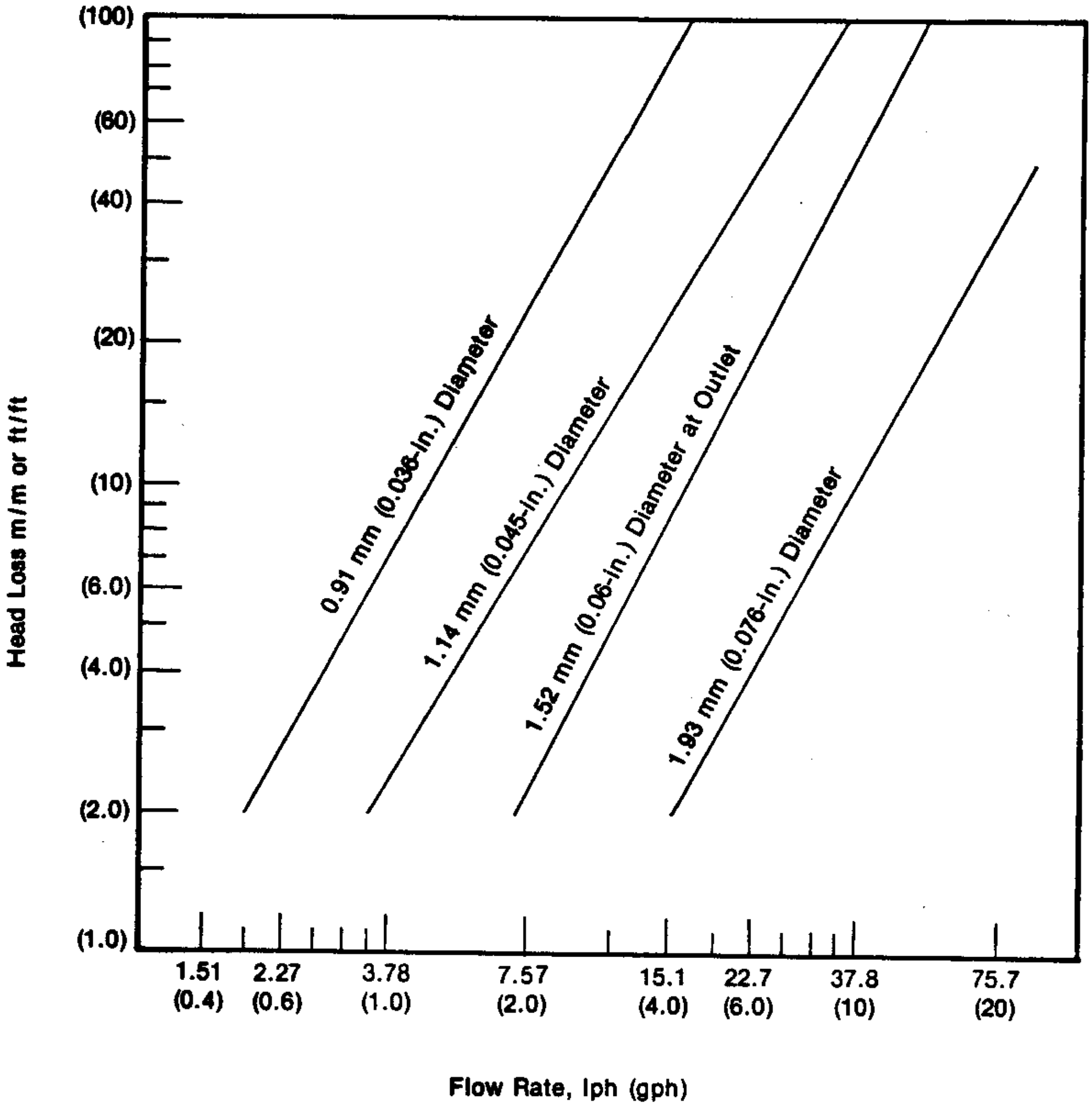


FIGURE 7. Head loss per unit length of various sizes of microtubing as a function of flow rate. Valves not valid for short pieces with high entrance and exit losses.

CHAPTER 5

EXPERIMENTAL EMITTERS

Introduction

From the data discussed thus far, it is obvious that a good emitter must have several characteristics. First, the emitter opening should be as large as possible to reduce plugging. If practical, an emitter should be adjustible to provide uniform water distribution along longer laterals with fewer submains.

For row crops, 1000 or more emitters are needed per irrigated acre. Therefore, emitters should be low in cost and easy to install. To avoid excessive costs for mains, submains and controls, emitter flow rates should be as low as possible. Often emitters have a hooded or serpentine outlet to shield the emitter opening from surrounding soil. Some emitters have a screened inlet. Preferably the emitter would have no moving parts. Several experimental emitters were designed and tested. A discussion of these protypes and their performance follows.

Improved Outlets for Microtubes

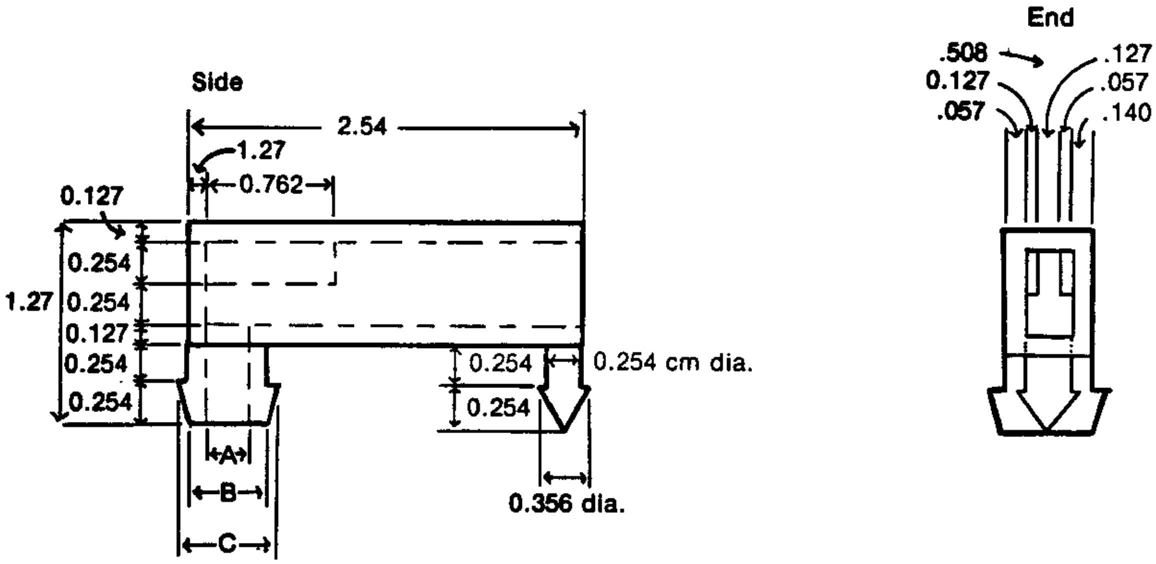
In 1973, Wilke (10) published an improved procedure for installing microtube drip irrigation emitters. This project-related publication is included in this report as an Appendix. A modification of the emitter described is being produced and sold commercially by Chapin Watermatics.

To further improve microtube emitters, injection-molded outlets and screens were constructed. Fig. 8 is a working drawing for the molded outlet and screen. This is the screened microtube emitter discussed in Chapter 3. Further field tests of the emitter as a subirrigation emitter are planned by the Texas Agricultural Experiment Station.

FIGURE 8. Sketch of an outlet and screen for 0.152 cm (0.06 in) diameter microtube.

All dimensions in cm
Tolerance 0.01 cm/cm

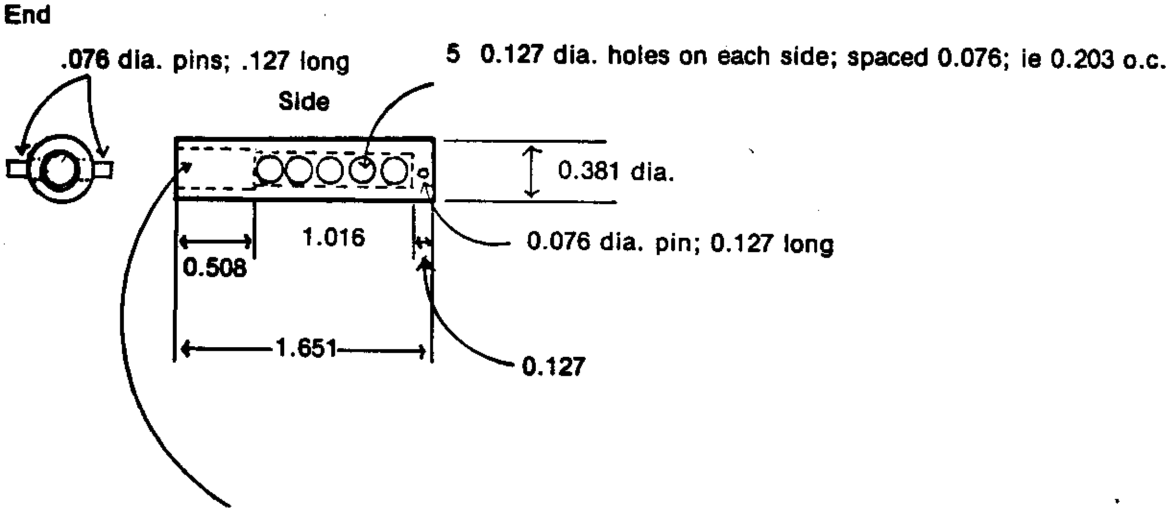
PART 1: OUTLET



A - Cylindrical opening; 0.267 cm dia. at dimension point; tapering to 0.254 cm dia. at 0.622 cm from inlet; then beveled 45° to 0.241 cm dia. at 0.635 cm from inlet.

B - 0.508 cm C - 0.610 cm dia.

PART 2: INLET SCREEN



Cylindrical Opening; 0.292 dia. at inlet; beveled 45° to 0.241 dia. at 0.05 from inlet; 0.241 dia. to 0.508 from inlet; then 1.524 dia. from 0.508 from inlet to 1.524 from inlet.

Vortex Diode Emitter

The Melnor-Tirosh emitter described in Chapter 3 utilizes a single vortex diode to dissipate energy. An experimental prototype (Fig. 9) with 6 vortex diodes was constructed. The hexogonal wafer can turned to vary the number of diodes in the flow path. Preliminary tests were conducted with a machined multiple vortex diode emitter with 0.89-mm (0.035-in.) diameter outlets. The emitter produced 2.8 ± 0.38 lph (1.0 ± 0.1 gph) at pressures ranging from 0.27 to 1.29 atm (4 to 19 psig). However, injection-molded emitters did not perform successfully because of leaks between the wafer and its housing. This problem could probably be prevented through the use of a threaded cap to compress the wafer between the sealing surfaces.

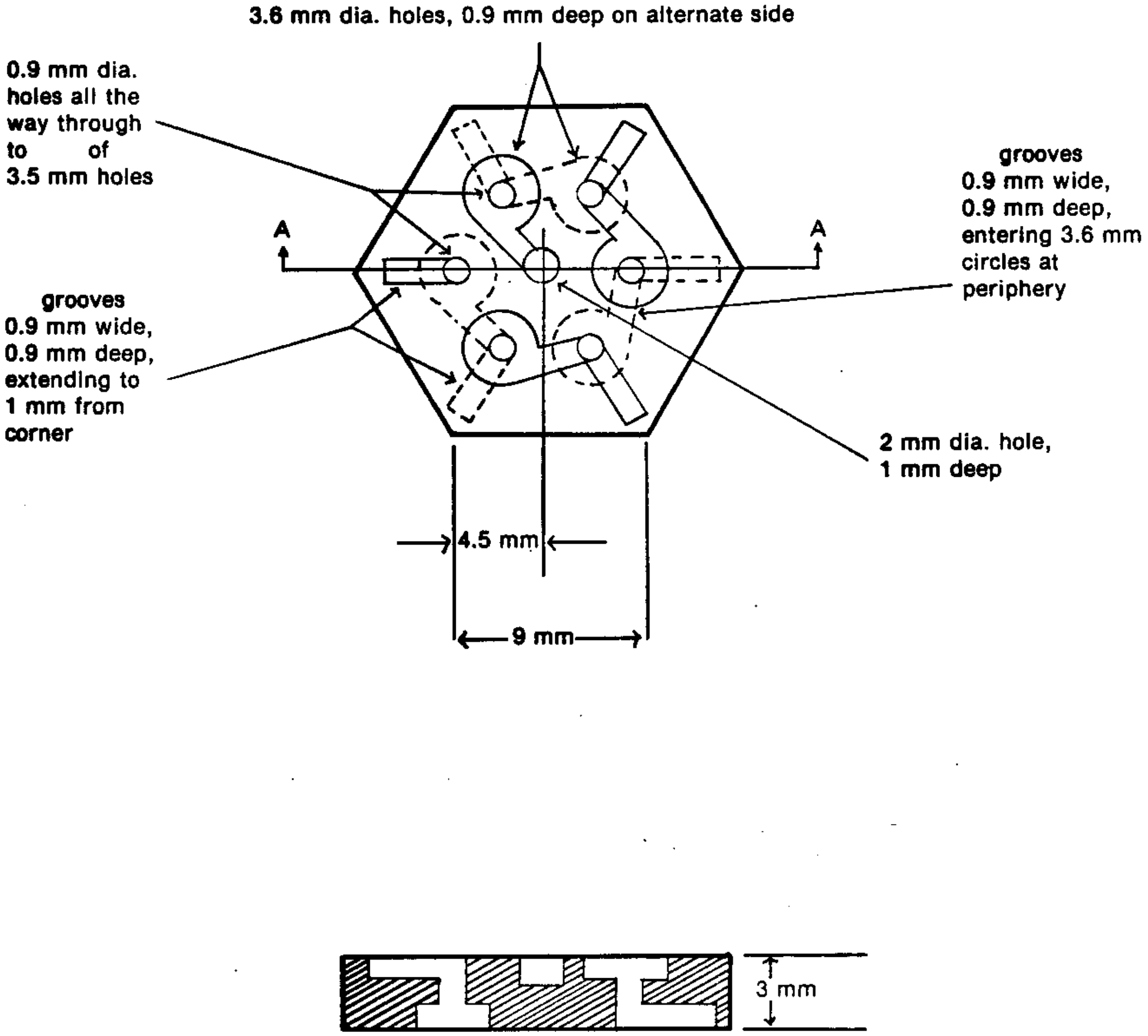
Postage Stamp Emitter

Because of the large number of emitters required for row crops, the cost of installing emitters in pipe laterals is a major cost. Therefore, an attempt was made to develop a low-cost emitter which could readily be automatically attached to the pipe. A mold for the emitter shown in Fig. 10 was constructed. Actually, Fig. 10 represents the end product of an evolutionary process. The one-piece emitter could be molded and automatically attached to pipe for an estimated cost of 2 to 3 cents per emitter.

This emitter produced 2.3 lph (0.6 gph) at 1.02 atm (15 psig) pressure. The emitter is clamped around ½-inch nominal diameter pipe by means of the ratcheted closures on the emitter. The emitter had to be molded from low-density polyethylene to obtain a water-tight seal between the emitter and the outer wall of the pipe. The emitter flow could be varied by changing the position of the inlet holes in the pipe wall.

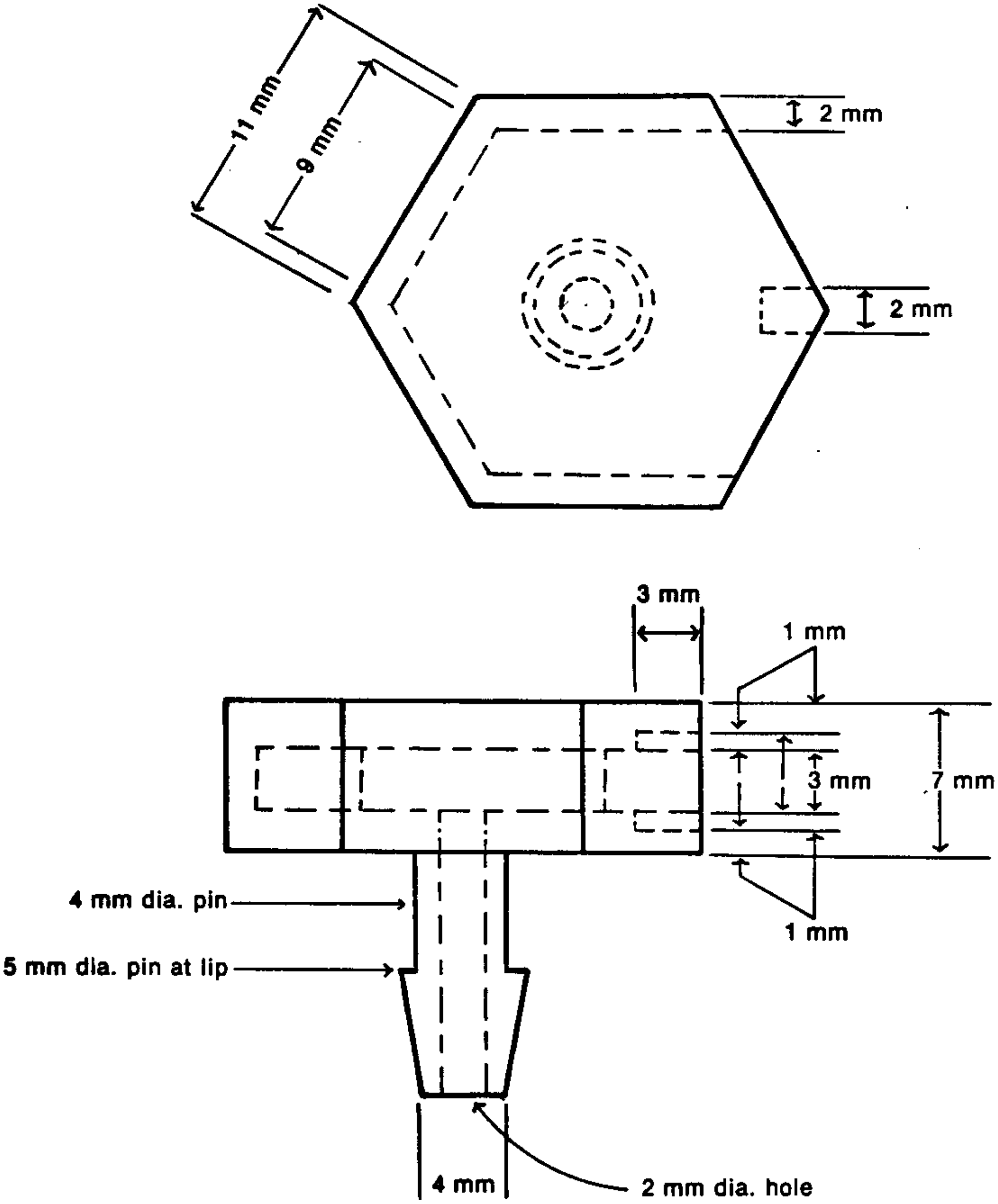
Tension and flexural stresses in the outside skin of the emitter

FIGURE 9A. Wafer portion of an adjustable multiple vortex diode emitter.



Section A-A

FIGURE 9B. Housing portion of an adjustable multiple vortex diode emitter.



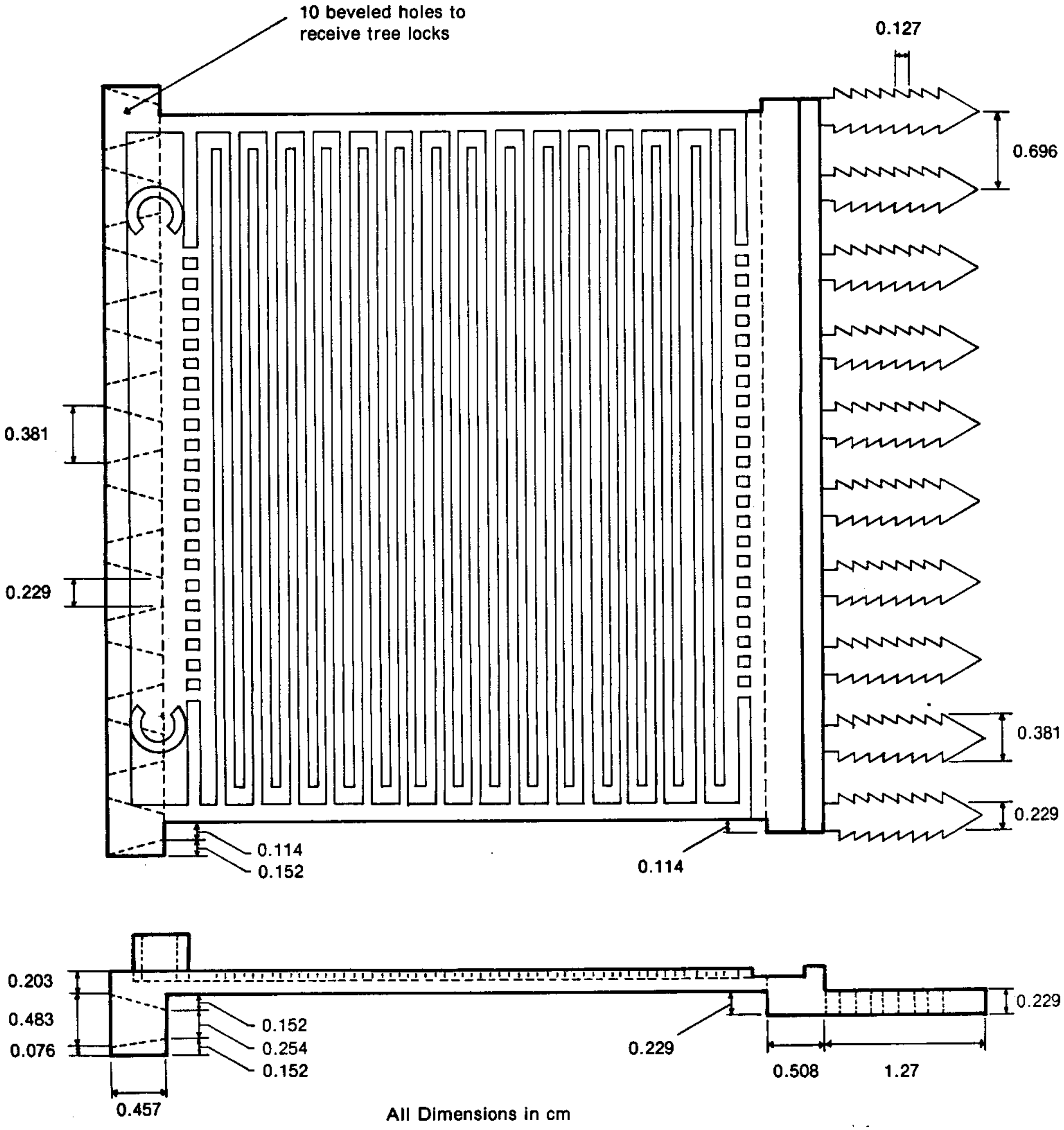


FIGURE 10. Sketch of an emitter which wraps around polyethylene pipe.

caused stress cracking. This fact gives rise to doubts about emitter longevity.

Summary

Four experimental emitters were constructed. A microtube with an expanded outlet is being sold commercially. The molded screen and outlet for microtubing are undergoing further tests. The vortex-diode emitter requires modification to obtain a water-tight seal. The postage stamp emitter has been abandoned because of doubts about the emitter's longevity.

Except for the 1.5-mm (0.060-in.) diameter screened microtubing, all prototypes had relatively low flow rates. Therefore, future modifications could have larger emitter openings which should be more resistant to plugging. Vortex diodes and 180-degree turns are a significant aid in dissipating energy.

CHAPTER 6

MOVEABLE DROP IRRIGATION SYSTEMS

The flow model discussed in Chapter 2 indicated that vertical water distribution improved as the depth of the water source was decreased. Therefore, surface drip irrigation may be nearly as efficient as subsurface irrigation. However, solid-set surface drip systems are expensive and may interfere with tillage operations. For these reasons, two moveable drip systems were studied.

One idea is the use of plastic drip irrigation trail lines, instead of sprinklers, attached to a pivot sprinkler system.

In studies conducted at Lubbock, three such plastic lines were attached to a pivot system made available through the cooperation of Gifford-Hill Western and Lubbock Christian College.

Advantages of using drip trail lines instead of sprinklers are that the water is applied only behind the drive wheels, lower operating pressures are needed, less water is lost to evaporation, and salty water does not contact plant leaves.

In this trial, the drip lines trailed the pivot system successfully, following the arc of wheel travel. However, the plastic pipe can be damaged by grazing cattle. In sandy soils it may be difficult to germinate seeds because the drip system may not wet the surface soil uniformly.

The second technique involves the development of a tractor-mounted rig to move drip irrigation pipes in cotton. Details of this technique have been published (11). One drip line can be used to apply a single irrigation to 40 rows of cotton during the fruiting period. Two funnels with belled entrances are attached to a tractor and are used to pick up the pipe and move it laterally two rows to water alternate furrows. Pipes are moved once or twice daily and can be moved without stopping the well pump.

The use of switching tensiometers to automate drip irrigation (7) has resulted in a 40 percent reduction in irrigation water requirements. Therefore, an automated pivot system with drip irrigation trail lines could provide very high water use efficiencies at a relatively low cost.

CHAPTER 7

RESULTS AND CONCLUSIONS

Two mathematical models describing one-dimensional flow were developed. One considered the consumption of water by roots. For the assumed distribution of the root consumption with time and depth, the 10-cm (4-in.) deep source provided better water distribution than did 20- and 30-cm (8- and 12-in.) deep sources. Irrigation from zero depth, as in the case of trickle irrigation, appeared to be the best system for the given conditions.

Plugging of emitters by particulate materials decreased as the cross-sectional area of the emitter opening was increased. Less than 0.06 atm (1 psig) vacuum had little effect on the flow of emitters tested. Higher vacuum amounts caused the reopening of plugged orifice emitters, but caused plugging of labyrinth emitters. Vacuum-induced plugging of labyrinth emitters resulted from accumulation of silt and fine sand within the flow path. Operation at higher pressures caused limited flow recovery.

A theory was proposed for determining pressure distributions in drip laterals where water is uniformly distributed along the lateral's length. The theory provided acceptable design in two tests. Computer-derived design curves were developed. Because 1000 or more emitters may be required for subirrigation of each acre, emitters need to be both inexpensive and resistant to plugging. Four experimental emitters were designed and constructed. A modification of one microtube emitter is being produced commercially.

Two moveable drip systems were proposed. Drip irrigation lines successfully trailed a center-pivot irrigation system. Also a tractor-mounted implement was developed for moving individual drip irrigation laterals.

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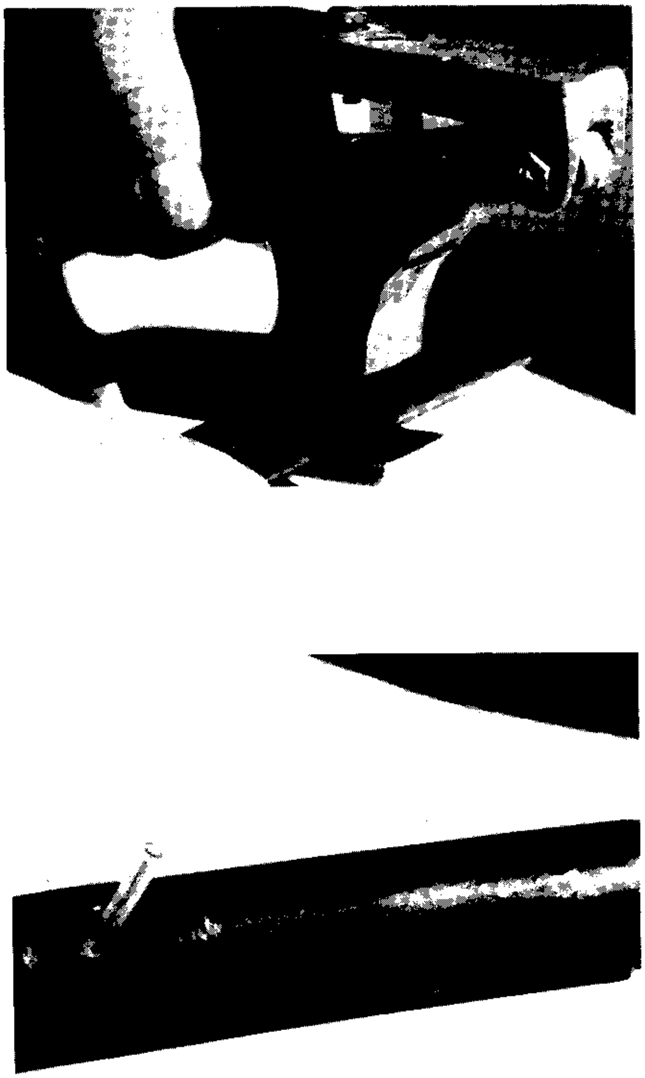
APPENDIX

EMITTER, TUBE AND PIPE LATERAL: The microtube emitter with a short piece of larger diameter tube attached and the 1/2 in. diameter polyethylene pipe lateral

Improved Installation of Microtube Drip Irrigation Emitters



THE DRIPPER INSTALLED: After punching a hole in the lateral pipe, the dripper is inserted. Black components prevent growth of algae

Otto Wilke
Associate Member ASAE

MICROTUBES as drip irrigation emitters have several distinct advantages—low cost, good hydraulic characteristics, ease of installation. But if the wall of the microtube is thin, the tube may be pinched partially or totally closed where the tube is inserted into a hole punched in the irrigation lateral pipe. If the microtube is extended from the irrigation pipe, it may be cut by rabbits. As microtube emitter flows are increased, the water stream may travel several feet from the emitter. Foliage may be wetted. As the plastic irrigation pipe twists due to contraction, the stream direction may change, altering the soil area wetted by the emitter.

These problems can be eliminated at negligible cost by sliding a short piece of black polyethylene tubing over the outlet end of the microtube. Stream velocities at the larger exit then are less and the distance traveled by the stream is less. The new exit tubing should be black to prevent algal growth and should fit snugly over the microtube emitter so that it is not easily dislodged. If the microtube is flexible, the microtube emitter can be protected by sliding it inside the pipe. Then only the end of the new outlet tube is exposed. This practice prevents constriction of the microtube and reduces the potential for damage by rodents. ●●

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