4 Emitter Performance

A key component of a trickle irrigation system is the emitter. The emitter is used to regulate the discharge rate at the emission points and to ensure that uniformity is maintained along the crop row.

The emitter regulates the flow rate by reducing the lateral line pressure to zero at the emission point. The method used for pressure reduction varies with emitter type. Most emitters use either a long flow path, a series of small orifices or a single small orifice to achieve the pressure dissipation required to obtain the desired low flow rate. Selecting an appropriate emitter must take into consideration the flow rate as well as the degree of filtration that will be required.

4.1 Emitter Types

Turbulent Flow Emitters

Most manufacturers sell turbulent flow emitters. These emitters have a tortuous path design causing a turbulent flow condition where fluid particles move in a random, disorganized motion. A turbulent flow emitter has many advantages:

- can be manufactured with a low variance coefficient (c_v)
- flow paths can be shorter with larger openings, therefore being less resistant to plugging
- has higher water flow velocities
- less sensitive to pressure fluctuations
- flow rate is unaffected by water temperature differences

As shown in Table 4.1 an emitter with turbulent flow characteristics will have a flow exponent range of 0.5 - 0.7. A fully turbulent flow emitter has a flow exponent of 0.50.

Many emitters have only partial turbulent flow characteristics. The flow exponent is useful in determining the pressure and temperature effects on the performance of an emitter. See Section 4.2.

The temperature and pressure effects on a turbulent flow emitter can be determined from Tables 4.2 and 4.3 once the flow exponent is known.

Although fully turbulent flow emitters are less susceptible to pressure fluctuations than laminar flow emitters, they should not be used as pressure compensating emitters. Careful design is required to ensure these emitters will operate correctly on sloping terrain.

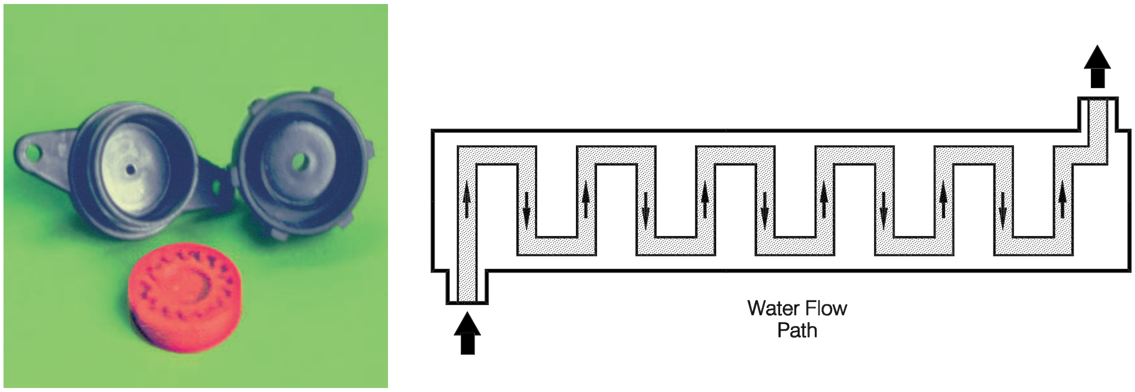


Figure 4.1

Some emitters are only partially turbulent flow. Although fully turbulent flow emitters are less susceptible to pressure fluctuations than laminar flow emitters, they should not be used as pressure compensating emitters.

Laminar Flow Emitters

A laminar flow condition occurs when fluid particles move in a slow organized fashion at a low velocity. Laminar flow emitters regulate discharge by using friction to dissipate energy and therefore emitters usually have long and narrow flow paths. Longer or smaller flow passages increase the frictional resistance to the flow of water, thereby reducing the emitter discharge rate. Microtube and spiral flow path emitters are good examples of laminar flow emitters.

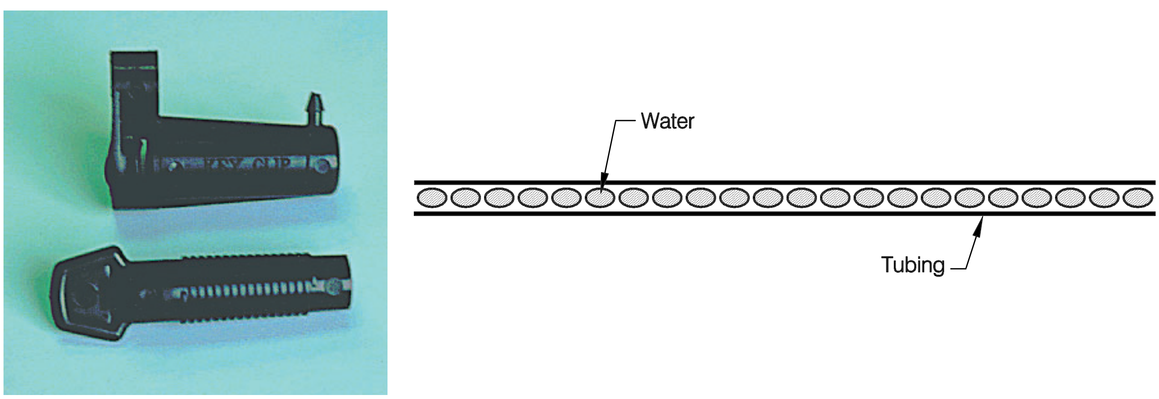


Figure 4.2 *Laminar Flow Emitter*

These emitters are simple, reliable and inexpensive providing they are installed properly. Due to the slow water velocity and narrow passages, laminar flow emitters are more susceptible to plugging than turbulent flow emitters. Good water quality must be maintained by adequate filtration, chemical treatment if necessary and line flushing.

Laminar flow emitters are very sensitive to pressure fluctuations and water viscosity. Flow rates will vary greatly with changes in pressure and water temperature.

Vortex Emitters

Vortex emitters use the principle that a reduced pressure exists at the centre of a vortex. The emitter outlet is located at the centre of the vortex chamber. Centrifugal force pushes water towards the centre where the discharge rate is reduced due to the lower pressure condition.

A true vortex emitter is less pressure sensitive than a turbulent flow emitter. Since a vortex emitter utilizes only a single orifice, good quality filtration is required to ensure that clogging isn't a problem.

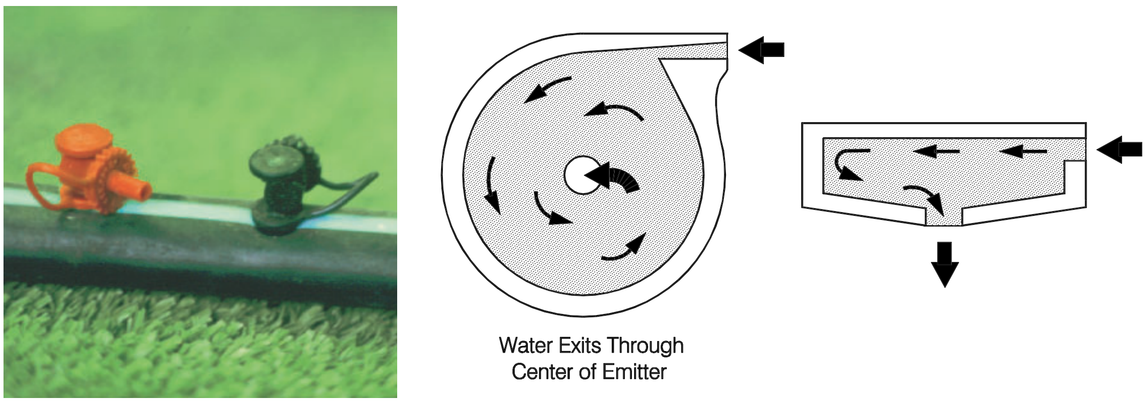


Figure 4.3 *Vortex Emitter*

Pressure Compensating Emitters

Pressure compensating emitters can be either turbulent or laminar flow but today's emitters are usually turbulent flow. A pressure compensating emitter utilizes the inlet pressure to modify the flow passage. This modification is accomplished by exerting pressure on an elastomeric disc or diaphragm which reduces the opening of the water passage. An increase in pressure will therefore reduce the size of the flow passage. The elastomeric disc is designed so that an increase in pressure over a smaller flow passage yields the same flow rate as a larger flow passage with less pressure. Pressure compensating emitters are therefore able to operate over a pressure range of 15-40 psi while maintaining the flow rate relatively constant. These emitters are more expensive than non-pressure compensating emitters but are a necessity in fields that have undulating terrain.

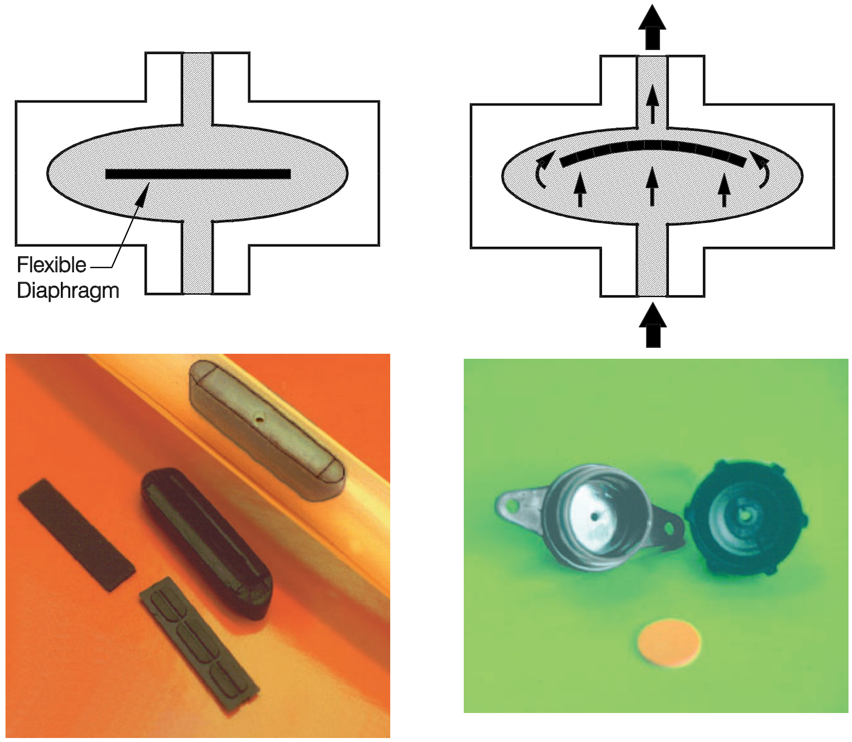


Figure 4.4 *Pressure Compensating Emitter*

4.2 Emitter Uniformity

Material from the "Hardie Irrigation Manual" *by Michael Boswell and* "Drip and Microirrigation for Trees, Vines and Row Crops" *by Charles Burt and Stuart Styles have been used in the preparation of this section.*

This section evaluates the effect of temperature and pressure variation on emitter performance.

Trickle irrigation systems should be designed to achieve an application uniformity of 90%. This means that the emitter discharge rates throughout an entire zone must be limited to a variation in flow of no more than 10%. The variables that affect the emitter discharge rate are operating pressure, temperature and emitter manufacturing characteristics (C_v). Formulas, tables and charts have been developed using these parameters to help determine emitter uniformity. The first step is to determine the emitter discharge exponent. Once the emitter discharge exponent is known or calculated the effects of pressure and temperature on emitter performance can be determined.

Emitter Discharge Exponent

Most emitters regulate flow by disposing of energy through frictional resistance. For non-pressure compensating emitters the flow rate of an emitter will increase with an increase in pressure. This relationship is expressed by Equation 4.1. The flow rate of an emitter can also be calculated by Equation 4.1.

Equation $$Q = K_d (P)^X$$

where

Q	=	Flow Rate (gph)
P	=	Operating pressure (psi)
K_d	=	Constant depending on the emitter and orifice size
x	=	Emitter discharge exponent

The constant K_d is related to the physical dimensions of the flow passage. Some manufacturers will supply both the constant (K_d) and discharge exponent (x) but for microjets or linear tape systems these values are hard to obtain.

The uniformity of application is affected by the discharge exponent. The lower the x value, the more pressure compensating the emitter is. A fully pressure compensating emitter will have an x value of 0. An emitter that is very pressure sensitive, or fully laminar flow , will have an x value of 1.0. Table 4.1 shows the discharge exponent (x) for various emitter types.

Table 4.1 Flow Exponent Values for Various Flow Regimes and Emitter Types

Flow Regime	Flow Exponent (x)	Emitter Type
Variable Flow Path	0.0	Pressure Compensating Emitter
	0.1	
	0.2	
	0.3	
	0.4	
Fully Turbulent Flow	0.5	Orifice Flow, Tortuous Path
	0.6	
Mostly Turbulent Flow	0.7	Long or Spiral Path
	0.8	
Mostly Laminar Flow	0.9	Microtube
Fully Laminar Flow	1.0	Capillary Flow

The value of x for a given emitter can be determined experimentally by operating the emitter at two pressures, P_1 and P_2, and measuring the respective flow rates Q_1 and Q_2. The operating pressures selected should be near the upper and lower limits of the emitter's normal operating range (10 and 25 psi). A time duration of possibly 30 minutes is required to obtain an accurate measure of water volume for drip emitters. The flow rate is determined by dividing the volume by the time duration. Manufacturer's product information may also provide the required information. Equation 4.2 can be used to determine the emitter exponent.

Equation 4.2

$$x = \frac{\log\left(\frac{Q_1}{Q_2}\right)}{\log\left(\frac{P_1}{P_2}\right)}$$

Where Q_1 and Q_2 are emitter flow rates measured at pressures P_1 and P_2 respectively.

Example 4.1 Discharge Exponent Calculation

A manufacturer's product information indicates that a spray emitter has the following discharge characteristics:

At 15 psi = 14.0 gph
At 30 psi = 19.9 gph

The discharge exponent is calculatedas:

$$\log\left(\frac{Q_1}{Q_2}\right) = \log\left(\frac{14.0}{19.9}\right) = \log(.703) = -0.1527$$

$$\log\left(\frac{P_1}{P_2}\right) = \log\left(\frac{15}{30}\right) = \log(0.5) = -0.301$$

$$x = \frac{-0.1527}{-0.301} = 0.507$$

Since a spray emitter is usually a simple orifice the discharge exponent is expected to be close to 0.50 as is the case in the above example. The manufacturer's reported exponent can be checked by determining the emitter flow at various operating pressures from the specification charts and inserting the values in the Equation 4.2.

The constant (K_d) can also be calculated by:

$$K_d = \frac{Q}{P^x}$$

$$K_d = \frac{14.0 \text{ gph}}{(15)^{0.507}} = 3.55$$

Emitter Flow Rate Correction for Temperature

Laminar flow emitters (x is close to 1.0) are very susceptible to variations in water temperature. To maintain a good application uniformity throughout the trickle system, the temperature effect must be known. Water temperatures tend to increase along the lateral line, as duration of exposure to the sun increases. The flow exponent (x) can be used to determine the temperature effects on emitter performance. Table 4.2 shows the temperature effects on emitters for various flow exponents.

Table 4.2 Temperature Effects on Emitter Performance

Temperature		Correction Factor		
ºC	ºF	x = 0.6	x = 0.8	x = 1.0
5	41	0.94	0.87	0.63
10	50	0.95	0.92	0.87
15	59	0.98	0.95	0.87
20	68	1.00	1.00	1.00
25	77	1.02	1.05	1.13
30	86	1.04	1.10	1.28
35	95	1.06	1.14	1.43
40	104	1.08	1.19	1.56
45	113	1.10	1.24	1.70
50	122	1.12	1.29	1.85

The application uniformity of a trickle system should only be affected by temperature for emitters with a flow exponent exceeding 0.70 on a hot day, when incoming cool irrigation water is slowly heated as it travels along the lateral. The severity of this process should be evaluated to determine if any corrective measures should be taken to maintain system uniformity.

Pressure Effects on Emitter Discharge

The flow exponent (x) determines the sensitivity of the emitter flow rate to pressure differences.

A larger exponent value indicates larger sensitivity. Table 4.3 shows the percentage flow rate change due to pressure changes for emitters with various exponents.

Table 4.3 Percentage of Flow Rate Change Due to Pressure Variation of Emitters with Various Flow Exponents

% Pressure Change	Flow Exponent (x)				
	0.4	0.5	0.6	0.7	0.8
10	3.9	4.9	5.9	6.9	7.9
20	7.6	9.5	11.6	13.6	15.7
30	11.1	14.0	17.1	20.2	23.3
40	14.4	18.3	22.3	26.6	30.9
50	17.6	22.5	27.5	32.8	38.3

A pressure compensating emitter (x = 0) will be able to deliver the same flow rate for a range of operating pressures. The flow rate from a fully laminar flow emitter (x = 1.0) will be directly proportional to the operating pressure, as shown in Equation 4.1.

Example 4.2 Temperature and Pressure Effects on Emitter Uniformity

An emitter has an exponent of 0.8. What will be the combined effect on emitter uniformity if an emitter close to the water source is operating at 10 °C and 15 psi while an emitter at the end of a lateral running downhill is operating at 20 °C and 19.5 psi?

From Table 4.2

For an exponent of 0.8:
Temperature Correction Factor 10 °C – 0.92
20 °C – 1.0
Difference is 8%

From Table 4.3

Percent pressure change from 15 psi to 19.5 psi

$$= \frac{19.5 - 15}{15} = 30\%$$

For an exponent of 0.8 and 30% pressure change the percentage flow rate change is 23.3%.

In this case, both the temperature and pressure effects will increase the emitter flow rate therefore they must be added together. The total difference in flow could therefore be 23.3% + 8% = 31.3%.

Temperature and pressure effects on system performance should be taken into consideration when selecting emitters and designing the system to a specific emission uniformity. Table 4.4 shows the flow exponent (x), emitter performance information and the merits and problems for various types of emitters. Table 4.4 can be used as a guide for selecting an emitter.

Table 4.4	Emitter Performance Data			
Path Type	**Description**	**Merits**	**Problems**	**Flow Exponent (x)**
Microtube	Long, small diameter spaghetti tube. Laminar Flow	a	2,5,6	0.7-0.9
Long, smooth	Coiled or spiral passageway in a molded emitter body		2,4	0.7
Vortex	Water enters tangentially into a chamber, casing a spinning action and exits through an orifice on the opposite side.	a,b,c	3,4	0.4
Tortuous	Labyrinth or zig-zag path. Turbulent flow at some points in the passageway.	c,d,e		0.5-0.55
Porous Type	Tubing "sweats" or emits water along its entire length.		2,3,5,6	greater than 1.0
Pressure Compensating	Some type of flexible membrane, O-ring or other design is used to reduce the path size at higher pressures.	b,c,d,e	1,4,6,7,8	0-0.5
Multiple Flexible Orifice	Water passes through several orifices in flexible membranes. Dirt caught in one orifice will create back pressure, expanding the orifice and moving dirt through.	d,e	1,7	0.7
Orifice	A single simple hole. Typical of spray emitters.	a,b,c,d,e	9	0.5

Key to Merits and Problems

Advantages:

a. Inexpensive
b. Flow rate insensitive to temperature changes
c. Low manufacturing Cv (i.e. little variation between emitters)
d. Typically a larger hole
e. Less susceptible to plugging than other emitters with the same hole size

Disadvantages

1. Expensive
2. Flow rate sensitive to temperature changes
3. Typically a larger hole
4. Relatively sensitive to plugging
5. Very sensitive to plugging
6. Large manufacturing Cv with some makes and models
7. Discharge characteristics of some makes and models may change after a few years
8. Some emitters are pressure compensating in name only. Check product carefully.
9. Spray emitters typically have higher flow rates

From *" Drip and Microirrigation for Trees, Vines and Row Crops"* by Charles Burt and Stuart Styles

4.3 Trickle System Emission Uniformity

The uniformity of a trickle irrigation system depends on system design, emitter performance and system management. Good uniformity cannot be achieved unless the emitter is installed and operated correctly. This section provides technical information that can be used to evaluate the trickle system performance and uniformity.

Two terms are often used interchangeably, emission uniformity (Eu) and distribution uniformity (Du). For purposes of this document emission uniformity assesses the uniformity of a brand new system while the distribution uniformity is an assessment of the actual uniformity determined by field measurements.

Emission Uniformity

The equation used in this section is to be used for new systems only. The trickle irrigation emitter emission uniformity for a new system can be expressed by the following equation:

Equation 4.3

$$Eu = \left(1 - \frac{1.27Cv}{\sqrt{n}}\right)\left(\frac{Qm}{Qa}\right)$$

where Eu = emission uniformity as a decimal
n = number of emitters per plant for point source emitters
= for line source emitters, the plant spacing divided by the orifice spacing or 1, whichever is greater.
Q_m = minimum emitter flow rate (gph) for the minimum pressure (Hm)
Q_a = the average emitter flow rate (gph) for the average pressure (Ha)
C_v = manufacturer's coefficient of variation for the emitter type. (Usually provided by the manufacturer)

The first term bracketed in the formula expresses emitter flow rate variance due to a manufacturing variation (C_v). It is a measure of the tolerance to which the emitter is manufactured. Table 4.5 indicates a classification of C_v for a new emitter. The formula used to calculate C_v is as follows:

$$C_v = \frac{\text{standard deviation}}{\text{mean}} \times 100$$

Table 4.5 Classification of New Emitter Manufacturer Quality

Classification	Cv
Excellent	< 0.03
Average	0.03 - 0.07
Marginal	0.07 - 0.10
Poor	> 0.10

The impact of the coefficient of variance is reduced significantly by increasing the number of emitters that are installed per plant (n). Installing two or more emitters per plant averages the flow rate variance due to emitter manufacture and therefore reduces the impact of this variation on system uniformity.

The emitter Cv is not always published by the manufacturer but should be available on request. Cv values less than 0.10 are acceptable but many products are now manufactured with a Cv less than 0.05.

The emitter flow rate variation resulting from pressure differences is expressed by (Q_m/Q_a), the efficiency of application. Table 4.5 shows the flow exponent (x), emitter performance information and the merits and problems for various types of emitters.

Distribution Uniformity

Distribution uniformity expresses the differences in the actual amount of water received by the plants in the field. There are various methods that can be used to determine the distribution uniformity. Section 4.5 provides more information on measuring distribution uniformity in the field.

Comparing Eu and Du

The calculated potential emission uniformity (Eu) and the actual distribution uniformity (Du) in the field can vary depending on:

1. Trickle irrigation system design – to achieve good uniformity the systems must be designed and installed correctly. Good uniformity in the field is achieved when Du is close to Eu.
2. Proximity of the emitters to the plant – incorrect positioning can affect distribution uniformity.
3. Site conditions – for example rodent damage to the laterals can affect distribution uniformity.
4. System management – pressure regulating devices must be maintained, the system flushed periodically and chemicals injected regularly to reduce system plugging.
5. Aging of the trickle system components. Over time the emitter components may deteriorate reducing the distribution uniformity. Emitters can also clog due to buildup of algae and chemicals, even though a regular treatment program was used.

The measured distribution uniformity after several years of operation will depend on the initial design and how well the system was managed and maintained. Regular filter maintenance, lateral flushing and chemical treatment will keep systems operating at optimum performance. System designers should keep the following in mind:

- *The allowable pressure difference in a zone is dependent on the Eu.*
- *The pump capacity should be determined from the estimated Du after several years of operation.*

Efficiency of Application

Efficiency of application can be described as:

$$EA = \frac{Q_m}{Q_a}$$

The efficiency of application can be related to pressure variation by using the equations:

$$Q_m = Kd\ (P_m)^X \text{ and } Q_a = Kd(P_{)}^{X}$$

Therefore:

$$EA = \left(\frac{Qm}{Qa}\right) = \left(\frac{Pm}{Pa}\right)^x$$

The efficiency of application is therefore a function of pressure variation (P_m/P_a) and the emitter flow exponent (x). Table 4.6 illustrates the relationship between efficiency of application and pressure variation for emitter flow exponent values of 1.0 and 0.5. As expected, the efficiency of application for a laminar flow emitter (x = 1.0) is much lower than turbulent flow emitters (x = 0.5) for severe pressure variations.

To obtain a minimum efficiency of application of 95% for a fully turbulent flow emitter (x = 0.5) the pressure variation (P_m/P_a) from the *minimum* to the *average* emitter pressure is 90%. See Table 4.6. The variation from the lowest operating to the highest operating pressure is therefore 20% of the emitter operating pressure.

For a laminar flow emitter (x = 1.0) the maximum operating pressure range would be 10% of the emitter operating pressure, as the ratio from the average operating pressure to the minimum for an application efficiency of 95% is 0.95.

Table 4.6 Efficiency of Application versus Pressure Variation

Pressure Variation (P_m/P_a)	Efficiency of Application (Q_m/Q_a)	
	x = 0.5	x = 1.0
95%	97%	95%
90%	95%	90%
85%	92%	85%
80%	89%	80%
75%	87%	75%
70%	84%	70%
60%	77%	60%
50%	71%	50%

4.4 Determining Allowable Pressure Variation

The operating pressure difference between emitters within a zone will be a function of:

- friction loss in the lateral
- friction loss in the submain
- elevation changes within the zone

The allowable pressure difference between emitters within a zone is determined by the following factors:

- The desired Eu of the system. A high Eu will severely restrict the allowable pressure variation.
- The number of emitters per plant. More emitters per plant will reduce the impact of the manufacturing variations. The discrepancy between the volume of water received per plant vs the amount applied by a single emitter will be less percentage wise for plants receiving water from a large number of emitters.
- The coefficient of manufacturing variation (Cv).

To design an efficient trickle irrigation system, the designer must be able to determine the maximum allowable pressure variation. The emission uniformity equation 4.3 can be rewritten as:

Equation 4.4

$$Eu = \left(1 - 1.27\frac{Cv}{\sqrt{n}}\right)\left(\frac{Pm}{Pa}\right)^{x}$$

This can be rewritten for pressure variation as:

$$\left(\frac{Pm}{Pa}\right) = \left(\frac{Eu}{1 - 1.27\frac{Cv}{\sqrt{n}}}\right)^{\frac{1}{x}}$$

The pressure variance (P_m/P_a) is described as the minimum pressure (P_m) divided by the average pressure (P_a). The actual operating pressure range P_{max} to P_{min} will be larger than the pressure variance term used in the Eu formula. P_{max} to P_{min} would normally be computed as two times the difference between P_{ave} and P_{min}. However, because the friction loss is not constant along a lateral and Eu is not calculated using absolute minimum values the allowable pressure variation can be slightly higher than a factor of 2 times the difference between P_{ave} and P_{min}. Equation 4.5 is used to calculate the allowable pressure difference.

Equation 4.5

$$\textbf{Allowable Pressure Difference} = 2.5 \times (P_{ave} - P_{min})$$

An alternative to using the formula is to use Table 4.7 to determine the allowable pressure variation between emitters within a zone. The information is expressed as a percentage of the average emitter pressure. To use the table, the term Eu_{cv} must be determined using equation 4.6. The emitter flow exponent must also be known.

Equation 4.6

$$Eu_{cv} = 1 - 1.27 \frac{Cv}{\sqrt{n}}$$

Table 4.7 Allowable Pressure Variation Between Emitters

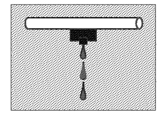
Eu_{cv}	Percentage of Average Emitter Pressure – Emitter Flow Exponent (x) 0.4	0.5	0.6	0.7	0.8
	Emission Uniformity Eu = 0.95				
0.99	24	20	17	14	13
0.98	19	15	13	11	10
0.97	13	10	9	7	6
0.96	6	5	4	4	3
0.95	0	0	0	0	0
	Emission Uniformity Eu = 0.90				
0.99	53	43	37	32	28
0.98	48	39	33	29	25
0.97	43	35	29	25	22
0.96	37	30	25	22	19
0.95	32	26	22	19	16
0.94	26	21	17	15	13
0.93	20	16	13	11	10
0.92	13	11	9	8	7
0.91	7	5	5	4	3
0.90	0	0	0	0	0
	Emission Uniformity Eu = 0.85				
0.99	79	66	56	49	43
0.98	75	62	53	46	41
0.97	70	58	49	43	38
0.96	66	54	46	40	35
0.95	61	50	42	37	32
0.94	56	46	39	33	30
0.93	50	41	35	30	27
0.92	45	37	31	27	24
0.91	39	32	27	23	20
0.90	33	27	23	20	17

From *" Drip and Microirrigation for Trees, Vines and Row Crops"* by Charles Burt and Stuart Styles

The recommended emission uniformity for new trickle irrigation systems is 90%. The minimum emission uniformities that should be used for point source systems is 85% and 80% for line source systems.

The following examples will illustrate how to use Table 4.7.

Example 4.3 Operating Pressure Range for Point Source Emitter



A grower is installing a new point source emitter system with 2 emitters per plant. An emission uniformity of 90% is desired. The manufacturer's coefficient of variance for the emitter is 0.07 and the flow exponent is 0.5. The system is to be operated at 15 psi. Calculate the allowable pressure difference for this system.

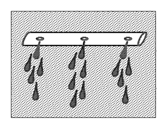
Using Equation 4.6 $$Eu_{cv} = 1 - 1.27 \frac{C_v}{\sqrt{n}} = 1 - 1.27 \times \frac{0.07}{\sqrt{2}} = 0.94$$

From Table 4.7

For an emission uniformity of 0.90, an Eu_{cv} of 0.94 and an x value of 0.5 the allowable pressure difference is determined to be 21% of the average emitter pressure.

The operating pressure range should be 15 psi x 0.21 = 3.15 psi. The minimum operating pressure will be approximately 13.5 psi and the maximum pressure should be 16.5 psi.

Example 4.4 Operating Pressure Range for Line Source Emitter



A grower is installing a linear source emitter system with 3 emission points per plant. An emission uniformity of 85% is desired. The manufacturer's coefficient of variance for the tape is 0.10 and the flow exponent is 0.8. The system is to be operated at 8 psi. Calculate the allowable pressure difference for this system.

Using Equation 4.6 $$Eu_{cv} = 1 - 1.27 \frac{C_v}{\sqrt{n}} = 1 - 1.27 \times \frac{0.10}{\sqrt{3}} = 0.93$$

From Table 4.7

For an emission uniformity of 0.85, an Eu_{cv} of 0.93 and an x value of 0.8 the allowable pressure difference is determined to be 27% of the average emitter pressure.

The operating pressure range should be 8 psi x 0.27 = 2.16 psi. The minimum operating pressure will be approximately 7 psi and the maximum pressure should be 9 psi.

4.5 Distribution Uniformity

Portions of this section have been obtained from "Drip and Microirrigation Management and Maintenance" by Farouk A. Hassen.

Distribution uniformity (Du) is a measurement of the differences in the amount of water applied to plants over the entire field or irrigated area. Equation 4.7 can be used to determine the distribution uniformity.

Equation 4.7

$$Du = \frac{\text{"minimum" water applied to the plants} \times 100}{\text{average water applied to plants}}$$

To obtain a good irrigation efficiency a high distribution uniformity (Du) must be met. Systems with a low distribution uniformity must apply sufficient water to satisfy the plant's needs in the spot with the lowest emission, thereby over applying to other parts of the field. Poor Du therefore leads to over irrigation and a resulting poor efficiency.

The Du is also affected by emitter leakage after system shutdown. Emitters that are on the end of a lateral installed on a long slope can leak for a long period after shutdown. Plants at the bottom of the slope may therefore receive much more water than plants near the top of the lateral.

The Du of an older system will be lower than a new system. This is mostly due to plugging of the emitters over time, deterioration of the physical properties of the emitter components and poor pressure regulation. A properly maintained trickle irrigation system will maintain a better distribution uniformity over time. Chemical treatment for algae and bacteria control, line flushing and proper filter maintenance will keep distribution uniformities high.

While distribution uniformities of 90% are achievable on a new system, distribution uniformities as low as 75% or lower can be found on older systems. For line source systems the values could even be much less. Fertigation systems should have a minimum Du of 90%. Lower Du's will cause poor fertilizer distribution.

A high Du is achieved by ensuring that all emitters are discharging the same flow rate. Uneven pressure and poor filtration and maintenance resulting in emitter clogging due to residue or chemical buildup are the main causes of poor uniformity. Measuring the uniformity of a new system will establish a baseline by which future measurements can be evaluated. Du measurements on older systems can help locate problem areas and maintenance needs.

Measuring Distribution Uniformity

Equipment Required

To measure the distribution uniformity the following equipment is required.

1. Pressure gauge (0-50 psi) with miscellaneous pipe fittings.		
2. Stop watch		
Drip Tape	**Point Source Emitter**	**Spray Emitter**
3. 8 litre container	3. 8 litre container	3. 8 litre bucket
4. 1000 ml graduated cylinder	4. 1000 ml graduated cylinder	4. 1000 ml graduated cylinder
5. 4 meter of 50 mm PVC pipe cut in half lengthwise		
6. 30 m measuring tape		

Preparing the System

1) Flush all of the system pipes and laterals thoroughly, moving from the larger piping to the smaller piping.
2) Clean all screens and filters on the system.
3) Set the pressure at the filtration system, inlet to the mainlines and submains as per system design.
4) Set the zone control pressure regulators as per system design.

Measuring the Emitter Discharge

Four laterals within a zone should be selected, the first near the control valve, another 1/3 of the distance along the submain, another 2/3 down the submain and the last one near the end of the submain.

Along each of the laterals selected the emitter flow rate should be measured at four locations, the first near the beginning of the lateral, a second 1/3 of the way down the lateral, a third 2/3 of the way along the lateral and the fourth near the end of the lateral. For drip tape a 4 m trough should be used to collect the discharge at the locations indicated. (See Figure 4.5).

Collect the discharge from the individual emitters or drip tape sections in a container and measure the volume in the 1000 ml graduated cylinder. For spray emitters the 25 ml hose is slipped over the spray head and the discharge collected in the 4 litre bucket. A 1000 ml graduated cylinder is used to measure the volume.

The flow rate for point source emitters should be collected for 30 minutes. For spray emitters the flow should be collected for 5 minutes. Line source systems should be measured for a minimum of 15 minutes.

Example 4.5   Emitter Flow Rate Determination

The measured volume from a single emitter is 990 ml for the 30 minute duration.

$$\text{The emitter flow rate} = \frac{990 \text{ ml}}{30 \text{ min}} = 33.5 \text{ ml / minute}$$

$$= \frac{33.5 \text{ ml}}{\text{min}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{60 \text{ minutes}}{\text{hr}}$$

$$= 2 \text{ litres/hour}$$

Drip tape is often specified in litres per hour / 100 m of tape or gallons per hour / 100 ft of tape. If measuring the flow in metric units count the number of orifices per 20 m of tape and multiply by 5 to determine the number per 100 m. If measuring the flow in gallons per hour per 100 ft of tape count the number of orifices in 20 ft of tape and multiply by 5 to determine the number per 100 ft. You also need to know the number of orifices from which the flow data is collected in the trough.

The flow rate for 100 m of tape is calculated as follows:

$$= \frac{\text{measured volume (ml)} \times \text{(number of orifices / 20 m)}}{\text{time (min)} \times \text{(number of orifices in collection trough)}} \times \frac{5}{16.67} = \frac{\text{litres / hr}}{100 \text{ m}}$$

The flow rate for 100 ft of tape is calculated as follows:

$$= \frac{\text{measured volume (ml)} \times \text{(number of orifices / 20 ft)}}{\text{time (min)} \times \text{(number of orifices in collection trough)}} \times \frac{5}{63} = \frac{\text{gallons / hr}}{100 \text{ ft}}$$

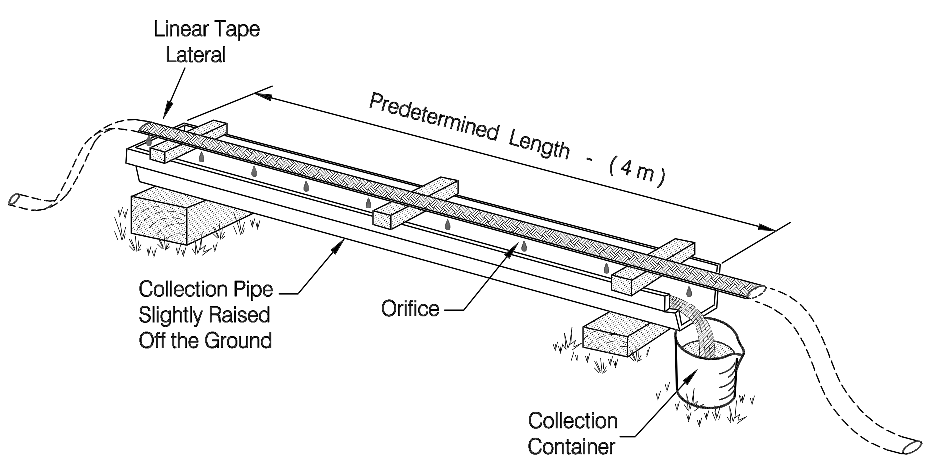


Figure 4.5 *Measuring the Flow Rate from Drip Tape*

Example 4.6 Line Source Flow Rate Determination

The measured volume from 13 orifices along the 4 m of drip tape is 2955 ml for 15 minutes. There are 66 orifices per 20 m of tape and 100 orifices per 100 ft of tape.

The tape flow rate is $= \dfrac{2955 \text{ ml} \times 66 \text{ orifices} \times 5}{15 \text{ min} \times 13 \text{ orifices} \times 16.67} = \dfrac{300 \text{ litres / hr}}{100 \text{ m}}$

or

$= \dfrac{2955 \text{ ml} \times 100 \text{ orifices}}{15 \text{ min} \times 13 \text{ orifices} \times 63} = \dfrac{24 \text{ gallons / hr}}{100 \text{ ft}}$

Measuring the Emitter Operating Pressure

Use the pressure gauge and appropriate fittings to measure the pressure in the submain and at the inlet and end of each of the four selected laterals within the zone. Use the same pressure gauge throughout to ensure that the effects of different pressure gauges are eliminated.

Computing Distribution Uniformity

The lower quarter emission uniformity method is used to calculate the Du. This methodology divides the average of the lowest quarter readings by the average of all the readings.

Equation 4.8

$$\text{LQDU} = \frac{\text{Lower Quarter} \times 100}{\text{Average}}$$

where

LQDU	=	Lower Quarter Distribution Uniformity
Lower Quarter	=	Average of the lower 25% of the sample size
Average	=	Average of the total sample

General criteria for the LQDU are:

> 90%	– excellent
80 - 90 %	– good
70 - 80 %	– fair
< 70%	– poor

Example 4.7 Distribution Uniformity Calculation

Measuring Location		Pressure	Measure Volume (ml)	Ranked Volume (ml)
Lateral 1	Start of lateral	18 psi	37	23
	1/3 down lateral		33	24
	2/3 down lateral		31.5	26
	end of lateral	15 psi	28	27
Lateral 2	Start of lateral	18 psi	36	28
	1/3 down lateral		33.5	28
	2/3 down lateral		30.5	30.5
	end of lateral	12 psi	26	31.5
Lateral 3	Start of lateral	16 psi	35	32
	1/3 down lateral		33	33
	2/3 down lateral		27	33
	end of lateral	14 psi	23	33.5
Lateral 4	Start of lateral	15 psi	33.5	33.5
	1/3 down lateral		32	35
	2/3 down lateral		28	36
	end of lateral	13 psi	24	37

The following data is collected for an emitter system. At this point the data need not be converted into a flow rate.

Average measured volume = (Sum of all values) / 16 = 30.7

Average of the lowest quarter = (Sum of lowest four values) / 4 = 25

LQDU = (25 / 30.7) x 100 = 81.5%

Assessing Lower Quarter Distribution Uniformity

Trickle systems that have operated for one year or more and have a LQDU of 80 % or better indicate good maintenance practices. Poor or fair LQDU indicate gradual clogging, emitter deterioration or poor pressure regulation. From the example note that even for an emission uniformity of 80% or better the actual emission rate can vary by more than 50% (23 ml - 37 ml).

Flow Measurements

The flow rates measured should be compared to the manufacturer's product specifications. An average discharge rate of 15% below the manufacturer's specified value is an indication that gradual clogging may be occurring. Closely inspect emitters at various locations throughout the field for precipitates or other deposits around the orifice. Clogged emitters will apply less water than what has been scheduled.

If the trickle system is being properly maintained but the Du is still low, the problem is most likely emitter deterioration. If the flow rate for a significant number of emitters deviates by more than 15% from the manufacturer's specifications emitter deterioration is likely. If these results are confirmed in a number of locations replacement of the emitters may be necessary.

Pressure Measurements

Poor pressure regulation is often the cause for emitters having low flow rates at the downstream ends of laterals and zones. The pressure variation throughout a zone should not exceed 10% for laminar flow emitters and 20% for turbulent flow emitters. A flow variation of 10% can be expected at these pressure variations.

For example, the maximum pressure variation within a zone for turbulent emitters operating at 20 psi near the zone inlet is 20 psi x 0.20 = 4 psi. The operating pressure at the furthest emitter should not be less than 16 psi to maintain good uniformity.

If repeated measurements indicate that pressure differences exceed the allowed variation, excessive lateral lengths, elevation difference or pipe sizing could be the reason. System redesign may then be required.

Chapter 11 provides information on the maintenance of trickle irrigation systems.