4.1 Field evaluation of Drip-Micro irrigation systems

Contents

4.1.1 System description

A micro-irrigation system consists of a network of lateral pipelines fitted with low discharge emitters or sprinklers. It encompasses a number of methods or concepts; such as drip, subsurface, bubbler and micro-spray irrigation.

In a drip system, water is discharged under low pressure from emitters mounted on or built into the laterals which may lie on or above the soil surface, or be buried below the ground in the crop root zone. Such systems are distinguished by the fact that water is delivered by the system to some point, for distribution laterally (and vertically) by the soil medium. Discharge rates are generally less than 8 L/h for point-source emitters and 12 L/h per metre for line-source emitters.

Micro-sprayer (micro-jet) and mini-sprinkler systems rely on aerial spread of water droplets to achieve significant lateral displacement before water enters the soil. There may be further lateral spread within the soil itself. Discharge rates are typically less than 60 L/h.

Micro-irrigation systems are potentially a very efficient way to irrigate. Water can be applied precisely to the point where it is required for crop growth, and not to inter-row or other non-beneficial areas. The system is virtually unaffected by wind or surface evaporation. Because of the very low labour requirement per irrigation, such systems allow frequent light irrigations as needed to best fit crop water requirements and optimise production.

4.1.1.1 This Schedule

This schedule was developed to provide guidelines for irrigators and others undertaking evaluations of such systems as a ‘snapshot exercise’ under prevailing field conditions.

It outlines procedures to be followed when assessing distribution uniformity of irrigation systems applying water through point-source or line-source emitters, micro-sprayers, or mini-sprinklers, where each plant is watered by one or more outlets.

The guidelines presented in this schedule are not intended for evaluations of sprinkler systems where one sprinkler serves more than one plant [See 4.2 Field evaluation of solid set irrigation systems or 4.3 Field evaluation of sprayline irrigation systems] except where that one sprinkler serves two plants equally.

4.1.2 Special features for analysis

4.1.2.1 Environmental factors

Wind conditions at the time of the test will not normally influence results from this test. The tests assume all water from an emitter, sprayer or sprinkler is allocated to a single tree (or halved between two trees) the influence of wind is negligible.

Testing is carried out over a very short time-frame, so evaporation will have no significant effect on evaluation results.

4.1.2.2 Soil moisture

The behaviour of water in the drip wetted zone is influenced by conditions existing in the soil at the time, and by previous irrigation practices. Examine the wetted zone under a number of representative emitters before the system is started, and record dimensions and approximate moisture content (see Fig. 4.1.2).

4.1.2.3 Distribution Uniformity

Overall field distribution uniformity of a micro-irrigation system is determined by system pressure variation and variation in emitter performance. In a brand new well designed system, overall system performance is determined by accepted pressure variation within the lateral network, emitter performance characteristics and variation in manufacture.

In older systems, these influences are compounded by damage to and deterioration of components, and by physical blockages of very small orifices. The nature of the system, with low pressures and very small orifices, requires that water quality be high.

4.1.2.4 Permanent set system

Because drip irrigation systems are typically set, each plant receives water from the same emitter(s) at every irrigation. Non-uniformity is repeated so there is an increased demand for high uniformity. There is no 'smoothing' effect as with moving systems, where non-uniformities vary between events and tend to cancel.

4.1.2.5 Multiple outlets per plant

In many cases individual plants are served by more than one emitter. Even small drip-irrigated row-crop plants can be considered to have multiple emitters if the wetted area per emitter is such that, if every other emitter was blocked, each plant would still receive (some) water.

4.1.2.6 Small root fraction wetted

Many drip-micro systems installed on permanent crops in New Zealand wet only a fraction of the available root area. Because most areas in New Zealand receive significant rain throughout the year, root systems generally cover the entire field.

4.1.2.7 Low operating pressures

Micro-irrigation systems usually operate at low pressures. This means a small actual pressure variation is large in relative terms, and can have a significant effect on flow variation. Typical pressures range between 200 – 400 kPa (30 – 60 psi) depending on system size and terrain undulation.

The emitters themselves usually operate in the range 35 – 170 kPa (5 – 25 psi).

4.1.2.8 Low discharge flows

Discharge rates for point-source emitters are generally less than 8 L/h and for line-source emitters less than 12L/h per metre. Micro-sprinklers have higher flow rates, typically under 175 L/h.

4.1.2.9 Field variability

The performance of drip irrigation systems may vary at different positions in the field. Contributing factors include topographic variation and elevation changes, lateral pipe lengths, and variable distances from headworks to lateral pipe inlets.

4.1.2.10 Field elevation

If the field is level, the hydraulically closest and furthest points for the headworks will normally have the highest and lowest inlet pressures respectively. These will be sampled as part of the basic testing procedure.

If field elevation varies significantly, consider increasing the number of tests to increase accuracy of distribution uniformity assessments. Record the (relative) elevations of each test site, and draw a profile sketch along a typical lateral if necessary.

4.1.2.11 Differences between drip and microsprinkler systems

The drip system discharges water directly to a point relying on the soil matrix to redistribute water within the root zone, whereas the microsprinkler discharges water through the air resulting in an immediate increase in area covered. This can mean that a smaller root volume is irrigated by drip systems.

Drip systems may have relatively long operation times, compared to micro-sprinklers which typically have higher flow rates (<175 L/h) and require shorter irrigation durations.

Because the area wetted by a drip system is typically less, the depth of watering for a given volume is greater, and care must be taken to avoid deep drainage losses.

4.1.3 Technical materials

4.1.3.1 Relevant standards

The schedule has been developed with reference to international standards and published practices. In the case of drip-micro there is (at June 2005) no accepted international standard for on-site evaluation of system performance. This schedule considers laboratory testing procedures and procedures described by the Irrigation Training and Research Center. Procedures determined are practical for implementation in a cost effective on-site evaluation.

ISO 9261:1991 Agricultural irrigation equipment – Emitting pipe systems – Specification and test methods [Laboratory testing of new manufactured drip-line]

ASAE EP405.1:2001 Design and installation of microirrigation systems

ASAE EP 458: 1995 Field evaluation of microirrigation systems (Withdrawn)

ITRC Irrigation Evaluation: Drip micro 2000 [de facto standard in California].

4.1.3.2 Technical references

Anon. 2001. The New Zealand Irrigation Manual: A practical guide to profitable and sustainable irrigation. Malvern Landcare/Environment Canterbury. Canterbury, New Zealand. (NZI)

Burt, C.M. and S.W. Styles. 1994. *Drip and Microirrigation for trees, vines and row crops (with special sections on buried drip)* Irrigation Training and Research Center (ITRC), California Polytechnic State University, San Luis Obispo, CA. 261pp

Smajstrla, A.G., B.J. Boman, D.Z.Haman, D.J.Pitts, and F.S.Zazueta. 1998. *Field evaluation of microirrigation water application uniformity.* Bulletin 265, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

4.1.3.3 Abbreviations

Reference abbreviations used in text

Cal	Burt, Walker, Styles and Parrish. 2000
DAM	Burt, C.M. and S.W. Styles. 1994.
NZI	Anon. 2001.
UFL	Smajstrla, A.G., et al. 1998.

4.1.3.4 Related schedules and appendices

3	Seasonal Irrigation Efficiency
4.2	Field evaluation of solid set irrigation systems
5.4	Reporting format

4.1.4 Test procedures

This schedule outlines procedures to be followed when assessing distribution uniformity of a micro-irrigation system as a 'snapshot exercise' under prevailing field conditions. To gain most benefit, conditions at the time of the test should be representative of those experienced in normal operation.

Because test conditions will vary, key conditions must be measured and recorded to assist any comparisons between subsequent tests of the same system, or when benchmarking against other systems.

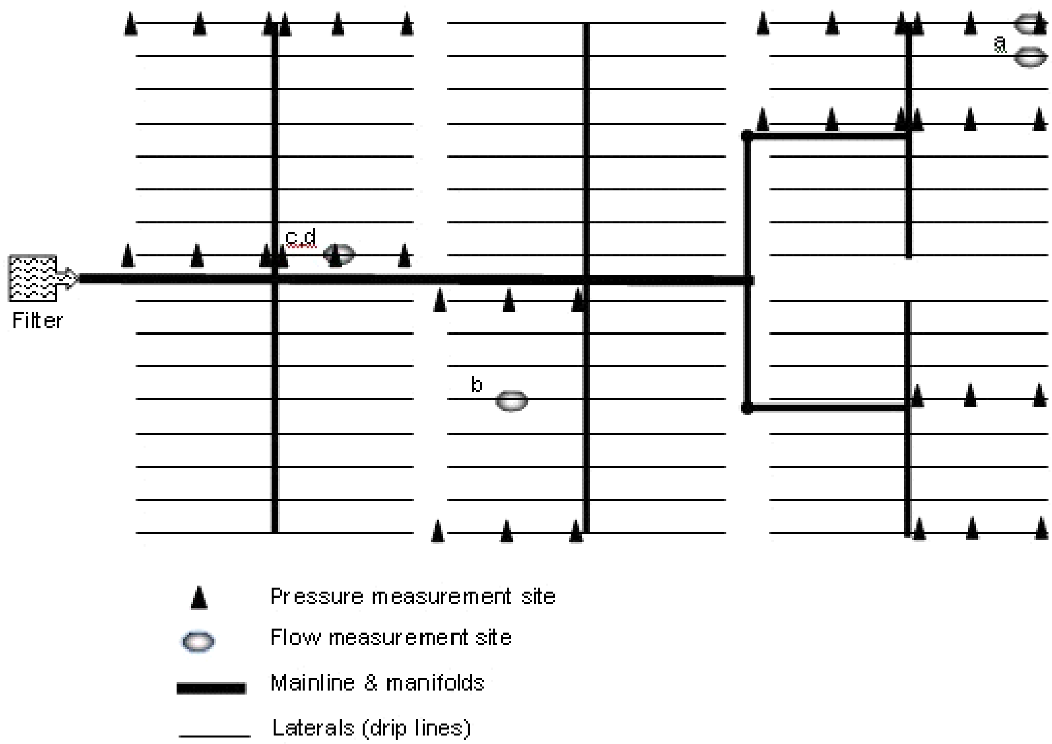

Fig. 4.1.1 Drip-micro irrigation system showing location of pressure and flow measurement sites

4.1.5 Test site

Specific locations are selected (Fig. 4.1.1) to allow an overall field uniformity to be calculated.

Emitter flow tests should be undertaken in three areas representing the cleanest, average and dirtiest parts of the system.

Pressure sampling is undertaken at defined points in as many blocks as practical.

4.1.6 System survey

4.1.6.1 System layout

Prepare a map of the system recording the headworks, mainline, take-off points, sub-mains, manifolds and laterals.

Mark location of pressure regulators, flush valves and positions where tests are to be conducted (see example Fig. 4.1.1).

4.1.6.2 Topography and elevation

If the field is not level, determine elevation differences between test sites and across the station as a whole.

Include a sketch of the profile along a typical lateral with the results unless the ground surface is level.

4.1.7 System operation

4.1.7.1 Emitter package

Before testing the system, verify that the emitters have been installed according to the design specifications, unless specified otherwise by the client (ISO).

4.1.7.2 System pressure

The test should be run at the normal operating pressure, or as mutually agreed upon by client and tester. Ensure the pressure is maintained during the test (~ISO).

Small pressure differences are proportionally large in systems operating at low pressures. To maintain constant pressure, ensure the system is not affected by other significant system draw-offs such as other irrigation machines or dairy sheds.

One test (4.1.13.7 Adjusted pressure test) requires that the system pressure be changed to allow determination of emitter coefficients. Ensure the system is stable at the new pressure before commencing and throughout this test also.

4.1.7.3 Water quality

The water used for the test should be the same as that normally used for irrigation. Water quality is of paramount importance for drip irrigation systems and is the subject of certain evaluations in the procedures that follow.

For personal health and safety reasons, particular caution is necessary if water has been treated for any purpose, such as with acid or biocides, or contains effluent or other potential bio-hazards.

4.1.7.4 Water temperature

The water used for the test should be the same as that normally used for irrigation. Water temperature in exposed black plastic lateral can increase markedly under intense sunlight. Note the water temperature at each test site.

4.1.7.5 Injection devices

If the system is designed with an injection device that is normally operative, perform the test with the injection device operating. Otherwise ensure it is not operational for the duration of testing.

4.1.8 Environmental measurements

Wind effects and evaporation impacts on collected volumes are likely to be insignificant with drip-micro systems. Measure and record if conditions suggest effects are possible.

Measure topographical variation if the field is not level. Ensure pressure measurements include lowest and highest blocks / areas.

4.1.9 Field observations

4.1.9.1 Crop type

Record the field's planting history for previous season and year.

Note crops planted in the area under examination, and stage of growth.

4.1.9.2 Crop appearance

Observe the crop for signs of stress or growth difference.

Check for plants receiving little or no water because of system faults or blockages.

Measure or estimate the crop ground cover proportion.

4.1.9.3 Soil appearance

Dig, or auger, several holes within the irrigated area.

Assess the level of water penetration at each site and record. Note any soil features that indicate wetness, poor drainage or related properties and identify causes.

4.1.9.4 Soil properties

Determine the soil texture and depth of rooting.

Estimate or otherwise determine soil infiltration rate and soil water holding capacity.

4.1.9.5 Emitter spacing

For each block determine the emitter spacing and the number of emitters per plant. The minimum number will be one (1.00), but may not be a whole number. If necessary, calculate the average number of emitters by counting along a number of plants.

4.1.9.6 Soil wetted volume

Assess the spread and depth of wetness under a number of drippers across the block and record.

Key dimensions include the surface wetted diameter, the wetted diameter at the widest point, the wetted diameter at about 30cm and the depth in relation to plant root zone (**Fig. 4.1.2**).

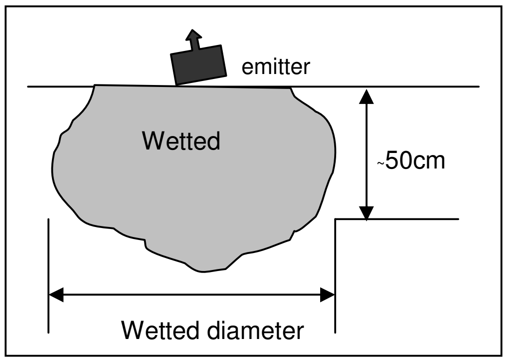

Fig. 4.1.2: Soil wetted volume

4.1.10 System checks

4.1.10.1 Sprinkler/emitter package

Before testing a system, verify that the sprinkler or emitter package has been installed according to the design specifications, unless specified otherwise by the client (ISO).

4.1.10.2 Filtration

In microirrigation systems there may be a number of in-line filters at off-takes and/or laterals in addition to the main headworks filters. Identify the type(s) of filter fitted.

Check filters and note nature and degree of contamination or blockage (Cal, IEP).

Identify when filters were last checked or cleaned and the frequency of flushing.

4.1.10.3 Lateral contamination

Randomly select at least three laterals in the block furthest from the filter. Inspect them for contaminants by flushing the lowest most distant ends through a nylon filter (sock) (Cal).

Record the time required for the water to run clear.

Rate the amount of material (sand, clay, bacteria/algae, other) caught in the nylon sock using scale:

1 = none 2 = slight 3 = medium 4 = major

4.1.10.4 Emitter blockages

Conduct a visual check to determine that emitters are operating correctly. Replace obvious failures before the test.

Determine and record the cause of blockage in any emitters that are non operational.

Remove five emitters from distant hose ends and rate the material (sand, precipitates, bacteria/algae, insects, plastic parts, other) causing plugging using the scale:

1 = none 2 = slight 3 = medium 4 = major

Note: This may require destruction, so ensure spares are available (Cal).

4.1.10.5 System leakages

Conduct an overall visual check (as possible) of headworks, mainline and the system to identify any leakages or other losses. Estimate percentage loss.

4.1.10.6 Pressure regulators

Identify locations of pressure regulators in the system, including automatic pressure control valves, manifold or off-take pressure regulators and pressure regulators on individual hoses.

Identify any other points where pressure adjustments have been made, noting any presence of regulation valves in series.

4.1.10.7 Unequal drainage

Observe the flow duration from emitters after the system is turned off.

Determine the length of time some emitters continue to run after most have stopped.

Assess the percentage of emitters that do this (Cal).

4.1.11 Flow measurement

4.1.11.1 Total system flow

Record the water flow rate as measured by a fitted water meter with the system operating as normal. Wait until flow rates stabilise (this may take up to 15 minutes) before taking reading.

It may be necessary to take beginning and ending meter readings over a set time period to determine flow rate.

4.1.11.2 Energy use

Obtaining energy consumption data for the period covered by flow measurement enables calculation of irrigation energy costs.

4.1.12 System pressure

Equipment specifications (see: 5.3.2 Pressure gauges).

1. Headworks pressures

With system operating, measure:

- Pump discharge pressure
- Mainline pressure after filters and control valves

Optionally measure:

- Filter head loss
- Pump control valve head loss
- Throttled manual valve head loss

2. Mainline pressures

Measure pressure at each off-take

3. Distribution network pressures

Pressure variation at emitters is one of the key factors influencing uniformity of a drip system.

Under this evaluation process, all pressure measurements are made using a pitot tube inserted into laterals (see: 5.3.2 Pressure gauges).

A number of measurements are required to assess variation in pressures after different pressure regulators (or off-takes), between laterals downstream of a pressure regulation point (on a manifold) and along the length of the laterals. The locations of pressure test points are therefore selected accordingly (Cal).

4.1.12.1 Pressure regulator variation

Variation in pressure regulator performance resulting from manufacturing variation, settings or design, is determined by selecting a minimum of three blocks. These should represent the highest, intermediate and lowest pressures. Typically they will be at the off-takes hydraulically closest, in the middle and furthest respectively from the headworks (see Fig. 4.1.1).

In greatly undulating fields, the blocks with the highest, intermediate and lowest elevations may represent the greatest variation. In this case, and in very large blocks, assess these as well, giving a minimum of six blocks measured.

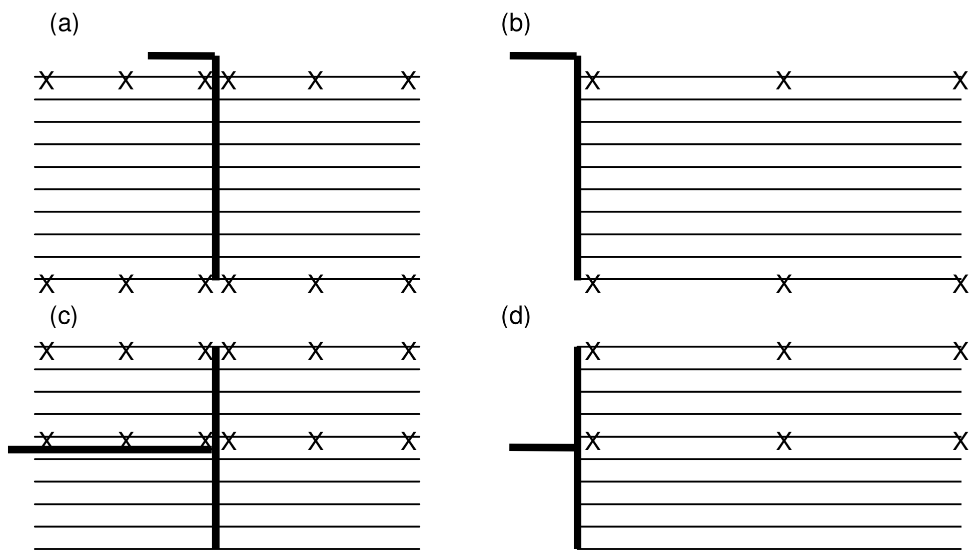

Fig. 4.1.3: Points for pressure testing

4.1.12.2 Manifold pressure variation

Variation in pressure reaching the inlet of individual laterals is determined by measuring the inlet pressure at both the first lateral after the pressure regulation point and the last lateral on the manifold, *in each assessed block* (see Fig. 4.1.3 a-d).

A total at least three blocks will be measured depending on system size and topography.

If the manifold is at one end of the block with laterals flowing in one direction only, it is treated as one block (see Fig. 4.1.3 b, d).

If paired laterals flow in both directions away from the manifold, the two sides are treated as separate blocks (see Fig. 4.1.3 a & c). Pressure readings may be taken on each side, counting as two separate blocks, in which case at least six individual blocks should be assessed.

4.1.12.3 Lateral pressure variation

Variation in pressure along the lateral is assessed by taking pressure measurements *along representative laterals.* Three pressure measurements are taken from each of two laterals at the end, the middle, and the inlet (see Fig. 4.1.3 a-d).

4.1.12.4 Station pressure variation

The variation in pressure across the entire station is determined from the above measurements. On small simple systems, a minimum total of 18 measurements will be used, comprised of six measurements from each of three blocks.

On larger or undulating systems, 36 or more pressure measurements will be used (six measurements from six or more blocks). Increasing the number of measurements will improve the quality of the results.

4.1.12.5 Lateral filter pressure loss

In-line filters or strainers fitted at the beginning of laterals can be the source of pressure variation either by inherent design or through becoming blocked.

If such filters are fitted, randomly sample five filters from the 'dirtiest' block.

Record the pressure in each lateral with the filter in, then remove the filter element and record pressure with it out. Calculate pressure loss as the average of the five readings.

4.1.13 Emitter performance

4.1.13.1 Emitter flow measurement

The purpose of these tests is to determine the variation in flow and the relative causes. These include emitter variation (whether the result of manufacturing variability, in-field damage or blockages) as well as pressure variation in the system (~Cal).

Emitter flows are measured at three different locations representing the 'cleanest', 'average' and 'dirtiest' areas within the station. The selected locations each have a different probability of emitter clogging. (Fig. 4.1.1 a-c)

If the emitter 'pressure-flow coefficient' must be determined (manufacturer's data is not available or is queried) the 'cleanest' test is repeated with the system pressure adjusted by 20%.

4.1.13.2 Flow collection

Flow from individual emitters can be collected in any container. Ensure all discharge is collected including any from leaks around the emitter, and any water that 'dribbles' along the lateral tubing. Split rubber rings placed either side of the emitter help avoid such dribbles.

Drip tape systems with many closely spaced inbuilt emitters may be measured by collecting all discharge from a known length of lateral. Useful lengths are either 1.0 or 0.5 metres, in which case a corresponding length of spouting, or PVC pipe cut in half lengthways, is convenient (see: 5.3.1 Collectors: Design, dimensions and orientation).

The minimum collection time should be five minutes or such time as is necessary to collect at least 250 mL. Measure volumes promptly especially in hot weather.

4.1.13.3 Collector placement

Check that lateral pressure within each test location (block) varies by no more than about 7 kPa. If necessary split the test across two adjacent laterals.

Note that measurement locations avoid inlet ends of laterals as pressure variation in the first 40% is typically too great.

To avoid pressure effects on flows, *all emitters in each measurement location (block) must be at the same pressure*. The pressure in *different* measurement locations (blocks) need not be the same.

4.1.13.4 Dirtiest area uniformity test

Usually the dirtiest location (that most likely to have clogging) is the one hydraulically furthest from the headworks and filters (Fig. 4.1.1 (a)). Often this is also a lower area. If a different area is known to be dirtiest, select that area instead.

Select twenty eight (28) adjacent emitters (or dripline sections) at the end of the lateral at the end of the manifold. If necessary use adjacent laterals to remain within pressure variation limits.

A larger sample set is used for this test to account for the greater variability that can be anticipated.

4.1.13.5 Average area uniformity test

This test should be conducted in an area typical of average conditions for the system. It is likely to be somewhere in the middle of the station, neither close to nor very far from the headworks and filters (Fig. 4.1.1 (b)).

Select sixteen (16) adjacent emitters (or dripline sections) near the middle of a lateral near the middle of the manifold.

For this and the 'clean area' tests, a sample size of 16 is sufficient assuming the system is clean and emitter variability is low.

4.1.13.6 Cleanest area uniformity test

Usually the cleanest location (that least likely to have clogging) is the one hydraulically nearest to the headworks and filters (Fig. 4.1.1 (c)). This provides information about the extent and effects of emitter variation on uniformity. If a different area is known to be cleanest, select that area instead.

Select sixteen (16) adjacent emitters (or dripline sections) near the middle of the lateral closest to the off-take. Avoid the inlet end as pressure variation will be too great.

4.1.13.7 Adjusted pressure test

The effect of pressure change on emitter flow is calculated using the discharge coefficient. If a manufacturer's value is unavailable, or is queried, the discharge coefficient can be determined from measurements of the same emitters at different operating pressures (Fig. 4.1.1 (d)).

Repeat the cleanest area uniformity test after adjusting the lateral pressure by about 20%.

If the normal pressure is 50 – 80 kPa try to increase pressure, if necessary by closing down some sections of the station. If normal pressure is 100 – 140 kPa reduce pressure.

After this test, reset the system to its normal operating conditions.

4.1.14 Optional tests

If desired, repeat tests may be run to determine distribution uniformity under different conditions, such as pressure, or in different locations.

4.1.15 Performance indicators

4.1.15.1 Distribution uniformity (DU_{lq})

A determination of 'Field DU_{lq}' is a prime output from evaluations conducted using this Code of Practice. The approach taken is to determine a base value of distribution uniformity from a critical field test procedure, and adjust the result to account for other contributing factors.

Where possible, the relative contribution made by each variable is estimated. This identifies those factors where system alterations may have most effect.

Distribution uniformity is not strictly an efficiency measurement so is reported as a decimal value.

4.1.15.2 Emission uniformity (EU)

The purpose of uniformity determination is to firstly assess the evenness with which individual plants receive water, and secondly to identify those factors causing non-uniformity.

The procedure established below estimates an overall Field Emission Uniformity, and estimates the relative contributions to non-uniformity made by pressure, emitter manufacture, wear and tear, drainage and uneven spacing.

The use of statistical uniformity assessments enables the different contributing factors to be separated out. The determinations will be imperfect but sufficiently accurate to identify areas where management can make changes to improve system performance.

In drip systems the coefficient often quoted is the emission uniformity coefficient (EU), which corresponds mathematically to the Christiansen coefficient used in sprinkler irrigation uniformity assessments.

EU strictly applies only to variation along a single lateral, which is not representative of a field as a whole. However, here a low quarter emission uniformity EU_{lq} is adopted to describe overall field performance.

Emission uniformity is not strictly an efficiency measurement so is reported as a decimal value.

4.1.15.3 Emission v's Distribution Uniformity

Statistically derived emission uniformity (EU_{stat}) can be related to low quarter distribution uniformity (DU_{lq}), here presented as EU_{lq}, assuming a statistically normal distribution. The relationship is given by equation Eqn 36 Emission v's Distribution Uniformity.

Acceptability classifications for whole field uniformity determinations for each measure are presented in Table 4.1.1 (based on ASAE EP458).

Table 4.1.1 Acceptability of Whole Field Determinations of Uniformity

Rating	Emission uniformity (EU_{stat})	Distribution uniformity (DU_{lq})
Excellent	> 0.95	> 0.94
Very Good	0.94 – 0.90	0.93 – 0.87
Good	0.89 – 0.80	0.86 – 0.75
Fair	0.79 – 0.70	0.74 – 0.62
Poor	0.69 – 0.60	0.61 – 0.50
Unacceptable	< 0.60	< 0.50

4.1.15.4 Application rate

Application rates under drip-micro irrigation are not generally considered in evaluations. They are complicated by the volume being applied at a point of very small area.

In drip systems some ponding is expected and assists horizontal displacement of water. In micro-jet or mini-sprinkler systems some ponding is often present.

4.1.15.5 Applied depth

In drip-micro irrigation, the volume applied must be adjusted for the area served to ensure that the depth of irrigation water applied is comparable with PET and water consumption (mm/day). Under micro-irrigation, not all the area available for plants is wetted.

4.1.15.6 Infiltration depth

The volume applied per irrigation is delivered to a fraction of the area available. The infiltration depth estimates the depth to which the wetting front will progress under the emitter. Compare infiltration depth to the root zone depth to determine whether excess irrigation is applied.

4.1.16 System uniformity

4.1.16.1 Required adjustments

The flow measurements used to assess uniformity are a non-random sample, and cover only part of an irrigation event. Determination of 'global uniformity' requires that adjustments are made to account for various factors, including multiple outlets serving individual plants and unequal system drainage.

Adjustments are not generally required to account for evaporative losses from collectors as collection times are short and measurement should be rapid.

If the station contains areas with different emitters, flows or spacings, these areas need to be assessed individually. The Irrig8 program allows up to three areas with different plant or systems spacing to be analysed.

4.1.16.2 Field emission uniformity, FEU_{lq}

Estimate overall field emission uniformity (FEU_{lq}) by combining contributing variable factors, using the Clemmens-Solomon statistical procedure (Eqn 27).

Overall uniformity incorporates the effects of pressure variation, emitter variation, and the smoothing effect of multiple emitters supplying individual plants.

In addition, it is adjusted for emitter defects (wear and plugging), unequal drainage after system shut-down and may be further adjusted to account for different plant or emitter spacings within the field.

$$FEU_{lq} = \left[1 - \sqrt{(1 - PEU_{lq})^2 + (1 - EEU_{lq})^2 + (1 - F_{drainage})^2 + (1 - F_{spacing})^2}\right]$$

Where:

- FEU_{lq} is low quarter field emission uniformity
- PEU_{lq} is low quarter pressure emission uniformity
- EEU_{lq} is low quarter emitter variation factor
- $F_{drainage}$ is the uneven drainage factor
- $F_{spacing}$ is the uneven plant spacing factor

4.1.16.3 Pressure emission uniformity (PEU_{lq})

The pressure emission uniformity coefficient describes a theoretical uniformity determined from pressure variation across the field, and the performance characteristics of the emitters.

Pressure emission uniformity (PEU_{lq}) is calculated from derived flows, using the low quarter uniformity formula.

4.1.16.4 Pressure derived flows

Pressure derived flows are calculated for each of the pressure measurements taken across the field (see 4.1.12 3 Distribution network pressures) using the emitter pressure flow relationship (Eqn 22).

If the emitter discharge exponent and coefficient are not available from manufacturers' data they can be determined as described in Section 4.1.13.7 Adjusted pressure test using Eqn 24 and Eqn 23.

4.1.16.5 Emitter emission uniformity (EEU_{lq})

Determine an emitter emission uniformity coefficient to account for manufacturing variation, wear and tear and blockages, and the number of emitters per plant.

Emitter variation is calculated from emitter manufacturing coefficient of variation, CV_{man} and the mean emitter defect coefficient of variation, CV_{defect} determined from emitter performance tests 1, 3 and 4, (see 4.1.13 Emitter performance). The statistical distribution parameter for a normal distribution, K_{lq}=1.27 is used to convert to a DU_{lq} form.

Determine the emitter variation factor, EEU_{lq} using Eqn 37.

4.1.16.6 Uneven drainage coefficient ($F_{drainage}$)

The uneven drainage coefficient is an estimate the impact of water draining from the system such that some plants receive greater amounts of irrigation than others. When short run times are used on undulating ground this can have a significant effect on overall system uniformity.

Calculate the uneven drainage coefficient using Eqn 38.

4.1.16.7 Uneven spacing coefficient ($F_{spacing}$)

The uneven spacing coefficient is an estimate of non-uniformity caused by unequal plant or emitter spacings in different zones within the main field. In general a full canopy planting should require a similar depth of water (but not volume per plant) regardless of the distance between plants, emitter spacing or emitter discharge rates.

Calculate the uneven spacing coefficient using Eqn 39.

4.1.17 Other uniformity factors

4.1.17.1 Pressure adjusted emitter flow

Determine pressure adjusted flows for each emitter measured in the emitter performance tests (see clean, middle and dirty area tests 4.1.13 Emitter performance).

Adjust the flow of each emitter to an equivalent flow at mean field pressure using Eqn 40.

4.1.17.2 Estimating Cv_{man}

In the absence of data from manufacturers or a testing facility, an estimated value of manufacturing variance can be calculated using data collected from the clean location emitter flow tests [see 4.1.13.6 Cleanest area uniformity test].

Calculations should follow the procedure set out in Eqn 20.

Table 4.1.2. Acceptable values for brand new emitter manufacture quality Cv_{man}

Classification	Manufacturing Coefficient of Variation (Cv_{man})	
	Burt & Styles	CATI (UFL)
Excellent	< 0.03	<0.05
Average	0.03 – 0.07	0.05 – 0.10
Marginal	0.07 – 0.10	0.10 – 0.15
Very Poor	> 0.10	>0.15

Adopted from Burt and Styles 1994 and Pitts (UFL)

4.1.17.3 Emitter defect coefficient of variation (Cv_{defect})

The emitter defect coefficient of variation quantifies the contribution to non-uniformity resulting from broken, worn or blocked emitters.

It is estimated as the difference between the coefficient of manufacturing variation (Cv_{man}) and the coefficient of pressure adjusted flow variation Cv_{Qpadj} in each test block 1,3 & 4 (4.1.13 Emitter performance).

Calculate Cv_{defect} using Eqn 41.

Note that Cv_{man} may have been determined in the field from the "cleanest area" flow test measurements. It is not possible to assess the individual contributions of emitter variation any more than as established above.

4.1.17.4 Sources of pressure variation

Non-uniformity arises from pressure variation in three identifiable places: variation between blocks, along manifolds, and along laterals.

Estimates of the relative contributions are made by calculating the maximum pressure variation (kPa) between laterals, and the maximum pressure variation along laterals. These should be expressed as a percentage of the total pressure variation.

4.1.17.5 Design Uniformity (EU_{des})

The design uniformity coefficient is an estimate of brand-new system uniformity determined from manufacturer's emission uniformity (EU_{man}), the number of emitters per plant, and accepted design pressure variation.

Design uniformity (EU_{design}) should be reported as a decimal, calculated using Eqn 42.

The equation utilises only mean low quarter and mean pressure values, so is not strictly a statistical measure.

4.1.18 Application calculations

4.1.18.1 Equivalent applied depth (Dz_{app})

In drip-micro irrigation, the volume applied must be adjusted for the area served to ensure that the depth of irrigation water applied is comparable with PET and water consumption (mm/day). Under micro-irrigation, not all the area available for plants is wetted.

The equivalent applied depth is calculated from emitter flow and number, irrigation duration and ground area per plant using Eqn 45.

4.1.18.2 Infiltration depth

Infiltration depth under drip-micro irrigation is calculated from applied volumes and the wetted area per emitter (Fig. 4.1.2) using Eqn 44 .

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