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IRRIGATION TRAINING & RESEARCH CENTER

Low-Pressure Testing
Microirrigation Emitters

Technical Report

August 2013

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Netafim
Olson Irrigation
RainBird
Toro

EXECUTIVE SUMMARY

The Irrigation Training & Research Center (ITRC) of California Polytechnic State University San Luis Obispo (Cal Poly) tested 28 different pressure-compensating (PC) models of microirrigation emitting devices from a total of nine manufacturers in order to compare independent laboratory testing with manufacturer specifications, because of:

- The complex design requirements of PC emitters, which create large potential discrepancies between in-field and expected performance
- The lack of independent verification of manufacturer specifications for PC emitters
- The excessive energy requirements of current standard design practices
- New combinations of irrigation system hardware such as filters and control valves that enable irrigation designers to minimize hose inlet pressures

It is the intention of this report to investigate the ability of currently marketed products to operate in a truly low pressure irrigation system where energy inputs, in the form of pump discharge pressures, can be minimized.

The test results indicate the following conclusions:

1) The majority of ~0.5 gallon-per-hour (GPH) emitters, regardless of manufacturer, exhibited:
   a. Excellent cv (< 0.03) values
   b. Minimum compensation inlet pressures (< 10 psi)
   c. Consistent flow rates within the nominal operating pressure range

2) The percentage of well-performing products decreases as the flow rate increases. In other words, fewer emitters performed well as nominal flow rates increased.

3) Observations during the testing identified some potential causes for individual emitter flow rate fluctuations. Although these performance characteristics were outside of the scope of this project and thus not quantified, they may be practical topics for future research. The characteristics include:
   a. *Repeatability*. Variation caused by cycling inlet pressure ON and OFF
   a. *Duration of pressurization*. While the average emitter flow rate tended to remain constant, some models exhibited an increase in discharge flow rate variation the longer they stayed under pressure.

4) The testing of numerous medium and high flow models received by ITRC identified faulty emitters. With several models, a single emitter out of the total test group of 30 would exhibit a substantially higher discharge flow rate than the average of the other same-model emitters. These faulty emitters had a measureable effect on the cv values for those models.

The ITRC test results are summarized in **Table 1** on the next page.

Table 1. Emitter performance comparison between manufacturer specifications and ITRC measurements

		MCIP, psi[1]		Average Compensated Flow Rate, GPH			Manuf. cv	
Manufacturer	Description	From ITRC test curve	From manufacturers' curve	Published	Actual[2]	% Difference	at Lower P[3]	at Higher P[4]
Bowsmith	Fan-Jet L. Blue Nozzle #40 PC-8 Orange Diaphragm	15.5	13	8	7.1	-12.7%	0.026	0.034
Bowsmith	Fan-Jet Yellow Nozzle #55 PC-14 Purple Diaphragm	18.3	18	14	13.3	-5.3%	0.023	0.027
Eurodrip	PC[2] Hose, with emitters	6	5	0.5	0.5	0.0%	0.055	0.078
Eurodrip	Corona 0.5 GPH	7.3	7.5	0.5	0.54	7.4%	0.024	0.018
Jain	Microsprayer 2002 AquaSmart Orange Nozzle	25	15	18.5	18.5	0.0%	0.055	0.069
Jain	Microsprayer 2002 AquaSmart Violet Nozzle	22	15	5.28	5.2	-1.5%	0.019	0.019
Jain	Clicktif Emitter Brown Outlet	9.2	10	0.5	0.48	-4.2%	0.020	0.026
Jain	Clicktif Emitter Black Outlet	9	10	1	1.01	1.0%	0.021	0.030
Jain	Flipper (Black Nozzle)	>50	35	6.6	6.58	-0.3%	0.036	0.037
Jain	Dan-Jet 12-JTX Blue Nozzle	30	15	10	10.74	6.9%	0.188*	0.106*
Jain	Eliminator (Orange)	25	22	18.5	19.39	4.6%	0.161*	0.176*
John Deere	Supertif Brown	9	9	0.58	0.61	4.9%	0.026	0.040
John Deere	S2000 Microsprinkler, Black Nozzle	27	29	6.3	5.47	-15.2%	0.038	0.013
John Deere	S2000 Microsprinkler, Blue Nozzle	28	29	8.2	8.4	2.4%	0.024	0.028
Plastro	HydroPC	10	11.8	0.95	0.85	-11.8%	0.047**	0.049**
Netafim	Emitter 01PC2, Red, Big	7	5	0.5	0.53	5.7%	0.022**	0.024**
Netafim	Emitter 01PC4 Black, Big	10	7	1	1.04	3.8%	0.022**	0.031**
Netafim	Emitter 01WPC8, Green, Big	12.7	9	2	2.31	13.4%	0.033	0.032
Netafim	Emitter 01WPCJL2, Red, Small	7	5	0.5	0.53	5.7%	0.027	0.036
Netafim	Emitter 01WPCJL4 , Gray, Small	8	5	1	1	0.0%	0.063*	0.066*
Netafim	Emitter 01WPCJL8, Green, Small	7	9	2	2.04	2.0%	0.057	0.031
Netafim	SuperNet	32	22	5.3	5.81	8.8%	0.048*	0.058*
Netafim	Techline 560 Hose Brown	9	5.9	0.53	0.57	7.0%	0.022	0.026
Netafim	Techline CV Hose Brown	13.2	7.5	0.61	0.57	-7.0%	0.018	0.023
Olson Irrig.	Vibra-Clean Emitter, Blue	10	5	1	1	0.0%	0.021	0.049*
RainBird	AG A5	6	7	0.53	0.53	0.0%	0.020	0.040
TORO	Drip In PC	11	15	0.5	0.56	10.7%	0.079	0.070
TORO	Waterbird VI-PC L. Green	23	22	14.5	13.65	-6.2%	0.035	0.037

[1] Estimation of the lowest emitter inlet pressure at which pressure compensation appeared to begin
[2] Minimum Compensating Inlet Pressure (MCIP): computed as weighted average GPH between the minimum inlet pressure and 15 psi above the minimum pressure
[3] The cv of 30 emitters at approximately 3 psi greater than the minimum pressure
[4] The cv of 30 emitters at 10 psi greater than the lower pressure cv
* One emitter of this model was identified as faulty. It is likely the cv would be substantially different if the emitters had functioned properly
** Three models were tested after flushing for a minimum of 18 hours; the remaining models were flushed for 48 hours.

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INTRODUCTION

Background

The term "emitter" is applied to a variety of devices utilized in microirrigation systems that are the last point in an irrigation system utilized to control water application and wetted area/pattern per plant for each irrigation event. It is therefore critical that emitters perform as expected to maximize water use efficiency, crop yields, and energy savings.

The microirrigation industry has been under development since the 1970's, providing the agricultural sector with a wide range of manufacturers and available products for virtually any orchard tree, vine and row crop application. The variety of irrigation requirements of these vastly different crops has created an equally complex array of emitting devices and designs.

Emitter Types

Pressurized water is supplied to microirrigation emitters through polyethylene hose ranging in diameter from 0.5" to 1.25". During an irrigation event the water pressure along these hoses will vary due to friction and elevation changes. When an irrigation system design is expected to have substantial pressure differences down a length of hose, it is common to install "pressure compensating" (PC) emitters. However, since PC emitters are more expensive than non-PC emitters, non-PC emitters are typically installed whenever pressure variations along a hose are within appropriate ranges.

Pressure Compensating Emitters

Pressure compensating emitters are marketed as having the ability to regulate flow rates despite variations in inlet pressures. The pressure-compensating component of the emitter involves an elastic diaphragm that enlarges or contracts an orifice open area in relation to inlet pressures to provide a more consistent flow rate. PC emitters are typically used more frequently in orchards than with other crops because they are generally installed with long lengths of above-ground hose that can be used in terrain with variations in elevation.

Because the act of pressure compensation requires water pressure to manipulate the elastic diaphragm, there exists a minimum compensating inlet pressure (MCIP) for every emitter. Many manufacturers publish discharge graphs that show the relationship between inlet pressure and emitted flow rates, where inlet pressures within a specified range above the MCIP produce a nominal flow rate.

Non-Pressure Compensating Emitters

Non-PC emitters are manufactured without moving parts such as an elastic diaphragm. They typically feature a formed slotted filter, tortuous path, and static orifice. These devices are widely used in applications with flat ground and shorter hose lengths.

Emitter Categories

Manufacturers have developed emitter configurations intended for use with crop types that require specific irrigation characteristics such as fruit, nut and citrus orchards, row crops, and vineyards. The most common emitter configuration categories (which all include both PC and non-PC emitters) are drippers, sprayers, and sprinklers.

Drippers are devices that tend to "drip" rather than continuously flow. These are intended for low to medium flow rates and are installed as follows:

- *Inline:* Emitters are welded or inserted inside of thick wall or thin wall polyethylene hose
- *Online:* Holes are punched into thick wall polyethylene tubing and emitters are pressed or inserted into the small (1/8") opening

Sprayers are devices that spray in a fixed pattern and **Sprinklers** are devices that spray in a revolving pattern. These are intended for medium to high flow rates and are installed as follows:

- *Online (direct):* Holes are punched into thick wall polyethylene tubing and emitters are pressed or inserted into the small (1/8") opening
- *Online (remote):* Holes are punched into thick wall polyethylene tubing and a length of small diameter "spaghetti tube" is installed between the hose and emitter

Importance of Accurate Emitter Specifications

Irrigation system designers have historically relied on manufacturer product specifications for critical design assumptions. Emitter characteristics play an important role in system design in the following ways:

- Average emitter flow rate
  - The expected flow rate of each irrigation set or "block" directly affects the design of other major system components including the pump, filters, pipe sizes, control valves, etc.
  - Differences between the actual and expected average emitter flow rate can have substantial effects on irrigation scheduling and in-field irrigation uniformity, subsequently affecting crop yields and revenue.
- Manufacturing coefficient of variation (cv)
  - The variation of individual emitter flow rates due to manufacturing tolerances is a critical characteristic used during the selection of the emitter product.
  - Differences between the actual and expected "cv" of newly installed systems will affect the irrigation uniformity.
- Minimum compensating inlet pressure (MCIP)
  - The MCIP is important when the design attempts to minimize system energy consumption by lowering pump discharge pressures.
  - Differences between the actual and expected minimum inlet pressure will directly affect irrigation uniformity if the MCIP is not supplied at lower pressure areas in the field (i.e., the ends of hoses, furthest laterals, highest elevations).

The installation and operation of highly efficient low pressure systems require an excellent design based on accurate performance information for irrigation emitters. The lack of independent testing, excellent products and accurate information has contributed to the continuation of designing and installing "standard pressure" systems. More specifically, developing true low pressure designs currently presents a high risk of failure or lower yields due in part to the current uncertainty of emitter specifications.

An "ideal" emitter for use in a low pressure irrigation system should provide sufficient performance in the following areas:

- Minimal variance from the nominal flow rate throughout the specified operating pressure range
- Minimal variance in flow rate due to manufacturing variations
- Minimal pressure required to emit the nominal flow rate

Purpose

It is well-known that current microirrigation system designs have substantial pressure differences (~30 psi) between pump discharges and microirrigation hose inlets. With rising energy costs and other market forces, minimizing energy costs by decreasing pump discharge pressures is a practical means of decreasing growing costs while conserving energy.

Current design practices are typically driven by upstream pressure requirements such as filtration and fertigation hardware. Fortunately, newer products provide designers with the opportunity to lower these pressure requirements, enabling lower upstream operating pressures, and thus lowering control valve and hose inlet pressures. Equally important to the goal of minimizing energy inputs is maintaining a high distribution uniformity.

Because this design methodology is still new in concept, most manufacturers of microirrigation emitters have not historically focused on low pressure product development. Testing of these products is necessary to gauge the feasibility of current emitter products for low pressure systems.

Testing

The testing of pressure compensating emitters is typically performed only after the samples are flushed with clean water to wash the elastic diaphragm of a talc powder used during the manufacturing process. All of the models tested were first flushed under pressure for a minimum of 18 hours. Discussions with manufacturers led to an increase in the flushing duration to a minimum of 48 hours. The majority of models were retested after being flushed for an additional 48 hour period. Table 2 lists the flushing times for each emitter model. The flushing time had no significant influence on the test results. Where applicable, the results from testing after flushing for 48 hours are provided. Few emitters were tested after flushing for only 18 hours.

Table 2. Flushing times for emitter types

Model	Flushing Period	
	18-hr	48-hr
Bowsmith Fan-Jet L. Blue Nozzle #40 PC-8 Orange Diaphragm	X	X
Bowsmith Fan-Jet Yellow Nozzle #55 PC-14 Purple Diaphragm	X	X
Eurodrip PC^2 Hose, with Emitters	X	
Eurodrip Corona 0.5 GPH		X
Jain Microsprayer AquaSmart 2002 Orange Nozzle		X
Jain Microsprayer AquaSmart 2002 Violet Nozzle		X
Jain Clicktif Emitter Brown Outlet	X	X
Jain Clicktif Emitter Black Outlet	X	X
Jain Flipper Black Nozzle		X
Jain Dan-Jet 12-JTX Blue Nozzle		X
Jain Eliminator (Orange)		X
John Deere Supertif Brown	X	X
John Deere S2000 Microsprinkler, Black Nozzle		X
John Deere S2000 Microsprinkler, Blue Nozzle	X	X
Netafim Emitter 01PC2, red, big	X	
Netafim Emitter, 01PC4 black, big	X	
Netafim Emitter 01WPC8, green, big	X	
Netafim Emitter 01WPCJL2, red, small	X	X
Netafim Emitter 01WPCJL4, gray, small	X	X
Netafim Emitter 01WPCJL8, green, small	X	X
Netafim SuperNet	X	X
Netafim Techline 560 Hose Brown		X
Netafim Techline CV Hose Brown		X
Olson Irrigation Vibra-Clean Emitter, Blue		X
Plastro HydroPC	X	X
RainBird AG A5	X	
Toro Drip In PC		X
Toro Waterbird VI-PC L. Green		X

ITRC conducted two tests to measure the performance and manufacturing characteristics of pressure-compensating emitting devices based upon the points above. The two tests are described below.

Test 1 – Flow vs. pressure

Manufacturers will typically publish the performance characteristics of available emitting devices that are necessary for irrigation system design. As mentioned earlier in this report, PC emitters are marketed to deliver stable discharge flow rates within a specified operating range. This performance characteristic is expressed through flow versus pressure graphs.

To verify the manufacturers' published performance characteristics, ITRC conducted laboratory flow testing. Groups of 30 emitting device samples were installed on a test bench and pressurized. The emitter discharges from all 30 emitters were combined, and the collected volume was divided by 30 to obtain the average emitter flow rate at a variety of emitter inlet pressures.

A sample flow-vs.-pressure graph from the manufacturer EurodripUSA for the Corona emitter is shown in **Figure 1**, which shows a constant, straight line of flow rate after the pressure compensation begins. Although this sample graph can be described as an exception, many manufacturers publish perfectly straight flow-vs.-pressure curves for all emitter models, which may or may not describe in-field performance. A flow-vs.-pressure graph from another Netafim emitter model, as measured by ITRC Test 1, is shown in **Figure 2**.

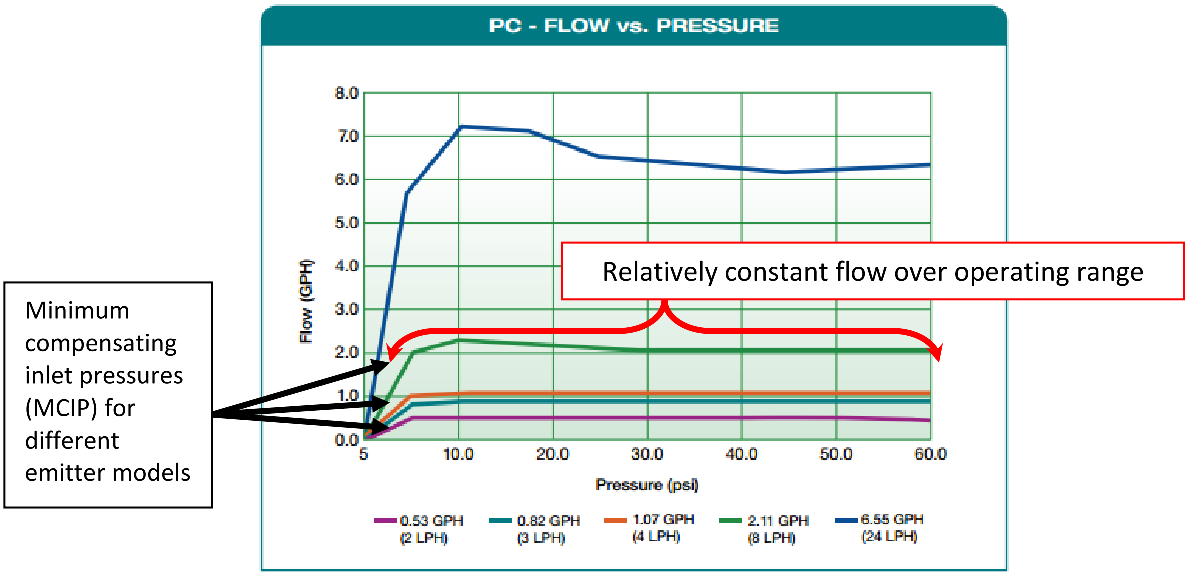

Figure 1. Sample manufacturer graph of emitter discharges over a range of inlet pressures *(from Eurodrip USA)*

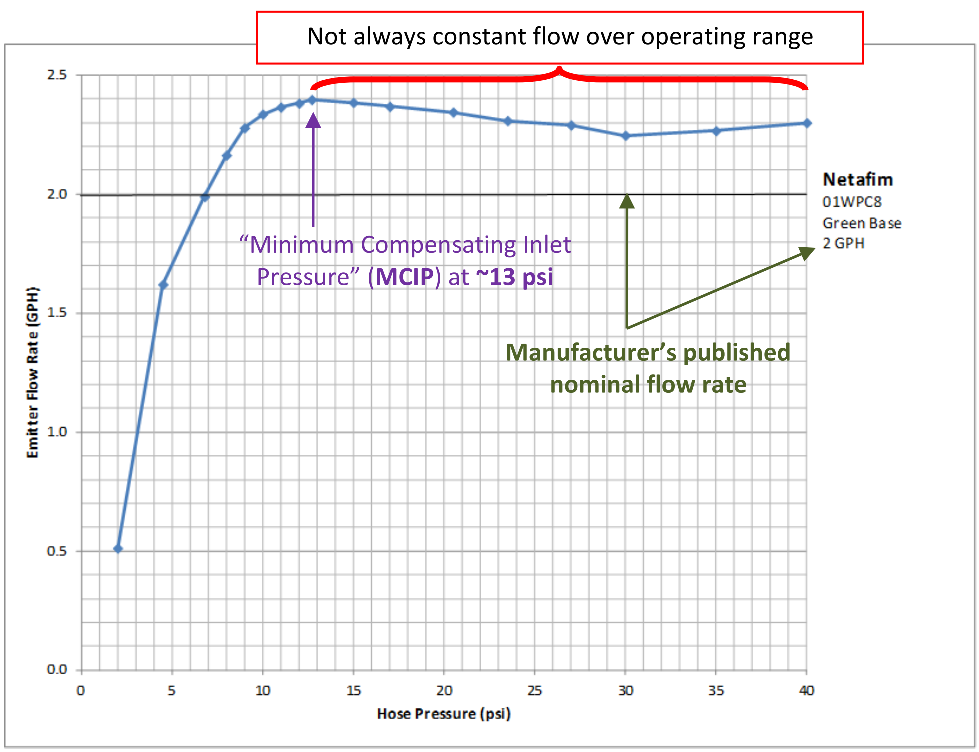

Figure 2. Sample ITRC pressure vs. flow rate graph

The graphs show three important performance characteristics quantified in Test 1:

a) The Minimum Compensating Inlet Pressure (MCIP) of the emitter, which is the pressure at which the emitter begins to compensate for emitter inlet pressure in order to maintain a constant flow rate. On the graph, this should be the point at which the blue line flattens out.
b) The ability of the emitting device to meet its nominal flow rate. On the graph, this is determined by the blue line's distance above or below the straight black line of the nominal flow rate.
c) The ability of the emitting device to maintain a consistent flow rate throughout a low pressure operating range. On the graph, this is represented by the amount that the blue line fluctuates at pressures above the MCIP.

Test 2 – Coefficient of variation due to manufacturing (cv)

Many manufacturers also publish cv values for emitting devices that reflect the discharge flow variability due to manufacturing tolerances. This value is computed by a simple statistical analysis of individual emitter discharges (by volume or weight) using the following formula:

$$cv = \frac{standard\ deviation}{mean}$$

Where,

Standard deviation = the standard deviation of individual emitter discharges
Mean = the arithmetic mean of individual emitter discharges

ITRC tested each emitting device using the same test stand from **Test 1**, but collected the volumes from each individual emitter to calculate the cv. During testing, several of the medium and high flow models tested had one emitter out of the total group of 30 tested emitters that would emit significantly higher flows than the other 29 of the same model. These "faulty" emitters had a measureable effect on the cv values for those models. In summary **Table 1**, models that had a faulty emitter in the test group are denoted by an asterisk (*).

Cv results are summarized in the *Executive Summary* while the individual emitter measurements are provided in ***Attachment C***.

Testing Protocol and Measurement Uncertainty

Details regarding the test protocols are provided in ***Attachment A***. Similarly, the measurement and calibration techniques as well as measurement hardware utilized during the valve testing is provided in ***Attachment B***.

TEST RESULTS

The emitting devices tested by ITRC were provided by manufacturers and distributors. Product representatives were given a specific description of the constraints of the testing and the expected abilities of the emitting device to perform well at a range of relatively low inlet pressures.

The testing results are grouped into three categories in order to better compare equivalent products with similar chart scaling. The following describes the three categories:

Group 1: Low Flow Emitters (0 – 2 GPH) – included online and inline drippers

Group 2: Medium Flow Emitters (2 – 5 GPH) – included sprayers and sprinklers

Group 3: High Flow Emitters (5 GPH – 20 GPH) – included sprayers and sprinklers

The following sections show the test results.

Performance of Low Flow Emitters

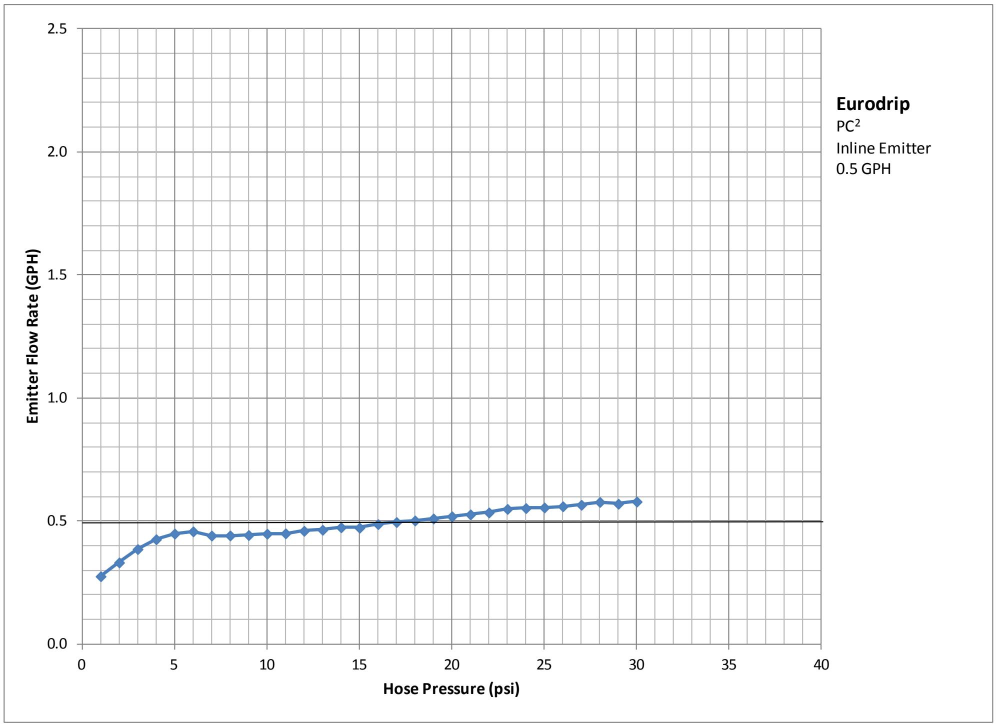

Figure 3. Eurodrip PC^2 0.5 GPH. Flow regulation at various inlet pressures

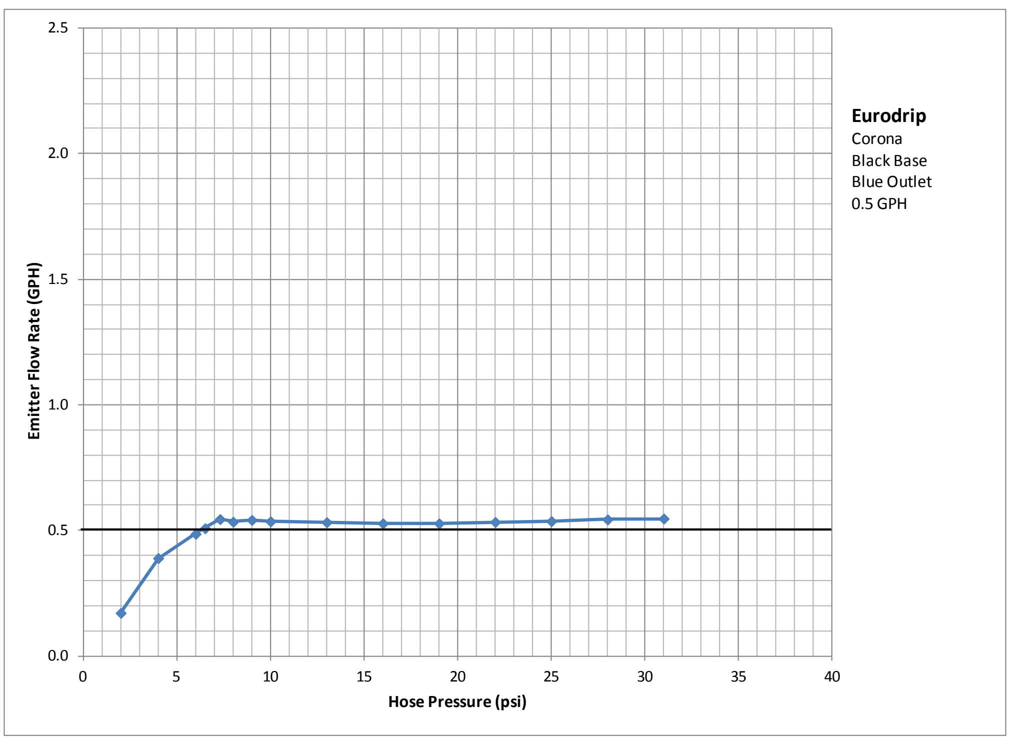

Figure 4. Eurodrip Corona 0.5 GPH. Flow regulation at various inlet pressures

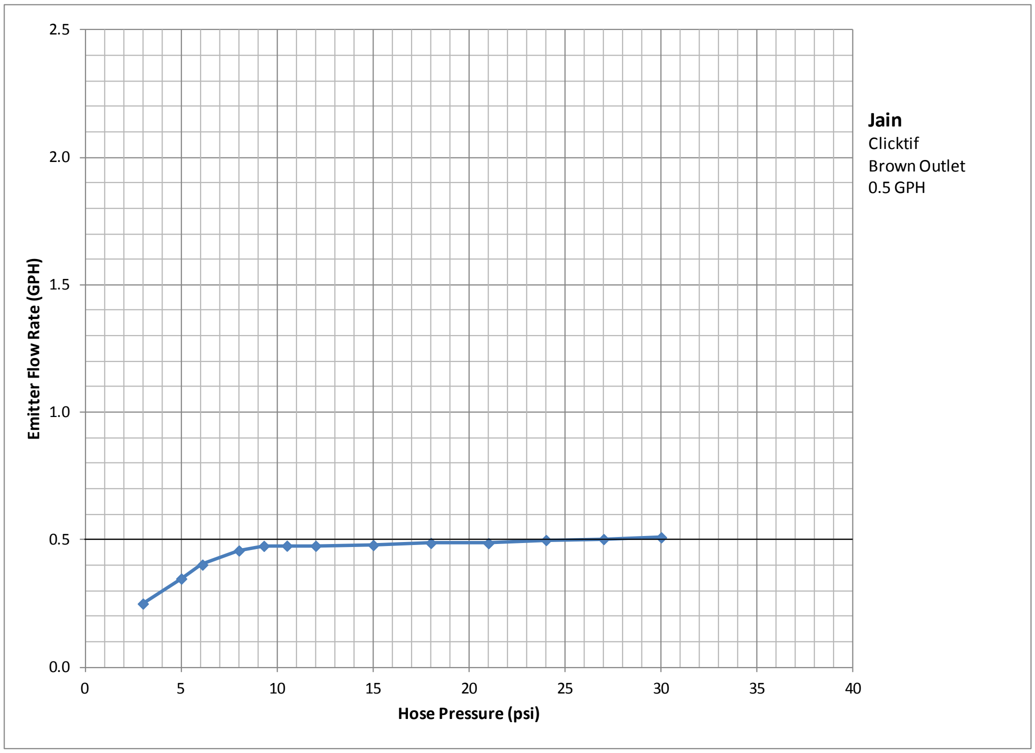

Figure 5. Jain Clicktif 0.5 GPH. Flow regulation at various inlet pressures

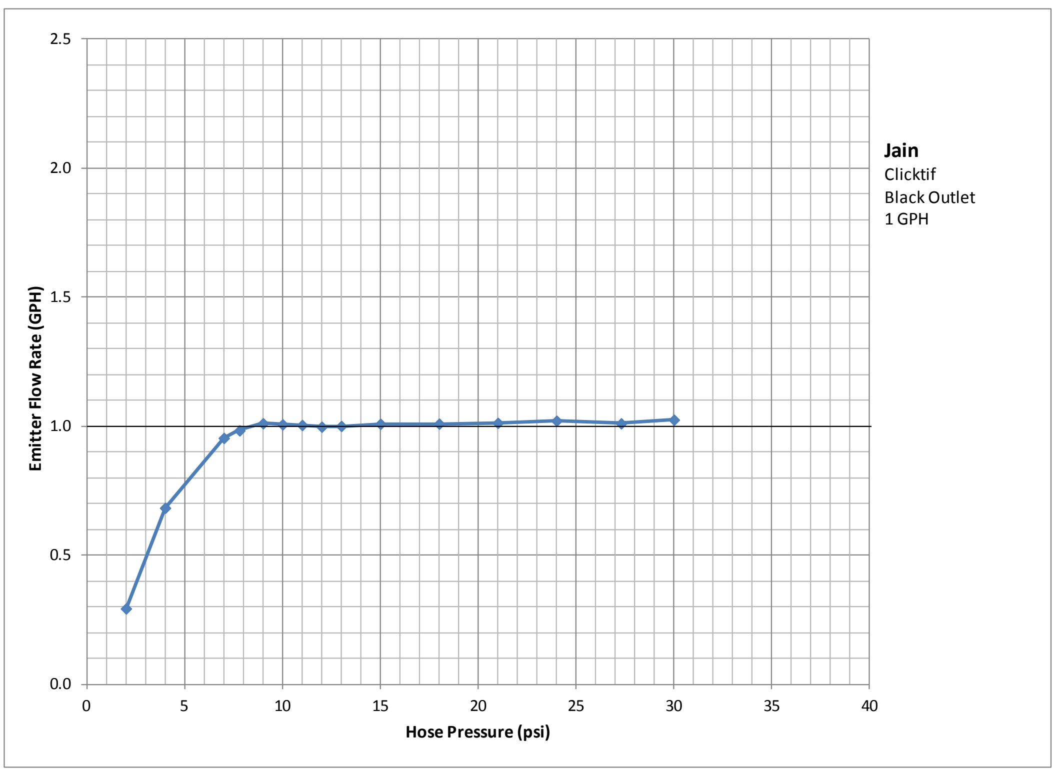

Figure 6. Jain Clicktif 1.0 GPH. Flow regulation at various inlet pressures

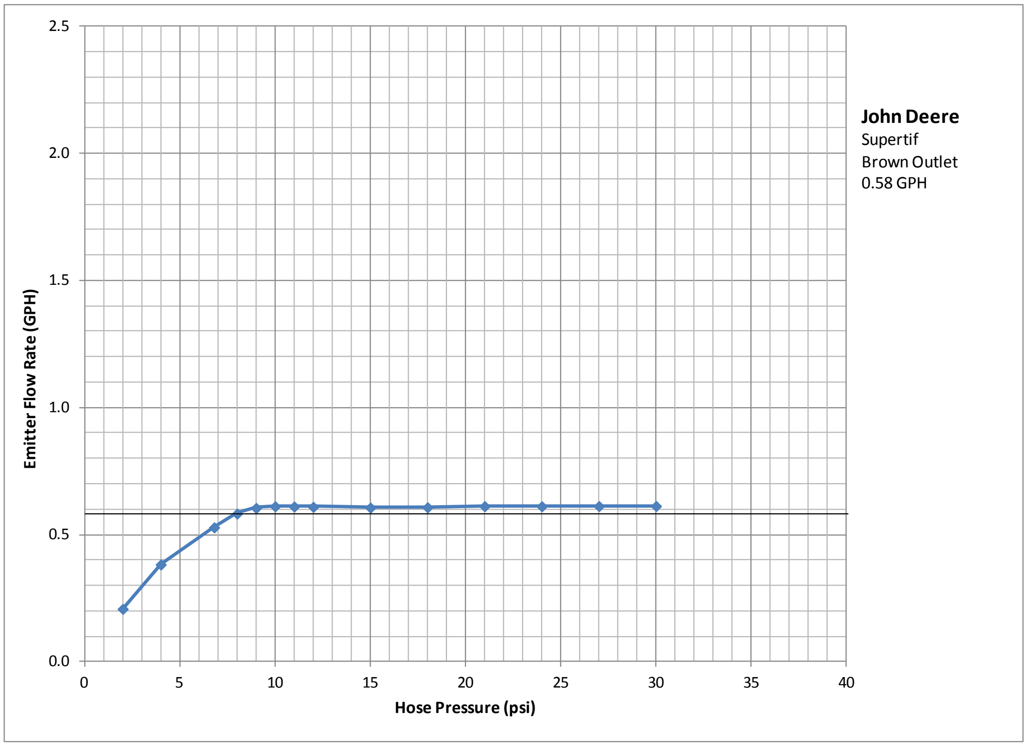

Figure 7. John Deere Supertif 0.58 GPH. Flow regulation at various inlet pressures

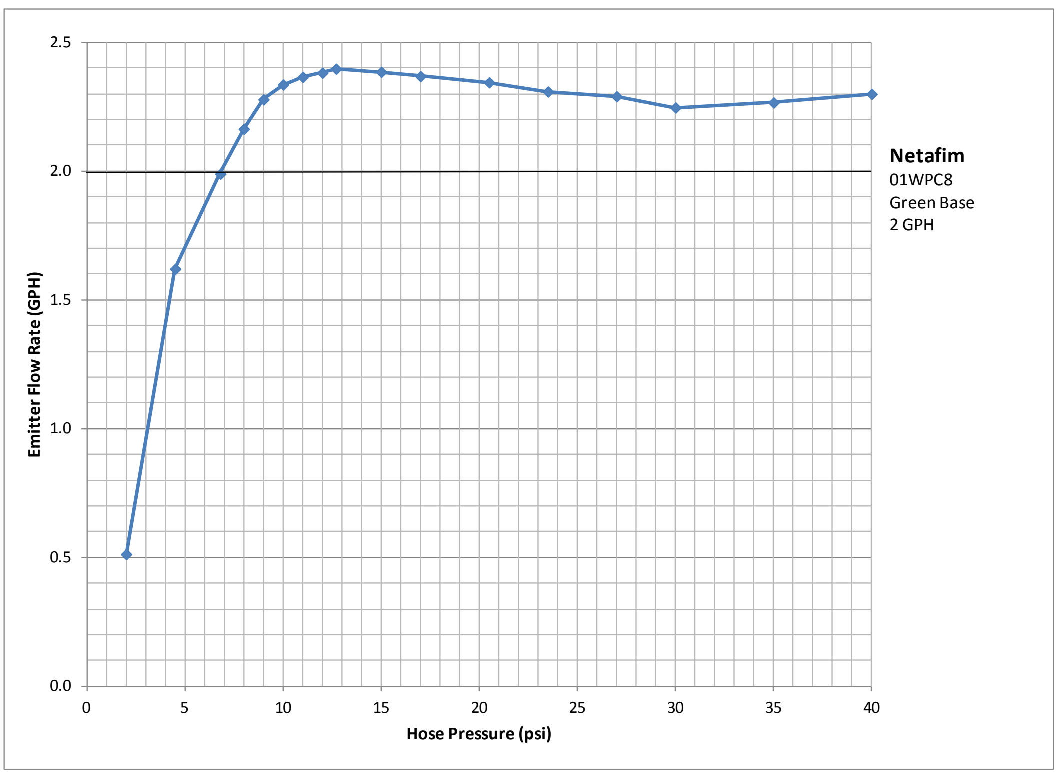

Figure 8. Netafim 01WPC8 2 GPH. Flow regulation at various inlet pressures

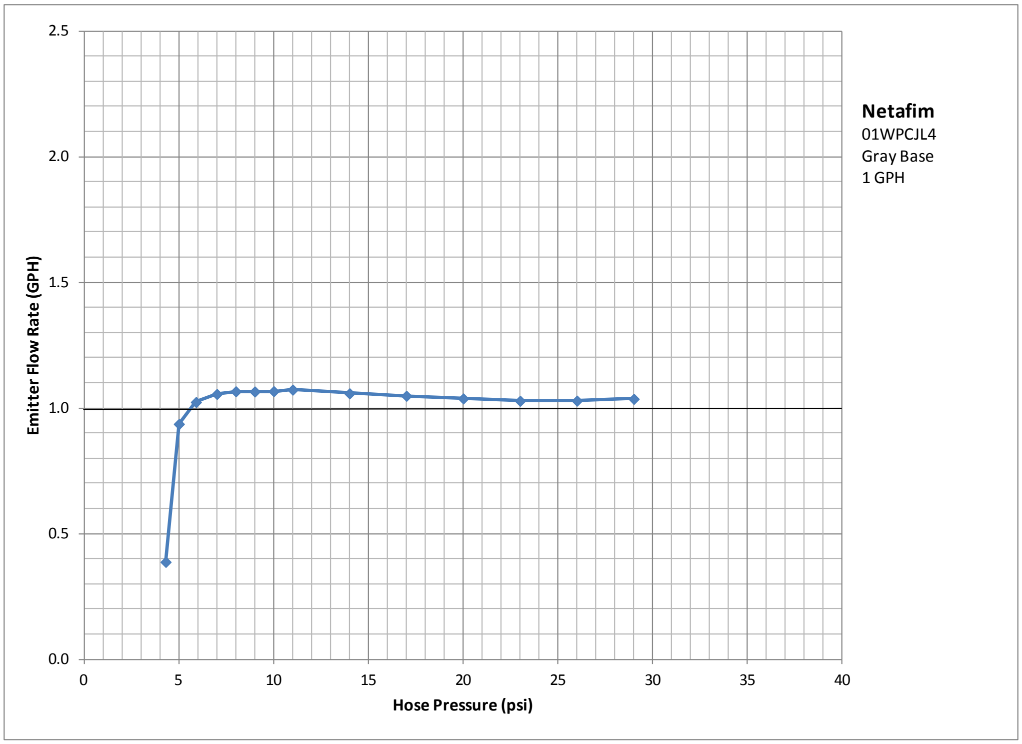

Figure 9. Netafim 01WPCJL4 1 GPH. Flow regulation at various inlet pressures

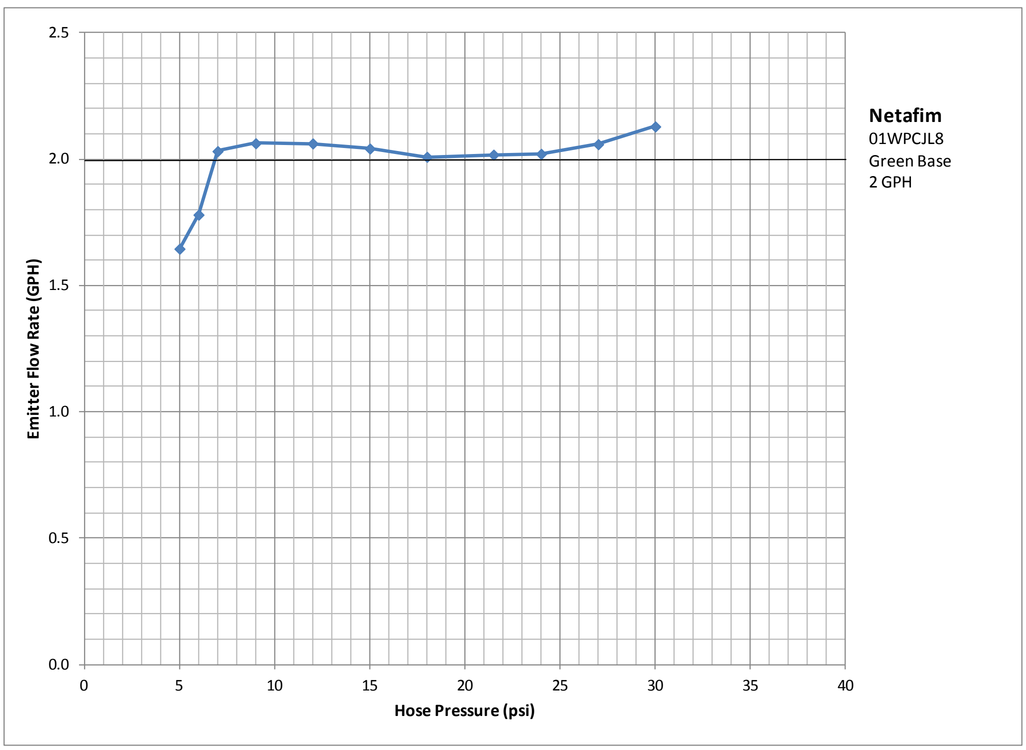

Figure 10. Netafim 01WPCJL8 2 GPH. Flow regulation at various inlet pressures

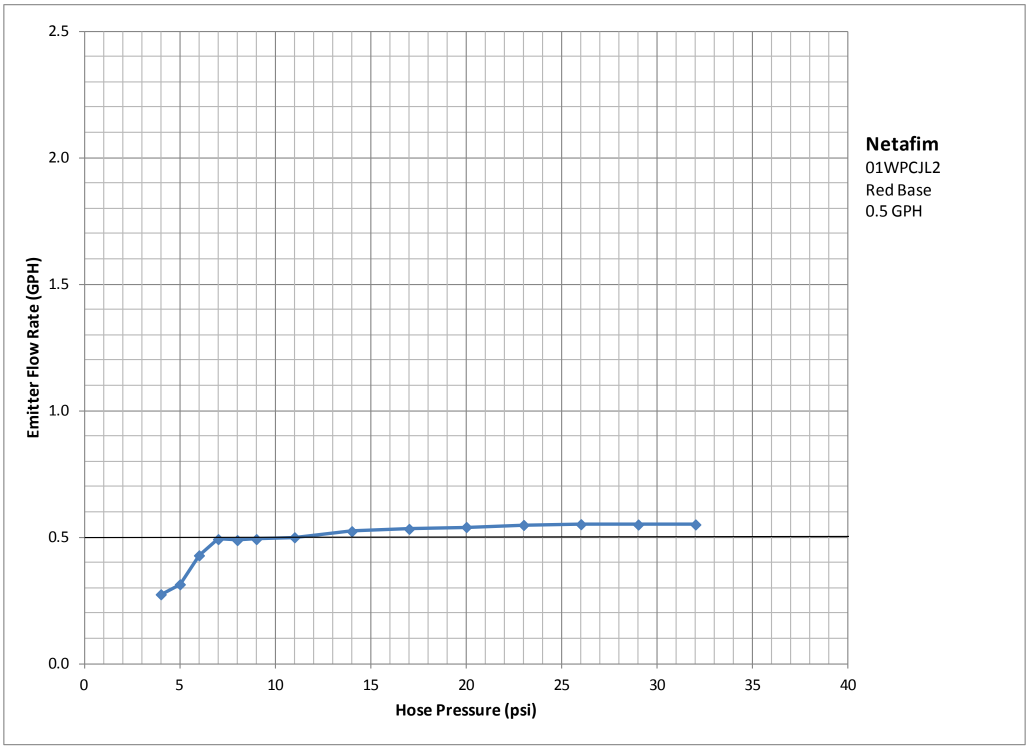

Figure 11. Netafim 01WPCJL2 0.5 GPH. Flow regulation at various inlet pressures

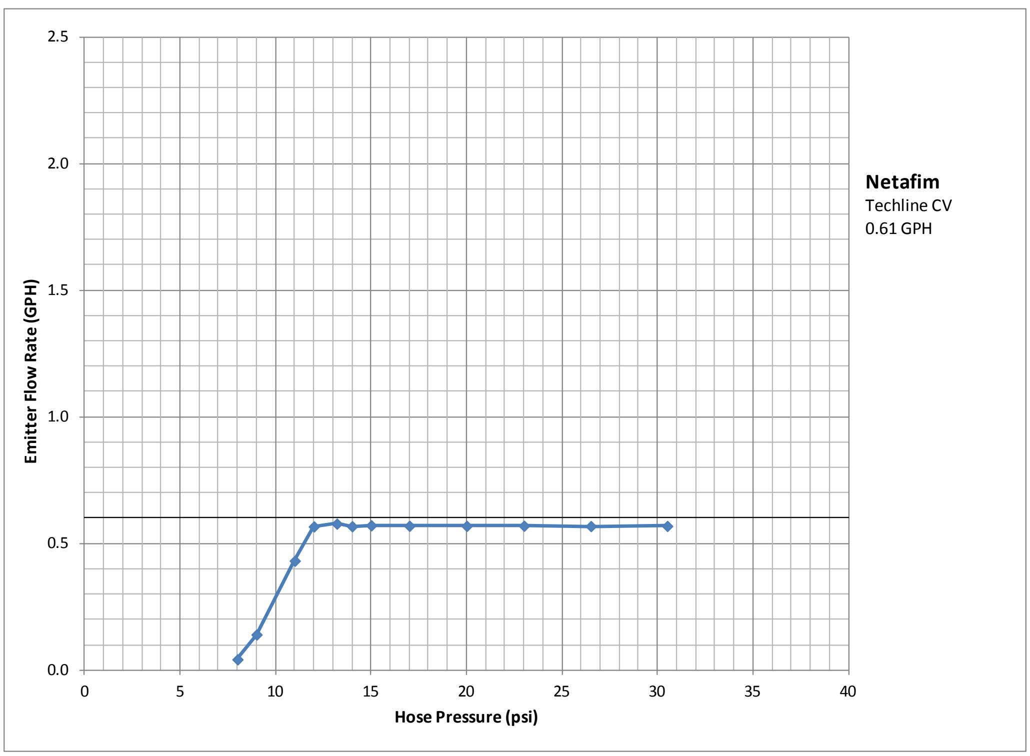

Figure 12. Netafim Techline CV 0.5 GPH. Flow regulation at various inlet pressures

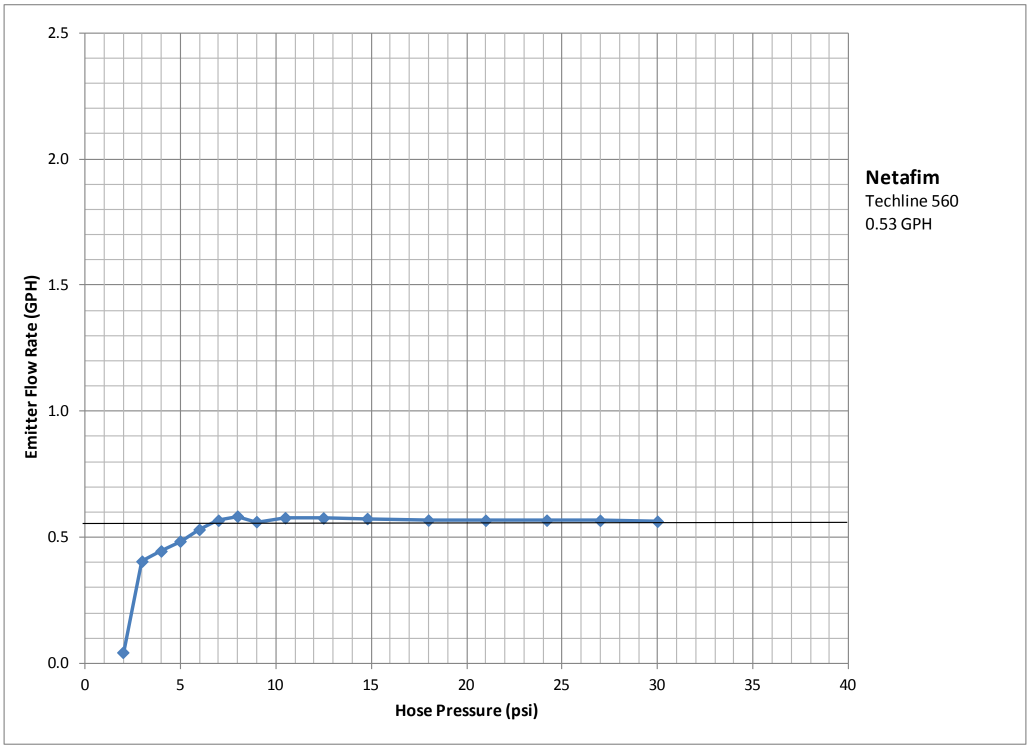

Figure 13. Netafim Techline 560 0.5 GPH. Flow regulation at various inlet pressures

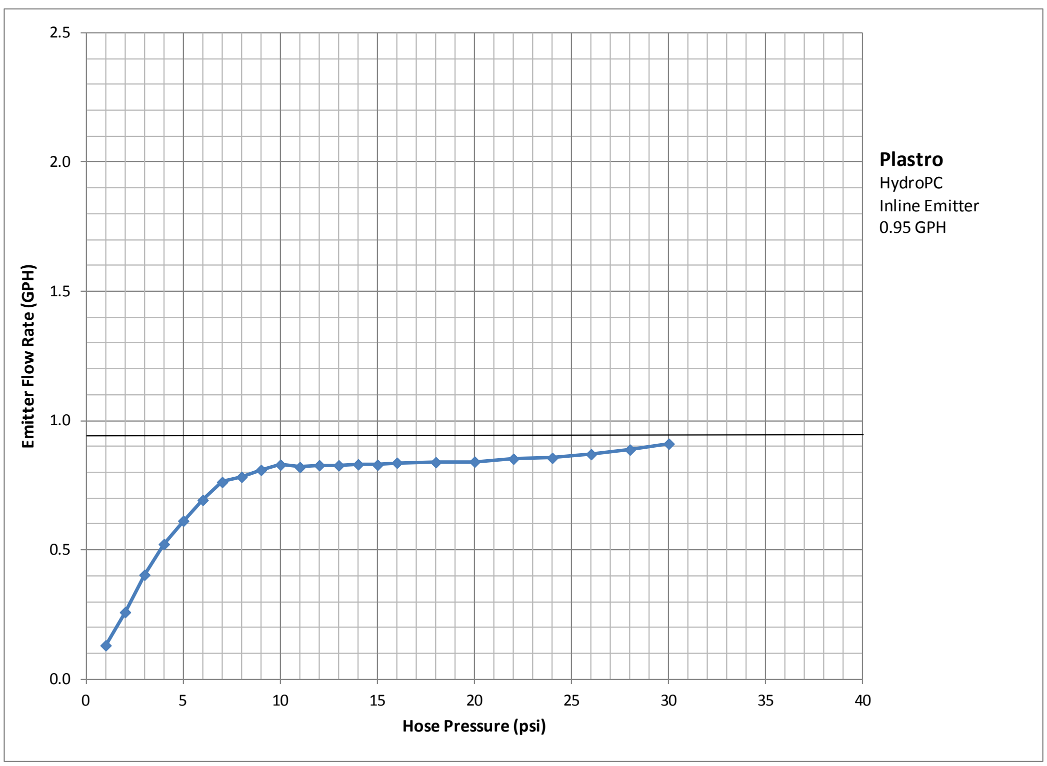

Figure 14. Plastro HydroPC 0.95 GPH. Flow regulation at various inlet pressures

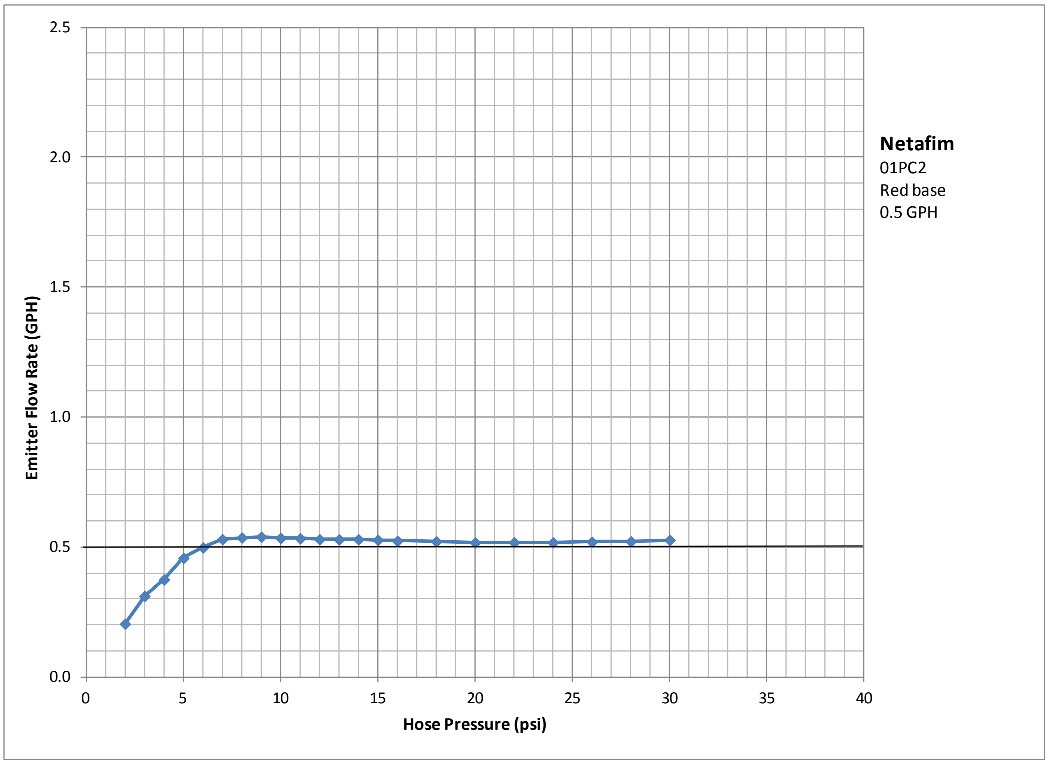

Figure 15. Netafim 01PC2 0.5 GPH. Flow regulation at various inlet pressures

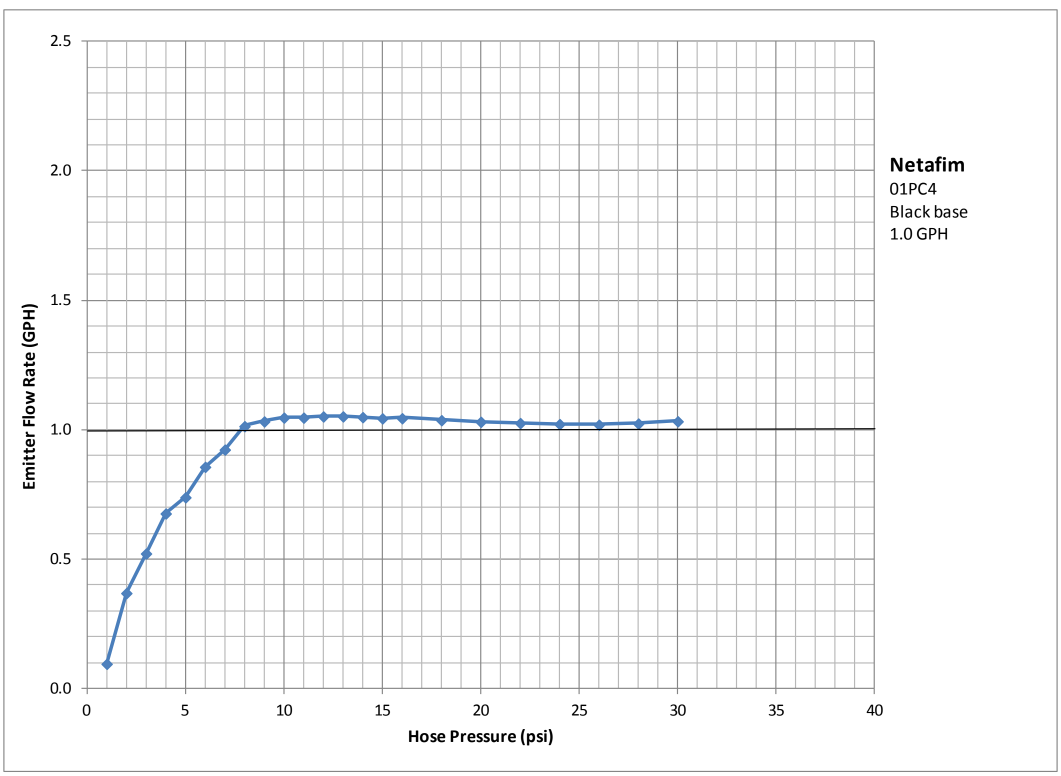

Figure 16. Netafim 01PC4 1.0 GPH. Flow regulation at various inlet pressures

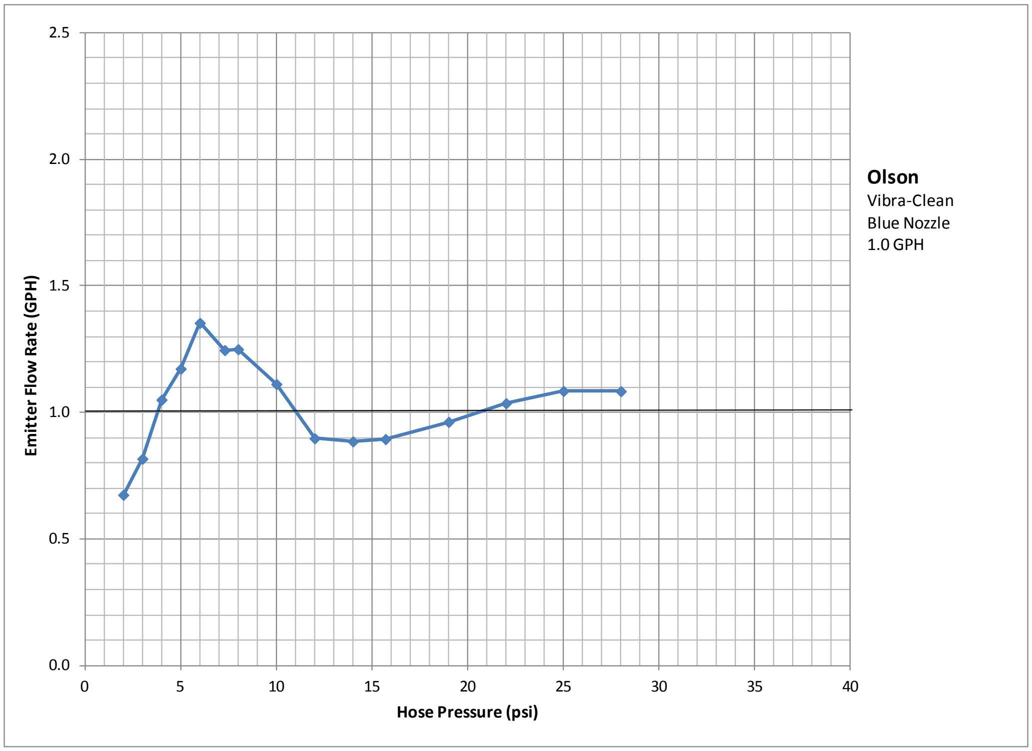

Figure 17. Olson Vibra-Clean 1.0 GPH. Flow regulation at various inlet pressures

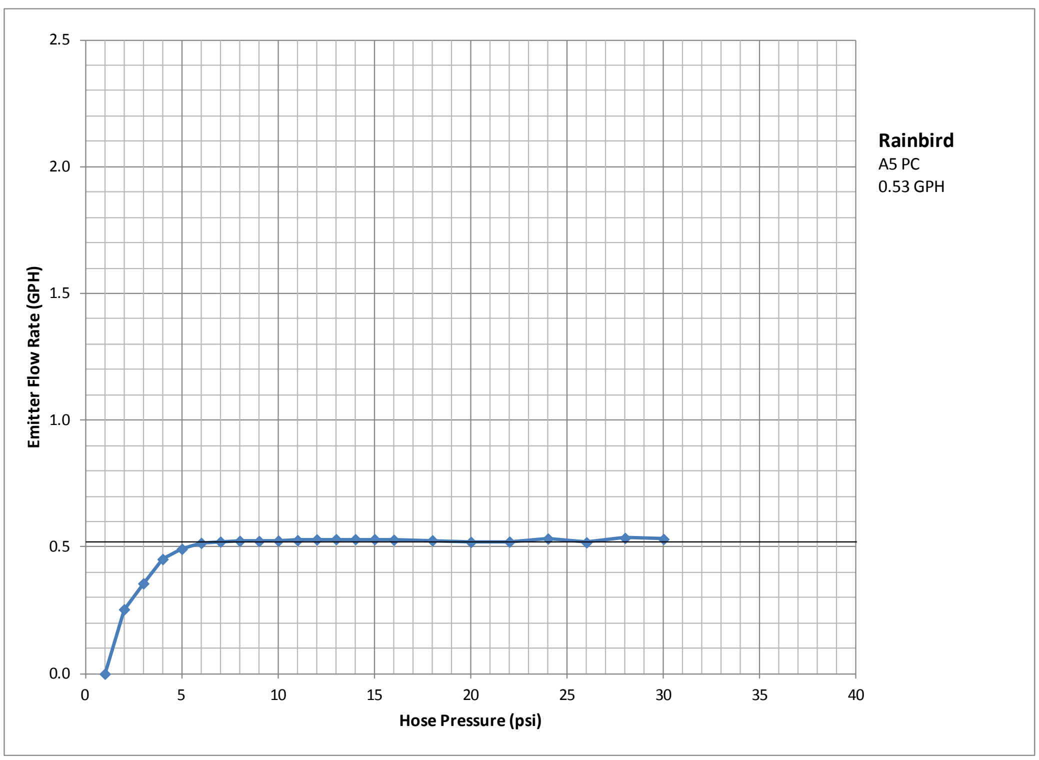

Figure 18. RainBird A5 PC 0.53 GPH. Flow regulation at various inlet pressures

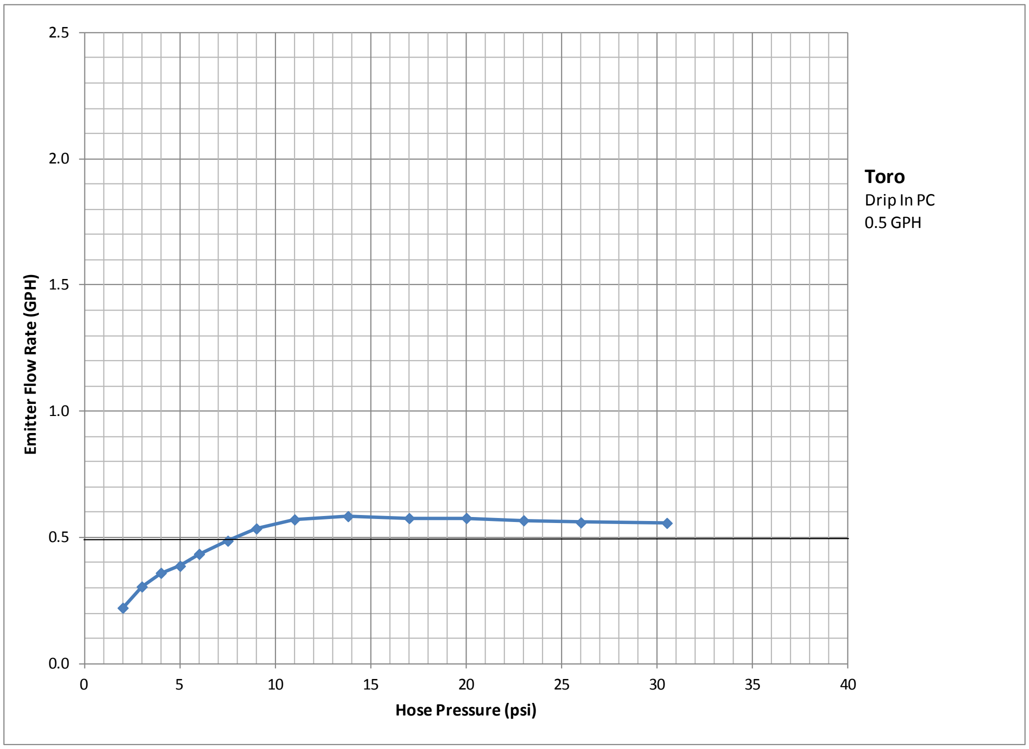

Figure 19. Toro Drip In PC 0.5 GPH. Flow regulation at various inlet pressures

Performance of Medium Flow Emitters

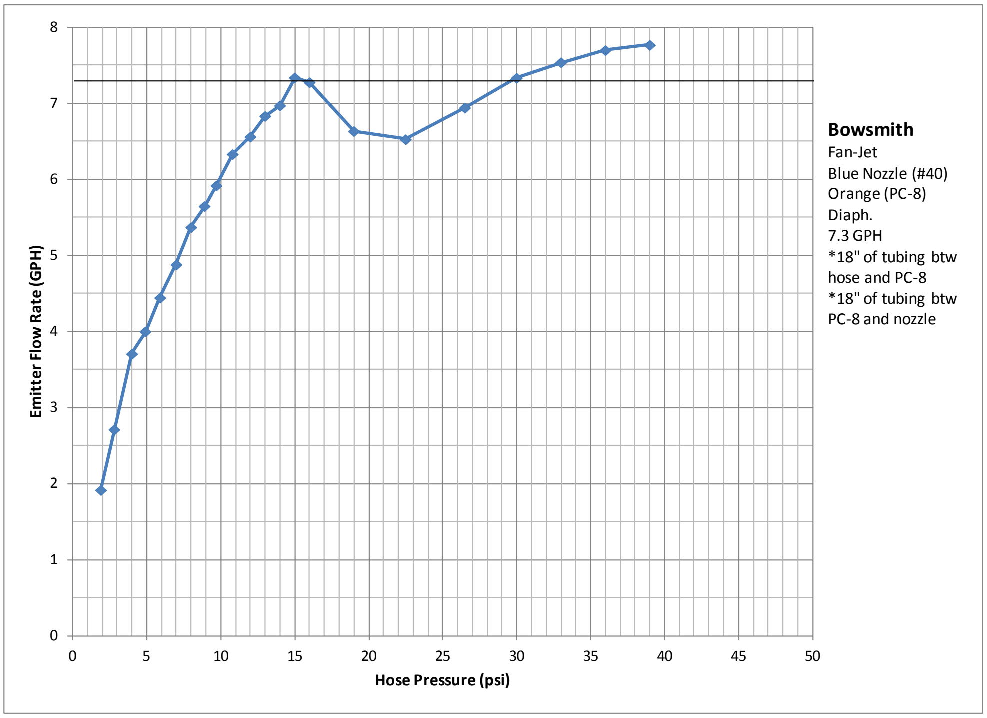

Figure 20. Bowsmith blue nozzle orange PC-8 diaphragm 7.3 GPH. Flow regulation at various inlet pressures

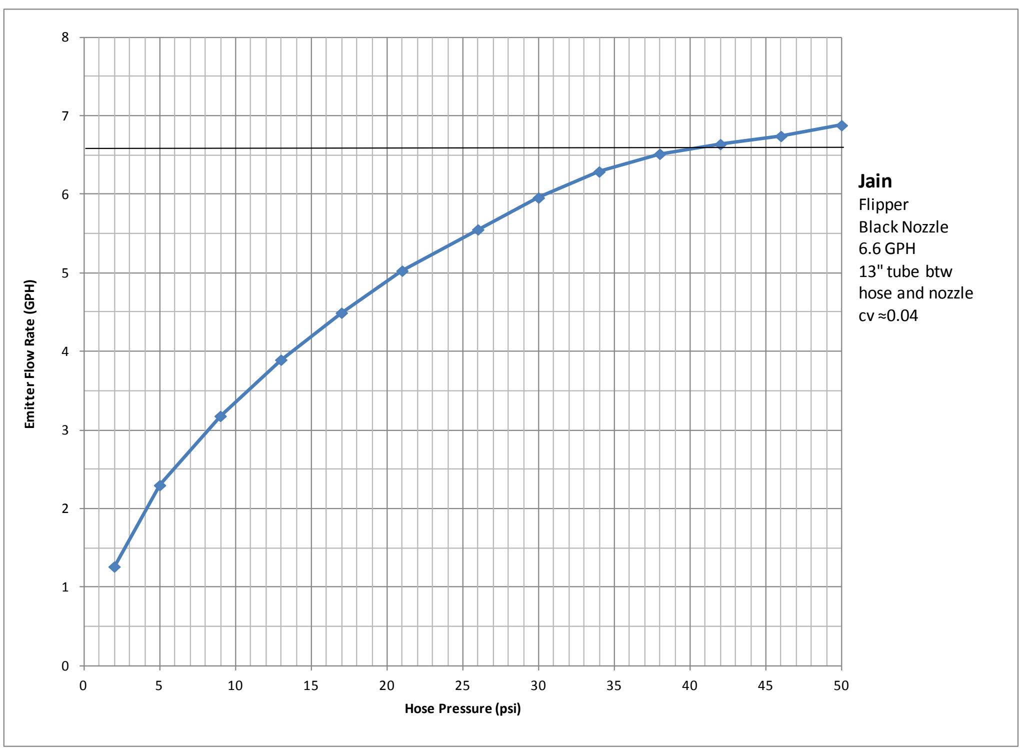

Figure 21. Jain Flipper black nozzle 6.6 GPH. Flow regulation at various inlet pressures

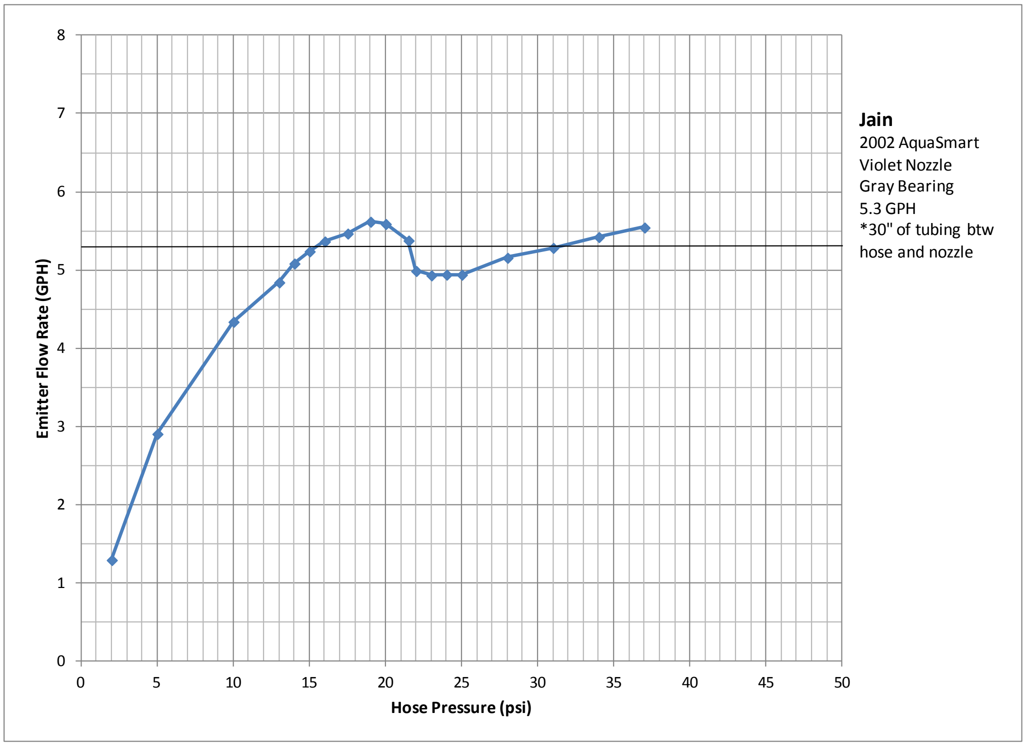

Figure 22. Jain 2002 AquaSmart violet nozzle gray bearing 5.3 GPH. Flow regulation at various inlet pressures

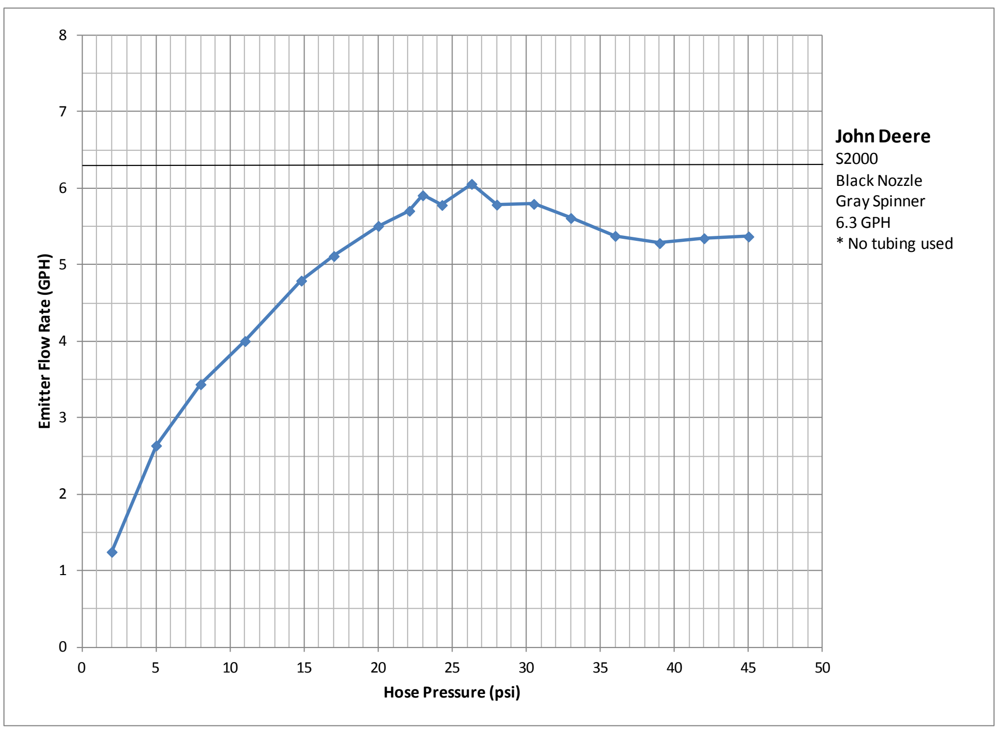

Figure 23. John Deere S2000 black nozzle gray spinner 6.3 GPH. Flow regulation at various inlet pressures

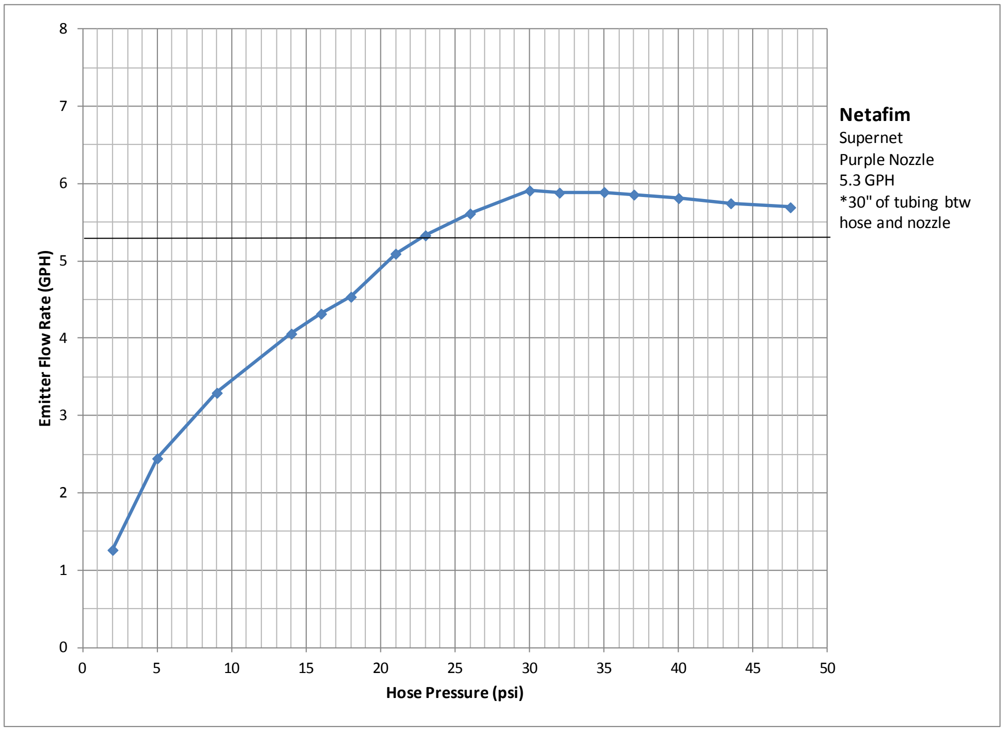

Figure 24. Netafim Supernet purple nozzle 5.3 GPH. Flow regulation at various inlet pressures

Performance of High Flow Emitters

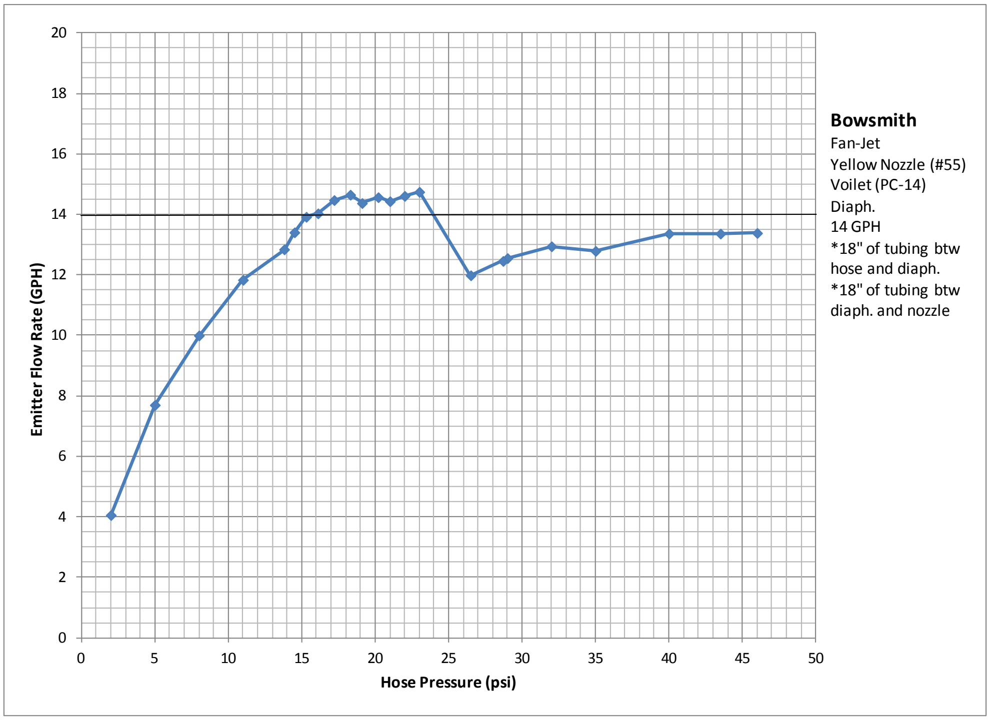

Figure 25. Bowsmith yellow nozzle violet PC-14 diaphragm 14 GPH. Flow regulation at various inlet pressures

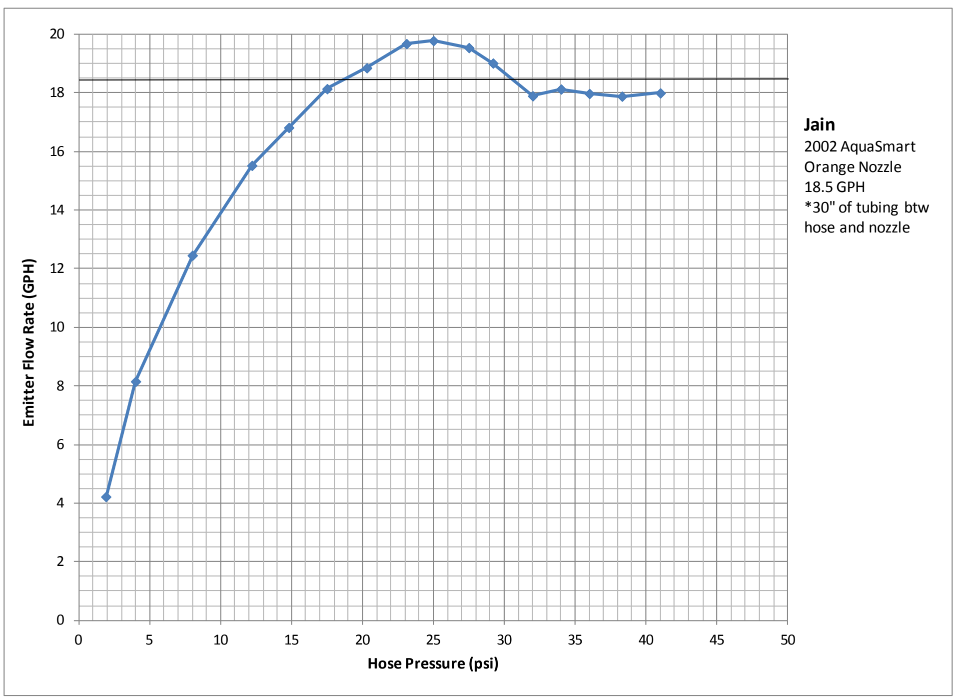

Figure 26. Jain 2002 AquaSmart orange nozzle 18.5 GPH. Flow regulation at various inlet pressures

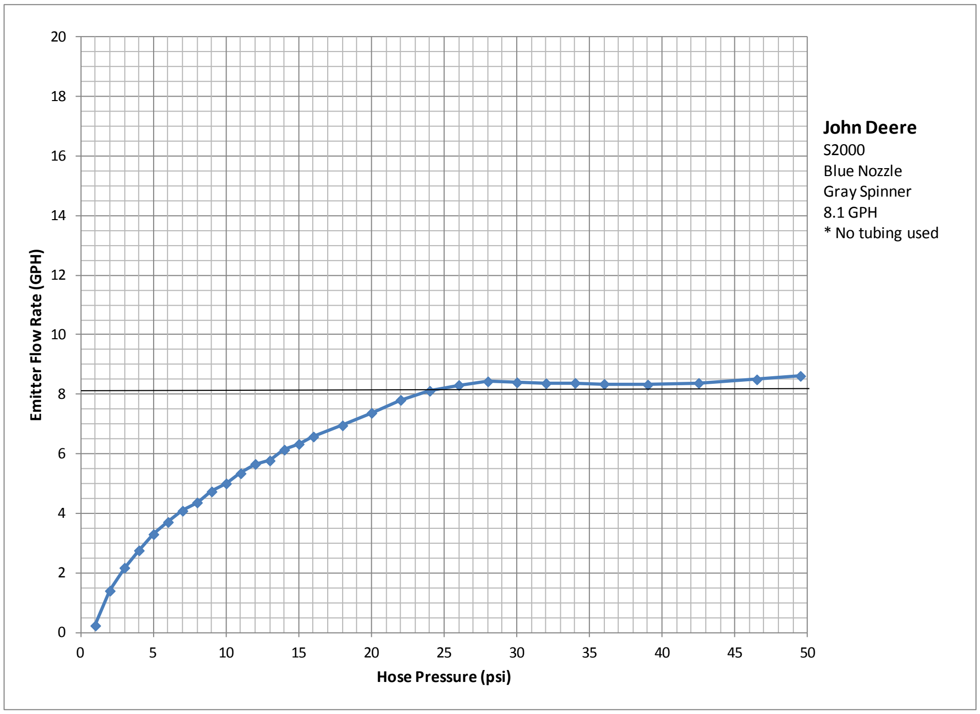

Figure 27. John Deere S2000 blue nozzle gray spinner 8.1 GPH. Flow regulation at various inlet pressures

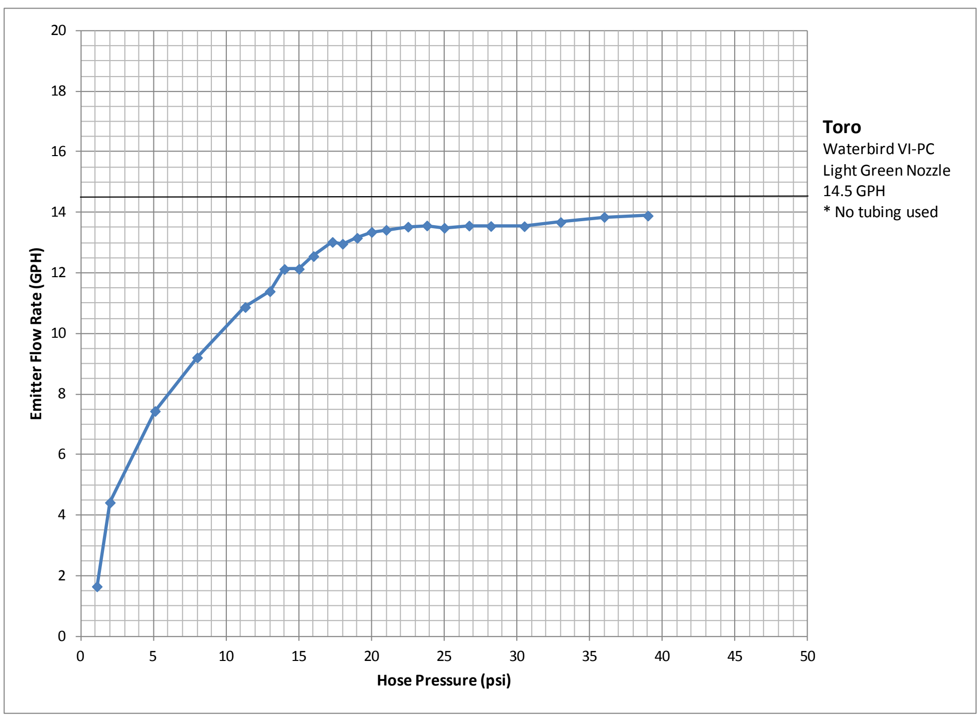

Figure 28. Toro Waterbird VI-PC light green nozzle 14.5 GPH. Flow regulation at various inlet pressures

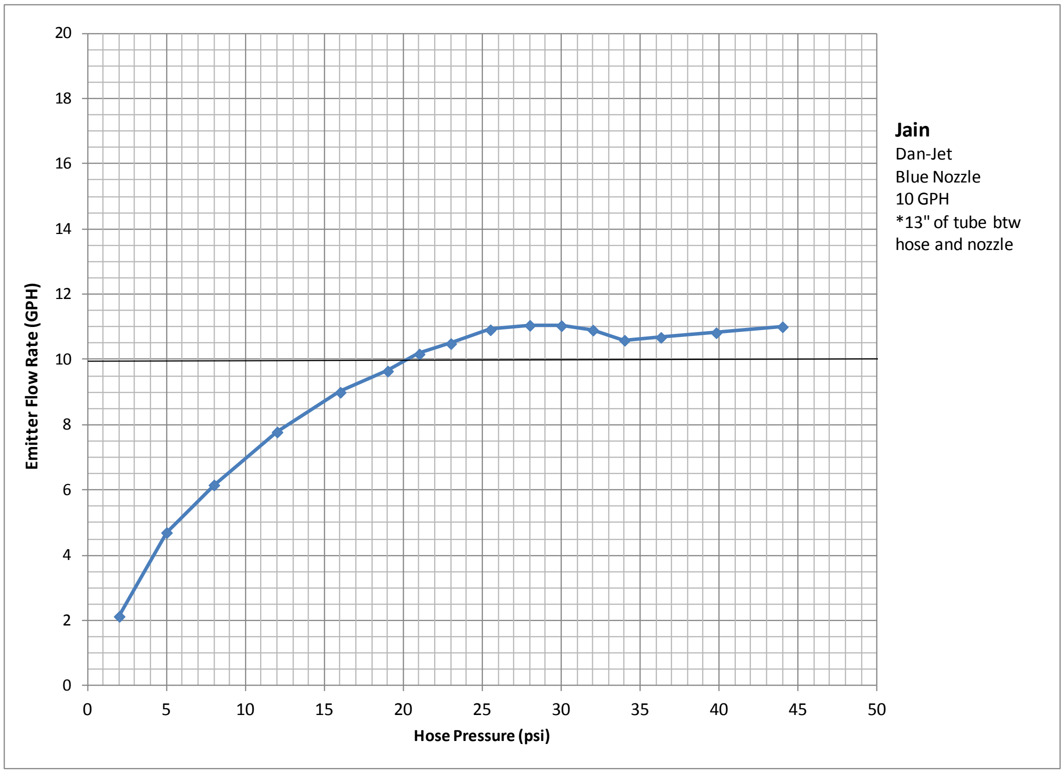

Figure 29. Jain Dan-Jet blue nozzle 10 GPH. Flow regulation at various inlet pressures

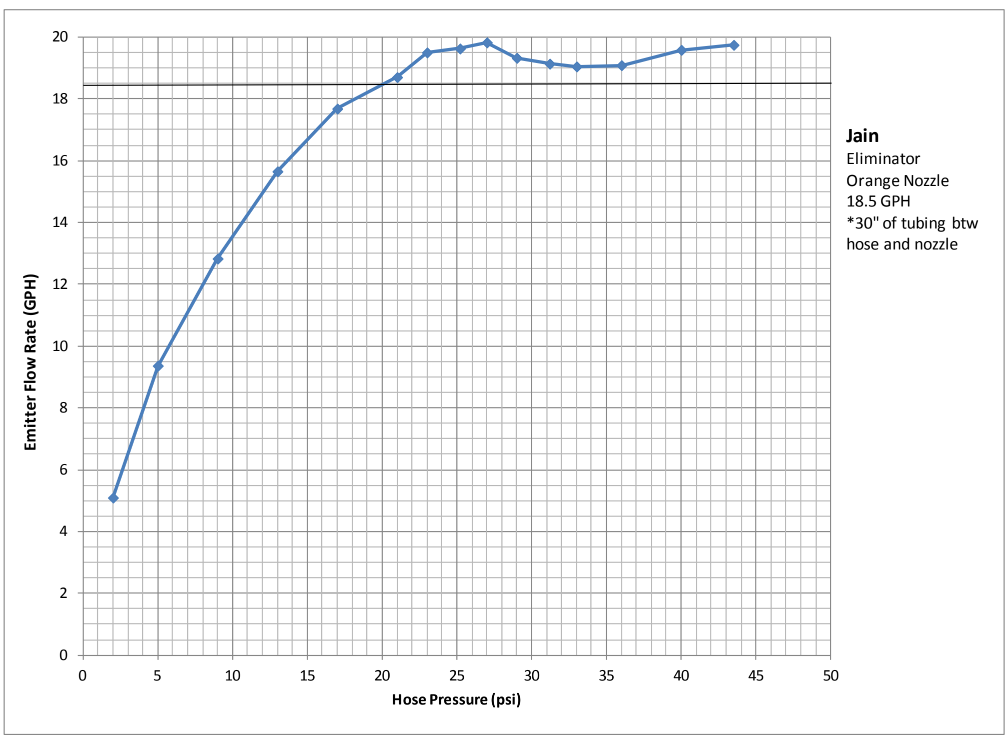

Figure 30. Jain Eliminator orange nozzle 18.5 GPH. Flow regulation at various inlet pressures

ATTACHMENT A
Emitter Testing Protocol

Attachment A
Emitter Testing Protocol

Setup

1. The hose or tape shall be installed on top of the funnels so that two sections of hose contain seven emitters each, and the other two sections of hose contain eight emitters each.
2. There will be 30 devices per test.
3. Select the appropriate load cell and test time based upon the following chart:

Table A1. Load cell selection by device GPH and respective test time (for 0.25% accuracy)

	Min GPH/em		Max GPH/em	
Load cell (lb)	**Min. GPH/em**	Min. test time (min)	**Max. GPH/em**	Min. test time (min)
25	**0.1**	15	**0.5**	4
75	**0.5**	8	**2**	4.5
500	**2**	12	**18**	4.5

4. Hang the load cell and corresponding container on the weighing stand.
5. Plug the load cell into the correct receptacle on the enclosure.
6. Select the correct individual emitter container and graduated cylinder size using the following chart:

Table A2. Emitter container and graduated cylinder sizes

	ml/5 min	**ml/10 min**	**Grad cyl ml**	**Container below funnel**
Very low flow tape	28	57	50	quart
High flow tape	83	167	100	quart
.33 GPH emitter	104	208	250	quart
1.0 GPH emitter	312	625	500	quart
8 GPH sprayer	2523	5047	4000	bucket
15 GPH sprayer	4684	9368	4000	bucket

7. If the quart-sized containers are being used, place the pedestals in the center of each 2×12 shelf. Then slide the 2×8 shelves over the pedestal and onto the upper brackets. This ensures a short distance between the individual emitter containers and the bottom of the funnels.
8. Place the individual containers underneath the funnels.
9. Turn on the PLC and laptop. Plug in the necessary communications cables.

Develop a Q vs. Pressure Curve

Individual cans will NOT be used for this test. Do NOT shut off the water between pressures.

1. Pressurize the sample of emitters for a minimum of 48 hrs with 15 psi of potable water.
2. Move the emitters over to center trough.
3. Adjust the trough diverter so that the water does not reach the load cell and weighing container.
4. Adjust the hose pressure to 1 psi. Water from the funnels will collect and discharge at the end of the trough.
5. Allow the flow rate to stabilize in the trough. This will take at least 1 minute.
6. Adjust the trough diverter so that the water is now filling the weighing container. Once the PLC program calculates the flow rate, re-divert the water to the drain.
7. Empty the weighing container.
8. Increase the hose pressure by 3 psi.
9. Repeat steps (6) through (8) until the emitter begins compensating.
10. Increase the hose pressure by 1 psi.
11. Continue measuring the flow of all emitters in increasing 1 psi increments until the flow rate begins to flatten out. Once this occurs, switch to 3 psi increments. In other words, once the emitters begin to compensate for an increase in hose pressure, adjust the test pressure interval to 3 psi (*see **Figure A1** for clarification*).
12. Complete a cv test after the first 3 psi interval (3 psi higher than the pressure at which the emitter is regulating).
13. Continue flow rate testing at 3 psi intervals until 3-4 data points have been collected over the compensating pressure range (*see **Figure A1** for clarification*).
14. Complete another cv test at a hose pressure that is 10 psi higher than the first cv test.

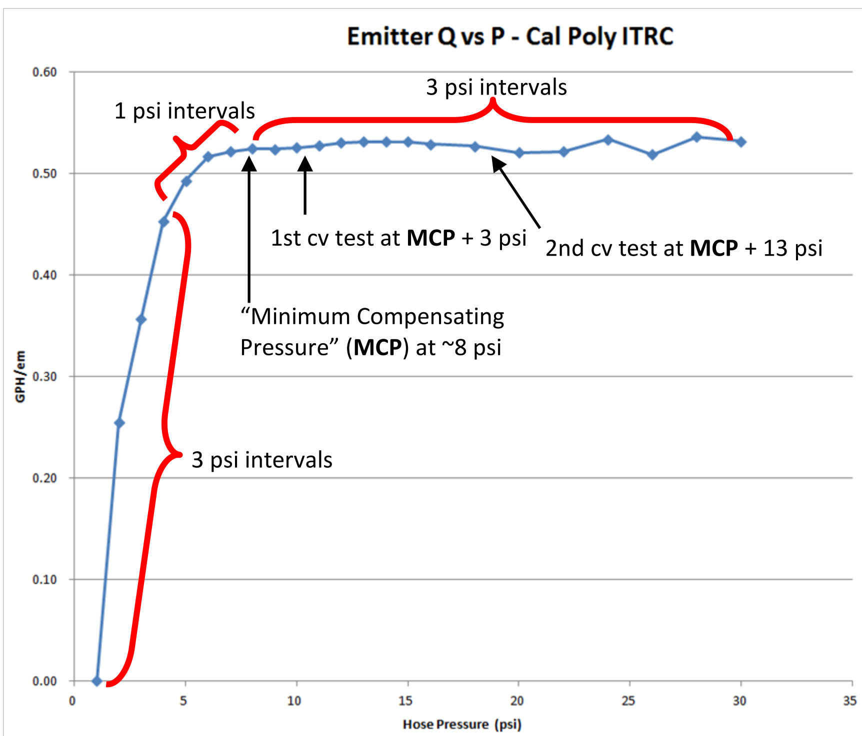

Figure A1. Example Q vs. pressure curve

Determine the cv of each Emitter Type

1. Adjust the trough diverter to discharge into the drain.
2. Move the emitters over the trough.
3. Verify the appropriately sized containers are placed under the funnels to catch ALL emissions.
4. Select an appropriate test time from **Table A1**.
5. Move the emitters over the individual containers. A proximity switch will automatically start the test timer.
6. Once the time has been reached, move the emitters back to the trough.
7. For high flow rates/large containers, weigh each container using the appropriate load cell.
8. The water from each individual rectangle should be carefully poured into an appropriately sized graduated cylinder. **See Table A2**. The collected volume for each emitter shall be recorded, along with the pressure.
9. Once all of the emitter discharges have been recorded, calculate the cv, where:

$$cv = \frac{std.\,deviation\ of\ volumes}{mean\ of\ volumes}$$

Other Notes

1. Use very sharp hose punches to avoid any leakage around the emitter barbs.
2. All emitters, microsprayers, etc. shall have no more than 15 emitters/hose. There will be two hoses.
3. Always test both hoses at the same time.
4. <u>For emitters:</u>
   a. Use the smaller diameter hose (approx. 0.72”).
   b. Place the hoses directly on top of the funnels. Check if the contact between the bottom of the hose and funnel edge forces any side flow into the funnel. If not, use radiator hose pieces to force the water to drip into the funnel.
5. <u>For microsprayers and microsprinklers</u>
   a. Devices must be directly connected to the hose – DO NOT USE microtubing, special barbs, etc.
   b. Devices must be covered by a plastic freezette during the testing, to ensure that all water hits the inside freezette and drips down into the funnel.
      i. First, put the hose through the two holes in each freezette.

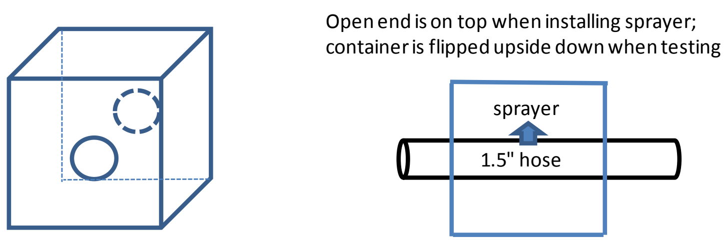

Figure A2. Inserting hose into freezette

      ii. Space the freezettes on 1 foot centers, with the open end facing up.
      iii. Attach the microsprayers/sprinklers with one inside of each freezette. They should be on the TOP of the hose.

iv. Install radiator clips over the hose, at the two inside edges of each freezette, to prevent leakage through the hose in the freezettes.
v. Flip the freezettes over so the water will drop down into the funnel.

Sample of Test Results

Figure A3 and **Tables A4** and **A5** depict samples of the collected data in graphical and tabular format.

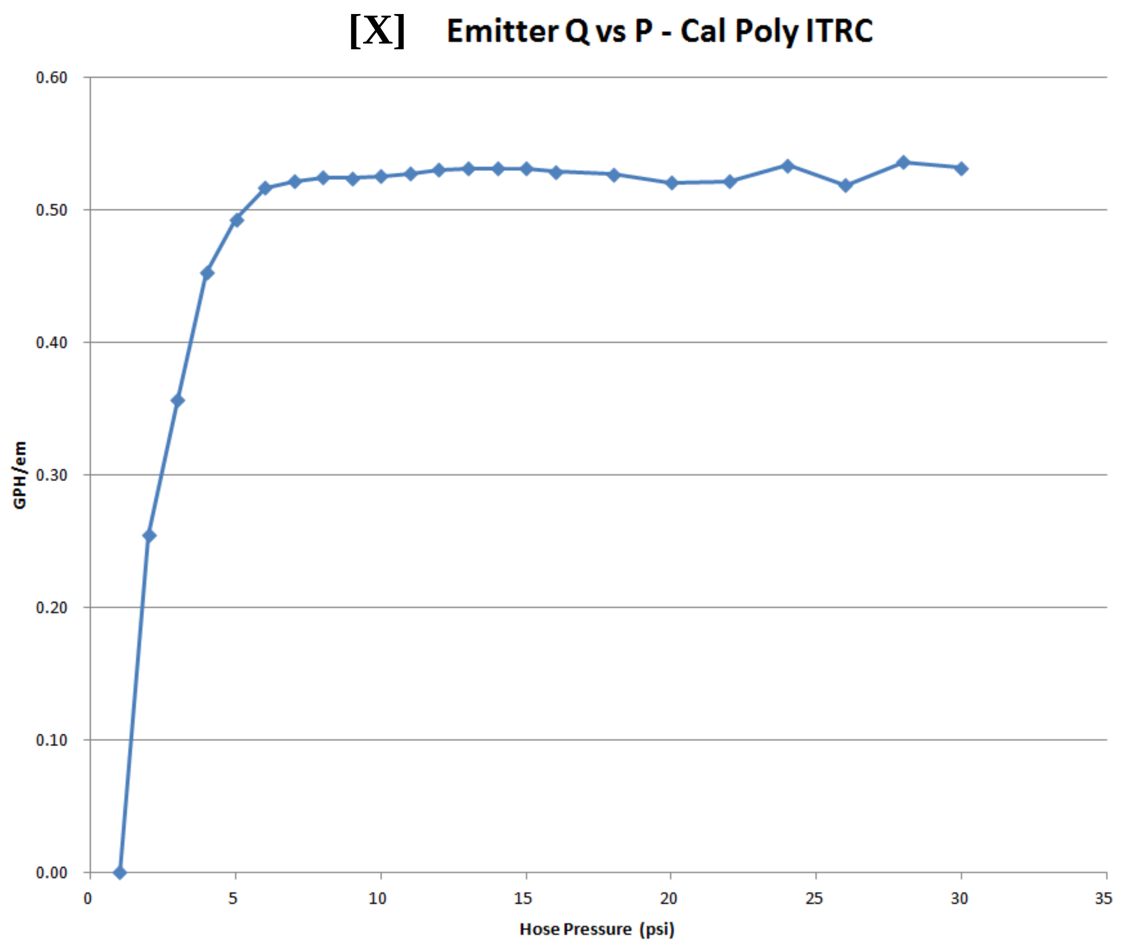

Figure A3. Sample of collected data

Table A3. Discharged volumes at two emitter inlet pressures

	Test Pressure (psi)	
	21	11
Emitter #	**Volume (mL)**	
1	238	238
2	236	240
3	228	246
4	232	240
5	226	245
6	242	248
7	249	245
8	244	245
9	250	238
10	244	227
11	230	244
12	226	244
13	235	232
14	241	252
15	217	242
16	234	246
17	242	241
18	228	240
19	238	226
20	237	245
21	246	241
22	244	253
23	250	238
24	245	247
25	236	243
26	238	231
27	240	251
28	246	247
29	247	242
30	230	245

Table A4. Coefficient of variation and statistics at each pressure

Test Pressure (psi)	21	11
Test Duration (min)	7	7
Min (mL)	217	226
Max (mL)	250	253
Std Dev (mL)	*8*	*7*
Mean (mL)	*238*	*242*
cv	**0.034**	**0.027**

ATTACHMENT B
Emitter Testing Laboratory

Attachment B
Emitter Testing Laboratory

The Cal Poly Irrigation Training & Research Center (ITRC) completed the construction of an emitter testing laboratory at the Water Resource Facility (WRF) for this testing. The new laboratory enables ITRC to conduct efficient testing of microirrigation emitting device flow rates and coefficients of variation due to manufacturing (cv).

The ITRC emitter testing laboratory comprises three components:

1) *Water Supply:* A gravity-fed, 10-inch pipeline supplies the laboratory with 85 psi static head. This water supply is then run through a 4-inch screen filter and subsequently through a pressure regulating valve to lower the inlet pressure to the laboratory.

2) *Test Bench:* A piping and structural system enables the installation of drip hose and tape at shoulder height along 60 lineal feet of movable track. Adjustable funnels are placed under individual emitting devices to catch all discharged water. The structural system allows all funnel discharges to be directed simultaneously to one of two sections: individual catch cans for cv tests or a single trough for flow measurement.

3) *Gravimetric Flow Measurement:* A weigh system is placed at the discharge of the single trough, where the entire flow is collected in one of three different tanks. Each tank has a different capacity (1, 5 and 50 gallons) and is suspended by a corresponding S-beam load cell system (25, 75, and 500 lb respectively).

Table B1 provides a summary of the flow capacities and corresponding uncertainties for each available tank.

Table B1. Summary of flow capacities and uncertainties

Component	Tank 1	Tank 2	Tank 3
Tank volume, gal	1	5	50
Tank material	HDPE	HDPE	LDPE
Scale type	S-beam load cell	S-beam load cell	S-beam load cell
Scale capacity, lb	25	75	500
Scale resolution, lb	0.005	0.015	0.1
Flow Range, GPH	0 - 0.5	0.5 - 2	2 - 20
Combined Flow Rate Uncertainty (65% confidence)	0.15%	0.15%	0.15%
Pressure Uncertainty	0.25 psi	0.25 psi	0.25 psi
Cv weight uncertainty (65% confidence)	0.10%	N/A	N/A

This document provides an overview of the measurement theory, measurement hardware, calibration schedules and an uncertainty analysis for measurements taken at the ITRC emitter testing laboratory.

Gravimetric Flow Measurement

Gravimetric flow measurement is a common method of liquid flow measurement, used in a larger scale at both ITRC's WRF and other facilities such as the Utah Water Research Laboratory and the National Institute of Standards and Technology (NIST). Fundamentally, gravimetric flow measurement pertains to the change in weight of a tank over time during filling. The flow rate is then calculated using the following equation:

$$Q = \frac{\Delta W_{tank}}{T} * \rho_{liquid}^{-1}$$

Where,

Q = flow rate (gal/hr)
$\Delta W_{tank} I$ = change in weight of the tank (lb)
T = time (hr)
ρ_{liquid} = density of liquid (lb/gal)

At the ITRC emitter testing laboratory, the flow from all emitting devices on the test bench is combined and collected into a single weighing container, as seen in **Figure B1**.

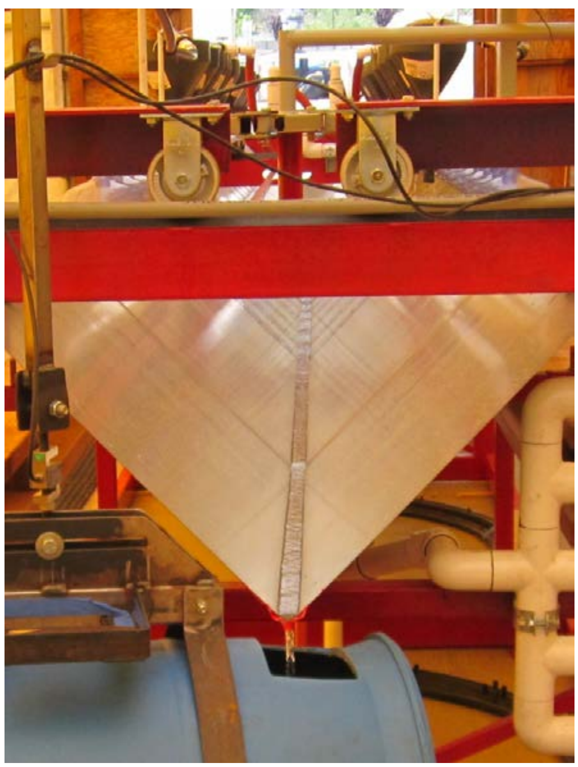

Figure B1. Flow measurement trough and collection (50 gallon) container

Collecting all emitter discharges using a central trough has proven to be an efficient means of measuring the average emitter flow rate without the laborious task of individualizing the emitters. This enables ITRC to economically identify flow-versus-pressure relationships for both pressure compensating and non-pressure compensating emitters.

Gravimetric Flow Measurement Hardware

The gravimetric flow measurement employed at the emitter testing laboratory relies on three types of measurement[1]:

- Weight
- Time
- Pressure

Weight

The weight component is measured by high-quality Rice Lake steel alloy S-beam load cells. The load cells are NTEP-rated at a resolution of 1:5000 with hysteresis at 0.02% full scale and non-linearity rated at 0.03% full scale. **Figure B2** shows the load cell installed on the test bench.

Figure B2. Rice Lake load cell

The ratiometric load cell output signal is sent to a signal conditioner to be converted to a 4-20 mA signal and subsequently to a high-quality SCADAPack 350 programmable logic controller (PLC) with 15-bit analogue to digital converter.

Time

The time measurement is taken internally by the PLC using a preset weight range for turning ON and OFF. The real-time clock of the PLC, shown in **Figure B3**, is rated for +/- 1 minute per month.

[1] Temperature variations affecting the density conversion are accounted for as a measurement uncertainty. Appropriate estimates of maximum and minimum temperatures of the large diameter buried supply pipeline were used in the analysis. Refer to the uncertainty analysis for further details.

Figure B3. SCADAPack 350 PLC with signal conditioners

Pressure

Emitter hose pressures are adjusted via a manifold of various needle and gate valve sizes (see **Figure B4**).

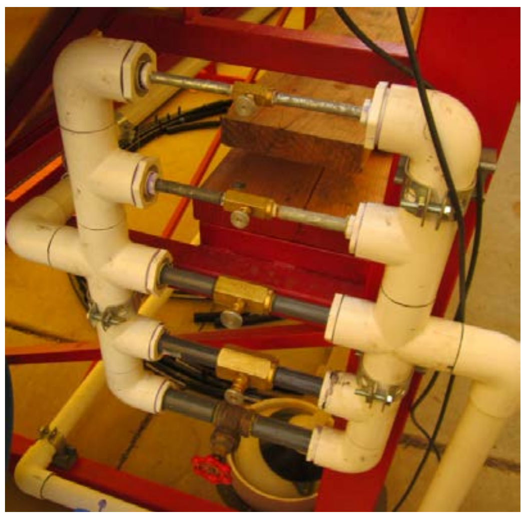

Figure B4. Valves for pressure adjustment

The pressures are monitored with redundant pressure gauges (**Figure B5**), including a high-quality Ashcroft 0-60 psi large-faced gauge.

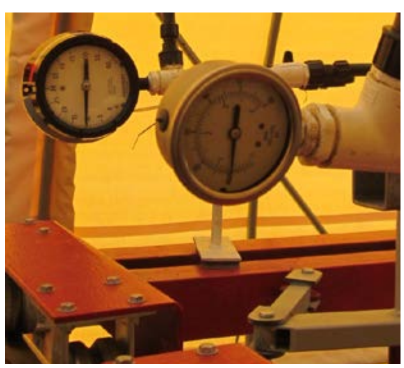

Figure B5. Redundant pressure gauges

Coefficient of Variation (cv) Due to Manufacturing Variability Testing

Cv testing using the ITRC emitter testing laboratory is completed using the same tape/hose configuration and placement as the flow measurement testing. As such, both flow rate and cv tests can be completed effectively with the same emitter samples without laborious adjustments.

Individual emitter discharges are directed by funnels positioned to flow into the central trough until the hose pressure matches a target value. After maintaining the target hose pressure, the entire tape/hose assembly is shifted via a mechanical linkage and track system to discharge into preset individual containers. The volume of each container is measured using high-quality graduated cylinders for collected volumes up to 500 mL, corresponding to a flow rate range of 0-8 GPH, as pictured in **Figure B6**. Collected volumes for higher flow rates are weighed with the 25 lb load cell.

Figure B6. Using graduated cylinders

Calibration Schedules

Maintaining a minimum measurement uncertainty requires judicious verifications and calibrations of measurement equipment. **Table B1** summarizes ITRC schedules, procedures and equipment used for calibration and verifications.

Table B1. Calibration procedures and schedules

Hardware Description	Procedure	Reference Standard	Procedural Description	Schedule*
25 lb Load Cell	Calibration	5 lb NIST-Traceable Weight Standards	NIST Handbook 44 – Substitution Method	Every 4 samples
75 lb Load Cell	Calibration	20 lb and 5 lb NIST-Traceable Weight Standards	NIST Handbook 44 – Substitution Method	Every 4 samples
500 lb Load Cell	Calibration	(2) 50 lb NIST-Traceable Weight Standards	NIST Handbook 44 – Substitution Method	Every 4 samples
Pressure Gauges	Verification	Druck DPI610 Pressure Calibrator	5-point comparison	Every 4 samples
PLC Real-time Clock	Verification	NIST-Traceable Stop Watch	Long Duration Testing	Every 10 samples

* This schedule refers to multiple and consecutive tests. For intermittent testing it can be assumed that all hardware is calibrated and verified for each sample.

Measurement Uncertainty

An analysis of component, combined, and expanded uncertainties for emitter testing measurements was completed using an uncertainty budget. This section will describe the analysis procedure by component and summarize the combined and expanded uncertainty calculations.

Flow Measurement

The uncertainty budget for the flow measurement testing of microirrigation devices is summarized in **Table B2** for both 65% and 95% confidence intervals.

Table B2. Uncertainty budget for flow measurement testing of microirrigation devices

	Component Uncertainty (%)		
Load Cell Capacity (lb)	25	75	500
Scale Indication	0.014	0.017	0.013
Scale Calibration	0.1	0.1	0.1
Uncollected Volumes	0	0	0
Buoyancy Correction	0.007	0.007	0.007
Evaporation	0	0	0
Time Uncertainty	0.02	0.02	0.02
Density Uncertainty	0.11	0.11	0.11
Combined Flow Rate Uncertainty (65% confidence)	**0.151**	**0.151**	**0.151**
Expanded Flow Rate Uncertainty (95% confidence)	**0.302**	**0.302**	**0.301**
Hose Pressure Uncertainty	**0.25 psi**	**0.25 psi**	**0.25 psi**

Scale Indication

The gravimetric measurement method for emitter testing utilized three separate load cell and container setups of various sizes. Uncertainty due to scale indication was calculated with the following equation:

$$Uncertainty_{indication} = \frac{Scale\ Indication\ (lb)}{Collected\ Weight\ (lb) * \sqrt{3}}$$

Due to the discrete nature of scale indications, the square root of 3 is added to convert a Normal Probability to Rectangular Probability Distribution.

Table B3 outlines the mass collection uncertainty by container size and scale indication.

Table B3. Weighing uncertainty by capacity and scale indication

	Load Cell Capacity (lb)		
	25	**75**	**500**
Mean Collected Weight (lb)	20	50	450
Load Cell Resolution (lb)	0.005	0.015	0.1
Uncertainty (%)	0.014%	0.017%	0.013%

Scale Calibration

The “calibration by substitution” guidelines laid out in *NIST Handbook 44* will inherently incur some uncertainty, the magnitude of which was computed for this analysis. Calibration slopes were compared to a computed average slope and plotted, using the formula:

$$y = \left(\frac{K}{K_{avg}} - 1\right) * 100\ \%$$

Where,

K = individual load cell PLC multiplier at each calibration (measured weight / PLC input in milliamps)

K_{ave} = average of individual load cell calibration multipliers

Figure B6 shows the data points from the calibrations of individual load cells.

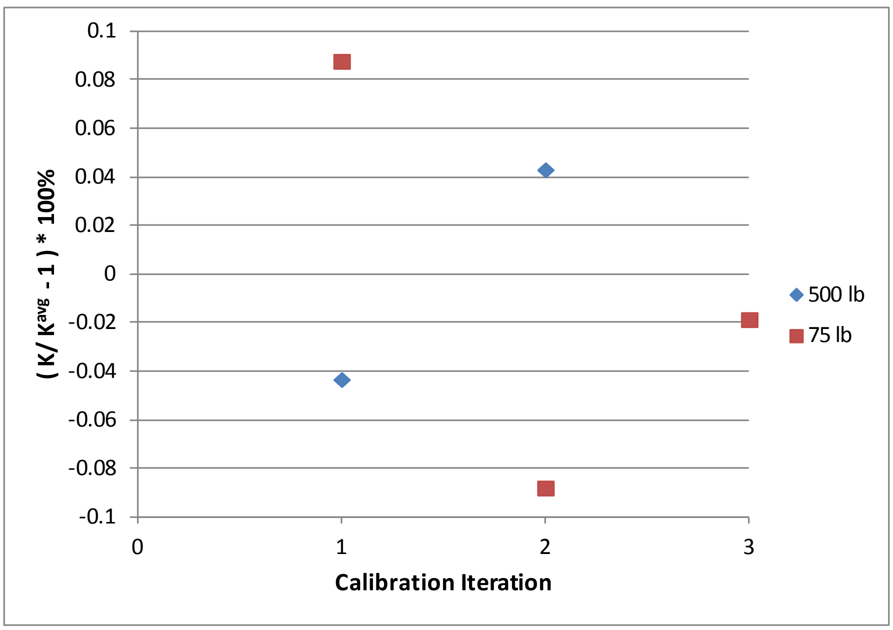

Figure B7. Load cell calibration uncertainty[2]

As shown above, the scale slopes from multiple calibrations were found to exhibit a maximum uncertainty of 0.10%. These values were added to the individual scale uncertainty budgets.

Uncollected volumes

Leaks from fittings and splashing water were either not observed or fixed before testing commenced. Thus, uncertainties due to uncollected volumes are assumed to be negligible.

[2] Average data for the 25 lb load cell is not shown in **Figure B7** due to limited low flow samples tested and reoccurring warranty issues with the load cell. It is assumed that the uncertainty due to calibration for the 25 lb load cell is similar to the data above for the different load cell capacities.

Buoyancy Correction

Buoyancy correction accounts for uncertainties in weight measurements due to the inequality of densities and mass between the measured water volume, air and calibration weights. The following formula was used to calculate the estimated uncertainty from buoyancy effects:

$$W^{true} = W^{measured} * \frac{\left(1 - \frac{\rho_{air}}{\rho_{calib.\ weight}}\right)}{\left(1 - \frac{\rho_{air}}{\rho^{water}}\right)}$$

Where,

W^{true} = true weight (lb)
$W^{measured}$ = measured weight (lb)
P_{air} = estimated air density (lb)
$P_{calib.\ weight}$ = density of NIST-traceable calibration weight standard (lb)
P^{water} = estimated water density (lb)

Table B4 summarizes the calculated uncertainty of the weight measurements due to buoyancy effects.

Table B4. Calculated uncertainty of weight measurements due to buoyancy effects

Container Capacity (gal)	Volume (ft^3)	Mass (lbm)	True mass (lbm)	Uncertainty
0.75	0.10	0.1942	0.1942	0.007%
4	0.53	1.0358	1.0357	0.007%
50	6.68	12.9476	12.9466	0.007%

Water Evaporation

Due to the relatively short 8-10 minute measurement, test characteristics such as filling durations, atmospheric conditions and container geometry minimize quantifiable water evaporation. The effects of evaporation are therefore assumed to be negligible.

Time Uncertainty

The PLC program logic for the weighing tank measured the weight of the collection tank between preset “start” and “stop” weights. Each flow rate data point is then calculated based on the change in weight within an internally measured time step. Flow rate uncertainty due to timing errors was compared to a NIST-traceable stop watch. Testing indicated timing uncertainties within the PLC specifications of 0.02%.

Density Uncertainty

Volumetric flow rates were derived from a conversion from the mass flow measurement. Density calculation uncertainty due to water temperature fluctuations was computed and added to the uncertainty budget. The water supply temperature variation was assumed to be within 10 degrees Fahrenheit, resulting in a density uncertainty of 0.11%.

Hose Pressure Uncertainty

Hose pressures were adjusted based on visual readings of high-quality pressure gauges. The resolution and readability of the pressures for both gauges incurred an uncertainty of +/- 0.25 psi.

Cv Testing

The uncertainty budget for the coefficient of variation testing of microirrigation devices is summarized in **Table B5** for both 65% and 95% confidence intervals.

Table B5. Emitter coefficient of variation testing uncertainty

Emitter flow rate range (GPH)	0 - 2	2 - 5	5 - 20
Collected Volume Uncertainty (65% confidence)	**0.46%**	**0.58%**	**0.01%**
Collected Volume Uncertainty (95% confidence)	**0.92%**	**1.15%**	**0.02%**
Hose Pressure Uncertainty	**0.25 psi**	**0.25 psi**	**0.25 psi**

Hose Pressure Uncertainty

Hose pressures were adjusted based on visual readings of high-quality pressure gauges. The resolution and readability of the pressures for both gauges incurred an uncertainty of +/- 0.25 psi.

Volume Uncertainty

Emitted volumes were measured using graduated cylinders for emitter flows up to 8 GPH. Emitters discharging more than 8 GPH were measured in larger individual discharge volumes, and were therefore weighed using a load cell as a hanging scale. **Table B6** outlines the component and expanded uncertainty for the more complex weighing method of measurement.

Table B6. Uncertainty in cv measurement for 8 GPH and higher emitters

	Component Uncertainty (%)
Load Cell Capacity (lb)	**25**
Scale Indication	0.014
Scale Calibration	0.1
Uncollected Volumes	0
Buoyancy Correction	0.007
Evaporation	0
Combined Flow Rate Uncertainty (65% confidence)	**0.101**
Expanded Flow Rate Uncertainty (95% confidence)	**0.202**

Table B7 summarizes the uncertainties for every cv measurement including volumes, resolution and measurement uncertainty corresponding to three ranges of flow rates.

Table B6. Cv discharge measurement uncertainty

Flow Range (GPH)	Measurement Device	Resolution	Measurement Capacity	Measurement Uncertainty
0 - 2	Graduated Cylinder	2 mL	250 mL	0.46%
2 - 5	Graduated Cylinder	5 mL	500 mL	0.58%
5 - 20	25 lb Load Cell	0.005 lb	25 lb	0.10%

ATTACHMENT C
Emitter cv Results

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Bowsmith	
Model	Fan-Jet Nozzle # 40 (blue) Pres-Comp. #8 (Orange)	
Nominal Q	7.3	GPH
Nominal P		
Spacing	12	inches
Date	5/9/2013	
Spagh. Hose length		

Test Pressure (psi)	23	16
Test Duration (min)	6.5	5.4
Min (lb)	6.11	5.73
Max (lb)	6.74	6.54
Std Dev (lb)	*0.17*	*0.21*
Mean (lb)	*6.43*	*6.17*
cv	**0.026**	**0.034**
Emitter #	Net Weight (lb)	
1	6.21	6.05
2	6.48	6.27
3	6.25	5.73
4	6.48	6.22
5	6.72	6.53
6	6.28	6.03
7	6.36	6.09
8	6.33	6.00
9	6.47	6.34
10	6.63	6.39
11	6.41	6.08
12	6.38	6.04
13	6.37	6.14
14	6.64	6.45
15	6.45	6.10
16	6.11	5.77
17	6.43	6.10
18	6.26	6.03
19	6.26	6.03
20	6.37	6.24
21	6.17	5.99
22	6.67	6.51
23	6.63	6.41
24	6.40	6.27
25	6.60	6.29
26	6.33	6.05
27	6.41	6.01
28	6.67	6.43
29	6.30	6.09
30	6.74	6.54

Raw Data

		Test P (psi)	
	Tare Weight (lb)	23	16
Emitter #		Gross Weight (lb)	
1	1.24	7.45	7.29
2	1.26	7.74	7.53
3	1.21	7.46	6.94
4	1.26	7.74	7.48
5	1.24	7.96	7.77
6	1.26	7.54	7.29
7	1.22	7.58	7.31
8	1.24	7.57	7.24
9	1.20	7.67	7.54
10	1.22	7.85	7.61
11	1.22	7.63	7.3
12	1.21	7.59	7.25
13	1.25	7.62	7.39
14	1.24	7.88	7.69
15	1.22	7.67	7.32
16	1.23	7.34	7
17	1.21	7.64	7.31
18	1.26	7.52	7.29
19	1.22	7.48	7.25
20	1.27	7.64	7.51
21	1.22	7.39	7.21
22	1.25	7.92	7.76
23	1.23	7.86	7.64
24	1.25	7.65	7.52
25	1.22	7.82	7.51
26	1.25	7.58	7.3
27	1.22	7.63	7.23
28	1.28	7.95	7.71
29	1.24	7.54	7.33
30	1.25	7.99	7.79

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Bowsmith
Model	Fan-Jet Nozzle #55 (Yellow) Pres-Comp. #14 (Violet)
Nominal Q	14 GPH
Nominal P	
Spacing	12 in
Date	5/9/2013
Spagh. Hose length (in)	

Test Pressure (psi)	39	49
Test Duration (min)	5	5
Min (lbs)	8.5	8.94
Max (lbs)	9.13	9.73
Std Dev (lbs)	*0.20*	*0.25*
Mean (lbs)	*8.81*	*9.36*
cv	**0.023**	**0.027**
Emitter #	Net Weight (lbs)	
1	8.65	9.14
2	8.92	8.94
3	8.63	9.14
4	9.08	9.68
5	8.85	9.38
6	9.13	9.73
7	8.65	9.17
8	9.05	9.61
9	8.56	9.05
10	8.78	9.31
11	8.66	9.16
12	8.85	9.42
13	8.87	9.40
14	8.56	9.05
15	8.62	9.14
16	8.69	9.21
17	9.08	9.67
18	8.56	9.04
19	8.67	9.17
20	8.98	9.56
21	8.73	9.27
22	9.06	9.64
23	8.97	9.64
24	8.68	9.21
25	8.85	9.38
26	9.13	9.73
27	8.76	9.60
28	8.60	9.58
29	9.08	9.65
30	8.50	8.99

Raw Data

		Test Pressure (psi)	
	Tare Weight (lbs)	39	49
Emitter #		Gross Weights (lb)	
1	1.24	9.89	10.38
2	1.26	10.18	10.20
3	1.21	9.84	10.35
4	1.26	10.34	10.94
5	1.24	10.09	10.62
6	1.26	10.39	10.99
7	1.22	9.87	10.39
8	1.24	10.29	10.85
9	1.20	9.76	10.25
10	1.22	10.00	10.53
11	1.22	9.88	10.38
12	1.21	10.06	10.63
13	1.25	10.12	10.65
14	1.24	9.80	10.29
15	1.22	9.84	10.36
16	1.23	9.92	10.44
17	1.21	10.29	10.88
18	1.26	9.82	10.30
19	1.22	9.89	10.39
20	1.27	10.25	10.83
21	1.22	9.95	10.49
22	1.25	10.31	10.89
23	1.23	10.20	10.87
24	1.25	9.93	10.46
25	1.22	10.07	10.60
26	1.25	10.38	10.98
27	1.22	9.98	10.82
28	1.28	9.88	10.86
29	1.24	10.32	10.89
30	1.25	9.75	10.24

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Eurodrip
Model	Corona
Nominal Q	0.5 GPH
Nominal P	
Spacing	12 in
Date	5/16/2013

Test Pressure (psi)	13	23
Test Duration (min)	6	6
Min (mL)	188	193
Max (mL)	215	210
Std Dev (mL)	*5*	*4*
Mean (mL)	*198*	*202*
cv	**0.024**	**0.018**
Emitter #	Volume (mL)	
1	203	203
2	197	202
3	197	198
4	198	203
5	199	210
6	193	203
7	194	201
8	201	205
9	204	207
10	197	201
11	193	200
12	198	201
13	202	207
14	196	203
15	192	193
16	198	200
17	196	201
18	196	200
19	194	202
20	188	198
21	199	206
22	195	202
23	203	206
24	195	196
25	200	203
26	194	198
27	215	197
28	199	201
29	198	201
30	195	199

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Eurodrip
Model	PC2
Nominal Q	0.5 GPH
Nominal P	6-65 psi
Spacing	36 in
Date	3/13/2013

Test Pressure (psi)	25	15	11	8
Test Duration (min)	4.5	5.5	5.5	5.5
Min (mL)	130	118	138	134
Max (mL)	173	185	172	175
Std Dev (mL)	*12.04*	*13.99*	*8.74*	*9.51*
Mean (mL)	*155.10*	*167.67*	*159.33*	*152.00*
cv	**0.078**	**0.083**	**0.055**	**0.063**
Emitter #				
1	157	171	160	134
2	161	175	165	140
3	152	163	152	146
4	166	178	170	168
5	154	169	162	156
6	157	168	158	158
7	135	158	138	163
8	142	153	162	146
9	161	179	169	137
10	158	167	147	148
11	171	161	162	151
12	148	167	159	150
13	158	171	159	145
14	164	181	158	160
15	130	163	152	157
16	170	141	154	149
17	173	185	171	139
18	138	177	165	156
19	141	163	155	155
20	165	174	163	153
21	157	173	162	175
22	151	118	152	147
23	170	183	172	151
24	165	183	172	165
25	145	172	147	141
26	168	180	168	163
27	168	182	172	160
28	142	162	155	151
29	146	157	146	149
30	140	156	153	147

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Jain	
Model	2002 AquaSmart Orange Nozzle	
Nominal Q	18.5	GPH
Nominal P		
Spacing	12	inches
Date	5/6/2013	
Spagh. Hose length	30	inches

Test Pressure (psi)	25	35
Test Duration (min)	4.3	4.3
Min (lb)	10.48	10.15
Max (lb)	13.63	13.71
Std Dev (lb)	*0.69*	*0.79*
Mean (lb)	*12.41*	*11.49*
cv	**0.055**	**0.069**
Emitter #	Net Weight (lb)	
1	11.60	11.09
2	12.42	11.62
3	12.10	11.06
4	12.78	11.74
5	13.32	12.68
6	12.92	11.44
7	12.52	10.81
8	12.72	11.27
9	10.48	10.15
10	12.21	10.76
11	11.85	10.77
12	11.62	10.82
13	12.36	11.72
14	12.46	11.14
15	13.63	13.71
16	13.13	12.29
17	11.42	10.78
18	12.56	11.35
19	12.85	11.69
20	12.73	11.29
21	12.74	11.62
22	12.88	11.70
23	12.21	11.25
24	12.26	10.94
25	11.37	10.62
26	11.53	10.64
27	12.64	12.68
28	13.16	12.50
29	13.16	12.70
30	12.70	11.91

Raw Data

		Test P (psi)	
	Tare Weight (lb)	25	35
Emitter #		Gross Weight (lb)	
1	1.24	12.84	12.33
2	1.26	13.68	12.88
3	1.21	13.31	12.27
4	1.26	14.04	13.00
5	1.24	14.56	13.92
6	1.26	14.18	12.70
7	1.22	13.74	12.03
8	1.24	13.96	12.51
9	1.20	11.68	11.35
10	1.22	13.43	11.98
11	1.22	13.07	11.99
12	1.21	12.83	12.03
13	1.25	13.61	12.97
14	1.24	13.70	12.38
15	1.22	14.85	14.93
16	1.23	14.36	13.52
17	1.21	12.63	11.99
18	1.26	13.82	12.61
19	1.22	14.07	12.91
20	1.27	14.00	12.56
21	1.22	13.96	12.84
22	1.25	14.13	12.95
23	1.23	13.44	12.48
24	1.25	13.51	12.19
25	1.22	12.59	11.84
26	1.25	12.78	11.89
27	1.22	13.86	13.90
28	1.28	14.44	13.78
29	1.24	14.40	13.94
30	1.25	13.95	13.16

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Jain	
Model	2002 AquaSmart Violet Nozzle Grey Bearing	
Nominal Q	5.3	GPH
Nominal P		
Spacing	12	inches
Date	5/9/2013	
Spagh. Hose length	30	inches

Test Pressure (psi)	27	37
Test Duration (min)	10	10
Min (lbs)	6.96	8.56
Max (lbs)	7.53	9.2
Std Dev (lbs)	*0.14*	*0.17*
Mean (lbs)	*7.23*	*8.93*
cv	**0.019**	**0.019**
Emitter #		
1	7.31	8.65
2	7.05	9.12
3	7.37	8.85
4	7.18	8.78
5	7.10	8.81
6	7.16	9.00
7	7.20	9.09
8	6.96	8.56
9	7.20	8.86
10	7.15	8.76
11	7.34	9.04
12	7.33	9.06
13	7.53	9.20
14	7.20	8.89
15	7.45	9.18
16	7.01	8.65
17	7.37	9.10
18	7.24	8.97
19	7.27	8.97
20	7.15	8.86
21	7.22	8.80
22	7.18	8.91
23	7.42	9.14
24	7.13	8.81
25	7.13	8.80
26	7.21	8.87
27	7.46	9.10
28	7.32	9.09
29	7.24	8.93
30	7.05	9.02

Raw Data

		Test P (psi)	
	Tare Weight (lb)	27	37
Emitter #		Gross Weight (lb)	
1	1.24	8.55	9.89
2	1.26	8.31	10.38
3	1.21	8.58	10.06
4	1.26	8.44	10.04
5	1.24	8.34	10.05
6	1.26	8.42	10.26
7	1.22	8.42	10.31
8	1.24	8.20	9.80
9	1.20	8.40	10.06
10	1.22	8.37	9.98
11	1.22	8.56	10.26
12	1.21	8.54	10.27
13	1.25	8.78	10.45
14	1.24	8.44	10.13
15	1.22	8.67	10.40
16	1.23	8.24	9.88
17	1.21	8.58	10.31
18	1.26	8.50	10.23
19	1.22	8.49	10.19
20	1.27	8.42	10.13
21	1.22	8.44	10.02
22	1.25	8.43	10.16
23	1.23	8.65	10.37
24	1.25	8.38	10.06
25	1.22	8.35	10.02
26	1.25	8.46	10.12
27	1.22	8.68	10.32
28	1.28	8.60	10.37
29	1.24	8.48	10.17
30	1.25	8.30	10.27

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Jain	
Model	Clicktif brown outlet	
Nominal Q	0.5	GPH
Nominal P	-	
Spacing	12	inches
Date	5/21/2013	

Test Pressure (psi)	13	28
Test Duration (min)	7	7
Min (mL)	198	218
Max (mL)	216	243
Std Dev (mL)	*4*	*6*
Mean (mL)	*209*	*229*
cv	**0.020**	**0.026**
Emitter #	Volume (mL)	
1	208	233
2	213	234
3	215	236
4	208	226
5	213	230
6	211	228
7	205	225
8	208	227
9	205	225
10	208	224
11	213	227
12	207	226
13	212	232
14	212	242
15	210	236
16	213	237
17	208	243
18	208	226
19	208	227
20	207	224
21	198	218
22	216	236
23	208	233
24	199	221
25	214	229
26	205	222
27	207	228
28	209	226
29	206	227
30	211	235

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Jain	
Model	Clicktif Black Outlet	
Nominal Q	1	GPH
Nominal P	-	
Spacing	12	inches
Date	5/24/2013	

Test Pressure (psi)	15	25
Test Duration (min)	7	7
Min (mL)	425	412
Max (mL)	460	475
Std Dev (mL)	*9*	*13*
Mean (mL)	*443*	*456*
cv	**0.021**	**0.030**
Emitter #		
1	430	445
2	447	420
3	437	457
4	445	457
5	447	455
6	460	475
7	460	467
8	432	442
9	445	467
10	450	465
11	442	460
12	440	455
13	450	465
14	457	470
15	442	452
16	447	465
17	435	455
18	437	447
19	452	465
20	440	465
21	425	445
22	442	465
23	427	450
24	452	462
25	440	455
26	447	460
27	440	455
28	425	412
29	440	455
30	442	467

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Jain	
Model	Flipper	Black
Nominal Q	6.6	GPH
Nominal P		
Spacing	12	inches
Date	5/29/2013	
Spagh. Hose length	13	inches

Test Pressure (psi)	38	48
Test Duration (min)	4.15	4.15
Min (lb)	5.77	5.87
Max (lb)	6.79	6.75
Std Dev (lb)	*0.22*	*0.24*
Mean (lb)	*6.22*	*6.42*
cv	**0.036**	**0.037**
Emitter #	Net Weight (lb)	
1	6.13	6.55
2	6.23	6.63
3	5.96	6.40
4	6.34	6.42
5	6.39	6.40
6	5.77	5.94
7	5.89	6.23
8	6.14	6.19
9	6.10	6.50
10	6.64	6.75
11	6.23	5.87
12	6.11	6.46
13	6.44	6.47
14	6.46	6.61
15	6.41	6.47
16	6.79	6.73
17	6.12	6.07
18	6.16	6.61
19	6.27	6.56
20	6.03	6.37
21	6.28	6.49
22	6.17	6.40
23	6.01	6.35
24	6.15	6.27
25	6.20	6.38
26	6.05	6.59
27	6.41	6.74
28	6.44	6.66
29	6.38	6.66
30	5.97	5.95

Raw Data

		Test P (psi)	
	Tare Weight (lb)	38	48
Emitter #		Gross Weight (lb)	
1	1.24	7.37	7.79
2	1.26	7.49	7.89
3	1.21	7.17	7.61
4	1.26	7.60	7.68
5	1.24	7.63	7.64
6	1.26	7.03	7.20
7	1.22	7.11	7.45
8	1.24	7.38	7.43
9	1.20	7.30	7.70
10	1.22	7.86	7.97
11	1.22	7.45	7.09
12	1.21	7.32	7.67
13	1.25	7.69	7.72
14	1.24	7.70	7.85
15	1.22	7.63	7.69
16	1.23	8.02	7.96
17	1.21	7.33	7.28
18	1.26	7.42	7.87
19	1.22	7.49	7.78
20	1.27	7.30	7.64
21	1.22	7.50	7.71
22	1.25	7.42	7.65
23	1.23	7.24	7.58
24	1.25	7.40	7.52
25	1.22	7.42	7.60
26	1.25	7.30	7.84
27	1.22	7.63	7.96
28	1.28	7.72	7.94
29	1.24	7.62	7.90
30	1.25	7.22	7.20

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Jain	
Model	Danjet	Blue
Nominal Q	10	GPH
Nominal P		
Spacing	12	inches
Date	5/29/2013	
Spagh. Hose length	13	inches

Eliminated Emitter #16

Test Pressure (psi)	34	44
Test Duration (min)	7	7
Min (lb)	8.8	9.08
Max (lb)	19.77	16.01
Std Dev (lb)	*1.88*	*1.11*
Mean (lb)	*9.99*	*10.50*
cv	**0.188**	**0.106**
Emitter #	Net Weight (lb)	
1	9.42	10.26
2	9.49	10.19
3	9.65	10.41
4	9.59	9.89
5	9.59	10.51
6	9.18	9.96
7	10.32	10.71
8	9.98	10.42
9	9.88	10.52
10	9.48	10.24
11	9.90	9.95
12	9.23	9.08
13	8.80	10.60
14	9.46	10.33
15	9.98	10.43
16	19.77	16.01
17	9.49	10.75
18	9.42	10.33
19	9.30	9.87
20	9.13	9.99
21	10.52	10.79
22	9.88	11.17
23	9.77	10.47
24	9.68	10.07
25	9.40	9.89
26	9.92	10.50
27	9.92	10.60
28	10.02	10.60
29	9.88	10.06
30	9.71	10.44

Raw Data

		Test P (psi)	
	Tare Weight (lb)	34	44
Emitter #		Gross Weight (lb)	
1	1.24	10.66	11.50
2	1.26	10.75	11.45
3	1.21	10.86	11.62
4	1.26	10.85	11.15
5	1.24	10.83	11.75
6	1.26	10.44	11.22
7	1.22	11.54	11.93
8	1.24	11.22	11.66
9	1.20	11.08	11.72
10	1.22	10.70	11.46
11	1.22	11.12	11.17
12	1.21	10.44	10.29
13	1.25	10.05	11.85
14	1.24	10.70	11.57
15	1.22	11.20	11.65
16	1.23	21.00	17.24
17	1.21	10.70	11.96
18	1.26	10.68	11.59
19	1.22	10.52	11.09
20	1.27	10.40	11.26
21	1.22	11.74	12.01
22	1.25	11.13	12.42
23	1.23	11.00	11.70
24	1.25	10.93	11.32
25	1.22	10.62	11.11
26	1.25	11.17	11.75
27	1.22	11.14	11.82
28	1.28	11.30	11.88
29	1.24	11.12	11.30
30	1.25	10.96	11.69

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Jain	
Model	Eliminator	Orange
Nominal Q	18	GPH
Nominal P		
Spacing	12	inches
Date	5/29/2013	
Spagh. Hose length	30	inches

Eliminating Emitter #1

Test Pressure (psi)	31	41
Test Duration (min)	4.25	4.25
Min (lb)	10.15	10.66
Max (lb)	20.67	22.11
Std Dev (lb)	*1.82*	*2.02*
Mean (lb)	*11.28*	*11.49*
cv	**0.161**	**0.176**
Emitter #	Net Weight (lb)	
1	20.67	22.11
2	11.22	11.27
3	10.93	11.01
4	11.11	10.98
5	11.08	11.10
6	11.60	11.49
7	10.95	11.18
8	10.87	11.10
9	10.40	10.77
10	11.28	11.17
11	10.84	11.06
12	10.70	11.07
13	11.64	11.09
14	10.58	10.95
15	11.30	11.31
16	11.31	11.30
17	10.64	11.16
18	10.15	10.66
19	10.88	11.31
20	10.43	10.67
21	10.56	11.01
22	10.62	11.05
23	11.50	11.17
24	10.84	11.12
25	11.84	11.94
26	11.28	11.62
27	11.24	11.38
28	10.67	10.80
29	10.70	10.82
30	10.67	11.01

Raw Data

		Test P (psi)	
	Tare Weight (lb)	31	41
Emitter #		Gross Weight (lb)	
1	1.24	21.91	23.35
2	1.26	12.48	12.53
3	1.21	12.14	12.22
4	1.26	12.37	12.24
5	1.24	12.32	12.34
6	1.26	12.86	12.75
7	1.22	12.17	12.40
8	1.24	12.11	12.34
9	1.20	11.60	11.97
10	1.22	12.50	12.39
11	1.22	12.06	12.28
12	1.21	11.91	12.28
13	1.25	12.89	12.34
14	1.24	11.82	12.19
15	1.22	12.52	12.53
16	1.23	12.54	12.53
17	1.21	11.85	12.37
18	1.26	11.41	11.92
19	1.22	12.10	12.53
20	1.27	11.70	11.94
21	1.22	11.78	12.23
22	1.25	11.87	12.30
23	1.23	12.73	12.40
24	1.25	12.09	12.37
25	1.22	13.06	13.16
26	1.25	12.53	12.87
27	1.22	12.46	12.60
28	1.28	11.95	12.08
29	1.24	11.94	12.06
30	1.25	11.92	12.26

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	John Deere	
Model	Supertif	
Nominal Q	0.58	GPH
Nominal P	9 to 50	psi
Spacing	n/a	
Date	5/22/2013	

Test Pressure (psi)	13	23
Test Duration (min)	7	7
Min (mL)	252	242
Max (mL)	282	292
Std Dev (mL)	*7*	*11*
Mean (mL)	*269*	*269*
cv	**0.026**	**0.040**
Emitter #	Volume (mL)	
1	260	265
2	272	267
3	272	267
4	265	275
5	267	255
6	280	270
7	282	265
8	267	250
9	267	272
10	267	267
11	272	280
12	267	257
13	270	270
14	280	292
15	272	282
16	255	270
17	275	280
18	270	270
19	270	275
20	260	270
21	262	265
22	252	242
23	267	287
24	262	260
25	275	285
26	267	270
27	277	262
28	270	275
29	270	275
30	277	260

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	John Deere	
Model	S2000 24 LPH Flow Regulated	
Nominal Q	6.1	GPH
Nominal P		
Spacing	12	inches
Date	4/26/2013	

Test Pressure (psi)	33	36
Test Duration (min)	10	11
Min (lb)	7.83	8.98
Max (lb)	8.97	9.47
Std Dev (lb)	*0.31*	*0.12*
Mean (lb)	*8.27*	*9.16*
cv	**0.038**	**0.013**
Emitter #	Net Weight (lb)	
1	8.10	9.25
2	8.00	9.21
3	8.67	9.10
4	7.86	9.06
5	8.31	9.05
6	8.34	9.12
7	8.27	9.07
8	8.24	9.13
9	7.95	9.10
10	8.20	9.37
11	7.84	9.03
12	7.90	9.09
13	8.21	9.05
14	8.49	9.47
15	8.97	9.37
16	8.60	9.25
17	8.48	9.08
18	8.45	9.24
19	8.39	8.98
20	8.94	9.28
21	8.05	9.32
22	7.83	9.08
23	8.08	9.22
24	8.45	9.23
25	7.99	9.31
26	7.94	9.08
27	8.28	9.07
28	8.52	9.11
29	8.73	9.17
30	8.10	9.04

Raw Data

		Test P (psi)	
	Tare Weight (lb)	33	36
Emitter #		Gross Weight (lb)	
1	1.24	9.34	10.49
2	1.26	9.26	10.47
3	1.21	9.88	10.31
4	1.26	9.12	10.32
5	1.24	9.55	10.29
6	1.26	9.60	10.38
7	1.22	9.49	10.29
8	1.24	9.48	10.37
9	1.20	9.15	10.30
10	1.22	9.42	10.59
11	1.22	9.06	10.25
12	1.21	9.11	10.30
13	1.25	9.46	10.30
14	1.24	9.73	10.71
15	1.22	10.19	10.59
16	1.23	9.83	10.48
17	1.21	9.69	10.29
18	1.26	9.71	10.50
19	1.22	9.61	10.20
20	1.27	10.21	10.55
21	1.22	9.27	10.54
22	1.25	9.08	10.33
23	1.23	9.31	10.45
24	1.25	9.70	10.48
25	1.22	9.21	10.53
26	1.25	9.19	10.33
27	1.22	9.50	10.29
28	1.28	9.80	10.39
29	1.24	9.97	10.41
30	1.25	9.35	10.29

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	John Deere	
Model	S2000 Blue Nozzle Grey Spinner	
Nominal Q	8.1	GPH
Nominal P		
Spacing	12	inches
Date	4/16/2013	

Test Pressure (psi)	24	16	11	8
Test Duration (min)	7	7	7	7
Min (lb)	7.44	6.44	5.27	4.82
Max (lb)	8.55	7.16	5.65	5.2
Std Dev (lb)	*0.23*	*0.17*	*0.09*	*0.09*
Mean (lb)	*8.27*	*6.88*	*5.49*	*5.08*
cv	**0.028**	**0.024**	**0.017**	**0.017**
Emitter #	Net Weight (lb)			
1	8.15	6.71	5.57	5.17
2	8.50	6.95	5.54	5.15
3	8.50	7.01	5.58	5.01
4	8.23	6.91	5.40	5.04
5	8.40	7.05	5.54	5.12
6	8.48	7.08	5.59	5.20
7	8.23	6.91	5.49	5.13
8	8.30	6.99	5.48	5.10
9	8.09	6.90	5.46	5.07
10	7.44	6.63	5.27	4.91
11	8.24	6.76	5.49	5.13
12	8.43	7.04	5.55	4.82
13	8.17	6.91	5.43	4.99
14	8.24	6.88	5.46	5.13
15	8.49	7.16	5.64	5.19
16	8.43	6.94	5.44	5.05
17	8.36	6.81	5.53	5.20
18	8.17	6.81	5.46	5.05
19	8.50	7.05	5.65	5.19
20	8.40	6.97	5.43	5.06
21	8.47	6.55	5.49	5.08
22	7.95	6.77	5.32	4.97
23	8.41	6.92	5.47	5.11
24	8.17	6.85	5.39	5.00
25	8.23	6.84	5.50	5.10
26	8.25	6.65	5.56	5.04
27	8.55	7.08	5.59	5.14
28	7.99	6.44	5.34	5.03
29	8.02	6.80	5.34	4.98
30	8.41	7.06	5.57	5.11

Raw Data

		Test P (psi)			
	Tare Weight (lb)	24	16	11	8
Emitter #		Gross Weight (lb)			
1	1.24	9.39	7.95	6.81	6.41
2	1.26	9.76	8.21	6.80	6.41
3	1.21	9.71	8.22	6.79	6.22
4	1.26	9.49	8.17	6.66	6.30
5	1.24	9.64	8.29	6.78	6.36
6	1.26	9.74	8.34	6.85	6.46
7	1.22	9.45	8.13	6.71	6.35
8	1.24	9.54	8.23	6.72	6.34
9	1.20	9.29	8.10	6.66	6.27
10	1.22	8.66	7.85	6.49	6.13
11	1.22	9.46	7.98	6.71	6.35
12	1.21	9.64	8.25	6.76	6.03
13	1.25	9.42	8.16	6.68	6.24
14	1.24	9.48	8.12	6.70	6.37
15	1.22	9.71	8.38	6.86	6.41
16	1.23	9.66	8.17	6.67	6.28
17	1.21	9.57	8.02	6.74	6.41
18	1.26	9.43	8.07	6.72	6.31
19	1.22	9.72	8.27	6.87	6.41
20	1.27	9.67	8.24	6.70	6.33
21	1.22	9.69	7.77	6.71	6.30
22	1.25	9.20	8.02	6.57	6.22
23	1.23	9.64	8.15	6.70	6.34
24	1.25	9.42	8.10	6.64	6.25
25	1.22	9.45	8.06	6.72	6.32
26	1.25	9.50	7.90	6.81	6.29
27	1.22	9.77	8.30	6.81	6.36
28	1.28	9.27	7.72	6.62	6.31
29	1.24	9.26	8.04	6.58	6.22
30	1.25	9.66	8.31	6.82	6.36

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	NETAFIM
Model	01PC2
Nominal Q	0.5GPH
Nominal P	-
Spacing	N/A 12IN
Date	3/26/2013

Test Pressure (psi)	24	16	11	8
Test Duration (min)	7.04	7.14	7.2	7.02
Min (mL)	227	232	253	232
Max (mL)	254	255	279	256
Std Dev (mL)	*6.13*	*5.69*	*5.84*	*5.66*
Mean (mL)	*238.77*	*241.77*	*266.30*	*243.57*
cv	**0.026**	**0.024**	**0.022**	**0.023**
Emitter #				
1	232	237	262	232
2	238	242	267	244
3	235	238	262	240
4	243	241	263	241
5	242	249	273	249
6	245	240	267	244
7	234	232	265	234
8	238	244	267	247
9	234	234	268	238
10	244	241	277	245
11	244	244	269	249
12	232	245	268	248
13	240	242	270	248
14	254	255	279	256
15	240	248	267	245
16	234	240	264	244
17	247	243	262	245
18	231	235	256	237
19	241	245	269	246
20	244	251	274	251
21	247	253	275	251
22	239	245	267	248
23	236	240	265	241
24	248	245	270	246
25	234	233	253	232
26	237	239	265	244
27	234	236	260	240
28	237	241	265	244
29	227	236	259	238
30	232	239	261	240

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	NETAFIM
Model	01PC4
Nominal Q	1.0GPH
Nominal P	-
Spacing	12IN
Date	3/28/2013

Test Pressure (psi)	24	16	11	8
Test Duration (min)	6.015	6.25	6.316	
Min (mL)	427	440	447	440
Max (mL)	487	487	487	462
Std Dev (mL)	*14.29*	*11.78*	*10.13*	*6.26*
Mean (mL)	*457.33*	*463.73*	*468.20*	*452.67*
cv	**0.031**	**0.025**	**0.022**	**0.014**
Emitter #				
1	452	462	472	455
2	455	465	467	460
3	465	472	480	462
4	440	450	455	447
5	453	460	465	450
6	453	463	470	455
7	442	450	457	450
8	450	460	465	450
9	460	467	475	457
10	447	455	460	450
11	475	487	485	462
12	475	480	480	462
13	455	467	472	462
14	462	472	477	447
15	450	453	457	447
16	462	470	472	457
17	452	455	460	452
18	460	467	472	445
19	475	475	475	450
20	482	485	487	462
21	487	475	475	457
22	465	467	472	455
23	470	472	475	455
24	455	467	470	452
25	472	472	475	455
26	427	440	450	445
27	455	460	465	442
28	442	447	452	447
29	427	440	447	440
30	455	457	462	450

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Netafim	
Model	01WPC8 Green Base	
Nominal Q	2	GPH
Nominal P		
Spacing	12	inches
Date	5/2/2013	

Test Pressure (psi)	15	25
Test Duration (min)	6.15	6.15
Min (mL)	880	860
Max (mL)	1015	997
Std Dev (mL)	*31*	*29*
Mean (mL)	*935*	*921*
cv	**0.033**	**0.032**
Emitter #		
1	940	915
2	950	937
3	950	930
4	952	940
5	962	952
6	930	922
7	885	860
8	880	880
9	975	955
10	952	930
11	927	910
12	947	935
13	930	925
14	935	920
15	920	905
16	930	905
17	895	895
18	957	940
19	955	940
20	920	897
21	910	892
22	880	872
23	940	930
24	932	910
25	935	925
26	995	977
27	925	900
28	920	900
29	1015	997
30	900	925

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Netafim	
Model	01WPCJL2 Red Base	
Nominal Q	0.5	GPH
Nominal P	10 to 50	psi
Spacing	12	inches
Date	5/17/2013	

Test Pressure (psi)	17	32
Test Duration (min)	6	6
Min (mL)	185	191
Max (mL)	207	219
Std Dev (mL)	*5*	*7*
Mean (mL)	*199*	*207*
cv	**0.027**	**0.036**
Emitter #		
1	198	207
2	201	201
3	198	202
4	204	203
5	195	205
6	198	211
7	195	196
8	185	191
9	203	215
10	207	211
11	200	214
12	201	215
13	197	212
14	198	210
15	198	201
16	202	199
17	205	219
18	191	200
19	188	192
20	206	215
21	201	214
22	196	213
23	194	211
24	198	211
25	193	197
26	196	211
27	203	216
28	205	205
29	206	208
30	198	212

ITRC Cal Poly

Emitter Testing

Emitter Manufacturer	Netafim	
Model	O1WPCJL4 Gray Base	
Nominal Q	1	GPH
Nominal P		
Spacing	12	inches
Date	3/19/2013	

Test Pressure (psi)	14	29
Test Duration (min)	7	7
Min (mL)	440	430
Max (mL)	617	607
Std Dev (mL)	*30*	*30*
Mean (mL)	*473*	*459*
cv	**0.063**	**0.066**
Emitter #		
1	472	460
2	440	430
3	455	452
4	487	445
5	617	607
6	470	480
7	450	450
8	477	440
9	460	455
10	462	447
11	465	455
12	485	450
13	475	462
14	460	455
15	460	447
16	457	445
17	457	445
18	490	440
19	460	482
20	480	447
21	472	470
22	470	462
23	480	450
24	460	462
25	482	455
26	462	447
27	490	452
28	480	472
29	460	460
30	455	450

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Netafim	
Model	01WPCJL8 Green Base	
Nominal Q	2	GPH
Nominal P		
Spacing	12	inches
Date	5/8/2013	

Test Pressure (psi)	11	21
Test Duration (min)	10	10
Min (lb)	2.54	2.69
Max (lb)	3.06	3
Std Dev (lb)	*0.16*	*0.09*
Mean (lb)	*2.79*	*2.86*
cv	**0.057**	**0.031**
Emitter #	Net Weight (lb)	
1	2.71	2.92
2	2.94	2.93
3	2.90	2.91
4	2.91	2.94
5	2.62	2.75
6	2.64	2.79
7	3.06	3.00
8	2.57	2.86
9	2.63	2.76
10	3.02	2.96
11	2.69	2.80
12	2.74	2.81
13	2.71	2.81
14	2.81	2.80
15	2.54	2.69
16	2.87	2.92
17	3.02	3.00
18	3.00	2.94
19	2.63	2.80
20	2.94	2.99
21	2.65	2.76
22	2.71	2.85
23	2.64	2.82
24	2.99	2.99
25	2.68	2.81
26	2.62	2.81
27	2.96	2.95
28	2.91	2.91
29	2.86	2.89
30	2.63	2.73

Raw Data

		Test P (psi)	
	Tare Weight (lb)	11	21
Emitter #		Gross Weight (lb)	
1	1.24	3.95	4.16
2	1.26	4.20	4.19
3	1.21	4.11	4.12
4	1.26	4.17	4.20
5	1.24	3.86	3.99
6	1.26	3.90	4.05
7	1.22	4.28	4.22
8	1.24	3.81	4.10
9	1.20	3.83	3.96
10	1.22	4.24	4.18
11	1.22	3.91	4.02
12	1.21	3.95	4.02
13	1.25	3.96	4.06
14	1.24	4.05	4.04
15	1.22	3.76	3.91
16	1.23	4.10	4.15
17	1.21	4.23	4.21
18	1.26	4.26	4.20
19	1.22	3.85	4.02
20	1.27	4.21	4.26
21	1.22	3.87	3.98
22	1.25	3.96	4.10
23	1.23	3.87	4.05
24	1.25	4.24	4.24
25	1.22	3.90	4.03
26	1.25	3.87	4.06
27	1.22	4.18	4.17
28	1.28	4.19	4.19
29	1.24	4.10	4.13
30	1.25	3.88	3.98

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Netafim	
Model	Supernet Purple Nozzle	
Nominal Q	5.3	GPH
Nominal P	20 to 60	psi
Spacing	12	inches
Date	5/7/2013	

Test Pressure (psi)	33	43
Test Duration (min)		
Min (lb)	6.06	5.91
Max (lb)	7.75	7.88
Std Dev (lb)	*0.31*	*0.37*
Mean (lb)	*6.43*	*6.34*
cv	**0.048**	**0.058**
Emitter #	Net Weight (lb)	
1	6.38	6.45
2	6.51	6.42
3	6.34	6.24
4	6.50	6.48
5	6.46	6.26
6	6.62	6.56
7	6.14	5.93
8	6.09	5.91
9	6.33	6.20
10	7.75	7.88
11	6.54	6.43
12	6.10	6.42
13	6.40	5.91
14	6.67	6.34
15	6.50	6.64
16	6.11	6.48
17	6.13	5.98
18	6.32	5.92
19	6.33	6.32
20	6.35	6.19
21	6.25	6.30
22	6.54	6.15
23	6.58	6.56
24	6.30	6.55
25	6.39	6.28
26	6.56	6.14
27	6.44	6.49
28	6.06	6.26
29	6.79	5.96
30	6.43	6.65

Raw Data

		Test P (psi)	
	Tare Weight (lb)	33	43
Emitter #		Gross Weight (lb)	
1	1.24	7.62	7.69
2	1.26	7.77	7.68
3	1.21	7.55	7.45
4	1.26	7.76	7.74
5	1.24	7.70	7.50
6	1.26	7.88	7.82
7	1.22	7.36	7.15
8	1.24	7.33	7.15
9	1.20	7.53	7.40
10	1.22	8.97	9.10
11	1.22	7.76	7.65
12	1.21	7.31	7.63
13	1.25	7.65	7.16
14	1.24	7.91	7.58
15	1.22	7.72	7.86
16	1.23	7.34	7.71
17	1.21	7.34	7.19
18	1.26	7.58	7.18
19	1.22	7.55	7.54
20	1.27	7.62	7.46
21	1.22	7.47	7.52
22	1.25	7.79	7.40
23	1.23	7.81	7.79
24	1.25	7.55	7.80
25	1.22	7.61	7.50
26	1.25	7.81	7.39
27	1.22	7.66	7.71
28	1.28	7.34	7.54
29	1.24	8.03	7.20
30	1.25	7.68	7.90

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Netafim	
Model	Techline CV	Drk Brwn
Nominal Q	0.61	GPH
Nominal P		
Spacing	12	inches
Date	6/7/2013	
Spagh. Hose length	n/a	inches

Test Pressure (psi)	13	23
Test Duration (min)	6.5	7
Min (ml)	222	242
Max (ml)	243	275
Std Dev (ml)	*4.08*	*5.86*
Mean (ml)	*232.90*	*257.47*
cv	**0.018**	**0.023**
Emitter #	Net Weight (lb)	
1	237	275
2	235	255
3	234	256
4	230	250
5	228	247
6	231	256
7	230	261
8	238	258
9	230	254
10	236	261
11	229	258
12	235	260
13	236	258
14	233	255
15	230	264
16	230	253
17	236	258
18	236	260
19	238	263
20	235	259
21	233	263
22	232	255
23	236	263
24	232	253
25	232	258
26	227	257
27	230	256
28	243	262
29	222	242
30	233	254

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Netafim	
Model	Techline 560	
Nominal Q	0.53	GPH
Nominal P		
Spacing	12	inches
Date	6/7/2013	
Spagh. Hose length	n/a	inches

Test Pressure (psi)	11	21
Test Duration (min)	5.3	5
Min (ml)	193	176
Max (ml)	210	194
Std Dev (ml)	*4*	*5*
Mean (ml)	*200*	*184*
cv	**0.022**	**0.026**
Emitter #	Volume (ml)	
1	194	178
2	197	178
3	195	187
4	202	186
5	203	185
6	206	189
7	200	184
8	201	184
9	199	185
10	196	180
11	200	183
12	204	190
13	200	183
14	196	183
15	203	184
16	194	176
17	203	188
18	195	177
19	197	179
20	193	181
21	210	194
22	194	177
23	194	176
24	202	186
25	203	187
26	204	189
27	195	178
28	201	187
29	201	189
30	204	189

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Olson	
Model	Vibra-Clean	Blue
Nominal Q	1	GPH
Nominal P		
Spacing	12	inches
Date	5/31/2013	
Spagh. Hose length	n/a	inches

Test Pressure (psi)	31	41
Test Duration (min)		
Min (ml)	362	350
Max (ml)	400	452
Std Dev (ml)	*8*	*18*
Mean (ml)	*379*	*373*
cv	**0.021**	**0.049**
Emitter #	Volume (mL)	
1	390	360
2	375	395
3	370	357
4	385	365
5	370	377
6	375	355
7	380	370
8	400	365
9	377	390
10	377	370
11	375	370
12	385	452
13	382	382
14	392	375
15	385	385
16	362	377
17	380	360
18	380	370
19	367	367
20	382	362
21	370	367
22	380	357
23	382	375
24	387	370
25	380	380
26	375	360
27	370	375
28	380	350
29	385	372
30	375	372

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Plastro
Model	Hydro PC
Nominal Q	0.95 GPH
Nominal P	12-50 psi
Spacing	12 in
Date	3/14/2013

Test Pressure (psi)	30	24	16	11	8
Test Duration (min)	7	7	7	7	7
Min (mL)	352	347	320	320	320
Max (mL)	430	417	407	395	370
Std Dev (mL)	*19.52*	*18.71*	*19.62*	*17.27*	*12.02*
Mean (mL)	*392.23*	*381.30*	*370.63*	*363.73*	*347.50*
cv	**0.050**	**0.049**	**0.053**	**0.047**	**0.035**
Emitter #					
1	375	380	395	380	360
2	397	382	390	368	360
3	377	367	355	355	340
4	395	387	376	370	370
5	420	407	380	376	355
6	392	377	385	364	350
7	415	395	357	355	335
8	412	382	385	375	360
9	370	362	370	360	335
10	382	362	370	355	330
11	380	348	325	320	328
12	390	375	405	380	358
13	415	372	360	355	345
14	407	390	380	377	350
15	405	402	368	365	348
16	400	390	365	365	350
17	352	377	320	325	320
18	372	347	360	344	330
19	362	348	355	345	340
20	357	370	370	357	345
21	405	402	363	360	348
22	380	377	350	355	345
23	395	392	370	368	350
24	415	417	407	395	360
25	372	392	370	365	345
26	395	367	365	350	340
27	400	370	368	368	345
28	430	412	395	395	365
29	405	410	390	390	363
30	395	380	370	375	355

ITRC Cal Poly
Emitter Testing - Cal Poly ITRC

Emitter Manufacturer	RainBird
Model	A5 PC
Nominal Q	0.53 GPH
Nominal P	7-60 psi
Spacing	36 in
Date	3/18/2013

Re-Test 4/9/13

(yellow) The 24 psi cv test was conducted again after finishing the 30, 24, 16, 11, and 8

(green) 24 psi cv test was conducted again after running the emitters overnight

Test Pressure (psi)	24	16	11	8
Test Duration (min)	7	7	7	7
Min (mL)	200	217	226	220
Max (mL)	276	250	253	242
Std Dev (mL)	*14.31*	*8.19*	*6.53*	*5.73*
Mean (mL)	*233.13*	*237.97*	*242.07*	*232.90*
cv	**0.061**	**0.034**	**0.027**	**0.025**
Emitter #				
1	200	238	238	233
2	244	236	240	232
3	222	228	246	240
4	240	232	240	234
5	244	226	245	231
6	212	242	248	230
7	230	249	245	238
8	237	244	245	242
9	225	250	238	238
10	230	244	227	233
11	235	230	244	226
12	240	226	244	241
13	215	235	232	234
14	238	241	252	223
15	246	217	242	240
16	235	234	246	229
17	216	242	241	230
18	235	228	240	231
19	232	238	226	229
20	226	237	245	224
21	247	246	241	232
22	228	244	253	233
23	276	250	238	242
24	252	245	247	234
25	225	236	243	230
26	231	238	231	234
27	217	240	251	228
28	248	246	247	242
29	234	247	242	234
30	234	230	245	220

Test Pressure (psi)	30	24	24 b	24c	16	11	8
Test Duration (min)	7	7	7	7	7	7	7
Min (mL)	219	222	220	212	227	225	228
Max (mL)	261	248	253	261	245	240	246
Std Dev (mL)	*8.16*	*6.55*	*7.19*	*10.52*	*5.18*	*4.56*	*4.63*
Mean (mL)	*245.93*	*235.23*	*236.50*	*245.63*	*236.57*	*231.73*	*235.83*
cv	**0.033**	**0.028**	**0.030**	**0.043**	**0.022**	**0.020**	**0.020**
Emitter #							
1	244	231	237	252	235	232	233
2	239	230	221	248	235	226	237
3	248	231	233	248	240	229	234
4	243	234	232	212	230	227	230
5	254	247	244	251	245	238	240
6	247	234	238	232	232	228	235
7	248	234	223	249	235	232	238
8	253	247	242	248	243	237	244
9	250	235	242	250	238	236	238
10	244	225	234	244	236	226	233
11	250	239	242	252	236	235	235
12	233	235	238	243	234	230	232
13	250	240	245	253	234	227	233
14	240	230	228	247	227	227	232
15	237	231	238	261	242	233	239
16	248	237	239	247	240	233	234
17	252	243	241	257	243	239	245
18	242	236	234	242	234	225	233
19	237	230	232	217	227	226	230
20	245	244	237	245	244	240	242
21	249	239	239	248	236	230	230
22	256	238	244	247	242	236	246
23	256	243	242	253	243	238	242
24	241	233	235	235	234	232	235
25	246	230	232	245	236	232	234
26	245	222	233	242	232	229	234
27	246	234	237	239	228	225	228
28	261	248	253	258	243	234	236
29	219	229	220	251	233	237	239
30	255	228	240	253	240	233	234

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Toro	
Model	Drip In-PC Inline Emitter	
Nominal Q	0.53	GPH
Nominal P		
Spacing	12	inches
Date	6/6/2013	
Spagh. Hose length	n/a	inches

Test Pressure (psi)	16	26
Test Duration (min)	5.3	5
Min (ml)	169	154
Max (ml)	230	207
Std Dev (ml)	*16*	*13*
Mean (ml)	*200*	*181*
cv	**0.079**	**0.070**
Emitter #		
1	187	167
2	224	196
3	192	166
4	189	170
5	196	182
6	211	182
7	184	166
8	198	182
9	196	174
10	206	180
11	196	188
12	217	190
13	230	207
14	194	180
15	176	173
16	187	166
17	183	162
18	208	182
19	195	185
20	207	186
21	218	192
22	176	191
23	215	173
24	184	188
25	218	163
26	208	191
27	217	184
28	218	198
29	169	200
30	210	154

ITRC Cal Poly
Emitter Testing

Emitter Manufacturer	Toro		
Model	Waterbird VI-PC Light Green Nozzle		
Nominal Q	14.5	GPH	55 LPH
Nominal P	20	psi	
Spacing	12	inches	
Date	5/10/2013		

Test Pressure (psi)	27	37
Test Duration (min)	6	6
Min (lbs)	10.54	11.01
Max (lbs)	12.18	13.01
Std Dev (lbs)	*0.38*	*0.43*
Mean (lbs)	*10.95*	*11.51*
cv	**0.035**	**0.037**
Emitter #	Net Weight (lbs)	
1	10.87	11.21
2	11.22	11.42
3	11.24	11.77
4	10.95	11.70
5	10.97	11.51
6	10.76	11.59
7	11.14	11.29
8	10.59	11.69
9	11.09	11.20
10	11.05	11.56
11	10.98	11.56
12	10.54	11.64
13	10.76	11.01
14	11.02	11.32
15	10.78	11.53
16	10.57	11.33
17	10.77	11.11
18	11.22	11.24
19	10.86	11.69
20	10.75	11.53
21	10.75	11.26
22	10.86	11.36
23	10.81	11.34
24	10.60	12.78
25	10.94	11.49
26	12.15	13.01
27	12.18	11.28
28	10.71	11.07
29	10.59	11.33
30	10.90	11.41

Raw Data

		Test P (psi)	
	Tare Weight (lb)	27	37
Emitter #		Gross Weight (lb)	
1	1.24	12.11	12.45
2	1.26	12.48	12.68
3	1.21	12.45	12.98
4	1.26	12.21	12.96
5	1.24	12.21	12.75
6	1.26	12.02	12.85
7	1.22	12.36	12.51
8	1.24	11.83	12.93
9	1.20	12.29	12.40
10	1.22	12.27	12.78
11	1.22	12.20	12.78
12	1.21	11.75	12.85
13	1.25	12.01	12.26
14	1.24	12.26	12.56
15	1.22	12.00	12.75
16	1.23	11.80	12.56
17	1.21	11.98	12.32
18	1.26	12.48	12.50
19	1.22	12.08	12.91
20	1.27	12.02	12.80
21	1.22	11.97	12.48
22	1.25	12.11	12.61
23	1.23	12.04	12.57
24	1.25	11.85	14.03
25	1.22	12.16	12.71
26	1.25	13.40	14.26
27	1.22	13.40	12.50
28	1.28	11.99	12.35
29	1.24	11.83	12.57
30	1.25	12.15	12.66