Pressure Compensating Emitter Characteristics

Charles M. Burt, Ph.D., P.E.
Chairman, Irrigation Training & Research Center (ITRC), California Polytechnic State University (Cal Poly), San Luis Obispo, CA 93407-0730, cburt@calpoly.edu

Kyle Feist
Engineer, Cal Poly ITRC, San Luis Obispo, CA 93407-0730

Abstract. *If a PC (pressure compensating) emitter can "lock in" to its design flow at a low pressure, the overall pressure requirement into a hose can be reduced. Twenty-eight (28) common PC emitter and PC microsprayer models from a range of manufacturers were tested to determine the minimum operating pressures, as well as the factors that impact uniformity (coefficient of variation at various pressures, and how steady the flows remain at various pressures). Implications on energy consumption are discussed. Many of the low flow PC emitters had remarkably constant flow rates above some minimum compensating inlet pressure (MCIP), although microsprayers tended to have poorer performances. Some PC emitters do not deliver the average flow rate that is advertised.*

Keywords. Pressure compensating emitter, microsprayer, pressure compensation, irrigation, drip irrigation, micro irrigation

Introduction

The Irrigation Training & Research Center (ITRC) of California Polytechnic State University San Luis Obispo (Cal Poly) tested 28 different pressure-compensating (PC) models of drip/micro irrigation emission devices from a total of nine manufacturers in order to compare independent laboratory testing with manufacturer specifications.

Pressure compensating (PC) 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 on 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.

This paper focuses on three aspects of PC emitter performance:

- 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).

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

Testing

The testing of pressure compensating emitters is sometimes 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 and "conditioned" under pressure for a minimum of 18 hours. Discussions with manufacturers led to an increase in the flushing and "conditioning" duration to a minimum of 48 hours. The majority of models were retested after being flushed for an additional 48 hour period. Table 1 lists the conditioning 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. Detailed testing protocol, including a description of equipment used, can be found in a more detailed report on ITRC's website (www.itrc.org).

Table 1. 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	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
Netafim Techline 560 Hose Brown		X
Netafim Techline CV Hose Brown		X
Olson Irrigation Vibra-Clean Emitter, Blue	X	X
Plastro HydroPC	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

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.

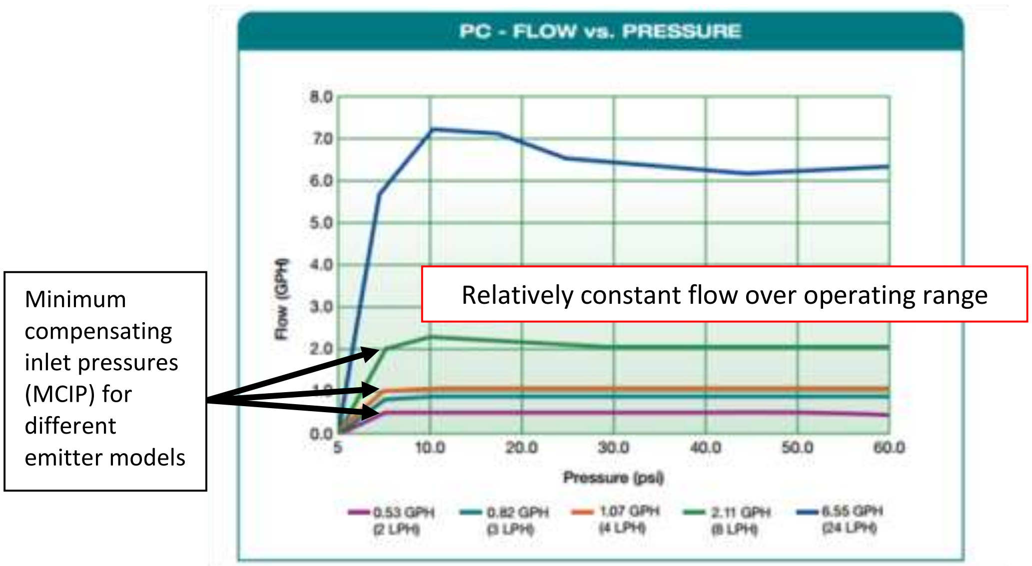

Figure 1. Sample manufacturer graph of emitter discharges over a range of inlet pressures (from Eurodrip USA)

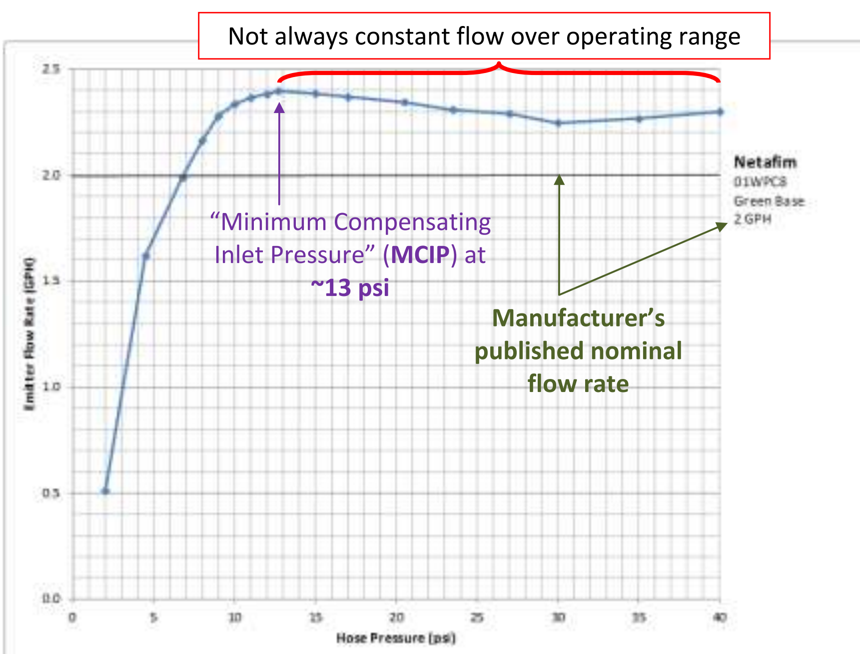

Figure 2. Example graph to illustrate key test items. It should be noted that most of the Netafim products showed excellent results.

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

1. 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 dotted line flattens out. The exact MCIP is somewhat subjective because of the nature of the curves.
2. The ability of the emitting device to meet its nominal flow rate. On the graph, this is determined by the dotted line's distance above or below the straight black line of the nominal flow rate.
3. 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 dotted 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 using the following formula:

$$cv = \frac{standard\ deviation}{mean} \qquad \text{(Eq. 1)}$$

Where,

Standard deviation is the standard deviation of individual emitter discharges

Mean is 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 2, models that had a faulty emitter in the test group are denoted by an asterisk (*).

Table 2. 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 manufacturer 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	25	15	18.5	18.5	0.0%	0.055	0.069

	Orange Nozzle							
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	10.7	6.9%	0.188*	0.106*
Jain	Eliminator (Orange)	25	22	18.5	19.4	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
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%	0.270	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*
Plastro	HydroPC	10	11.8	0.95	0.85	-11.8%	0.047**	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 that emitter had functioned properly
** Three models were tested after operating for a minimum of 18 hours; the remaining models were operated for 48 hours before testing.

Conclusion

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. Low 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. Few microsprayers had excellent PC performance.
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
    b. *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. 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.

Graphs of results can be found in Figures 3-7.

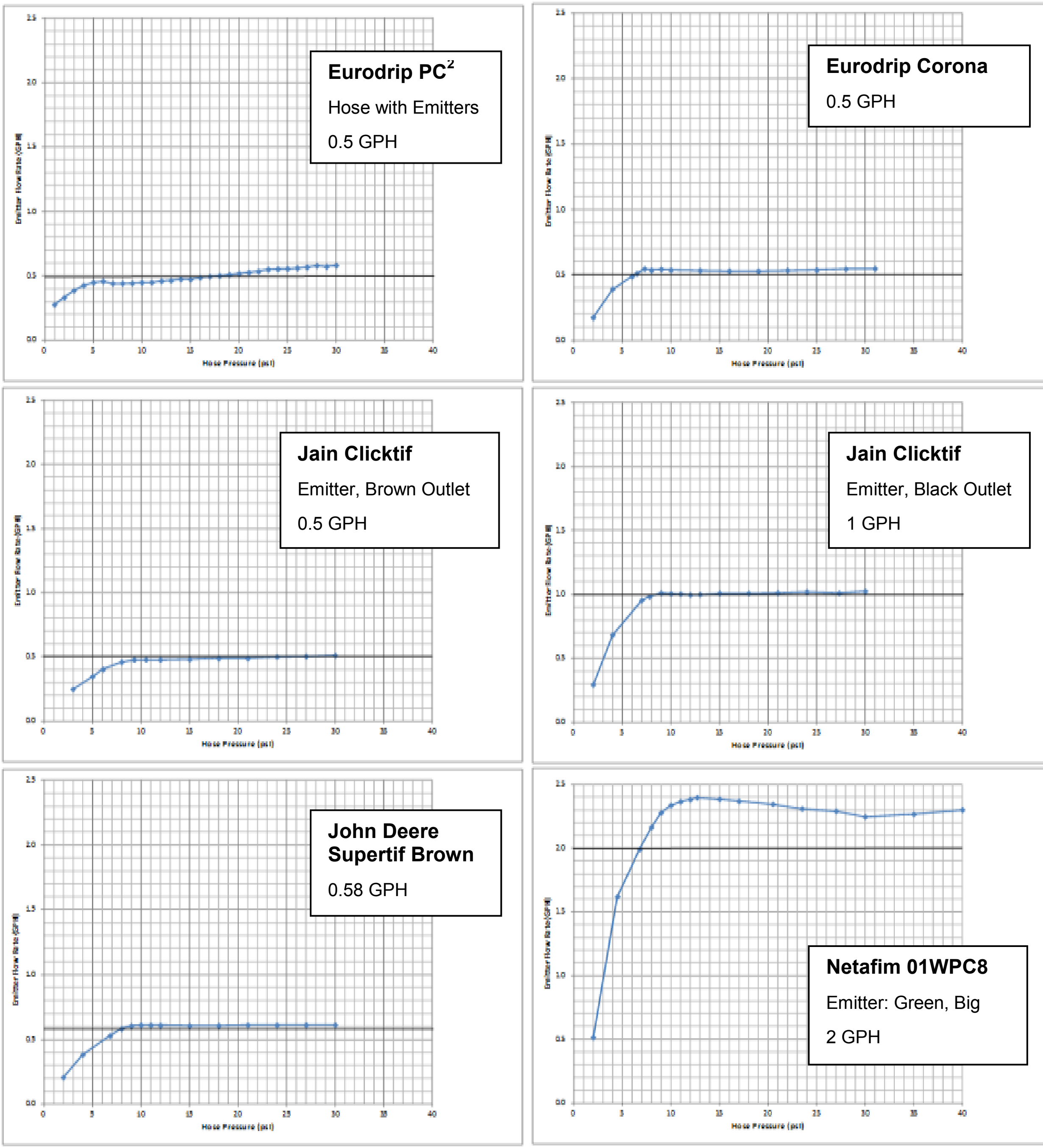

Figure 3. Flow regulation at various inlet pressures with low flow emitters

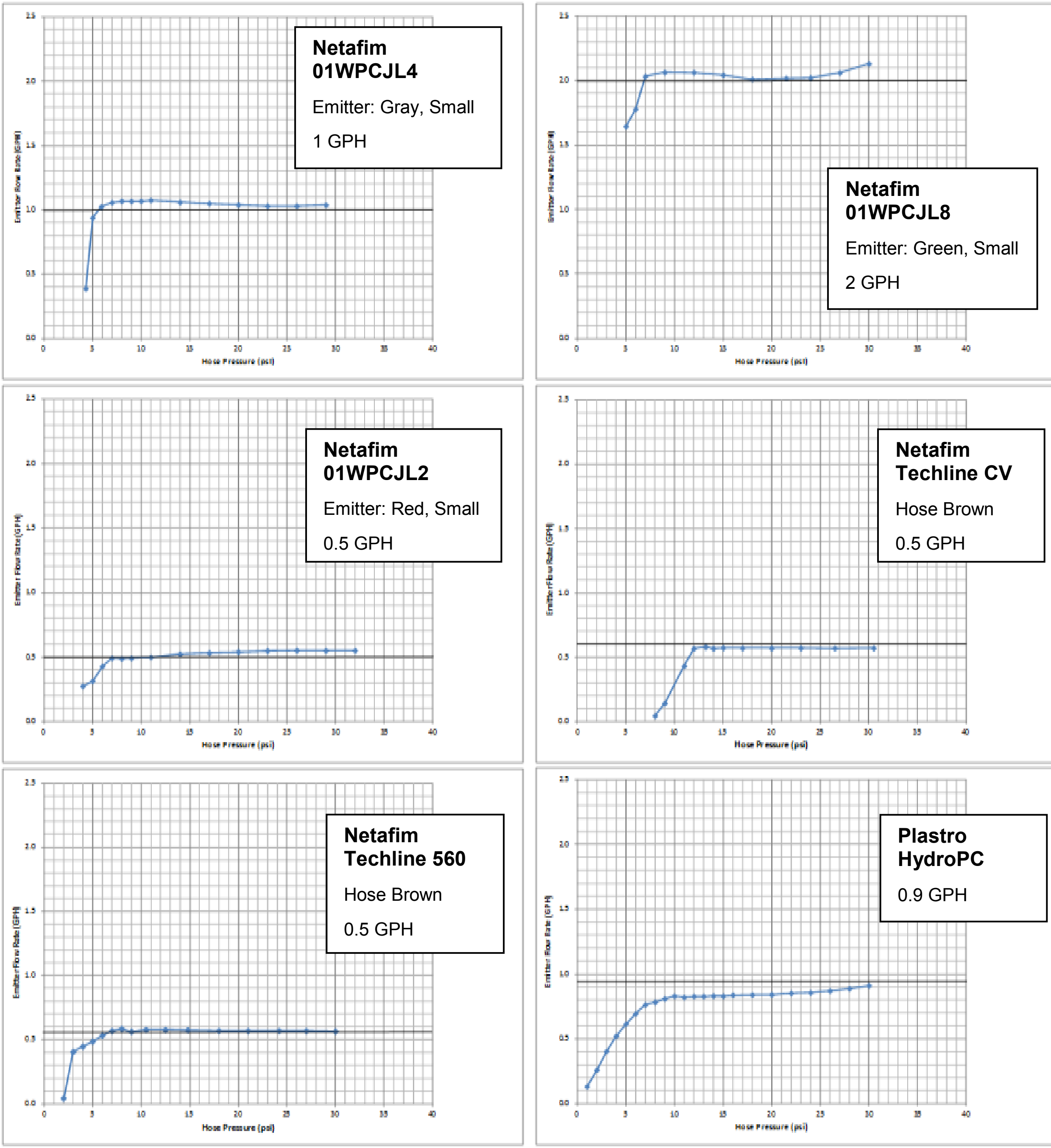

Figure 4. Flow regulation at various inlet pressures with <u>low</u> flow emitters (2)

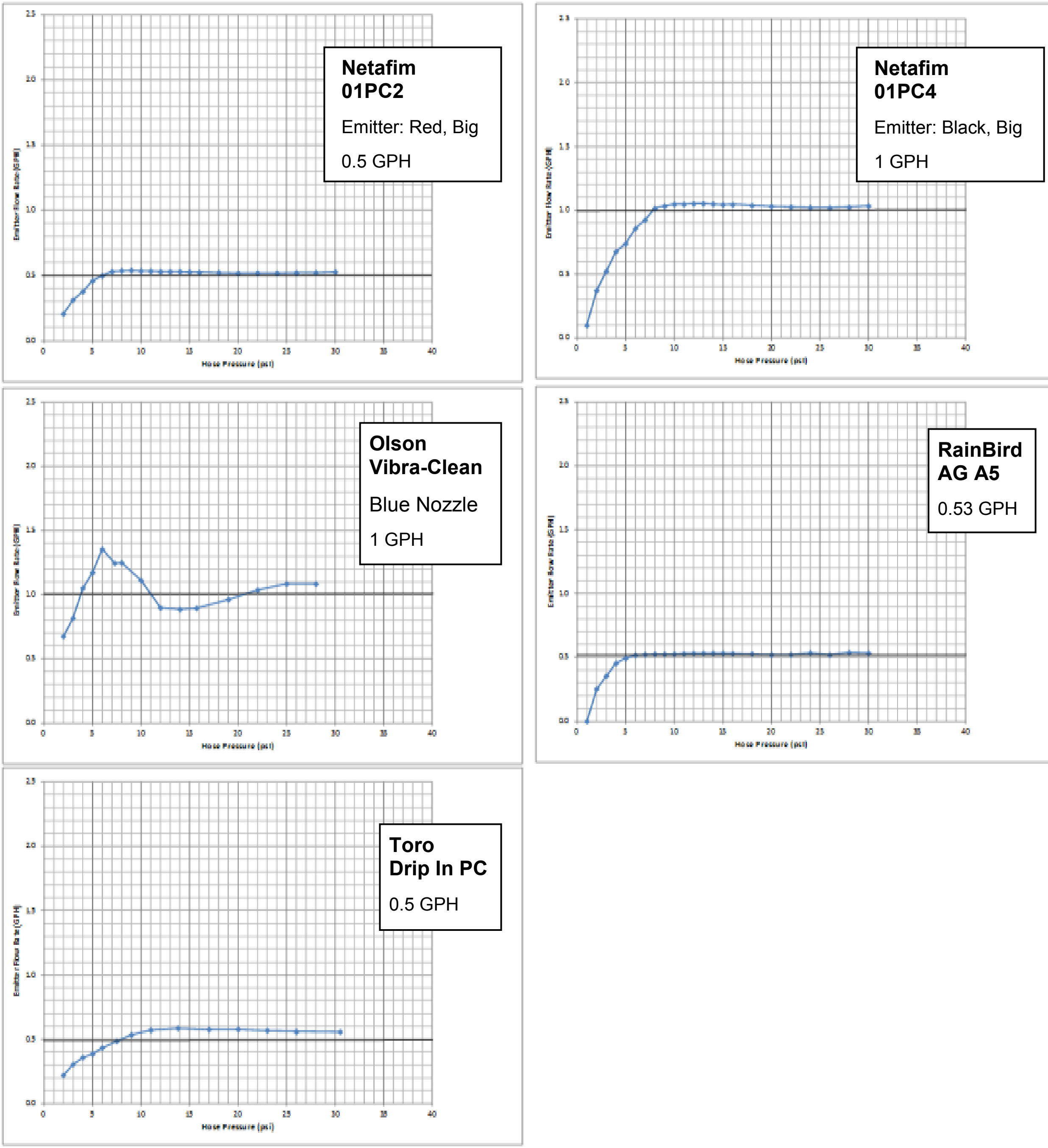

Figure 5. Flow regulation at various inlet pressures with <u>low</u> flow emitters (3)

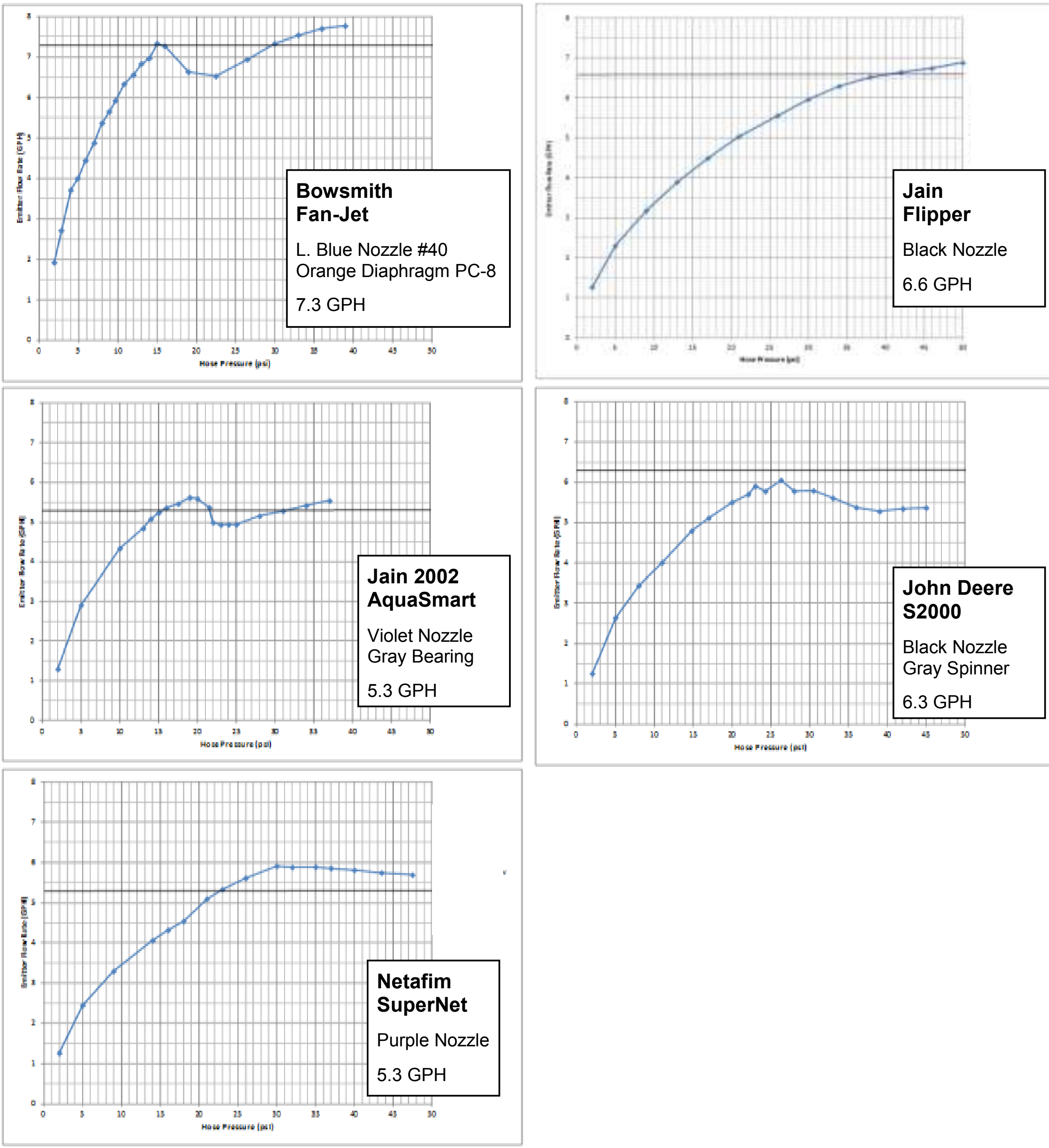

Figure 6. Flow regulation at various inlet pressures with <u>medium</u> flow emitters

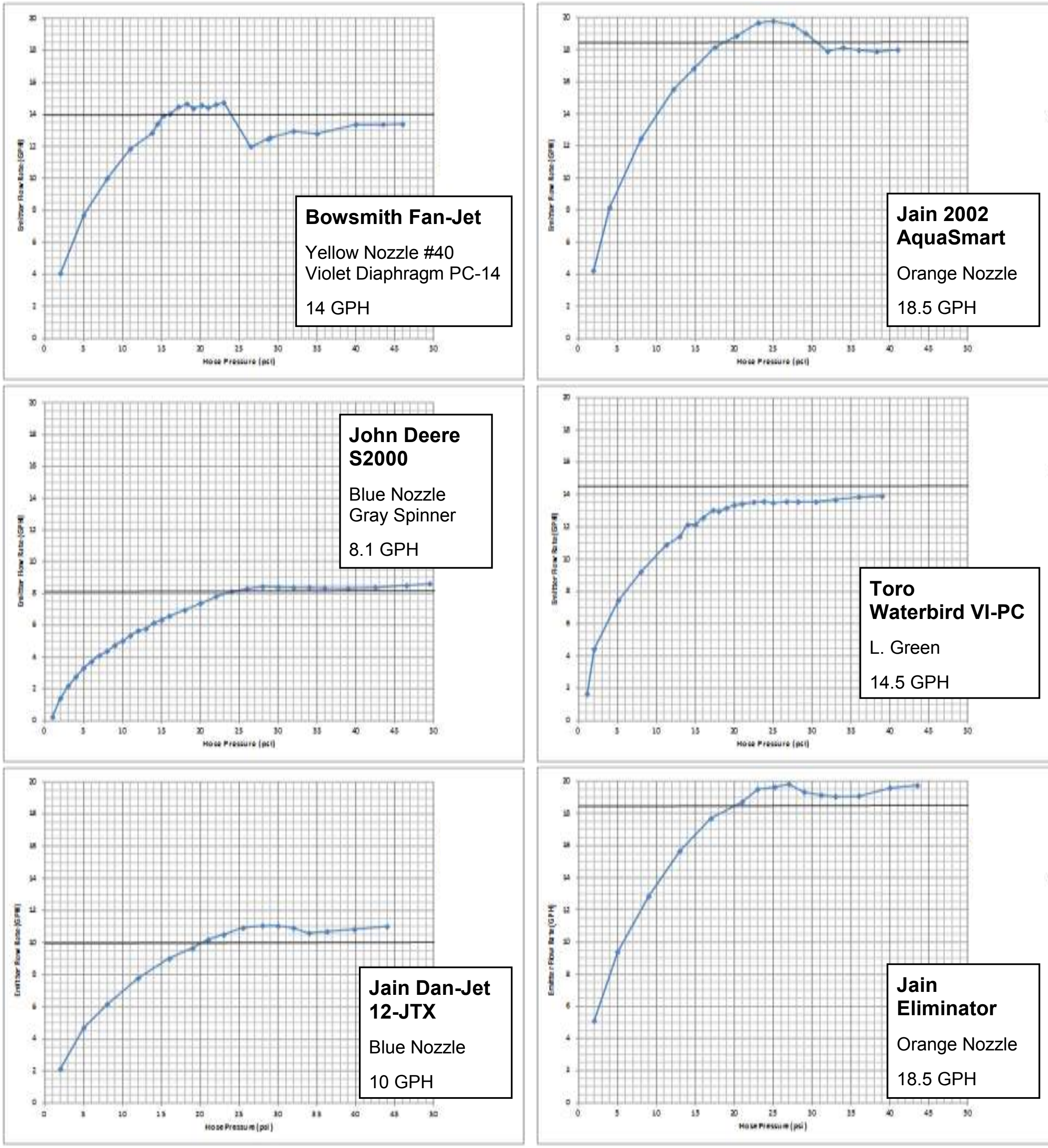

Figure 7. Flow regulation at various inlet pressures with <u>high</u> flow emitters