

Pressure Regulating Valve 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. *The Cal Poly ITRC tested performance characteristics of pressure regulating valves from a variety of manufacturers. The purpose of the testing was to evaluate the ability of different models of valves to regulate the pressure in a low-pressure system. The testing concentrated on three specific valve performance characteristics: minimal variance from the target downstream pressure caused by changes in flow rate or inlet pressure; minimal hysteresis in outlet pressures; and minimal pressure loss (at low inlet pressures) across the valve. The testing indicated that valves with 2-way pilots are not suited for truly low pressure systems due to an inherently higher pressure differential. However, most of the comparable valves with 3-way pilots have the ability to maintain an outlet pressure of +/- 1.5 psi.*

Keywords. Pressure regulating valve, microsprayer, pressure compensation, irrigation, drip irrigation, micro irrigation

Introduction

Agricultural irrigation systems, especially drip and microirrigation systems, require constant pressures in order to avoid variations in application rates or pipe breaks due to sudden pressure surges (called “water hammer”). Therefore, in areas where pressure drops or surges are common, pipelines to the irrigation system often require pressure regulating valves at the heads of submains or manifolds.

Pressure regulating (PR) valves have a two-fold purpose for agricultural irrigation: they must be able to maintain a pre-set maximum operating pressure in the water line downstream of themselves, and they also serve as isolation valves that can be used to turn an irrigation system or block on and off. Since all pressure regulating valves currently on the market can successfully provide on/off control, the testing conducted by ITRC focused solely on measuring the performance of the valves’ pressure regulation.

An “ideal” PR valve should provide sufficient performance in the following areas:

- *Minimal variance from the target downstream pressure caused by changes in flow rate or inlet pressure.* In other words, regardless of increases in the pressure or flow rate upstream of the valve (the valve’s “inlet pressure”), the valve must be able to maintain the maximum pressure in the downstream pipeline (the valve’s “outlet pressure”).
- *Minimal hysteresis in outlet pressures caused by cyclical (on/off) operation as exhibited between irrigation events.* Irrigation systems undergo frequent pressure changes due to blocks or systems turning on and off, backflushing filters, plugged emitters, or other reasons. The pressure regulating valve must be able to respond quickly to changing flow rates and pressures with minimal variations in performance.
- *Minimal pressure loss (at low inlet pressures) across the valve to enable low pump outlet pressures.* All pressure regulating valves require an inlet pressure that is larger than the

target outlet pressure. The “pressure loss across the valve” is the difference between the target outlet pressure and the minimum inlet pressure required to produce a constant outlet pressure. In an ideal PR valve, the loss would be minimal, meaning that the valve would not require much excess inlet pressure in order to maintain a low outlet pressure.

Tests

ITRC created three separate tests to measure the performance characteristics of each pressure regulating valve based upon the points above. The three tests were designed to determine the following characteristics:

- (1) The ability of pressure regulating valves to maintain a constant outlet pressure, with changes in upstream inlet pressures.
- (2) The ability of pressure regulating valves to maintain a constant outlet pressure, with changes in flow rates.
- (3) The minimum inlet pressure required to regulate an outlet pressure of 13 psi at various flow rates

Valve Assortment

The valves tested by ITRC were provided by manufacturers, distributors and irrigation dealers specifically for this project. Product representatives and dealers were given a specific description regarding the constraints of the testing and the expected abilities of the valves to perform at low inlet and outlet pressures. A variety of valve configurations and sizes were received by ITRC for testing that produced a range of results, sometimes directly related to the valve size or configuration.

ITRC used all valves received in Test 1. During the test, two issues became apparent:

- Pressure regulating valves are commonly controlled by either a 2-way pilot or a 3-way pilot. Due to the design characteristics of the 2-way pilot valves, none of the 2-way pilot valves were able to perform within the requirements of a true low pressure system application, but instead all required a substantial pressure loss across the valve body to enable downstream pressure regulation. Therefore, it was determined that ***two-way pilot valves are not suited to low-pressure system applications.***
- Multiple valves were received by ITRC with incorrect hardware combinations such as pilot springs and diaphragms, which negatively affected the performance of the valves. ITRC was able to identify certain elements that made these valve combinations unsuitable for low-pressure system applications.

As a result of the two discoveries mentioned above, only ***correctly-equipped 3-way pilot valves*** were used for Tests 2 and 3.

Test Results

Test 1: Performance with Changing Inlet Pressures

The intention of the first test was to start testing the valves at an inlet pressure above a low pressure system target level (13 psi), and then slowly decrease the inlet pressure until the inlet pressure reached 10 psi, forcing the valve to fully open in order to attempt to regulate the outlet pressure. Then, the flow was slowly increased until it reached the original test starting pressure. After the initial pilot adjustments, the pilot setting was not adjusted throughout the test.

As seen in Figure 2, the graphs provided were intended to show two lines: The blue line represents the valve’s outlet pressure in relation to the inlet pressure as the inlet pressure decreases. The red line represents the outlet pressure as the inlet pressure increases back to

the test's starting pressure. A "good" valve performance would look something like the graph in Figure 2, where the valve is able to maintain the target pressure relatively well until the inlet pressure drops to slightly above to the target outlet pressure, and the valve can no longer regulate. Then, a well-performing valve should be able to repeat the same relationship in reverse, as the pressure increases again (i.e., with minimal *hysteresis*).

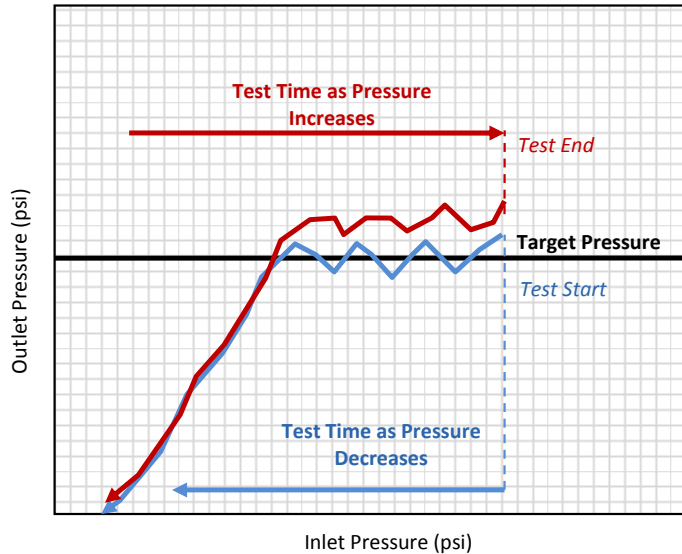


Figure 1. Example Test 1 graph

Pressure Regulating Valves with 2-Way Pilots

ITRC was supplied with PR valves that were plumbed with 2-way pilots. As shown in the following graphs, none of the 2-way pilot valves were able to perform satisfactorily during Test 1, because all of the models required inlet pressures that were significantly higher than the "low-pressure" test scenario of a 13 psi target outlet pressure.

Two-way pilot PR valves are much better suited for situations where the inlet pressure is substantially higher than the target outlet pressure. However, since this set of tests was focused on low-inlet pressure applications, testing on these models was halted after the first half of Test 1, and none of the valves with 2-way pilots were included in Tests 2 and 3. Therefore, the graphs for the 2-way pilot designs only show the results of the decreasing-pressure part of Test 1.

Table 1 lists the 2-way pilot models and their performance graphs are included in Figure 2.

Table 1. List of pressure regulating valve models with 2-way pilot designs used in Test 1

Manufacturer	Model	Size (in.)	Pilot Type	Pilot Model	Spring Model	Spring P Range (psi)	Diaphragm Type
Bermad	IR-120	4	2-way	PC-20	K	7 to 45	Standard
Bermad	IR-120	6	2-way	PC-20	K	7 to 45	Standard
John Deere	V2000	3	2-way/3-way hybrid	T	Standard	7 to 44	Standard

Oval	PH3N00G001	3	2-way	P-21	Blue	7 to 144	Standard
Oval	PH0400G001	4	2-way	P-21	Red	7 to 220	Standard
Oval	ZH3NRDTWO2	3	2-way	P-21	Blue	7-145	Standard
Oval	ZH3NRDTWO2	3	2-way	P-21	Red	7 to 220	Standard
Oval	ZH04RDG001	4	2-way	P-21	Red	7 to 220	Standard

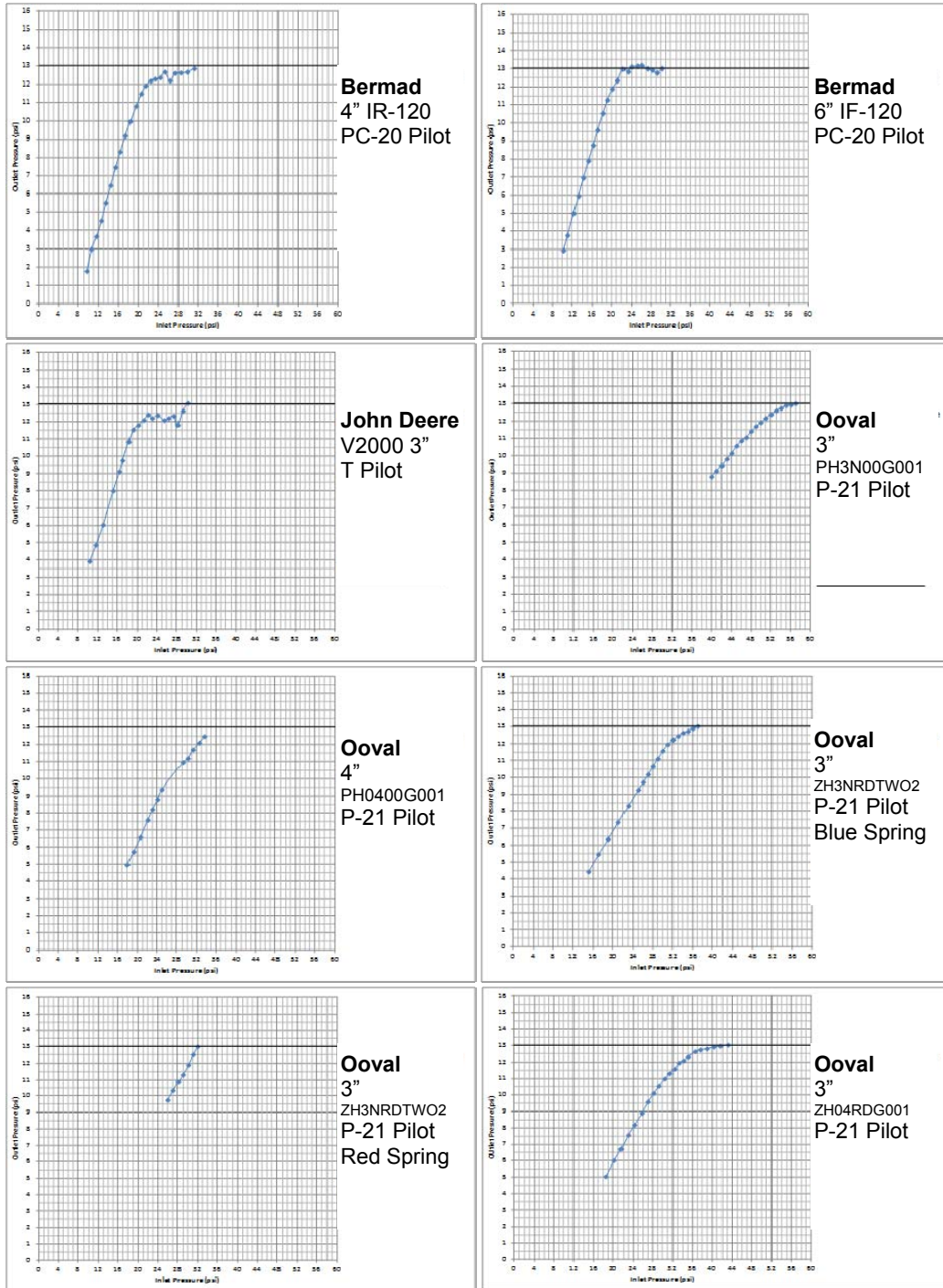


Figure 2. Pressure regulating valve models with 2-way pilot designs used in Test 1

Pressure Regulating Valves with Incorrect Configurations

Four of the PR valves received showed erratic results during Test 1. Upon further inspection, it was apparent that all four had arrived with the incorrect hardware for the testing configurations: three contained diaphragms for high inlet pressure applications, and one had a high-pressure pilot spring. Therefore, these four valves were not used for Tests 2 and 3.

Table 2 lists the low-performing valves used in Test 1, and their performance graphs are shown in Figure 3.

Table 2. List of pressure regulating valve models with incorrect hardware used in Test 1

Manufacturer	Model	Size (in.)	Pilot Type	Pilot Model	Spring Model	Spring P Range (psi)	Diaphragm Type	Hardware Issue
Dorot	Series 100	3	3-way	29-100	Yellow	7 to 30	032 (HP)	HP Diaphragm
Dorot	Series 100	4	3-way	29-100	Yellow	7 to 30	032 (HP)	HP Diaphragm
Dorot	Series 100	4	3-way	29-100	Yellow	7 to 44	032 (HP)	HP Diaphragm
Ooval	ZH04RDG001	3	3-way	P-31	Red	8-88	Standard	HP Pilot Spring

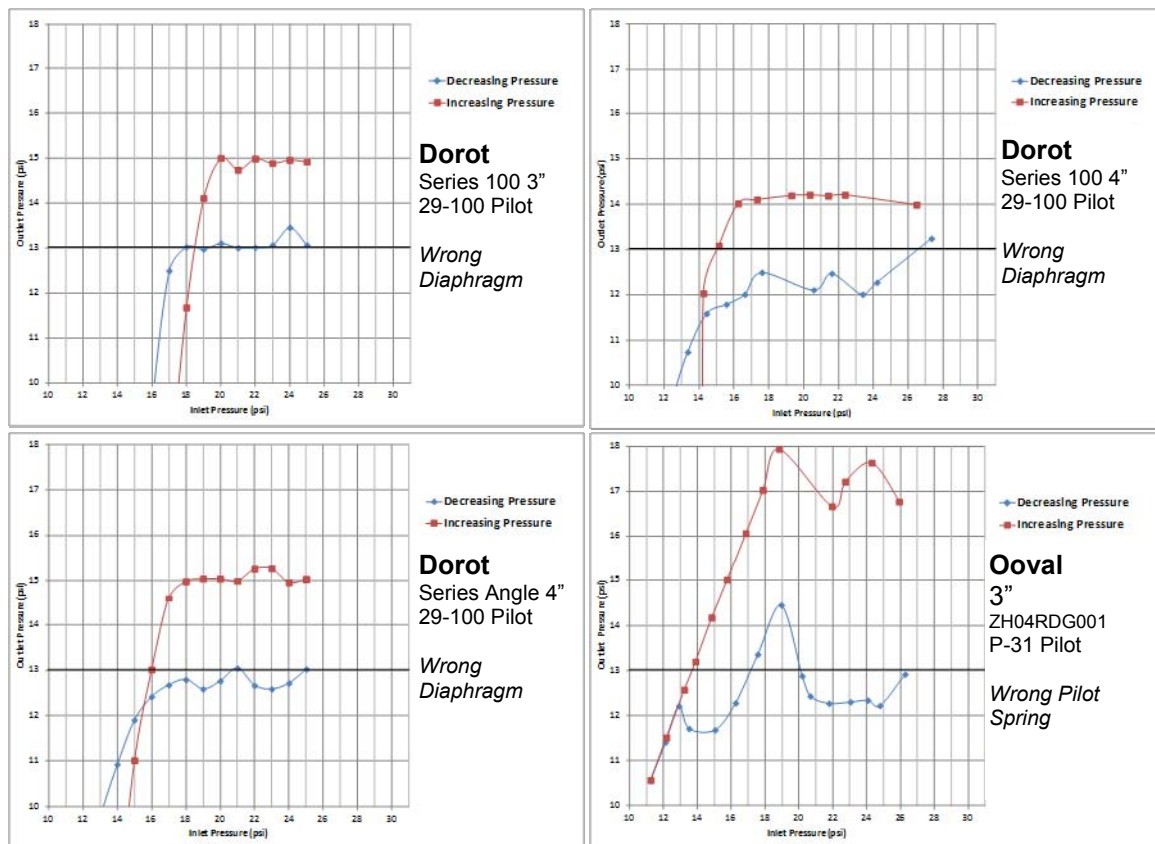


Figure 3. Pressure regulating valve models with incorrect hardware used in Test 1

Pressure Regulating Valves with 3-Way Pilots and Correct Design

Fourteen of the pressure regulating valves provided to ITRC for testing contained 3-way pilots and the appropriate design for the low inlet pressure test scenarios (see Table 3). Three of the valves performed poorly despite having the correct hardware, and were not carried forward to Test 2 and Test 3. Performance graphs for these valves are included in Figure 4 through Figure 5.

Table 3. List of appropriate valves used in Test 1

Valve ID	Manufacturer	Distributor	Model	Size	Pilot Type	Pilot Model	Spring Model	Spring P Range (psi)	Diaphragm Type
5-A*	Bermad	Bermad	IR-120	6	3-way	PC-X	K	7 to 45	Standard
4-A	Bermad	Bermad	IR-120	4	3-way	PC-X-A-P	K	7 to 45	Standard
4-B	Dorot	Netafim	Series 96	4	3-way	29-100	Yellow	7 to 30	095 (HP)
4-C*	Dorot	Netafim	Series 96	4	3-way	31-310	Yellow	7 to 30	095 (HP)
4-D	Dorot	Netafim	Series 96	4	3-way	31-310	Yellow	7 to 30	179 (LP)
4-E	Dorot	Netafim	100	4	3-way	29-100	Yellow	7 to 30	005 (LP)
4-F	Nelson	Nelson	800	4	3-way	Standard	Standard	5 to 50	Standard
4-G	Ooval	Eurodrip	PH0400G001	4	3-way	P-31	Blue	5 to 36	Standard
4-H	Ooval	Eurodrip	ZA04RDA001L	4	3-way	P-31	Blue	5 to 36	Standard
4-I	Rafael	Jain	RAF-P	4	3-way	PC	Blue	7 to 22	Standard
3-A	Bermad	Bermad	DN80	3	3-way	PC-X-A-P	K	7 to 45	Standard
3-B	Dorot	Netafim	Super Gal	3	3-way	29-100	Yellow	7 to 30	Standard
3-C	Ooval	EuroDrip	ZH3NRDG001	3	3-way	P-31	Blue	5 to 36	Standard
3-D	Rafael	Jain	RAF-P	3	3-way	PC	Blue	7 to 22	Standard

*Three valves tested did not perform well during Test 1; therefore, these valves were not tested further

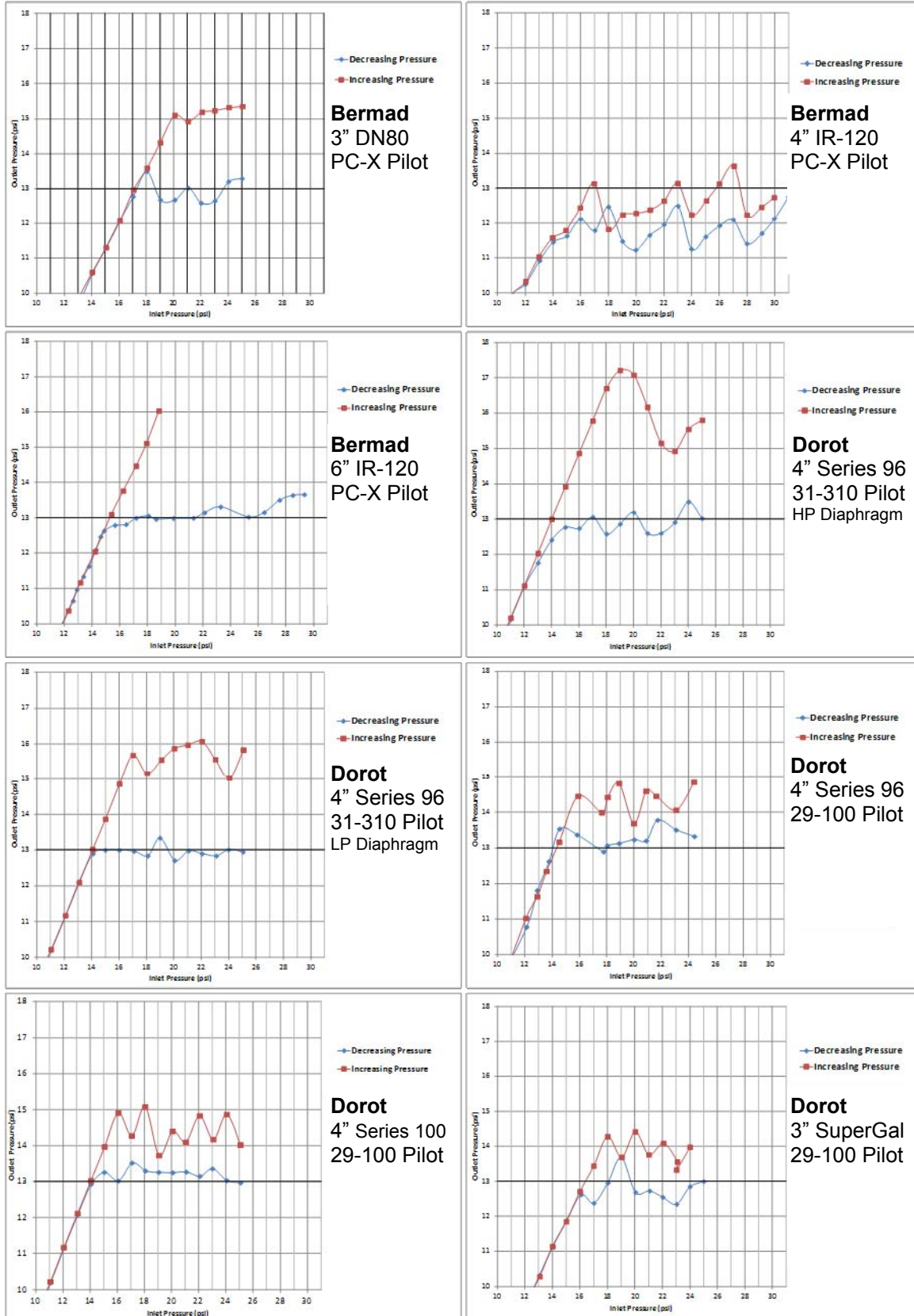


Figure 4. Appropriately configured valves used in Test 1

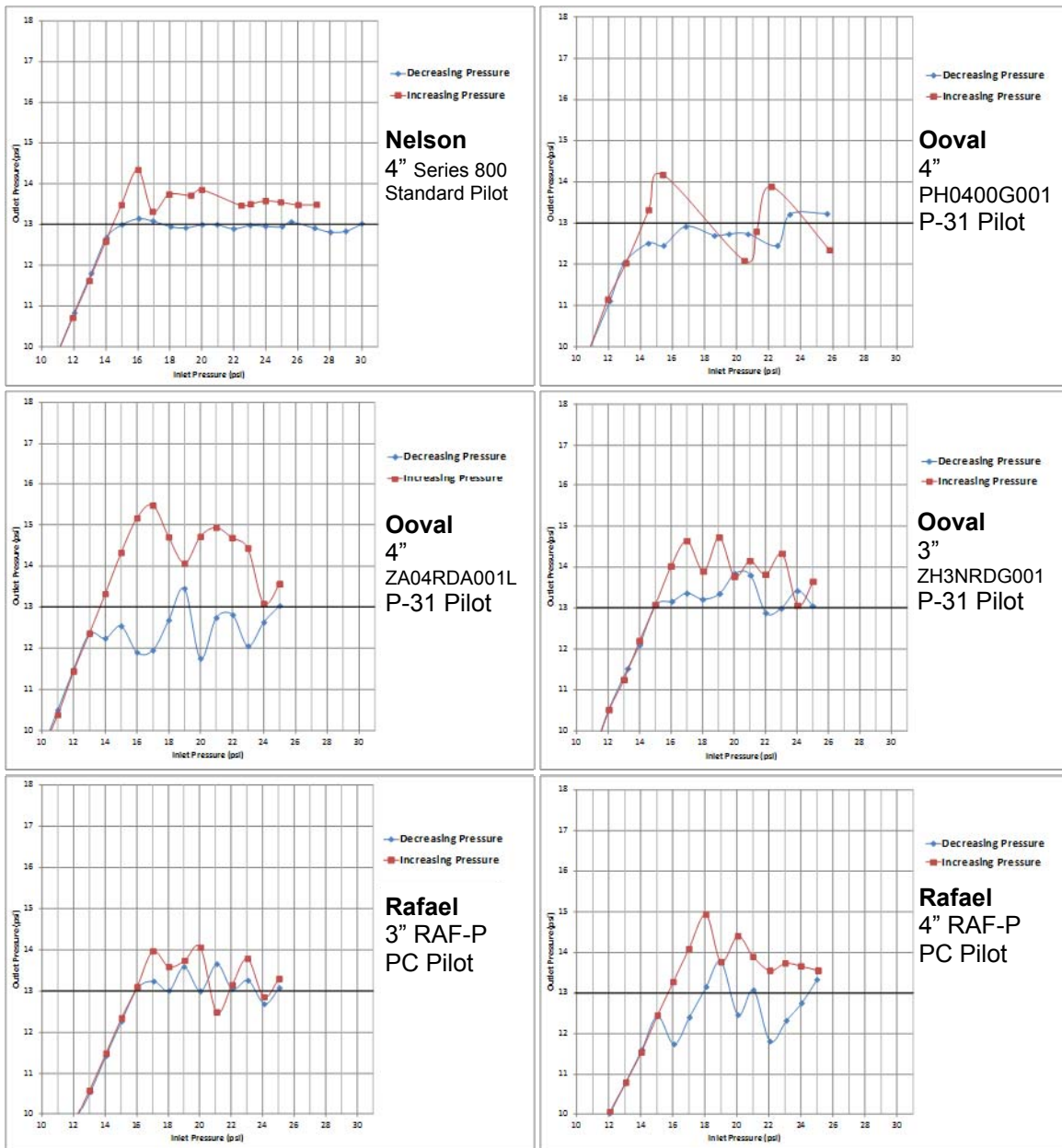


Figure 5. Appropriately configured valves used in Test 1 (continued)

Test 2: Performance with Changing Inlet Flow Rates

The intention of the second test was to configure the valve inlet and discharge pressures at conditions replicating a low pressure system at a low flow rate of 100 GPM. The test proceeded by substantially increasing the flow rate to 500 GPM while maintaining the initial inlet pressure and monitoring the subsequent outlet pressure. Due to large pressure losses with some valves, a flow rate of 500 GPM was not reached. After the initial pilot adjustment, the pilot setting was not changed throughout the test.

As seen in Figure 6, the graphs provided were intended to show two lines: The blue line represents the valve’s outlet pressure in relation to the flow rate through the valve. The red line

represents the inlet pressure in relation to the flow rate, which remained constant throughout the test. An “ideal” valve performance would show nearly parallel lines, meaning the valve was able to maintain the target pressure relatively well throughout a large range of flow rates.

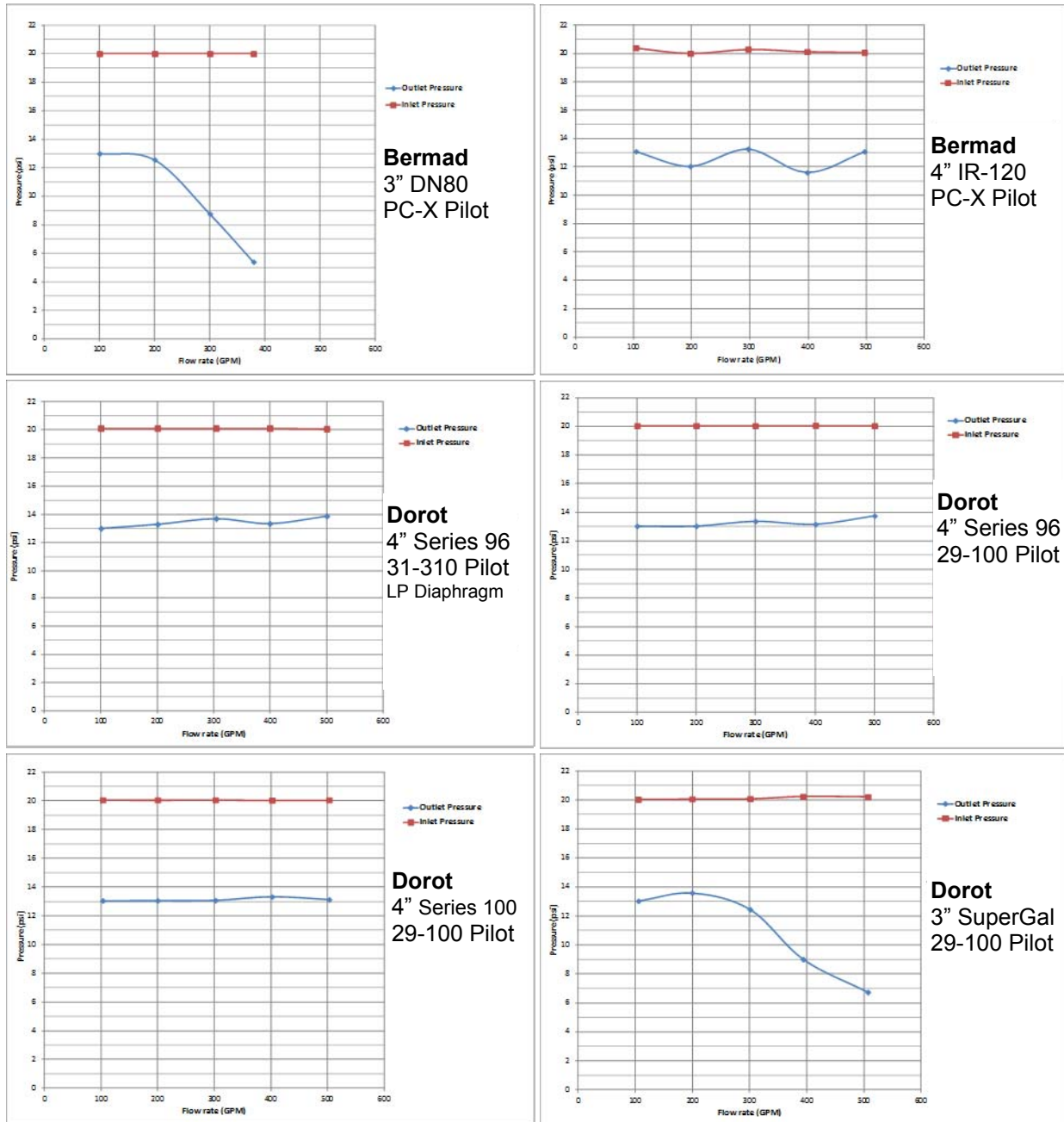


Figure 6. Test 2 results

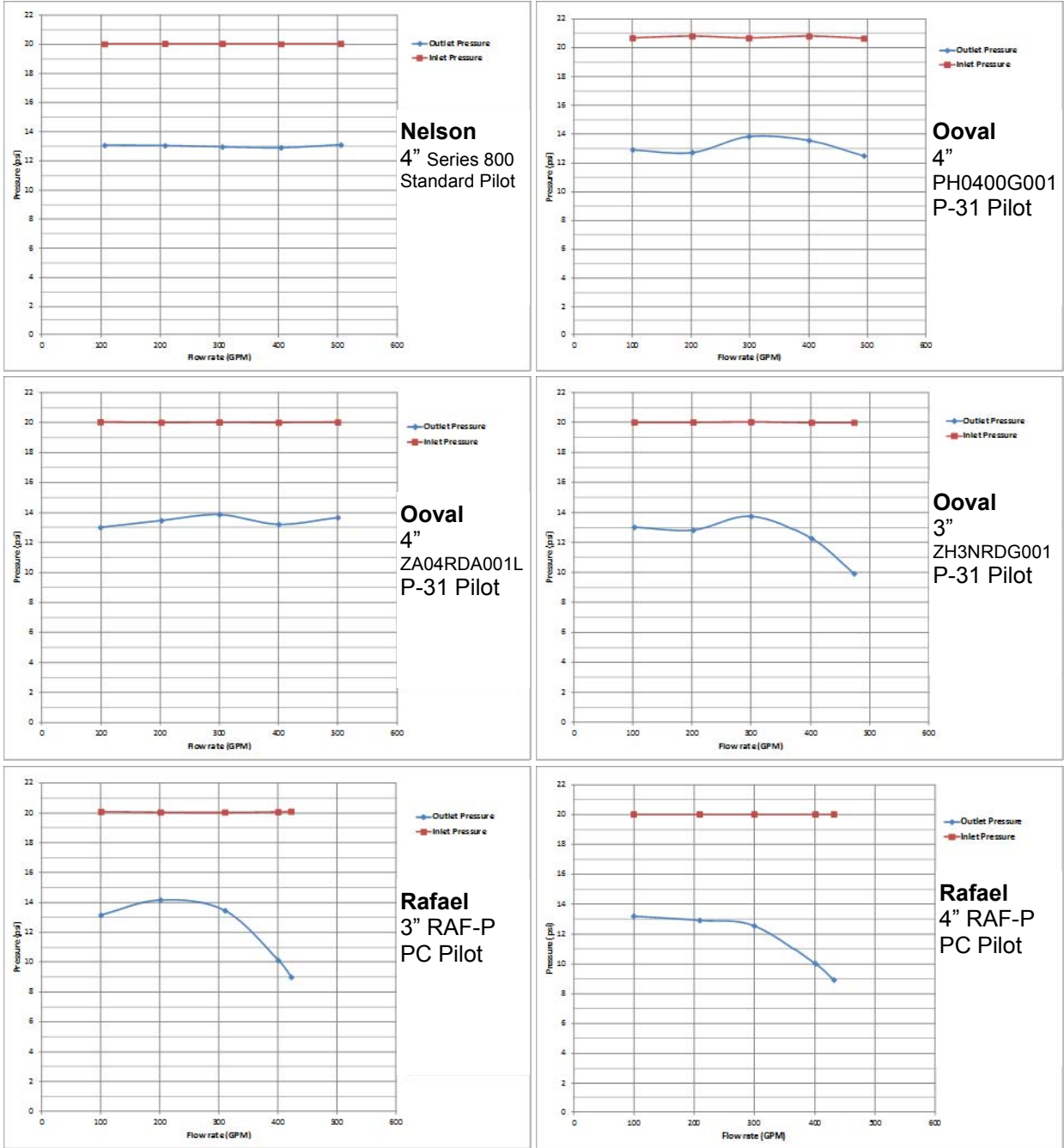


Figure 7. Test 2 results (continued)

Test 3: Minimum Valve Pressure Loss at Various Flow Rates

Test 3 examined the minimum valve pressure loss at various flow rates. This was determined by subtracting the downstream pressure at each measured flow rate from the minimum upstream pressure that still maintained the target downstream pressure. The results of the ITRC testing were then compared with the values for minimum valve pressure loss listed for each model in the manufacturers' published specifications, as well as the values provided by the equipment distributor (if available).

The overall results are presented graphically in Figure 8 and in table format in Table 4. The test vs. manufacturer value graphs are presented for each model individually in Figure 9 through Figure 10.

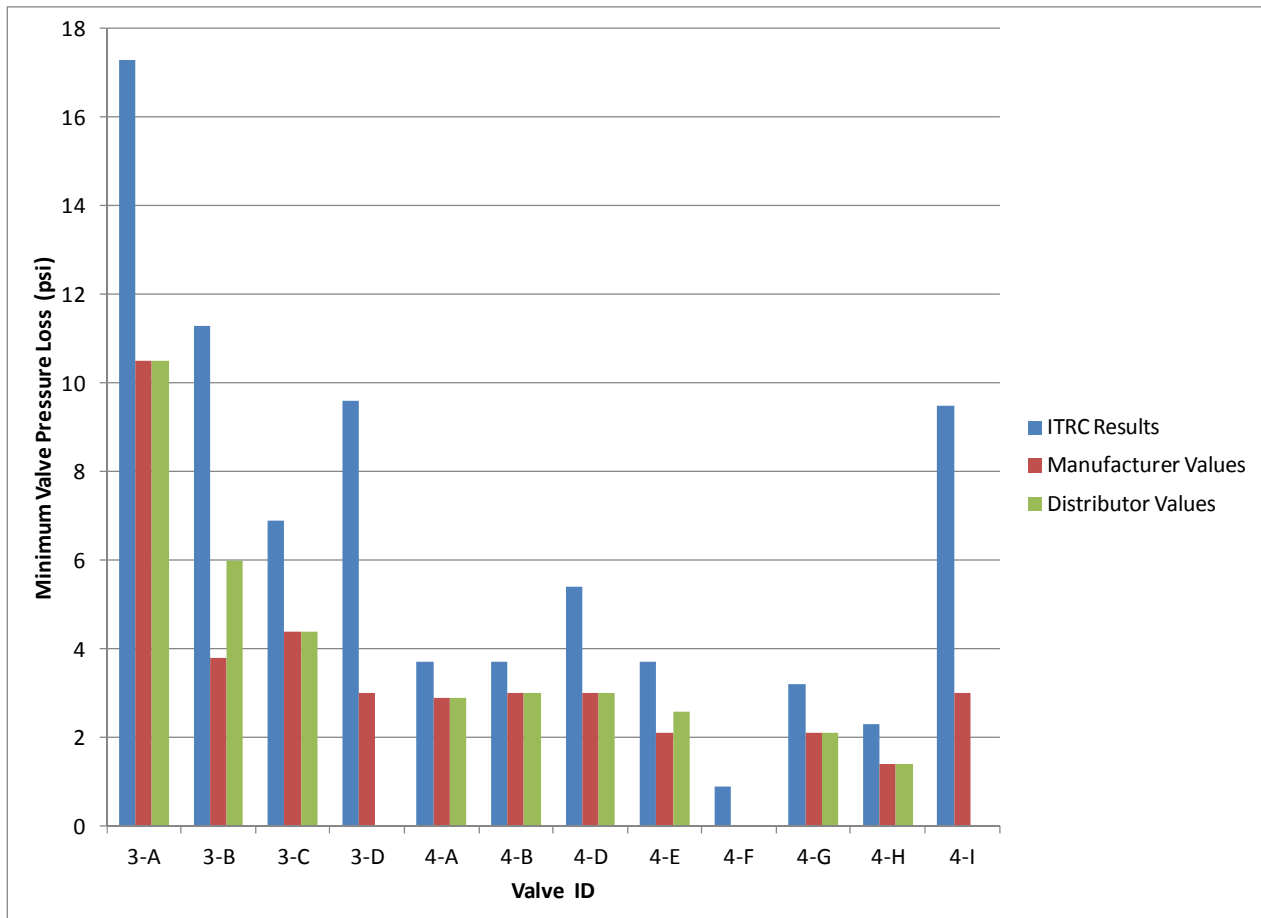


Figure 8. Minimum valve pressure loss (during operation by pilot control) at 13 psi outlet pressure at 400 GPM

Table 4. Minimum valve pressure loss (during operation by pilot control) at 13 psi outlet pressure at 400 GPM

										Minimum Valve Pressure Loss (During Operation by Pilot Control) to Outlet 13 PSI @ 400 GPM		
Valve ID	Manufacturer	Distributor	Model	Size	Pilot Type	Pilot Model	Spring Model	Spring P Range (psi)	Diaphragm Type	ITRC Measured Value (psi)	Manufacturer Stated Value (psi)	Distributor Stated Value (psi)
4-A	Bermad	Bermad	IR-120	4	3-way	PC-X-A-P	K	7 to 45	Standard	3.7	2.9	2.9
4-B	Dorot	Netafim	Series 96	4	3-way	29-100	Yellow	7 to 30	095 (HP)	3.7	3	3
4-D	Dorot	Netafim	Series 96	4	3-way	31-310	Yellow	7 to 30	179 (LP)	5.4	3	3
4-E	Dorot	Netafim	100	4	3-way	29-100	Yellow	7 to 30	005 (LP)	3.7	2.1	2.6
4-F*	Nelson	Nelson	800	4	3-way	Standard	Standard	5 to 50	Standard	0.9		
4-G	Ooval	Eurodrip	PH0400G001	4	3-way	P-31	Blue	5 to 36	Standard	3.2	2.1	2.1
4-H	Ooval	Eurodrip	ZA04RDA001L	4	3-way	P-31	Blue	5 to 36	Standard	2.3	1.4	1.4
4-I*	Rafael	Jain	RAF-P	4	3-way	PC	Blue	7 to 22	Standard	9.5	3	
3-A**	Bermad	Bermad	DN80	3	3-way	PC-X-A-P	K	7 to 45	Standard	17.3	10.5	10.5
3-B**	Dorot	Netafim	Super Gal	3	3-way	29-100	Yellow	7 to 30	Standard	11.3	3.8	6
3-C**	Ooval	EuroDrip	ZH3NRDG001	3	3-way	P-31	Blue	5 to 36	Standard	6.9	4.4	4.4
3-D*	Rafael	Jain	RAF-P	3	3-way	PC	Blue	7 to 22	Standard	9.6	3	

* No pressure loss information available

** ITRC value was extrapolated; best estimate for manufacturer stated value

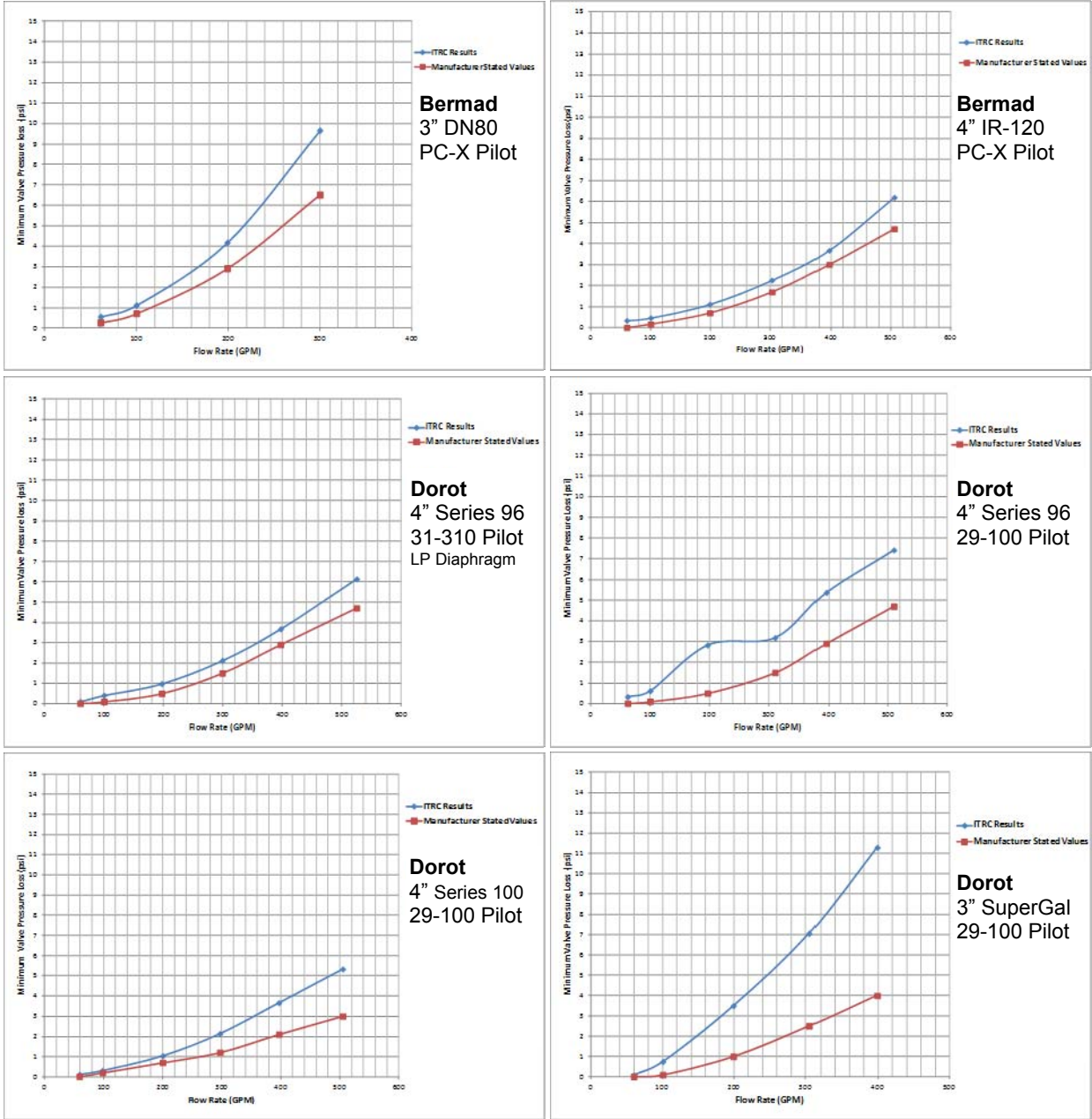


Figure 9. Test 3 results

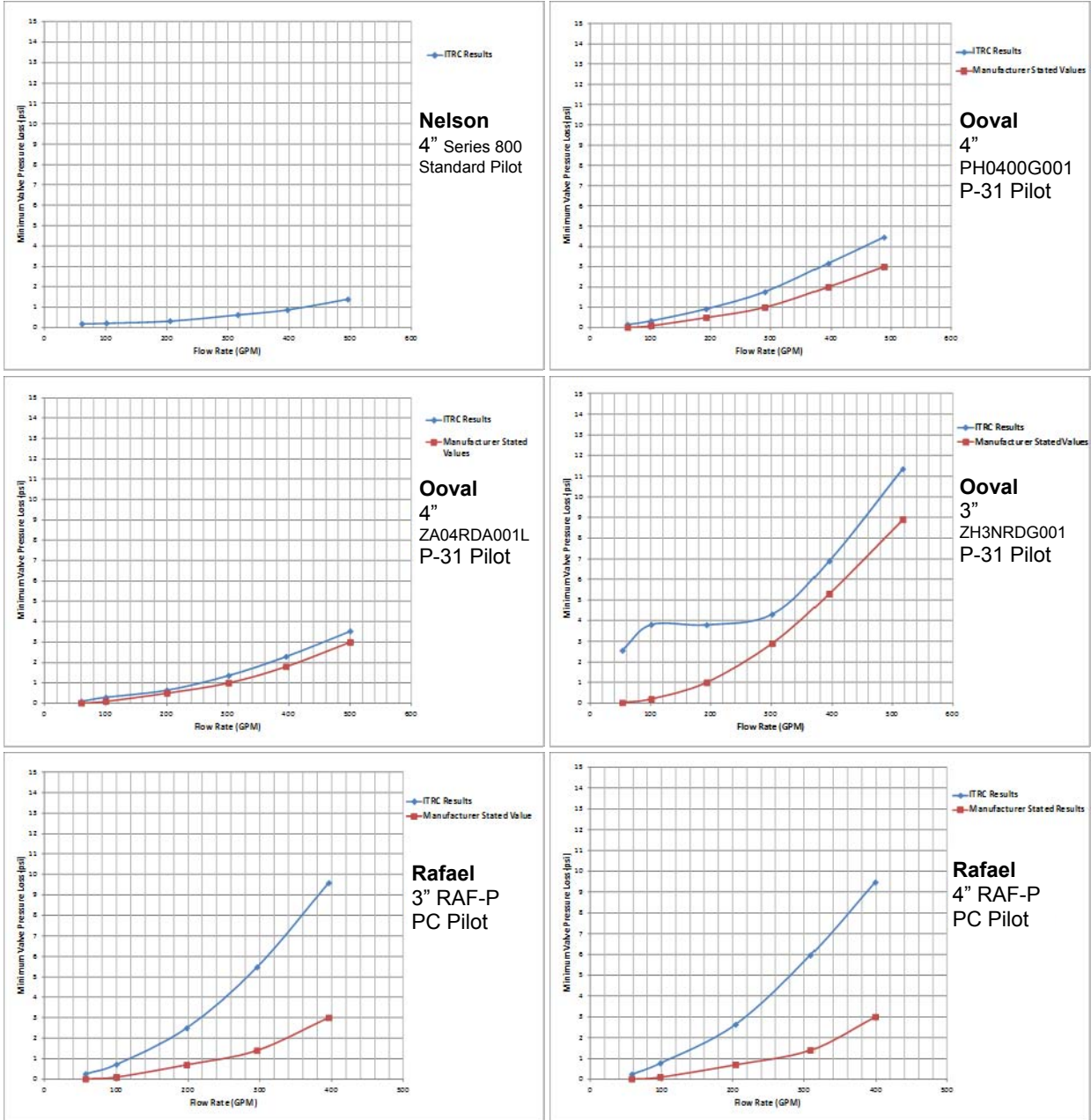


Figure 10. Test 3 results (continued)

Conclusion

The test results indicate the following conclusions:

1. Pressure regulating valves with 2-way pilots are not suited for low truly low pressure systems due to an inherently higher pressure differential requirement. In other words, if they valves with 2-way pilots are adjusted to regulate an outlet pressure of 13 psi, the majority of valves tested required an inlet pressure of over 20 psi to function.

2. All of the comparable valves with 3-way pilots were affected by the following performance characteristics:
 - a. *Regulated outlet pressure consistency.* Within a specific operating range, the majority of valves with 3-way pilots have the ability to maintain an outlet pressure of +/- 1.5 psi. Only one valve was able to maintain an outlet pressure within +/- 0.5 psi.
 - b. *Hysteresis.* All of the valves with 3-way pilots operated differently during decreasing inlet pressures compared to increasing inlet pressure conditions. Some valves exhibited as much as a 2 psi difference in regulated outlet pressures due to hysteresis.
3. Many of the valves received by ITRC had incorrect diaphragms or pilot springs installed despite extensive specification of performance requirements. It is therefore critical that end users supply specific performance requirements to irrigation dealers and perhaps verify the configuration before installation.

Acknowledgements

ITRC would like to acknowledge the following valve manufacturers for cooperation during the testing: Eurodrip USA, Jain Irrigation, John Deere Water Technologies, Nelson Irrigation, and Netafim.