Smart Valve Test Report

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1. Introduction

1.1. Purpose of Test Report

The purpose of this document is to summarize the strategy that was used for testing of the smart valve and their results. This test report will contain information on the types of tests performed, necessary assumptions or constraints for each test, test procedure, the list of resources used, test results and conclusions.

1.2. Scope of Testing

The smart valve will be tested for its functionality features such as arresting flow rate variability, resistance against sudden pressure surges and rectification of water meter reading error against air in the pipeline. Tests to be conducted to prove each of the above features will be defined in section 2 of this document.

2. Test Strategy

In order to test and prove the promised functionality features of the smart valve, it has to be exposed to various tests. To do so, the test setup should allow:

a. Variation in fluid flow rate
b. Variation in supply pressure
c. Introduction of air in the flow
d. Measurement of flow and volume in the system for various combinations of parameters mentioned in points a. to c.

Based on these combinations various cases have been designed for the testing of the valve.

2.1. Test Cases

a. Case 1: Flow Rate Test

In this case, water will be introduced into the test set up at same pressure as that supplied by the municipality. The flow rate will be adjusted with the help of a globe valve. Outlet pressure, flow rate and the volume of water flowed through the system will be measured to verify the benefit of smart valve at different flow rates.

b. Case 2: Pressure Surge Test

A sudden spike in the supply pressure will be created with the help of a centrifugal (non-positive displacement) pump at the inlet of the system. The objective of this test case is to verify the benefit of smart valve against sudden pressure surges in pipe lines.

c. Case 3: Air Bubble Test

Air bubbles will be added to the water flow using an air compressor and pressure regulator. A perforated disc will be used to ensure air bubble formation in the water flow stream. This test will be used to verify if the smart valve can subdue water bubbles that are present inherently in the pipeline thereby reducing water meter reading error.

d. Case 4: Air Test

Only air will be supplied through the system. This is to check the effect of the smart valve on the large air pockets that are present in pipelines in places where there is intermittent supply of water.

e. Case 5: Fixed Volume Test

A fixed volume of water will be supplied through the system without any time constraints. This is to test the effect of smart valve on water meter readings when a known amount of water is passed through it.

f. Case 6: Variable Flow Rate Test

A continuous rise and fall in flow rates will be generated in the system with the help of the pump. This is to test the effect of smart valve on varying flow rates in pipe lines.

3. Test Preparation

3.1. Test Environment

a. Test Facility

The test setup was developed, and the valve was tested at Process Engineering Research and Development Center (PERDC) at Texas A&M University, Rellis Campus.

b. Test Setup

All tests stated in section 2 were conducted on the test set up as represented in the figure 1. The test setup is divided into four lines distinguished by different colors. These four lines are: Water (Blue), Air (Yellow), Smart Valve (SV) (Green) and Bypass (Red). Water line supplies water to the system at either municipal supply pressure or higher (using pump). Air line supplies air to the system which shall be used to introduce air bubbles in the water stream. Smart valve is installed on the SV line which runs parallel to the bypass line. Bypass line is used to measure readings when the smart valve is not in the system. Three way valves, TV1 and TV2, can be used appropriately to direct the flow through either SV line or the bypass line. Pressure regulating valves, PRV1 and PRV2, are installed to regulate water and air inlet pressures respectively. Pressure gauges, PG1, PG2 and PG3, indicate pressures at the inlet, after water meter, and at the outlet respectively. Globe valve, GV1, is installed to control the volume flow rate of water. Flow rate meters, FT1 and FT2, indicate real-time volume flow rate of the fluid flowing through the system at the inlet and outlet respectively. Water meter, WM, is installed to indicate the fluid volume flowed through the system for each test case. A 5 gallon capacity volumetric container is also added at the outlet to measure the volume of water flowed through the system. With this setup, all the test requirements can be addressed. Refer Annexure 1 for actual images of the test setup and Annexure 2 for scaled P&ID.

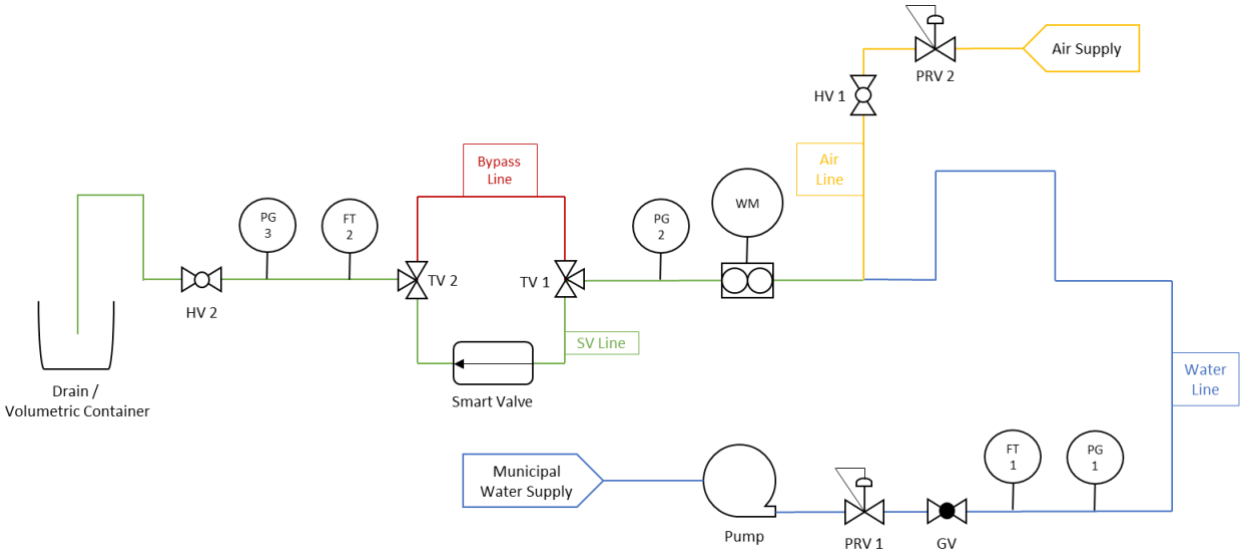


Figure 1: P&ID of the smart valve test setup

c. List of equipment

Based on the process and instrumentation diagram in figure 1, following equipment were used for development of the test setup:

Sr. No.	Item	Size/ Specification	Qty
1	PVC pipes (Transparent)	¾" Sch 40	12 ft
2	PVC pipes (Opaque)	¾" Sch 40	10 ft
3	T joints	¾" Sch 40	4
4	L joints	¾" Sch 40	13
5	Socket Couplings	¾" Sch 40	1
6	Threaded Coupling (w/ Male thread)	¾" Sch 40	20
7	Threaded Coupling (w/ Female Thread)	¾" Sch 40	15
8	Reducer T joint for pressure gauge	0.75" to 0.25"	3
9	Union joints	¾" Sch 40	4
10	Shut-off Valve (Ball valve)	¾"	2
11	Globe Valve	¾"	1
12	Three way valve	¾"	2
13	Water pressure regulator	¾" (Range: 0 – 100 psi)	1
14	Air pressure regulator	¼" (Range: 0 – 100 psi)	1

Sr. No.	Item	Size/ Specification	Qty
15	Pressure Gauge	2.5” dial (Range: 0-100 psi)	3
16	Flow Rate Meter	¾” (Range: 0-25 gpm)	2
17	Water Meter	¾” (Precision: 0.01 gallons)	1
18	Centrifugal pump	-	1

4. Test Procedures

All the tests were performed at three settings of the smart valve spring:

1. Minimum setting (0 clicks)
2. Mid Setting (8 Clicks)
3. Max Setting (15 Clicks)

Each test condition was conducted three times for ensuring the repeatability of test results. Refer to P&ID in
Figure 1 to navigate along the test procedures.

Note: Before the start of each test run, it is to be ensured that all valves are in a position such that there is no fluid flow in the system.

4.1. Flow Rate Test

Objective: To test the effect of smart valve at different water flow rates.

Procedure:

1. Turn the water supply on. Ensure three way valves are positioned such that there is no flow in the system yet.
2. Regulate the static supply pressure to normal municipal water supply pressure (50 psi).
3. Open shut-off valve, HV2.
4. Open the globe valve, GV, to set a flow rate.
5. Record initial water meter (WM) reading.
6. Using three way valves, TV1 and TV2, direct the flow to bypass line and start the timer.
7. Measure readings on PG1, FT1, PG2, PG3 and FT2.
8. Stop the flow using TV1 when timer indicates 60 sec.
9. Measure final water meter (WM) reading.
10. Reset flow meter (FT) readings to zero.
11. Record initial water meter reading.
12. Using three way valves, TV1 and TV2, direct the flow to smart valve line and start the timer.
13. Repeat steps 8 to 11.
14. Repeat the test for different flow rates by controlling GV.

4.2. Pressure Surge Test

Objective: To test the effect of smart valve on sudden pressure surges.

Procedure:

1. Turn the water supply on. Ensure three way valves are positioned such that there is no flow in the system yet.
2. Regulate the supply pressure to normal municipal water supply pressure (50 psi).
3. Open shut-off valve, HV2.
4. Fully open the globe valve, GV1, for maximum supply flow rate (~8.5gpm).
5. Record initial water meter (WM) reading.
6. Using three way valves, TV1 and TV2, direct the flow to bypass line and start the timer.
7. Record readings on PG1, FT1, PG2, PG3 and FT2 as normal condition readings.
8. As the timer indicates 25 sec, turn the pump on, to create a pressure surge of ~10-15psi.
9. Measure readings on PG1, FT1, PG2, PG3 and FT2 as spiked condition readings.
10. When the timer hits 55 sec, turn the pump off to turn the flow back to normal.
11. Stop the flow using TV1 when timer indicates 70 sec.
12. Measure final water meter (WM) reading.
13. Reset flow meter (FT) readings to zero.
14. Record initial water meter reading.
15. Using three way valves, TV1 and TV2, direct the flow to smart valve line and start the timer.
16. Repeat steps 7 to 13.

4.3. Air Bubble Test

Objective: To test the air bubble reduction feature of smart valve

Procedure:

1. Turn the water supply on. Ensure three way valves are positioned such that there is no flow in the system yet.
2. Regulate the supply pressure to normal municipal water supply pressure (50 psi).
3. Set static air supply pressure at 15 psi using PRV2.
4. Open shut-off valve, HV2.
5. Open the globe valve, GV1, to set required water flow rate (~7gpm).
6. Record initial water meter (WM) reading.
7. Using three way valves, TV1 and TV2, direct the flow to bypass line and start the timer.
8. Record readings on FT2 as normal condition readings.
9. As the timer indicates 10 sec, open shut-off valve HV1, to turn the air supply on.
10. Measure readings on FT2 as 'air supply on' condition readings.

11. Observe the air bubbles in the line.
12. When the timer hits 40 sec, turn the air supply off.
13. Stop the flow using TV1 when timer indicates 60 sec.
14. Measure final water meter (WM) reading.
15. Reset flow meter (FT) readings to zero.
16. Record initial water meter reading.
17. Using three way valves, TV1 and TV2, direct the flow to smart valve line and start the timer.
18. Repeat steps 8 to 15.

4.4. Air Test

Objective: To test the effect of smart valve on air flow

Procedure:

1. Set static air supply pressure at 11 psi using PRV2.
2. Open shut-off valves, HV2 and HV1.
3. Record initial water meter (WM) reading.
4. Using three way valves, TV1 and TV2, direct the flow to bypass line and start the timer.
5. Stop the flow using TV1 when timer indicates 10 sec.
6. Record final water meter reading.
7. Using three way valves, TV1 and TV2, direct the flow to smart valve line and start the timer.
8. Repeat steps 5 to 6.

4.5. Fixed Volume Test

Objective: To test the effect of smart valve on water meter reading when a known volume of fluid is flowed through it.

Procedure:

1. Place a volumetric container, with a measuring capacity of 5 gallons, at the outlet of the test setup.
2. Turn the water supply on. Ensure three way valves are positioned such that there is no flow in the system yet.
3. Regulate the supply pressure to normal municipal water supply pressure (50 psi).
4. Open shut-off valve, HV2.
5. Fully open the globe valve, GV1, for maximum supply flow rate (~9gpm).
6. Record initial water meter (WM) reading.
7. Using three way valves, TV1 and TV2, direct the flow to bypass line and start the timer.
8. When flow rate meter indicates that 5 gallons of volume has passed through the system, turn the supply off using TV1.
9. Check if the water level on volumetric container has hit 5 gallons.
10. Record the final water meter reading.
11. Reset the flow rate meter to zero.
12. Using three way valves, TV1 and TV2, direct the flow to smart valve line and start the timer.

13. Repeat steps 8 to 11.

4.6. Variable Flow Rate test

Objective: To test the effect of smart valve continuously varying flow rates.

Procedure:

1. Turn the water supply on. Ensure three way valves are positioned such that there is no flow in the system yet.
2. Regulate the supply pressure to normal municipal water supply pressure (50 psi).
3. Open shut-off valve, HV2.
4. Fully open the globe valve, GV1, for maximum supply flow rate.
5. Record initial water meter (WM) reading.
6. Turn the pump on to generate a higher flow rate (~9.8 gpm).
7. Using three way valves, TV1 and TV2, direct the flow to bypass line and start the timer.
8. After 10 sec, turn the pump off to reduce the flow rate (~8.3 gpm).
9. Turn the pump back on after 10sec.
10. Repeat the cycle 5 times.
11. Using TV1, turn the supply off when timer indicates 110sec.
12. Record the final water meter reading.
13. Reset the flow rate meter to zero.
14. Using three way valves, TV1 and TV2, direct the flow to smart valve line and start the timer.
15. Repeat steps 8 to 13.

5. Test Observations and Results

Based on the recorded test data (Refer annexure 3), following results are observed from each test:

5.1. Flow Rate Test

a. Smart valve set at minimum setting (0 clicks)
Output Conditions when Smart Valve was introduced in the system:

Inlet Flow Rate	**~6.5 gpm**	**~8.5 gpm**	**~10 gpm**
Dynamic water pressure upstream of Smart Valve	Increased by 50%	Increased by 26.67%	Increased by 15.78%
Dynamic water pressure downstream of Smart Valve	Decreased by 16.67%	Decreased by 10%	Decreased by 7.69%
Flow rate	Decreased by 5%		
Volume of fluid recorded by water meter	Decreased by 4.35% (0.325 gal in 60 sec)		

b. Smart valve set at mid setting (8 clicks)

Output Conditions when Smart Valve was introduced in the system:

Inlet Flow Rate	**~6.5 gpm**	**~8.5 gpm**	**~10 gpm**
Dynamic water pressure upstream of Smart Valve	Increased by 104%	Increased by 69%	Increased by 40%
Dynamic water pressure downstream of Smart Valve	Decreased by 22.2%	Decreased by 12.12%	Decreased by 23.9%
Flow rate	Decreased by 14.9%	Decreased by 8.5%	Decreased by 10.7%
Volume of fluid recorded by water meter	Decreased by 13.58% (0.881 gal in 60 sec)	Decreased by 8.13% (0.895 gal in 60 sec)	Decreased by 10.12% (0.998 gal in 60 sec)

c. Smart valve set at max setting (15 clicks)
Output Conditions when Smart Valve was introduced in the system:

Inlet Flow Rate	**~6.5 gpm**	**~8.5 gpm**	**~10 gpm**
Dynamic water pressure upstream of Smart Valve	Increased by 140.74%	Increased by 80.97%	Increased by 47.76%
Dynamic water pressure downstream of Smart Valve	Decreased by 33.33%	Decreased by 34.24%	Decreased by 31.68%
Flow rate	Decreased by 21.21%	Decreased by 15.52%	Decreased by 17.15%
Volume of fluid recorded by water meter	Decreased by 22.41% (1.447 gal in 60 sec)	Decreased by 14.55% (1.203 gal in 60 sec)	Decreased by 17.31% (1.715 gal in 60 sec)

Thus, with this test it can be concluded that, after the introduction of smart valve:

1. There was a rise in upstream pressure.
2. There was a fall in downstream pressure.
3. Flow rate in the system reduced.
4. Volume recorded by the water meter in a set amount of time reduced.
5. These differences increased after the smart valve spring was tightened.

5.2. Pressure Surge Test

a. Smart valve set at minimum setting (0 clicks)
Output Conditions when Smart Valve was introduced in the system:

Dynamic water pressure spike upstream of Smart Valve	Decreased by 30.7%
Dynamic water pressure spike downstream of Smart Valve	No change observed
Rise in flow rate due to pressure spike	Decreased by 16.37%
Volume of fluid recorded by water meter	Decreased by 4.75% (0.476 gal in 70 sec)

b. Smart valve set at mid setting (8 clicks)
Output Conditions when Smart Valve was introduced in the system:

Dynamic water pressure spike upstream of Smart Valve	Decreased by 44.04%
Dynamic water pressure spike downstream of Smart Valve	Decreased by 29.01%
Rise in flow rate due to pressure spike	Decreased by 9.95%
Volume of fluid recorded by water meter	Decreased by 9.34% (0.9916 gal in 70 sec)

c. Smart valve set at max setting (15 clicks)
Output Conditions when Smart Valve was introduced in the system:

Dynamic water pressure spike upstream of Smart Valve	Decreased by 63.98%
Dynamic water pressure spike downstream of Smart Valve	Decreased by 28.57%
Rise in flow rate due to pressure spike	Decreased by 10.98%
Volume of fluid recorded by water meter	Decreased by 16.35% (1.74 gal in 70sec)

Thus, with this test it can be concluded that, after the introduction of smart valve:

1. Downstream and upstream pressure spike decreased.
2. Rise in flow rate caused by pressure spike decreased.
3. Volume of fluid recorded by water meter in a set amount of time decreased.
4. Above difference increased as the smart valve spring was tightened.

5.3. Air Bubble Test

Output Conditions when Smart Valve was introduced in the system:

Smart Valve Spring Setting	Minimum (0 Clicks)	Mid (8 Clicks)	High (15 Clicks)
Volume of fluid recorded by water meter	Decreased by 5.05% (0.355 gal in 60 sec)	Decreased by 12.79% (0.886 gal in 60 sec)	Decreased by 19.26% (1.33 gal in 60 sec)
Air Bubbles in the system	Large volume of air bubbles visible	Low Volume of air bubbles visible	Low Volume of air bubbles visible

Thus, with this test it can be concluded that, after the introduction of smart valve:

1. Volume of air bubbles in the system reduced.
2. The rate of reduction increased as the smart valve spring was tightened.

5.4. Air Test

Output Conditions when Smart Valve was introduced in the system:

Smart Valve Spring Setting	Minimum (0 Clicks)	Mid (8 Clicks)	High (15 Clicks)
Volume of air recorded by water meter (in 10 sec)	Decreased by 3.07 gal	Decreased by 8.53 gal	No air flow recorded

Thus, with this test, it can be concluded that: smart valve reduced the flow of air in the system, thereby preventing rise in water meter reading.

5.5. Fixed Volume Test

Output Conditions when Smart Valve was introduced in the system:

Smart Valve Spring Setting	Minimum (0 Clicks)	Mid (8 Clicks)	High (15 Clicks)
Volume recorded by water meter	Very Small change observed (0.17%)	Very Small change observed (0.11%)	Very Small change observed (0.05%)
Time taken to fill 5 gallon water container	4.57% (~1.6 sec) more	11.12% (~3.97 sec) more	17.38% (~6.05 sec) more

Thus, with this test it can be concluded that, after the introduction of smart valve:

1. No to very small change was observed in the volume recorded by water meter.

2. It took more time to fill the 5 gallon volumetric container at the outlet.
3. Time difference increased as the spring was tightened.

5.6. Variable Flow Rate Test

Output Conditions when Smart Valve was introduced in the system:

Smart Valve Spring Setting	**Minimum (0 Clicks)**	**Mid (8 Clicks)**	**High (15 Clicks)**
Flow Rate 1 (Original = ~9.8 gpm)	Reduced to ~9.4gpm	Reduced to ~8.9gpm	Reduced to ~8.4gpm
Flow Rate 2 (Original = ~8.3 gpm)	Reduced to ~8gpm	Reduced to ~7.3gpm	Reduced to ~6.9gpm
Volume recorded by water meter	Decreased by 2.82% (0.465gal in 110sec)	Decreased by 9.65% (1.59gal in 110sec)	Decreased by 14.7% (2.44gal in 110sec)

Thus, with this test it can be concluded that, after the introduction of smart valve:

1. There was a reduction in flow rates.
2. Volume of fluid recorded by water meter decreased.
3. Above difference increased when the smart valve spring was tightened.

6. Conclusion

6.1. Smart Valve's functionality in reducing water flow rate, reducing effect of pressure spikes, and reducing air bubble volume in a piping system is validated.

6.2. The effect of smart valve on each of the above conditions is dependent on its spring setting.

a. Low to no effect is observed when the spring is in lowest setting.
b. The effect increases as the spring is tightened.

7. Annexures

Annexure 1: Smart Valve Test Setup

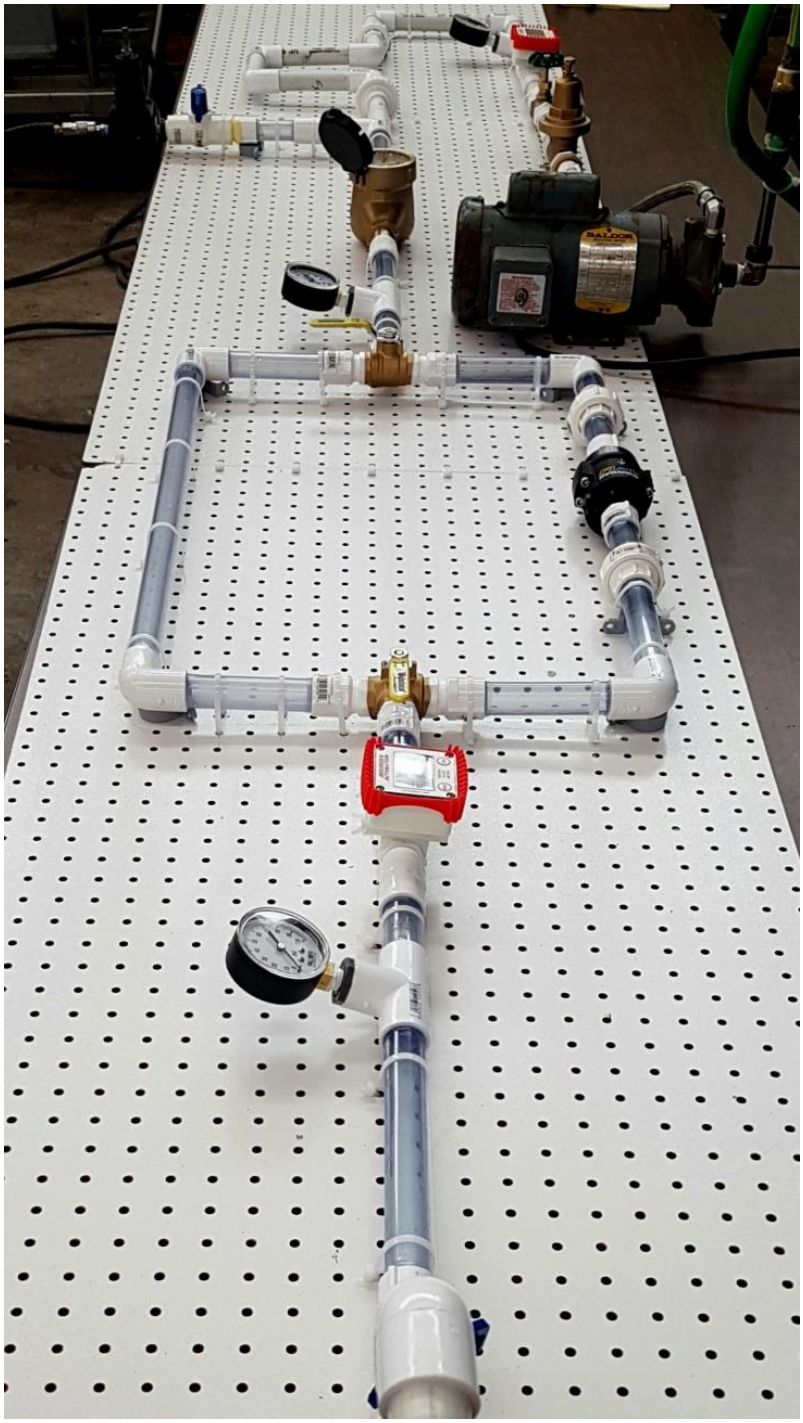


Figure a: Full assembly of the test setup

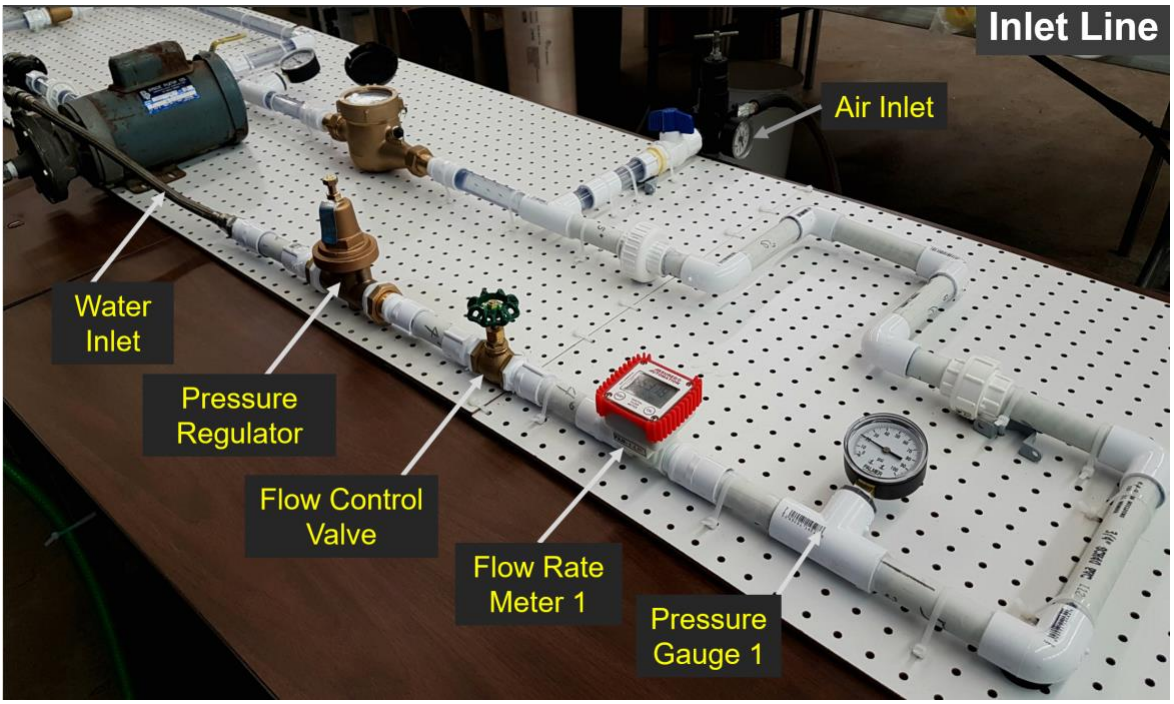


Figure b: Inlet lines of the test setup

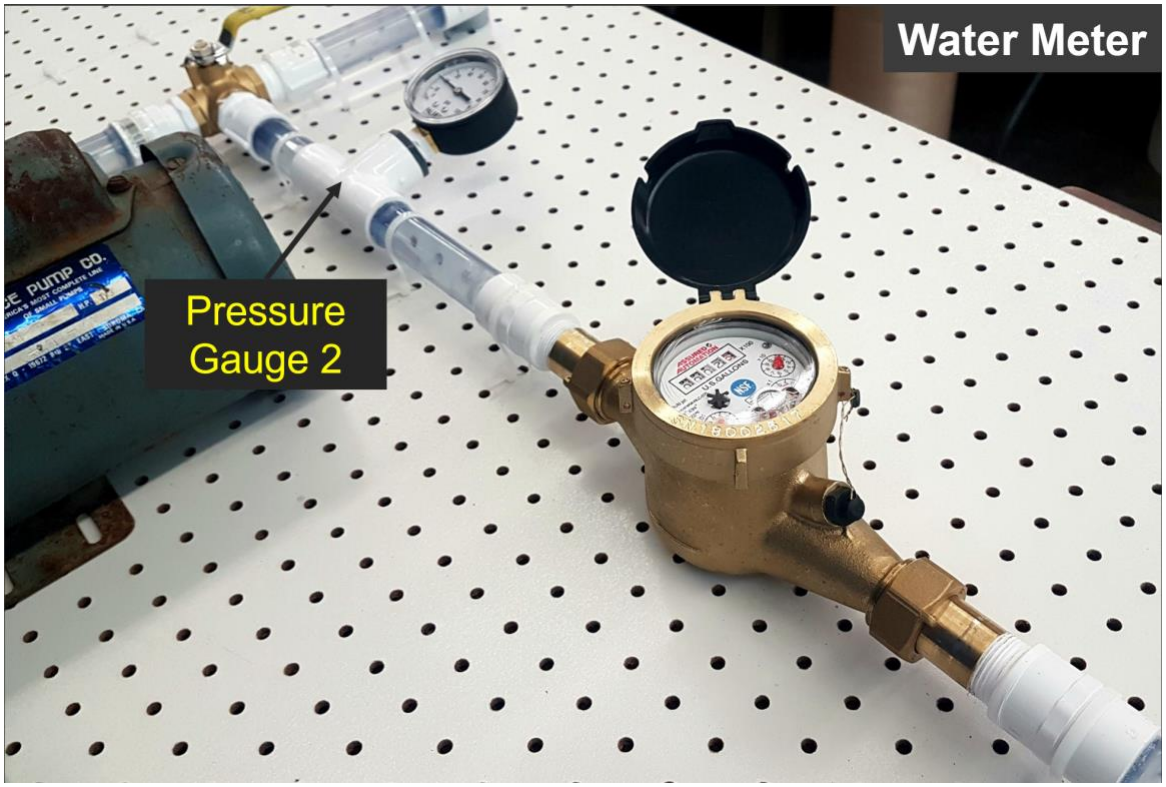


Figure c: Residential Water Meter

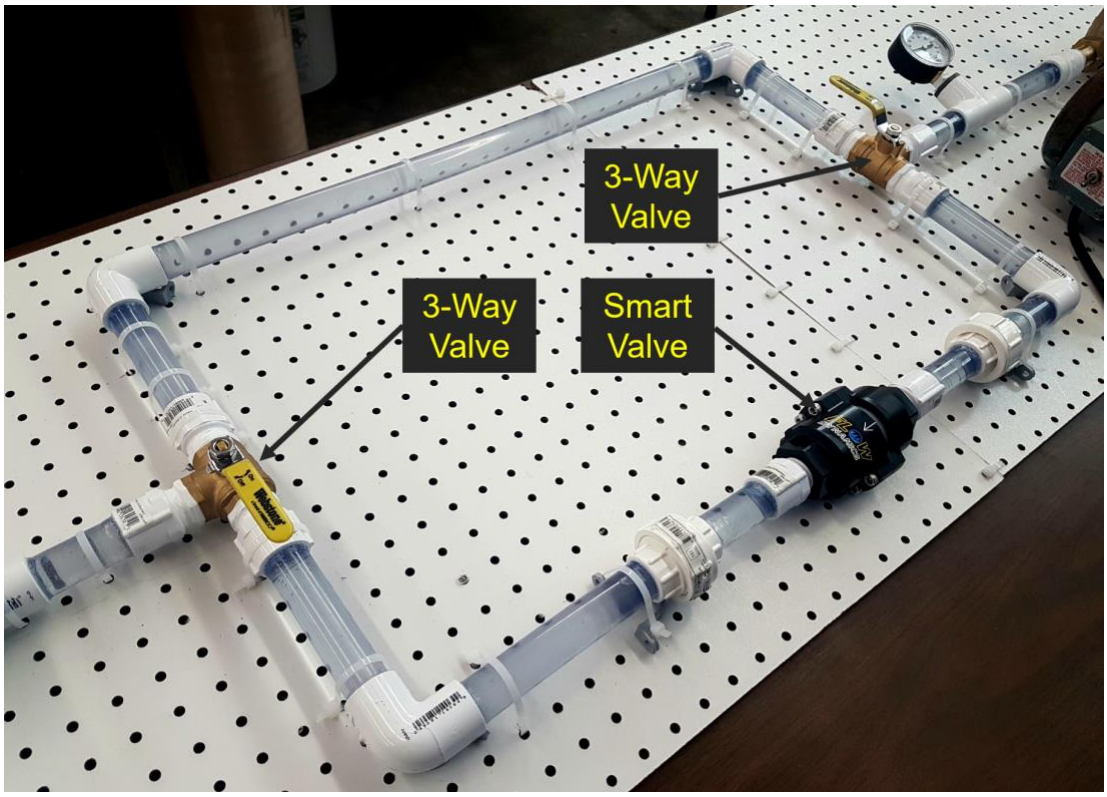


Figure d: Smart Valve and bypass lines

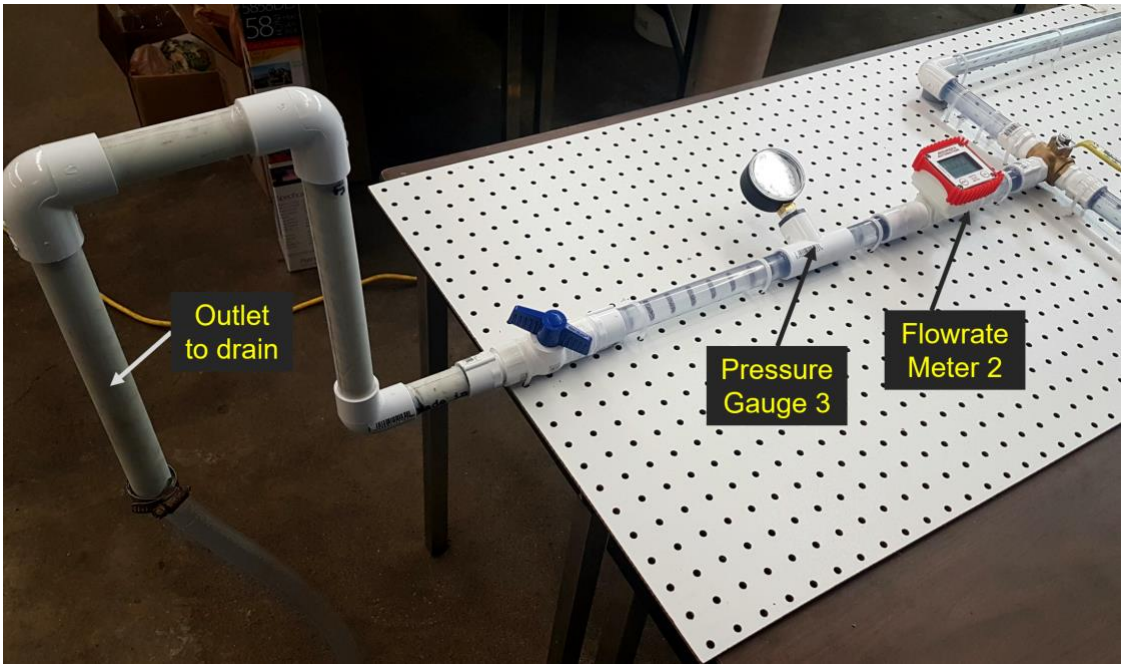
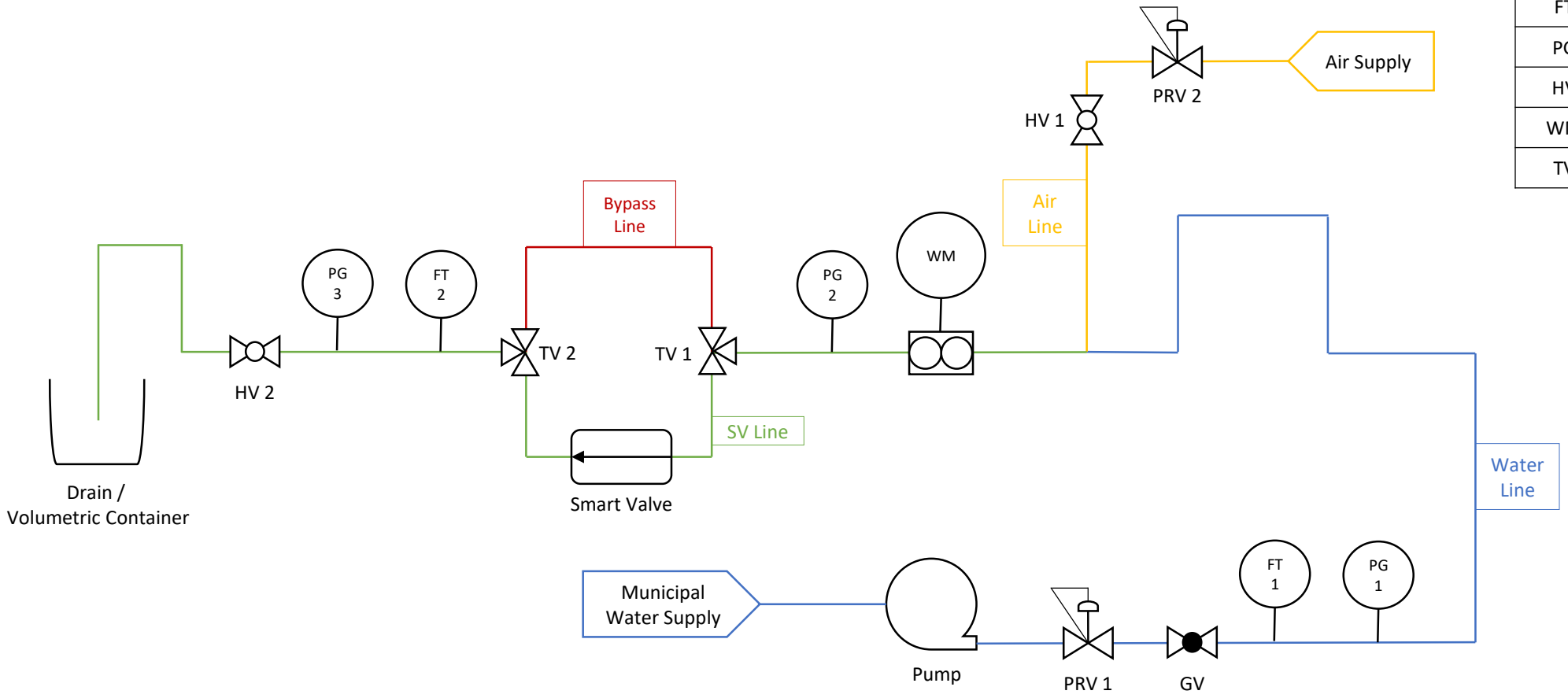


Figure e: Outlet line of the test setup

Annexure 2: P&ID of the Test Setup

Legend	
Symbol	**Description**
PRV	Pressure Regulating Valve
GV	Globe Valve
FT	Flow Rate Meter
PG	Pressure Gauge
HV	Hand Valve (Shut-off Valve)
WM	Water Meter
TV	Three Way Valve



TEXAS A&M ENGINEERING EXPERIMENT STATION

Title: P&ID of Smart Valve Test Setup

Date: 08/13/19

Annexure 3: Test Readings

TEXAS A&M ENGINEERING EXPERIMENT STATION

Flow Rate Test										Date =07/30/19		
Smart Valve Setting = Lowest (0 clicks)												
Test Time = 60 sec			Static Water Pressure = 50 Psi									
Test Condition	#Run	Smart Valve Condition	Flow Rate		Water Meter		Pressure Gauge Readings			Volume passed		
			Inlet	Outlet	Initial	Final	Inlet	Center	Outlet	Flow Meter reading at inlet	Flow Meter reading at outlet	Water Meter
	Units:	(Open/Close)	gpm		gallons		psi			gallons		
1	1	Open	5.7	5.9	1312.595	1318.34	12	11	5	5.503	5.625	5.745
		Close	6	6.2	1306.12	1312.205	8	7	6	5.839	5.96	6.085
	2	Open	5.7	5.9	1330.915	1336.7	12	11	5	5.539	5.663	5.785
		Close	6	6.2	1324.495	1330.57	8	7	6	5.832	5.949	6.075
2	1	Open	6.7	6.9	1356.93	1363.635	15	13	7	6.492	6.602	6.705
		Close	7	7.1	1349.41	1356.41	11	9	7	6.758	6.866	7
	2	Open	6.7	6.9	1371.31	1377.96	15	13	7	6.435	6.544	6.65
		Close	7	7.12	1364.17	1371.1	11	9	7	6.699	6.808	6.93
3	1	Open	7.6	7.8	1444.605	1452.135	19	16	9	7.289	7.411	7.53
		Close	8.1	8.2	1397.5	1405.615	15	13	10	7.819	7.956	8.115
	2	Open	7.6	7.8	1437.04	1444.605	19	16	9	7.317	7.442	7.565
		Close	8	8.2	1428.605	1436.255	15	12	10	7.623	7.733	7.65
4	1	Open	8.6	8.8	1469.11	1477.635	22	19	12	8.244	8.397	8.525
		Close	9	9.2	1459.63	1468.5	19	15	13	8.597	8.732	8.87
	2	Open	8.5	8.6	1487.51	1495.93	22	19	12	8.132	8.287	8.42
		Close	9	9.2	1478.185	1486.965	19	16	12	8.612	8.747	8.78

TEXAS A&M ENGINEERING EXPERIMENT STATION

Flow Rate Test											Date = 08/01/19		
Smart Valve Setting = Mid (8 Clicks)													
Test Time = 60 sec			Static Water Pressure = 50 Psi										
Test Condition	#Run	Smart Valve Condition	Flow Rate		Water Meter		Pressure Gauge Readings			Volume passed		
			Inlet	Outlet	Initial	Final	Inlet	Center	Outlet	Flow Meter reading at inlet	Flow Meter reading at outlet	Water Meter
	Units:	(Open/Close)	gpm		gallons		psi			gallons		
1	1	Close	8.2	8.3	2463.48	2471.55	13	12	9	7.78	8.18	8.07
		Open	7.7	7.9	2496.83	2504.61	25	22	9	7.512	7.617	7.78
	2	Close	8.6	8.7	2471.55	2480.19	15	14	11	8.35	8.482	8.64
		Open	7.6	7.9	2504.61	2512.34	25	22	9	7.466	7.57	7.73
	3	Close	8.6	8.8	2480.19	2488.76	16	14	11	8.293	8.418	8.57
		Open	7.7	7.8	2489.14	2496.83	24	22	9	7.425	7.532	7.69
2	1	Close	10	10.2	2513.16	2523.125	22	18	14	9.797	9.655	9.965
		Open	8.9	9.1	2523.33	2532.23	30	26	11	8.624	8.758	8.9
	2	Close	10	10.2	2532.38	2542.34	22	18	14	9.658	9.803	9.96
		Open	9	9.2	2542.51	2551.42	29	26	10	8.624	8.759	8.91
	3	Close	10.1	10.3	2560.34	2569.99	20	16	14	9.335	9.472	9.65
		Open	9	9.1	2551.42	2560.19	29	26	11	8.489	8.629	8.77
3	1	Close	6.5	6.7	2577.1	2583.59	9	8	6	6.271	6.374	6.49
		Open	5.7	5.8	2602.41	2608.09	18	16	4	5.441	5.531	5.68
	2	Close	6.5	6.7	2583.59	2590.06	9	8	6	6.252	6.355	6.47
		Open	5.4	5.6	2608.68	2614.15	18	15	5	5.25	5.324	5.47
	3	Close	6.5	6.7	2590.06	2596.58	9	8	6	6.303	6.405	6.52
		Open	5.6	5.7	2596.725	2602.41	19	16	5	5.447	5.536	5.685

TEXAS A&M ENGINEERING EXPERIMENT STATION

Flow Rate Test											Date = 08/01/19		
Smart Valve Setting = Highest (15 Clicks)													
Test Time = 60 sec			Static Water Pressure = 50 Psi										
Test Condition	#Run	Smart Valve Condition	Flow Rate		Water Meter		Pressure Gauge Readings			Volume passed		
			Inlet	Outlet	Initial	Final	Inlet	Center	Outlet	Flow Meter reading at inlet	Flow Meter reading at outlet	Water Meter
	Units:	(Open/Close)	gpm		gallons		psi			gallons		
1	1	Open	7.2	7.3	1797.86	1805.08	28	25	7	6.959	7.091	7.22
		Close	8.6	8.8	1788.18	1796.725	16	14	11	8.266	8.394	8.545
	2	Open	7.2	7.5	1819.94	1827.215	28	26	7	7.014	7.146	7.275
		Close	8.5	8.7	1809.87	1818.235	15	13	10	8.187	8.322	8.365
	3	Open	7.3	7.5	1900.57	1907.95	29	25	7	7.121	7.252	7.38
		Close	8.8	8.9	1890.945	1899.64	16	14	11	8.431	8.56	8.695
2	1	Open	8.4	8.5	1844.335	1852.66	32	29	10	8.029	8.177	8.325
		Close	10	10.2	1833.66	1843.61	22	17	14	9.654	9.801	9.95
	2	Open	8.1	8.3	1863.56	1871.65	32	29	9	7.788	7.931	8.09
		Close	10.2	10.2	1853.205	1863.31	22	18	14	9.81	9.962	10.105
	3	Open	8.1	8.3	1882.035	1890.135	32	29	9	7.8	7.942	8.1
		Close	9.7	9.9	1872.245	1881.85	21	16	13	9.302	9.444	9.605
3	1	Open	5	5.2	1924.23	1929.415	22	21	4	4.975	5.074	5.185
		Close	6.5	6.6	1917.06	1923.495	9	8	6	6.221	6.326	6.435
	2	Open	5.1	5.3	1936.45	1941.25	21	20	4	4.972	5.068	4.8
		Close	6.5	6.6	1929.76	1936.21	9	7	6	6.231	6.339	6.45
	3	Open	5	5.1	1948.48	1953.51	22	20	4	4.828	4.918	5.03
		Close	6.5	6.6	1941.81	1948.28	9	7	6	6.243	6.349	6.47

TEXAS A&M ENGINEERING EXPERIMENT STATION

Pressure Surge Test												Date =07/30/19
Smart Valve Setting = Lowest (0 clicks)												
Total Test Time = 70 sec		Surge Started at 25 sec		Surge Stoped at 55 sec		Static Water Pressure = 50 psi						
#Run	Smart Valve Condition	Pressure Condition	Pressure Gauge Readings (Dynamic)			Water Meter Readings		Flow Rate		Volume passed		
			Inlet	Center	Outlet	Initial	Final	Inlet	Outlet	Flow rate Meter at inlet	Flow rate Meter at outlet	Water Meter
Units:	(Open/Close)		psi			gallons		gpm		gallons		
1	Close	Normal	14	12	10	1229.865	1239.815	7.8	8.1	9.625	9.761	9.95
	Close	Spiked	20	17	13			9.3	9.5			
	Open	Normal	18	16	9	1240.565	1250.075	7.8	7.7	9.211	9.379	9.51
	Open	Spiked	24	22	13			8.9	9.2			
2	Close	Normal	14	12	9	1250.76	1260.89	8	8.2	9.697	9.856	10.13
	Close	Spiked	21	17	13			9.4	9.6			
	Open	Normal	19	16	9	1261.39	1270.935	7.8	7.8	9.297	9.456	9.545
	Open	Spiked	25	21	13			9.1	9.2			
3	Close	Normal	14	12	9	1271.63	1281.575	7.8	8.1	9.611	9.77	9.945
	Close	Spiked	21	17	14			9.4	9.5			
	Open	Normal	18	16	9	1282.085	1291.625	7.7	7.8	9.237	9.408	9.54
	Open	Spiked	24	21	12			9	9.1			

TEXAS A&M ENGINEERING EXPERIMENT STATION

Pressure Surge Test												Date = 08/01/19
Smart Valve Setting = Mid (8 Clicks)												
Total Test Time = 70 sec		Surge Started at 25 sec		Surge Stoped at 55 sec		Static Water Pressure = 50 psi						
#Run	Smart Valve Condition	Pressure Condition	Pressure Gauge Readings (Dynamic)			Water Meter		Flow Rate		Volume passed		
			Inlet	Center	Outlet	Initial	Final	Inlet	Outlet	Flow rate Meter at inlet	Flow rate Meter at outlet	Water Meter
Units:	(Open/Close)		psi			gallons		gpm		gallons		
1	Close	Normal	16	13	10	2395.835	2406.43	8.4	8.7	10.307	10.467	10.595
	Close	Spiked	21	17	14			9.9	10.1			
	Open	Normal	24	22	9	2407.09	2416.64	7.6	7.8	9.269	9.414	9.55
	Open	Spiked	29	25	11			9	9.1			
2	Close	Normal	15	13	10	2416.905	2427.55	8.5	8.7	10.338	10.496	10.645
	Close	Spiked	21	17	13			9.9	10.1			
	Open	Normal	25	23	8	2427.755	2437.315	7.6	7.7	9.262	9.408	9.56
	Open	Spiked	30	26	10			8.9	9.2			
3	Close	Normal	16	14	10	2437.635	2448.23	8.6	8.7	10.261	10.418	10.595
	Close	Spiked	21	17	13			10	10.1			
	Open	Normal	25	21	9	2448.31	2458.06	7.5	7.8	9.342	9.486	9.75
	Open	Spiked	29	26	11			9	9.2			

TEXAS A&M ENGINEERING EXPERIMENT STATION

Pressure Surge Test										Date = 08/01/19		
Smart Valve Setting = Highest (15 Clicks)												
Total Test Time = 70 sec		Surge Started at 25 sec		Surge Stoped at 55 sec		Static Water Pressure = 50 psi						
#Run	Smart Valve Condition	Pressure Condition	Pressure Gauge Readings (Dynamic)			Water Meter		Flow Rate		Volume passed		
			Inlet	Center	Outlet	Initial	Final	Inlet	Outlet	Flow rate Meter at inlet	Flow rate Meter at outlet	Water Meter
Units:	(Open/Close)		psi			gallons		gpm		gallons		
1	Close	Normal	16	13	10	1961.5	1972.19	8.6	8.8	10.367	10.529	10.69
	Close	Spiked	22	17	14			10	10.1			
	Open	Normal	27	25	7	1972.405	1981.32	6.9	7.3	8.498	8.65	8.915
	Open	Spiked	32	28	9			8.2	8.3			
2	Close	Normal	15	13	10	1981.86	1992.455	8.7	8.8	10.268	10.424	10.595
	Close	Spiked	21	16	14			10	10.2			
	Open	Normal	28	26	7	1992.82	2001.72	7.2	7.3	8.58	8.73	8.9
	Open	Spiked	32	28	9			8.2	8.3			
3	Close	Normal	15	13	10	2011.15	2021.79	8.7	10.468	10.318	10.468	10.64
	Close	Spiked	22	18	14			9.9	10.1			
	Open	Normal	28	26	7	2001.72	2010.61	7	7.3	8.568	8.718	8.89
	Open	Spiked	31	28	9			8.2	8.3			

TEXAS A&M ENGINEERING EXPERIMENT STATION

Air Bubble Test						Date = 07/30/19	
Smart Valve Setting = Lowest (0 clicks)							
Total Test Time = 60 sec			Static Water Pressure = 50 Psi				
Static Air Pressure = 15 psi			Air Supply Started at 10 sec and Stopped at 40 sec				
#Run	Smart Valve Condition	Air Supply Condition	Water Meter Readings		Flow Rate	Volume	
			Initial	Final	Outlet	Flow rate meter at outlet	Water Meter
Units:	(Open/ Close)	(On/Off)	gallons		gpm	gallons	
1	Close	On	1114.610	1121.565	7.4	6.929	6.955
		Off			7		
	Open	On	1124.520	1131.170	6.8	6.55	6.65
		Off			6.7		
2	Close	On	1121.170	1128.250	7.3	6.995	7.08
		Off			7		
	Open	On	1149.575	1156.280	6.8	6.602	6.705
		Off			6.7		
3	Close	On	1166.345	1173.380	7.3	6.951	7.035
		Off			7		
	Open	On	1182.845	1189.495	6.9	6.552	6.65
		Off			6.8		

Air Bubble Test						Date = 08/01/19	
Smart Valve Setting = Mid (8 Clicks)							
Total Test Time = 60 sec			Static Water Pressure = 50 Psi				
Static Air Pressure = 15 psi			Air Supply Started at 10 sec and Stopped at 40 sec				
#Run	**Smart Valve Condition**	**Air Supply Condition**	**Water Meter Readings**		**Flow Rate**	**Volume**	
			Initial	**Final**	**Outlet**	**Flow rate meter at outlet**	**Water Meter**
Units:	**(Open/ Close)**	**(On/Off)**	**gallons**		**gpm**	**gallons**	
1	Close	Off	2331.760	2338.870	7	7.533	7.110
		On			8.5		
	Open	Off	2339.620	2345.820	6.3	6.089	6.200
		On			6.4		
2	Close	Off	2346.020	2352.910	7	7.665	6.890
		On			8.5		
	Open	Off	2353.870	2359.730	6	5.796	5.860
		On			6		
3	Close	Off	2359.860	2366.620	6.8	7.416	6.760
		On			8.6		
	Open	Off	2366.740	2372.780	6	5.949	6.040
		On			6		

TEXAS A&M ENGINEERING EXPERIMENT STATION

Air Bubble Test						Date = 08/01/19	
Smart Valve Setting = Highest (15 Clicks)							
Total Test Time = 60 sec			Static Water Pressure = 50 Psi				
Static Air Pressure = 15 psi			Air Supply Started at 10 sec and Stopped at 40 sec				
#Run	Smart Valve Condition	Air Supply Condition	Water Meter Readings		Flow Rate	Volume	
			Initial	Final	Outlet	Flow rate meter at outlet	Water Meter
Units:	(Open/ Close)	(On/Off)	gallons		gpm	gallons	
1	Close	Off	2083.800	2090.890	7	7.59	7.090
		On			8.7		
	Open	Off	2099.860	2105.490	5.6	5.52	5.630
		On			5.7		
2	Close	Off	2153.740	2160.490	7.1	7.527	6.750
		On			8.5		
	Open	Off	2161.230	2166.760	5.5	5.401	5.530
		On			5.6		
3	Close	Off	2170.840	2177.690	6.9	7.408	6.850
		On			8.4		
	Open	Off	2177.950	2183.490	5.6	5.419	5.540
		On			5.6		

Air Test				Date = 07/30/19	
Smart Valve Setting = Lowest (0 clicks)					
Total Test Time = 10 Sec					
#Run	Smart Valve	Static Air Pressure	Water Meter Readings		
			Initial	Final	Volume
Units:	(Open/ Close)	psi	gallons		gallons
1	Open	11	883.24	889.61	6.37
	Close	11	891.935	898.8	6.865
2	Open	11	903.37	910.75	7.38
	Close	11	921.595	934.28	12.685
3	Open	11	949.38	957.405	8.025
	Close	11	962.765	974.21	11.445

Air Test				Date = 08/01/19	
Smart Valve Setting = Mid (8 Clicks)					
Total Test Time = 10 Sec					
#Run	Smart Valve	Static Air Pressure	Water Meter Readings		
			Initial	Final	Volume
Units:	(Open/ Close)	psi	gallons		gallons
1	Close	11	2281.465	2289.085	7.62
	Open	11	2278.58	2279.83	1.25
2	Close	11	2289.085	2298.55	9.465
	Open	11	2298.76	2299.96	1.2
3	Close	11	2301.22	2313.105	11.885
	Open	11	2313.25	2314.17	0.92

Air Test				Date = 08/01/19	
Smart Valve Setting = Highest (15 Clicks)					
Total Test Time = 10 Sec					
#Run	Smart Valve	Static Air Pressure	Water Meter Readings		
			Initial	Final	Volume
Units:	(Open/ Close)	psi	gallons		gallons
1	Close	11	2247.13	2255.6	8.47
	Open	11	2255.62	2255.625	0.005
2	Close	11	2257.16	2266.12	8.96
	Open	11	2266.23	2266.23	0
3	Close	11	2267.79	2275.17	7.38
	Open	11	2275.17	2275.17	0

Fixed Volume Test						Date = 08/08/19	
Smart Valve Setting = Lowest (0 clicks)							
Static Water Pressure = 50 Psi							
Fixed Volume Flowed = 5gallons							
#Run	Smart Valve Condition	Water Meter Readings		Flow Rate	Time taken to fill a 5 gallon container	Volume	
		Initial	Final			Flow rate meter at outlet	Water Meter
Units:	(Open/ Close)	gallons		gpm	sec	gallons	
1	Closed	3769.02	3774.1	8.8	34.54	4.956	5.08
	Open	3774.395	3779.575	8.6	35.85	5.046	5.18
2	Closed	3803.61	3808.775	8.9	35.04	5.033	5.165
	Open	3808.83	3814.01	8.6	36.99	5.041	5.18
3	Closed	3814.065	3819.235	8.9	35.58	5.038	5.17
	Open	3796.87	3802.03	8.6	37.13	5.017	5.16

Fixed Volume Test						Date = 08/08/19	
Smart Valve Setting =Mid (8 clicks)							
Static Water Pressure = 50 Psi							
Fixed Volume Flowed = 5gallons							
#Run	Smart Valve Condition	Water Meter		Flow Rate	Time taken to fill a 5 gallon	Volume	
		Initial	Final			Flow rate meter at outlet	Water Meter
Units:	(Open/ Close)	gallons		gpm	sec	gallons	
1	Closed	3819.235	3824.42	8.9	35.62	5.054	5.185
	Open	3824.475	3829.645	8	39.37	5.031	5.17
2	Closed	3829.705	3834.86	8.9	35.65	5.023	5.155
	Open	3834.915	3840.08	7.9	39.79	5.028	5.165
3	Closed	3840.13	3845.28	8.8	35.9	5.014	5.15
	Open	3845.33	3850.505	7.8	39.93	5.0355	5.175

Fixed Volume Test							Date = 08/08/19
Smart Valve Setting =High (15 clicks)							
Static Water Pressure = 50 Psi							
Fixed Volume Flowed = 5gallons							
#Run	Smart Valve Condition	Water Meter		Flow Rate	Time taken to fill a 5 gallon	Volume	
		Initial	Final			Flow rate meter at outlet	Water Meter
Units:	(Open/ Close)	gallons		gpm	sec	gallons	
1	Closed	3861.065	3866.22	8.9	34.72	5.032	5.155
	Open	3866.27	3871.435	7.6	40.88	5.042	5.165
2	Closed	3871.49	3876.66	8.9	34.85	5.047	5.17
	Open	3876.84	3881.995	7.6	40.95	5.027	5.155
3	Closed	3882.045	3887.23	9	34.93	5.061	5.185
	Open	3887.28	3892.44	7.6	40.84	5.033	5.16

Variable Flow Rate Test						Date = 08/07/19	
Smart Valve Setting = Lowest (0 clicks)				Total Test Time = 110 sec			
Static Water Pressure = 50 Psi							
Air Supply Started at 10 sec and Stopped at 20 sec. Cycle Repeated 5 times.							
#Run	**Smart Valve Condition**	**Water Meter Readings**		**Flow Rate**		**Volume**	
		Initial	**Final**	**Normal**	**Reduced**	**Flow rate meter at outlet**	**Water Meter**
Units:	**(Open/ Close)**	**gallons**		**gpm**		**gallons**	
1	Closed	3655.655	3672.13	9.8	8.3	16.107	16.475
	Open	3672.285	3688.37	9.4	8	15.736	16.085
2	Closed	3688.55	3705.015	9.8	8.3	16.334	16.465
	Open	3705.455	3721.355	9.5	8	15.559	15.9
3	Closed	3721.53	3737.945	9.8	8.3	16.078	16.415
	Open	3738.135	3754.11	9.5	8	15.629	15.975

Variable Flow Rate Test						Date = 08/07/19	
Smart Valve Setting = Mid (8 clicks)				Total Test Time = 110 sec			
Static Water Pressure = 50 Psi							
Air Supply Started at 10 sec and Stopped at 20 sec. Cycle Repeated 5 times.							
#Run	**Smart Valve Condition**	**Water Meter**		**Flow Rate**		**Volume**	
		Initial	**Final**	**Normal**	**Reduced**	**Flow rate meter at outlet**	**Water Meter**
Units:	**(Open/ Close)**	**gallons**		**gpm**		**gallons**	
1	Closed	3556.82	3573.495	9.8	8.4	16.321	16.675
	Open	3573.665	3588.635	9	7.5	14.673	14.97
2	Closed	3588.82	3605.285	9.8	8.3	16.098	16.465
	Open	3605.48	3620.44	8.8	7.3	14.672	14.96
3	Closed	3621.23	3637.71	9.8	8.3	16.117	16.48
	Open	3637.84	3652.74	8.8	7.2	14.597	14.9

Variable Flow Rate Test						Date = 08/07/19	
Smart Valve Setting = Highest (15 clicks)				Total Test Time = 110 sec			
Static Water Pressure = 50 Psi							
Air Supply Started at 10 sec and Stopped at 20 sec. Cycle Repeated 5 times.							
#Run	**Smart Valve Condition**	**Water Meter**		**Flow Rate**		**Volume**	
		Initial	**Final**	**Normal**	**Reduced**	**Flow rate meter at outlet**	**Water Meter**
Units:	**(Open/ Close)**	**gallons**		**gpm**		**gallons**	
1	Closed	3524.69	3541.38	9.8	8.4	16.333	16.69
	Open	3436.94	3451.055	8.5	6.9	13.795	14.115
2	Closed	3461.01	3477.515	9.7	8.4	16.072	16.505
	Open	3478.77	3492.87	8.5	6.9	13.79	14.1
3	Closed	3493.215	3509.87	9.8	8.3	16.194	16.655
	Open	3510.07	3524.375	8.6	7	13.992	14.305