ITRC Float Valve
Surge Pressure Protection Evaluation

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Abstract: The Irrigation Training and Research Center (ITRC), California Polytechnic State University, San Luis Obispo, evaluated the performance of the ITRC Float Valve during several visits to Delano-Earlimart Irrigation District (DEID). The purpose of the trips was to evaluate the new ITRC Float Valve, investigate water hammer problems resulting from rapid valve closures, demonstrate the effect of water hammer to DEID operators, and provide recommendations for the current pressure surge problems. The results showed that a significant reduction in the water hammer potential to the DEID concrete pipelines could be achieved with the use of the new ITRC Float Valve design combined with educating operators to slow down the closure of on/off valves. The ITRC Float Valve minimized both pressure surges and the pressure fluctuations that are common with the existing on/off valves.

Keywords: float valve, water hammer, pressure surge, butterfly valve

Background

Pipelines and their fittings are designed to operate safely under certain specified pressures. Excessive high pressures, encountered as a sudden shock wave or continuously, will damage irrigation and water conveyance hardware (Figure 1).

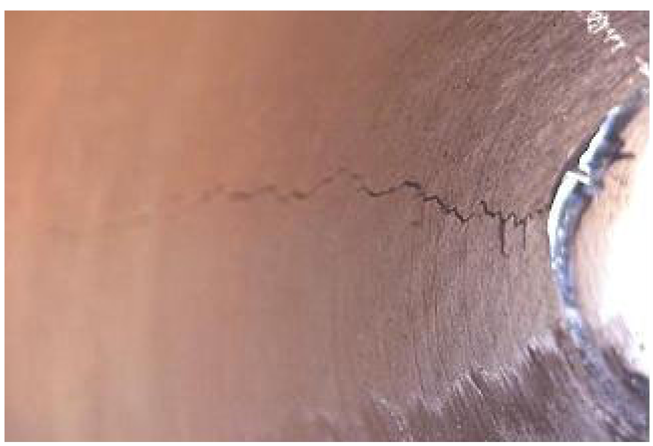

Figure 1. Water Hammer Damage in Concrete Pipeline

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These pressure surges are caused by a sudden change in the velocity of water in a pipeline, as is caused by the closure of a valve. The increase in pressure is a function of both the water velocity and the wave velocity. The wave velocity is the speed at which a pressure surge is transmitted by the pipe walls, and is dependent on the pipe material.

For several years, the Delano Earlimart Irrigation District (DEID) has been concerned about water hammer damage to their pipes. DEID distributes water through concrete pipelines in southern Tulare County and northern Kern County, California. Each turnout has a standpipe that is used as an air vent in the line to prevent back flow if a negative pressure occurs. Under a technical support agreement with the US Bureau of Reclamation (USBR), the Irrigation Training and Research Center (ITRC) has worked with DEID since 1999 to research and design a system to decrease the pressure in these pipes. The result of this research is the ITRC Float Valve.

The ITRC Float Valve has evolved through several stages of design. The final design and research results can be found at the ITRC website (www.itrc.org/reports/deidfloatvalve/floatvalve.pdf). The valve is designed to float as water in the standpipe rises. The float is connected to the valve through linkages. As the float rises the valve closes, regulating the flow into the standpipe to maintain a desired water level regardless of the pressure upstream of the valve.

ITRC personnel have tested and installed pressure regulating or float valves at a few sites within DEID. Figure 2 shows the turnout configuration showing the location of the ITRC Float Valve, the DEID operational (On/Off) valve, and Grower flow control valve. The ITRC Float Valve was installed at the inlet to the 36" inside-diameter concrete standpipe.

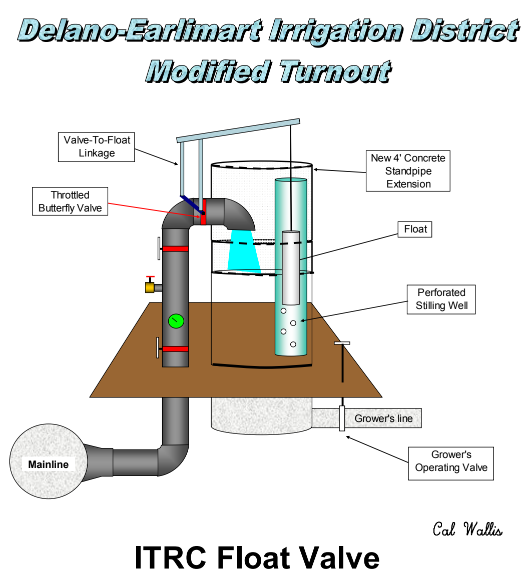

Figure 2. Turnout Configuration

After the ITRC Float Valves had been in place for some time at DEID it was determined that more research was needed on whether the speed of opening and closing valves (both ITRC Float Valves and the district's standard operational butterfly valves) has a significant effect on the pressure surges through the system. To this end, ITRC conducted two days of pressure tests in February 2004 to measure pressure surges created by different valve opening and closing speeds, and led a workshop with DEID operators to demonstrate proper techniques.

Pressure Tests

Two pressure tests were conducted at DEID to determine whether on/off valve closure speed will substantially affect surges in pressure. The flow rate was measured using a propeller flow meter upstream from the DEID operational valve. The pressure transducer for this test was installed upstream from the flow meter on the vertical section of the pipe.

The first test was performed during a preliminary test run by ITRC personnel. Five days later, ITRC personnel prepared and presented a workshop to the DEID operators. During the workshop each of the operators was allowed to close or open valves to demonstrate the effect on water hammer at different flow rates.

Pressure was measured for 55 seconds starting with the closing or opening of the valves. Throughout the test, the "standard" valve closing and opening represents the DEID accepted practice. Closing and opening of the operational (butterfly) valve and ITRC Float Valve were tested under the following conditions:

Field Check – Pressure Test 1

	Operational valve	**ITRC Float Valve**
Standard Closing	500 gpm	500 gpm
	1,000 gpm	1,000 gpm
	1,500 gpm	1,500 gpm
	2,000 gpm	2,000 gpm
Rapid Closing	250 gpm	
	500 gpm	
	1,000 gpm	
	1,500 gpm	
Rapid Opening	2,000 gpm	

Workshop – Pressure Test 2

	Operational valve	**ITRC Float Valve**
Standard Closing	500 gpm	500 gpm
	1,000 gpm	2,000 gpm
	2,000 gpm	
Rapid Closing	500 gpm	
Standard Opening	2,000 gpm	
Closing of the downstream On/Off valve		Standard closing (< 10 sec)
		Medium closing (10-30 sec)
		Very slow closing (> 30 sec)

Test Site

The pressure tests were conducted outside the DEID office from a turnout of a 30" diameter mainline. The DEID main pipeline elevation difference between the Friant Kern Canal and the district office is about 104 feet. The static pressure with no flow rate at this location is about 45 psi (conversion from 104 ft/2.31 ft per psi).

Pressure Test Equipment

Tests were conducted using a pressure transducer, scopemeter, and a portable computer. A 100 psig **Druck** pressure transducer (PDCR 900-0983) was used to measure the pressure in the inlet pipe to the standpipe. The sensitivity of the transducer is 0.10 mV/V/psi. The transducer was powered by a regulated DC power supply (Samlex RPS 1204) and the voltage adjusted to 10 volts using a potentiometer. The transducer was installed four feet upstream of the flow meter, float valve, and gear and handwheel butterfly valve.

The output signal from the transducer was recorded using the **Fluke ScopeMeter** Model No. 196. The ScopeMeter was set for amplitudes of 50 mV/division and 50 msec/division. The meter recorded data every 2 milliseconds (0.002 seconds) for a total time of 55 seconds (Figure 3). The data was transferred to a portable computer using the FlukeView program.

The **FlukeView** program Version 4.0 was installed in a portable computer connected to the ScopeMeter. The data was transferred to the computer after every run and Excel was used to process and plot the data.

Results

Data for pressure change with time were collected during each of the tests. Figure 3 is an example of the data collected from a test. Below is a description of what is happening at each of the points on the graph.

1. The test below started with a 1,500 gpm flow rate with a dynamic pressure of about 35 psi. Pressure readings were recorded every 0.002 seconds and can be seen on the graph as the blue dots. For this test, a DEID operator was instructed to close the butterfly valve located upstream of the ITRC Float Valve as quickly as possible (about 2-3 seconds). Immediately, there is a pressure surge caused by the closing of the valve and the velocity of the water that was moving down the pipeline from the source.

2. The pressure increased up to readings of 70 to 75 psi about 5 to 6 seconds after the valve was closed. These values may be too high for the concrete pipe and may be causing failures in the pipelines due to the high pressure. The maximum pressure surge was about 35 psi (75 psi-40 psi). Once the water

was stopped and the pressure surge reached its peak, the water moving towards the valve was reflected back, causing a decrease in the pressure.

3. At about 25 seconds, a severe pressure drop occurred in the pipeline resulting in a pressure that appears to be zero or even a negative pressure. Concrete pipes can handle negative pressure, but the large pressure changes may result in long-term fatigue failures in the concrete pipe.

4. At about 50 seconds, the pressures are starting to stabilize to reflect the static (no flow) pressure in the pipeline.

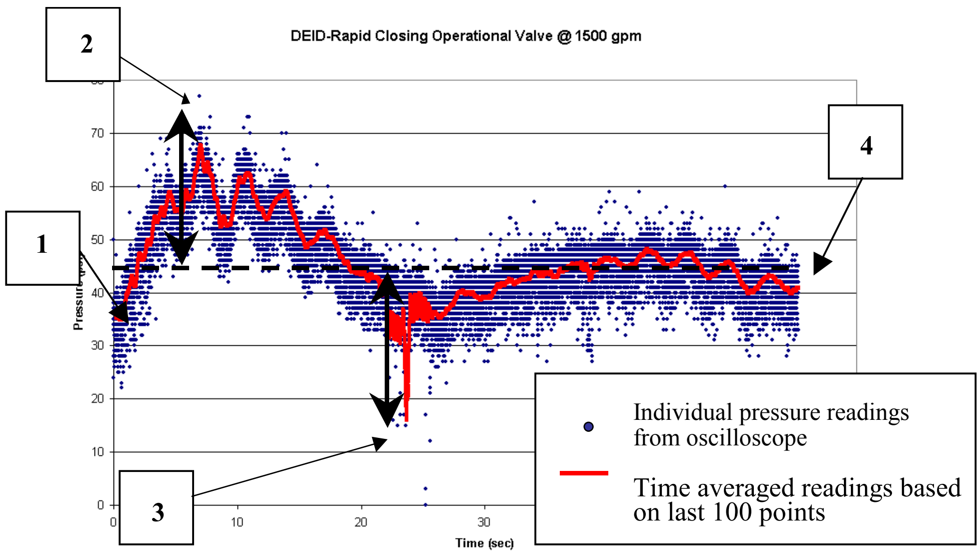

Figure 3. Graph of a Sample Test with Explanation of the Data

<u>The effect of the speed of closing a valve</u>

In order to compare the differences in hardware or the operation of the valves, several comparison graphs were created to look at two or three test results on the same graph. Figure 4 is an example of combining three field tests together on one graph. Below is a description of what is happening at each point on the graph.

1. The test below started with a 2,000 gpm flow rate with a dynamic pressure of about 25 psi. For this set of tests, a DEID operator was instructed to close the butterfly valve located downstream of the ITRC Float Valve at 3 different speeds (slow, medium, and fast). For the fast and medium closing speeds, a defined pressure surge occurs. For the slowest closing speed (the green line), there is a very small pressure surge.

2. The maximum pressure was about 68 psi when rapidly closing the line valve on the downstream side of the ITRC Float Valve. The maximum surge pressure was about 20 psi (68 psi-48 psi).

3. The maximum pressure was about 62 psi when closing the line valve on the downstream side of the ITRC Float Valve over a time period of about 15 seconds. The maximum surge pressure was about 14 psi (62 psi-48 psi).

4. At about 55 seconds, the pressures are starting to stabilize at 48 psi to reflect the static (no flow) pressure in the pipeline.

5. The pressure difference between the dynamic pressure at the beginning of the test (25 psi) and the static pressure at the end of the test (48 psi) reflect the friction losses (23 psi) at a flow rate of 2,000 gpm.

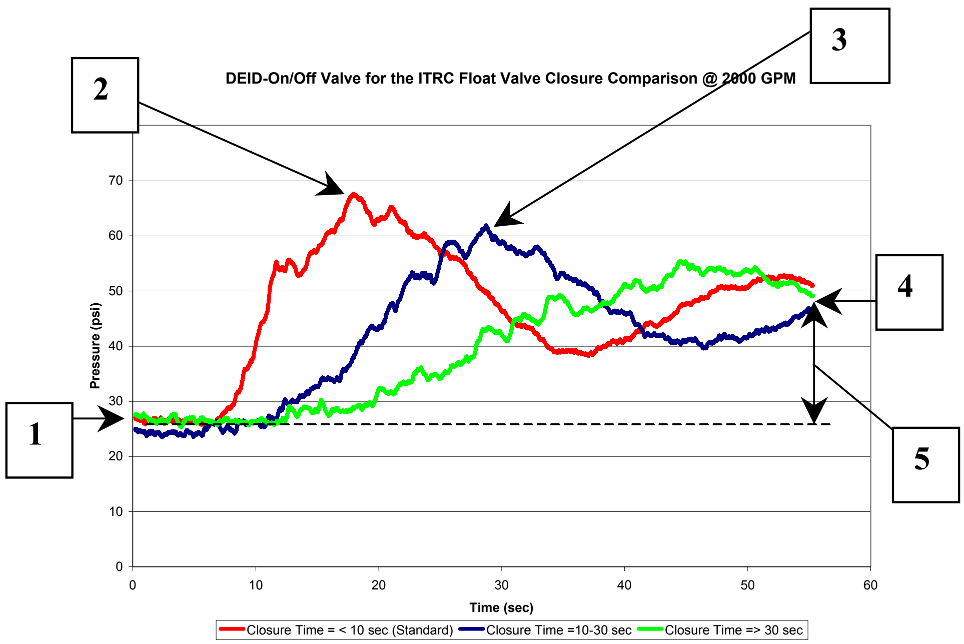

Figure 4. Comparison Between Different Times Required for the Closing of the On/Off Valve Downstream of the ITRC Float Valve. The Lines Represent a 0.2-Second Moving Average.

The graph shows a clear benefit of slowing down the closure of the valves. Even where an ITRC Float Valve has been installed, the grower should use at least 30 seconds in closing the flow control valve downstream of the Float Valve.

The effect of flow rate on pressure surges

The flow rate of water delivered to the farmer influences the pressure surges. Pressures were measured during standard closing of the operational valve at different flow rates (Figure 5). The results show that higher pressures and greater pressure differences were observed at higher flow rates. Note the surging of the pressure that takes place at 2,000 gpm as the valve is incrementally closed. At the end of the test, all of the lines reached a common static pressure even though they started at different dynamic pressures.

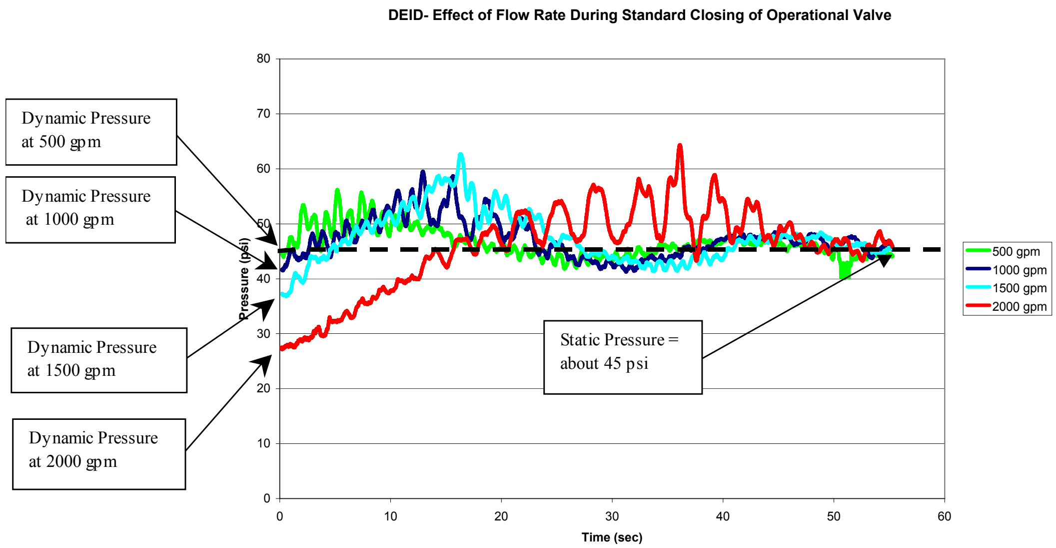

Figure 5. Comparison of Pressure Surges Caused by Different Flow Rates During Standard Closing of the Operational Valve Upstream of the ITRC Float Valve. The Lines Represent a 0.2-Second Moving Average. Operational Valve was Closed by DEID Operator.

The data indicate that much greater care must be taken at higher flow rates. The surge pressures generated at 2,000 gpm could be high enough to break a concrete pipe. The valve closure speed at 2,000 gpm should have been longer than 35 seconds.

<u>The effect of valve type on pressure surges</u>

The ITRC Float Valve reduced the rapid pressure fluctuations compared with the standard closing of the operational valve (green line in Figure 6). The ITRC Float Valve almost eliminated the rapid surge in pressure. The rapid closing of the operational valve caused high frequency (i.e. large number of waves per time) pressure waves, which continued for almost 30 seconds.

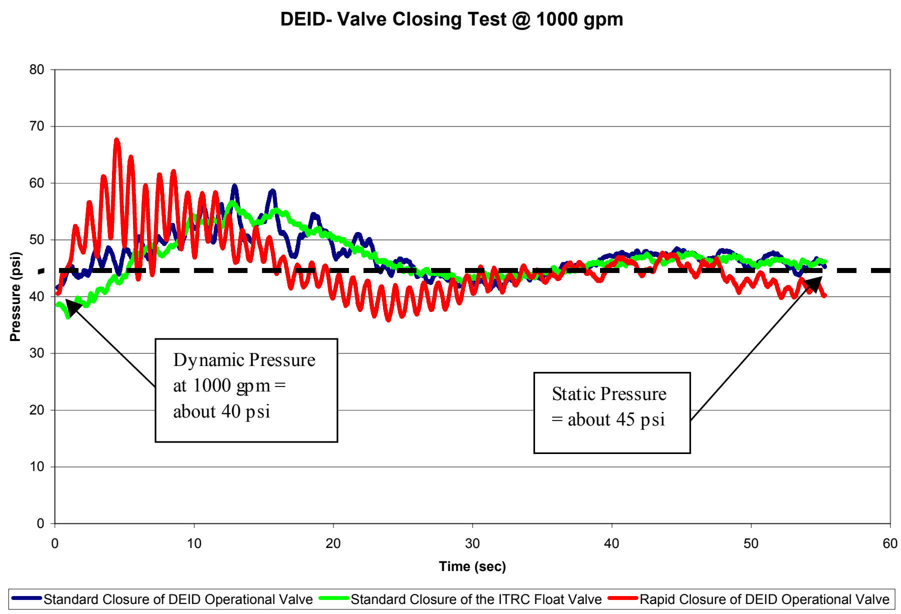

Figure 6. Comparison of ITRC Float Valve Closure versus Standard and Rapid Closure of the Operational Valve. The Lines Represent a 0.2-Second Moving Average.

The results show that the ITRC Float Valve helps to minimize pressure surges especially when an inexperienced operator closes the valve too quickly.

Human operator effect on pressure surges

Operators also have a significant effect on the pressure surges in the pipe (Figure 7). Two operators closed the operational valve at standard closing speed. However, one of the operators closed the valve slower (green line) than the other operator, with a closing time of almost a minute. The slower closing speed eliminated the pressure surges even at the high flow rate of 2,000 gpm.

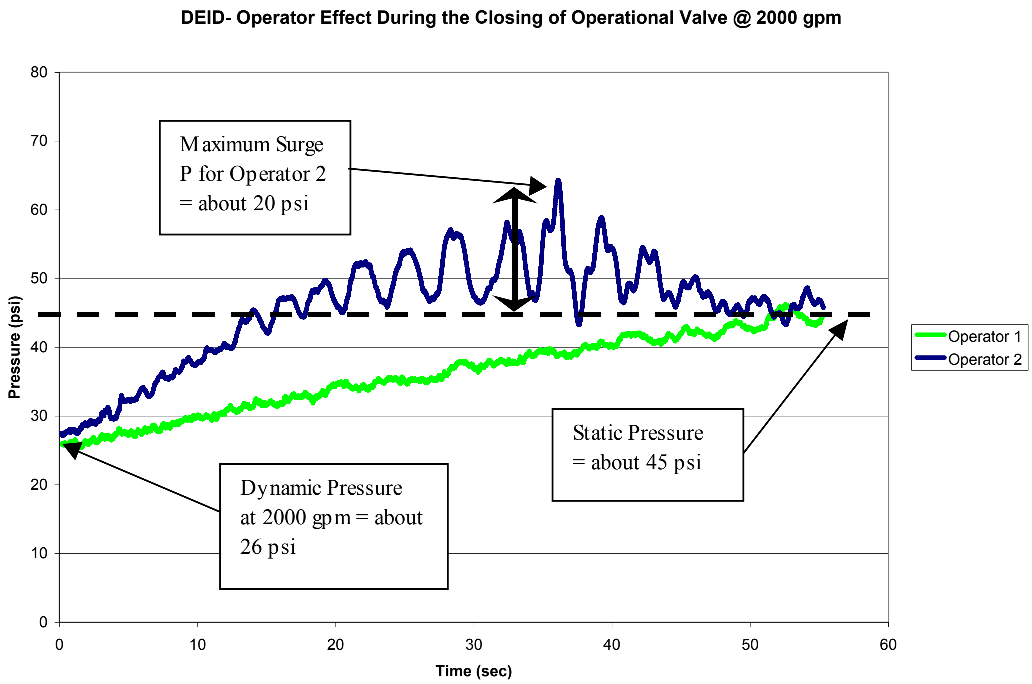

Figure 7. Comparison of Two DEID Operators During the Closure of the Operational Valve at a Flow Rate of 2,000 gpm. The Green Line Indicates a Slower Closing Speed. The Lines Represent a 0.2-Second Moving Average.

The data indicate Operator 1 probably has seen a line break due to water hammer pressure surges and took a much greater time period to close the valve. The results would tend to indicate that for high flow rates, the minimum closure time should be at least 1 minute for turnouts that do not have an ITRC Float Valve installed.

Conclusions

From this set of tests run at DEID, the following conclusions were made:

- Rapid closure of either the grower flow control valve or the DEID operational on/off valve will cause pressure surges high enough to create damage to the concrete pipelines at DEID. Care should always be taken when closing the manual valves at DEID even if an ITRC Float Valve has been installed.

- Based on the pressure tests conducted at DEID, the ITRC Float Valve significantly reduced the pressure surges during water deliveries. The ITRC Float Valve eliminated the high frequency pressure surges. The overall pressure surge was further reduced by increasing the time required to close the On/Off valve downstream of the ITRC Float Valve.

- The rapid closure of the DEID operational valve caused high frequency pressure surges even at flow rates as low as 500 gpm. Standard DEID closure time caused some pressure surges at the turnout. The pressure surges were considerably reduced when the operator took more than a minute to close the valve.

- Pressure tests conducted during the opening of the DEID operational valve also recorded pressure surges and significant negative pressures within the line. The opening of a valve should follow the same rules as the closing of a valve.

Recommendations

ITRC recommends the following items to minimize water hammer pressure surges and to reduce the pressure variations during the closing or opening of the valves:

1) ITRC Float Valves should be installed at turnouts where growers want to operate their own valves for flow rate control. The district operational on/off valve handle should be locked or removed to prevent being used by unauthorized personnel.

2) The time required for a grower closing or opening the flow control valve downstream of the ITRC Float Valve must be at least 30 seconds. The grower should use his watch to time the valve movement.

3) For those sites with only a standard operational valve, the time required for closing or opening the valve must be at least 1 minute. The operator should use his watch to time the valve movement.

Reference:

Gaudi, Franklin. 2001. Evaluation and Modification of a Float Valve for the Delano Earlimart Irrigation District (DEID). Senior Project. California Polytechnic State University. San Luis Obispo, CA 93407.