MODERNIZING AGING PIPE INFRASTRUCTURE IN IRRIGATION DISTRICTS

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ABSTRACT

Many irrigation and water districts in California convey water through aging concrete pipelines. In addition to huge problems with leaks and failures, districts also struggle to provide turnout deliveries with more flexible schedules. This paper discusses the problems that are encountered, and various approaches that have been or can be used. The specific pipeline designs that are discussed in this paper are generally gravity flow, flowing downhill from a canal. Most of these pipelines were originally installed under the assumptions that farmers would need high flows at low pressures for surface irrigation.

INTRODUCTION

Water was originally delivered on a fairly inflexible basis, and irrigation district employees typically operated/adjusted the individual turnout valves. The turnouts typically discharge into atmosphere or into an open standpipe, so there is sometimes an "air gap" between the district pipeline and the on-farm system. This is most common on the oldest pipeline systems.

There are two general challenges:

1. In some cases, the pipelines need to be replaced because:
    a. The actual life has exceeded the useful life. They are leaking badly and failing. The cost to frequently repair these pipelines (often with diameters of greater than 3') is high and is complicated with recent urbanization and lack of access.
    b. The old pipelines, which were designed for a rotation delivery, cannot be converted to provide flexible deliveries that are needed by modern on-farm irrigation systems and management. Flexibility requires some minimum pressure, and many of these old pipelines can only withstand pressures of about 9', often have few control structures, and operate with upstream control.
2. For pipelines that are in good enough condition to operate at pressures of 100' or so, the focus is not on replacement but rather on adaptation. As farmers transition to pressurized irrigation systems with more sophisticated irrigation management, they want more flexible water delivery service. Most farmers prefer to be able to operate the individual turnouts themselves. Furthermore, many farmers would like to reduce

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their pumping bills by utilizing any pressure that is available in the district pipeline – as opposed to having that pressure reduced when it flows into a standpipe. If districts allow farmers to connect booster pumps directly to district structures, there are three typical problems:

a. Although some farmers in a district will have booster pumps, others will still have surface irrigation (furrow, border strip). For the surface irrigators, a slight change in district pipeline pressure will change their turnout flow rates – which makes irrigation management difficult. Traditionally, this problem was minimized by having district operators only make occasional flow changes, at scheduled times, and they followed up on a turnout change by re-adjusting flows at the other open turnouts. Clearly, this is impractical with flexible delivery schedules.
b. Individual valves or pumps connected directly to district turnouts and operated quickly, will cause small pressure surges that will result local pipe damage and will also lead to fatigue failures at the fittings.
c. Regional power outages will cause multiple direct-connected pumps to shut off simultaneously, thus generating large surges throughout the pipeline. Figure 1 illustrates potential surge pressures in Shafter-Wasco ID due to a regional power outage, with pumps shutting off instantaneously. Obviously, the pipes would burst before those high pressures are reached. It is clear that even with slow closure (such as could occur with float valves), there are unacceptably high surge pressures for this condition.

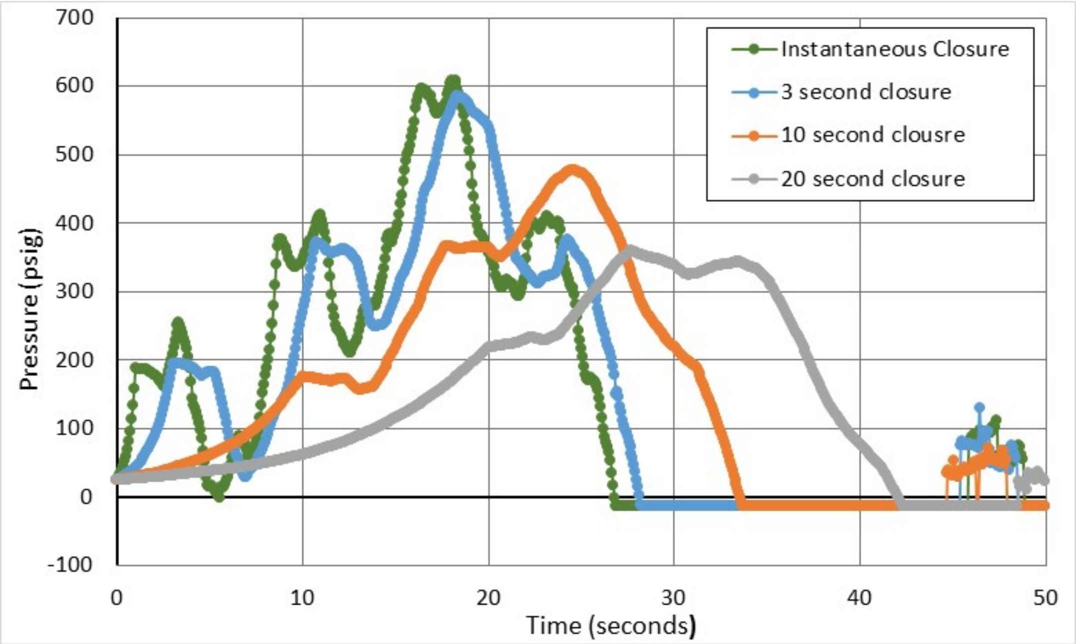

Figure 1. Simulated pressures at one location in a large irrigation district gravity-fed pipeline network, with a regional power outage. Different colors indicate the impact of various closure times.

Situation #1 – Old Low-Pressure Concrete Pipelines that Need Replacement

When this situation is encountered, the following questions need to be addressed:

1. If the district plans to provide water on a flexible basis (large latitude in frequency and duration), how does one determine the appropriate pipe section flow rates? Considerations include:
    a. The assumption of the hours/week that water will be available.
    b. The allowable size of a turnout. Should it match typical existing drip/micro designs, or should it be based on an assumption of peak ET and efficiency?
    c. What is the design assumption for congestion? Is there a 99% probability of not exceeding the design flow rate, or 95%, or 90%? There is a huge difference in the required pipe sizes with varying assumptions.
2. What pressure should be provided? If all existing groundwater wells already provide about 104' discharge pressure at the surface, it would be good to provide a minimum of 104' at the new turnouts. However, if there are no existing pressurized systems, the question is always one of whether it is best for the district to pressurize the water, or if each turnout should have its own pump.
3. What degree of filtration is needed? Typically there is a mix of sprinklers, microsprinklers, and drip irrigation in an area – each with a different level of filtration needed. Usually, districts will provide filtration sufficient for sprinklers, but not for microsprinklers or drip irrigation.
4. Once you know the design flow rate in a pipe section, how do you determine the appropriate pipe size? Do you use some rule of "do not exceed 4 feet per second"? Is there a concept of a critical path? What are the assumptions regarding life of the hardware, power costs, and interest rates?
5. How are the existing surface irrigation fields going to be serviced, until everyone converts to pressurized irrigation? In many districts with rotations, the individual field turnouts have flow rates of 10-25 CFS, regardless of the field size (the flow rate is constant in the pipe; with a rotation schedule the duration varies depending on the size of the field). Using the new pipelines for both pressurized deliveries and large surface flows is problematic because the schedules are quite different, and the surface deliveries need large pipelines to the very downstream ends.

After those fundamental questions have been asked, there are numerous details about the configuration and layouts of new pipelines. Because of right-of-way issues and road crossings, it may be desirable to utilize existing pipeline easements for the new pipelines. However, a different orientation may be much more cost-effective.

Figure 2 shows the existing layouts of canals and pipelines (mainly cast-in-place concrete) in South San Joaquin ID (near Manteca, CA). There are about 400 miles of pipelines, servicing about 55,000 irrigated agriculture acres. ITRC is currently working with SSJID to develop a modernization plan that supplies both pressurized and low pressure water.

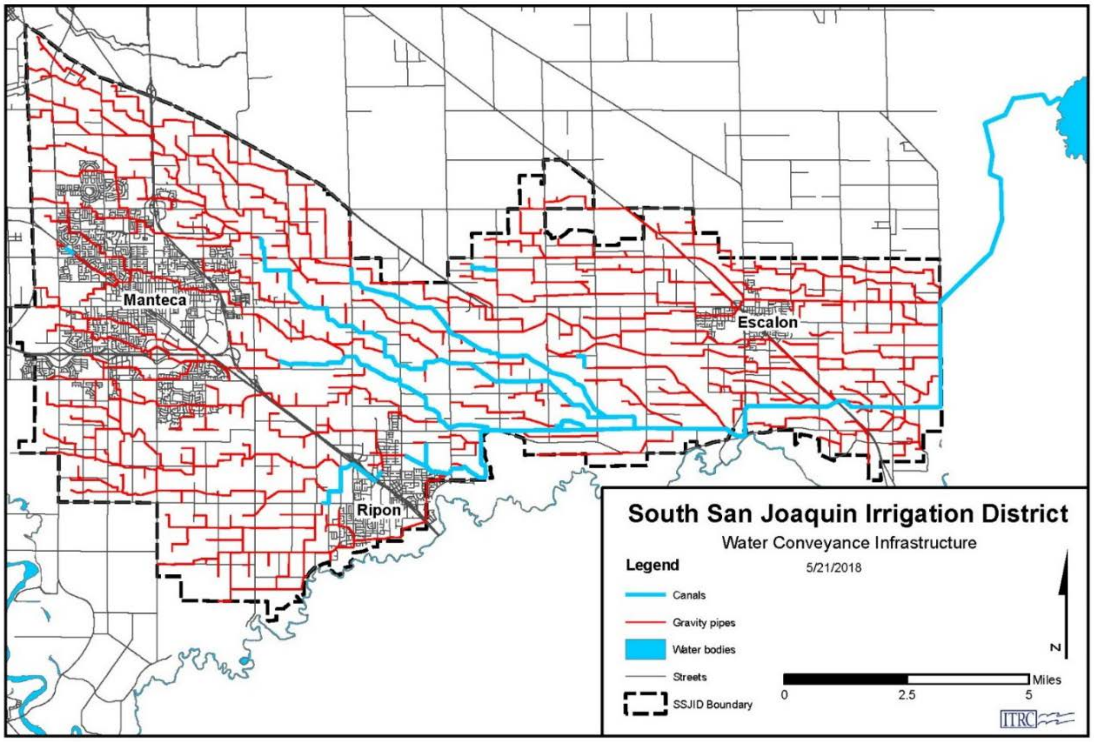

Figure 2. South San Joaquin ID – existing canal and pipelines

Situation #2 – Pipelines are in Good Condition

In this situation, the district is concerned about uncontrolled flow rate changes at turnouts, as well as water hammer problems. The solution must incorporate:

- A pressure regulation device
- Water hammer protection

Commercial pressure regulators are typically incapable of delivering the low pressures needed for surface irrigation. Therefore, locally manufactured float valves are sometimes used to provide a reduced, constant downstream pressure in an open standpipe. Gaudi (2001) presented an ITRC design that was implemented on about 900 turnouts at Delano-Earlimart ID in California. It is a float valve configuration that provides pressure regulation as well as relatively slow closure to minimize water hammer. At the time that solution was developed, there was little consideration of direct connections to farmer booster pumps.

The valve closure time will depend upon the valve linkage, the standpipe diameter, and the initial opening of the butterfly valve. Recommendations given here are intended to provide a relatively slow closure time. Nevertheless, even a small surge can damage a pipeline that is operating close to its pressure rating. For that reason, it is recommended that for such cases (operation close to the pressure rating of the pipe, accounting for old age), a pressure relief valve plus a vacuum relief/air release valve be installed upstream of the float-actuated butterfly valve. Details can be found in ITRC Report No. R 18-001, at www.itrc.org/reports/waterhammerprotection.htm

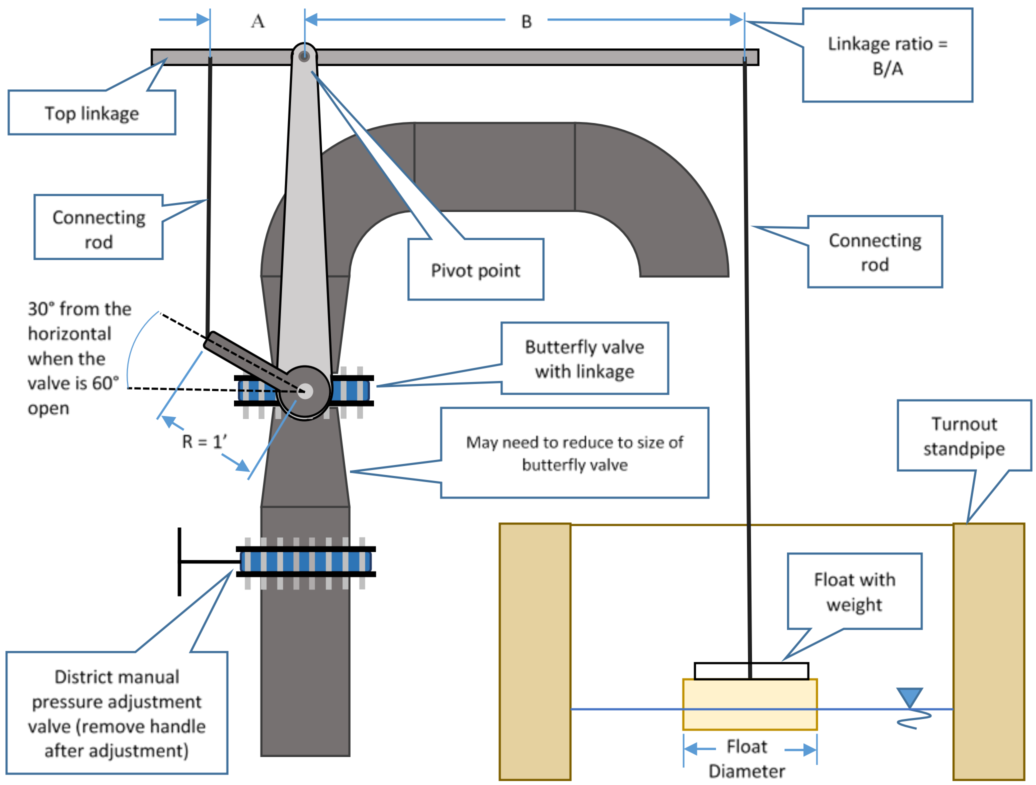

Figure 3. Conceptual sketch of float valve mechanism. Not to scale. Does not show flow meter, pressure relief, and vacuum relief valves.

When fully assembled, the float mechanism will look similar to the assembly shown in Figure 4.

Figure 4. Assembled float mechanism on a turnout at Delano-Earlimart Irrigation District – without the recommended manual pressure reducing valve, or pressure relief and vacuum relief valves.

Situation #3 - Turnouts with Pumps for Sprinkler/Drip/Micro irrigation, with Good Pipelines

For turnouts with pumps, there is no need for pressure regulation. The pump's flow into drip/micro and sprinkler systems will have minimum changes as the district line pressures change. However, one option is to use the float valve assembly with additional valves, as described in the previous section.

For installations in which farmers do not want to lose available district pressure, two other options are suggested. For both of these cases, pumps must be installed with VFDs. The VFD controls must have ramp up (start) and a ramp down (stop) durations of 20 seconds. This will help protect the pipeline on an individual turnout basis during regular operation; it will not protect the pipeline in the instance of a regional power outage, or in case there is a motor overload and automatic shutdown of a pump.

To further protect the pipeline from the pressure surge that will occur during a power outage, one of the two following solutions should be used:

1. Vertical standpipes
2. A combined pressure relief valve and a vacuum breaker valve equipped with a continuous-acting air release valve installation plumbed downstream of a pressure regulation valve. This a non-standard configuration, and may be confusing to operators unless they are properly trained.

Table 1. Turnout designs to minimize water hammer problems

Solution	Application	Advantages	Disadvantages
Float valve with a float in an open standpipe. A pressure relief valve and a vacuum relief valve located immediately upstream of the float-controlled butterfly valve.	Surface irrigation, or sprinkler/drip/micro	• Float valve acts as a pressure regulator • Flows to turnout are not changing all the time • Float opens and closes the valve slowly, reducing water hammer during normal operation	• Loses all available pressure by discharging into the open standpipe
Vertical standpipes	Sprinkler/drip/micro	• Simple design that does not require additional valves • Farmers are able to use all of the available pressure from the district pipeline	• Unrealistically tall standpipes at turnouts located more than 30' below the canal elevation
Pressure regulating valve with a pressure relief valve and a vacuum relief valve. Plus, a very slow opening/closing manual butterfly valve and all pumps need VFD slow start/stop.	Sprinkler/drip/micro	• Can be used at low elevations where standpipes become unrealistic • Farmers are able to use most of the available pressure from the district pipeline	• More expensive • May be difficult for operators to understand and adjust the automatic valves

Solution 1: Vertical Standpipes

Figure 5 shows an example of a vertical standpipe installed at a farmer's turnout in the Kanawha-Glide Water Districts (KGWDs). A vertical standpipe will provide both surge and vacuum relief.

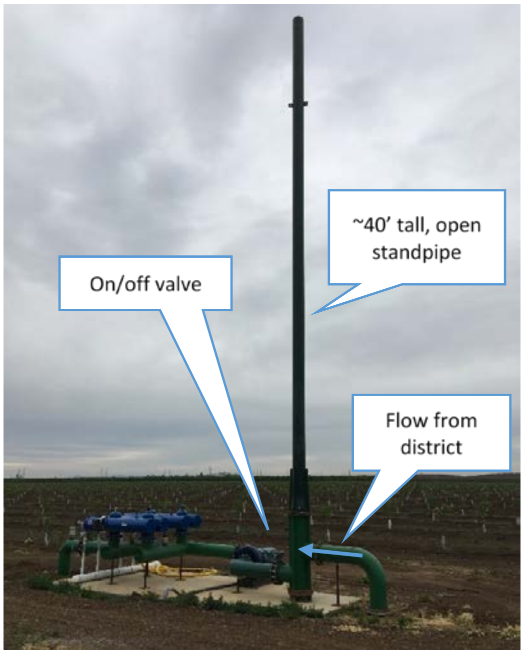

Figure 5. Example of a vertical standpipe at the Kanawha-Glide Water Districts (KGWDs)

The water level in the standpipe is related to the pressure at the on/off valve. **The height of the standpipe should not exceed the pipe pressure rating, minus 5'**.

After the initial surge, a pressure wave can travel away from the standpipe, causing a temporary localized reduction in pipe pressure. The water stored in the standpipe will draw down, preventing any vacuum from occurring. This will prevent the pipeline from collapsing, and also cushion any returning surge wave.

The main advantage of using a vertical standpipe is its simplicity: there are no additional valves needed. However, standpipes become unreasonable for turnouts that are lower than 30' below the elevation of the canal because the standpipes become too tall and expensive.

Recommendations

1. Standpipes should always be installed upstream of the farmer's on/off valve to protect the district's pipeline from water hammer.
2. The pump should have a VFD with a slow start/stop controller.
3. The district on/off valve should have a very large gear reduction so that it cannot be closed quickly.

4. The height and diameter of each standpipe will be determined by the flow rate and the difference between the canal elevation and the turnout elevation. The height of the standpipe should not exceed the pressure rating of the pipeline, minus 5'. For example, if the pipeline has a 50' pressure rating the standpipe should not exceed 45' in height. Figure 6 is for a condition of no spill during water hammer.

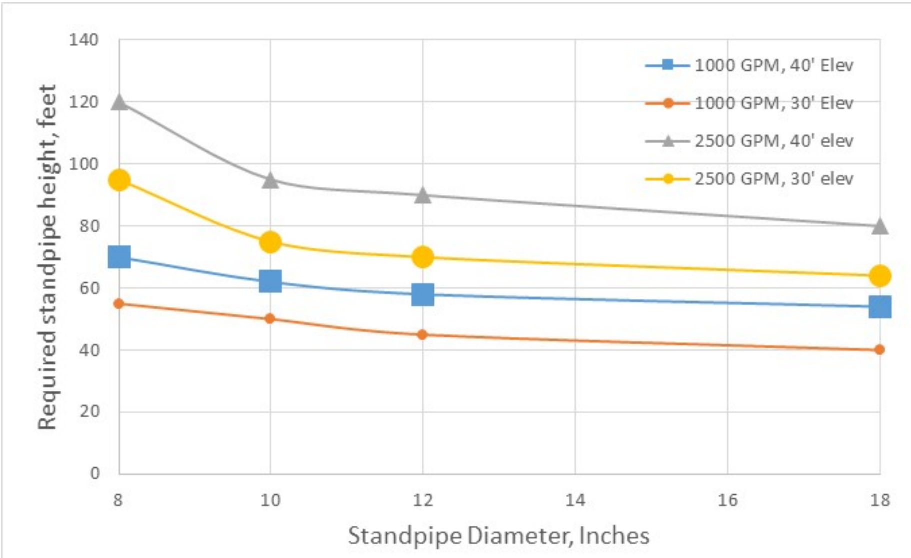

Figure 6. Required standpipe heights to have no spill during water hammer. Elevation refers to the elevation change between the canal water surface and the turnout.

5. In addition, the following items must be considered whenever proposing a new standpipe design:
   a. The proposed standpipe's proximity to power lines. Some districts have witnessed arcing between standpipes and nearby power lines, creating a dangerous environment for district operators and irrigators alike. Future installations should meet utility service or county guidelines, and permit requirements should be determined as well.
   b. Lightning strikes and grounding. The standpipes can serve as lightning rods, and they may cause damage to nearby equipment or physical harm to people if not properly grounded.
   c. Crop dusting operations. The height of the standpipes could interfere with crop dusters, and may require warning lights and special paint to catch the attention of pilots.

Solution 2: Combined Pressure Relief Valve/Vacuum Relief Valve Installation Downstream of a Pressure Regulation Valve

At lower elevations (i.e., higher pressures), both standpipes and float valves become disadvantageous: standpipes become too large and expensive, and farmers will not be able to use most of the available pressure if they use float valves. Figure 7 shows a solution for turnouts with higher pressures.

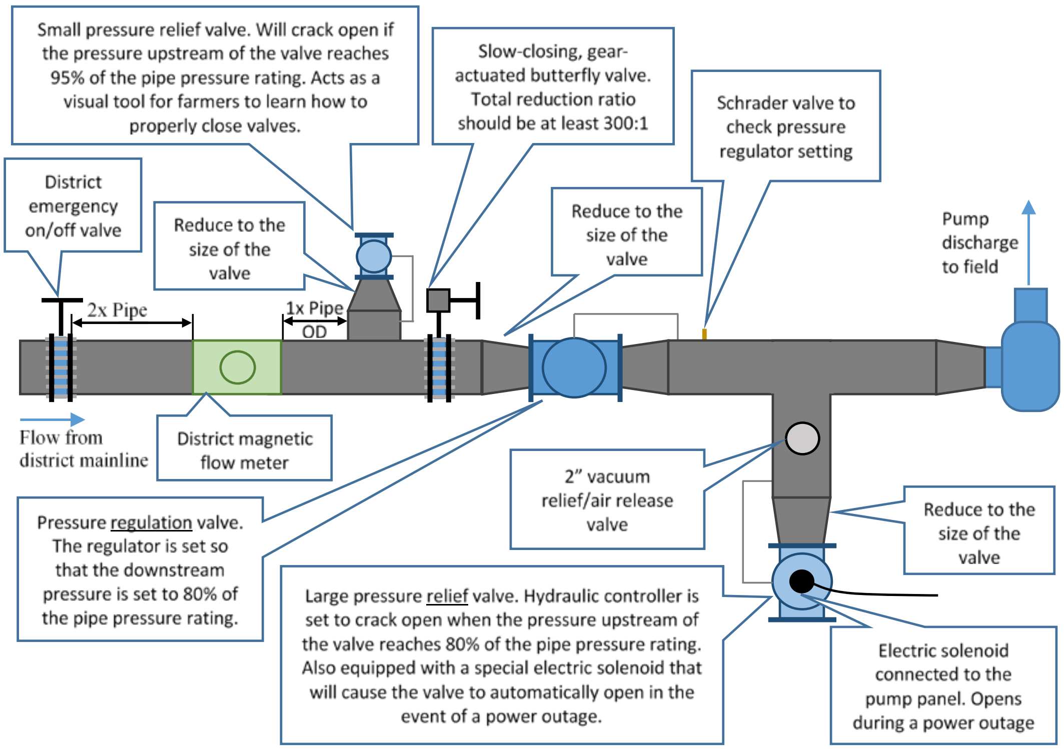

Figure 7. Plan view of Solution 2 configuration. Not to scale.

Connections for All Valves. The short sections of pipe that connect the pressure relief valves to the turnout pipe should be the same diameter as the turnout pipe itself. This will allow free flow of water. Reducing cones should be used immediately adjacent to valves, if needed.

Field Adjustment of Valve Pressure Settings. Check with the valve manufacturer to locate the equipment necessary to activate and adjust the pilot valves, without needing to actually pressurize the pipe to the target pressure in the field.

Pressure Relief Valves. The pressure relief valves shall match the specifications found in report referenced in the float valve section, with the following extra points:

- For the pressure relief valve located downstream of the pressure regulating valve: The cracking pressure of this pressure relief valve should be factory set to equal 80% of the pipe pressure rating. The valve must discharge the turnout flow rate with a loss of no more than 9' of pressure, with an opening time of 1 second or less.
- For the pressure relief valve located upstream of the pressure regulating valve: The cracking pressure for these pressure relief valves should be factory set to equal 95% of the pipe pressure rating. The valve must discharge ¼ of the turnout flow rate with a loss of no more than 9' of pressure, with an opening time of 1 second or less.

Slow-Acting, Gear-Operated Butterfly Valve. A total reduction ratio for the butterfly valve actuator is suggested to be at least 300:1. This can be accomplished in one of two ways:

1. Purchasing an off-the-shelf gear operator with the appropriate amount of gear reduction from the factory, as shown in Figure 8.

Figure 8. An Emerson AT-IS quarter-turn worm gear operator is one option that is available with a huge range of available gear ratios including 293:1 and 315:1 (www.emerson.com). Alternatives, such as the Sclumberger DYNATORQUE series are also available.

2. Installing additional hardware on a standard butterfly valve. One of many alternative configurations for this options is using a right-angle speed reducer, as seen in Figure 9. These reducers are available through suppliers such as McMaster-Carr and Surplus Center.

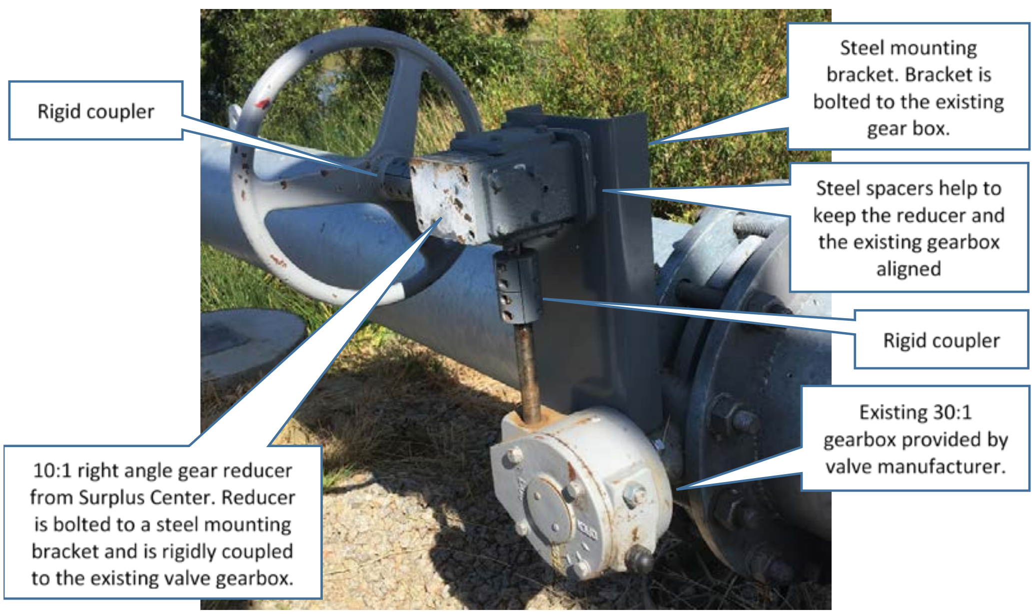

Figure 9. Additional gear reducer attached to a 12" Grayline butterfly valve

REFERENCES

Gaudi, Franklin. 2001. Evaluation and Modification of a Float Valve for the Delano-Earlimart Irrigation District. Irrigation Training & Research Center, California

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