

Water Hammer Protection for Pumped Turnouts on Aging Pipelines



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Executive Summary

Many irrigation and water districts in California convey water through aging pipelines. The specific pipeline designs that are discussed in this report have gravity flow, flowing downhill from a canal. Most of these pipelines were originally installed under the assumption that farmers would need high flows at low pressures for surface irrigation.

Water was originally delivered on a fairly inflexible basis, and irrigation district employees typically operated/adjusted the individual turnout valves – partly to ensure slow valve closure, and partly because a flow change at one turnout would influence the flow at all other turnouts on the same pipeline. The turnouts typically discharge into the atmosphere or into an open standpipe, so there is an “air gap” between the district pipeline and the on-farm system.

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 their pumping bills by utilizing any pressure that is available in the district pipeline – as opposed to losing that pressure when water flows into a standpipe. If districts allow farmers to connect booster pumps directly to district structures, there are two potential scenarios that can cause water hammer damage to the district pipelines:

1. Individual valves or pumps shutting off quickly will cause small pressure surges that will cause local pipe damage and will also lead to fatigue failures at the fittings.
2. Regional power outages will cause multiple pumps to shut off simultaneously, generating large surges throughout the pipeline.

This report provides three potential solutions to water hammer at turnouts, with each solution having its own unique advantages and disadvantages:

For surface irrigation turnouts or turnouts with pumps for sprinkler/drip micro irrigation:

- A float valve (with the float located in an open standpipe) downstream of the district turnout. A pressure relief valve and a vacuum relief valve would be installed between the district turnout and the float valve.

For turnouts with pumps for sprinkler/drip/micro irrigation only:

- Tall vertical open standpipes immediately downstream of the district on/off valve, but upstream of any farmer on/off valve or pump
- A pressure regulation valve immediately downstream of the district on/off valve, but upstream of any farmer on/off valve or pump. Between the pressure regulation valve and the farmer on/off valve/pump, two on-line valves are needed: (a) a pressure relief valve, and (b) a vacuum relief valve.

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 | <ul style="list-style-type: none"> • 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. | <ul style="list-style-type: none"> • Loses all available pressure by discharging into the open standpipe |
| Vertical standpipes | Sprinkler/drip/micro | <ul style="list-style-type: none"> • Simple design that does not require additional valves • Farmers are able to use all of the available pressure from the district pipeline | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • Can be used at low elevations where standpipes become unrealistic • Farmers are able to use most of the available pressure from the district pipeline | <ul style="list-style-type: none"> • More expensive • May be difficult for operators to understand and adjust the automatic valves. |

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Water Hammer Protection for Aging Pipelines

Background

Water hammer (surge) in an irrigation district pipeline is typically caused by sudden changes in turnout flow rates. A sudden shutoff of a booster pump (which is directly connected to a district pipeline), or a rapid closure of a turnout valve, can potentially cause surge damage. The problem occurs if the pressure exceeds the pressure rating of the pipeline. As pipes age, their pressure rating typically declines.

For irrigation district turnouts there are two scenarios of concern:

1. Typical on/off operation. For example, a single pump or single valve that shuts off quickly can cause water hammer damage.
2. A regional power outage. In this case, every pump would shut off simultaneously, and can cause a major pressure surge. Slow-closing valves and slow-shutoff VFDs will not be effective in this scenario.

There are several techniques or devices districts can use to minimize water hammer damage:

1. **Slow valve closures or pump starts/shutoffs.**
 - a. Manually operated valves can be equipped with gear operators with large reduction ratios.
 - b. A butterfly valve connected to a float in an open standpipe can be designed to close slowly; water must fill the standpipe to make the float rise.
 - c. Pumps can be equipped with variable frequency drives (VFDs) having slow start/stops.
2. **Pressure relief valves.** If water hammer does occur, the resulting increase in pressure can be limited by having an on-line pressure relief valve that will discharge water into the atmosphere. The pressure relief valve will automatically open once the pressure reaches a pre-set level. These pressure relief valves must be of high quality, very fast-acting, and designed to fully open at the target pressure.
3. **Surge standpipes.** A tall open standpipe – higher than the maximum static water level in the pipeline – will effectively dampen surges if the standpipe has sufficient diameter.
4. **Allow air to enter the pipeline when there is a vacuum.** In some cases, an initial surge can be followed by a vacuum, which can then collapse the pipe and can also cause a secondary “reverse” surge. Allowing air to enter the pipeline will prevent the pipeline from collapsing.

This report describes three different solutions (listed in Table 1 of the Executive Summary and described in the body of this report) that utilize a combination of these techniques/devices to provide district pipeline protection from water hammer.

Solution for Surface Irrigation Turnouts – Float Valve

Turnouts supplying water for surface irrigation need pressure regulation to keep the flows to the fields constant. Since these turnouts are usually not connected (either directly or indirectly) to a pump, the main source of water hammer will be from valves closing quickly; valves will need to be closed slowly to ensure water hammer does not occur. However, there should be safeguards in place in case of water hammer if the pipeline pressure is close to the pipeline pressure rating.

A major advantage of using a float valve is that it will act as a pressure regulator, ensuring that the flows to the field remain relatively constant even though others on the irrigation district pipeline change their flows. The major disadvantage of using float valves is that the farmers will lose most of the available district pipeline pressure.

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.

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.

Float Valve with a Pressure Relief Valve and Vacuum Relief Valve Installation

Float and Float Standpipe

The float valve will act as a pressure regulator, and will keep the turnout flow rate fairly constant by maintaining a constant water level in the open standpipe. The farmer will control the flow rate by adjusting the flow out of the standpipe (not into the standpipe).

When an irrigation event stops, the water level in the standpipe will rise, pushing the float up with it. As the float continues to rise, a butterfly valve is closed by a mechanical linkage between the valve and the float. Less flow enters the standpipe as the valve closes, causing the rate at which the float rises to decrease with time. This ensures a slow valve closure, which will help to minimize or prevent water hammer. Recommendations are:

1. Standpipe diameters must be a minimum of 30" (preferably 36" or larger) because a float valve on a 24" diameter standpipe will close too quickly.
2. The float diameter depends on the minimum pressure at the turnout:
 - a. If the minimum pressure at the turnout is **less** than 12' (or 5 psi), then use a **15"** diameter float
 - b. If the minimum pressure at the turnout is **greater** than 12' (or 5 psi), then use a **12"** diameter float
3. The float depth should be 30" for a 12" diameter, and 20" for a 15" diameter.

As the float valve closes, the water level in the standpipe will rise approximately 4'-5' above its normal operating level, as shown in Figure 1. The top of the standpipe should be 1'-2' above the water level in the standpipe when the float valve is closed.

Existing stands may not be tall enough to meet this requirement, and additional sections will have to be added to the standpipe.

A 45 lb. weight should be placed on top of the float to ensure that it drops when needed.

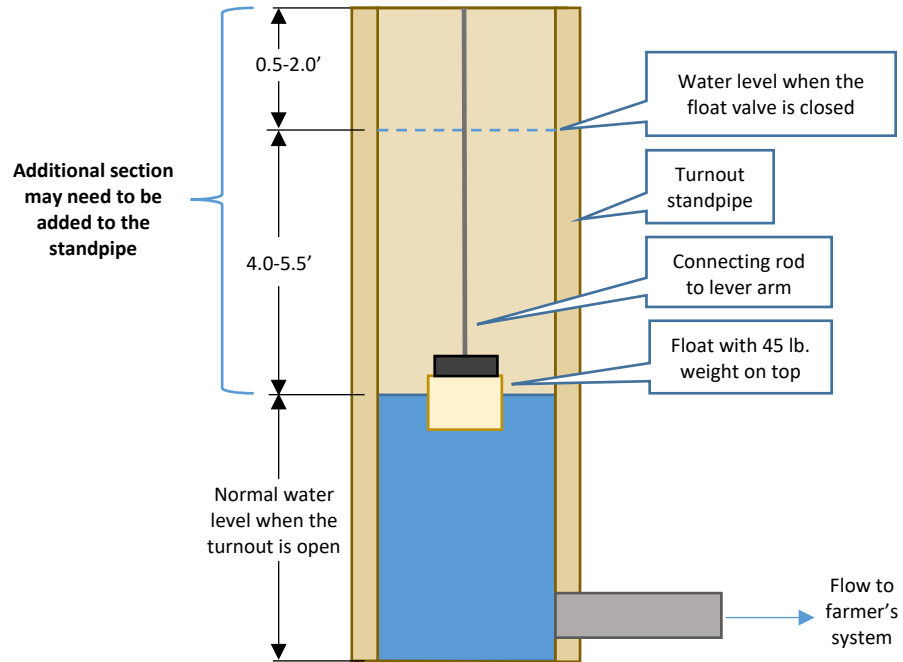


Figure 1. Water levels in a typical turnout standpipe when the float valve is open and closed. Not to scale.

Linkage Ratio

The linkage ratio is the ratio of the length of the float lever arm to the length of the valve lever arm. A greater linkage ratio results in a smaller valve lever arm length for a given float lever arm. Figure 2 shows a conceptual sketch of the linkage ratio.

To attain the necessary linkage ratios for all scenarios presented in Table 2, the top linkage of the float valve mechanism will need to be modified per the detail drawings provided in Attachment A. It can be seen from Table 3 that as the irrigation district pressure increases (as evidenced by a taller standpipe), the linkage ratio also increases – providing a more gradual closure.

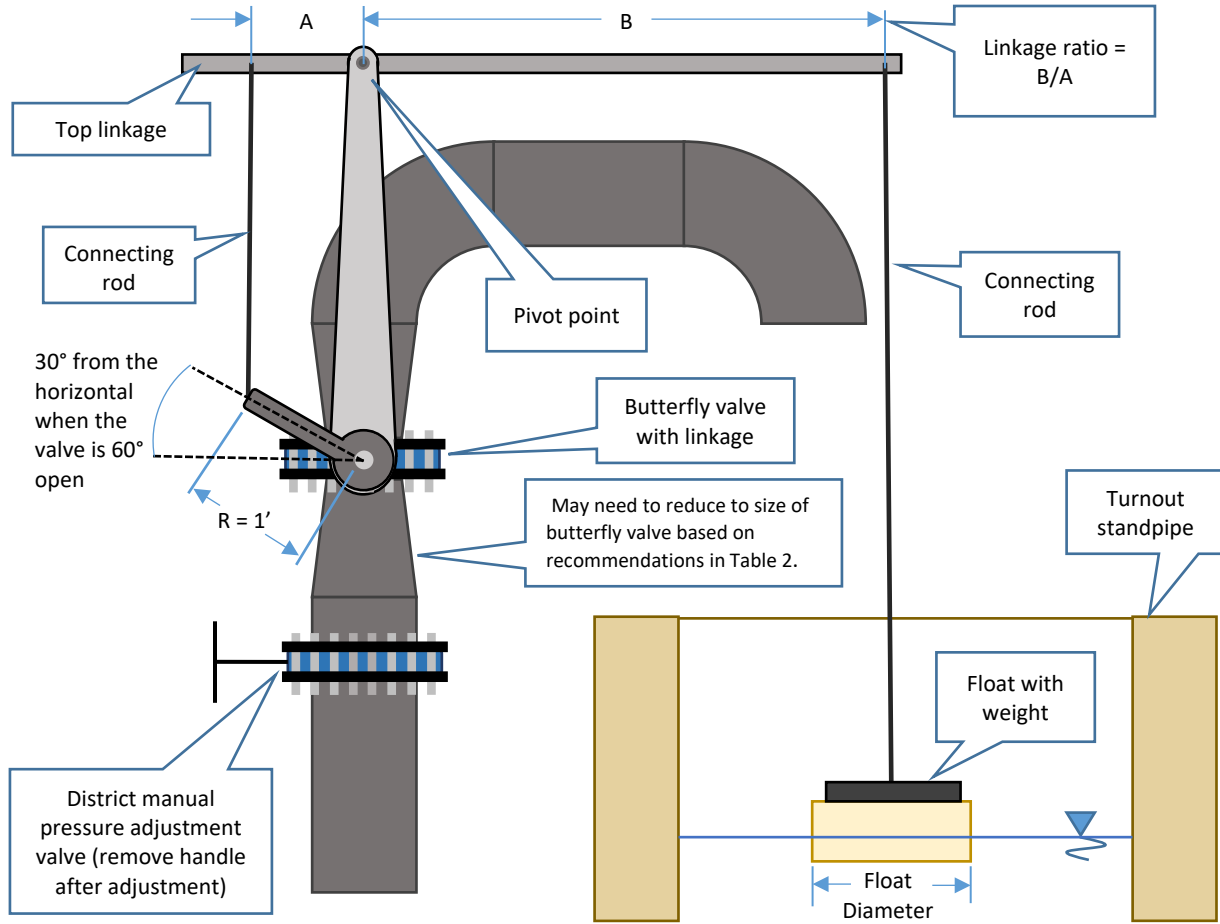


Figure 2. Conceptual sketch of float valve mechanism. Not to scale.

When fully assembled, the float mechanism will look similar to the assembly shown in Figure 3.



Figure 3. Early float mechanism on a turnout at Delano-Earlimart Irrigation District, discharging into a reservoir. This lacks features such as an upstream manual adjustment butterfly valve, pressure relief valve, and vacuum relief valve.

Butterfly Valves and Initial Adjustments

The butterfly valve shown previously in Figure 2 will open and close based on the inlet pressure and flow rate requirement. At the maximum desired flow rate, the butterfly valve should be about 60 degrees open, which would put the handle at 30 degrees above horizontal (see Figure 2). When closed, it will be 30 degrees below horizontal. This 60 degrees of movement will provide a relatively slow closure time.

A large valve at a high pressure, with a low flow requirement, might only be open by 10 degrees or so. The movement between open and fully closed of only 10 degrees would happen quickly and could cause water hammer. Therefore, the design must include two special butterfly valve features to maximize the closure time:

1. The butterfly valve attached to the float linkage must be appropriately sized for the maximum desired flow rate, and not be too large.
2. A “manual adjustment valve” needs to be located upstream of the float-actuated valve (see Figure 4). This valve needs to be manually closed enough that the float-actuated valve will be about 60 degrees open at the maximum flow rate desired. In other words, once it is properly adjusted this “manual adjustment valve” will reduce the pressure on the float-actuated valve. The “manual adjustment valve” is typically only adjusted once, and the handle is removed.

The float-actuated butterfly valve can potentially be damaged by cavitation. The valve manufacturer should be contacted for a recommendation of the materials to specify to minimize cavitation damage.

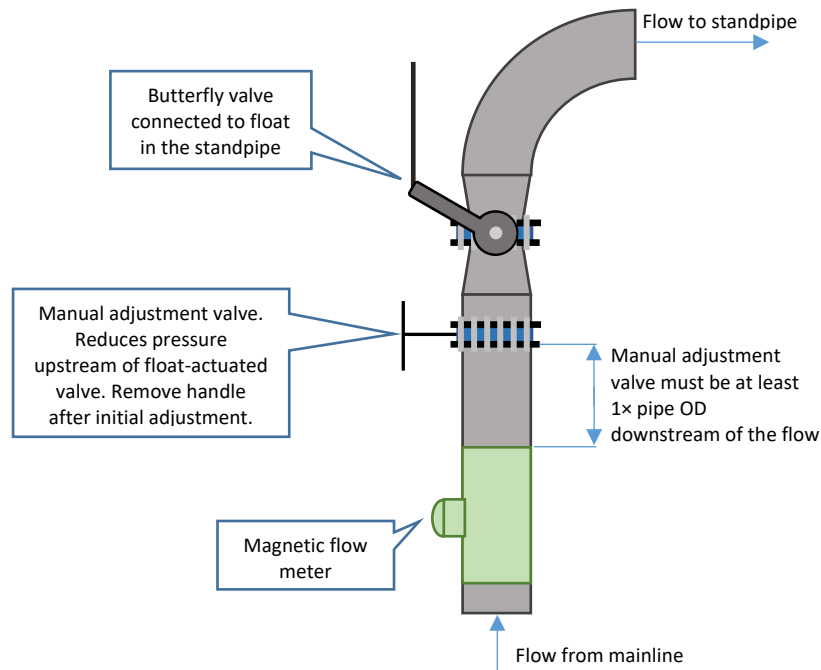


Figure 4. Manual adjustment valve located upstream of the float-actuated valve

Table 2 provides recommendations for butterfly valve diameters and linkage ratios.

Table 2. Recommendations for butterfly valves used in the float valve assembly

| Turnout Flow (GPM) | Valve Diameter (in) | Standpipe Height (ft) | | | |
|--------------------|---------------------|-------------------------|--------------------------|-------------------------|----------------------|
| | | 1' - 5' Tall Standpipes | 6' - 10' Tall Standpipes | 10'-14' Tall Standpipes | >15' Tall Standpipes |
| | | Linkage Ratio | Linkage Ratio | Linkage Ratio | Linkage Ratio |
| 500 | 6 | 6.00 | 7.00 | 8.00 | 9.00 |
| 1000 | 8 | 6.00 | 7.00 | 8.00 | 9.00 |
| 1500 | 10 | 6.00 | 7.00 | 8.00 | 9.00 |
| 2000 | 10 | 6.00 | 7.00 | 8.00 | 9.00 |
| 2500 | 10 | 6.00 | 7.00 | 8.00 | 9.00 |

Pressure Relief Valve and Vacuum Relief Valve

If the static pressure at a turnout is within 20 psi of the pipe pressure rating, then a combined installation of a pressure relief valve and a vacuum relief valve is recommended upstream of the district on/off valve (See Figure 6). This will provide an extra level of protection in case the system is not adjusted properly. This additional valve combination will protect the pipeline from both the initial pressure surge and the subsequent vacuum that will occur during water hammer.

The pressure relief valve must discharge directly into the atmosphere (i.e., have no discharge piping). Spring-loaded valves are completely unsatisfactory; special quick-acting, pilot-operated valves are required. There must be an oversized, easy-to-clean filter installed upstream of each pilot valve. The inlet and outlet ports of the filters must be at least ¼" NPT, and the filter screen must be at least 80 mesh. Filters should be checked on a monthly basis.

The cracking pressure for each pressure relief valve should be factory set to equal the pipe pressure rating, minus 5 psi, and then field-verified with a special testing kit. The valve must be sized to discharge the full turnout flow with no more than a 4 psi loss, with an opening time of 1 second or less.

The blowdown time (the time it takes the valve to close once the upstream pressure drops below the set pressure) can be adjusted using a needle valve upstream of the pilot valve as shown in Figure 5 (note: some valve manufacturers supply pilot valves that come with pre-built needle valves). For all valves, the blowdown time should be at least 30 seconds.

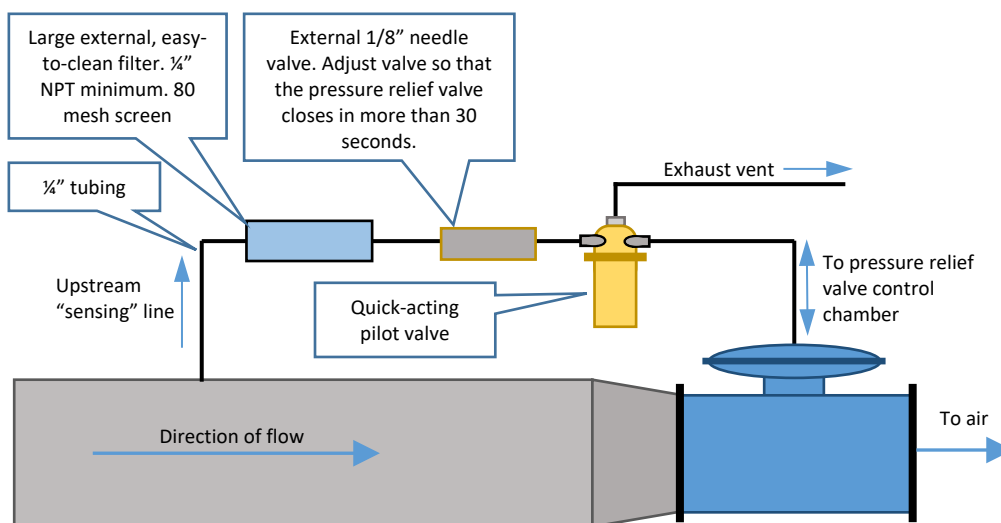


Figure 5. Conceptual drawing showing where to install the large external filter and needle valve for a pressure relief valve. Not to scale.

A 2" vacuum relief/air release valve must be installed upstream of the pressure relief valve to allow air to enter the pipeline when a vacuum occurs to prevent the pipe from collapsing. Figure 6 shows where to install the pressure relief valve and the vacuum relief/air release valve.

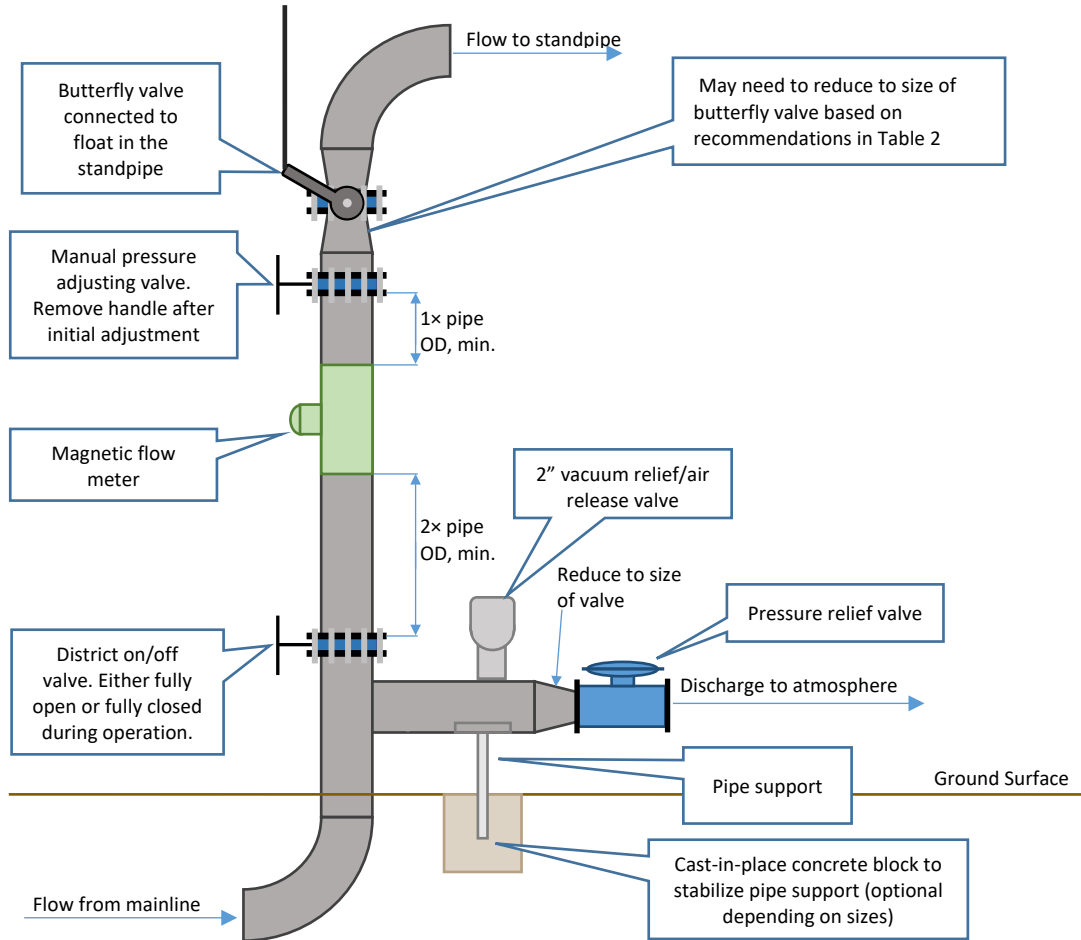


Figure 6. Complete valve package except for float assembly. Not to scale.

Solutions for Turnouts with Pumps

For turnouts with pumps, there is no need for pressure regulation. The pump flows into drip/micro and sprinkler systems will have minimal changes as the district line pressures change. However, one can still use the float valve assembly as described in the previous section, if desired. The float assembly dampens water hammer considerably.

For installations in which farmers do not want to lose available district pressure, two other options can be considered. For both of these options, pumps must be installed with VFDs. The VFD controls must have ramp up (start) and 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 pressure relief valve and a vacuum relief valve plumbed downstream of a pressure regulation valve. This a non-standard configuration, and may be confusing to operators unless they are properly trained.

Solution 1: Vertical Standpipes

Figure 7 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.

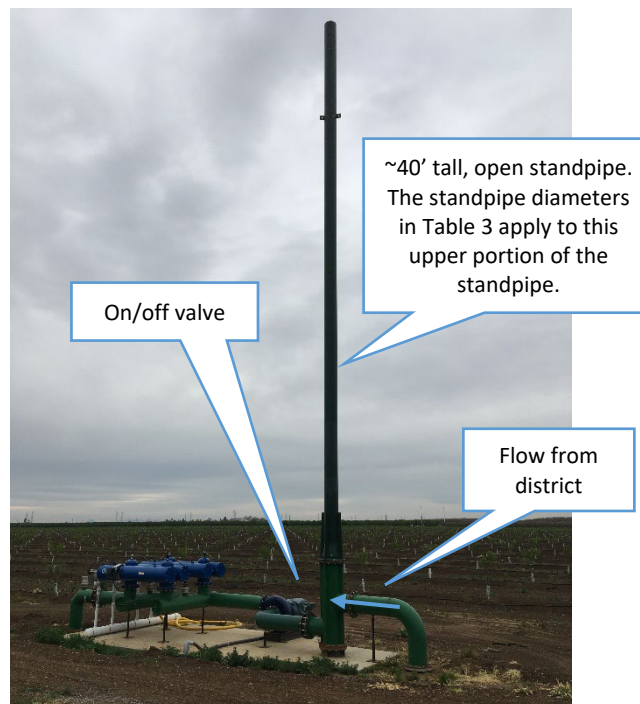


Figure 7. Example of a vertical standpipe at the Kanawha-Glide Water Districts (KGWDs)

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. See a later section and Attachment B for details.
4. Table 3 summarizes the recommended dimensions for using standpipes for protection against water hammer. 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.

Taller standpipes will require more support structures, and the cost of these additional structures is not included in the estimates shown in Table 3. The estimates also do not include equipment and labor costs.

Table 3. Standpipe recommendations. Pipe material only.

| Flow | Canal Elev - TO Elev | 6" Diameter Pipe | | 8" Diameter Pipe | | 10" Diameter Pipe | | 12" Diameter Pipe | | 14" Diameter Pipe | | 18" Diameter Pipe | |
|------|----------------------|------------------|---------|------------------|---------|-------------------|----------|-------------------|----------|-------------------|----------|-------------------|----------|
| | | Height | Cost | Height | Cost | Height | Cost | Height | Cost | Height | Cost | Height | Cost |
| GPM | ft | ft | \$ | ft | \$ | ft | \$ | ft | \$ | ft | \$ | ft | \$ |
| 1000 | 30 | 55 | \$4,000 | 50 | \$5,000 | 50 | \$7,000 | 45 | \$8,000 | 45 | \$11,000 | 40 | \$12,500 |
| | 20 | 45 | \$3,000 | 40 | \$4,000 | 35 | \$5,000 | 35 | \$6,000 | 35 | \$8,000 | 30 | \$9,500 |
| | 10 | 30 | \$2,000 | 30 | \$3,000 | 25 | \$3,500 | 20 | \$4,000 | 20 | \$5,000 | 20 | \$6,500 |
| 1500 | 30 | 70 | \$5,000 | 60 | \$6,000 | 55 | \$8,000 | 55 | \$10,000 | 50 | \$12,000 | 45 | \$14,000 |
| | 20 | 55 | \$4,000 | 50 | \$5,000 | 45 | \$6,500 | 40 | \$7,000 | 40 | \$9,000 | 35 | \$11,000 |
| | 10 | 40 | \$3,000 | 35 | \$3,500 | 30 | \$4,500 | 30 | \$5,000 | 25 | \$6,000 | 25 | \$8,000 |
| 2000 | 30 | 80 | \$6,000 | 70 | \$7,000 | 65 | \$9,000 | 60 | \$10,000 | 55 | \$13,000 | 55 | \$17,000 |
| | 20 | 65 | \$5,000 | 60 | \$6,000 | 50 | \$7,000 | 50 | \$9,000 | 45 | \$11,000 | 40 | \$13,000 |
| | 10 | 55 | \$4,000 | 45 | \$4,500 | 40 | \$5,500 | 35 | \$6,000 | 30 | \$7,000 | 30 | \$10,000 |
| 2500 | 30 | 95 | \$7,000 | 80 | \$8,000 | 75 | \$11,000 | 70 | \$12,000 | 65 | \$15,000 | 60 | \$20,000 |
| | 20 | 80 | \$6,000 | 65 | \$7,000 | 60 | \$9,000 | 55 | \$10,000 | 50 | \$12,000 | 45 | \$15,000 |
| | 10 | 65 | \$5,000 | 55 | \$5,500 | 45 | \$7,000 | 45 | \$8,000 | 40 | \$9,500 | 35 | \$12,000 |

5. In addition, the following items must also 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 the 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 8 shows a solution for turnouts with higher pressures.

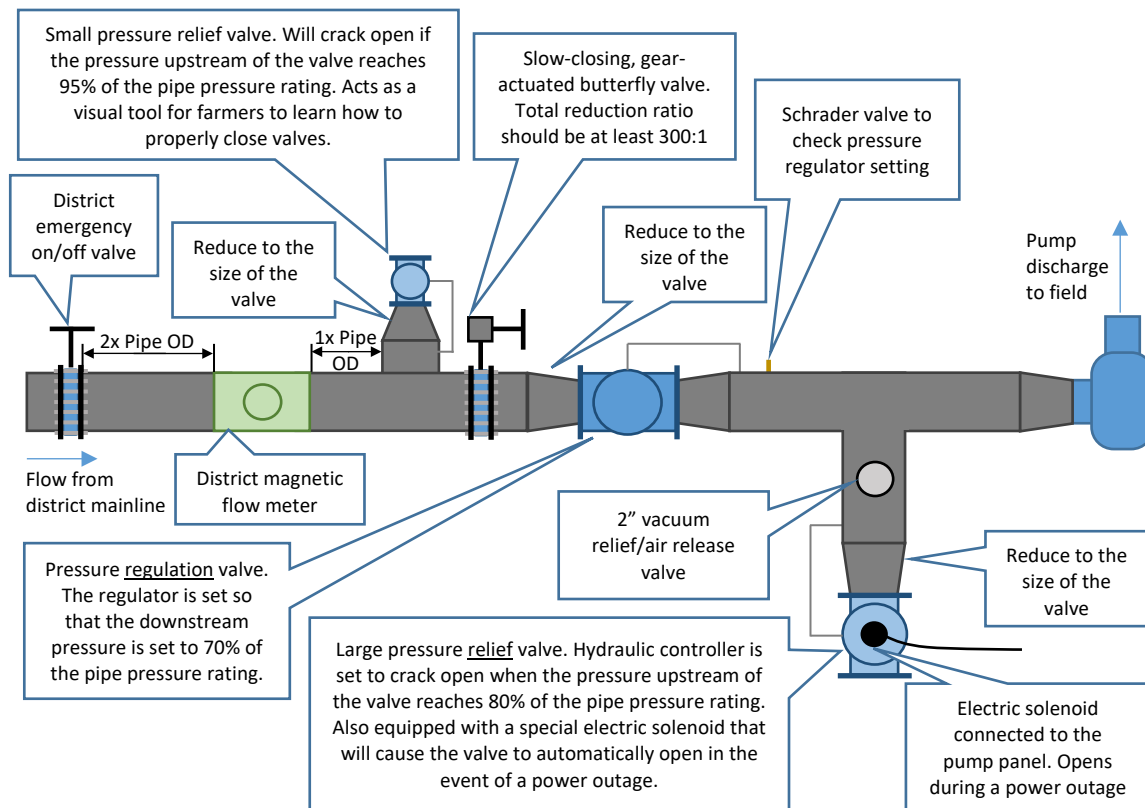


Figure 8. Plan view of Solution 2 configuration. Not to scale.

During normal operations, the large pressure relief valve located upstream of the pump will open if a surge is generated by the pump stopping too quickly. This will prevent the pressure from rising too high.

The initial surge may be followed by a vacuum as the pressure wave travels away from the pump. The 2" vacuum relief valve will allow air to enter and fill the pipeline if there is a slight vacuum, and this will prevent the pipeline from collapsing.

The large pressure relief valve upstream of the pump should be equipped with a solenoid actuator that fails in the open position, so that the valve will open when the power is lost. This is important if there is a regional power outage. This power connection must be installed with a small independent circuit, so that it remains energized if the pump is manually shut off.

The advantages of this solution are that farmers are able to receive the majority of the available pressure upstream of their pumps, which can work for farmers at high pressure locations. The main disadvantage of this solution is the complexity.

Recommendations

1. There must be a straight, unrestricted pipe section that is at least 2× the pipe's outside diameter in length upstream of the magnetic flow meter. There must be a similar straight, unrestricted pipe section that is at least 1× the pipe's outside diameter in length downstream of the flow meter.
2. The short sections of pipe connecting the turnout pipeline to the pressure relief, pressure regulating, and vacuum relief valves should have the same diameter as the turnout pipe itself. Reducing cones should be used on valves that have smaller diameters than the pipe.
3. The small pressure relief valve located downstream of the flow meter should crack open when the measured pressure is 95% of the pipe pressure rating.
4. A slow-closing, gear operated butterfly valve can be purchased with a total reduction ratio of at least 300:1. This can be accomplished by coupling two or more gearboxes in series, or by retrofitting the butterfly valve with one 300:1 gearbox. Note that with a 300:1 ratio, 75 turns on the wheel are required to change a butterfly valve position by 90 degrees.
5. The pressure regulating valve should maintain the downstream pressure to 70% of the mainline pressure rating.
6. A Schrader valve should be installed downstream of the pressure regulating valve and should be checked regularly to ensure that the valve is functioning properly and that it has not been tampered with.
7. The pressure relief valve located downstream of the pressure regulation valve should crack open when the measured pressure is 80% of the pipe pressure rating.
8. The pressure relief valve located downstream of the pressure regulation valve should be equipped with an electric solenoid that will fail open during a power outage. This will cause the pressure relief valve to open when the power fails.

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 Regulating Valves

Pressure regulating valves must have quick-opening pilots. There must be an oversized external filter installed upstream of each pilot valve. The inlet and outlet ports of the filters must be at least ¼" NPT, and the filter screen must be at least 80 mesh. Filters should be checked on a monthly basis.

The pressure regulating valve should be set to maintain a downstream pressure of 70% of the pipe pressure rating. At the full-open condition, the valve must be able to pass the maximum turnout flow rate with no more than a 4 psi pressure loss.

Pressure Relief Valves

The pressure relief valves shall match the specifications found 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 for these pressure relief valves should be factory set to equal 80% of the pipe pressure rating. The valve must discharge the turnout flow rate with no more than a 4 psi loss, 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 no more than a 4 psi loss, 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 9. The Emerson AT-IS quarter-turn worm gear operator is available with a wide range of gear ratios including 293:1 and 315:1 (www.emerson.com). Alternatives such as the Schlumberger DYNATORQUE series are also available.

2. Installing additional hardware on a standard butterfly valve. One of many possible configurations is a right-angle speed reducer, as seen in Figure 10. These reducers are available through suppliers such as McMaster-Carr and Surplus Center.

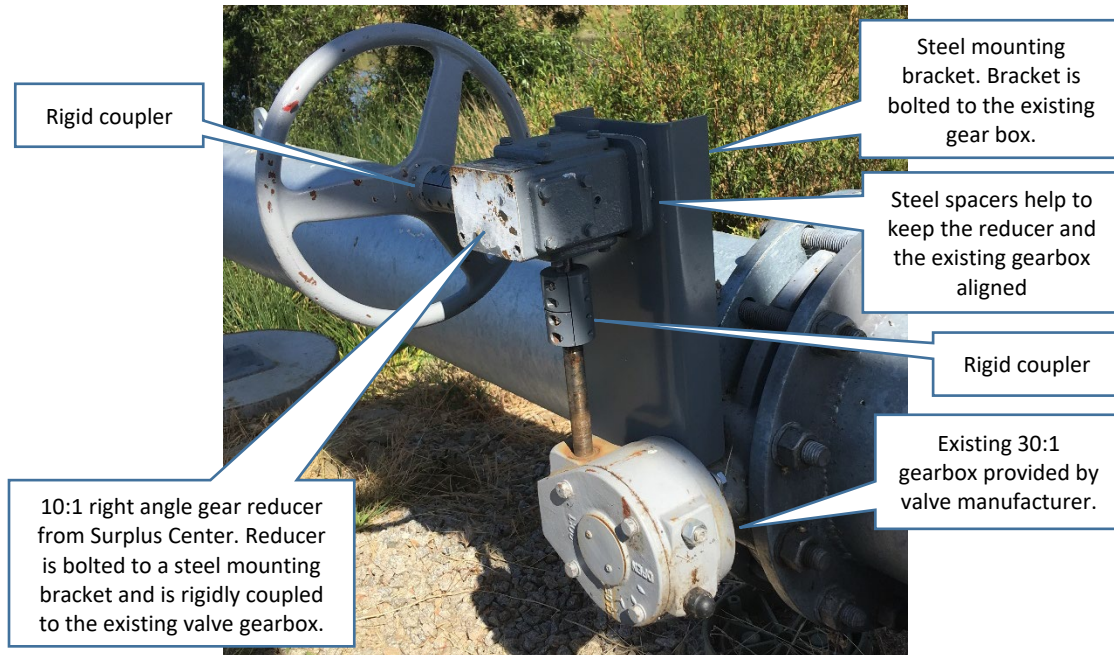


Figure 10. Additional gear reducer attached to a 12" Grayline butterfly valve

To determine the required reduction ratio of the reducer, divide 300 by the reduction ratio of the manufacturer's gearbox that is supplied with the valve. Round up the result to the nearest whole number. Do not round down, as this will lead to selecting an inadequate reducer. If the valve manufacturer does not provide a gearbox with the valve, then use either a 300:1 reducer or a combination of two reducers where the total reduction ratio is 300:1.

If an additional reducer is used, it will need to be rigidly mounted to the valve so that the reducer's output shaft will not bend or shear. Figure 11 shows a mounting bracket made by the ITRC for an 8" - 12" Grayline butterfly valve and a 10:1 speed reducer from Surplus Center (part number 13-133-10-R). Detailed drawings are provided in Appendix B. The hole sizes and locations, as well as the overall bracket dimensions, will vary based upon the valve and the reducer. Spacers were used to ensure that the reducer output shaft was aligned with the input shaft of the valve gearbox.

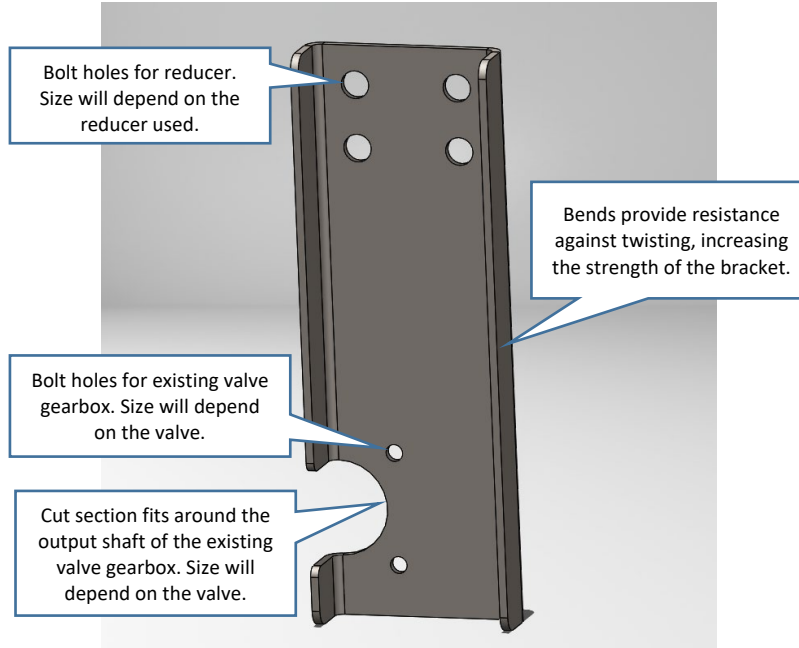


Figure 11. Conceptual 3D model of the ITRC gear reducer bracket. Not to scale.

Figure 12 shows how to mount the bracket onto the face of the existing valve gearbox.

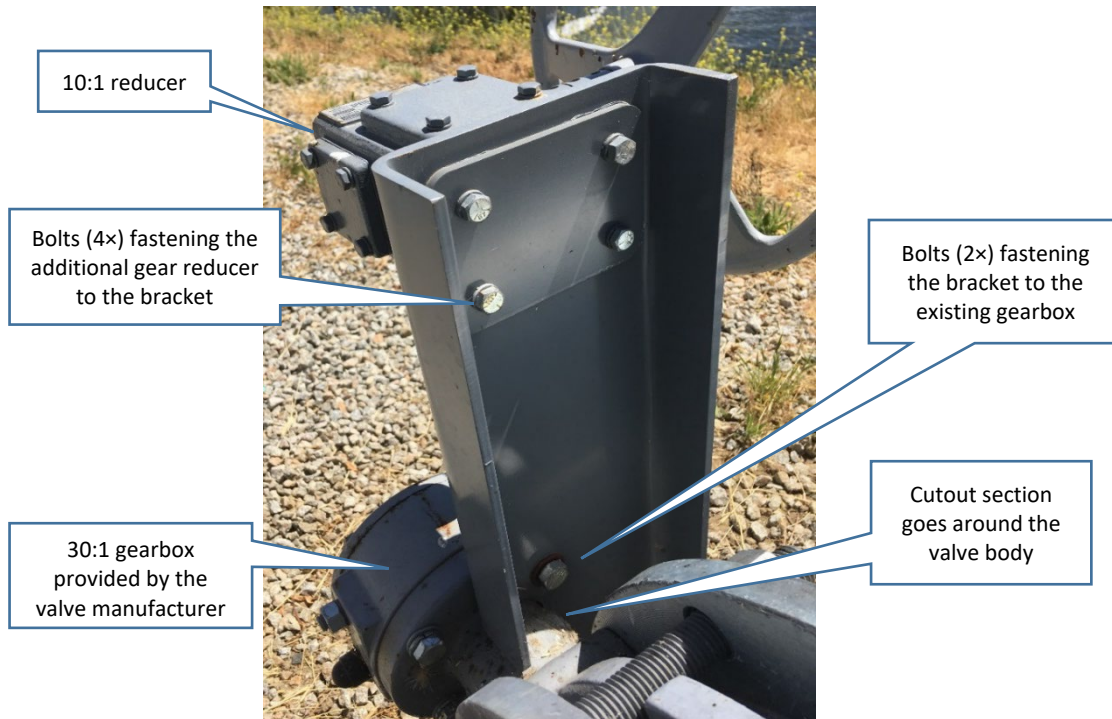


Figure 12. 10:1 gear reducer on a bracket mounted to a 30:1 gearbox on a 12" Grayline butterfly valve

Mounting Bracket Fabrication

The mounting bracket can be made from A36 steel plate, steel C-section channel, or square HSS tubing. The thickness of the material should be at least $\frac{1}{4}$ ".

The bolt holes for the valve can be drilled into the face of the bracket, and should be sized and spaced based on the valve flange. The bolt holes for the gear reducer can also be drilled, and should be sized and spaced based on the reducer.

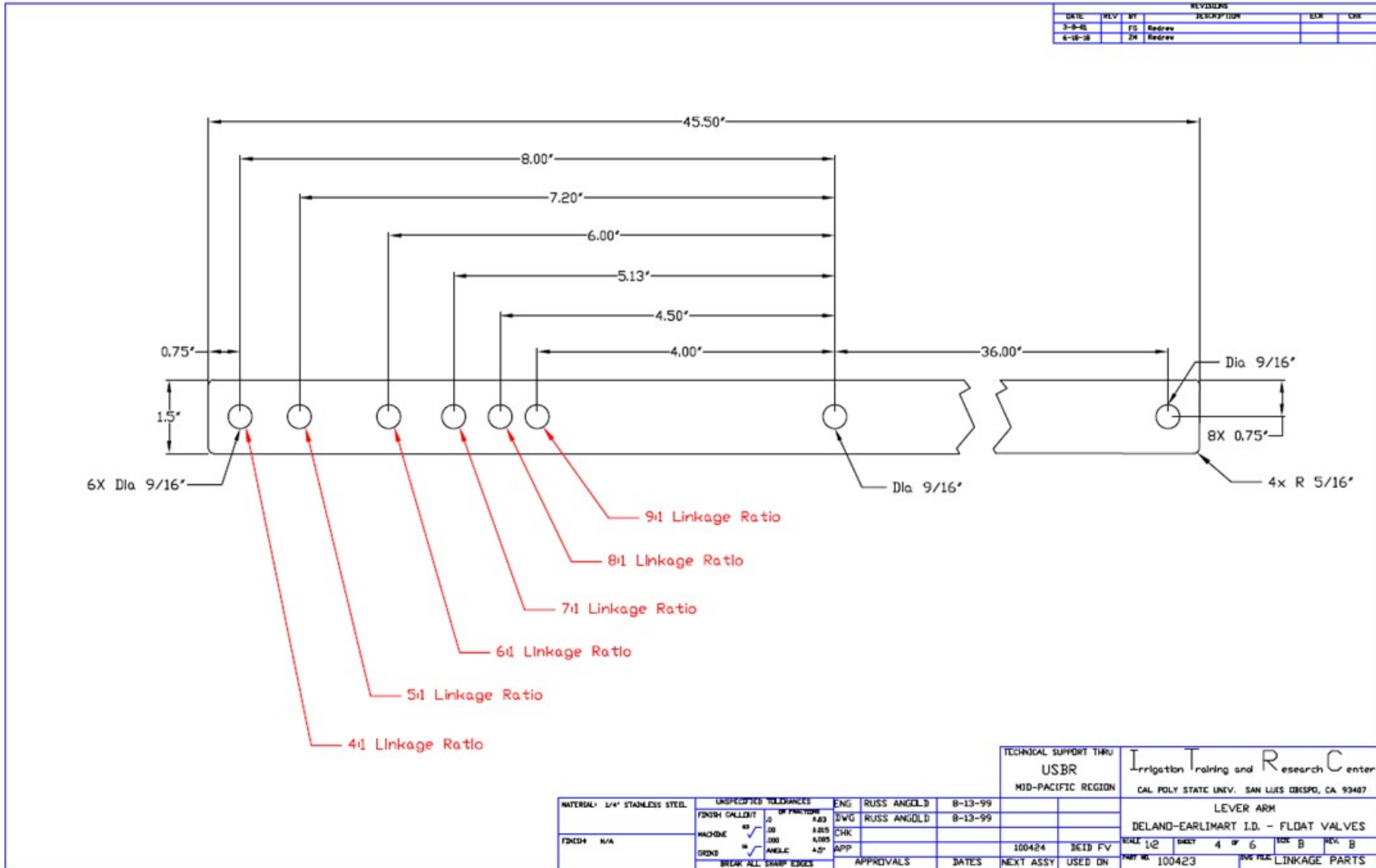
The cutout section can be cut using a CNC plasma or an oxy-acetylene torch. It should have a diameter that is larger than the valve body so the mounting bracket can fit around the body.

The "ribs" of the mounting bracket, whether they were bent using a press or were cast (if steel channel or square tubing is used), should be at least 2" long.

Steel spacers should be installed if the mounting bracket and the face of the gear reducer do not align perfectly. These spacers can be made from $\frac{1}{8}$ " A36 steel plate, and can be installed either at the valve flange or at the gear reducer. The size and location of the bolt holes will be based on either the valve flange or the reducer, depending upon where the spacer will be installed.

Attachment A

Float Valve Top Linkage Drawing



Attachment B

Gear Reducer Mounting Bracket

2
1

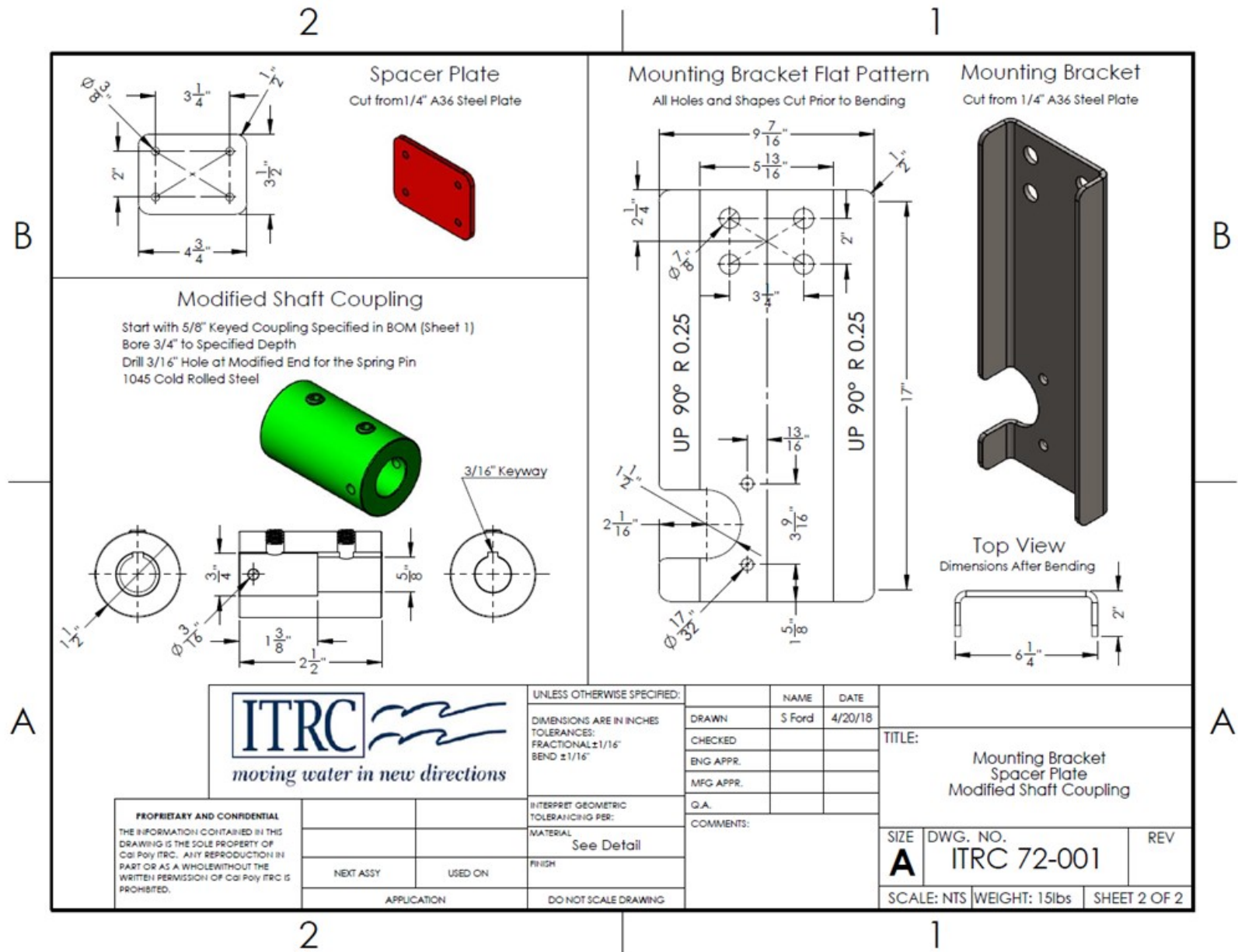
B
B

A
A

2
1

| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|----------|---------------------------------|---|------|
| 1 | Fresno (F085-80~100~120-10) | 8"-12" Gear Operated Valve | 1 |
| 2 | McMaster-Carr(3724T52) | Spoked Aluminum Handwheel | 1 |
| 3 | Surplus Center (1-1563-B) | Modified Shaft Coupling (See Sheet 2) | 1 |
| 4 | Custom Fabricated (See Sheet 2) | Mounting Bracket | 1 |
| 5 | Custom Fabricated (See Sheet 2) | Spacer Plate | 3 |
| 6 | McMaster-Carr (94705A209) | 1/2"-13 x 2" Extra-Wide B7 Hex Head Screw | 2 |
| 7 | McMaster-Carr (91247A592) | 5/16"-18 x 2-1/2" Grade 5 Hex Head Screw | 4 |
| 8 | McMaster-Carr (98023A33) | 1/2" Zinc Plated Grade 8 Washer | 2 |
| 9 | McMaster-Carr(98023A030) | 5/16" Zinc Plated Grade 8 Washer | 4 |
| 10 | Surplus Center (13-133-10-R) | 10:1 RA Gear Reducer 0.77 HP Right Output | 1 |
| 11 | McMaster-Carr (92373A261) | 3/16" Dia 18-8 SS Slotted Spring Pin | 1 |

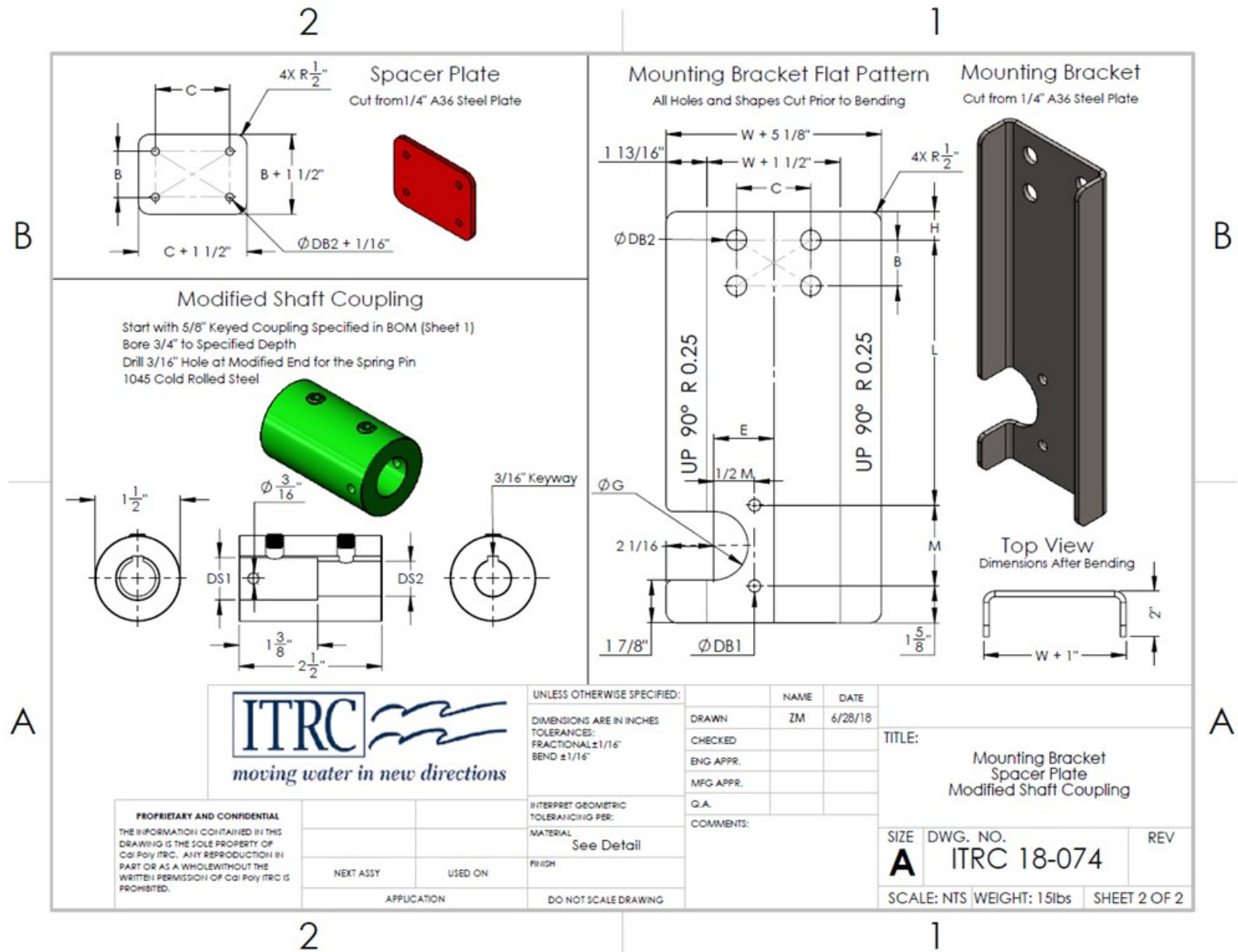
| | | | | | | |
|---|---------|--------------------------------------|-------------------|-------------|----------------|--|
| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | TITLE: Additional Gear Reducer for 8"-12" Greyline 8500 Series Gear Operated Valves |
| | | DIMENSIONS ARE IN INCHES | | DRAWN | S Ford | |
| TOLERANCES: | | CHECKED | | | | |
| FRACTIONAL: ± | | ENG APPR. | | | | |
| ANGULAR: MACH ± BEND ± | | MFG APPR. | | | | |
| TWO PLACE DECIMAL ± | | Q.A. | | | | |
| THREE PLACE DECIMAL ± | | COMMENTS: | | | | |
| PROPRIETARY AND CONFIDENTIAL THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF Cal Poly ITRC. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF Cal Poly ITRC IS PROHIBITED. | | INTERPRET GEOMETRIC TOLERANCING PER: | | | | |
| | | MATERIAL | See Details & BOM | | SIZE | DWG. NO. |
| | | FINISH | See Details & BOM | | A | ITRC-72-001 |
| NEXT ASSY | USED ON | FRIG | | | REV | |
| APPLICATION | | DO NOT SCALE DRAWING | | SCALE: 1:10 | WEIGHT: +29lbs | SHEET 1 OF 2 |



| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|----------|---------------------------------|--|------|
| 1 | District Valve XX | District Turnout XX Butterfly Valve | 1 |
| 2 | HW1 | Spoked Aluminum Handwheel | 1 |
| 3 | RC1 | Modified Shaft Coupling (See Sheet 2) | 1 |
| 4 | Custom Fabricated (See Sheet 2) | Mounting Bracket | 1 |
| 5 | Custom Fabricated (See Sheet 2) | Spacer Plate | 3 |
| 6 | HHS1 | DB1" UNC x 2" Extra-Wide B7 Hex Head Screw | 2 |
| 7 | HHS2 | DB2" UNC x 2-1/2" Grade 5 Hex Head Screw | 4 |
| 8 | W1 | DB1" Zinc Plated Grade 8 Washer | 2 |
| 9 | W2 | DB2" Zinc Plated Grade 8 Washer | 4 |
| 10 | GR1 | Gear Reducer | 1 |
| 11 | McMaster-Carr (92373A261) | 3/16" Dia 18-8 SS Slotted Spring Pin | 1 |

| DIMENSIONS (See Sheet 2) | DESCRIPTION |
|--------------------------|--|
| B | Vertical hole spacing on additional gear reducer. |
| C | Horizontal hole spacing on additional gear reducer. |
| DB1 | Existing valve gearbox hole diameter OR valve flange hole diameter |
| DB2 | Additional gear box hole diameter |
| DS1 | Existing valve gearbox OR existing valve input shaft diameter |
| DS2 | Additional gear reducer output shaft diameter |
| E | Offset between valve stem and existing valve gearbox shaft (E= |
| G | Clearance hole diameter, based on valve body |
| H | Distance from top of gear reducer to the center of the top bolt hole |
| L | Combined length of the gear reducer shaft, coupler, and valve shaft |
| M | Vertical hole spacing on existing valve gear box OR valve flange |
| W | Width of additional gear reducer |

| | | | | |
|---|---|-------------|---------|---|
| | UNLESS OTHERWISE SPECIFIED: | NAME | DATE | TITLE: |
| | DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ± | DRAWN ZM | 6/28/18 | |
| PROPRIETARY AND CONFIDENTIAL THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF CAL POLY ITRC. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF CAL POLY ITRC IS PROHIBITED. | INTERPRET GEOMETRIC TOLERANCING PER: | CHECKED | | SIZE DWG. NO. REV A ITRC-18-073 |
| | MATERIAL See Details & BOM | ENG APPR. | | |
| NEXT ASSY | USED ON | MFG APPR. | | SCALE: 1:10 WEIGHT: 30+lbs SHEET 1 OF 2 |
| APPLICATION | DO NOT SCALE DRAWING | Q.A. | | |
| | | COMMENTS: | | |



| | | | |
|--------------------------------------|--|-----------|---------|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
| DIMENSIONS ARE IN INCHES | | ZM | 6/28/18 |
| TOLERANCES: | | DRAWN | |
| FRACTIONAL $\pm 1/16$ " | | CHECKED | |
| BEND $\pm 1/16$ " | | ENG APPR. | |
| | | MFG APPR. | |
| | | Q.A. | |
| | | COMMENTS: | |
| INTERPRET GEOMETRIC TOLERANCING PER: | | | |
| MATERIAL | | | |
| See Detail | | | |
| FINISH | | | |
| DO NOT SCALE DRAWING | | | |

| | | |
|---|---------------|--------------|
| TITLE: | | |
| Mounting Bracket Spacer Plate Modified Shaft Coupling | | |
| SIZE | DWG. NO. | REV |
| A | ITRC 18-074 | |
| SCALE: NTS | WEIGHT: 15lbs | SHEET 2 OF 2 |

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| | |
|-------------|---------|
| NEXT ASSY | USED ON |
| APPLICATION | |