Performance Factors and Installation Procedures for AWWA Butterfly Valves

by Joseph W. Hoff, P.E. and Albert W. Libke, P.E.

As basic as a butterfly valve is, there are many performance factors to consider when locating or installing AWWA butterfly valves in a pumping, distribution, or plant piping system. These factors include the direction of fluid flow through the valve; the presence of upstream and downstream fluid disturbances; the shaft orientation; the rotational direction of disc closure; the proper swing clearance for the valve disc; the valve's proximity to liquid or solid chemical injection systems; fluid hammer; and the requirements of installation, start-up and maintenance.

The influence of each of these factors on a butterfly valve's performance, and a set of guidelines for its proper installation, are important for those who must specify and use these valves.

There are as many AWWA C504 valve designs and disc structures offered in the municipal industry as there are manufacturers. When designing a piping system, the engineer usually does not specify the manufacturer and therefore cannot design the system around a particular design. For this reason, the engineer, contractor and owner must have a basic knowledge of the performance factors and installation requirements of AWWA Butterfly valves.

Although specific information and data offered here are based on unique valve designs, the guidelines presented are meant to be universal in nature and should always be confirmed by the manufacturer.

Flow Direction

When speaking of flow direction through a butterfly valve, the flow is commonly described as either toward the "seat side" or "non-seat side" of the valve, or toward the "flat side" or "dome side" of the disc, as shown in Figure 1. In the case of an "on-center" seated valve with a lens shaped disc design (Fig 2), the valve is typically symmetrical about its centerline, making flow direction a non-issue. However, with an "off-set" seated valve, the disc design is typically of a dome structure, making the valve non-symmetrical about its centerline. The direction of flow through a non-symmetrical valve design will typically influence the dynamic torque, the full open flow capacity, the seating performance, and the seat adjustment capabilities of the valve.

Before the significance of dynamic torque can be discussed, a basic understanding of the torque influences on a butterfly valve is necessary. In simplified terms, the total torque required to operate a butterfly valve is a combination of the seating torque, the bearing friction torque, the fluid dynamic torque and hydrostatic torque. The seating torque is the torque required to physically move the valve disc into or out of the seated position while the disc edge is in contact with the rubber seat. The bearing friction torque is the torque required to physically turn the valve against the friction force between the valve's shaft and bearings. The dynamic torque is the torque required to hold the disc in position while the flow of a fluid through the valve creates a torque that tends to open or close the disc. The hydrostatic torque is the torque caused by a hydraulic gradient when a butterfly valve is installed with a horizontal shaft and an empty pipe line downstream of the valve (Fig 3).

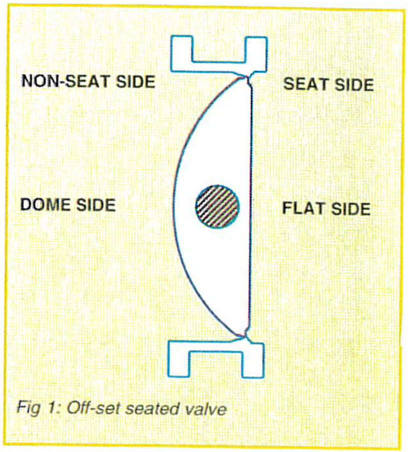


Fig 1: Off-set seated valve

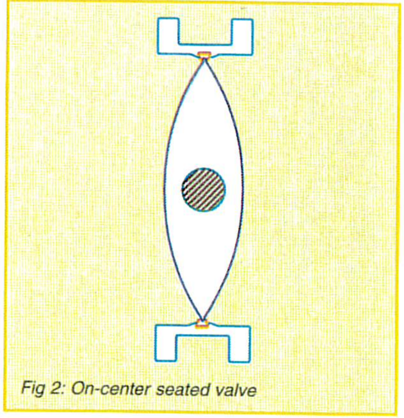


Fig 2: On-center seated valve

The dynamic torque at any valve

Fig 3

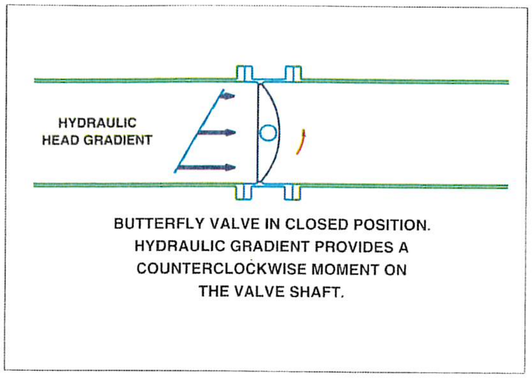
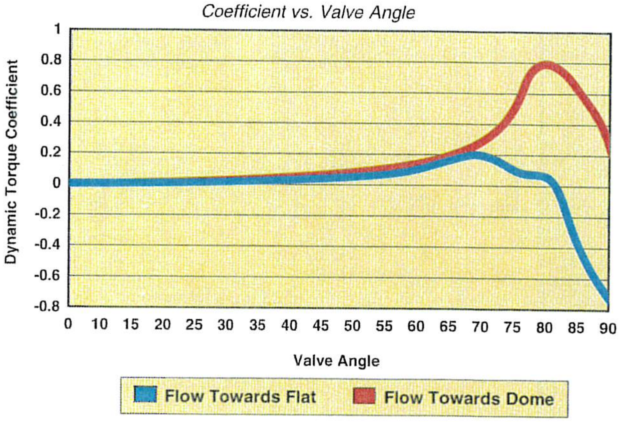


Fig 4: Typical offset disc dynamic torque



angle is a function of the pressure drop across the valve, the valve size and the dynamic torque coefficient. The dynamic torque coefficient (Fig 4) is an empirical value that is unique for each disc profile. The relationship between the dynamic torque and the flow direction affects the valve's performance in two ways.

First, the actual dynamic torque with flow toward the dome side of the disc can be more than twice the dynamic torque with flow toward the flat side of the disc. The significance of this is, when the specification allows, a manufacturer will often size the actuator based on flow toward the flat side of the disc. If the valve is installed incorrectly, with the flow toward the dome side of the disc, it is possible that the actuator will be undersized, preventing proper operation of the valve or causing premature failure of the actuator. In reality, this is typically an issue only on valve sizes greater than 20 in. That is because the combined seating torque and bearing friction torque exceed the fluid dynamic torque on valve sizes 20 in. and smaller unless the following unique situations exist: a flow velocity in excess of 16 feet per second; the valve is located within six pipe diameters of a pump discharge nozzle or other turbulence causing component; or, the valve is located within six pipe diameters of an elbow and oriented incorrectly.

Second, notice in Figure 4 that the dynamic torque coefficient for flow toward the flat side of the disc crosses from positive to negative. The point at which the torque coefficient equals zero is called the torque reversal point. At this valve angle, which is dependent on disc design, the disc is unstable and may flutter. Operating the valve for an extended period of time at this angle will lead to premature failure of the torque transmitting components, including the actuator; the actuator mounting; the shaft to actuator connecting key; and the shaft to disc connecting pin. This can be a problem on valves as small as 12 in. or even less, especially when the valve is located near a pump, elbow or tee.

In most installations, the full open flow capacity of the valve or the pressure loss across the valve is not a critical design factor. However, when it is, one must realize the significance of flow direction on the flow capacity of the valve. Figure 5 shows the difference in body contours on either side of the valve seat. It is this difference that makes the flow capacity of the valve sensitive to flow direction. As shown in Figure 6, the flow capacity can vary by as much as 10 percent with the direction of flow, depending on valve design.

When a valve is under pressure in the seated position, the valve disc will deflect or move in the direction of flow. With an off-set seat design, pressure toward the flat side of the disc will move the disc away from the seat, while pressure toward the dome side of the disc will move the

Fig 5: Body contour

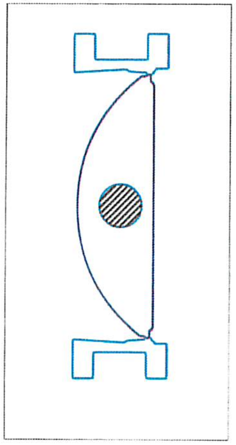


Fig 6: Relative full open flow capacity

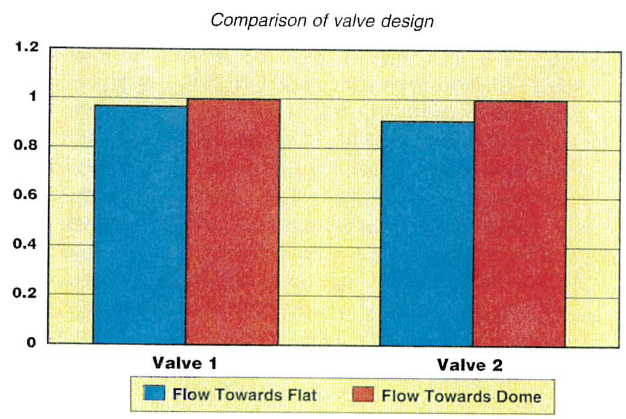
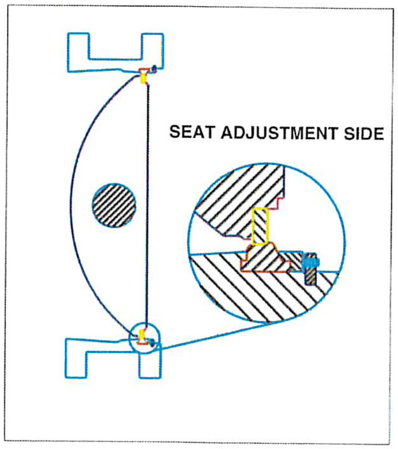


Fig 7: Adjustable seat



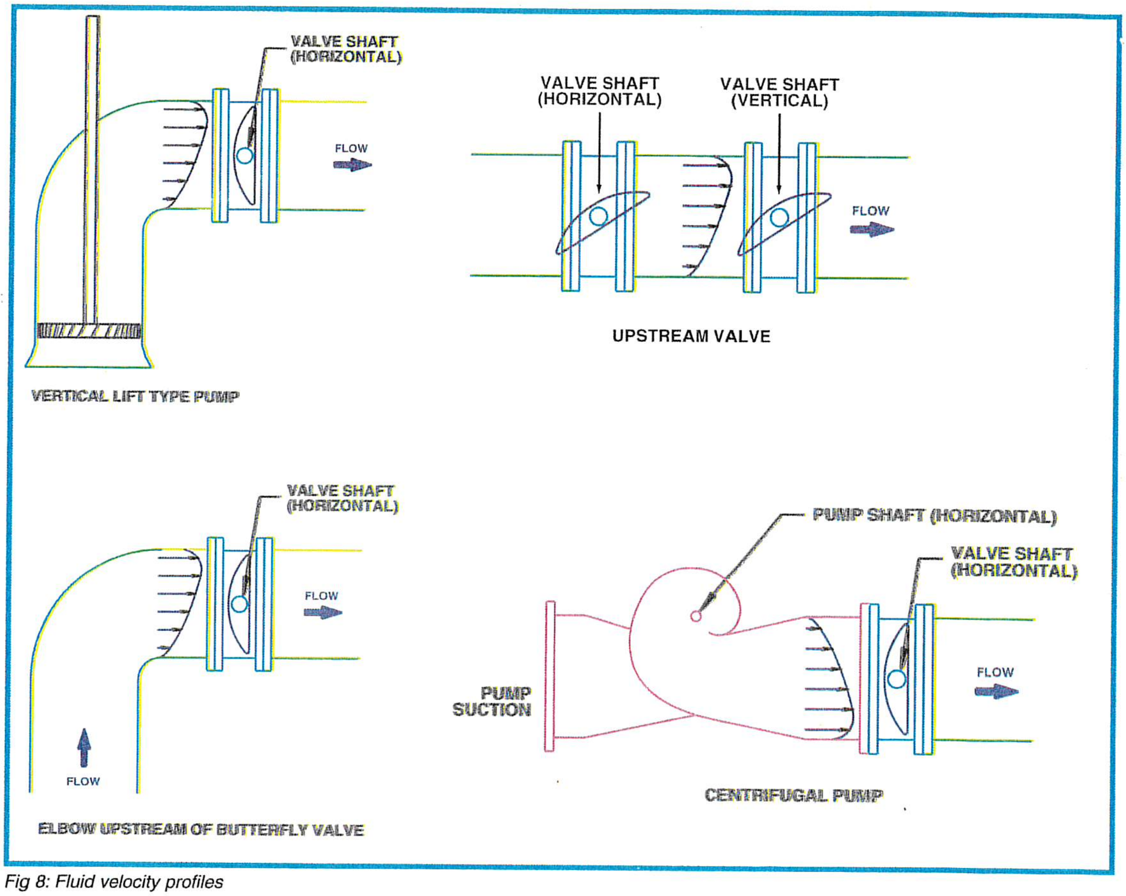


Fig 8: Fluid velocity profiles

disc further into the seat. With the on-center seat design, pressure typically will move the disc out of the seat. Although all AWWA Butterfly valves are designed to be leak tight at the design pressure in both directions, an off-set seat design will typically perform well beyond the design pressure when pressure is pushing the disc into the seat. By installing the valve with flow toward the dome side of an off-set seated valve, a contractor can usually get approval to test the pipe line at elevated pressures from the valve manufacturer.

All AWWA C504 butterfly valves larger than 24 in. have adjustable and replaceable seats. Although actual designs vary, most AWWA butterfly valves in the industry have a mechanical adjustment feature for adjusting the valve seat in the field. One manufacturer's seat design for 30-in. and larger butterfly valves is shown in Figure 7. As is typical in the industry, this design is adjustable only from the flat side of the disc. If one wants the ability to adjust the valve seat while the valve is installed in a pipe line, then it is critical that the valve be installed with the pressure toward the dome side of the disc. Since this is not always the case, it is necessary to contact the valve manufacturer for proper installation instructions.

Upstream Disturbances

Over half of the AWWA Butterfly valves sold in the municipal market are installed in the piping networks of water and wastewater treatment plants and pumping stations. When designing and installing butterfly valves in such confined areas, it is necessary to understand the effects of upstream disturbances on the performance of the valve. Upstream disturbances can be caused by pumps, other valves and elbows. These disturbances will influence the dynamic torque of the butterfly valve and may reduce the total flow capacity of the valve.

The most common upstream disturbances are caused by the close proximity of valves and elbows. Ideally, when locating a valve in a piping network, one should provide enough unobstructed straight piping to ensure uniform, steady flow at the valve entrance. However, not only is this prohibitive due to space and economics, there is no one good source to identify the required distance needed for every possible situation. A few well known sources suggest that the ideal installation would require flow straightening vanes followed by 8 unobstructed pipe diameters upstream of every valve, or 18 unobstructed pipe diameters without using straightening vanes.

Although these guidelines may be necessary for flow testing, practical experience, unqualified testing by valve manufacturers, and references tell us that these guidelines are not necessary for proper valve

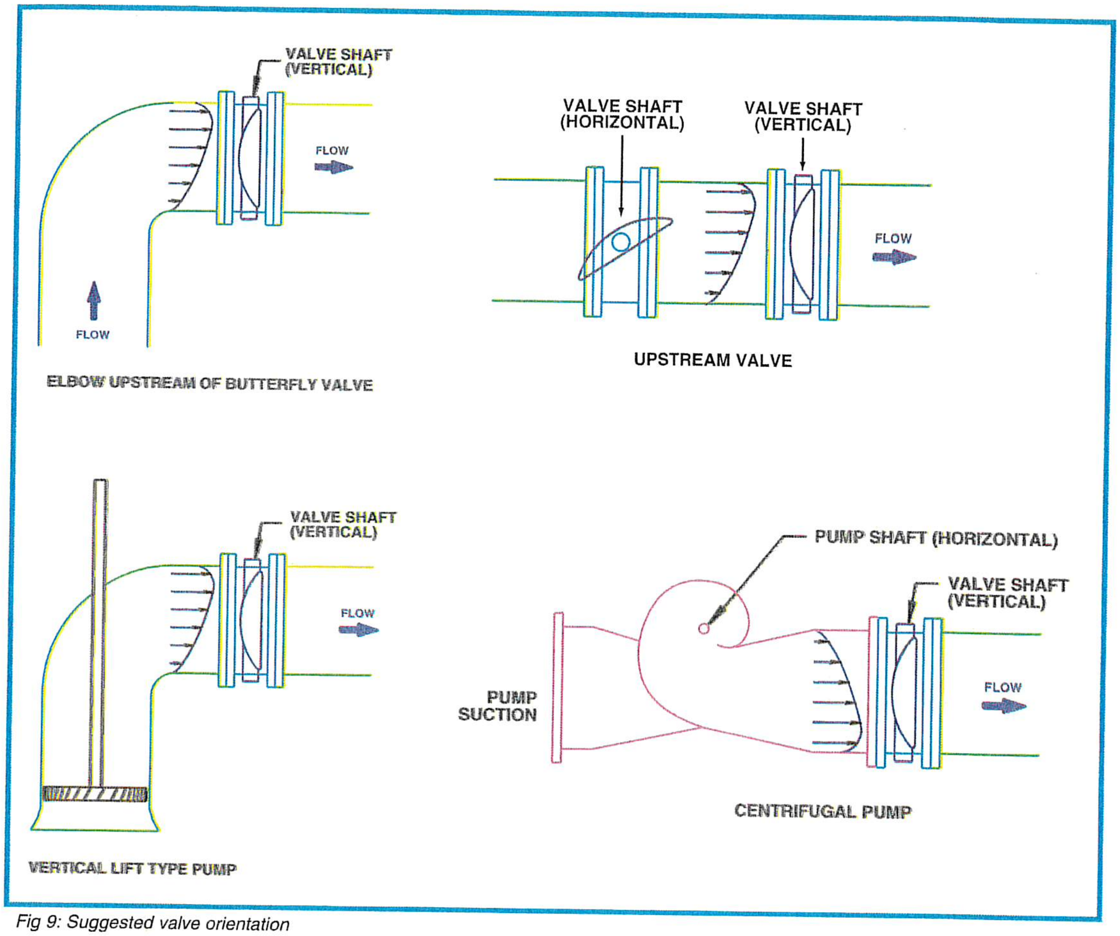
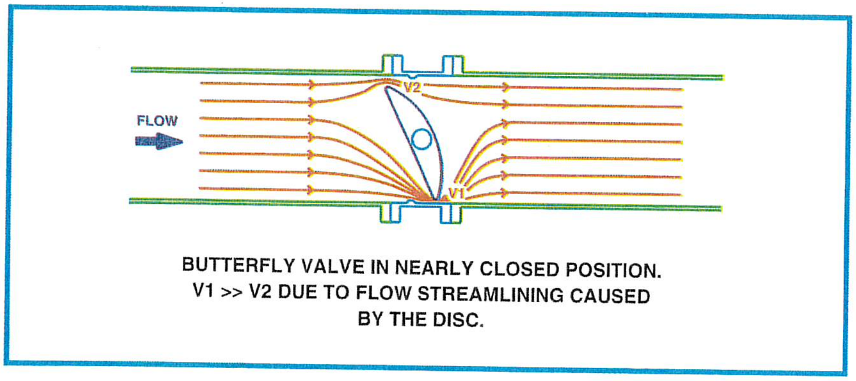


Fig 9: Suggested valve orientation

Fig 10: Disc closure direction



performance. Most valve manufacturers recommend between 6 and 8 unobstructed pipe diameters upstream of every valve. Such a distance alleviates the influences of flow disturbances on butterfly valves. However, even this distance is often unavailable in confined piping galleries. When this distance is not available, incorrect valve orientations or unspecified disturbances can lead to undersized valve actuators and premature valve failure.

Figure 8 shows the fluid velocity profile when entering a butterfly valve with upstream disturbances caused by an elbow, a valve, a vertical turbine pump and a centrifugal pump. In all cases, there is a higher flow velocity to one side of the pipe when compared to the other. This forces more water to one side of the valve than the other.

If the valve shaft is oriented as shown in Figure 8, then this unbalanced flow will force more water to one side of the valve shaft, increasing the dynamic torque on the valve by a factor of 1.5 or more. In addition to the increased dynamic torque, the added fluid turbulence may cause the valve disc to flutter.

If this increased dynamic torque is unaccounted for in the actuator sizing, an otherwise properly sized actuator can be overworked or caused to stall. Allowing an actuator to be continuously overworked will lead to long-term actuator maintenance problems and/or failures. In addition, prolonged disc fluttering caused by flow turbulence can further complicate maintenance problems. Disc fluttering is often the cause of worn bearings, worn or broken shaft-disc connecting pins and connecting keys, internal actuator problems and actuator mounting failures.

Figure 9 suggests a valve shaft orientation for close proximity upstream elbows, valves, centrifugal pumps and vertical turbine pumps. In the case of upstream elbows or valves, orienting the valve shaft in a manner that splits the uneven flow to both sides of the valve shaft may alleviate undesirable effects. In the case of a close-proximity centrifugal or vertical turbine pump, proper valve shaft orientation will minimize the undesirable effects of uneven flow profiles and extreme fluid turbulence on the valve, but it will not totally alleviate the problem.

In addition to influencing the dynamic torque and stability of the valve disc, uneven flow profiles caused by upstream disturbances can influence the effective Cv of the valve and increase the valve's headloss by a factor of 2 or more. When valve headloss is of concern (e.g. in pumping applications), valve location and orientation should be closely monitored.

Valve Shaft Orientation

If upstream disturbances are not a concern, larger butterfly valves should always be installed with the shaft axis being horizontal. This orientation provides several advantages.

If the shafts are vertical, the trunnion bearings of the valve can be damaged due to settling of fines and scale and even snails into the bearing clearances. This might occur prematurely due to construction debris during installation, or over a period of time due to settling out of fines from water hardness, calcification, raw water solid content, or a variety of other sources. In all cases, the results can be detrimental to the expected long-term performance of the valve.

In addition, buried manually-actuated valves are easier to design and install if the operating valve shaft is horizontal and the gearbox input shaft is oriented toward the ground surface.

One concern with orienting the valve shaft axis horizontally is hydrostatic torque. Hydrostatic torque is a sizable operating torque component on large valves. This phenomena is caused by a hydraulic gradient when a butterfly valve is installed with a horizontal shaft and an empty pipe line downstream of the valve. (Hydrostatic torque is graphically shown in Figure 3 of Part I.) Hydrostatic torque can hinder or aid in opening or closing the valve depending on the valve's disc rotational direction. This effect is covered in the appendix of 1987 and earlier editions of ANSI/AWWA Standard C504 "AWWA Standard for Rubber-Seated Butterfly Valves."

Disc Closure Direction

The direction of closure of the valve disc can have a major impact on long-term valve operation. Looking at Figure 10, consider that construction debris and/or system fines will settle to the bottom of the pipe and valves. This solids buildup can cause damage to the valve seat and disc edge or prevent total shutoff. If the valve is installed so that the bottom disc edge creates a high local velocity of fluid at the bottom edge of the seat and disc, this higher velocity will sweep out built-up debris during valve closure.

Disc Swing Clearance

AWWA short body butterfly valve discs protrude beyond the valve end faces when the valve is fully opened. If this design is not accounted for, interference problems with mating pipe flanges or close proximity obstructions can occur. The valve manufacturer can supply the required disc swing clearance information to prevent installed disc interferences. However, the system designer should verify this clearance to prevent disc interference with the mating piping or other potential obstructions.

Valve Location with Respect to Fluid Treatment Chemical Injection

Performance can be negatively affected by locating valves too close to chemical injection ports. The introduction of powdered chemical treatment media immediately upstream from the valve can cause the valve to lockup. This is due to bearing and seat friction induced by the solid chemicals that have not had adequate transit time to dissolve the solids. The powdered chemicals can be compared to grit between a rubber tire and an ice surface.

A second effect of installing valves too close to where chemicals are introduced is the chemical (whether solid or liquid) may not be adequately diluted in the water. In some instances, the high concentration of the added chemicals may even attack the valve elastomer seats. High concentrations of chlorine and chloramines are known to cause degradation of common nitrile rubber seats. Other chemical additives, such as petroleum based products, can degrade EPDM materials.

Fluid Hammer

Fluid hammer (often referred to as water hammer) is a transient phenomenon that can occur in systems with liquids, gases or steam media. The results of fluid hammer can range from an irritating banging noise to catastrophic failure of valves, pumps or entire piping systems.

Transients can occur during initial filling of the pipeline, the starting or stopping of pumps, sudden shifting of inadequately supported pipe, inadequate air removal, or valve stroking times that are less than critical for the specific piping system.

The concept of fluid hammer is generally known to engineers and operators. However, the specific technology related to calculating transient characteristics and valve closure times is very complex and not as well known. A case study of low pressure transients in the Austin, Texas, water system has been documented (December 1994 *Journal of AWWA*).

Quarter turn butterfly valves are inherently easy and fast to close, therefore, the actuator and system design must be carefully accomplished to prevent water hammer. The typical way to address valve closure rates is with manual actuators that take many, sometimes hundreds, of turns to stroke the valve. It can also be done with speed controls on pneumatic, hydraulic or electric actuators. In lengthy pipe systems such as power plants and municipal water distribution systems, the required minimum stroking time to control transients can be many minutes. Chapters 8 and 9 of *Hydraulics of Pipelines* by Paul J. Tullis provides methods and examples for calculating closure times for butterfly and other valve types. Designers and operators of butterfly valve installations should be aware that overly rapid opening or closure of butterfly valves can cause significant system problems.

Installation, Start-up and Maintenance

Manufacturers ship butterfly valves with the discs slightly off the tight shutoff seat location but not protruding from the body faces. Flange protectors are installed to protect the flange faces, seats and discs from shipping damage and site storage debris. The protectors should be left in place until the valve is ready to be installed in the pipeline.

When the valve is ready to be installed, the flange protectors and accompanying wire, tape or bolts that hold the protectors to the valve during shipping should be removed. The valve should be carefully hoisted into position between the pipe flanges and gaskets, and radially centered between the flanges. The mating pipe ends and flanges should be closely aligned so as not to require undue force to jack the flanges into alignment with the valve.

Significant misalignment of the rigid pipe or use of the valve body to provide piping support can be detrimental to valve performance and mating flange gasket sealability. There are a number of good references relative to proper pipe support and alignment.

Once the valve is located between well-fitted flanges and gaskets, the flange bolts should be installed and tightened in a standard crisscross sequence. The bolt torques should be uniform and consistent with standard bolt strength charts. Prior to system test, the piping should be slowly filled with test water, using care not to shock piping off its supports or cause even more catastrophic consequences.

The manufacturer should have leak-tested the valve with the actuator installed and with closed position stops set to provide shutoff at specified pressure. However, damage may have occurred during shipment. During the initial system pressure test, the valve may exhibit leakage. If so, the actuator stops should be adjusted for tight shutoff. If the leakage persists, larger valves have adjustable seats. If necessary, follow the manufacturer's instructions for seat adjustment.

During the system test, the valve packing should also be checked for leaks. If leaks are present, and the packing is supplied with an adjustment gland, adjust as necessary to stop the leakage. Be sure to avoid over tightening the packing gland which may cause unnecessary high torques and premature packing failure. If no adjustment gland is provided, cycling the valve 3 to 5 times should help to seat the packing.

In a well designed, constructed, and chemically controlled system, valve maintenance should be minimal. If velocities are within specification, and the design considerations outlined here are followed, maintenance should be limited to packing leakage inspection. ■

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