White Paper

Tilted Disc® Check Valve Pump Discharge Service

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Introduction

The purpose of this guide is to provide background information on pump discharge applications and recommendations for specifying and installing Tilted Disc® Check Valves. The valve is energy efficient and also provides non-slam closure by utilizing a short disc stroke of 40°. The energy savings produced by its 140% flow area, streamlined body and hydrodynamically designed disc make it an excellent choice for pump discharge applications. The valve will pay for itself many times over in ease of maintenance and energy savings.

Description of Valve

Val-Matic®'s Tilted Disc® Check Valve is a rugged valve with excellent headloss characteristics. The valve is ideally suited for raw water, cooling water, and treated water/wastewater applications. The valve's tapered metal-to-metal seats are constructed of wear resistant aluminum bronze alloys and provide tight seating and long life even in the most severe applications. The operation of the valve is self-contained and fully automatic.

The valve can be equipped with bottom or top mounted oil dashpots for various applications. The bottom dashpot controls the last 10% of valve closure with a hydraulic cylinder. The top mounted dashpot also independently controls the full opening and closing strokes to reduce surges on longer systems.

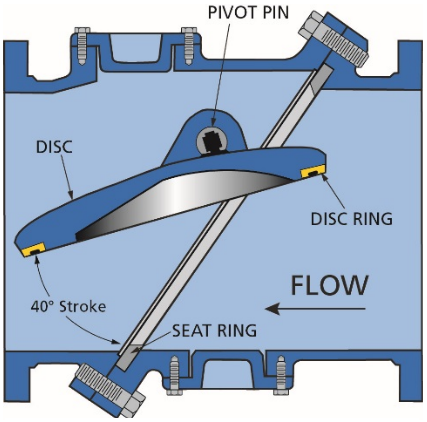

FIGURE 1. Tilted Disc® Check Valve Construction

Valve Function

In pump discharge service, the valve must open wide during pumping and close tightly after pump shutdown to prevent reverse flow. To prevent slam during pump shutdown, the valve should either close rapidly before flow reversal, or with the use of oil dashpots, close slowly to provide soft seating action. Controlled opening and closing strokes are available with top mounted dashpots to reduce the potential for surges during operation.

Headloss Calculation

The headloss across any valve in feet of water column is easily computed using the equation:

$$H = 2.31\left(\frac{Q}{Cv}\right)^2 S_g$$

Where:

H = headloss, ft.
Q = flow rate, gal/min
Cv = valve flow coefficient
S_g = specific gravity

For example, a 30 in. Tilted Disc® Check Valve with a Cv of 42,000 and operating at a flow rate of 26,500 gal/min (12 ft/sec), will have a headloss of only 0.92 ft. of water column. Compare that to a silent check valve with its headloss of 6.74 ft. in the same service.

Energy Calculations

One of the primary reasons for selecting Tilted Disc® Check Valves for pump discharge is to obtain low energy consumption. The equation for calculating the yearly energy costs is as follows (AWWA M49):

$$A_{cost} = 1.65 \times Q \times H \times S_g \times C \times U / E$$

Where:

A_{cost} = Annual energy cost, $/year
Q = Flow rate, gpm
H = Headloss, ft. of water
S_g = Specific gravity, dimensionless
C = Cost of electricity, $/kWh
U = Pump usage percentage, 100% (1.0) equals 24 hrs per day
E = Efficiency of pump a motor set, (0.80 typical), dimensionless

The equation can also be used to compare operating costs between two types of valves by using their corresponding headlosses (H). For example, the difference in headloss between a 30 in. Silent Check Valve and a Tilted Disc® Check Valve operating at 26,500 gpm (12 ft/sec) is 5.82 ft., and assuming a combined pump and motor efficiency of 0.8, and a cost of electricity of $.08/kWh, the annual energy savings gained by using the Tilted Disc® Check Valve is $25,450. Over the 40-year life of the valve, the savings would be over $1.0 million. It is clear that the energy savings alone justifies the investment in Tilted Disc® Check Valves.

Surge Control

Sudden changes in flow velocity will cause a pressure surge or water hammer in a piping system, which can damage equipment. As a rule of thumb, the magnitude of the surge is typically 50 psi for every 1 ft/sec of velocity change. For example, if a flow of 8 ft/sec is suddenly introduced or stopped in a pipeline, a surge pressure as high as 400 psi above the static pressure may be produced. On long systems, the change in velocity produces a pressure wave which travels at the speed of sound in water from one end of the system to the other. The elapsed time is called the **Critical Time**. Any change in flow velocity that occurs within the Critical Time has the same effect as if the change occurred instantaneously (AWWA M11). For example, on a 5000 feet steel pipe, the critical time is about 3.3 seconds. Hence, a flow stoppage within 3.3 seconds will produce the same surge as if the flow was stopped instantaneously. Because of this principle, long systems require careful analysis and are usually computer modeled. Most systems greater than 3000 feet will have a surge protection system and possibly a pump control valve set to open and close very slowly, typically 5-10 times the critical time.

Single Pump System

A single pump system or one where only one pump is operated at a time is illustrated in Figure 2. Tilted Disc® Check Valves are commonly used with both centrifugal and vertical turbine pumps which produce flow rates in the range of 4-20 ft/sec. and pressures to 300 psig. The water level on the suction side of the pump can be either above or below the pump as shown in Figure 2.

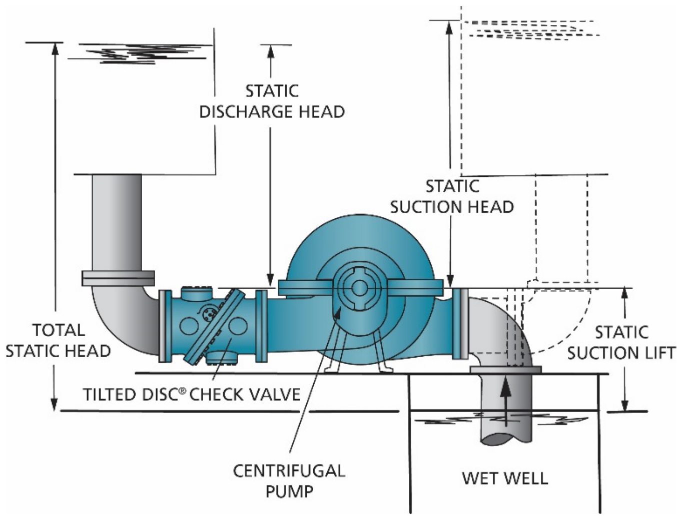

FIGURE 2. Single Pump System

The total static head and the system resistance (i.e., pipe friction) are used to determine the severity of an application. When the static head is high and the system resistance low, the system will have rapid flow reversal when the pump is stopped. Conversely, on low static head systems with high resistance, the flow reversal may take several seconds. On longer systems, the changes in velocity from starting and stopping pumps can cause surges which are relieved with the use of surge relief valves mounted on the discharge header. These valves typically sense the high and/or low pressure fluctuations and open to relieve water back to the wet well. On more severe applications, surge tanks can be employed.

Multiple Pump System

Multiple pump systems are often used to help reduce surges, provide high system capacity, and provide for varying output flows to meet water demand. Surges are reduced in a multiple pump system because the pumps are started and stopped one at a time. The pumps, therefore, have a much smaller impact on the velocity changes in the main header. Also, by running a different quantity of pumps or different combinations of pumps, varying output flows can be produced. Depending on the system pressure, the check valves may need a dashpot because parallel pumps cause a rapid reversal of flow after shutdown. It should also be noted that after a power failure, the pumps stop simultaneously and cause a significant change in the pipeline velocity. For this reason, most multiple pump installations will often have surge relief valves or a surge tank.

Closed Surge Tank Applications

A common type of surge tank is called a hydro-pneumatic tank (Figure 3) because it is filled with both water and compressed air. The tank is connected to the discharge header. After pump shutdown or power failure, the tank forces water into the line to prevent column separation. A few seconds later, an upsurge in pressure occurs and water re-enters the tank dissipating the surge. In these applications, the check valve must close rapidly to prevent reverse flow through the pump after pump stoppage. Also, the surge tank pressure causes a rapid reversal of flow back toward the pump which may slam ordinary check valves. When used with surge tanks, check valves require a bottom mounted oil dashpot which will allow the valve to rapidly close, yet prevent slamming.

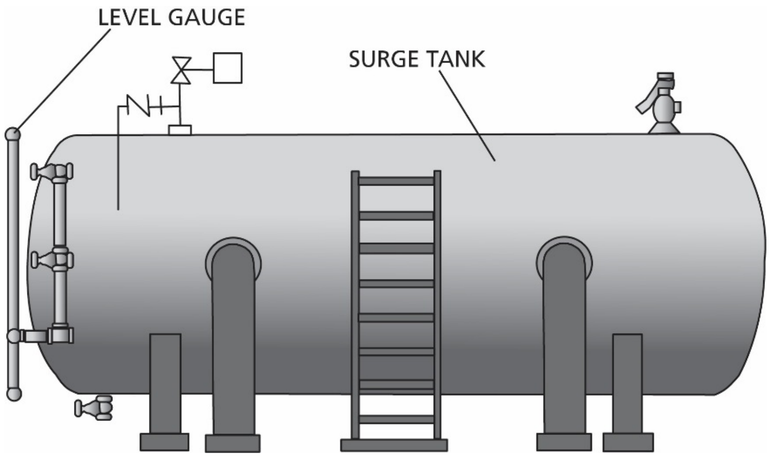

FIGURE 3. Typical Hydropneumatic Surge Tank

Application Criteria

The general operating parameters for Tilted Disc® Check Valves are summarized in the table below. A comprehensive presentation of features and dimensions is presented in Val-Matic® Bulletin 9000.

Standard Operating Parameters	
Parameter	Typical Range of Use
Size Range	2" - 66"
Pressure Classes	125, 150, 250, 300
Max Temperature	250°F
Flow Range	4-20 ft/sec.
Orientation	HORIZ OR VERTICAL
Connection	FLANGED: ANSI, ISO

TABLE 1. Operating Parameters

The Tilted Disc® Check Valve is versatile and can be used in more demanding applications with the use of special materials of construction upon request. The valve is available in three configurations: base valve, bottom mounted oil dashpot and top mounted oil dashpot. It is important to note that the dashpot configurations include high pressure oil cylinders and full rated disc connections. With oil dashpots, the disc is rigidly controlled as opposed to an air cushion which only produces a mild damping effect.

To select the proper valve configuration, several criteria must be considered. The number of pumps and the static head will affect how rapidly the water column will reverse when a pump is stopped. The type of pump control will affect the required closing characteristic of the valve. Typical types of control include on-off, soft-start, variable speed, and electrically operated control valves. The length of the piping system is used to estimate surges from changes in flow velocity. The type of surge relief system dictates the required closing time for the valve. Surge tanks require a quick-closing valve to prevent the loss of stored water back through the pump. The criteria listed in Table 1 are used to select the best valve configuration as follows.

1. Base Valve

The base valve features a short stroke angle of 40° which provides rapid disc closure in less than ½ second. This feature will provide non-slam closure in low service pumping applications. Basic valves are typically used when the static head is less than 100 feet in single or multiple pump applications. A common application is the filter backwash pumps in a water treatment plant.

2. Bottom Mounted Oil Dashpot

Dashpots are used on high service pumping applications where there is a propensity for rapid flow reversal. The bottom mounted dashpot (Figure 4) consists of a hydraulic cylinder and a snubber rod which contacts the disc during closing. A spring and oil accumulator are used to provide return force to the snubber rod and oil for the opening stroke to make up for the cylinder rod volume. The dashpot controls the last 10% of valve closure to reduce water hammer and prevent slamming of the disc. The valve is effective on shorter length systems with static heads up to the valve rating. The dashpot is also used on longer systems where rapid flow reversal occurs due to the use of surge tanks or in multiple pump systems. The dashpot is field adjustable with a speed control valve and typically set to control the last 10% of closure in 1-5 seconds. A greater closure time may produce excessive reverse flow through the pump.

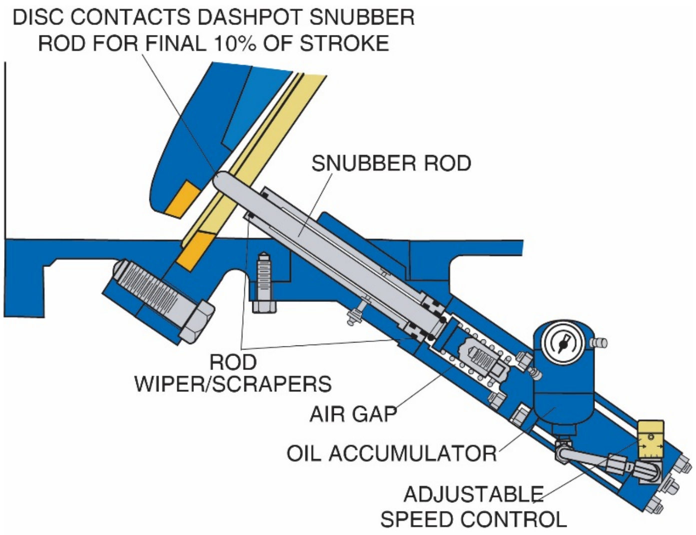

FIGURE 4. Bottom Mounted Oil Dashpot

3. Top Mounted Oil Dashpot

The top mounted oil dashpot (Figure 5) controls both the full opening and full closing stroke of the valve. Also, the last 10% of travel of valve closure is independently controlled by an adjustable internal hydraulic cylinder speed control. With the top mounted oil dashpot, the disc is mechanically linked to a hydraulic cylinder equipped with speed control valves. The high-pressure hydraulic cylinder and linkage are designed to withstand the full thrust of the disc when subjected to line pressure. An oil accumulator is used to provide return force to the linkage rod and oil for the opening stroke to make up for the cylinder rod volume.

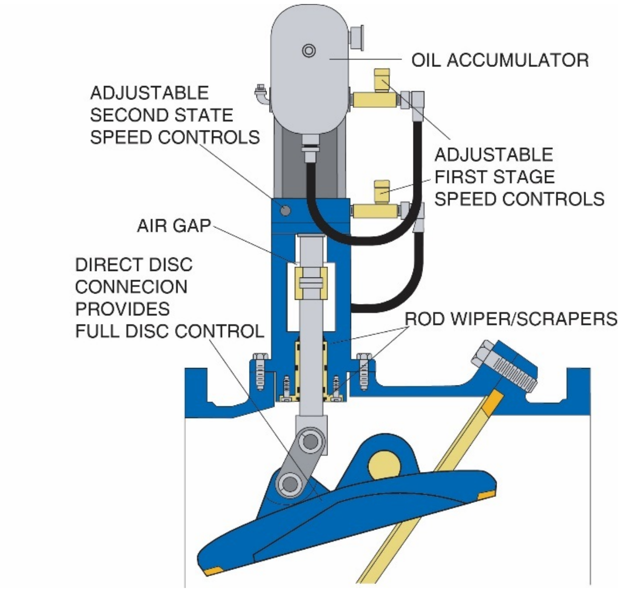

FIGURE 5. Top Mounted Oil Dashpot

Valves equipped with top mounted oil dashpots are used in high service applications up to the full flow and pressure rating of the valve. When there is insufficient space to provide the recommended 5 diameters of straight run of pipe between the pump and the valve, the top mounted dashpot will control the disc movement and prolong the life of the valve. The opening and closing strokes are field adjustable in the 5-30 second range. The final 10% of closure is adjustable in the 1-5 second range to prevent slam. By setting the valve opening time to 20 seconds, the system flow rate will rise to 50% in about 2 seconds which equates to the critical time period of a system 3000 feet in length. On longer systems, the dashpot may not have an appreciable effect on pressure surges; therefore, a surge analysis and surge equipment are recommended.

On very long systems, where the critical time exceeds the 30 second closure of a top mounted oil dashpot, a power operated pump control valve is sometimes used. The control valve is electrically wired to the pump control and is programmed to slowly open and close to gradually change the flow rate in the system over a 60-300 second period. However, after a power outage, the control valve may not be capable of closing rapidly enough to prevent back spinning of the pump or loss of water from a surge tank. In these cases, a Tilted Disc® Check Valve is often installed upstream of the control valve.

Installation Guidelines

To ensure proper operation of the valve, several guidelines should be followed in the piping design. Table 2 presents general guidelines for valve selection.

1. The base valve can be installed in both horizontal or vertical flow-up runs. Valves in raw water service should be installed in horizontal runs to prevent debris from collecting on the disc.
2. The valve should be the same size as the discharge line and located a minimum of five straight pipe diameters from the pump or an elbow. If there is insufficient room to provide straight pipe, consider a top mounted oil dashpot to stabilize the valve operation.

3. An isolation valve such as an eccentric plug valve or butterfly valve should be installed downstream for servicing the pump and check valve. Butterfly valves should be located one diameter downstream to prevent disc interference.
4. A minimum velocity of 5 ft/sec is required to open the valve fully. If there is insufficient velocity, consider a top mounted oil dashpot to stabilize the valve operation.
5. Options include special materials for corrosive service, limit switches for remote valve indication, and bypass ports for backflushing suction lines.
6. For pipelines with velocities greater than 10 ft/sec and lengths exceeding 3000 ft, a water hammer or transient analysis should be conducted to determine the performance of the pump and valves together in controlling surges.

In Table 2, the application chart illustrates the range of use for three valve configurations: 1) basic valve, 2) bottom mounted oil dashpot, and 3) top mounted oil dashpot. For example, on a 2500 ft. long water transmission main operating at 150 ft. of head, a Tilted Disc® Check Valve with a top mounted oil dashpot would be selected. Or, if a surge relief system is provided, then the bottom mounted oil dashpot configuration can be used.

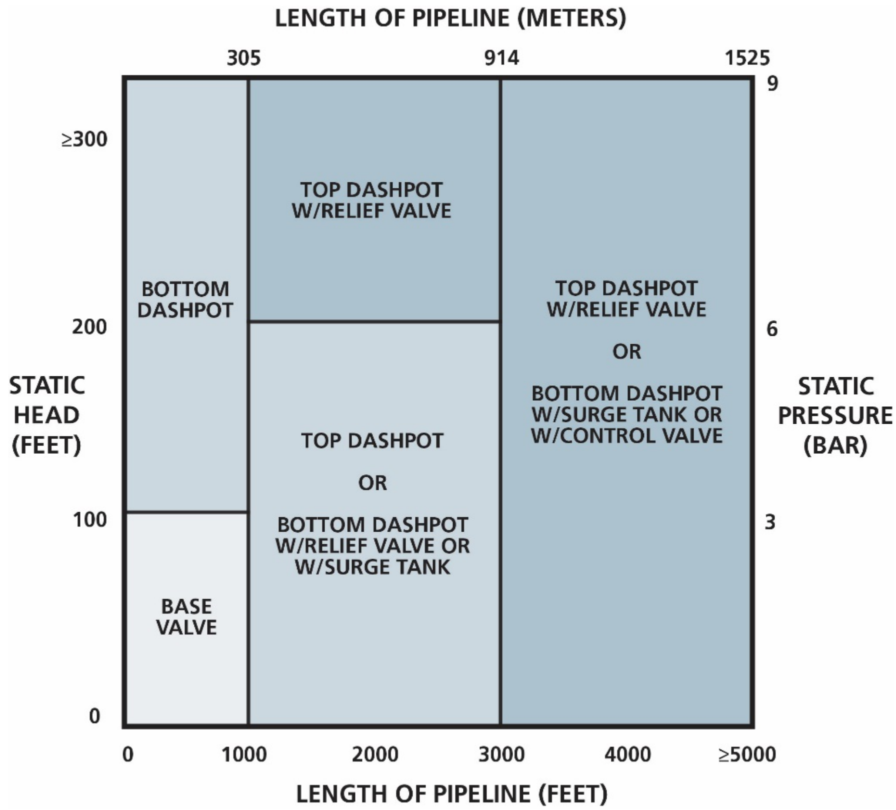

Table 2. Application Chart

References

1. American Water Works Association, AWWA M11 "Steel Pipe -A Guide for Design & Installation"; 4th ed., 2004, pp 51-56.

2. American Water Works Association, AWWA M49 "Quarter-Turn Valves: Headloss, Torque, and Cavitation Analysis"; 3rd ed., 2017, p 33.