White Paper

Design and Selection of Check Valves

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INTRODUCTION

An essential element in the design of water and wastewater pumping systems is the proper selection of the pump discharge check valve, whose purpose is to automatically open to allow forward flow and automatically return to the closed position to prevent reverse flow when the pump is not in operation. Another function that is often overlooked is the valve's ability to minimize energy consumption. Patton estimated that water and wastewater plants in the United States consume 75 billion kW·h of energy annually and nearly 80% of that energy is consumed for high service pumping costs to overcome the static head and friction losses. But just as important, the valve should protect the pumping system and piping from pressure surges caused by sudden closure. Every pump station designer has witnessed check valve slam, which is caused by the sudden stoppage of reverse flow through a closing check valve. To prevent slam, an automatic check valve must either close very quickly or close slowly by using oil dashpot devices.

FIGURE 1. Typical Pumping System with Swing Check Valves

Three general categories of check valves will be presented in detail. First, Lift Check Valves such as the fast-closing silent and nozzle check valves, have spring-loaded discs, which move along the pipe axis over a short distance to close automatically in a fraction of a second. Because of their fast closure, these check valves rarely slam and hence have earned the name "silent". The second category of check valve is the Swing Check Valve such as the traditional swing check valve, which has a flat disc that pivots or swings about a hinge pin. Traditional swing check valves are by far the most common, can be equipped with various accessories such as a lever and weight, and unfortunately may be the most likely to slam. Lastly, Dashpot-Assisted Check Valves have controlled closure to control the changes in pipeline fluid velocity over a long period of time (i.e. 5 to 30 seconds) to help prevent surges in distribution systems. These three categories of check valves, Lift, Swing, and Dashpot-Assisted are each designed with unique features for specific applications and each contribute differently to the system response and costs. There is no “universal” check valve for all applications.

Even when all of the various categories and types of check valves are understood, it is still difficult to make a rational decision about which type of check valve is best for a given application. Buying a check valve is similar to buying a car. There are many to choose from because every model is designed to meet different needs. The best car is not necessarily the fastest one. You may be looking for compactness, high performance, low cost, or advanced features; whatever the case, just as there is a car that best meets your requirements, there will similarly be a check valve that best meets your requirements. This paper will therefore describe the various types of check valves and discuss the common selection criteria such as cost and fluid compatibility, which can be used to narrow down the field of selection. Finally, the check valves will be rated on every criteria so that a methodical decision process can be used to identify the best valve solution to meet a given application.

LIFT CHECK VALVES

Lift Check Valves are simple, automatic, and cost effective but can result in high energy costs in the long run. Examples of lift checks include nozzle check, silent check, and ball check valves. These valves have no external moving parts and can be economical to produce and reliable in operation. Unfortunately, they do not provide indication as to whether they are open or closed, which may be an important feature in a pumping system.

Silent Check Valve

Silent Check Valves are commonly used in high-rise buildings and high head applications because of their quiet closure. They consist of a threaded, wafer, or flanged body; a corrosion resistant seat; and a disc with integral stems. When the flow is initiated, the disc is pushed to the right to allow forward flow. When the pump is stopped, the compression spring in the valve forces the valve closed before the flow reverses, which provides silent closure. They close very quickly (in about one tenth of a second) because of a short linear stroke, which is equal to one fourth of their diameter. It is interesting to note that even though the stroke is short at D/4, the cylindrical area between the open disc and the seat ($\pi \cdot D \cdot D/4$) equals the full port area ($\pi \cdot D^2/4$) where D equals the port diameter. Unfortunately, because the disc remains in the flow stream, a Silent Check Valve has high head loss and is mostly used for clean water applications with high head.

Nozzle Check Valve

Nozzle Check Valves operate similar to Silent Check Valves but have a smooth venturi-shaped flow path and annular disc with lower head loss than the Silent Check Valve, but with a longer laying length. Like the Silent Check Valve, the nozzle check has a spring-assisted, short linear stroke, which provides the best non-slam characteristic of check valves. Nozzle Check Valves are commonly made in steel for high pressure classes to meet the rigors of industrial and power plant applications.

Ball Check Valves are simple and compact and commonly used on small water or wastewater pumps where economy is important. A Ball Check Valve consists of a threaded or flanged body with internal features that guide a rubber-coated ball in and out of the seat as the flow goes forward and reverse. The ball rolls during operation and has a tendency to clean itself. The valve's top access port provides ease of maintenance without removal of the valve from the line. They can be used for both water and wastewater applications but have a high tendency to slam in high head applications or when there are parallel pumps because the ball has high inertia and must travel a long distance. In single pump and low head systems, Ball Check Valves may perform adequately and provide low head loss.

Ball Check Valve

SWING CHECK VALVES

Swing Check Valves have historically been the most common category of check valve used in water and wastewater pumping systems. They are readily available, low cost, and have low head loss characteristics when full open. They are automatic in that they require no external power or control signal and operate strictly from the change in flow direction. However, there are many types of valves that fall into this category, and each has distinct advantages that should be understood. Swing Check Valves get their name because they generally consist of a body and a closure member or disc that pivots or "swings" about a hinge pin.

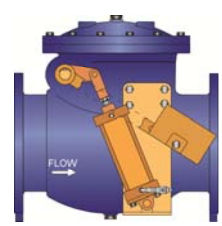
The most compact Swing Check Valve is the Dual Disc® Check Valve as defined in American Water Works Association (AWWA) Standard C518. The body is a wafer design (fits between two pipe flanges) and has a hinge pin about which two opposing D-shaped discs rotate. There is another pin called the stop pin, which centers and stabilizes the discs in the flow stream when the valve is full open. This valve can be subject to vibration and wear in service and should include stabilization spheres at the ends of the pins to prevent pin vibration. The resilient seat is typically molded to the body and the spoke that runs across the body. Given that the spoke is in the flow stream and can collect debris, the Dual Disc® Check Valve is not used in wastewater containing solids. The valve port is about 80% of the pipe size so the headloss should be considered. The closure is assisted by a torsion spring which wraps around the hinge pin and presses against the back faces of the disc. Like lift checks, this type of valve does not provide any indication of open and close but because of the spring has good non-slam characteristics.

Dual Disc® Check Valve

Design and Selection of Check Valves

Swing Check Valve

The traditional Swing Check Valve is defined in AWWA Standard C508, has metal or resilient seats, and swings through a 60 to 90 degree stroke. Because of the long stroke, inertia of the disc, and friction in the packing, the valve may slam in multiple-pump and vertical-pipe installations. These valves are therefore often outfitted with a wide array of accessories, which are beyond the scope of the C508 Standard. Probably the most common accessory is a lever and weight. While it is normally assumed that the weight makes the valve close faster, it actually reduces slamming by limiting the stroke of the disc, but in return, may cause a significant increase in headloss. However, manufacturers usually publish flow coefficients for full open valves and rarely for partially open ones. The valve closure is also slowed by the inertia of the disc and weight and the friction of the stem packing. Some Swing Check Valves have slanted seats (typically about 5 degrees) to promote closure and sealing at low pressures but as long as the center of gravity of the disc and arm assembly are upstream of the seating surface and pin, there will be a closing moment to provide adequate closure and sealing at low pressures. The external lever provides good indication of valve position and the full port provides good service in both water and wastewater.



Air Cushion

In more severe high head applications, an air cushion is sometimes used to prevent slamming. Everyone has experienced the positive effect of an air cushion on a slamming storm door. But the conditions in a water pipeline are significantly different. When a door slams, its momentum is smoothly absorbed by the air cushion because as the door slows, the forces from the closing spring and outside wind become less and less. Conversely, when a check valve in a water pipeline closes, the reverse flow is quickening at a tremendous rate so that every fraction of a second that the valve closure is delayed, the forces on the disc will increase by an order of magnitude. In actual practice, the air cushion holds the disc open long enough for the reverse flow to intensify thereby slamming the disc even harder into the seat. Since air cushions use air which is compressible, they provide very little positive restraint of the closing disc and cannot counteract the enormous forces being exerted by the reverse flow. If faster closure is needed or desired, a lever and spring is a better accessory. Springs inherently have little inertia and are very effective at accelerating the disc movement and providing fast closure and better slam characteristics. Swing Check Valves can also be equipped with oil dashpots to provide effective means of slam prevention.

Resilient Hinge Check Valve

The newest type of Swing Check Valve listed in AWWA C508 and the valve having the greatest impact in the water/wastewater industry today is the Resilient Hinge Check Valve. As the name implies, the swing action occurs from flex action in the rubber molded disc instead of rotation about a hinge pin. The Resilient Hinge Check Valve is highly dependable with virtually no maintenance because the only moving part is the flexible disc. This valve has a 100% port slanted at a 45-degree angle, which provides a short 35-degree stroke, quick closure, and low head loss. The valve is also available with a mechanical indicator and limit switches. A special model of this valve has even faster closure due to the addition of disc accelerators or springs which provide non-slam characteristics similar to that of a silent check valve.

Tilted Disc® Check Valve

On the other end of the swing check valve spectrum is the Tilted Disc® Check Valve, which has extremely low headloss because of its 140% port area and its butterfly valve-type disc design wherein the flow is allowed to pass on both sides of the disc. The Tilted Disc® Check Valve also has reliable aluminum-bronze metal seats and can be equipped with top or bottom mounted oil dashpots to provide effective means of valve control and surge control for medium length systems. Like other swing check valves, the Tilted Disc® Check Valve is fully automatic and requires no external power or electrical signal from the pump control system. It has an external position indicator and is limited to water or treated effluent because the pins extend into the flow stream and can collect debris.

<u>DASHPOT-ASSISTED CHECK VALVES</u>

A proven accessory for dampening swing check valve closure is an oil cushion, also referred to as a bottom-mounted oil dashpot. As shown in the figure below, when the check valve disc is near the closed position, it strikes a snubber rod, whose linear motion is controlled by a high-pressure oil hydraulic cylinder and flow control valve so that this last 10% of travel occurs over 1-5 seconds. The reverse velocity through the check valve will be dampened over a few seconds thus reducing the water hammer associated with sudden check valve closure. These dashpots can be a furnished with swing check and tilted disc check valves. While expensive, they positively prevent check valve slam.

FIGURE 2. Tilted Disc® Check Valve Bottom-Mounted Oil Dashpot

CHECK VALVE SELECTION CRITERIA

In order to match the best type of check valve with a given application, several operating parameters must be defined. These selection criteria may or may not be important for a given application, but they all play a role in the selection process. The criteria that will be discussed in detail are listed in Table 1.

SELECTION CRITERIA	SIGNIFICANCE
Initial Costs	Valve purchase costs can vary widely and should also include installation costs.
Maintenance Costs	The more complex the valve, the greater the maintenance costs.
Headloss and Energy Costs	Some valves can cost far more in energy cost than their initial cost.
Non-Slam Characteristics	It is essential to match the closing characteristic of the valve with the dynamics of the pumping system.
Fluid Compatibility	Only certain check valves can tolerate sediment and solids in the flow.

TABLE 1. Selection Criteria for Check Valve Selection

INITIAL COSTS

The purchase cost of various check valves are readily available from local distributors or manufacturers and can vary widely based on features and the level of quality. It is important to understand that the purchase cost only represents a portion of the initial cost. The installation cost may be even greater than the purchase cost. Some check valves are very compact (wafer type) with short laying lengths and may result in shorter piping runs and smaller dry wells or piping galleries. At the same time, however, many compact check valves require three to five straight diameters of straight pipe upstream to avoid vibrations and premature wear of the valve. The laying length should therefore include the additional piping recommended by the valve manufacturer. Some valves may not be suitable for vertical pipe runs and therefore may require an additional horizontal section of pipe to accommodate them. Again, extra pipe translates into larger pipe galleries.

Certain types of check valves and most large check valves will require some means of weight support. Lift Check Valves are typically supported just like a pipe fitting and are supported by the pipe itself. Large Swing Check Valves may have considerable weight and require concrete pads to support the valve weight. In summary, the initial cost of the check valve should consider its laying length and the laying length of required piping and the cost of installation and supports. Typical initial costs for 12 inch check valves are shown in Table 2.

Estimated 12 in. Check Valve Installed Costs			
TYPE OF VALVE	Purchase Cost	Mechanical Cost	Installed Cost
Ball Check Valve	$9,000	$300	$9,300
Silent Check Valve	$4,500	$300	$4,800
Nozzle Check Valve	$9,500	$500	$10,000
Dual Disc® Check Valve	$1,900	$200	$2,100
Swing Check Valve / Weight	$7,500	$500	$8,000
Resilient Hinge Check Valve	$5,500	$300	$5,800
Tilted Disc®, Bottom Dashpot	$18,000	$1500	$19,500

* Based on 2017 market pricing

TABLE 2. Estimated 12 In. Check Valve Costs

MAINTENANCE COSTS

It is usually safe to say that the more moving parts in a valve, the greater the need for maintenance. A simple Lift Check Valve can provide service for decades without maintenance because the disc stem slides through permanently lubricated bearings. Lift Check Valve springs are typically proof of design tested to at least 50,000 cycles and can last far longer. The only maintenance on Lift Check Valves would be to regularly listen to the valve when the pump is not running and try to hear for seat leakage. Leakage sounds like a hissing noise and can be easily detected with a doctor's stethoscope. Once leakage becomes steady, it will just be a matter of months before the metal seat trim begins to erode and allow excessive leakage. The leakage erodes the seat in localized areas and is often described as wire draw because it looks like a thin abrasive wire was pulled across the seating surface. Chattering should also be observed, which consists of clanking against the open stop or seat, which may be a result of swirling flow or insufficient velocity to peg the valve open. It is tempting for engineers to sometimes install a check valve that is three or more sizes larger than the pump discharge nozzle to reduce the headloss. That is admirable, but check valves require a minimum velocity for proper operation. Chattering or spinning of the disc during constant flowing conditions may reduce the bushing and spring life to less than one year. The use of variable frequency drives are sometimes dialed down to produce velocities less than 4 feet per second which can prevent full opening of the check valve and higher head loss through the valve.

Depending on the model selected, Swing Check Valves can require costly regular maintenance to adjust packing or lubricate bearings, which may drive up the cost of the valve, or on the other hand, be the best friend of the maintenance crew at the plant. Either way, the manufacturer's recommended maintenance plan should be reviewed and figured into the lifetime cost of the valve. Most manufacturers post their instruction manuals on the Web so it is a simple matter to review the applicable section on maintenance. More specifically, when a Swing Check Valve has an external lever and weight, there must be a seal around the stem where it penetrates the body. These seals tend to leak and require regular maintenance and if the adjustment is not done correctly, the packing may be too tight, causing excess friction thereby slowing the valve closure and causing valve slam.

The Resilient Hinge Swing Check Valve benefits from the fact that the hinge pin is contained within the resilient disc, and it does not penetrate the body; hence, no packing. This valve basically has only one moving part, the flexible disc, so there is no regular maintenance needed. Both types of swing check valves have a bolted top access port so if leakage is observed, the valve can be inspected and repaired without removing it from the line.

When Swing Check Valves are equipped with air or oil dashpots, additional maintenance will be needed. As was said before, the more moving parts, the more maintenance. The cylinders and controls are subject to external corrosion and can seize up so they should be inspected at least every six months. Oil systems often have accumulator tanks with a set air pressure in them that should be maintained. The air may be needed to assist in the operation of device (i.e. extend its rod) so if the air pressure is lost, the device may become inoperable and the valve may slam. And air always tends to find a way out of a pressurized system including fittings, cylinder seals, and even pressure gauge mechanisms. Spraying the air piping with soap solution is an easy way to detect minute leakage.

Table 3 illustrates the difference between the maintenance costs of the various types of check valves in the 12-24 in. size range.

CHECK VALVE TYPE		DESCRIPTION OF MAINTENANCE	ESTIMATED ANNUAL COST (Rate = $75/hour)
LIFT	Ball Check	Simple valve requires only annual check for leakage.	$150
	Silent Check	Simple valve requires only annual check for leakage.	$150
	Nozzle Check	Simple valve requires only annual check for leakage.	$150
SWING	Dual Disc® Check	Simple valve requires only annual check for leakage.	$150
	Traditional Swing Check with Lever and Weight	Stem packing and accessories require regular maintenance.	$600
	Resilient Hinge Swing Check	Simple valve requires only annual check for leakage.	$150
	Tilted Disc® Check Valve with Oil Dashpot	Monthly lubrication and attention to the dashpot system are needed.	$1800

TABLE 3. Estimated Check Valve Maintenance Costs

HEADLOSS

The pump discharge head is needed to overcome the combination of the static head and the friction head of the distribution system. The static head represents the difference in elevation between the source and the highest point of water storage or service. The friction head is caused by roughness in the pipe and local flow disturbances such as fittings and valves. Pumping and distribution system valves come in many varieties, but they all cause some friction head.

Valve body geometry dictates the general flow area through the valve. Some valves restrict the flow area to below 80% of the pipe area. Also, the internal contours of the body and seat should be smooth to avoid creating excessive turbulence. Valve bodies and laying lengths are sometimes much greater than the pipe size to achieve a smooth flow pattern. If the port area is equal to the pipe size, then the closure member or disc needs to be somewhat larger to affect a seal. Then the body is contoured outward around the disc to achieve a full flow area through the valve such as the globe style Silent Check Valve. Other valves take advantage of an angled seat so that the pipe area can be maintained through the port without greatly increasing the size of the valve body such as the Resilient Hinge Check Valve.

The design of the closure member is also important in reducing headloss for two reasons. First, the lowest headloss will be achieved if the disc swings or rotates out of the flow path. Second, discs can also have special contours and shapes to fully open at low fluid velocities and create a smooth flow path through the valve.

There are many flow coefficients and headloss formulas in general use today for rating of various valves on the basis of headloss. Probably the most common flow coefficient for water valves is the C_v flow coefficient, which is defined as the amount of water in gallons per minute (gpm) that will pass through a valve with a 1 psi pressure drop. Hence, the more efficient the valve, the greater the valve C_v. Table 4 illustrates typical flow coefficients for 12 in. check valves in order of increasing C_v.

Typical 12 in. Valve Flow Data			
TYPE OF VALVE	PORT SIZE	C_v	K_v
Silent Check Valve	100%	2480	3.00
Swing Check Valve	100%	3395	1.60
Ball Check Valve	100%	3500	1.50
Dual Disc® Check Valve	80%	4100	1.10
Nozzle Check Valve	100%	4700	0.83
Resilient Hinge Check Valve	100%	4800	0.80
Tilted Disc® Check Valve	140%	5400	0.63

TABLE 4. Valve Types and Flow Coefficients

Another flow coefficient to use for evaluating valve headloss is the resistance coefficient K_v used in the general valve and fitting flow formula:

$$\Delta H = K_v v^2 / 2g$$

where:

ΔH = headloss, feet of water column

K_v = resistance coefficient (valve), dimensionless

v = fluid velocity, ft/sec

g = gravity, ft/sec^2

The flow factor K_v can also be related to the C_v by the formula:

$$K_v = 890\, d^4 / C_v^2$$

where:

d = valve diameter, in.

K_v factors for various valves are similar in magnitude and similar from size to size. For example, a geometrical similar 12 in. valve and a 72 in. valve may have nearly identical K_v's. Because of this similarity, K_v's are ideal for use in comparing valves and fittings. With the understanding that a run of 100 feet of steel pipe has a K of 1.5, and a pipe exit has a K of 1.0, an engineer can easily understand the relative impact a valve has on the total piping system pressure loss. For example, the Silent Check Valve has a K_v of 3.0 which would be equivalent to the loss produced by about 200 feet of pipe.

Comparisons can also be made between various manufacturers for the same type of valve. For example, the published K_v's for 12 in. Silent Check Valves from three prominent suppliers in the US water industry varies from 2.7 to 3.0. The magnitude of this difference is not significant when compared to the total K of a piping system which may range from 50 to 200. The lesson here is that while it is important to consider the headloss between types of valves, the headloss between various suppliers of a given valve type does not typically produce significant changes in system operation. This fact is also the reason that piping system computer simulations accurately model system behavior based on generic valve characteristic data. Given that design differences between brands are small and testing methods can vary, slight differences in published flow data among manufacturers can usually be ignored.

ENERGY COSTS

The headloss from valves can be converted into an annual energy cost related to the electrical power needed by the pump to overcome the additional headloss from the valve with the equation from AWWA M49:

$$A = (1.65\ Q\ \Delta H\ S_g\ C\ U) / E$$

where:

- A = annual energy cost, $/yr
- Q = flow rate, gpm
- ΔH = head loss, ft. of water
- S_g = specific gravity, dimensionless (water = 1.0)
- C = cost of electricity, $/kW·h
- U = usage, percent x 100 (1.0 equals 24 hours per day)
- E = efficiency of pump and motor set (0.80 typical)

For example, the difference in headloss between a 12 in. Tilted Disc® Check Valve (K = .63) and a Silent Check Valve (K = 3.0) in a 4500 gpm (12.76 ft/sec) system can be calculated as follows:

$$\Delta H = K\ v^2 / 2\ g$$

substituting:

$$\Delta H = (3.0 - 0.63)\ (12.76)^2 / 2 \cdot 32.2$$
$$= 6.0 \text{ ft. wc}$$

This difference in headloss can then be used to calculate the difference in annual operating costs assuming an electricity cost of $.08 per kW-hr. and 50% usage.

$$A = (1.65 \times 4500 \times 6.0 \times 1.0 \times 0.08 \times 0.5) / (0.8)$$
$$= \$2230$$

The calculation shows that the use of a 12 in. Tilted Disc® Check Valve in the place of a 12 in. Silent Check Valve can save $2,230 per year in energy costs. If the pump station had four such valves operating for forty years, the total savings would be about $356,000 over the life of the plant. It is clear that the pumping costs can be more significant than the installed costs. Further, the larger the valve, the greater the impact from the energy costs. A comparison of the 40-year energy costs for the various types of check valves is shown in Table 5.

<u>TOTAL VALVE COST</u>

The total valve cost is simply the sum of the initial cost, maintenance costs, and energy costs over the life of the valve as shown in Table 5 and Figure 3.

12 inch Check Valve Total Cost over 40 Years

TYPE OF CHECK VALVE		Installed Cost	Energy Cost*	Maintenance Cost	Total Cost
LIFT	Ball Check	$9,300	$56,300	$6,000	$71,600
	Silent Check	$4,800	$112,700	$6,000	$123,500
	Nozzle Check	$10,000	$31,100	$6,000	$47,100

SWING	Dual Disc®	$2,100	$41,300	$6,000	$49,400
	Swing Check & Weight	$8,000	$60,100	$24,000	$92,100
	Resilient Hinge	$5,800	$30,000	$6,000	$41,800
	Tilted Disc® with Bottom Dashpot	$19,500	$23,600	$72,000	$115,100

*For 40 Years, based on 50% usage, $.08/kW-h, 12.76 ft/sec velocity.

TABLE 5. 12 in. Check Valve Projected Costs for 40 Years

By looking at the table of 40-year costs, it is clear that energy costs are significant in the overall cost of the valve.

NON SLAM CHARACTERISTICS

Pumping systems are often plagued from day one with the problem of check valve slam and the effects of the resultant system pressure surge. Significant research has been conducted to understand the dynamic closing characteristics of various automatic check valves including Ball Check, Swing Check, Tilted Disc®, Resilient Disc, Dual Disc®, and Silent Check Valves (Ballun). Check valve slam is a two-step process. First, after pump stoppage, the flow reverses and flows backwards through the check valve before it can fully close. Second, the closure member suddenly shuts off the reverse flow. When flow velocity is suddenly changed in a piping system, the kinetic energy of the flowing fluid turns into pressure. For every 1 ft/sec change in velocity, there will be approximately a 50 psig pressure spike. It only takes about a 0.5 ft/sec change in velocity or 25 psig to produce a mild slam. A 1 ft/sec change in velocity or 50 psig may produce an audible noise that will carry across the building annoying operating personnel or even neighboring houses. When a slam is observed, it sounds like the noise is caused by the closure member hitting the seat, but in actuality, the slam noise is caused by the pressure spike which instantaneously stretches the pipe wall causing the audible water hammer sound wave. Knowing that the sudden stoppage of reverse flow and the resultant pressure spike is the cause of the slam, an ideal check valve will close before any reverse velocity occurs. Unfortunately, all check valves allow some reverse velocity depending on the dynamics of the system.

The slamming potential of various check valves and their ability to prevent reverse flow can be understood with consideration to the valve geometry. As was said earlier, the best way to prevent slam is to close the valve very fast. But what makes a valve close fast?

The disc location contributes greatly to the closure. If the disc moves or pivots out of the flow stream when open, it will be difficult for the reverse flow to rapidly close the valve. Of the three Lift Check Valves discussed, it can be seen that the Ball Check's closure member is pushed out of the flow stream up an angled channel by the flow while the Silent Check Valve's disc remains in the flow stream. Hence, when the flow reverses, the reverse flow will immediately impact the Silent Check Valve disc causing it to close faster than the Ball Check Valve. Even though a Silent Check Valve closes in about one tenth of a second, reverse flow is still flowing through the valve, but at a negligible amount. When it comes to Swing Check Valves, they all have the closure member in the flow stream which will assist in rapid closure. A related geometric feature of the valve is the length of stroke. It only makes sense that the further the disc must travel, the longer it will take to close. Of the Lift Check Valves, the Silent and Nozzle Check Valves have the shortest stroke (one fourth of the diameter) and the Ball Check Valve has the longest (one diameter). Of the Swing Check Valves, the Resilient Hinge Check Valve has the shortest stroke (35 degrees) and the traditional Swing Check the longest (60 to 90 degrees).

If the deceleration of the forward flow can be estimated, such as with a transient analysis of the pumping system, the slamming potential of various check valves can be predicted. The non-slam characteristics of check valves are shown for various system decelerations in Figure 3. The valves whose curves are furthest to the right have the best non-slam characteristics. The reverse velocities and resultant slams may be higher for larger size valves.

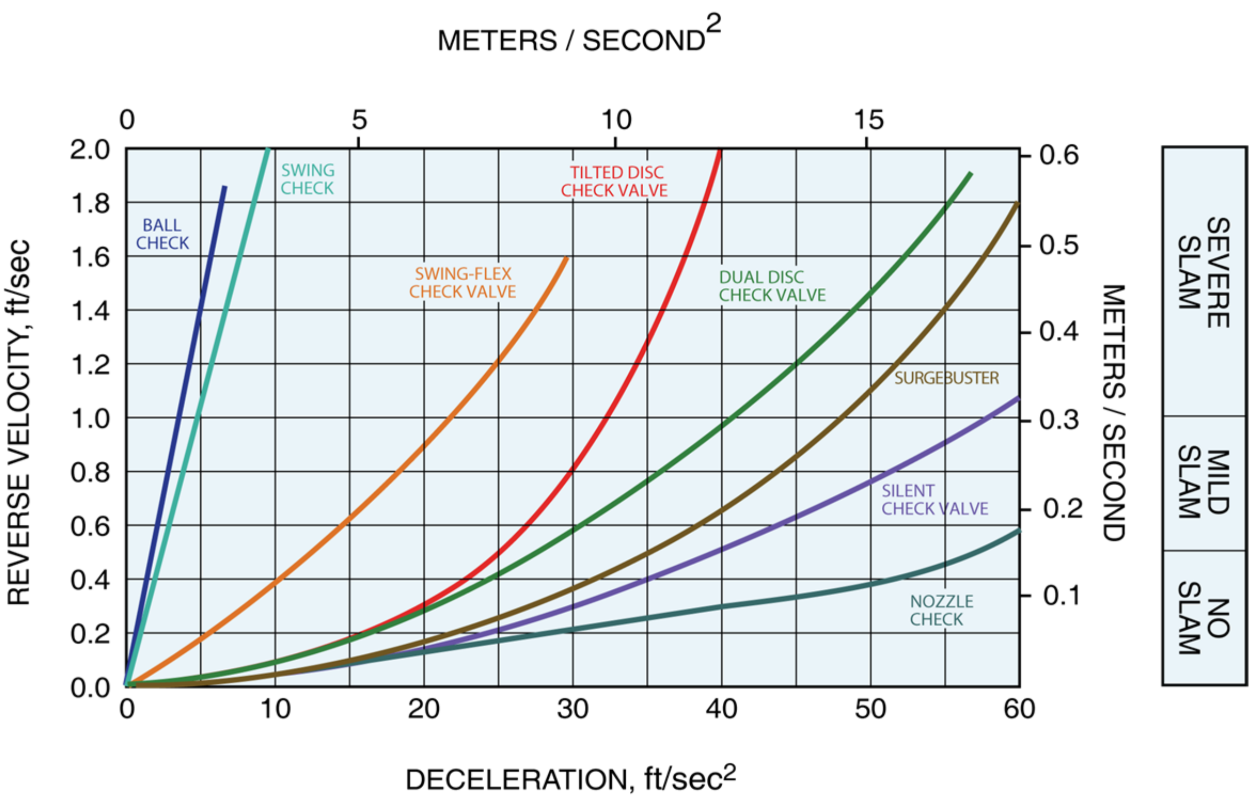


FIGURE 3. Non Slam Characteristics of Various 8 In. Check Valves

Finally, the non-slam characteristics of check valves can be affected by the orientation of their installation. Regardless of design, all check valves can be installed in the horizontal position even with a slight slope of the pipe. However, special considerations should be given to valves installed in vertical installations. In vertical flow-up applications, slamming problems can be amplified because a vertical column of water rapidly reverses. Also, in vertical pipes, the valve disc may be in the vertical plane and will have no gravity assistance in closing. While a lever may counterbalance the disc, the added inertia may cause the rapid reverse flow to force the disc violently into the seat. The best valves for vertical pipe applications are the valves with short linear strokes or valves with angled seats.

FLUID COMPATIBILITY

Line media is critical to check valve selection. The rule of thumb regarding check valve selection and suspended solids is the higher the concentration of suspended solids, the more care required when selecting a check valve. All check valves on the market today will handle water or treated wastewater, but as we move from potable to raw water to waste water to screened sewage to raw sewage, many valves must be excluded. There are several factors to consider. Will the valve seat properly if suspended solids are present? Are there shafts, stems, spokes, or discs in the flow stream? Geometry of the body is also important because voids or areas where solids can become trapped may impede operation. The higher the solids content the more desirable a full ported design becomes to avoid clogging. If the valve has a straight, smooth flow path, the potential for clogging is greatly minimized. With these concepts in mind, Nozzle Check, Silent Check, Dual Disc® and Tilted Disc® valves should not be used for wastewater containing high solids.

CHECK VALVE TYPE		FLUID COMPATIBILITY
LIFT	Ball Check	Water or Wastewater
	Nozzle Check	Clean service only
	Silent Check	Clean service only
SWING	Dual Disc®	Clean Service Only
	Traditional Swing Check with Lever and Weight	Water or Wastewater
	Resilient Hinge Swing Check	Water or Wastewater
	Tilted Disc® Check Valve	Clean Service Only

TABLE 6. Check Valve Application Data

SELECTION METHODOLOGY

With the understanding of the three selection criteria for various types of check valves, the design engineer now needs a rational decision process to assist in narrowing down the field of available valves and identify the best valve for the given application.

Table 7 illustrates one possible methodology wherein each criterion is assigned a weight for the given application. The various criteria are listed across the top of the table. The types of valves under consideration are listed down the side of the table. In the example shown in the figure, the highest weight (5) was assigned to Non-Slam because the application was in a residential area where no noise can be tolerated. Next, based on valve data, a rating was given to each valve in each category. Finally, each rating is multiplied by the criteria weight and summed to the right for each valve. The engineer can then judge which valve is best for the given application.

In this example, the engineer might give the nod to the Resilient Hinge Check Valve with spring. As the weights and ratings are assigned, the results will, of course, vary.

WEIGHT:	3	5	2	TOTAL SCORE
VALVE TYPE	TOTAL COST	NON-SLAM	FLUID COMP.	
Ball Check	5	1	5	30
Silent Check	5	5	2	44
Nozzle Check	5	5	2	44
Dual Disc®	5	4	2	39
Swing Check, Weight	4	2	5	32
Resilient Hinge (RH)	5	3	5	40
RH With Spring	4	5	5	**47**
Tilted Disc®, Dashpot	3	5	2	38

TABLE 7. Check Valve Selection Table with Sample Weights and Ratings

CONCLUSION

Now that the types of check valves and their performance characteristics are better understood, a rational decision process can be applied to selecting check valves for specific applications that satisfy individual preferences and system parameters. There is no single check valve that is the best for all applications. Every installation will require the selection criteria to be given different weights, so it follows that there are applications suitable for all of the check valves available.

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