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TECHNICAL BULLETIN

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Design and Use of Check Valves

The simplicity of the check valve should not hide the importance of its function or its potential to cause problems. Check valves are installed to protect piping systems, equipment, and our health. Improperly installed check valves can result in costly repairs and system shutdowns.

CHECK VALVE APPLICATION

The check valve is an automatic shut-off valve. Under pressure and flow, the closure mechanism opens allowing the media to flow freely. When the flow and pressure stops, the closure mechanism returns automatically to the closed position, preventing the media from returning upstream. The most common installation is at the pump. A check valve may be installed on the suction side of the pump to maintain the pump's prime in the event of a pump shutdown. A check valve will be used commonly on the discharge of the pump to prevent backflow from the downstream system, when the pump shuts off.

Check valves are used to prevent contaminated media in branches from flowing back into the main trunk line. The most common example is the use of backflow-prevention devices installed on any connection to a city water main. The backflow prevention device, a special form of check valve, prevents possibly contaminated water at a facility from flowing into the city water system when there is a sudden loss of water pressure in the main utility line.

There are several other applications for check valves, but the purpose is always the same.

Check valves rely on backpressure to affect a seal. The greater the backpressure the tighter the seal, but there is normally no stem to add mechanical pressure to guarantee the tightness of the seal. An elastomeric-sealing surface does not necessarily provide a bubble tight seal. Some backflow should always be expected through a check valve.

CHECK VALVE DESIGN

Swing Check Valve: The closure mechanism is a disc attached to an arm that swings or rotates on a hinge outside the seat area. The disc swings in a full 90° arc from fully opened to fully closed. Closure of the disc is caused by gravity pulling the disc and the reversal of flow pushing against the disc. The swing check valve is a relatively slow-closing valve, due to the distance the disc must travel to seat itself. Reversal of media flow begins before the valve closes. The advantage of the swing check valve is that it offers a full-flow waterway with minimal pressure drop across the valve.

Double-Disc Swing Check Valve: This variation of the swing check valve splits the disc into two D-shaped discs. Each disc rotates on a shaft in the center of the waterway. This reduces the path that the discs travel to effect closure. This short travel distance, along with springs attached to the disc, allows the check valve to close before the reversal of flow begins. The disc and pivot-pin obstruct the waterway and cause a greater pressure drop than a full-swing check.

Rubber-Flapper Check Valve: A one-piece, elastomeric flapper, rather than a disc, is the closure mechanism used in this special swing check design. The elastomer is reinforced for strength. A 45° seat angle reduces the travel of the flapper to only 45°; thus creating a faster closing valve than the swing check valve. The rubber flapper provides a more positive shut-off but the elastomer limits the applications of this valve, especially to low temperatures.

Slant-Disc Check Valve: The disc of this style of check valve rotates around a pivot-pin in the center of the valve. The hinge pin is attached directly to the disc with approximately 30% of the disc area above the pivot point to offer resistance against the 70% disc area below the pivot point. The shut-off seating angle is 55°. The result is a very short travel arc from fully opened to fully closed, thus allowing a minimal reversal in flow. This type of check valve is sometimes assisted mechanically with the use of hydraulic attachments to control the rate of closure. The disc and pivot-pin obstruct the waterway and will cause an increased pressure drop. The slant disc is usually manufactured in larger sizes - 4" and larger.

Lift Check Valve: The closure member of a lift check valve rises directly off the seat in a line perpendicular to the plain of the seat and in a direct line with the flow. The more traditional design resembles a globe valve. The disc is free floating without an operating stem. Flow enters the valve from under the seat and pushes the disc off of the seat. After passing through the seat area, the media turns 90° and flows out the valve.

The linear-lift check (also called a poppet or silent check) has a straight flow path. The poppet (disc) is center guided and remains in the flow path. The media must flow around the poppet producing a significant pressure drop. Wafer and flanged (commonly referred to as a globe design, but different from the traditional globe described above) designs are both available. The flange-globe design has a longer laying-length that allows for a greater flow area than the wafer style. The poppet and guide remain in the flow path and can easily foul and hang up in high viscous applications.

A third design uses a ball rather than a poppet. This type is used in both the linear and traditional globe-body styles. The ball does not require guides, as the poppet does, and is not as prone to hanging up in high-viscous or dirty-media applications.

The relatively short travel distance of the closure member to the fully opened position gives the lift check the advantage of a fast closure. A spring is often used to assist the closure that will force the poppet or ball closed before backflow begins.

Foot valves are a special linear lift check valve used on the suction side of a pump, located at the entrance end of the pipe in the well. A screen over the upstream side protects the valve from foreign materials.

Diaphragm Check Valves: An elastomeric membrane is used as the closure mechanism in a family of check valves used primarily in the chemical industry and for slurries. The membrane is pushed open by the flow and collapses when the flow stops and the reversal of flow comes in behind the membrane. The elastomer limits the applications to low pressures and low temperatures.

SIZING

The common practice in piping is to size the check valve to fit the pipe size. The check valve, however, relies on flow and pressure to hold the closure member open. A buildup of pressure will open the flapper or poppet, but if the flow is not sufficient and continuous, the flapper will reseat. This fluttering causes premature wear and failure of the valve. Flow through a check valve should be sufficient to force the closure member firmly against the stop in the fully opened position.

Properly sizing a check valve requires matching an established minimum pressure drop (psi) to the actual flow (gpm) of the system. The following quote from the Crane Number 60 Catalog gives a good explanation:

"An extensive study of tests conducted by Crane on check valves of all types resulted in establishment of the minimum amount of flow sufficient to lift the disc fully. It was found that the minimum flow to lift the disc varied with different types of fluids but the measured pressure drop across the valve was constant for all fluids. As a result, minimum pressure drops required across various check and foot valves were established and are shown on page 424."

The minimum pressure drop values that Crane lists are; 0.5 psi for swing check valves and 2.0 psi for lift checks. *The Guide for the Selection, Installation and Maintenance of Silent Check Valves* by the Fluid Controls Institute Inc. recommends a 3 psi loss at normal flow for linear lift checks. At these pressure drops, the volume (gallons per minute) varies, but the velocity remains around the ten feet per second range.

An example of how to use these pressure drops is in order. Assume a 6" piping system with an average flow of 450 gallons per minute (this equates to a velocity of 5.0 feet per second). Using this in a Cv formula (page 108 in the NIBCO *Bronze and Iron Valve catalog*):

1)	Q	=	$C_V \sqrt{(\Delta P/S)}$
	Q	=	450 gpm
	ΔP	=	0.5 psi or 3.0 psi below
	S	=	1 (specific gravity of water)
2)	C_V	=	$Q/\sqrt{(\Delta P/S)}$
3)	Determine the valve size by calculating the C_V:		

F-918 ΔP = 0.5	**F-918 ΔP = 3.0**
$C_V = 450 / \sqrt{(0.5/1)}$	$C_V = 450 / \sqrt{(3.0/1)}$
$C_V = 450 / .707$	$C_V = 450 / 1.732$
$C_V = 636$	$C_V = 260$

The F-918 with the closest Cv value in the catalog chart is the 4". The F-91 0 with the closest Cv value is also the 4". You will note that this is similar to sizing a stop check valve.

HYDRAULIC SHOCK

Hydraulic shock is caused by the sudden change in velocity of a non-compressible media, such as water, causing a dramatic spike in pressure. Check valves slamming shut on reversal of flow are one of the primary causes of this shock. The potential to create hydraulic shock is directly related to the distance the disc, poppet, or ball travels. The swing check, with a 90° arc to swing through from fully opened to fully closed, is the worst. A significant amount of reverse flow takes place before the movement is initiated and closure is completed.

The lift check has a stroke of approximately 1/4 of the size of the valve (i.e., a 4" valve would have approximately a 1" distance from the open poppet to the seat). This short distance allows the poppet to close very quickly with a minimal reversal of flow. When a spring is used to assist the poppet closing, the valve is closed as the forward flow reaches zero velocity and *before* any flow reversal occurs.

The short travel to closure of the slant disc and the double disc swing check valves similarly minimize flow reversal. When a spring is added to assist the closure, flow reversal is eliminated.

TURBULENCE

Laminar flow is straight, non-disturbed flow through a straight pipe. Turbulent flow results when the direction is changed or something in the media path disrupts the flow. Turbulent flow through any check valve will vibrate the disc or poppet and the connecting arm. Discs and poppets are left free to spin on the hanger or guide to compensate for wear when seating. Turbulence will cause rapid spinning of the disc and premature wear on the guide, hanger, or disc holder. Turbulence is found at the discharge side of pumps, elbows and valves. Check valves should be installed downstream from the source of the disturbance a minimum of 5 pipe diameters, preferably 10 pipe diameters.

PULSATING PRESSURE

Most valve catalogs will have a footnote advising against using check valves on reciprocating pumps and air compressors. Actually the check valve should not be used in any application with pulsating pressures - rapidly rising and falling pressures. The rapid fluctuation in pressure results in the disc arm or poppet guide constantly moving back and forth, thus wearing out the guide or hinge-pin hole. This wear will quickly become severe, allowing the disc or poppet to move off center and hang up against the body wall. Special lift checks with a piston-controlled poppet are used for these applications.

BACK PRESSURE

The nominal size of the upstream, as well as the downstream, piping must be considered when choosing and installing check valves. If the differential pressure upstream and downstream is minimal, when the disc or poppet tries to open it will begin to flutter. Pressure will build up until the disc rises off the seat. The pressure is immediately equalized, and the disc slams back into the closed position. The fluttering continues until the disc, poppet, or seat is so damaged that the valve no longer holds back flow. The flutter is noisy and, as in any piping application, noise is not desirable. You should look downstream to the main header, or other sources, for a strong backflow.

PROPER INSTALLATION

1. Do not use a full, 90° arc, swing check valve, where strong backflow occurs that will slam the valve shut.
2. Do not use a lift check or other style of valve, where the closure member remains in the waterway containing highly viscous media.
3. Do not expect any check valve to be bubble tight.
4. Use a spring-assisted, linear-lift check or double-disc check valve on the discharge side of the pump.
5. The size of a check valve shall be determined by the specified pressure drop (0.5 psi for swing checks, 3.0 psi for linear lift checks), not on pipe size.
6. Check valves shall be installed at least 5 pipe diameters (mild velocity and turbulence) to 10 pipe diameters (high velocity and turbulence) from the pump or other sources of turbulence.
7. Do not install check valves in systems with pulsating pressures.

Check valves need a significant pressure differential across the disc in the closed position to open properly.