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Why Check Valves Slam

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Check valves are important in water and wastewater pumping systems: They automatically open to allow forward flow and automatically close to prevent reverse flow when the pumps are not in operation.

The valves need to be low cost, and they should minimize energy consumption and require minimum maintenance. But most importantly, they should not slam and generate damaging pressure surges in the piping system.

Figure 1. Multiple pumping system with resilient hinge check valves

CHECK VALVE SLAM

Check valve slam occurs after pump stoppage when reverse flow passes by the check valve disc before the valve is fully closed. The reverse flow is stopped instantaneously by the closed check valve, which causes a loud shock wave as well as water hammer in the pipe (Figure 2). The noise associated with the slam is not due to the impact of the disc slamming into the seat, but rather the rapid stretching of the pipe from the water hammer. Surprisingly, a resilient-seated check valve can make the same metallic slam sound as a metal-seated valve.

To prevent slam, a check valve must either be able to close in a fraction of a second or be fitted with oil dashpot devices or actuators to control its closure over several seconds or (depending on the length of the piping system) minutes. The dynamics of the pumping system (i.e., deceleration of the velocity from head, slope and pipe friction) dictates the necessary closure time. Systems with high head, steep slope, vertical pipe or surge tanks require the check valves to close rapidly (e.g., 20 milliseconds) versus a low-head, relatively flat system where a closure time of one second might suffice. This article provides an understanding of how the design and geometry of check valves affect their closure speeds.

A LOOK AT VALVE DESIGN

Laboratory tests and flow simulations have demonstrated that, to close rapidly, a check valve should contain the following design characteristics (Thorley, 1991):

- The disc should have low inertia and friction.
- The travel of the disc should be short.
- The motion should be assisted with springs.

With these three characteristics in mind, we can predict the closure speed of various waterworks check valve designs.

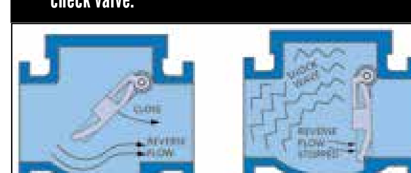
A ball check valve (Figure 3) is simple, compact and commonly used on small water or wastewater pumps where economy is important. Such valves consist of a threaded or flanged body with internal features that guide a rubber-coated ball in and out of the seat as the flow goes forward and reverses. Because the ball has high inertia, it must travel a long distance and it employs no spring, the valve closes slowly and often slams. Because of this, the valves should only be used in single-pump and low-head systems such as small lift stations.

Similarly, the traditional swing check valve (Figure 4) described in AWWA C508 swings through a 90-degree stroke and is typically provided with a lever and weight. Again, because of the long stroke, inertia of the disc and weight, as well as the friction in the packing, the valve will close slowly and may slam in multiple-pump and vertical-pipe installations.

Ironically, it might be assumed that the weight makes the valve close faster. In actuality, it reduces slamming by limiting the stroke of the disc, but in return, may cause a significant increase in headloss. The valve closure is also slowed by the inertia of the friction in the stem packing. Slamming can be minimized by removing the weight and adding an external spring.

Conversely, silent check valves (Figure 5) do not slam and are commonly used in high-rise buildings where slamming sounds would be objectionable. When the flow is initiated, the disc is pushed to the left to allow forward flow. When the pump is stopped, the compression spring in the valve rapidly forces the valve closed before the flow reverses, which

Figure 2. Slam is caused by reverse flow through the check valve.



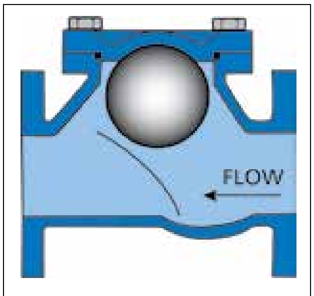


Figure 3. Ball check valve

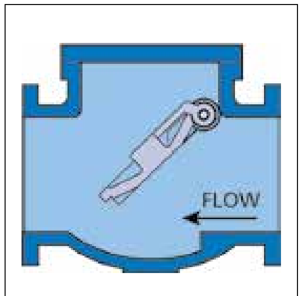


Figure 4. Swing check valve

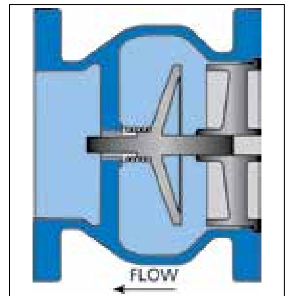


Figure 5. Silent check valve

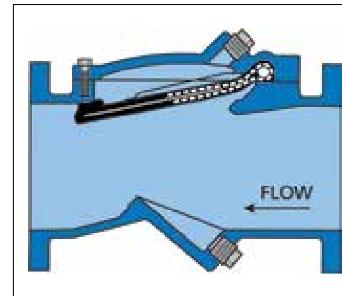


Figure 6. Resilient Hinge check valve

provides silent closure.

Silent check valves close very quickly (i.e., in about one tenth of a second) because of their short linear stroke and strong spring. 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.

The newest type of check valve described in AWWA C508 and the valve having the greatest impact in the water/wastewater industry today is the resilient hinge check valve (Figure 6). As the name implies, the swing occurs from flex action in the rubber molded disc instead of rotation about a hinge pin. This valve has a short, 35-degree stroke, a spring and low inertia, which results in rapid closure similar to a silent check valve but without the head loss.

DYNAMIC CHARACTERISTICS OF CHECK VALVES

The valves presented above have varying degrees of closure speed. But how fast is fast enough?

Significant research has been undertaken to understand the dynamic closing characteristics of various check valves with the goal of predicting check valve slam (Ballun 2007). Figure 7 was developed to depict graphically the slam potential of various 8-inch waterworks check valves. The chart is based on measuring the reverse velocity through the check valve in a laboratory just before closing while exposed to varying ranges of system dynamics. The valves with a high potential to slam are presented on the left side. The horizontal axis displays the system deceleration (i.e., the speed at which the water column stops after pump stoppage).

In practical terms, a single lift pump system operating at 50 psig may have a deceleration of only 5 feet per second squared (ft/sec^2) and a ball or swing check may operate without a severe slam. But if a parallel pump system such as the one shown in Figure 1 is operating at higher pressures, then the deceleration may be 30 ft/sec^2, and a faster closing check valve is needed such as the resilient hinge check valve with spring.

The dynamic characteristics of the valves depend on valve size but no data is available at this time to predict the exact effect of size. Larger valves have heavier discs and longer strokes and will likely produce higher reverse velocities than predicted in Figure 7. A valve manufacturer should also be consulted for the potential impact of orientation and size on the performance of the selected valve.

SUMMARY

Every valve design has unique and predictable closing characteristics. Dynamic characteristic data for check valves offers the designer the tools necessary to evaluate the non-slam characteristics of various check valves. This information, combined with other readily available valve characteristics such as headloss, laying length, waterway design for fluids containing solids and cost will provide the designer with all the tools necessary to make reliable valve selections. VM

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REFERENCES

1. American Water Works Association (2017), AWWA C508, "Swing-Check Valves for Waterworks Service, 2-In. Through 48-In. (50-mm Through 1,200-mm) NPS." Denver, CO.
2. Ballun, John V., (2007). "A Methodology for Predicting Check Valve Slam," Journal AWWA, March 2007, Denver, CO., 60-65.
3. Thorley, A.R.D., (1991). Fluid Transients in Pipeline Systems, D&L George Ltd, Hadley Wood, England, 22-23.

Figure 7. Characteristic data for 8-inch ball, swing, resilient hinge (RHCV), tilted disc (TDCV), double disc (DDCV), RHCV with spring (RHCV-S), and silent check (SCV) valves