InTech

Proper Valve Stem Sealing Best Practices

By Lisa Miller

There are many methods of sealing valve stems on control and isolation valves. When chosen carefully, a valve stem seal provides years of reliable service, reduces environmental emissions, and minimizes product loss. When inappropriately applied, a valve stem seal can leak constantly, increase maintenance costs, create environmental issues, and place operating personnel at risk. The right valve stem seal increases efficiency by minimizing product loss, which in turn reduces energy use, because less product needs to be made to satisfy demand.

Valve stem seals explained

Before delving into the details of selecting a valve sealing method, it is best to understand the challenges of sealing a valve stem and

Less leakage results in reduced product loss, increased efficiency, and improved energy management.

Figure 1. This control valve is subjected to EPA's Method 21 "sniff" test to determine the fugitive emission leak rate after a prescribed number of mechanical and thermal cycles.

explain how this might be done. Control and block valves fall into one of two major categories: sliding stem or rotary.

A sliding stem valve has a rod protruding from the body that rises and falls to open and close the valve. A rotary valve has a shaft extending out the side of the valve that is connected to a plug, disc, or ball. As the shaft turns, the rotary valve opens and closes. In either design, the valve stem must exit the body and be capable of relatively friction-free movement, while containing the process and preventing leaks.

The valve stem sealing assembly makes that possible. Sealing is usually accomplished in one of two ways: conventional packing or bellows seals. Details of how these methods work, along with pros and cons of each method, follows.

Measuring valve stem seal performance

Valve stem seals must accomplish two contradictory goals. First, they must seal the valve stem completely and reduce—and ideally eliminate—any fugitive emissions from the process. Second, they must accomplish this feat while allowing the valve stem to move freely and continue sealing, even as the valve stem cycles thousands of times. Several industrial standards address these requirements, but the required performance and test methods vary significantly.

The three main fugitive emissions standards are TA Luft, FCI 91-1, and ISO 15848. TA Luft is the least comprehensive of the three, offering leak rate standards based on gasket size and process temperature. However, it lacks specific test parameters for the number of test cycles required or the travel distance, so it is hard to compare the leakage results among different valve designs.

FCI 91-1 was created by the Fluid Control Institute and is more closely aligned with the leak detection and repair requirements mandated by the Environmental Protection Agency (EPA). It uses EPA's Method 21 to "sniff" the valve packing and determine the leak rate (figure 1). This standard provides details on how to test a valve. A valve stem seal design achieves various classification ratings based on the resulting leak rate after a specified number of mechanical and thermal cycles.

By far, the most comprehensive standard is ISO 15848. It has a variety of leakage classification rates for both control and isolation valves based on mechanical cycles, thermal cycles, and stem size. It also allows testing with either helium or methane, and it dictates two different ways to measure stem seal leakage for helium, each of which is much more involved than a simple sniff test. Specifically, the upperworks of the valve are encased in an airtight enclosure and either flushed with a test gas or subjected to a full vacuum, while the inside of the valve is pressurized with helium. The amount of leakage can then be precisely measured.

When evaluating the performance of a valve stem seal arrangement, it is important to determine how the valve was tested and what specific classification it met. It is relatively easy to achieve very low leakage rates if the valve is mechanically cycled a small number of times. It is much more difficult to achieve and maintain very low leakage rates when the valve is mechanically cycled thousands of times, while enduring thermal cycles as well. The thermal cycles affect sealing due to the high expansion rate of PTFE (a synthetic fluoropolymer of tetrafluoroethylene, also known as Teflon) and the poor recovery rate of graphite, making packing design challenging.

Sealing valve stems with packing

The most common method of valve stem sealing employs a series of PTFE or graphite rings that encircle the valve shaft (figure 2 left). The rings are compressed with a combination of a packing follower, packing flange, and bolts to push down and squeeze the packing rings against the shaft. The compressed rings allow the valve stem to move while maintaining a seal against the valve body and shaft to keep process fluids from passing through the stem and escaping. In certain applications, the packing need only protect against gross process leaks, so relatively minor fugitive emissions are not a concern and free stem movement is considered a more important requirement.

To achieve and maintain low emissions, packing must be "live loaded" to keep constant pressure on the sealing rings (figure 2 right). This is usually accomplished using compressed Belleville-type springs. These springs maintain a constant force on the packing, ensuring it seals over time, even as the rings wear from stem movement. Unfortunately, the increased pressure tends to restrict valve movement, so

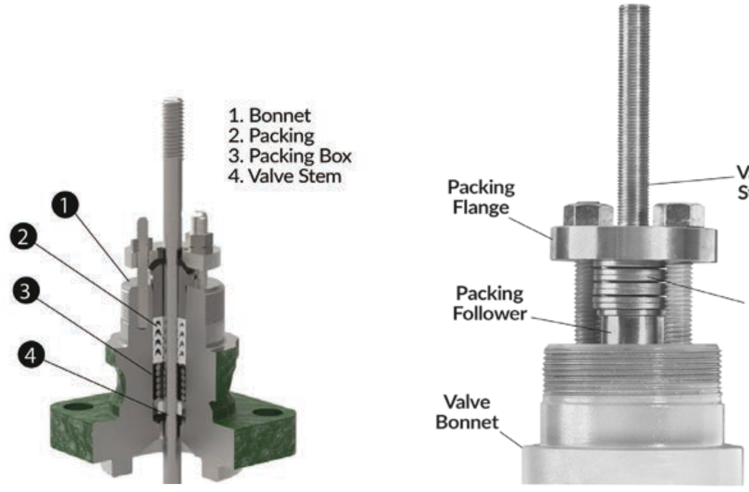


Figure 2. The picture on the left shows a typical rising stem control valve with standard packing. More modern packing designs, shown on the right, employ compressed Belleville-type or other special springs to maintain constant pressure on the packing rings. This ensures the fugitive emissions are limited to 100 ppm or less, even as the rings wear.

the sealing materials and valve stem finish must be carefully chosen to minimize fugitive emissions, while allowing valve stem movement.

Sealing valve stems with bellows

An alternative to valve packing is a valve bellows seal. A bellows seal uses a welded or mechanically formed metal barrier around the valve stem that can compress and stretch like an accordion (figure 3). Because the seal is made of metal with a very low rate of deformation in critical areas, bellows seals achieve virtually zero leakage.

Welded leaf bellow seals (figure 3 left and middle) are manufactured by welding together a stack of washer-like plates of thin metal to make a flexible seal with many folds over a given length. A formed bellows (figure 3 right) uses a flat sheet of metal formed and welded into a tube. The tube is then mechanically and hydraulically formed into a bellows.

Both designs can stretch about the same distance per fold, but because the formed bellows has far fewer folds per inch, its overall length is usually three times longer (figure 4). However, the reduced number of welds and corresponding mechanical stress allow formed bellows to last significantly longer in most applications.

Because bellow seals are constructed of relatively thin metal and subjected to mechanical stress and corrosion, they can crack and fail over time. For this reason, a bellows seal valve usually has a standard packing above it to contain the process should the bellows fail in operation.

Packing versus bellows

Each method of valve stem sealing has pros and cons, so the best choice depends on the application. Perhaps the biggest advantage of standard or environmental packing is its comparatively low cost, along with a wide variety of valve packing materials and designs to suit most applications. Valve packings can also be adjusted and replaced without disassembling the valve.

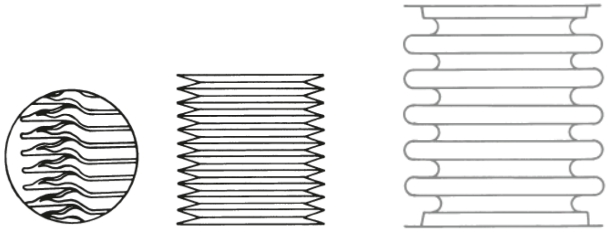


Figure 3. Bellows seal designs usually employ a welded leaf design (detail left and middle) or a mechanically formed design (right). A formed design can withstand many more cycles than a welded leaf design, but it is usually about three times longer.

The biggest advantage of a bellows design is its ability to deliver zero leakage. Such a specification is critical for lethal service applications. The bellow materials can also be chosen to handle higher temperatures and corrosive applications. Because the operational life of a bellows seal is based on the number and length of strokes, the estimated time to failure can be predicted with some accuracy, so replacement can be planned.

Each design has disadvantages as well. The performance and lifetime of packing is based on many variables, which are not always easily predicted. Small leaks usually can be addressed by tightening the packing, but at some point, the packing must be replaced. Also, the surface finish of the valve stem can have a big impact on the life and performance of a packing design. Regardless, all valve packing will leak to some extent, and this may not be acceptable in certain applications.

As mentioned previously, bellows seals will fatigue and eventually fail. When that occurs, the valve must be fully disassembled to replace the bellows seal. For this reason, the total cost of ownership for a bellows seal is typically higher than that of packing.

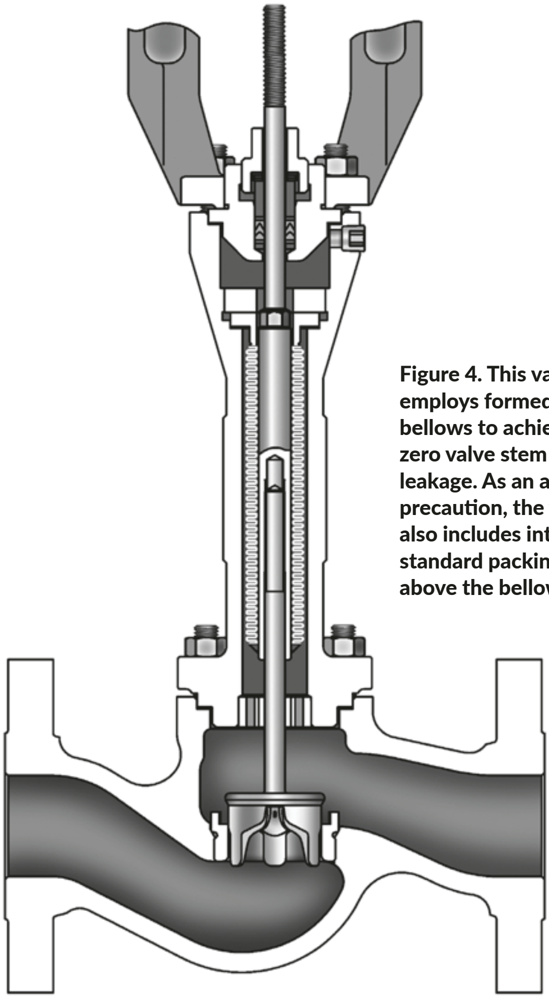


Figure 4. This valve employs formed bellows to achieve zero valve stem leakage. As an added precaution, the valve also includes integral standard packing above the bellows.

Application examples

When properly selected and applied, both packing and bellows seals can handle challenging applications. In one liquified natural gas application in Australia, a 24-inch by 30-inch letdown valve used a specially designed environmental packing arrangement and had very low valve stem leakage, despite operating at cryogenic temperatures around –300°F (figure 5). Any fugitive emission from this valve translated into lost product, lost energy, and environmental damage—so it was critical to minimize leaks.

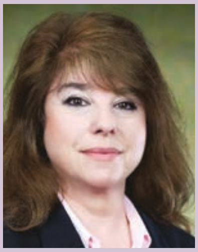
A Chinese chemical plant had a lethal service hydrogen cyanide application requiring virtually zero leakage while in operation, so a bellows seal design was selected. Upon commissioning, the plant reported zero measurable emissions, and after six years, still had no reported leakages. The valves went through 50,000 full cycles and more than 10,000 partial cycles annually.

Final thoughts

Proper selection of valve stem sealing is a critical component of the valve specification process. When chosen wisely, the design will perform reliably for the long term, translating into significant reductions in environmental emissions, product losses, and maintenance costs. Losing less product improves efficiency and is a key component of energy management.

The number of design options are extensive, so end users may find it helpful to consult with their valve vendor to determine the best sealing design, materials of construction, and other details for their specific applications. ■

All figures courtesy of Emerson



ABOUT THE AUTHOR

Lisa Miller is a senior engineering manager for Fisher sliding stem valves at Emerson Automation Solutions. She has been the primary technical consultant for Fisher packing and bellows for more than 20 years, and she has 25 years of expertise with cryogenic valve design, testing, and manufacturing. Miller is the chairperson of the ISA75.27.01, Cryogenic and Low Temperature Seat Leakage Testing of Control Valves committee, and has been a member of ISA for 10 years. She has a BS in mechanical engineering from the University of Iowa.

Figure 5. This 24-inch by 30-inch letdown valve employs a specially designed large stem diameter environmental seal for extremely low leakage rates, as demonstrated here during a test at –56°F.