The selection and maintenance of valves for the control of fugitive emissions

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Upgrading existing valve stem sealing systems is probably the most cost-effective means to achieve compliance with industry guidelines.

The Environmental Protection Agency (EPA) is developing stringent end-user standards to control emissions from a broad spectrum of hazardous organic and inorganic chemicals used in the pulp and paper industry. Under these regulations, major sources are expected to be required to inspect valves and other equipment on a regular basis and repair reportable leaks. A leak is expected to be defined as drippage or a reading of 500 ppm or greater on an organic vapor analyzer (OVA). Valves have been singled out as one of the greatest potential leak sources. When the percentage of leaking valves in a plant exceeds defined limits, the mill will be required to implement a quality improvement program (QIP) that will involve upgrading valves to the maximum achievable control technology (MACT).

Industry guidelines exist to limit leakage of volatile hazardous air pollutants (VHAP). Rotary and linear valve stem designs offer different challenges in maintaining low emissions. Valve stem leakage control technologies have been developed for a broad range of seal types and materials of construction.

Upgrading existing valve stem sealing systems to the latest available technology is likely the most cost effective means to achieve compliance.

Introduction

"Fugitive" is a name given to prisoners who have escaped from confinement. It is also the name the EPA now gives to chemicals that escape from a process. Of course, we had "fugitive emissions" long before the EPA coined the term. We just called them something simpler—leaks.

Indeed, preventing leaks has always been an integral part of the design and selection of valves for the pulp and paper industry. A leaking valve reduces yield, makes a mess, creates safety hazards, damages other equipment, causes the valve to stick, and can even create health problems for workers and for the community.

It is this latter concern—the potential for creating health problems for workers and the community—that motivates government to impose tight restrictions on equipment leaks.

Requirements

It is expected that EPA regulations for valve leakage in the pulp and paper industry will parallel the regulations recently promulgated for the chemical process industry. Those regulations have two important features.

First, the regulations do not apply to all process valves. They apply only to the valves that meet all the following criteria:

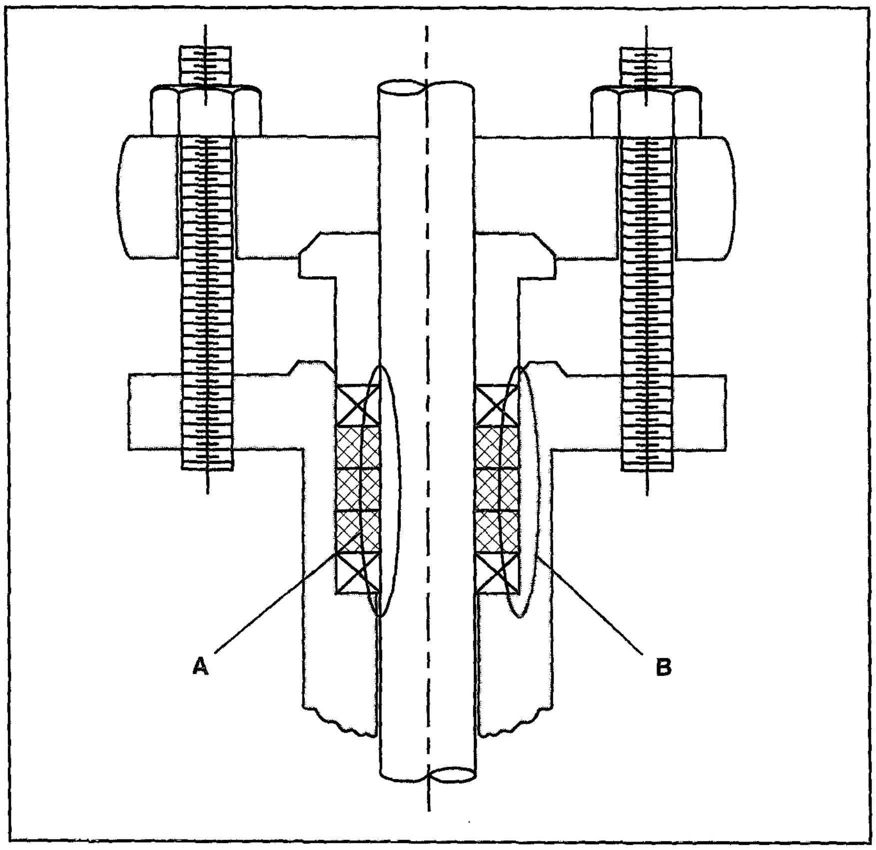
1. The valve is used in a process on the EPA list of covered processes.
2. That process is operated for a minimum number of hours each year.
3. The valve carries a fluid on the EPA list of hazardous fluids.
4. It is practical to monitor and repair the valve.
5. There are at least a specified minimum number of valves that meet the above criteria. In other words, the EPA is not going to impose its regulations on only a handful of valves.

Second, the regulations do not directly control or limit valve leakage. Instead, the regulations require that each covered valve be monitored for leakage and then repaired if the leakage exceeds the EPA threshold. Thus, the regulations should not be considered as a limit on leakage, but rather as a mandated inspection and maintenance program.

The frequency of inspection mandated by the EPA depends on the number of valves found needing maintenance. If only a few valves have leak rates high enough to require repair, the EPA allows inspection to occur less frequently; if a large number of valves are found to leak, the EPA requires more frequent inspection and repair. If too large a number of valves consistently need maintenance to stop leakage, then the EPA mandates that a valve quality improvement program must be implemented to identify and solve the problem.

It is the cost of performing the inspections and managing the quality improvements programs that give these regulations their clout. Plants that have very few leaking valves will have

1. Valve packing leakage paths. A: between packing and stem. B: between packing and stuffing box.



But remember that the fugitive emission regulations do not directly address the initial leak rate. Rather, the regulations focus on the valve's ability to retain its low leakage rate even after years of operation in the process environment. So, what counts is how well the packing will continue to seal, even after the stem has been stroked thousands of times, the packing has become contaminated with process fluids and external dust, and the stem has corroded and perhaps even bent.

To understand how packing and valves can be designed to retain low leakage in the face of such conditions, it is important to look closely at the details of how packing works. Like a gasket, packing is a resilient material that is forced into the void space between stem and stuffing box. Forcing the packing into this space creates stress in the resilient packing material. Like a bundle of tiny springs, the stressed packing pushes itself against the stem and forms a tight seal. Any process fluid that leaks past the stem must either pass through the packing or through the space between the packing and the stem (**Fig. 1**). Modern packing, especially PTFE and expanded graphite, are virtually impermeable, so the primary leakage concern is between the packing and stem. Of course, leakage can also occur between the packing and the stuffing box (Fig. 1). But, if the leak path between packing and stem is controlled, the leak path between packing and stuffing box is also controlled.

So long as the packing remains stressed, it will continue to seal the stem. Any leakage that occurs will be caused by any of three situations:

1. The process pressure is greater than the sealing force between packing and stem.
2. Surface irregularities in the stem create leak paths that the resilient packing cannot fill.
3. The stem does not remain centered in the packing, so the packing is not resilient enough to fill the gaps caused by radial stem movement.

Each of these three leakage sources can be reduced by increasing the stress on the packing. This increased stress will seal against the process pressure and deform the packing so that it fills any large leak paths. Indeed, increasing stress in the packing is the traditional way that stem leakage is reduced. If a valve is leaking, the mechanic tightens the follower. This increases the stress on the packing so that the leak paths are sealed.

low overall costs for valve inspection and maintenance; plants that have a large number of leaking valves will have to perform these costly inspection and maintenance tasks more frequently and may even have to implement a quality improvement program.

The bottom line is: leaking valves won't cause fines; they will increase the frequency and cost of inspection and maintenance.

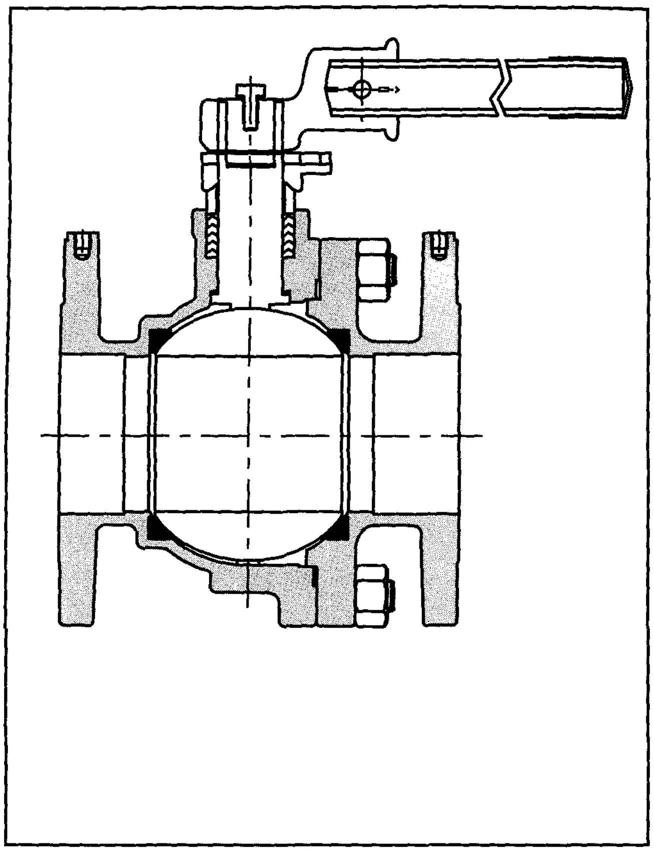
The challenge

The EPA requires that the measure of valve leakage by "sniffing" the area around the valve stem and measuring the concentration of leaking material. Thus, any leakage from the valve's bonnet gaskets or connecting pipe flanges could contribute to the leak measurement. For most purposes, leakage from the stem area will be the highest contributor to the total leakage.

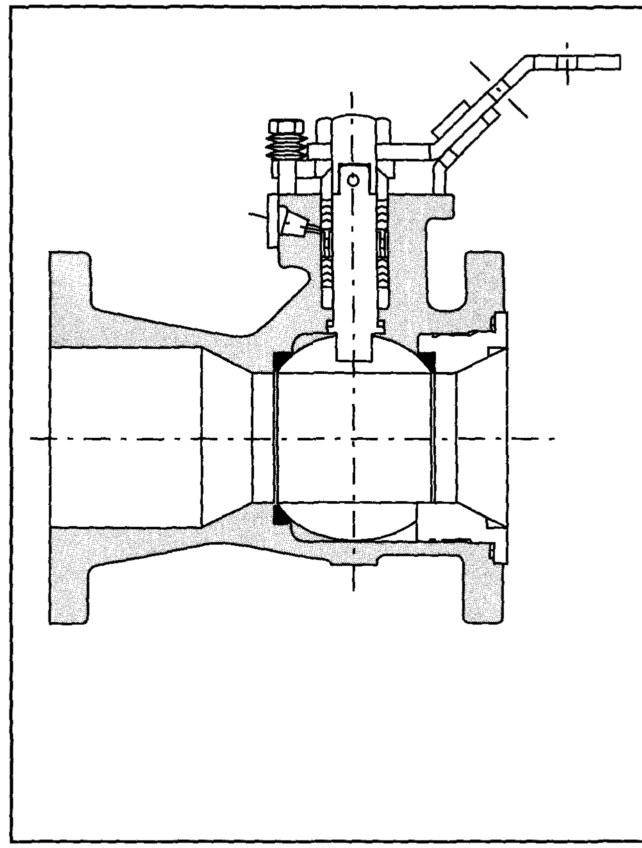
Some types of valves, such as diaphragm and pinch valves and self-contained regulators, inherently do not leak from the stem. Valves with bellows stem seals also have no stem leakage.

For most valves used by the pulp and paper industry, the valve stem is sealed with packing. Therefore, the bulk of this paper focuses on the design and performance of valve stem packing. Any valve packed with a decent commercial packing will have low stem leakage rates when it is new. In virtually all cases, this leak rate should be well below the EPA threshold.

2. Quarter-turn flanged ball valve



3. Fugitive emissions style quarter-turn flanged ball valve



Under the EPA regulations, any valve stem that leaks enough that the follower has to be tightened is considered to be a leaking valve. It doesn't matter that the leak can be fixed immediately. The valve is a leaker and counts toward increasing the required monitoring frequency. Therefore, it is important that the stress in the packing be maintained at the required amount at all times, without tightening the follower.

There are two ways to maintain stress in the packing. One way is to use a packing that is itself an elastomer. The other way is to use an external spring on top of the packing to assure continued stress.

The external spring, or "live load," has become the method of choice for most valves designed for a long, low-leak service life. An external spring can be designed to apply virtually any load the packing requires, and the magnitude of that load can be determined by observing the compression distance of the springs. Belleville washers are often used as the springs for live loading because they take up little space on top of the follower, yet can deliver a high compressive load.

Live loading also compensates for changes in packing volume. This feature is especially important with polytetrafluoroethylene (PTFE) packing. PTFE packing changes volume three ways—consolidation, thermal expansion/contraction, and cold flow.

Consolidation is the contraction of packing volume due to the gradual expulsion of air from between packing rings. It is most prevalent when the packing system consists of a large number of separate components or rings between which air may be trapped.

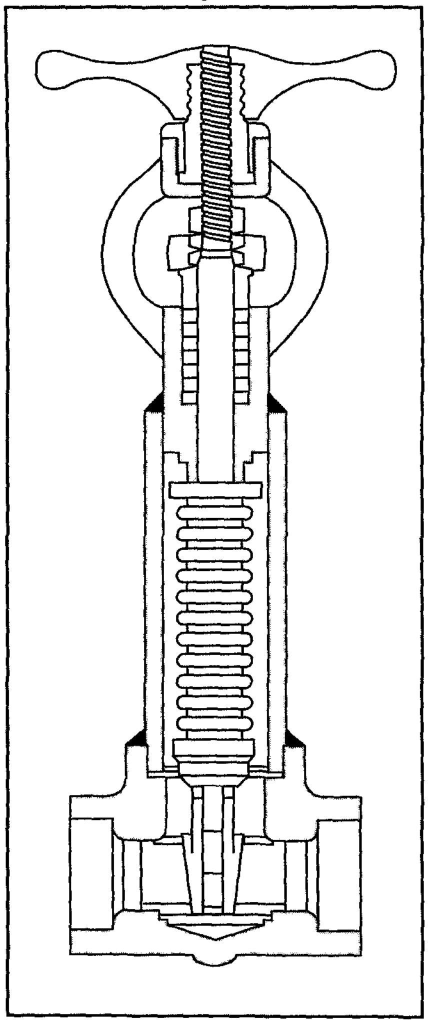
Thermal expansion and contraction is particularly serious with PTFE packing, since PTFE has a very high coefficient of thermal expansion compared to metal. Without a live load, the packing stress would increase dramatically as the temperature changed.

Cold flow—the loss of packing material due to extrusion out of the packing area—can also be a significant characteristic of PTFE packing. Cold flow, if not controlled, will cause a permanent loss of packing volume and a resultant loss of packing stress.

High packing stress is not a high panacea for minimizing stem leakage; however, packing that pushes strongly against the stem may seal against leakage, but it also increases stem friction and makes the valve difficult to operate. For manual valves, high stem friction causes more than the inconvenience of needing a longer lever to operate the valve. High stem friction can damage the packing. As the stem moves against the high shear forces exerted by the packing, the packing can abrade or even shear.

Excess stem friction presents a more serious problem with automatic valves and modulating control valves. Costly, oversize operators may be required to overcome the stem friction, and—even then—jerky or unreliable valve movement may occur.

4. Bellows stem seal gate valve



Stem friction presents its most serious problems with graphite packing. Graphite packing is frequently used for high-temperature applications above 450°F (232°C) and for flammable liquid service when fire safety is an issue. It is rarely required in pulp and paper operations. However, *stem friction must* be considered in the selection and loading of virtually any packing. Even low-friction PTFE packing is not completely free of friction.

High packing stress can also cause the packing to cold flow, or ooze out, of the packing box. Cold flow is especially prevalent in PTFE packing. Cold flow reduces packing volume and requires that the follower be tightened frequently to maintain the required stress. Only a live load can assure that the proper stress will be maintained in spite of loss of packing volume. However, eventually the live-load spring will complete its travel and cease exerting sufficient stress to prevent leakage. Therefore, it is essential that (a) the packing not be stressed so highly as to cause excessive loss and (b) the packing materials and their arrangement in the stuffing box be selected to minimize this loss.

Excess packing

Many people have assumed that if a little packing was good, then a lot was even better. The theory was that a deeper section of packing would create a more torturous leak path. That theory is both incorrect and counterproductive. Excess friction adds friction, not sealing. It also contributes to reduced packing life because friction between the packing and the stem creates a force that opposes the force from the follower. This friction is additive, so a cross section of packing some distance away from the follower will be subjected to very little stress and will not seal against leakage. Thus, only the top part of the packing serves to seal the stem. Excess packing only adds stem friction and increases the potential for radical changes in packing volume due to consolidation and thermal expansion.

Quarter-turn valve designs

Quarter-turn or rotary stem valves have the reputation of being easier to seal than linear stem valves. This is one of the few pieces of conventional wisdom about valve stem packing that is generally correct. Unlike linear stem valves, a rough or contaminated stem on a quarter-turn valve will not gouge a leak path through the packing. In fact, since the portion of a quarter-turn stem which seals against the packing comes in contact only with the packing, neither process fluids nor external dust affects the stem directly. Even if a surface irregularity were to occur on that part of the stem, it would cut a radial, not longitudinal, gouge into the packing that would have little or no effect on the leak rate.

But quarter-turn valves are not a panacea. The stem of a quarter-turn valve rotates between two pivot points, or bearings (**Fig. 2**). The lower bearing is attached to the valve body within the process fluid; the packing serves as the upper bearing. If the lower bearing is not tight, the stem will move radially within the packing area. To prevent leakage, the packing must have enough stress to deform—and accommodate—this stem movement. To minimize this radial movement, the lower bearing should be as tight as feasible. It is also helpful if the stem is large enough to resist bending caused by the lateral forces within the valve body.

Packing arrangements

There are a host of packing materials used today, but two types dominate applications for sealing valve stems. Graphite is used almost exclusively when fire safety is required or high operating temperatures are encountered. For more moderate temperatures—450°F (232°C)—PTFE is the most common packing. PTFE has a low coefficient of friction and provides an excellent seal.

For some fugitive emissions applications, the most effective PTFE packing sets consist of two sections of "U"- or "V"-shaped PTFE rings separated by a lantern ring (**Fig. 3**). Each section contains 3–5 rings with the narrow portion of the ring pointed toward the follower. Axial load imposed by the follower causes radial deformation of the lips of each chevron ring to assist in affecting a seal against the stem.

Although a single set of rings provides sufficient sealing, most users prefer two sets separated by a lantern ring. A sample tap on the lantern ring then provides the opportunity to detect failure of the bottom seal before the leak penetrates the outer seal and enters the environment.

Bellows seals

When the fugitive emission standards were first conceived, many plants in the chemical and petrochemical industry considered converting to valves with bellows sealed stems (**Fig. 4**). Bellows seals don't leak at all; however, two factors—cost and bellows failure—have prevented a wholesale conversion.

Bellows valves still serve a very important role in spite of their high cost, since they are often the only prudent technique for containing deadly materials such as phosgene and cyanide.

Recommendations

The pulp and paper industry has long needed valves that (a) have extremely low stem leakage when they are new and (b) need little or no maintenance to retain that low leakage over their service life. The EPA fugitive emission regulations provide additional impetus for the pulp and paper industry to buy such valves and for the valve and packing industry to produce such valves.

Even if particular operations are not covered by the fugitive emissions regulations, it is—and always has been—in a mill's best interest to have valves whose stems don't leak and need little or no maintenance to prevent that leakage.

Here are some recommendations on how to meet that objective:

- *Select the right packing material.* PTFE will often be the right material for most pulp and paper applications. Use as little as possible, and make sure it is well contained within the packing box.
- *Apply the right amount of stress to the packing.* Usually, this means using external live load springs. Make sure the load is at the right level when the packing is installed, and check the spring compression each time the valve is monitored for leakage. A loss of packing volume will often show up as a change in spring compression before the valve begins to leak.
- *Install the packing correctly.* Make sure the valve stem is smooth, round, and well centered; keep the packing box free of dirt and other abrasives. Install the live load springs correctly and compress them the right amount.
- *Use rotary valves where practical.* Generally, the packing in a rotary valve will have a longer service life than the packing in a rising stem valve. Make sure that the valve is designed so the stem does not bend or move radially within the packing box.

Following these guidelines will extend valve packing life, minimize valve maintenance costs, and reduce the mess made by leaking valves. It will also help control the costs of compliance with fugitive emission regulations. TJ

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