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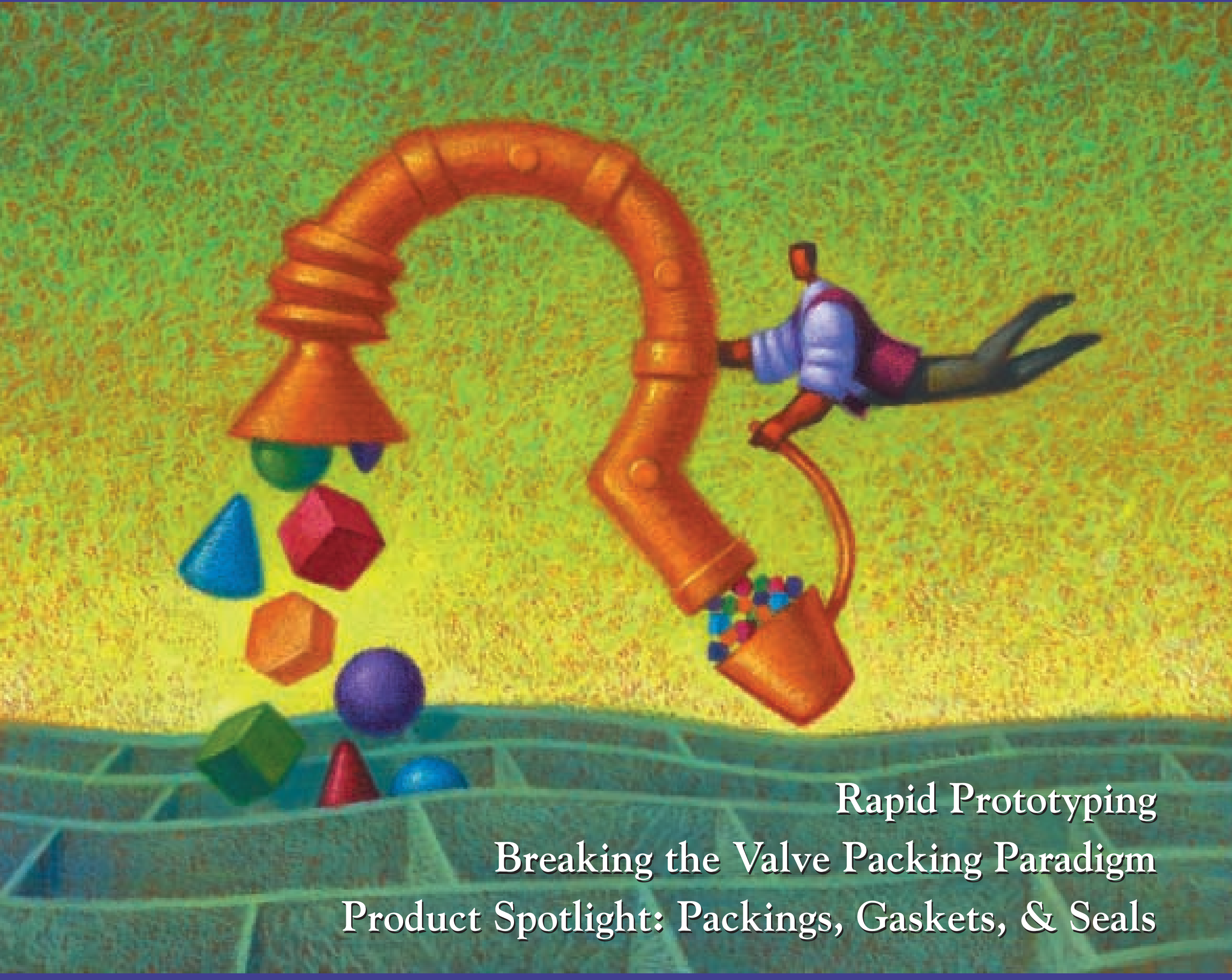

Rapid Prototyping

Breaking the Valve Packing Paradigm

Product Spotlight: Packings, Gaskets, & Seals

The Challenge of Multi-Channel Distribution

breaking THE VALVE PACKING PARADIGM

by Meredith Miller, Floyd Jury, & Stan Koloboff

"Rules of Thumb" have been with us for centuries, even millennia, probably ever since the first cave man looked at a tomato and decided not to eat it because he thought it was poisonous. We love Rules of Thumb because they simplify our lives. When faced with a familiar situation, we don't have to think in order to make a decision; we simply apply the appropriate "Rule of Thumb."

Most "Rules of Thumb" have been designed to keep people safe from bad decisions. For example, no one has ever been poisoned by not eating a tomato. On the other hand, by not thinking about the implications of our decision each time we apply a "Rule of Thumb," we miss out on all the costs associated with that decision. Often, we are not even aware of those costs because they are costs of lost opportunity, or they are simply costs that are hidden by the veil of time. Often we are not even consciously

THE PACKING PARADIGM

You are probably wondering what all this has to do with you and control valves. For many years now, there has been a rule of thumb, or paradigm, about valve packing that has prevailed within the processing industry. In essence, this paradigm maintains that one type of packing design is essentially as good as another and that the only important function of packing is to prevent leaks. The paradigm further states that you will be okay if you pick an inexpensive packing that is easy to install and if you use PTFE materials up to application temperatures of 450°F and graphite materials for higher temperatures.

This old packing paradigm has gained great popularity over the years because it is easy *(no thinking is required)* and it usually results in what appears to be a safe solution. Unfortunately, and often unbeknownst to the user, this out-of-date paradigm has tremendous costs associated with it. These costs are both time-veiled costs and costs of lost opportunity.

Typical valve packing *(i.e., those selected by the old packing paradigm)* whether it has been supplied by the manufacturer or purchased by the user as replacement packing, will appear to do its job for some period of time *(i.e., it will give several months of leak free service.)* When it does start to leak, a maintenance person can easily get it to stop by simply tightening the packing compression further. Of course, we know that this tightening will increase the stem friction, but the old packing paradigm takes care of this too. It says that as long as the valve will still stroke, it's okay. Usually after one or two years, the user will discover that continued tightening of the packing will no longer keep the valve from leaking. At this juncture, the entire packing will have to be replaced, which likely means that the valve will be pulled from the line.

Of course, all this packing inspection, adjustment, and eventual replacement costs money. This is really part of the time-veiled cost of the decision to use that style of packing. If we only had an opportunity to purchase a different type of packing arrangement that could operate leak-free, without adjustment or inspection, for approximately three to ten times longer than traditional packing. This might be worth consideration, even if it did cost more initially. Just think of the savings over the life of the packing. Even as significant as these savings can be, we will shortly learn that there are also costs of lost opportunity which often dwarf these obvious time-veiled costs. Unfortunately, the power of the old packing paradigm prevents us from even considering these possibilities.

VALVE PACKING PRINCIPLES

In the early 1990s, a manufacturer developed a new packing design, that was designed to meet the U.S. government's strict emission standards for volatile organic compounds (VOC). The new design was capable of meeting and maintaining emission requirements of 500 parts per million volume (ppmv) or better with no adjustments needed for several years. Although the design incorporates specially designed packing shapes and materials, its main feature is a spring-loaded packing arrangement that maintains constant packing compression without continual adjustment.

The extensive research program that the manufacturer underwent during the development program resulted in several revelations that led the manufacturer to an entirely new way of thinking about packing and eventually to a new packing paradigm. They learned that there are four major packing design principles that are required to ensure a long, low-maintenance service life that will meet stringent low emission requirements. These principles are:

Principle 1: The design must keep the valve stem properly aligned using stem bushings installed near the packing. Sealing a valve stem that does not remain concentric to the valve bore requires the packing to change its shape continually. This places unreasonable demands on a packing system. A packing system of "graded pliability" components can help keep the stem aligned. The most pliable material, the packing itself, must be retained by a less pliable anti-extrusion ring, which in turn must be retained by a very hard bushing. This bushing serves to keep the stem aligned and prevents extrusion of the inner components of the packing system. In this system, the packing follower has been redesigned to serve as a PTFE–lined bushing. This absorbs any side loads created by the actuator and keeps the stem centered.

Principle 2: The design must minimize the adverse effects of thermal cycling by using only the minimal amount of packing required to effect a seal. If loss of packing material is a major cause of valve leaks, one would be tempted to believe that extra packing material should be used. However, the manufacturer's research demonstrated that the location of maximum radial packing deformation, and thus the position of the seal between the packing and the stem, occurs over a very limited area. The length of this sealing area does not increase with packing height, so using additional pliable material adds nothing to the sealing ability of the packing. In fact, additional packing can actually detract from both the sealing ability and service life of the packing in several different ways.

First, additional packing material increases the packing-to-stem contact area, thereby increasing stem friction. This additional friction often can increase the required actuator size, add to the erosion loss of packing material, and worst of all, dramatically decrease the control performance of the process.

Second, excessive packing can cause loss of packing volume since it eliminates voids in and between packing rings. This has the same effect on the packing's sealing ability as the loss of packing material itself.

Third, packing loss caused by thermal cycling will increase because of the added material trying to expand out of the packing area.

Principle 3: To prevent the packing from extruding out of the packing area, the design must include less pliable anti-extrusion rings on either side of the packing. Packing must deform in order to seal the space between the stem and the packing bore. The deformation occurs by pushing against the packing with a follower ring. This axial load stresses the packing and causes it to bulge radially. Unless special measures are taken to contain it, the packing material will gradually be lost from the packing system due to erosion from the stem or to extrusion past the follower ring.

Principle 4: The packing design must apply a constant and proper packing stress with live-load springs. The proper stress depends on the type of valve and the type of packing system. With ordinary packing used in the past, one can tighten the packing just enough to prevent leakage and keep the friction within reasonable bounds. Unfortunately, after a few days of valve cycling, the packing will wear and begin to leak, almost immediately. Therefore, it has become common

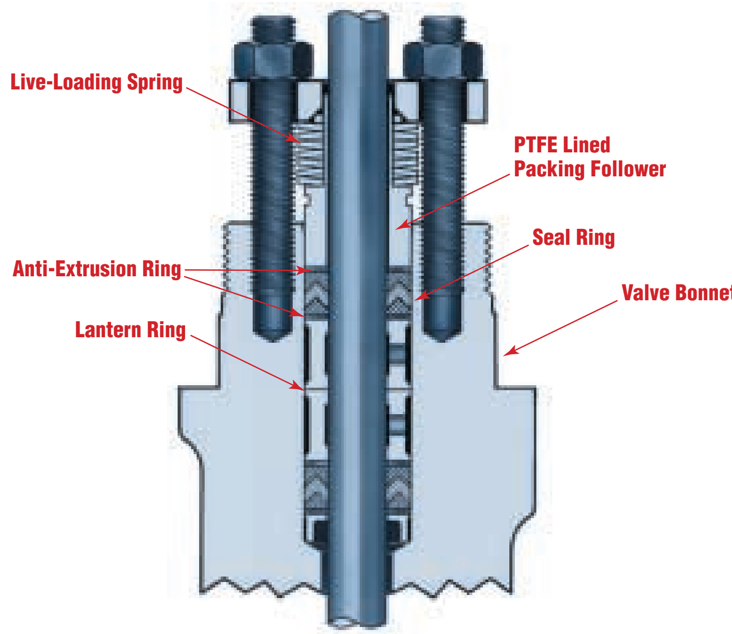

Figure 1: PTFE-based packing system features anti-extrusion rings above and below the packing ring set.

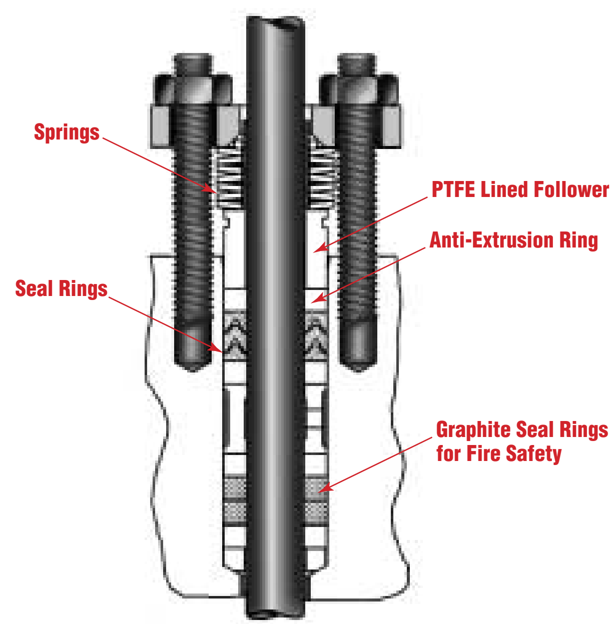

Figure 2: Duplex packing system utilizes both PTFE and graphite rings to provide emission control and fire safe operation.

practice to provide an excess amount of packing stress in order to extend the sealing life before an adjustment is needed. This not only increases friction unnecessarily, but it also shortens the eventual life of the packing. Spring loading of the packing allows the packing stress to be adjusted the right amount to prevent leakage and then to be retained at a constant level.

Some controversy has surrounded the use of live-loaded packing in the past, but research has shown that the problems which gave rise to this controversy occurred due to violation of one or more of the four basic principles.

For example, in the absence of anti-extrusion rings *(violation of Principle 3)*, packing that is constantly stressed will continuously lose material by extrusion. As the packing volume decreases, the spring expands, which reduces the stress on the packing and loses the integrity of the seal.

The live load will not contribute to a rapid extrusion loss of packing material and shorten the packing service life if it is used in conjunction with the correct anti-extrusion system (assuming that the load applied is correct for the packing system being used.) It has also been found that live loading can cause stem alignment problems unless the packing set contains stem-alignment bushings near the packing ***(Principle 1)***.

Figures 1 and 2 illustrate how the manufacturer's packing design successfully incorporates all four of these essential packing design principles. Figure 1 illustrates both PTFE and graphite options for linear, sliding-stem valves. Figure 2 illustrates a similar packing design design for rotary valves.

VALVE PACKING PERFORMANCE

The traditional valve selection process entailed selecting a valve design based on pressure and temperature capabilities, flow characteristics, and material compatibility. Packing selection was seldom given a second thought since we had a simple packing paradigm to take care of that issue. According to this antiquated paradigm, packing selection was primarily based on process temperature [i.e., PTFE was selected for temperatures below 450°F (232°C) and graphite was selected for temperatures above 450°F.] That's all there was to it.

However, as a result of the manufacturer's extensive packing research program, it became clear that new thinking was needed and that the old packing paradigm had to go. It became obvious that an additional factor—engineering of the packing selection—must be involved

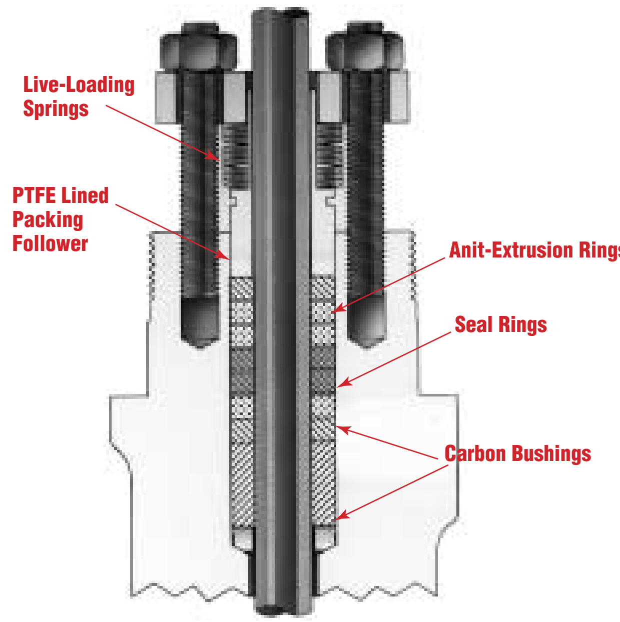

Figure 3: In contrast to PTFE-based system (Figure2) the graphite emission-control packing system combines anti-extrusion rings, packing rings, and carbon guide bushings.

in the valve selection process.

The manufacturer's research showed that the valve packing selection process is influenced by so many factors that the selection process becomes quite difficult to quantify. Given the variety of process applications and installation conditions that affect the packing selection process, it was clear that an engineered approach to packing selection was required. Fisher research identified four important factors to consider in engineering the packing system.

Sealing Performance: Of course, the ability of the packing system to prevent leaks around the valve stem is a primary consideration. In recent years, the Clean Air Act Amendments, subsequent EPA (Environmental Protection Agency) regulations, and society's concern for the environment have driven this issue.

For low temperature and moderate pressure applications, conventional PTFE V-ring packing can meet the EPA low emission criteria with a reasonable seal life and low friction. On the other hand, for higher temperatures and pressures, braided graphite filament packing often has been selected. Over time, the braided graphite filament will break down and compress, and sealing force will be lost. Due to these characteristics, braided graphite filament will not provide the required seal performance for environmental services. The braided graphite filament arrangement is susceptible also to

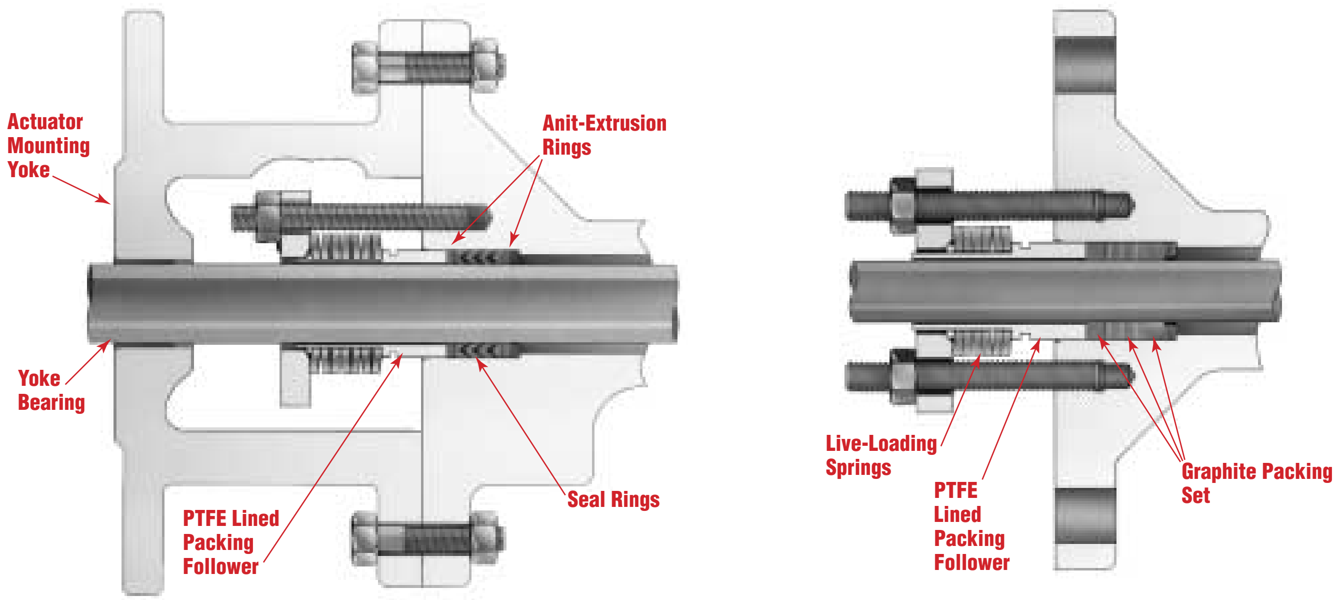

Figure 4: PTFE (left) and Graphite (right) packing systems for rotary valves.

stick-slip action, which can cause process control deviations. The deviation from setpoint results in poor control capability and lots of lost opportunity costs due to out-of-spec product, waste, or reduced production capacity, not to mention the losses due to premature seal failure.

Seal Life: The old packing paradigm tacitly assumed that if the selected packing began to leak a little bit, it was not big deal—a little leakage wasn't going to hurt anything. Besides, it was a simple matter to have a maintenance technician tighten the packing a little bit and restore the sealing capability. If that didn't work, the packing could be replaced, often at the expense of having to pull the valve from the line.

In light of the strict EPA regulations, however, this was no longer an acceptable procedure. Huge fines could result (time-veiled costs). In addition, the growing maintenance costs (more time-veiled costs) associated with continuous monitoring of the valve packing and increased down-time for packing repair and replacement was causing increasing concern among plant operators.

The manufacturer's research program produced several advanced packing design options that not only could meet the stringent environmental leakage requirements of 500 ppmv, but could do so for three to ten times longer than conventional packing. Furthermore, due to the live load design of these packing arrangements, the need for packing adjustment could be eliminated.

Packing Friction: Under the old packing paradigm, one of the undesirable side effects of trying to achieve a tight packing seal for extended periods of time was a considerable increase in packing friction. This packing friction causes a stick-slip action of the valve, which is a major killer of valve performance. When a process error occurs and the control system tries to correct, it sends a signal to the valve for a change in valve position. But, if the valve stem refuses to move due to friction, the process error must build up unnecessarily higher than normal to get the corrective action needed. This means that there will be a wide error band about the process set point where the process control loop will be unable to achieve control. Field audits conducted by the manufacturer during their extensive research program showed that these process errors could often be as high as 2-5%, resulting in thousands or even millions of dollars annually in lost-opportunity costs of lowered production capacity, off-spec product waste or reprocessing costs, etc.

By utilizing the four packing principles identified earlier, the manufacturer was able to develop advanced packing designs, such as the one in this article, which could not only achieve the sealing capability required, but with much improved seal life. In addition, the live-load feature of these advanced packing designs helps to maintain the friction at a relatively constant value, thus improving control performance.

Fire Safety Requirements: Meeting fire safety requirements typically means the use of graphite packing, even below 450°F. This of course, means increased packing friction and perhaps even increased costs associated with larger actuators being required. Fortunately, the manufacturer's packing research program showed the way to combine the best characteristics of PTFE and graphite to produce fire-safe packing designs with considerably lower friction than the conventional graphite packing systems ***(Figure 2)***.

THE NEW PACKING PARADIGM

Clearly, a new packing paradigm is needed. Unfortunately, the new paradigm is not as simple and clear cut as the old one because there are more factors to consider. Packing can no longer just be selected as an afterthought when buying a valve. The packing system itself must be considered as a highly-engineered component, just like the other parts of the valve assembly.

It is also clear that there is no single "right answer" when it comes to valve packing. Packing performance is influenced not only by valve geometry *(i.e., plug valve, globe valve, ball valve, etc.)*, but also by valve design features, such as valve stem diameter as well as packing box diameter and depth. Packing materials not only need to be selected for their physical composition, but for their geometric shape as well.

Minimizing valve friction and maintaining it at a constant value is an extremely important consideration in maximizing the dynamic control performance of the valve assembly. To maximize overall performance, the entire packing system must comply not only with the four packing principles, it also must be designed as an integral part of the specific valve style in which it is to be used. For example, ***Figure 4*** shows the packing design for rotary valves, which differs from that used in globe valves.

SUMMARY

No longer should purchase price and ease of installation be major factors in the selection of a packing system. The initial cost of the packing can pale into insignificance compared to the time-veiled costs of continually adjusting and replacing the packing, or even the potentially more significant lost opportunity costs. VM

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