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In search of zero-flush seals

Uncontrolled flow represents a preventable waste

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Packing on rotating equipment sometimes uses large quantities of water, often at uncontrolled flow rates. Reducing the water flow can degrade equipment reliability. High flow rates mask inadequacies in the packing. Packing material and construction becomes critical when flush flow rates are reduced or eliminated. Quick break-in and long-term leakage control are two attributes packing requires if it is to function under reduced or zero flush rates. The fiber and construction of new braided packing allows for reduced water consumption. On another front, injectable packing offers zero water consumption.

Driving forces on water conservation

Reduction in water use is an issue for plants around the world. Water use in rotating equipment is often high but can be reduced dramatically. Plants that reduce leakage from rotating equipment realize reductions in the amount of effluent treatment required. This can be a significant factor in achieving compliance with Environmental Protection Agency regs. In some cases, flow rate reduction assists in averting capital improvements in wastewater treatment facilities.

Economic concerns concerning water also drive water conservation. The cost of water ranges widely depending on access, region, and accounting practices. The cost of typical filtered and treated water used for sealing devices can exceed $0.10 per 1,000 gallons. In pulp mills that use black liquor as fuel, one gallon per minute of water dilution can cost more than $5,000 per year in evaporation expense. An area often overlooked is the cost of reheating when diluting a process at an elevated temperature. The cost of reheating flush water can easily reach $400 per year for each gpm of flush water injected into a process.

To operate flush free over time, the packing must exhibit excellent leakage control. One of the most common packing failure modes is delaying gland adjustment once the packing begins to leak.

Combining packing material and construction with a focus on water reduction produces flush water savings. Proper packing selection is critical to ensure both minimized water use and no decrease in equipment reliability.

Flush water use on packing

Little attention has been paid to the amount of flush water used on some equipment and water has been used at relatively high flow rates. The concern is that flush water reduction is detrimental to equipment reliability. High flush flow rates hide a multitude of deficiencies in the packing, its installation, break-in, leakage control, and other aspects. Conversely, reducing flush flow rates can lead to increased shaft sleeve wear, short packing life from thermal degradation, abrasion, and increased effluent leakage. One must take into account the break-in period and leakage control before selecting the correct packing for reduced flush or flush-free service.

In reducing the water flow to packings, quite often there is interest in how much water is being consumed and the associated cost. The common piping arrangements for flushing packing are the *flow through* method and the *conventional* method. While the flow through method is increasing in popularity, the conventional method, with one line connected to the lantern ring, is also still very popular. It is worthwhile to analyze the flush flow rates and leakage rates on both of these arrangements.

Flush through packing arrangement

This arrangement uses a flush line to a lantern ring port on the stuffing box and allows water to exit from a port on the opposite side. This arrangement is also called *in-line flush*. Its primary advantage is that it typically does not dilute the product. The flush pressure in the lantern ring connection is very close to atmospheric pressure. Therefore, flush water does not enter the process.

The disadvantage of this arrangement is that product leakage rates are often indistinguishable from the normal flow from the lantern ring outlet. Valuable process fluid can easily be sent to drain as the flush dilutes and masks the process leakage. Ultimately, the bottom rings below the lantern ring become sacrificial because flush water does not lubricate them and leakage through them is not easily detectable.

Also, the load on the packing gland can be too low for adequate sealing at the bottom rings. Typically, the packing gland is adjusted on the basis of the flush water leakage from the top ring—the packing ring closest to the gland. Pressure in the lantern ring is low since it is open to drain in this arrangement. This results in a low pressure drop across the top packing rings—those rings between the lantern ring and gland. The gland load required to seal this low-pressure flush is now very light. The low gland load does not provide adequate pressure on the bottom rings of the packing set, resulting in high process leakage to drain and poor packing life.

Conventional packing flush arrangement

The most common flush arrangement is to connect a flush line directly to the lantern ring connection on a stuffing box. The pressure of the flush water is set at a pressure exceeding that at the lantern ring and bottom of the stuffing box. This ensures flow of a relatively clean, cool fluid to the packing above, and below, the lantern ring.

The advantage of this flush arrangement is that it decreases the amount of process fluid and abrasives entering the packing set. It also decreases leakage and associated cost of lost process fluid. Its primary disadvantage is that it injects water into the process. This dilution affects quality. It also has a cooling effect on an elevated temperature process, the cost of which can be significant.

In a conventional flush arrangement, the flush flow separates into two components—flow toward the packing gland becomes leakage, flow away form it enters the process fluid at the bottom of the stuffing box. It is not easy to determine the amount of flush water entering the process. It is a function of factors such as packing construction and condition, gland adjustment, sleeve wear, stuffing box construction, and flush pressures.

Packing performance testing

Break-in and long term leakage control are vital to the success of a zero or low-flush packing. We developed performance tests to evaluate both parameters in which we tested packings to determine performance characteristics. Holding shaft diameter, speed, stuffing box pressure, and installation procedures constant eliminated these as variables.

We held break-in leakage to between 5 and 15 milliliters per minute. Gland bolt adjustment was limited to 60 angular degrees at a time. A data acquisition system recorded packing gland temperature, packing leakage, and motor current. The test data clearly illustrates desirable and undesirable break-in and long term leakage control behavior in packing.

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or glaze, and the loss of break-in lubricants, blocking agents, and fillers may cause unrecoverable damage.

Flush water cools and lubricates the packing set. A flush hides most break-in problems. A poor break-in only increases flush water use and fluid leakage. Re-tightening a flushed packing set reduces excessive leakage with no permanent packing damage caused by abrasives. Eliminating the flush makes a fast break-in period desirable. Slow packing break-in is characterized by:

- varying power consumption,
- temperature fluctuations, and
- high leakage rates during the initial hours after start up.

Figure 1 illustrates undesirable break-in behavior. Seven 30-degree gland adjustments were made to control leakage. Sharp spikes in power consumption, followed by an increase in gland temperature, can be seen clearly. Packing leakage dropped initially, but soon increased. Packing leakage rates of 50 milliliters per minute are excessive and the sensitivity of the packing made adjustments difficult. Very small gland adjustments initiated large increases in power consumption and temperature—a big problem with packings that are susceptible to thermal damage.

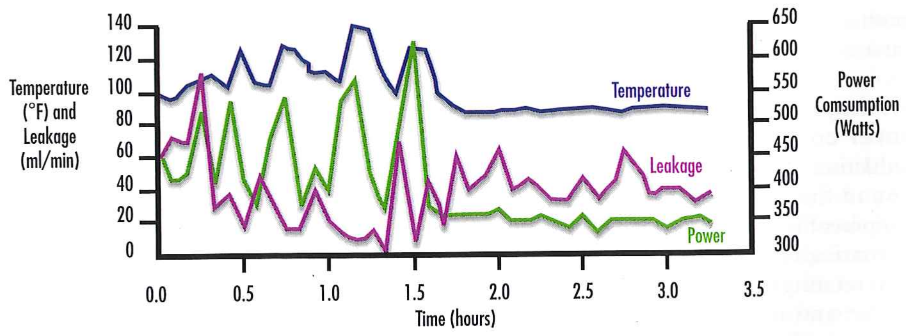

Figure 1: Slow break-in characteristics (7 adjustments)

Critical break-in period

Breaking in the packing is critical if flush water is to no longer be used. Excessive leakage of abrasive fluids embeds solids in the packing. Upon subsequent tightening, the particles create excessive wear on the shaft sleeve resulting in premature failure. Allowing too little leakage during the break-in period can overheat the packing. When this happens, some yarns such as polytetrafluoroethylene breakdown

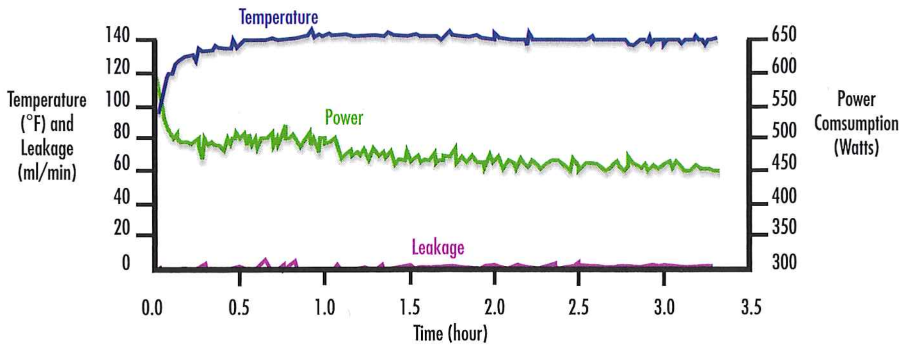

Figure 2: Quick break-in characteristics (no adjustments)

Clearly, stable power consumption, low heat buildup, little leakage, and few packing adjustments are the hallmarks of a quick break-in. Leakage was below 5 milliliters per minute during the break-in. No adjustments were necessary to control leakage. Power consumption and temperature reached steady state within minutes. This performance allows the user to establish sealing quickly. There is minimal thermal and abrasive damage during the critical break-in period. However, once broken-in, long-term leakage control takes over as the critical performance parameter.

Long term leakage control

To operate flush free over time, the packing must exhibit excellent leakage control. Lower leakage rates lead to higher packing temperatures that damage packings. Therefore, the packing must have high thermal conductivity, low coefficient of friction, and be constructed of high-temperature yarns and lubricants. Without these, loss of packing volume, consolidation, and thermal damage result in high leakage rates as one attempts to reduce leakage.

If leakage increases with time quickly, process fluid particles move between the packing and shaft and cause premature failure. One of the most common packing failure modes is delaying gland adjustment once the packing begins to leak. Even when using a flush, long-term leakage control can be dicey if the supply of flushing fluid carries solids and abrasives.

Testing of a PTFE packing with graphite dispersion clearly demonstrates unstable leakage. After a three-hour break-in period and a number of adjustments, leakage dropped below 5 milliliters per minute. While power consumption and temperature were at their maximum during this period, leakage remained low. Packing leakage increased during the next eighteen hours, however, to more than 30 milliliters per minute. After adjustment, leakage dropped and power consumption and temperature increased. Again, the leakage began to increase. This cycle was repeated three times. Clearly, this packing cannot operate at low leakage rates for extended periods.

Figure 3 shows a different result. No gland adjustments were necessary during this test. Power consumption and temperature remained stable after break-in. Long-term leakage control for this packing was excellent. This testing on break-in and leakage control led to field testing of three types of packings.

Zero- and reduced-flush packing

Three packing alternatives reduce or eliminate water consumption. Each demonstrated excellent test results with quick break-in and long term leakage control. The three types are heat-resistant, thermoset fiber packing; a twisted, pure graphite tape with carbon reinforcement yarn; and an injectable packing compound.

Heat-resistant, thermoset fiber packing

Heat-resistant braided thermoset fibers are viable for use in low leakage applications. These fibers offer temperature-resistance at reduced flush flow and low leakage because the base yarn is resistant to thermal breakdown and glazing. These materials are white or off-white in color to addresses concerns with coloration of the process fluid, a issue sometimes raised when investigating carbon or graphite packings.

During the first few hours, the packing ran with zero leakage. Later, it leaked less than 5 milliliters per minute. The test required no gland adjustments. Break-in adjustments were not required because the temperature-resistance of the yarn eliminated the high initial leakage necessary with PTFE-based packings. Long term leakage was low and stable over the length of the test.

In one application, this packing reduced water use by 90 percent—a reduction not possible with PTFE-based packings. At slower speeds—under 1,200 feet per minute—heat-resistant, thermoset fiber

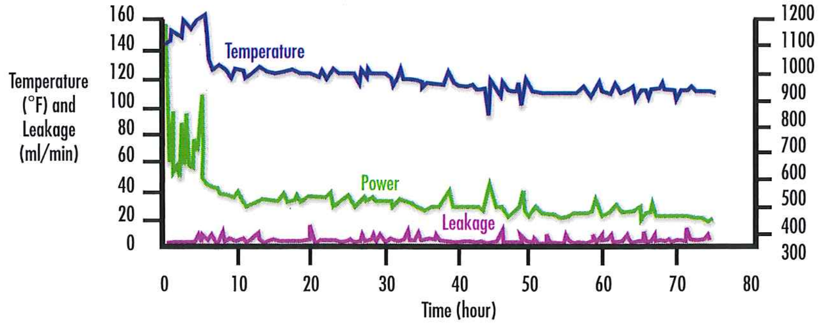

Figure 3: Controlled leakage

packing eliminates the use of flush water entirely. This is tough, general-purpose white packing that provides quick break-in times, excellent leakage control, and resistance to high temperatures.

Braided graphite packing with carbon reinforcement

Graphite is often perceived as an ideal material for flush-free service. It generates little heat, has high-temperature capability, and has high thermal conductivity. Braided graphite yarn, however, is costly and does not have the strength required for abrasive effluent applications.

Braided graphite tape packing has shown great success. Under compression, the graphite in the stuffing box forms a homogeneous mass. In effect, the entire packing set becomes die-formed in the stuffing box. Typical braided packings contain voids that must be filled with blocking agents, such as PTFE, to prevent wicking and provide good leakage control. Used in large amounts, these lubricants and blocking agents contribute to packing volume loss, relaxation, and increased leakage.

The excellent conformability of graphite lets it seal well on worn sleeves. This is an advantage over carbon fiber packing that requires sleeves to be in very good condition. The disadvantage of conventional graphite tape packing, however, is that it may extrude through the clearances around a worn stuffing box, shaft, and packing gland. For this reason, graphite tape packing is often used with braided carbon end rings to prevent extrusion, thereby putting two types of packing in one stuffing box. Industry feedback indicated a desire for one type of packing per stuffing box.

Braiding the carbon yarn into the foil provides the reinforcement that minimizes the extrusion problems associated with graphite tape packings while not affecting sealing performance. The reinforcing fiber also makes packing removal much easier. Now, one type of packing can serve different flush-free applications. Figure 4 shows a five-ring set comprised of graphite tape with carbon reinforcement installed on a properly sized bushing. The flush port is plugged.

Break-in time is extremely short with few adjustments required. Thermal degradation is not a concern. Short-term volume loss is negligible since large amounts of break-in lubricants are not required. Long-term leakage control is excellent since the packing forms a homogeneous mass with little chance for wicking.

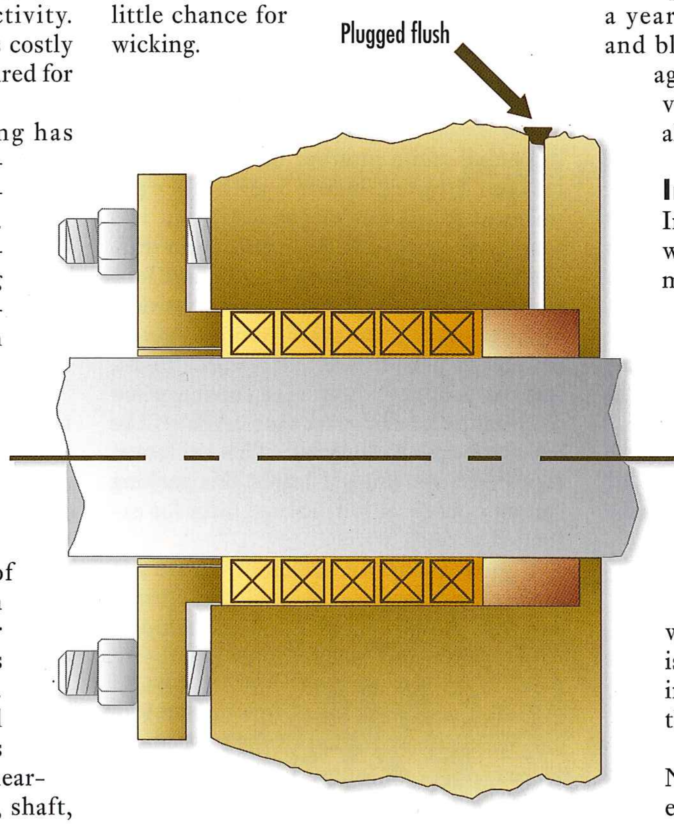

Figure 4: Five-ring set of reinforced graphite tape packing.

Nine large rotating shafts were converted from carbon yarn packing to the graphite tape packing. Previous total leakage for the nine shafts was 12 million gallons per year. Total flush flow and dilution rates were not measured. After being repacked with the graphite tape packing, these shafts not only use no flush and have no dilution, but total leakage rate for all nine is well below one-half million gallons per year.

The conversion of four agitators with more than 9,000,000 gallons of leakage per year and twelve stock pumps using more than 19,000,000 gallons per year were similar. Large leakage rates were so common in this plant that it was necessary to apply tags reading "Waterless Packing" to the gland studs to prevent mechanics and operators from loosening the packing gland to achieve "normal" leakage.

In a paper mill, more than 30 centrifugal stock pumps have been flush free for over a year. Vacuum pumps; white, green, and black liquor pumps; hydropulpers; agitators; soot blowers; and steaming vessels have been sealed successfully, also flush-free.

Injectable packing

Injectable packing material based on white, heat-resistant thermosetting materials can be used with no flush. A piston pump forces the packing material through the flush port into the stuffing box where it is contained by two braided end rings. A portion of the compound rotates with the shaft—the material itself does the sealing. Being an amorphous mass with no definable shape, injectable packings are extremely conformable materials that work well on worn sleeves. Repacking is not necessary—if a leak develops, injecting more material reestablishes the seal.

Leakage control is excellent. No flush is needed because heat generation is extremely low. Break-in is immediate. Installation requires both the stuffing box and gland to be in good condition and the end rings to be properly installed.

No follow-up injections were necessary during the test. The uniform loading of the injected packing quickly established steady-state temperature conditions. Long-term leakage control was easy and no gland adjustments were necessary during the test.