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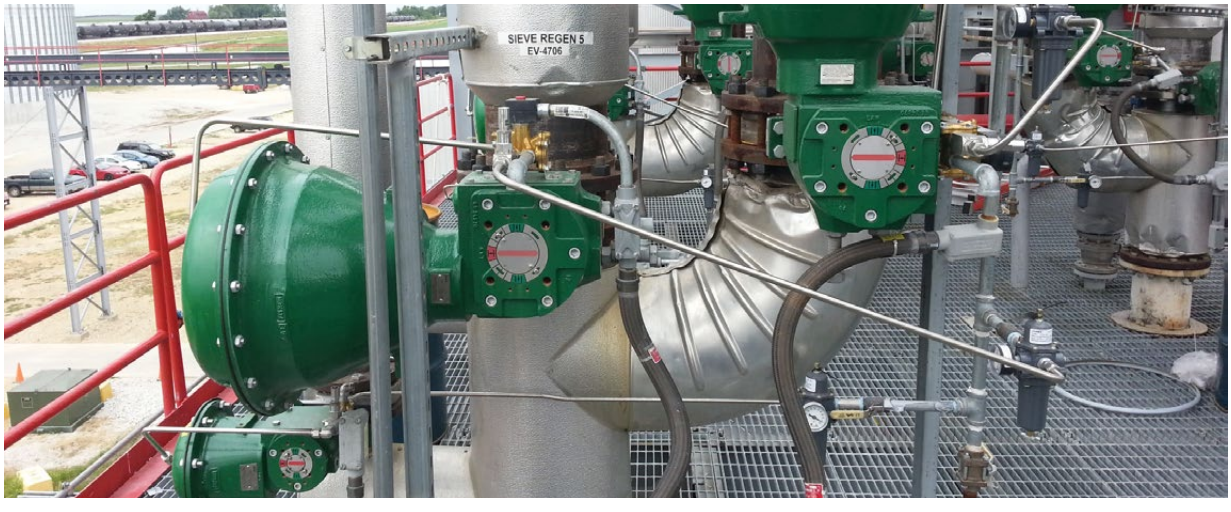
Select the Right Valves for Adsorption Processes

High cycling necessitates extra attention to tight shutoff and robust design

By Keith Nehring, Emerson Automation Solutions

Many plants rely on adsorption to remove or separate specific components of a liquid or gaseous mixture. This mass transfer process typically involves multiple valves (Figure 1). Stroking frequency of those valves can exceed 60,000 cycles per year and maintaining industrial gas purity and efficiency requires tight shutoff to Class VI.

Many problems occur from using the wrong valves. Poorly performing valves can lead to increased maintenance, unit trips and decreased efficiency. For example, when



ADSORPTION PROCESS
Figure 1. Reliable operation requires multiple specialty valves designed for high cycles.

surveying ethanol producers from around the world, some of the most commonly reported maintenance problems related to adsorption include:

- poor control and reduced cycle life due to oversized butterfly valves;
- accelerated bearing wear, often seen after only a few months;
- multiple mechanical failures because of inferior valve-actuator-positioner linkages; and
- inadequate performance from low-quality valve positioners in both the adsorption and regeneration cycles.

Improper selection of control valve assemblies for adsorption processes can cause unscheduled downtime. During this downtime, a typical 50-million-gal/yr ethanol facility can suffer more than $10,000/hr in lost revenue.

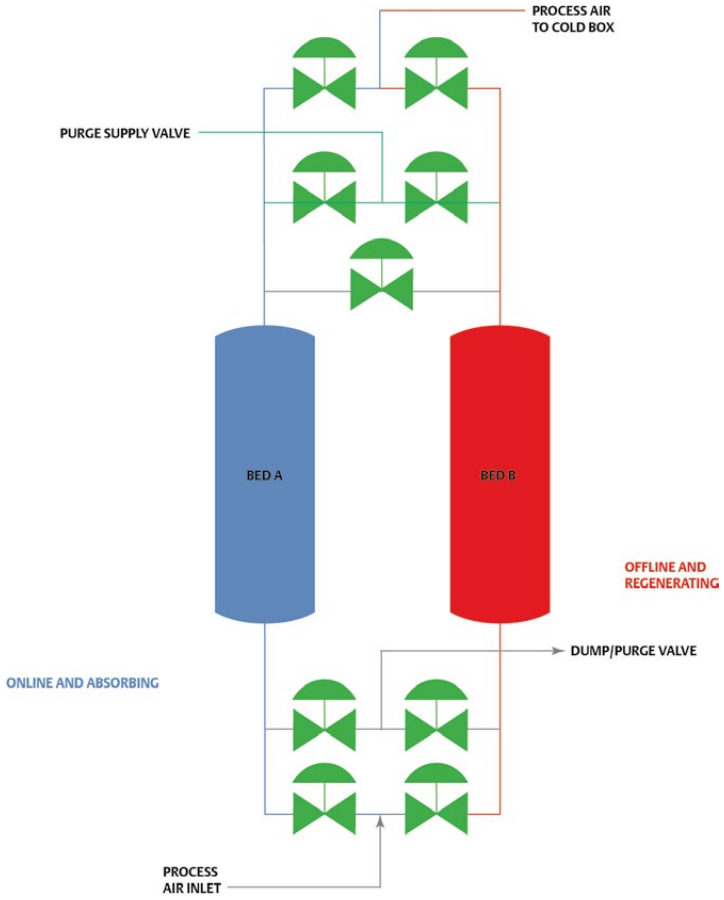
So, we'll look at how to select the proper valves. But, first, let's begin with some adsorption basics.

HOW ADSORPTION WORKS

Adsorption is the adhesion of atoms, ions or molecules to a solid surface. This binding primarily takes place on the walls of a porous material. The component held within the pores then is purged from the adsorbent bed.

There are three common types of adsorption regeneration processes: pressure swing adsorption (PSA), temperature swing adsorption (TSA) and vacuum pressure swing adsorption (VPSA).

Figure 2 shows a simple PSA scheme for air separation; it uses two beds of molecular sieves, with one adsorbing and the other regenerating at any given time. An air



AIR SEPARATION

Figure 2. Simple pressure-swing adsorption process switches between two beds — with one online while the other is regenerating.

separation process primarily aims to separate oxygen or nitrogen. During the production step, air goes into a cylinder containing beads of adsorbent material at pressure. During the regeneration step, a small amount of nitrogen or oxygen flushes the waste gas through an exhaust port, preparing the vessel for another production cycle.

A common use of the TSA process is for moisture removal. Wet gas is pumped into a cylinder filled with adsorbent beads at pressure. After adsorption of the moisture, dry gas leaves the vessel. Once the beads are loaded with moisture, the bed is taken offline for regeneration. Here, heated purge gas raises the temperature of the loaded bed, driving off the adsorbed moisture. Before returning online, the desorbed bed must cool down so that it can adsorb again in the next cycle.

VALVE ROLES

Now, let's look at the various valves required in an adsorption process.

Switching valve. It cycles the beds between online and offline. This valve is very important because, if incorrectly controlled, it can fluidize or fluff the adsorption beds, causing damage to the adsorbent materials and the bed itself. Such fluffing can be a very expensive problem and must be prevented.

Cycle times depend on the regeneration method. In the TSA process, the cycle time is around eight hours. In contrast, the PSA and VPSA switching processes take one to three minutes. The marked difference reflects how much faster pressure changes can take place than temperature ones.

Dump/purge valve. This removes impurities from the process. Because the impurities leave as off-gas, this often is called the off-gas process.

Feed gas valve. It introduces feed gas (air, hydrogen, biogas, etc.) into the clean adsorbent bed. It opens simultaneously with the product valve to ensure the feed gas passes through the bed, allowing the bed to adsorb impurities to make the finished product.

Purge supply valve. This enables purge gas to enter the beds by connecting bed A to bed B. Gas then flows from the higher pressurized bed into the lower pressurized one. Keeping pressure in the lower pressurized bed as low as possible minimizes the impurity partial pressure and maximizes adsorbent regeneration. This valve also can perform equalization between the beds.

Product/repressurization valve. It permits the final product to pass through the top of the adsorption beds and then into product storage tanks. This valve works in conjunction with the feed gas valve so that feed gas goes through the bed and gets treated before the final product leaves the vessel. It also can perform equalization between the beds.

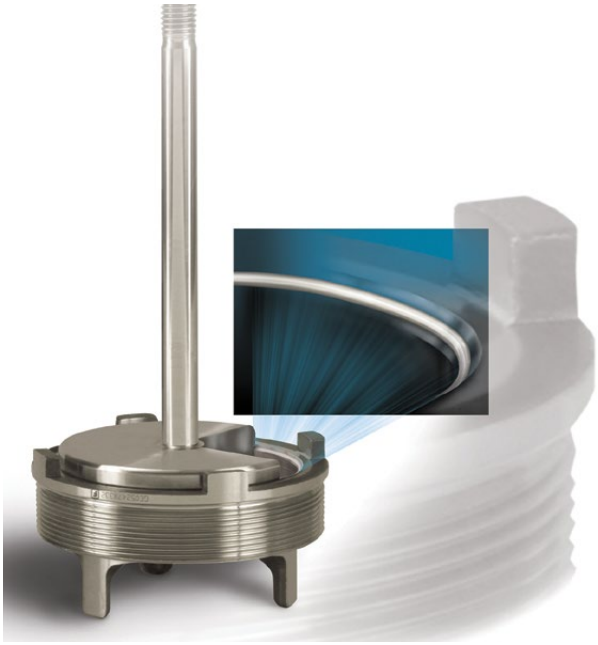
KEY CONSIDERATIONS

Proper selection of all adsorption valves requires adequate attention to two major concerns: tight shutoff and robust design.

Tight shutoff. If the valves don't shut tightly, the beds will leak and, therefore, decrease the process efficiency and increase costs. A recommended practice is to specify Class VI shutoff for all valves in the adsorption process to ensure the highest process efficiency.

Typical process temperatures allow for the use of soft seals. Opting for a form of polytetrafluoroethylene (PTFE) for soft seals (Figure 3) will give the durability needed for the multitude of cycles while also providing a tight seal and Class VI shutoff. PTFE is a fairly low friction material, thus reducing the force needed to seat and unseat the valve. However, PTFE is limited to 450°F. So, if the adsorption units run above that temperature, the best option is to select a metal seal despite its drawbacks such as higher leakage rate, torque and wear. It's critical to choose a valve with at least Class IV shutoff to ensure the smallest leakage possible as well as a hard-faced seat material to lengthen the life of seats.

Selecting a soft seal on a globe valve will allow for Class VI shutoff; additionally, it can limit wear between the seat and the plug, which also will lengthen valve life.



SOFT SEAL

Figure 3. A PTFE seal suits most applications and can ensure tight shutoff.

Robust design. This is crucial because valves must withstand a high cycle count. Not selecting a robust-enough design may lead to premature failure, which will incur increased cost through process downtime and additional equipment expenses. Choose a valve that has been tested to one million or more cycles to ensure reliability. Verify the testing took place at pressures equal to or greater than those expected in your process.

When selecting butterfly valves, check that the components in the valve's drive train — the shaft, disk and connection to the actuator — are tightly connected to avoid any loss of motion. Loss of motion will translate to additional wear on parts that can lead to premature failure. Using a

Typical process temperatures allow for the use of soft seals.

splined shaft-to-actuator connection will provide the tightest connection and least loss of motion.

The connection between the shaft and the disk must be strong and tight. The disk of the butterfly valve must contact the seat correctly to ensure tight shutoff, avoid additional part wear and minimize valve torque.

Also, consider bearings when selecting valves. PTFE-lined polyetheretherketone (PEEK) bearings are a great choice for high-cycle butterfly valves in adsorption units. These low-friction and low-wear bearings allow the control valve to operate under high pressure drops and high cycles while maintaining low torque needs from the actuator. This ensures that early bearing failure doesn't lead to early valve failure.

However, PTFE-lined PEEK bearings also have a 450°F limit. Therefore, in some higher temperature units, you may need to opt for metal bearings. Insist upon metal bearings that use a hard material or have been hardened. Two possibilities are solid R30006 bearings or nitriding a softer material such as S31600. Both options will ensure greater life of the valve and help maintain its functionality through the high cycle demand of the adsorption process.

A valve with metal bearings requires increased torque to operate, so you must select an actuator with suitably higher output torque.

When using sliding stem valves, opt for stainless steel trim with hard-facing. Hard-facing critical trim components such as the valve plug will keep wear to the minimum. Using a hard-faced plug also will minimize galling and increase valve life. Not selecting a hard-faced trim can lead to plugs getting stuck, which, in turn, will cause process downtime.

The last thing to consider when selecting both butterfly and globe valves is the packing system. It helps align the stem of a globe valve and the shaft of a rotary valve to operate and shut off properly, and, of course, also serves to prevent leaks. An adsorption process usually requires tight emissions control. Leaks to the atmosphere not only decrease efficiency but also could lead to fines. Many packing systems experience increased wear over time that can lead to greater atmospheric leaking. Using a live-loaded PTFE packing will ensure emissions are limited.

Also, consider valve assembly upgrades — such as integrated internal air passageways in actuators and linkage-less non-contact

WIDER CONTROL RANGE
Figure 4. Butterfly valves with special disk geometry can work effectively at around 15–70% open.

positioners — that can increase reliability. Internal air passageways obviate actuator air tubing, removing a failure point from the control valve assembly. Linkage-less, non-contact positioners eliminate problems with positioner linkage.

In addition, valve sizing must be taken into consideration. It's very common for valves to be oversized, which can lead to increased wear on the valve and poor control. Butterfly valves often are selected based on the process line size. However, that may be too large for the process. This is especially critical for butterfly valves where the optimal process range is within 30–60% open.

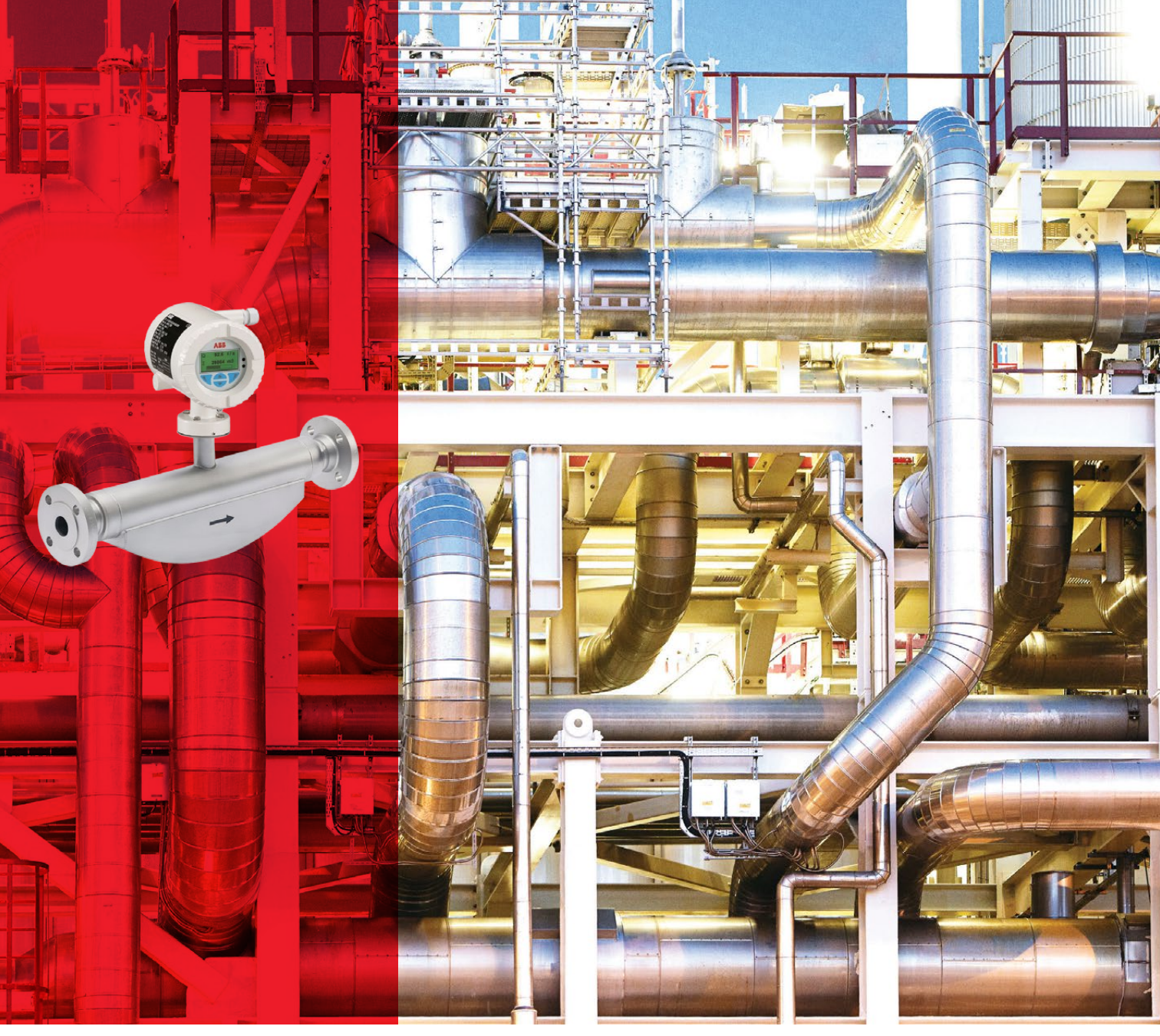
Operating outside that control range can cause the process to react too drastically to an input change. The control loop may not be able to adapt properly, which could lead to the control valve hunting for the right set point. This will upset the process and create additional wear on the control valve, both increasing costs and decreasing overall efficiency. Therefore, when selecting a butterfly control valve, ensure the operating range is within 30–60% open. If not, consider using a smaller-size control valve.

For highly demanding process conditions, some butterfly valves feature disk geometry that expands the acceptable control range to around 15–70% open (Figure 4).

CHOOSE WISELY

Adsorption is a high-cycle process that creates wear on valves. Proper selection of packing and seals, along with ensuring the valve design is robust enough to withstand multiple cycles, will lead to a longer life and trouble-free operation.

KEITH NEHRING is Marshalltown, Iowa-based chemical industry manager for Emerson Automation Solution's flow control products. Email him at keith.nehring@emerson.com.



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Consider a U-Turn

Replacing straight tube bundles in heat exchangers may offer benefits

By Andrew Sloley, Contributing Editor

A bit of extra surface area in your heat exchangers may enable you to push plant capacity. In certain situations, you can get that area by making some compromises. The Tubular Exchanger Manufacturers Association (TEMA) standards define shell-and-tube exchanger configurations with a three-letter code such as AES. The first letter refers to the front head (tube-side) configuration, the second to the shell configuration and the third to the rear head (tube-side) configuration.

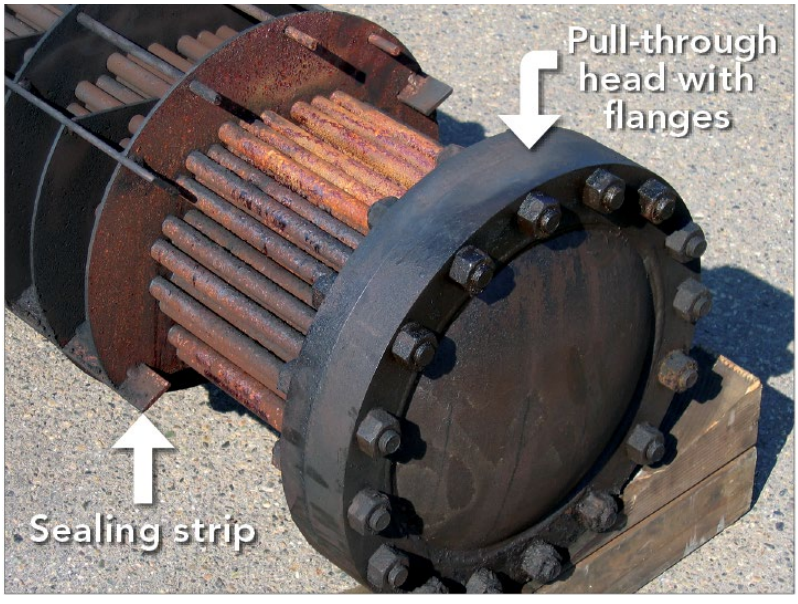
Many heavier-duty exchangers use an S- or T-type rear head. These head types handle straight tubes and feature an internal chamber with a flange to accommodate the return of the tube-side flow. In these exchangers, you can remove the entire bundle from the shell by pulling it out through the shell. Therefore, the return head must fit inside the bundle.

Figure 1 shows a T-style return head. The head's flange with its bolting circle must fit through the exchanger shell. The flange prevents installation of tubes around the outer edge of the bundle. The smaller the tube bundle is, the larger the tube-count reduction that's caused by the flange. The higher the pressure of the tube side is, the larger the flange and, so, too, the tube-count reduction. The exchanger shown has a relatively small bundle with a moderate tube-side pressure rating. The tube-count reduction (and lost area) is relatively large.

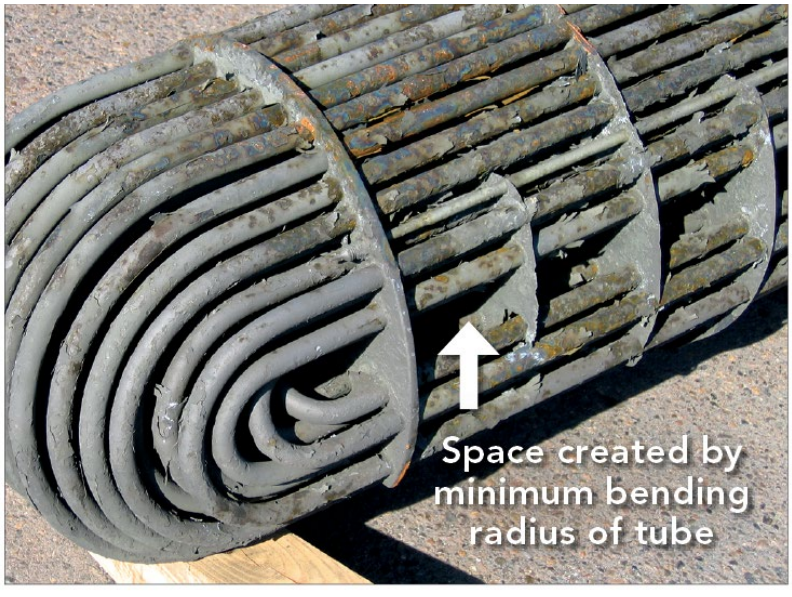
Additionally, the distance between the tube and the shell opens up a larger area where

shell-side liquid can bypass the tube bundle. Bypassed flow reduces heat-transfer effectiveness. Using sealing strips as shown in Figure 1 reduces the flow bypass but doesn't eliminate it.

A TEMA U-type return uses u-tubes. Figure 2 shows a u-tube bundle. Unlike the S- or T-type returns, it doesn't have a flange. The absence of the flange allows the tubes to be very close to the exchanger shell. On the inside of the tube bundle, the minimum radius possible for the u-bend creates a space between the inside tube rows. Nevertheless, a u-tube bundle has a larger surface area than a S- or T-type of the same diameter.



T-STYLE RETURN HEAD
Figure 1. The necessary flange limits the number of tubes in a bundle.



U-TUBE BUNDLE
Figure 2. This provides greater surface area but can make cleaning harder.

The u-tube bundle has other performance differences as well.

First, it rarely suffers from thermal expansion problems. Each tube can expand or contract slightly differently than the other tubes around it.

Second, cleaning the tube-side may be more difficult. One benefit of the S- and T-type heads is that they use straight tubes. So, hydraulic cleaning is straightforward. In contrast, cleaning inside the tubes on a u-tube

You might be able to increase exchanger surface area by 10–15%.

bundle necessitates cleaning around the return bend.

Third, when a tube corrodes or leaks and is plugged, the amount of tube surface lost is double that of an exchanger with a flanged rear head. This shouldn't be a major consideration, though. If so many tubes are leaking that the area lost by plugging u-tubes is significant, you should resolve the problem by using more appropriate materials, more stringent fabrication or changing system chemistry (i.e., using suitable additives).

While the u-tube bundle isn't suitable for every service, such a bundle gives you one more tool to increase plant capacity. Depending upon the flange sizes and exchanger dimensions, you might be able to boost exchanger surface area by 10–15% by using u-tube bundles in place of flanged ones. You can minimize cost by incrementally switching exchanger types when you need to replace worn-out bundles. ●

ANDREW SLOLEY is a contributing editor for *Chemical Processing*'s Plant InSites column. He can be reached at ASloley@putman.net

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Protect Your Centrifugal Pumps

Check if crucial ones lack sufficient safeguards

By Dirk Willard, Contributing Editor

An important question dawned upon me: "How is the caustic pump protected if the expansion joint at its suction port splits open?" That pump was the only one capable of keeping the plant running at full capacity. Thinking about this issue a bit more, I realized that many pumps in lots of plants I'd been to had little or no protection.

One of four culprits usually kills a pump:

1. a loss of flow from the feed tank caused by a suction line failure or a drop in tank level;
2. a blocked suction or discharge line;
3. a mechanical failure such as a broken shaft due to debris fed to pump, change in pumping fluid, corrosion, etc., or running a pump with a variable-speed drive (VSD) too fast or too slow; and
4. mis-application, e.g., using a centrifugal pump to move a viscous, corrosive, bubbly or high density liquid.

Now, let's consider some options for protecting centrifugal pumps. These involve monitoring of level, pressure, flow, temperature or power.

By far the cheapest method is level control. Plants usually monitor the level in feed tanks. Take advantage of this measurement to program a trip to turn off the pump when the level nears the point at which gas enters the pump instead of liquid. As a rule of thumb, I use 1 ft above the top of the suction line but you can calculate this by looking into "submergence" online; I suggest checking "Cameron Hydraulic Data." If your pump seal is rugged, you might set a

lower level for the trip. Also, you certainly will want to confirm that the net positive suction head available ($NPSH_A$) suffices at the trip point. Cheapest isn't best, though. Level control only thwarts running the pump dry (culprit 1).

An option that's a little more expensive is a high-pressure switch (PSH) at the pump discharge. This approach catches (1) and (2) successfully but (3) and (4) only sometimes. Set the PSH to match the deadhead pressure but put a 15-sec. delay on the trip. Changes in liquid specific gravity affect the setting because pump discharge head remains the same but pressure varies with density. The PSH is a robust instrument; that's why it's typically used to protect pumps where local instrument support is minimal. (A low-pressure switch (PSL) could be used to detect an open discharge line.)

Flow measurement is the best approach. However, it's not foolproof because flow is inferred from another parameter — usually, velocity or pressure drop. Fluids affect these measurements. Ideally, you should measure downstream flows that can be used to trip a pump if sufficient flow isn't headed its way. If that's not feasible, install flow switches on suction lines. Flow monitoring protects against (1), (2) and (3) to a large degree and even (4) in most situations. An alternative approach for timer-controlled pumps relies on on/off feedback from automatic valves. In critical pump applications, you could use this feedback as an additional layer of protection even where flow measurement is available. Set the flow at the temperature limit where liquid vaporizes; vendors generally provide minimum flow in data sheets.

Then, there's temperature measurement, an option available in vendors' pump monitoring packages. However, temperature always suffers from lag. By the time the system reports a temperature high enough to cause damage, it's already done. Set the trip high but to respond instantly.

One of four culprits commonly kills a pump.

Don't rely on power monitoring to gauge pump condition. It can detect altered power draw from a change in fluid viscosity and density but won't alert you to a broken impeller. Unless it's completely destroyed, which is rare, the impeller still turns and the pump draws power. Power monitoring is useful to tell you if a motor is running at a high speed or, worse, a low speed. Totally enclosed fan-cooled (TEFC) motors rely on shaft speed to avoid burning the motor coil insulation. A power monitor represents an inexpensive approach to protect motors; include it whenever you use a VFD.

Consider using multiple approaches. Level and power are cheap options while flow and power may provide the most protection. Perhaps opt for level, flow and power for some overlap. Regardless, realize a spare pump isn't really a long-term solution if you can't prevent the first pump's failure.

DIRK WILLARD is a contributing editor for *Chemical Processing*. He can be reached at dwillard@putman.net.

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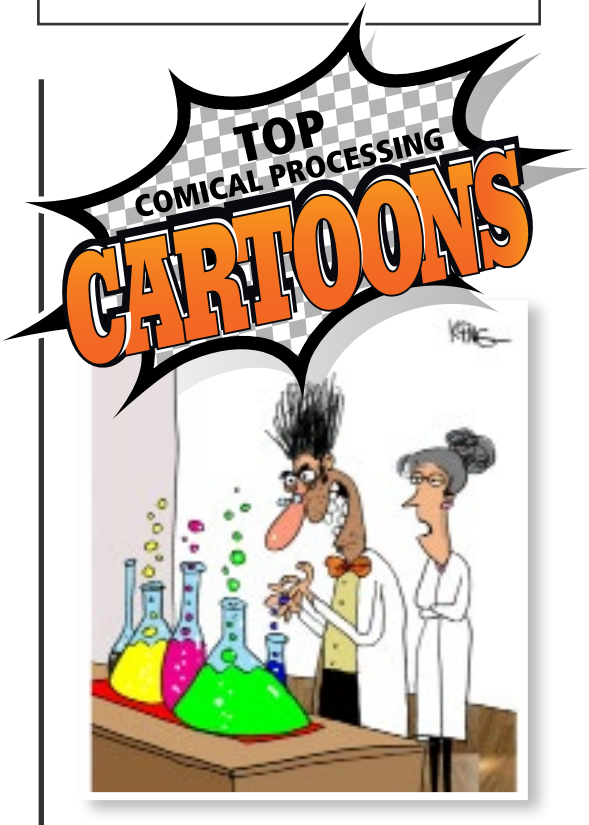

Visit the lighter side, featuring drawings by award-winning cartoonist Jerry King. Click on an image and you will arrive at a page with the winning caption and all submissions for that particular cartoon.