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Features ease installation and minimize pressure drop

The Epic series check valve product offering consists of in-line spring-loaded poppet-type check valves designed to be cost effective, simple, rugged and efficient while operating in any flow orientation. The valves are machined from 300 series stainless steel bar stock with Aflas seat/seals and a 1/2-psi stainless steel spring (cracking pressure). It is streamlined so that media flows through the valve over smooth, contoured surfaces with a minimum change in direction. The check valve also achieves a high flow capacity and reduced pressure loss compared to other poppet style check valves of similar sized connections. These features minimize the pressure drop across the valve. The valve closes quickly and smoothly for silent operation and eliminates water hammer.

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Take Advantage of Liquid-Ring Compressors

These compact devices boast several benefits and suit numerous small services

By Amin Almasi, rotating equipment consultant

Liquid-ring compressors possess a number of desirable features. They provide a fairly steady gas flow with very small pressure fluctuations, and have low noise levels and smooth running characteristics. Including ancillary equipment, they offer a favorable capacity-to-weight ratio and small footprint, which are important advantages for small compressor packages that should be lightweight and compact. Moreover, their full-load and part-load performance is reasonably good, often better than many other compressors. A back-pullout design enables maintenance of the compressors without disassembly of piping and service liquid connections.

A liquid-ring compressor (Figure 1) is a rotating positive-displacement device that is very similar to a rotary vane compressor; it differs in having vanes that are an integral part of the rotor that churn a rotating ring of liquid to form the compression chamber seal. Both types of compressors are inher-

LIQUID-RING COMPRESSOR

Figure 1. A unit such as this can handle a variety of small services. *Source: Gardner Denver.*

ently low-friction designs, with the rotor being the only moving part. Sliding friction often is limited to the shaft seals, although other frictions might exist. Many points presented in this article actually apply to both types.

An induction motor typically powers a liquid-ring compressor. The motor rotates a vaned impeller located within a cylindrical casing to compress gas. Liquid (often water) is fed into the compressor and, by centrifugal acceleration, forms a moving cylindrical ring against the inside wall of the casing. This liquid ring creates a series of seals in the space between the impeller vanes, forming compression chambers. The eccentricity between the impeller's axis of rotation and the casing geometric axis results in a cyclic variation of the volume enclosed by the vanes and the ring. Gas is drawn into the compressor via an inlet port in the end of the casing; the gas is trapped in the compression chambers created by the impeller vanes and the liquid ring. The reduction in volume of the gas caused by the impeller rotation compresses the gas, which exits through the discharge port in the end of the casing.

Liquid-ring compressors come in single- and multi-stage versions. A multi-stage compressor typically has up to two compression stages (in rare cases, three) on a common shaft. Such units handle many small vacuum and compression services, e.g., in distillation, and vapor and flare-gas recovery.

BROAD APPLICABILITY

Water commonly serves as sealant for liquid-ring compressors, with oil the second most-popular choice. However, the devices can use any fluid compatible with the process (provided it has the appropriate vapor-pressure properties) as the sealant liquid. This ability to use any liquid makes the liquid-ring compressor an ideal choice for solvent (vapor) recoveries and similar services. If an operation such as vacuum, drying, etc. is generating vapors of difficult-to-handle compounds (such as toluene), then it's possible to use the same material in the liquid form (liquid toluene in this example) as the sealant, provided the cooling system (usually cooling water) can keep the vapor pressure of the sealant liquid low enough to pull the desired vacuum to suck and compress the vapor.

In vacuum services, the vapor pressure of the ring liquid usually limits the attainable pressure reduction. As the generated vacuum approaches the vapor pressure of the ring liquid, the increasing volume of vapor released from the ring liquid diminishes the remaining vacuum capacity. The efficiency of the system could decline as a result. As a general rule, single-stage vacuum compressors typically produce vacuum to 0.06 bar and two-stage units can produce vacuum to 0.03 bar (or sometimes lower), assuming air is being pumped and the ring liquid is water at a temperature of 15°C or less. Most manufactures use dry air and 15°C sealant-water temperature as the basis for their standard performance curves.

For compression, single-stage liquid-ring compressors usually are used. As a rough guide, their maximum discharge pressure most often is less than 6 barg, while two-stage versions can provide discharge pressures up to around 16 barg.

DESIGN AND OPERATION

Liquid-ring compressors employ a rotor centrally positioned in an oval-shaped casing. The rotor does not touch the casing, which contains a precise amount of liquid. During rotation, centrifugal force causes the liquid to form a ring that follows the shape of the casing's inside wall. Because of that oval shape, the volumes between the rotor's blades differ. At two points, the liquid completely fills the volumes. In between these two points, the liquid recedes in the beginning and up to half way, thus creating suction; it then advances, creating pressure. The gas enters the casing through the inlet port, where suction is generated, and leaves, after compression, through the outlet port. A dedicated line supplies the sealant liquid, which flows continuously. This liquid absorbs the heat of compression. It usually leaves the casing together with the compressed gas, and is split off in a discharge separator tank.

The operation of rotary vane compressor is slightly different: the centrifugal force acting on the blades due to rotor rotation pushes the blades radially outward to continuously contact the cylinder bore and form closed pockets or cells filled with gas when open to the inlet port during the (nearly) half of revolution on the inlet side of the cylinder. During the second half of revolution, a cell moves toward the discharge port while its volume decreases due to the progressively

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diminishing space between the cylinder and rotor. Thus, a blade is subjected to a pressure differential between its preceding cell at a higher pressure and the following cell at a lower pressure. This pressure differential can cause the blade to rub against the outer corner of the rotor slot as it slides in and out of the slot.

Cylindrical gas distributors and relatively large inlet-gas passages can reduce friction losses to the minimum. An overhung arrangement often is preferred for these small compressors because it requires only one shaft seal and bearing housings are externally accessible.

Liquid-ring compressors usually come fitted with rolling-element bearings. Unfortunately, the compressor's small size often rules out more-reliable bearings such as hydrodynamic ones. So, it's essential to select rolling-element bearings that promise reasonable reliability and performance. As a very rough guide, choose rolling elements that have an 8-y theoretical operating life or more; a basic life (L10) exceeding 60,000 hours or more is preferred. The bearing life calculation should consider all possible loads — for instance, all potential dynamic loads, high loads due to compressor degradation and fouling, and all other non-ideal cases. Review of many failed rolling-element bearings has shown they were subjected to actual loads much greater than the theoretical (assumed) ones; such higher actual loads can reduce the bearing life to 5–10% or less of the expected life.

LUBRICATION

Lubrication requirements vary. In some liquid-ring compressors the oil is recirculated, in others it leaves the compressor with the discharge gas, and in some others it serves a dual purpose of lubrication and cooling. A force-feed lubricator with adjustable capacity usually pumps the lubrication oil through tubing lines to several drilled openings in the side of cylinder and to each bearing.

Often lubrication oil is expected to protect bearings and sliding surfaces and to remove heat. The lubrication oil also assists the smooth operation of sliding motions of compressor components and reduces wear between different components.

The lubrication oil encounters temperatures that are much lower than those in other positive-displacement compressors such as the corresponding reciprocating ones. The lubrication oil rarely faces temperatures over 100°C; the temperature typically is 90°C or less.

Elevated temperatures because of suction-gas high temperatures or compressor malfunction can adversely affect petroleum oils (mineral oils), causing them to break down to form carbon and varnish deposits. The liquids or condensates often change the oil's properties and may react with some of its additives. In the case of a hydrocarbon gas compressor (such as one for natural gas or flare-gas recovery), some heavy hydrocarbons may condense into liquids in so-called cold places (such as close to the cooling-water jackets) and dilute the oil. This dilution is especially serious in the bearing cavities where the oil dwells for a relatively longer time than elsewhere. Being diluted, the lubrication oil no longer has the proper viscosity for sufficient lubrication. In other cases, the gas may be acidic in nature or the intake gas may be laden with acid fumes or other pollutants.

Because the lubrication oil may have encountered relatively high temperatures or other harsh conditions, it usually should not be reclaimed and reused. The diversity of conditions faced by such compressors precludes developing a general rule for the quantity of lubrication oil to be used. If possible, check successful operating references to verify the manufacturer's recommendations and then closely follow these recommendations.

Bearing failures in liquid-ring compressors have been reported. Some stemmed from too low a viscosity of the lubrication oil at the actual working temperature or from the presence of slugs or dirt in the oil. Bearing manufacturers vary in their opinion about the minimum viscosity at the operating temperature. As a very rough indication, the recommendations for some liquid-ring compressors is to use an oil with ISO viscosity grade 46 and a viscosity index exceeding 100 for operating temperatures of around 90°C or below. Operating temperatures over 90°C require a more-viscous grade or lubrication oil with a higher viscosity index.

RELIABILITY AND PERFORMANCE

Older designs of liquid-ring compressors used a minimum quantity of oil, which only served for lubrication. Those units provided relatively low volumetric efficiencies and, sometimes, high discharge-gas temperatures due to internal gas leakages; they suffered considerable blade and cylinder wear. Today's designs afford proper lubrication, forcing comparatively large quantities of oil into the machine, and overcome the disadvantages of earlier machines. Modern liquid-ring compressors are rugged and reliable, as well as cost-effective for small compression services.

If a liquid-ring compressor isn't properly designed, it might work at "over-compression" or "under-compression" situations. The over-compression occurs when the compressor is operating at a lower pressure ratio than that for which it was rated (or designed). In practice, this happens if the working delivery pressure drops below the designed value or if the inlet condition rises above its rated value. A simple explanation for over-compression is that the gas is compressed until the outlet port opens, where-upon there is a sudden rush of gas from the rotor cell. Instead of the pressure drop being instantaneous, it usually takes place over a very short period of time, which depends upon the pressure difference between the outlet manifold and the rotor cell, the speed of the rotor cell, the rotor-stator geometry, and the flow characteristics of the outlet ports. There are additional power losses due to over-compression; actual losses usually exceed those indicated by theoretical predictions.

The under-compression occurs when the compressor is operating at a higher-than-design pressure ratio. In practice, this happens if the working delivery pressure rises above the designed value or if the inlet pressure falls below its rated value, which could happen at some part-load conditions. A simple explanation for under-compression is that gas is compressed until the outlet port opens; then the gas at discharge suddenly rushes into the rotor cell. The gas that has flowed back into the rotor cell must be expelled again, requiring additional work compared with a machine designed for the higher pressure.

FLARE GAS RECOVERY

Flammable waste gases, whether generated by process upsets or normal operation, usually go to a flare system. This typically includes a flare-gas recovery unit. Recovering these gases, which can be used for fuel or other purposes, can significantly reduce emissions and fuel gas costs. A liquid-ring compressor is ideal for flare gas or off gas. Such gas usually contains liquids, dust and dirt particles. Intensive contact between gas and operating fluid enables nearly isothermal compression. A liquid-ring compressor can withstand with ease wet process streams and fouling that would damage other mechanical compressors. ■

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Get Into the Thick of Things

Consider several types of pumps to handle viscous fluids

Dirk Willard, Contributing Editor

I was surprised: a centrifugal pump actually pumped a 300-cP detergent. A careful examination later showed the pump was near its thermal minimum-flow limit. This means it couldn't be expected to reliably pump continuously. Nonetheless, another presumption of pump lore bites the dust.

So, let's look at pumping of viscous liquids — and limit our discussion to pumps for regular processing, not metering or sampling.

Viscosity in pumping is a great bugaboo of our business. Most pump manufacturers will tell you not to use a centrifugal pump for liquids with viscosities beyond 100 cP. And, despite what I witnessed, let's agree that a centrifugal pump usually isn't a good choice for viscosities above 100 cP, let alone 300 cP. Such services generally call for some type of positive displacement pump (see: "Consider Positive Displacement Pumps," http://goo.gl/Wbz8sl). These pumps are self-priming.

A good choice often is the lobe pump ("Keep Lobes in Mind," http://goo.gl/ZOyHpq). It's a rotary pump good up to its maximum case pressure; it can handle a maximum of perhaps 2,000 cP (which is about the viscosity that honey has at 25°C).

If you need to move a really high viscosity material, you must avoid pumps that require high pressure. Keep in mind the operating limit on 150-psi flanges is only 276 psig up to 100°F; clamps may have a lower rating depending upon the manufacturer.

CHECK OUT PAST FIELD NOTES

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One popular choice is the progressive cavity pump, which is limited to below one million cP. Other potential options include the piston pump or the gear pump ("Get Up to Speed on Gear Pumps," http://goo.gl/qNSQeu). Both the progressive cavity and piston pump require a much greater suction pressure than that needed for lobe, gear or centrifugal pumps. Piston pumps and rotary pumps are very sensitive to abrasives while progressive cavity pumps aren't.

What if you need a pump for a wide variety of products, say, with viscosities ranging from 4 cP up to 2,000 cP? Believe it or not, a progressive cavity pump is a good choice. It can pump almost anything. If this pump type has a limitation, it relates to handling lower flow rates. In addition, as I recall with TiO_2 slurries, seals and bearings sometimes are a problem with progressive cavity pumps.

A lobe pump usually has a lower limit of 100 cP but might work if you go with a smaller model with tighter space between the lobes and case wall, and operate at very high speed to compensate for slippage. Indeed, a lobe pump might be preferable because it is more compact and perhaps more reliable than a progressive cavity pump.

There really isn't a good way to know whether a lobe pump will work with 4-cP liquid. The best option may be to increase the motor size to raise the flow rate to 10–15% above the design rate; this may compensate for the slippage that is expected at low viscosity. Hopefully, testing provides a happy surprise.

Now, let's consider viscosity itself. Too often it's difficult to find reliable viscosity data: safety data sheets frequently don't include this valuable information. If you're not afraid to get your hands dirty, consider measuring viscosity yourself. While spindle-type viscometers run $2,000–$3,000 and require annual calibration, a set of Zahn cups costs less than $600 and easily fits in a suitcase. You only may need a single Zahn cup, which is a bargain at about $135. Measuring with a Zahn cup requires a 500-ml beaker, 400 ml of sample, a stopwatch as well as a scale and a 100-ml beaker for estimating density. Adding a hook above the beaker will allow you to free the hand that otherwise would hold the beaker during the test. Zahn cups measure viscosity in cSt: cP = specific gravity × cSt. Run the test at 25°C. Take measurements at other temperatures to enable you to develop viscosity/temperature correlations. For more information, go to: http://goo.gl/HUiXZ0 and http://goo.gl/ymFMte.

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EXPRESS LINE

Optimize Energy Measurements

Flow meters with integrated pressure and temperature compensation can help monitor energy use

By Steffen Baecker, KROHNE Inc.

Accurate energy measurement is a must in process applications that involve heating and cooling; compressed air; steam production and distribution; heavy fuel oil consumption; energy monitoring; and custody transfer. After all, any error is directly translated into energy costs.

In the past, the needed combination of instruments to measure energy use would include a flow meter, temperature sensor, pressure sensor and flow computer.

Recently developed technologies integrate tasks that used to take several different devices to perform. The measurements taken are more accurate than those of the older systems as well.

One innovation example is a vortex flow meter featuring integrated pressure and temperature compensation. With accuracy of 1.5%, it is two to three times more accurate than older systems in which the individual measurement devices have accuracies between 3 and 5%.

Let's look more closely at why each area needs accurate measurement and at solutions and practices that increase energy measurement precision.

HEATING & COOLING

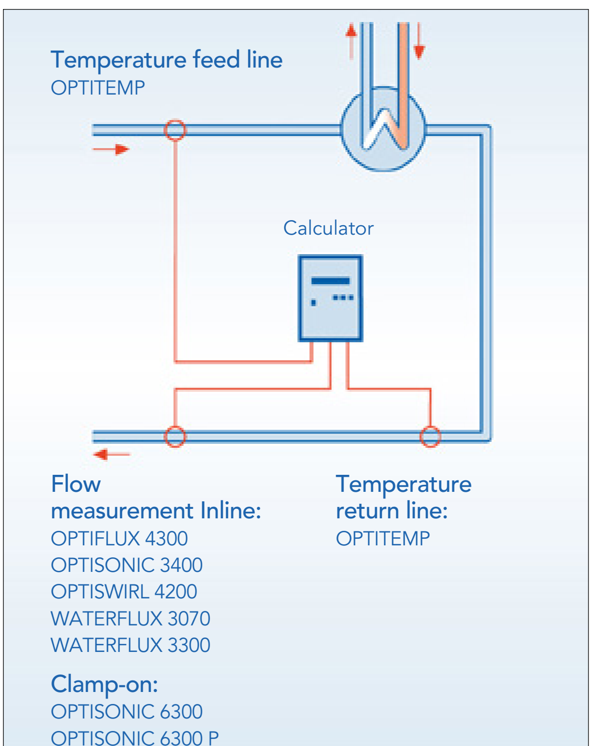
A further incentive to accurate measurement in heating and cooling of industrial workspaces and office buildings involves regulatory concerns related to reducing CO_2 emissions.

Many different type solutions are installed, involving wide ranges of pressure, temperature or flow.

For example, a heat meter installation includes supply and return lines equipped with temperature measurement devices. Flow measurement is inline and clamp-on options are available, regardless of whether heating or cooling is involved. Figure 1 is an example of a heat meter configuration, along with devices available for each measurement task.

Also common is the need to measure heat quantities consumed in industrial production areas by equipment like steam generators, clean-in-place systems, heating-circuit production, or ventilation systems. Here, both the flow rate of the heating fluid (typically water) and the difference in temperature before and after each consumption point must be precisely measured. Operators are looking to determine both individual and total heat demand for allocation of operating costs to appropriate consumers and to establish total heat balancing.

Ultrasonic flow meters are meant for these types of heat measurements. Clamp-on options retrofit to existing heating and cooling applications when processes cannot be interrupted.



HEAT METER CONFIGURATION

Figure 1. This illustration shows the devices available for each measurement task.

COMPRESSED AIR

Virtually every production operation has a compressed air network but rarely are these networks monitored for actual consumption rates. This is a major, and costly, oversight. Easy, significant cost reduction is possible if the compressors providing compressed air are controlled against actual consumption. Even with energy prices below 10 cents per kilowatt-hour, it is worth monitoring the compressed air system since annual costs created by leaks or untapped output can easily run up into the five-figure range. Only when consumption rates are measured can processes be controlled and optimized.

Studies show even a flawless compressor with maximum efficiency achieves only 85% of rated efficiency. Oil filters, air filters, motor speed and humidity at the inlet of the compressor and inlet filters are among factors that contribute about 8 to10% of this efficiency reduction. That is why it is extremely important to measure the compressor's free air delivery (FAD), which is defined as the amount of atmospheric air (free air) that can be sucked in by the compressor at the inlet condition (suction side) under the following conditions:

- Atmospheric pressure of 1 atmosphere
- Atmospheric temperature of 20 °C/15 °C
- Relative humidity of 0% (100% dry air)
- Motor speed (rpm) of 100% of its rated speed

For example, the Krohne Optiswirl 4200 vortex flow meter is used to identify leaks, as well as monitor compressor efficiency, consumption profiles and peak consumption through integrated temperature and pressure compensation and free-air delivery (FAD) software. It essentially measures the amount of free air that meets the stated air conditions, providing an assessment of compressor efficiency.

Suppose for example a compressor is set to run at 800 rpm, and should suck in 8,000 cubic feet per hour, which represents the compressor's highest state of efficiency. If the meter says it is sucking in only 7,500 cubic feet per hour, this signifies that the compressor is not as efficient as it could be.

DAILY WEAR & TEAR

There is a certain amount of wear on a compressor that runs every day, and efficiency goes down gradually. Every compressor has a maintenance interval after which it is shut down for maintenance. A typical production line shuts down every four to six months, during which the crew maintains the compressor and changes parts.

Using a vortex meter allows maintenance crews to report actual compressor efficiency and adjust maintenance intervals accordingly. Let's say there was a maintenance shutdown two months ago, but the device shows compressor efficiency falling rapidly. The maintenance crew can shut down and maintain the compressor before it breaks and time is wasted waiting for spare parts.

On the other hand, let's say compressor efficiency is excellent. Instead of shutting down, one can leave the compressor running and schedule the maintenance to take place only when the meter indicates reduced compressor efficiency. Working this way allows plants to reduce maintenance intervals.

Operators want the compressor to work efficiently so less energy is needed for the same output Many companies have compressed air systems with leaks everywhere in the plant; each leak fixed may save a plant as much as $250 a month.

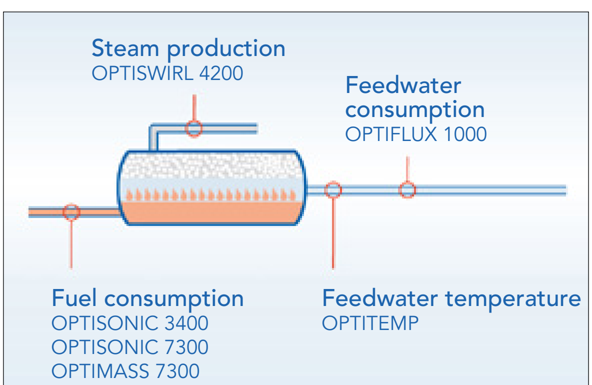
STEAM PRODUCTION & DISTRIBUTION

Every major production process, including pasteurization, brewing, sterilization, washing and cleaning requires steam for heating. Supplying steam consumes energy because boilers are fired with liquid fossil fuels or natural gas. Accurate measurement of steam produced is a prerequisite to efficient burner control.

Steam generation is dependent on temperature and pressure. As pressure changes, steam changes from super-heated to saturated and then to condensate; a change can come with every valve or pump or elbow in a process line.

Steam processes are inconstant, and steam is affected each time a process changes. To regulate steam, operators must be aware at all times. Unfortunately, many plant operators do not understand steam regulation importance, or lack the right equipment. With the pressure- and temperature-compensated vortex flow meter, operators always know if it's at super-heated steam, saturated steam or condensate steam.

Figure 2 shows devices used to measure fuel consumption, steam production and distribution, and boiler feedwater consumption, to fully analyze steam system efficiency.
Even though steam boilers are efficient, the steam system as a whole is considerably less so, due to non-insulated steam lines, leaks, contaminants or faulty condensate separators. Often operators overlook the pressure and temperature fluctuations that can occur during the process. These fluctuations impact the measuring error of a system, which can result in a high loss of energy. Exact measurements help identify losses and increase efficiency.



STEAM PRODUCTION

Figure 2. These devices measure fuel consumption, steam production and distribution, and boiler feedwater consumption to fully analyze steam system efficiency.

Figure 3 shows energy costs when measuring saturated steam and superheated steam. Small changes in steam temperature or pressure make a huge difference in what customers pay. As noted, a classic system with a variety of devices has an accuracy of between 3 and 5%, while one with integrated pressure and temperature compensation like the vortex flow meter in question has an accuracy rate of 1.5%. Depending upon application and design, use of the standard measurement configuration could be as much as $50,000 more a year than use of a system with integrated pressure and temperature compensation.

FUEL OIL CONSUMPTION

Oil is used for energy and heat in industrial production. Often combined coal-oil burners can be used. To start the combustion process and support the coal fire, oil is used for the booster and supporting burner. Also, fuel oil is used to start natural gas turbines.

To get the ideal fuel ratio between oil and air, operators need precise mass measurement in the oil and air lines. Because of heavy oil use, a circulation line is used to heat the oil and reduce viscosity. To get the correct consumption value, the supply and return lines to the oil tank must be monitored.

	Saturated steam		Superheated steam		
Operating pressure	75 psi	250 psi	25 psi	40 psi	65 psi
Temperature	+320 °F	+406 °F	+350 °F	+330 °F	+350 °F
Measuring error at pressure deviation ±15 psi	16%	5.50%	39%	28%	19.50%
Measuring error at temperature deviation ±18 °F	21%	18%	2.50%	2.50%	2.50%
Unaccounted energy costs* at pressure deviation ±15 psi [$] p.a.	$163,764	$127,152	$165,176	$170,302	$169.613
Unaccounted energy costs* at temperature deviation ±18 °F p.a.	$218,658	$415,027	$9,989	$15,249	$22,228

ENERGY COSTS WHEN MEASURING SATURATED AND SUPERHEATED STEAM

Figure 3. Small changes in steam temperature or pressure make a huge difference in energy costs.

**Nominal pipe size 4 in., 60% capacity, energy costs %12.85/1,000 lbs

One way to measure the consumption of heavy fuel oil (HFO) on each boiler is with a Coriolis mass flow meter. Accurate measurement allows operators to monitor the usage of HFO closely and precisely and to evaluate the plant efficiency.

When oil or gas is transferred from one party to another, the parties have to agree on the product quantity and quality. This type of custody transfer involves assurances for both parties. Devices must be calibrated and certified according to international standards, such as Organization Internationale de Métrologie Légale (OIML), API (American Petroleum Institute), AGA andNational Type Evaluation Program (NTEP).

Calibration should be done in accordance with ISO/IEC 17025, accredited and traceable to international and national standards. Regular inspections by national metrology institutes, round robin tests and alignments with national and international metrological standards according to ISO 9000 and EN 45000 should be made to guarantee the quality and comparability of calibration rigs used for these meters.

Depending on line size, the length of straight run and simple customer preference, either a Coriolis mass flow meter or an ultrasonic meter is used here.

Savvy plant operators are looking for ways to make processes more efficient. Appropriate technology solutions and best practices can lead to significant energy savings for plants of all kinds. ■

STEFFEN BAECKER is a product specialist – Flow for KROHNE Inc. He can be reached at s.baecker@krohne.com.

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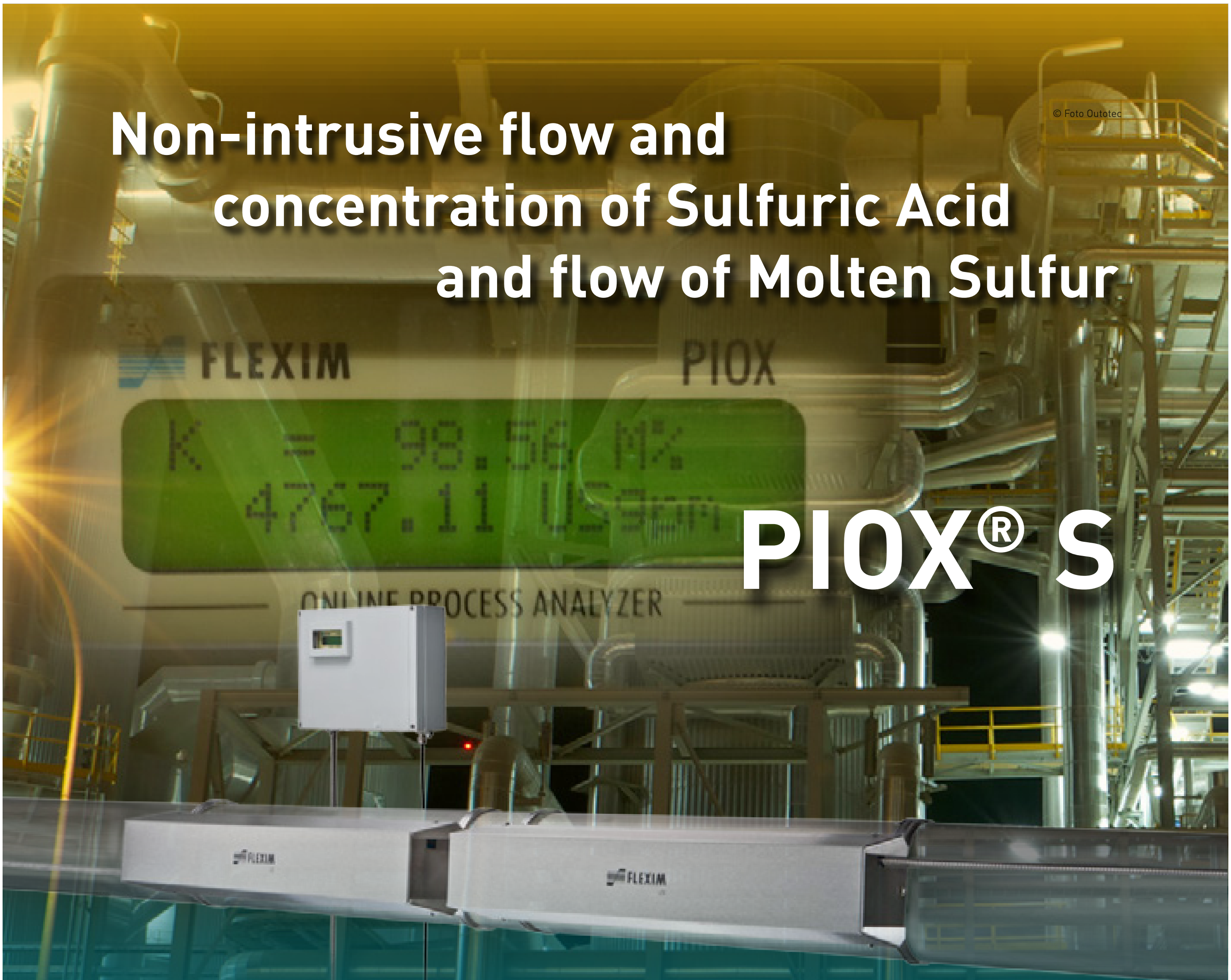

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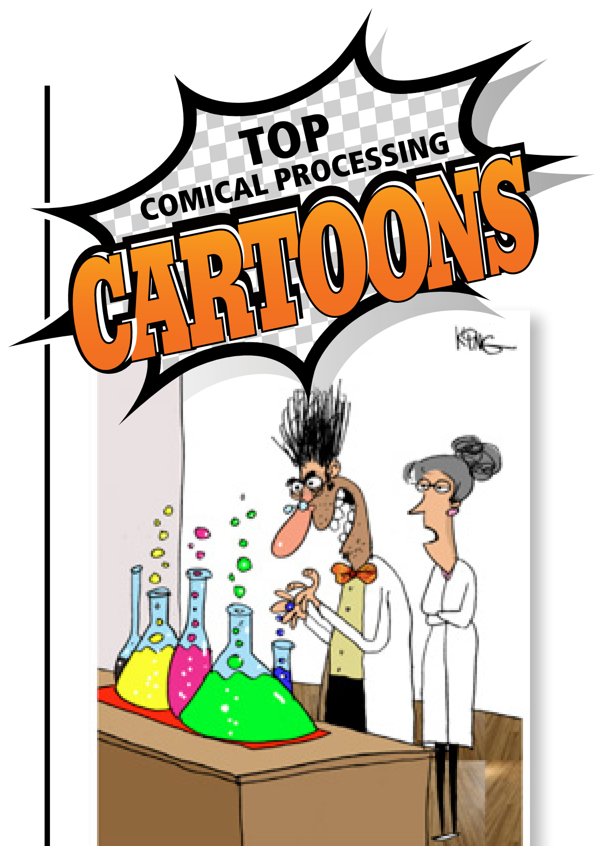

Visit the lighter side, featuring drawings by award-winning cartoonist Jerry King. Click on an image and you will arrive at a page with the winning caption and all submissions for that particular cartoon.