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Coriolis Flow Transmitter Delivers Detailed Data

Device translates measurements into useful information for deeper process insight

THE MICRO Motion Model 5700 Coriolis flow transmitter is designed to translate measurement data into meaningful insight and instruction. It provides users access to detailed measurement history for troubleshooting or optimizing the process. The graphical user interface was designed for intuitive operation, with simplified installation, configuration, maintenance and troubleshooting. The transmitter translates Coriolis measurement data through robust, time-stamped history files for process and meter health data, and logs for configuration changes and alarms.

THE MODEL 5700 digital signal processing architecture provides fast flow response time, making it optimal for custody transfer proving and short batching applications. The historian feature also improves Micro Motion Smart Meter Verification, which provides measurement of the full meter health without process interruption, improving measurement confidence and easing regulation compliance.

COMPATIBLE WITH new and previously installed Micro Motion ELITE Coriolis sensors, the Model 5700 has a field-mount design that's suitable with most hazardous area installation practices and with both integral and remote installation options. It currently includes options for analog, pulse, discrete and Modbus outputs and an analog or HART input.

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Portable Ultrasonic Flow Meters

Phenol Plant Solves Flow Measurement Problem

Non-contact ultrasonic meter eases maintenance and improves accuracy

By Peter Chirivas, Flexim Americas

A MAJOR Philadelphia petrochemical company had a problem. Actually, it had more than one. The firm recently acquired an old phenol plant from a competitor. The facility was run down and didn't meet the high safety standards required by its new owners. That meant some serious revisions.

"The plant is more than 100 years old. There were problems all over the place," said Mike, the new owner's reliability engineer. "We started by cleaning all of the equipment. It was a huge task, but we knew what shape the plant was in when we bought it. One cooling tower was in such bad shape that cleaning it was hopeless. We simply replaced it."

THE PROBLEMS WITH PHENOLS

Demand for phenols continues to grow because they are important intermediates in chemical manufacturing, particularly for producing precursors to plastics. This particular plant uses the cumene process, which makes phenol by reacting cumene with oxygen in the presence of an acid catalyst.

Phenol at the production temperature of 300°F is a viscous fluid like cold maple syrup. As it cools, the fluid thickens; if it drops below 105°F, it solidifies. Therefore, to prevent severe damage to the plant's equipment, the phenol can't be allowed to cool too much. It's maintained at a temperature slightly below 300°F until shipped.

Phenol's toxicity poses another serious concern. The chemical is very hazardous — exposure to it can be fatal if untreated. It absorbs quickly through the skin and attacks the central nervous system as well as the liver and kidneys. So those dealing directly with phenol must wear hazmat gear to avoid touching or inhaling it.

METERING THE PHENOL

When acquired, the plant was using differential pressure (dP) flow meters. Such meters place a restriction within the pipe, often an orifice plate, which creates a pressure drop; an increase in flow raises the pressure drop and vice versa. By measuring the pressure

Figure 1. Because of the criticality of the flow measurement, the phenol manufacturer painted a key component of the meter red.

before and after the restriction, the transmitter can determine the flow rate via Bernoulli's equation, which relates fluid velocity to pressure.

"In one building, there are two coolers, one larger than the other, and they both had orifice plates with dP flow meters," noted Mike. "In the smaller cooler, the orifice plate was too restrictive, so it was replaced with a self-contained differential flow meter. It was intrusive, too, but didn't restrict the flow too much. However, the meter got plugged fairly quickly, so we routinely removed it, disassembled it, cleaned it and reinserted it. It was tedious and time consuming. It was also dangerous. The technician had to wear hazmat equipment when removing it, cleaning it and replacing it. Early on, we started looking for a non-intrusive method of monitoring the flow of phenol."

The plant asked Jim Pletcher from Technical Devices, Inc., one of its major suppliers and a technical consultant, if he had any ideas.

"It looked like a great application for one of our suppliers, Flexim Americas," said Pletcher. "They make ultrasonic flow meters with remarkable range. Their turndown ratio is 100 to 1, where a differential pressure flow meter is about 30 to 1. Plus, they are clamp-on meters and do not intrude into the flow."

HOW ULTRASONIC METERS WORK

"One of the major benefits of ultrasonic flow meters is that, unlike traditional meters, they contain no moving parts and do not need frequent calibration and maintenance," explained Pletcher. "Measurements are made using the transit time difference method. It exploits the fact that the transmission speed of an ultrasonic signal depends on the flow velocity of the carrier medium. An ultrasonic signal moves slower against the flow direction of the medium and faster when it is in the flow direction.

"For the measurement, two ultrasonic pulses are sent through the medium, one in the flow direction and the second against it. The meter's transducers work alternately as transmitter and receiver. The transit time of the signal sent in the flow direction is shorter than that of the signal sent against the flow. The meter measures the transit time difference and calculates the average flow velocity. Since the ultrasound signals propagate in solids, the meter can be mounted directly onto the exterior of the pipe non-invasively.

"Flexim ultrasonic flow meters are not affected by density, which make them ideal for multiple applications from slurries to gas measurements. They automatically compensate for variations in viscosity."

In May 2013, Pletcher gave a presentation and brought along a portable Flexim meter.

"Initially, he showed us a hand-held portable that we put on a pipe and it gave us the reading we thought we should have," noted Mike. "We put it on different types of liquid and it gave us the good readings we were looking for. It also calibrated itself. We decided to use it for information, not control. We've got a system installed at a location and it works just fine. When we first installed it, we left the differential flow meter in place so we could check the measurements over time. The differential meter was a lot more noisy; it read higher flow than the Flexim. And the measurements would drop over time as it plugged. The ultrasonic gave us good, flat readings with minimal noise. For three months we tested it and then installed it permanently. It is now one of the plant's safety interlocks and is still giving accurate, noise-free measurements. And we don't have to take it out to clean it."

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PETER CHIRIVAS is senior staff engineer and quality control manager at Flexim Americas Corp., Edgewood, N.Y. E-mail him at pchirivas@flexim.com.

Select the Right Spray Nozzle

Consider several factors to determine the best choice

By Charles Lipp, Lake Innovation

SPRAY TECHNOLOGY ranges from rudimentary (a hose-end nozzle for watering lawns) to rocket science (liquid injectors in rocket engines). Hundreds of different spray nozzles are available for process plant applications. So picking the optimum one can be challenging. However, the right choice can provide important benefits such as reducing the amount of material sprayed, providing a more-consistent product or cutting energy cost.

Before getting into nozzle selection, let's first review some functions that sprays can perform:

- generating additional surface area to enhance evaporation, heat transfer or mass transfer;
- distributing material over a surface;
- dispersing material through a volume of gas; and
- producing surface impact force to better clean equipment.

Many applications require a combination of these functions to yield the desired results.

One useful way to classify spray nozzles is on the basis of their energy input, because all require energy to overcome surface tension to produce a dispersion of drops. Some nozzles rely on kinetic energy — in the form of high-velocity liquid in a single-fluid (hydraulic) nozzle or high-velocity gas in a two-fluid (atomizing gas or air atomized) nozzle. Other nozzles use mechanical energy in the form of vibration in an ultrasonic nozzle or rotation in a rotary atomizer wheel. These four types of nozzles account for the vast majority of atomizing technology used at process plants.

Single-fluid nozzle. This is the most common nozzle. A precision device, it comes in a wide variety of materials, including metals, plastics and ceramics. Fluid pressure results in a high-velocity stream of liquid at the nozzle outlet. The nozzle's design provides a specific spray angle and spray pattern; these are the first two characteristics to use to narrow the choice of nozzles for an application. The effective spray angle is the included angle of the visible boundary of the spray at the nozzle tip. The nozzle's internal components and liquid passages are used to produce a variety of spray shapes, which are known as patterns or footprints, and liquid distributions. Figure 1 depicts some common spray patterns.

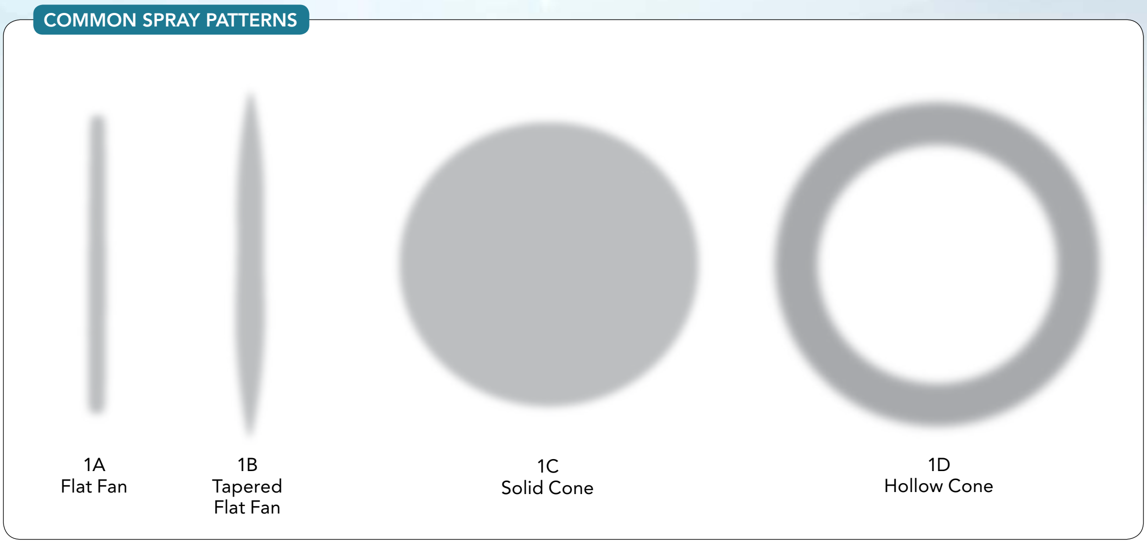

Figure 1. Nozzles use internal elements and flow passages to create the desired pattern.

You can find a number of videos showing the spray patterns and qualitative characteristics of sprays on YouTube and spray-nozzle-vendor websites. These videos clearly illustrate that sprays are three-dimensional and vary with time.

Two-fluid nozzle. This is the second most common type of nozzle. Compressed air usually is the atomizing gas but many other gases, including steam, oxygen and methane, can be used. The nozzle provides two advantages: it can spray more-viscous material, and enables the average drop size to be adjusted independent of liquid flow. The downside is that the energy input is much higher per mass of material sprayed. The hidden cost of supplying the compressed air is easily overlooked.

Ultrasonic nozzle. This nozzle is used in specialty applications where a very narrow range of drop diameters and low velocity sprays are valuable. It has significant limitations, including a low flowrate (under 20 kg/h), a maximum temperature limit on the nozzle, and a limited maximum effective viscosity of the material sprayed. The cost per nozzle is much higher than that of a single- or two-fluid nozzle with equal liquid capacity.

Rotary atomizer. This device, widely used in spray dryers, discharges liquid from the perimeter of a wheel rotating at high speed. One key advantage is that the wheel's rotational speed can be adjusted to fine-tune the average drop size. The disadvantages are that the required high-speed drive mechanism (shaft, bearings and wheel) adds cost and can pose reliability problems.

PROCESS CONSIDERATIONS

The quantitative spray characteristics your system requires depend upon the application. The most common spray parameter is the average drop size. As Table 1 indicates, different drop sizes suit different services — so, use the application as the starting point for selecting a nozzle. A smaller average drop size will produce a larger total surface area, i.e., drop surface area per volume of liquid. Because a high specific surface area is best for enhancing mass transfer or heat transfer, a fine spray is used in such cases. On the other hand, drop size

DROP SIZE

TYPE OF SPRAY	RANGE OF VOLUME MEDIAN DROP DIAMETER, D_{v50} (TYPICAL VALUE), MICRONS	APPLICATION EXAMPLES	SPECIFIC SURFACE AREA, m^2/L
Fine	100–500 (300)	Rapid gas cooling, coating	30.0
Medium	400–1,000 (700)	General process applications	8.7
Coarse	1,000–5,000 (3,000)	Liquid distribution	2.0

Table 1. The application is the first factor to consider when selecting a nozzle

is irrelevant in cleaning applications. Spray impact force is critical there. The distribution of the impact force is a key metric of performance. Surface impact force depends upon the distance between the nozzle and the surface as well as the attack angle between the spray and the surface.

It's also important to consider quantitative liquid distribution, which is called liquid flux distribution (LFD) or patternation (Figure 2). Comparing LFD data from different nozzles is useful in determining the best nozzle to achieve a uniform application of material. An array of tubes (like rain gauges) collects liquid across a spray plume (Figure 3) and then the local flux distribution is calculated as gpm/ft^2 or $m^3/sec\text{-}m^2$. The LFD data, for example, allow direct comparison of the uniformity of different solid-cone nozzles so you objectively can select the most suitable nozzle based on a specific flow, spray angle, nozzle spacing, arrangement and nozzle capacity.

DROP SIZE DISTRIBUTION

The phrase "the drop size" incorrectly implies only a single drop diameter. Spray nozzles produce a range of diameters as the photograph at the beginning of this article shows. Some sprays consist of many small drops, others contain a few large drops, while still others vary between these extremes (Figure 4). The range of sizes in a spray is often about 30:1. Back in the slide-rule days, the average drop size was the only practical means for doing engineering computations. Today, the distribution is essential in design.

The challenge is that there are a number of commonly used "averages," which sometimes are referred to as moments. The average can be created by weighting the distribution on number, drop surface area, drop volume or ratios of these. For example, the *number mean* is the simple average of the drop diameters. With the distribution shown in Figure 4, the number mean emphasizes the small drops. The *Sauter mean*, which is the diameter that represents the volume-to-surface-area ratio of the overall spray, is useful in many situations. The *volume median*, not volume mean, a weighting based on cumulative volume of the spray, is the most frequently used. Half of the total amount of liquid sprayed is

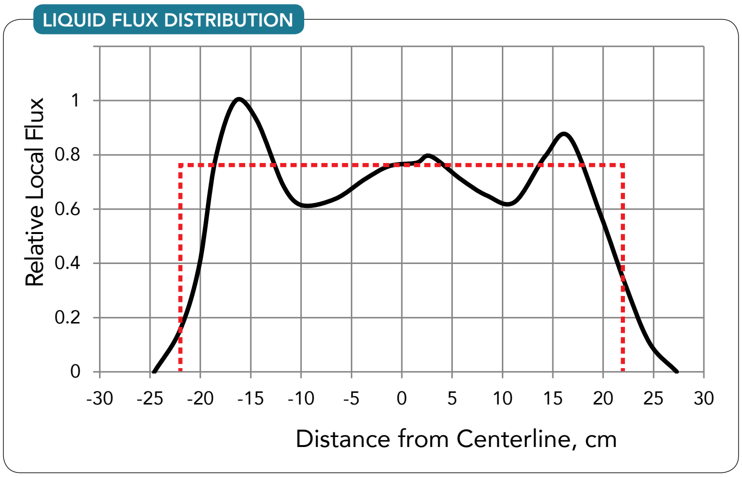

Figure 2. Graph shows an example of measured (black) versus ideal (red) distribution for a solid-cone spray pattern.

smaller than the volume median, D_{V50}, and half is larger (Figure 5). The large diameter portion of the distribution may be characterized by the D_{V90} (90% of the volume of the liquid is in drops less than this diameter). Similarly, the small fraction may be characterized by the D_{V10} (10% of the volume of the liquid is in drops less than this diameter). These three measures provide the essential information on the distribution.

The small diameter portion of the drop size distribution is a design constraint when entrainment is a critical issue. The largest drop fraction is a design constraint in many applications, for example combustion of fuels. Large diameter drops evaporate much more slowly than small drops; evaporation time is approximately proportional to the initial drop size squared. In some applications you must pay attention to both large and small drops. For instance, in spray drying a product, small drops evaporate quickly and so material may degrade because of excessive high-temperature exposure. On the other hand, large drops must reach a level of dryness to avoid adhering to the vessel walls.

Mono-size drop spray is more of a laboratory curiosity than a practical means of spraying material. Drop size distribution is important to every design. For your application, consider how small drops and large drops will affect system performance. Think of the distribution, not the average.

The drop diameter and initial velocity influence the drop trajectory. Larger drops are more ballistic, penetrating further into a flowing gas stream than the smallest drops. This can yield undesirable consequences in some cases where drops strike a wall, for example in a dry-wall quench. Drop impingement may damage the wall material due to localized thermal stresses.

LIQUID COLLECTION TUBE ARRAY

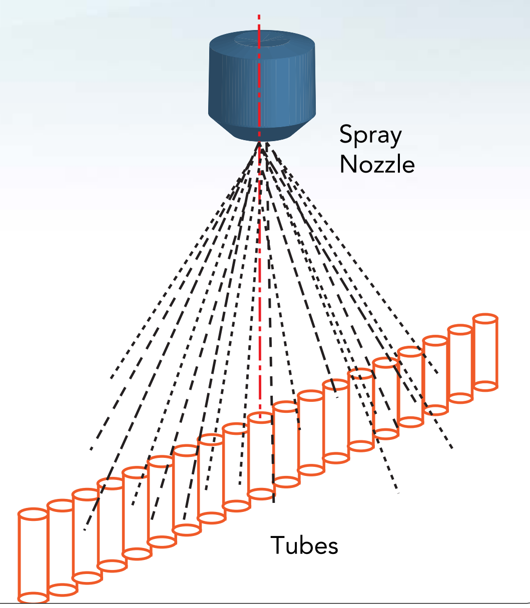

Figure 3. Measurement of liquid that goes into each tube allows calculation of liquid flux distribution.

Computational fluid dynamics (CFD) models provide complex mathematical description of the process. They use the entire drop distribution to portray the spray. These models are essential to optimize the position and spray characteristics of many applications such as gas quenching.

MATERIAL PROPERTIES

The material being sprayed influences the spray quality, especially drop size distribution. These effects are related to the physics of atomization, which is controlled by the liquid's density, viscosity and surface tension. Process applications span a wide range of liquid physical properties. Most spray nozzles are developed and characterized with

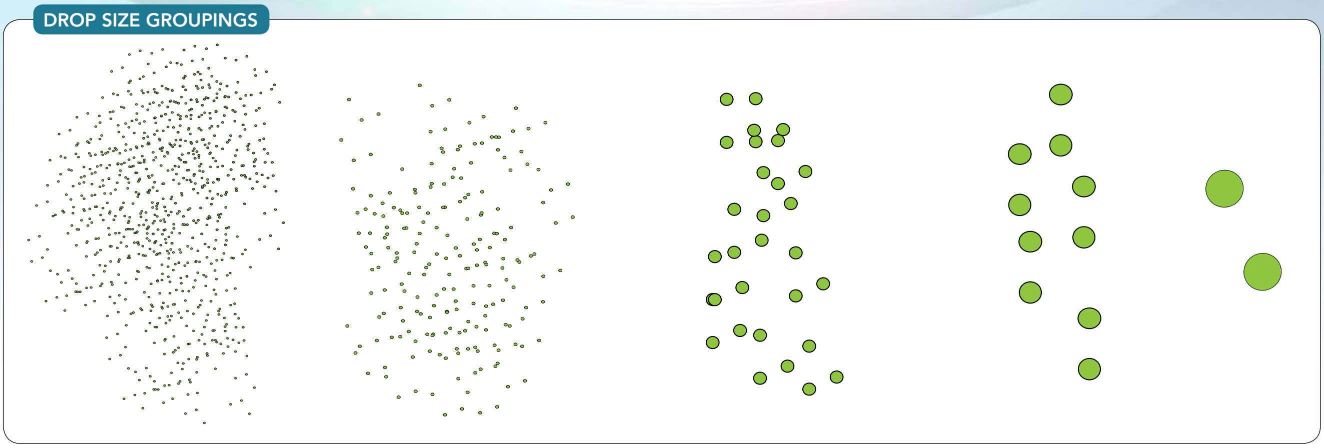

Figure 4. Nozzles can produce sprays that have different populations of droplet sizes.

water. The manufacturers of spray nozzles provide nozzle performance information on average drop size and sometimes drop size distribution based on water.

The density of liquid sprayed impacts the delivery rate. Spray nozzle vendors provide tables of flow versus nozzle pressure (pressure drop) for water. For single-fluid nozzles, there's a simple relationship:

$$F_p = F_w(\rho_w/\rho_p)^{1/2}$$

where F is volumetric flowrate, ρ is density, and the subscript w is for water and p for process liquid. For example, a liquid with a density of 10 lb/gal will flow at $(8.33/10)^{1/2} = 0.913$ or about 91% of the flow given in the vendor tables at the desired pressure. This correction often is overlooked, sometimes inconsequentially. Liquids with a specific gravity less than one have a flow higher than that listed in the tables. If a very exact flowrate is necessary, applying this liquid density correction to the flow is crucial.

Process applications in which the liquid's temperature or composition change pose an added complication. Both viscosity and surface tension vary with temperature, therefore the temperature of the sprayed material is critical. Table 2 lists a few common compounds and their physical

EXAMPLE PHYSICAL PROPERTIES

MATERIAL	DENSITY, kg/m^3	VISCOSITY, cP	SURFACE TENSION, N/m
Water (25°C)	1,000	0.9	0.075
Water (90°C)	965	0.3	0.060
Ethanol (25°C)	789	1.0	0.022
n-Hexane (25°C)	655	0.29	0.018
Glycerol (25°C)	1,264	1,010	0.062
Glycerol (90°C)	1,230	21.3	0.056
Calcium chloride,			
40% solution in water (25°C)	1,420	7.0	0.094

Table 2. Density affects flow through a nozzle while viscosity and surface tension influence drop formation.

properties. Increases in viscosity and surface tension both inhibit breakup of liquid into drops.

The most common design concern is the viscosity of the atomized material. With higher viscosity and surface tension, the average drop size increases. The effect of a tenfold increase in viscosity (from 1 cP of water to 10 cP) depends upon the specific single-fluid nozzle. The rule of thumb is to double the average drop size with this change in viscosity. Reducing the surface tension by a factor of two from water decreases the average drop size by about 25%.

Some materials, including concentrated slurries, paints and materials with polymeric components, have complex non-Newtonian behavior. Non-Newtonian fluids have effective viscosity that varies with time and the forces on the fluid. When in doubt about spraying such a material, either characterize the shear sensitivity of the material or spray the actual material. Measuring viscosity at high shear rates can be challenging, especially with slurries, because the effective shear rate in many spray nozzles is in the range of 3,000 to 30,000 1/sec. So, whenever feasible from an environmental and safety standpoint, spray the actual complex mixture.

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CUMULATIVE VOLUME VERSUS DROP SIZE

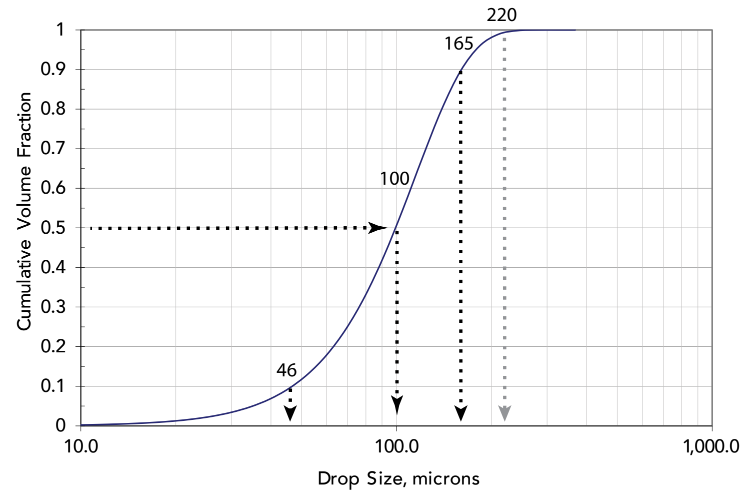

Figure 5. The drop sizes that represent 10%, 50% and 90% of the volume in the spray provide essential information on the distribution.

CHOOSE CORRECTLY

The critical word in describing sprays is distribution: distribution of drop diameters and distribution of liquid across a spray pattern.

The critical fluid properties are liquid viscosity and surface tension. This information is essential to effectively select the optimum spray technology and nozzle for an application.

Spray nozzles are used in rocket science but picking most nozzles for process applications involves engineering science and technology — not rocket science. ●

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Note: This article is based on the author's book "Practical Spray Technology: Fundamentals and Practice," which is available through lakeinnovation.com and Amazon.com.

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Resist the Temptation

One option to infer internal flow rate in a column rarely makes sense

By Andrew Sloley, Contributing Editor

SOME PROCESSES reward close control of liquid and vapor rates inside distillation columns. Conventional control approaches use a variation of flow metering based on either imposing a pressure drop inside the tower or drawing the stream out of the tower, metering it, and returning the stream to the tower (see: "Get Some Inside Information," http://goo.gl/g3DNja and "Ease Measurement of Column Internal Flow," http://goo.gl/Aqq2kJ).

Analysis of system fundamentals might suggest a different approach. Figure 1 illustrates a conventional distillation tower. Any heat and material balance (HMB) envelope must have energy in equal to energy out and mass in equal to mass out. Figure 1 shows the HMB envelopes drawn through the tower. An internal vapor stream and an internal liquid stream both cross the HMB boundaries.

With sufficient data, you can solve the heat and material balances to calculate the internal streams, which, in this case, are the mass of the calculated vapor, M_v, and the mass of the calculated liquid, M_l. You can calculate either stream from analysis of the upper HMB or the lower HMB. The decision to choose between the upper and lower balances depends upon availability of plant data and data accuracy.

The material balance for the upper section is:

$$M_f + M_{cv} = M_{cond} + M_v + M_l + M_{cl} \qquad (1)$$

where M is mass flow, f is feed, cv is the calculated vapor stream, $cond$ is condensate, v is vapor product, l is liquid product and cl is the calculated liquid stream.

The energy balance for the upper section is:

$$Q_f + Q_{cv} = Q_{cond} + Q_v + Q_l + Q_{cl} \qquad (2)$$

where Q is energy flow, which equals the stream enthalpy, h, times its mass flow rate and allows for substituting $M_i h_i$ for the stream energy flows.

With some algebra, we get an equation for calculating the internal liquid rate, M_{cl}, from the top HMB:

$$M_{cl} = [Q_{cond} + M_{cv}(h_v - h_{cv}) + M_l(h_l - h_{cv}) + M_f(h_{cv} - h_f)]/(h_{cv} - h_l) \qquad (3)$$

and an equation for calculating the internal liquid rate from the bottom HMB:

$$M_{cl} = [M_b(h_b - h_{cv}) - Q_{rebl}]/(h_{cl} - h_{cv}) \qquad (4)$$

where b is bottoms and $rebl$ is reboiler.

None of these HMB calculations violate any engineering basics. However, while accurate, are they useful?

Most occasions requiring tight control or measurement of internal liquid rates arise from large incentives from either:

- operating at close to minimum reflux; or
- operating at close to minimum or maximum equipment capacity.

Drivers for operation at close to minimum reflux include high energy prices and extremely different values between the overhead and bottoms. When the product value differences are high, the purpose of the distillation column is to remove a trace contaminant but with a minimum slip of the high-value product into the low-value one. This is a process consideration driven by system behavior (relative volatility, compositions, stages available) and economics.

Drivers for operation at close to equipment limits normally are capacity and equipment performance. Flooding sets an upper capacity limit on equipment. For trays, either vapor handling or liquid flow regime on the trays may determine the lower capacity limit. For packed beds, liquid distribution quality at low liquid rates usually establishes the lower limit. This is a hardware consideration driven by the installed equipment (diameter, device type as well as fabrication and installation tolerances).

Let's now consider whether the flow rate equations actually are useful for controlling the stream rates very close to an "optimum" value. Equation 5 summarizes the situation:

Flow rate = (large number - large number)/ (medium number - medium number) (5)

Both subtractions include potential errors in measuring composition, flow rate and temperature.

You must calculate stream enthalpies based on stream compositions, flow rates and temperatures. Calculation of condenser duty and reboiler duty must be based on utility flow rates and temperatures. My experience is that as long as the column products remain on-specification the effect of composition errors is small on the calculation.

In contrast, the effect of flow-rate and temperature measurement errors often is large. Routinely, the possible error exceeds 100% of the calculated value. Often, an arbitrary offset is added to prevent negative flow rates from being calculated. These arbitrary offsets indicate a fundamental flaw in the logic of using the HMB approach.

All control systems that use the difference between two large measured values as a target require high-precision measurement. For example, if the internal liquid rate is 10% of the feed rate and the control objective is to restrict the variation in the internal liquid rate to 1% of the feed rate, what's the likelihood of success? It's a rare plant flow meter that has a precision higher than 1% of the flow rate. Most standard thermocouples offer roughly 0.75% accuracy. The combined impact of flow-rate and temperature measurement errors makes precise control difficult.

DISTILLATION TOWER

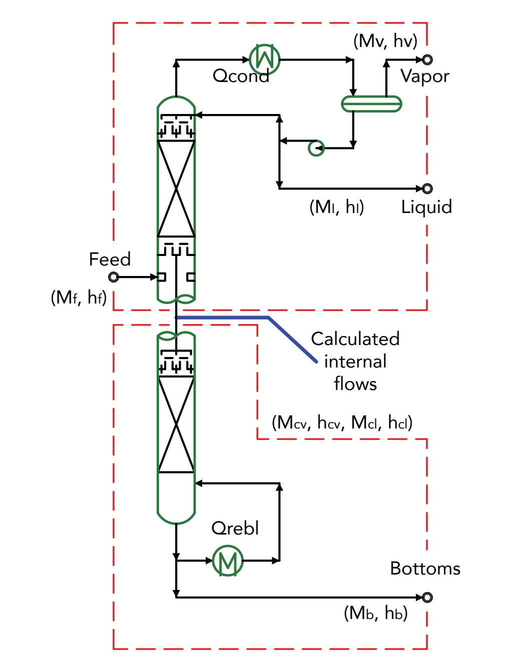

Figure 1. An internal vapor stream and an internal liquid stream both cross the heat and material balance boundaries.

I routinely see controllers with liquid rates targeted at 3.0±0.3% to 5.0±0.5% of the feed rate. The calculations routinely generate negative flow rates. They can't have a relative accuracy of 10%!

The HMB calculation for internal liquid rates obeys the laws of physics. However, the situation that makes knowing the internal rates most important usually is when the rates are very low. This demands extremely precise flow and temperature measurements. Plant instrumentation rarely can meet these requirements. Unless every other choice simply is unacceptable, don't opt for HMB calculation methods to infer internal liquid rates. If you must use them, conduct statistical checks to confirm their suitability and expected value.

ANDREW SLOLEY, Contributing Editor
ASloley@putman.net

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Using Coriolis mass flowmeters provides reliable indication of gas entrainment

By Jack Roushey, KROHNE, Inc.

ENTRAINED GAS can disturb the sensitivity of mass flow measurement of liquids, decreasing accuracy or even stopping measurement completely. New Coriolis mass flowmeter technology has come on the market that ensures both stable and uninterrupted measurements with high gas content. The new meters, including KROHNE's OPTIMASS 6400, offer reliable indication of gas bubbles in the process by using a combination of various measurements to detect a two-phase flow. With values between zero and 100% gas or air content in the line, it maintains continuous mass density measurement and provides measured values at all times. At the same time, it can report the two-phase status and output a preconfigured alarm, in accordance with NAMUR NE 107 requirements.

WHAT IS GAS ENTRAINMENT?

Gas entrainment refers to the presence of gas bubbles in a process. It can occur for many reasons and particularly in terms of sensitive dosing processes, it causes aggravation and headaches for users. Gas bubbles can form, for example, due to degassing; leaks upstream of, or in, a negative pressure area; excessive cavitation and levels falling below the minimum in supply containers; as well as agitators in tanks or long drop distances for media into tanks. However, they can also occur due to status transitions in process control, such as when starting or shutting down the system, or cleaning it.

Other examples include production processes in which gas bubbles are introduced deliberately and the gas flow is measured upstream of the sprayer. This can happen, for example, in the production of shower gels, or processes in which the bubbles are used for control purposes.

The effect of gas entrainment shouldn't be underestimated, because it affects process control measurements and thus results in unreliable product quality. Because of this, NAMUR recommendation NE 107, "Self-monitoring and diagnosis of field devices" for Smart flow measurement processes classifies the presence of entrained gas as an error condition in the highest category, Category 1.

On the other hand, some in the industry caution against making this a bigger problem than necessary, arguing that gas entrainment actually occurs in significantly fewer processes than measurement devices might suggest. "Gas bubbles in chemical processes are one of the most frequent reasons that system operators call service employees to test a supposedly faulty device," explains Frank Grunert, Global Product Group Manager for Coriolis mass flowmeters at KROHNE.

"The user is often astonished to find that the meter is measur tent can be discovered based on the saved density changes."

GAS ENTRAINMENT MEASUREMENT TECHNOLOGY

The reason for these measurement difficulties stems in part from gas measurement technology used. From a measuring technology standpoint, gas entrainment is considered a liquid-gas flow, one of the most frequently posed a great challenge for Coriolis mass flowmeters. The relative movement of the different phases damps the vibration of the measuring tube, and this damping leads to inconsistent vibration amplitudes of the measuring tube. These inconsistent amplitudes then interfere with the electronics' capability to determine the actual resonant frequency of the measuring tube.

In addition, the damping effect caused by the gas content in the liquid in the electro/mechanical driver system of the Coriolis mass flowmeter can be larger than

Figure 1. Newer Coriolis flow meters can more accurately detect gas entrainment and changing process conditions.

observed forms of two-phase flows. Many measured values are required to characterize a two-phase flow, including the percentage volume of the dispersed phase in the continuous phase, the densities of both phases, the morphology (size, shape, distribution) of the dispersed phase that occurs, the viscosity of the continuous phase, the operating pressure and the surface tension of the continuous phase.

Liquid-gas flows demonstrate very different characteristics, and currently there's no measuring principle that can measure all of the parameters. A combination of various measuring principles helps to create a better description of these flows, but the technical effort and expense for such a system would be quite high.

The Coriolis mass principle is very well suited for detecting gas entrainment because it precisely recognizes mass and density changes in the measurement substance. However until recently, gas entrainments the driver input power. If the vibration of the measuring tube can't be maintained, the result, in an extreme case, is the interruption in measurement.

RELIABLY DETECT PROCESS CHANGES

Fortunately, new technology is now coming on the market to counteract both these effects. For example, KROHNE recently developed the OPTIMASS 6400, which detects and signals gas entrainment reliably and maintains the active measurement in all measuring conditions with gas content from zero to 100% by volume. The device is "gas bubble resistant." The measuring sensor and signal converter were designed to offer complete digital signal processing, from the production of the drive oscillation of the measuring tube to the evaluation of the sensor signals. In this way, it's possible to reliably detect changes in the process and to accurately indicate the actual conditions in the production line.

For many years, digital signal processing has been used in Coriolis mass flowmeters, but initially, it was used only in the evaluation of the sensor signals. Until recently, an analog signal circuit was used for drive vibration that amplifies the measured resonant frequency of the measuring tube and returns it to the measuring tube as an impulse signal.

Figure 2. The OPTIMASS 6400 is not affected by crosstalk.

In the case of gas bubbles, the vibration signal is disturbed due to the transients in the damping and the density of the medium. With the analog drive system disturbance recorded and amplified, the impulse signal is disturbed as well. This means a loss in output because the excitation only occurs in the resonance of the measuring tube, which is not efficient, and also leads to a fault in the frequency measurement. Both end up increasing deterioration of the measurement of the tube oscillation and, as a result, the mass flow measurement. They also risk losing control of the driver system, which requires a restart of the meter before measurement can be restored.

The new technology used in the OPTIMASS 6400 has a synthetic driver oscillation and high resolution digital signal processing: the oscillation is produced using a digitally generated and therefore known impulse frequency. The measuring tube oscillation occurs due to this impulse, so the frequency of the measuring tube is known precisely. This connection doesn't change, even with gas bubble disturbance. The control loop remains "clean" and isn't disturbed by interspersed and amplified frequencies. In this way, the OPTIMASS 6400 can accurately measure amplitudes and phases, even in disturbed conditions, and regulate them in the resonance. The device remains in continuous measuring operation, even if there is gas content or air pockets of 0 to 100% by volume in the medium.

Different indicators for gas bubbles are set in the signal converter, which use cross-sensitivities to combine two or more indicators for a reliable diagnosis. According to NAMUR NE 107, the most important requirement is that the results of the diagnosis be reliable, so that the user can take the correct actions.

For many users, a crucial criterion for selecting a measuring device is the accuracy with which it measures the occurrence of gas bubbles. Despite the advances in technology, practice demonstrates that even with these devices, gas bubbles cause changes in the processes. This results in variations of accuracy with mass flow measurement, depending on the process conditions and the system operation of interest to the customer. In addition, gas bubbles can vary widely in size and frequency of occurrence. Likewise, there are changes in temperature, pressure or viscosity that need to be considered. Therefore, users still have to be cautious regarding accuracy of the various available measurements in indicating the occurrence of gas bubbles and changing process conditions.

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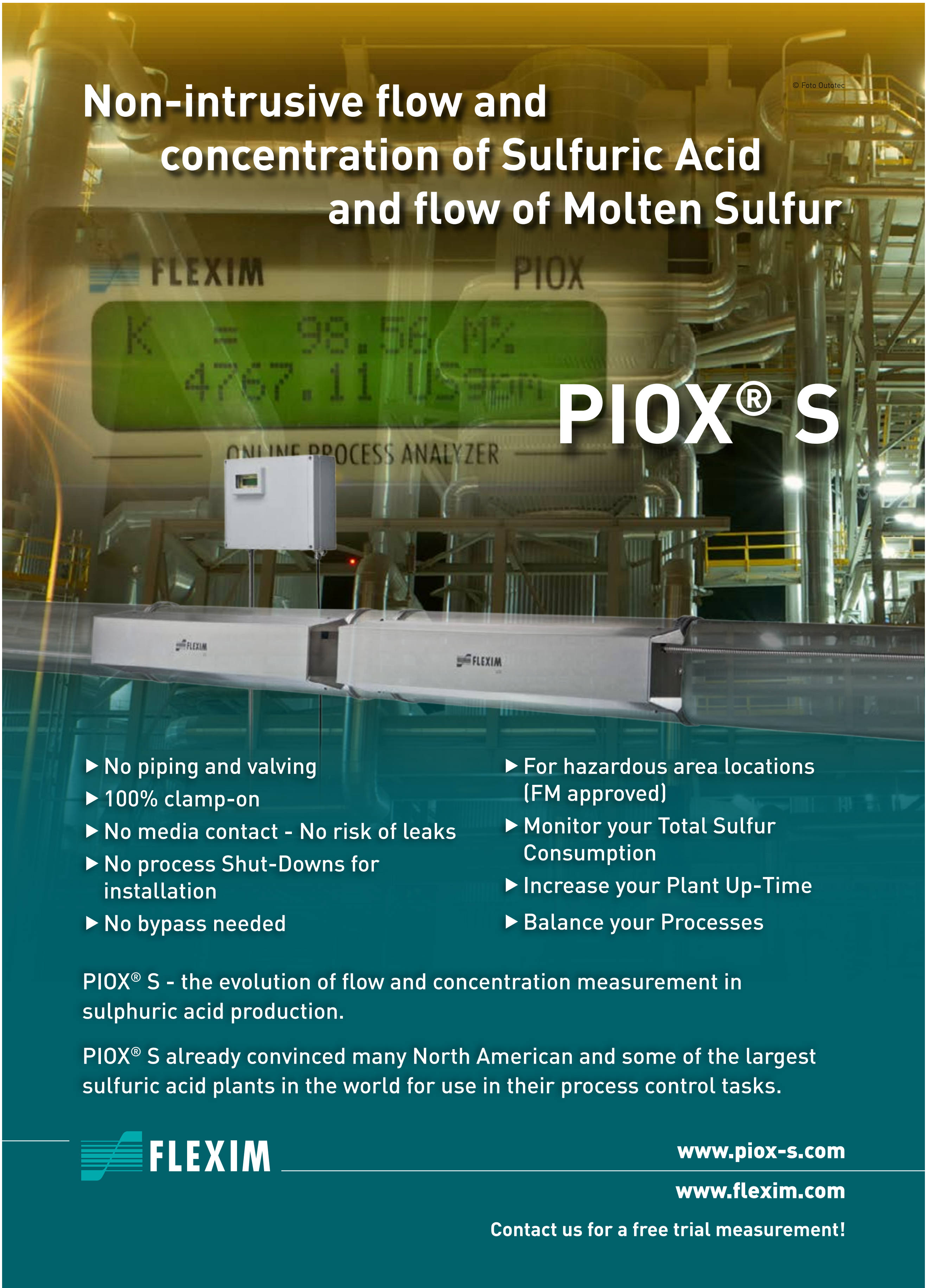

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Case Study: Speed Pipe Installation

Pipe-joining system eliminates need to weld or thread connections

VIP PLUMBING of Cleveland, Ohio, used press fittings to make water- and air-tight connections when installing a stainless system at Royal Chemical's Macedonia, Ohio plant. VIP installed approximately 3,000 ft of 316 stainless steel pipe for use with chemical processing equipment.

VIP Plumbing specializes in residential and commercial service, new construction and remodeling throughout northeastern Ohio. The ability to easily press stainless steel opened the door for VIP to install new chemical transport lines for Royal Chemical. The company had worked with Royal Chemical to install plumbing for a new bathroom as well as water and gas lines at its Twinsburg location. When Royal Chemical wanted to replace existing process piping for chemical transport between its storage tanks and mixing tanks with stainless steel pipe, as well as add additional processing lines to its facility, VIP was able to offer quick, flameless installation using Viega ProPress.

Viega ProPress uses press fittings to make water- and air-tight connections. The system comprises stainless steel pipe, valves and fittings in sizes up to 4 in. It takes less than seven seconds to make a pressed connection, compared to more than an hour for some threaded and welded connections. Its Smart Connect feature helps installers easily identify unpressed connections.

"If Royal Chemical had wanted welded stainless steel, we wouldn't have been the ones to do the installation. VIP Plumbing would not have even submitted a bid on the project if it had to be welded," says Paul Episcopo, president of VIP Plumbing. "By using pressing to join the piping, the labor was cut at least in half. Royal Chemical didn't have to shut down its operation and it was easier to get the pressing tool into smaller spaces where welding would not have been an option."

The process line installation at Royal Chemical was the first project where VIP used Viega ProPress for stainless. The company previously had rented the pressing tool for various copper tubing installation projects to increase time savings or use in environments where water couldn't be shut off for long periods of time.

"For this project, purchasing the pressing tool was a good investment for us and it's also opened up our capabilities to include work on stainless

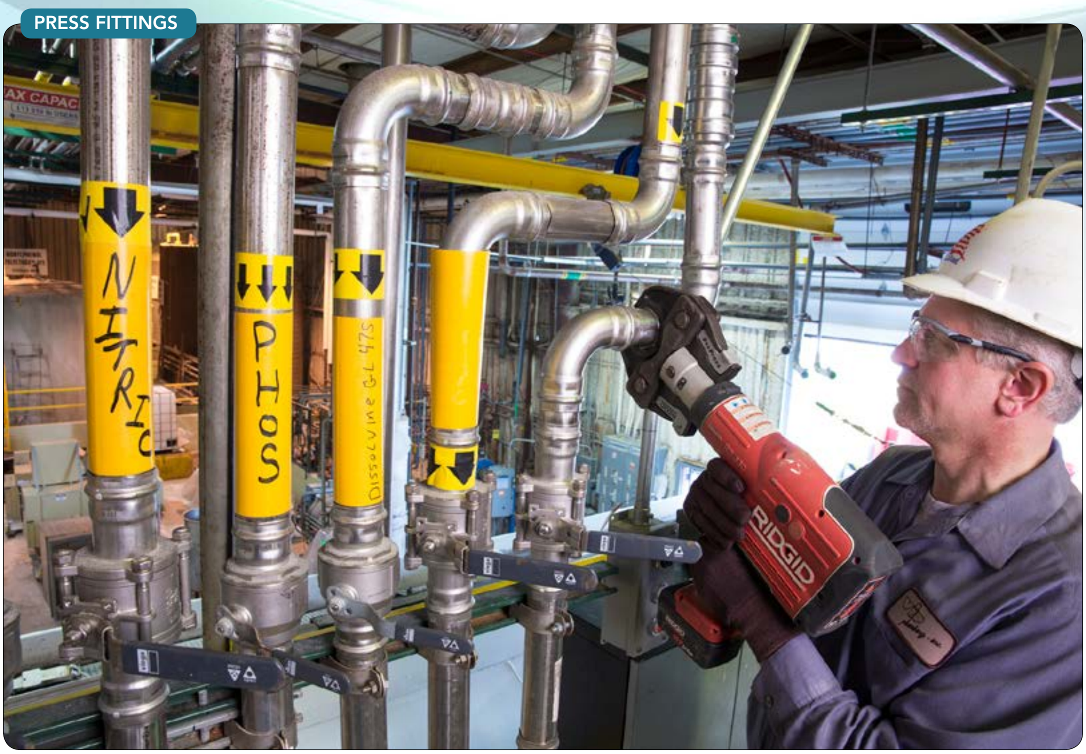

Figure 1. VIP Plumbing used press fittings to make water- and air-tight connections when adding and replacing process lines in a chemical facility.

steel systems," explains Episcopo. "It's convenient now that we have the tool — we have done other projects with pressing and we can use the same tool on multiple kinds of pipe."

MATERIALS MATTER

VIP installed 2 in. to 2½ in. Viega 316 stainless steel lines for five mixing tanks and used approximately 130 fittings including tees, 90º and 45º fittings, couplings and 12 three-piece ball valves which are a new addition to the Viega ProPress for stainless product line. The valve features a three-piece construction with a full-port ball that can be removed for repair and maintenance without removing the press ends from the system. It also features an ISO pad for actuation.

"The original valve that we installed on the nitric acid line didn't work correctly. Our Viega rep introduced us to the new three-piece ball valve that worked perfectly," says Rocky Iammarino, the plumber who performed the work at Royal Chemical. "The three-piece ball valve was perfect for the corrosive chemicals, like the nitric acid. It can be locked and if any of them ever need to be fixed, the valves won't have to be taken out."

For the installation, VIP used a combination of fittings with the standard EPDM sealing element and the FKM sealing element for increased resistance against corrosive chemicals.

"Because Royal Chemical transports caustic chemical through the lines, we knew that they needed fittings with highly chemical-resistant sealing elements," says Episcopo. "We worked with our Viega representative to make sure that the sealing elements were approved for use with the specific chemicals used on those lines."

FLAMELESS INSTALLATION

Viega ProPress for stainless proved to be ideal for Royal Chemical's needs due to the chemical resistance of the materials, as well as the safety and time-savings the flameless aspect of the system offered.

TIGHT SPACE

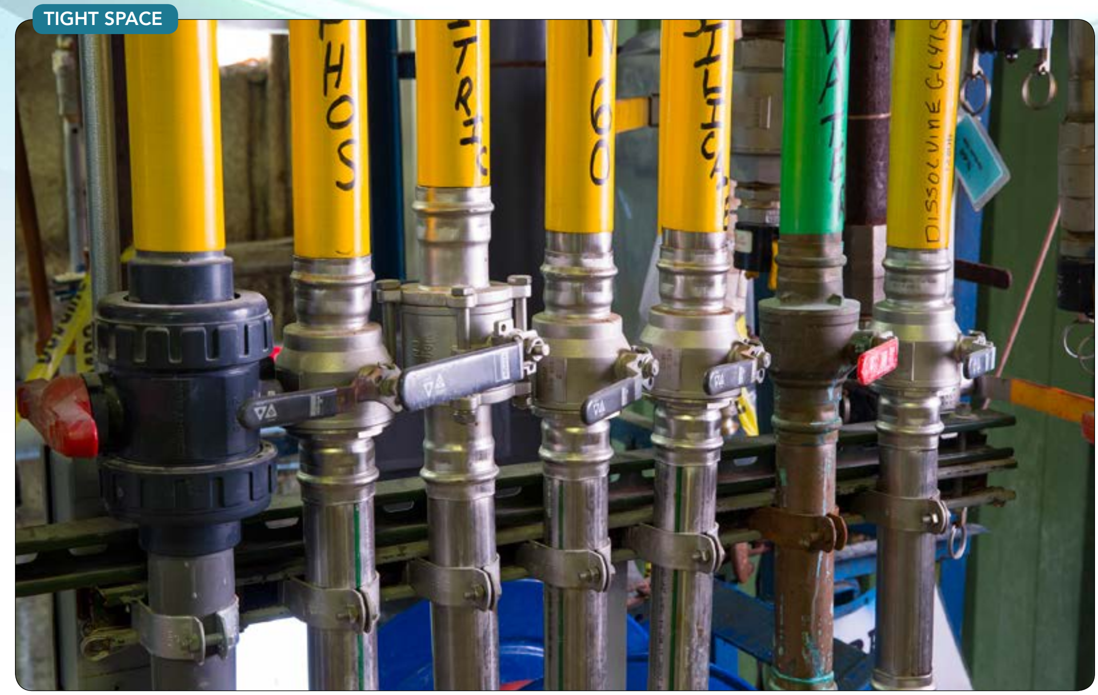

Figure 2. The pressing tool could get into smaller spaces where welding would not have been an option.

"By using Viega ProPress on this project, we kept Royal Chemical from having to shut down for long periods of time and avoided the need for hot permits that would have been required if the pipe had been installed with welding," notes Episcopo.

During the first phase of the installation, Iammarino installed support brackets and five new lines to replace the original welded stainless steel lines as well as sagging PVC lines. In other phases of the project, approximately 12 lines were installed.

"With all of the supports in place, installing the stainless steel piping is extremely quick," says Iammarino. "We could work around everyone at Royal Chemical and they were able to keep their facility running during the entire process. With the caustic chemicals, a welding installation was out of the question, and threading the pipe would have been much less flexible and more time-consuming."

"Royal Chemical looked into a variety of different materials for their lines. Since the plant is composed of primarily stainless steel for its other systems, it was an easy decision to select 316-grade stainless pipe and fittings for the new lines," Iammarino adds. "Even though it was our first time using Viega ProPress on stainless pipe, we had used it on other pipe material and knew how it worked."

"The security against leaks that the system provides is extremely important with chemical transporting," notes Iammarino. "I was alerted to a fitting that hadn't been pressed yet with the Smart Connect feature that ensures no fitting is left unpressed, and after that fitting was pressed, we pressure tested the lines and there weren't any leaks."

The flameless pipe-joining system allowed VIP to not only complete the installation of the chemical transport lines but also established the company's capabilities in the industrial market. "We are looking forward to getting involved with additional commercial and industrial projects that involve stainless and may not have been in our repertoire prior to our experience with Viega ProPress for stainless," says Episcopo.

VIEGA, headquartered in Wichita, Kan., manufactures press technology that provides an alternative to traditional pipe joining methods such as soldering, welding and grooving. For more information, visit www.Viega.us or call 800-976-9819.

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