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Flow Measurement Spring 2020





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Going with the flow

Advances in inline blending offer fresh opportunities to optimize profits.

by John Rezabek

The last gasoline blender upgrade was a decade or more in the past, and once again claimed millions in benefits thanks to controlling the blend so precisely that giveaway was next to nothing. Giveaway, simply put, is shipping a fuel that exceeds the specifications. By blending gasoline precisely on spec, a refinery can minimize the proportion of valued and less abundant (e.g., high octane) components, and maximize the amount of cheap components (i.e., butane), which are extremely profitable to sell as gasoline. Millions are claimed for shaving the spec a tenth one way or the other.

Many of us who ascribe a price or a premium for quality might be dismayed that so much effort and attention is paid to delivering the very least the specification allows. But blending a fuel or synthesizing a commodity chemical differs from, say, manufacturing a car. There are few secrets and the products are virtually interchangeable. In a commodity business, the enterprise wins through volume, reliability and efficiency.

Many of the largest fuel producers blend directly to a pipeline, which in turn ends up in terminals where the petrol is combined with ethanol and other additives before shipping to retail outlets. Keeping this substantial stream of precisely blended fuel on specification requires the same of the instruments providing flow control and online analysis. While an off-spec tank at a terminal can sometimes be “doctored” to correct an octane or vapor pressure deficiency, it’s still a substantial disruption to the quickly consumed inventory.

For decades, the turbine flowmeter has been the staple of gasoline and similar blending operations. It's a positive-displacement, volumetric meter that relies on a spinning turbine immersed in the flowing stream. The turbine meter is innately digital—the raw signal is the frequency generated as a transducer (e.g., magnetic pickup) effectively counts the blades spinning by. The frequency is directly proportional to volumetric flow. But such simplicity is complicated by its mechanical design—bearings immersed in a flowing stream will eventually wear out and fail, so meters are routinely pulled or exchanged for freshly calibrated sensors. Straight runs are required to ensure a symmetrical flow and limit turbulence, and the streams must be filtered to prevent entrained particulates and other flotsam from corrupting the precision-engineered vanes and bearings. Each stream must be reliably single-phase (all gas or all liquid) and the flowing temperature (and pressure for gas applications) must be monitored to account for the density of the stream.

While it sometimes seems like refinery cultures cling to past practices, the more modern Coriolis flowmeter can help ensure a blender upgrade's million-dollar return-on-investment is realized. Particularly when integrated over fieldbus, Ethernet, or equivalent high-speed and time-sensitive digital network, Coriolis meters equal or exceed the turbine meter for accuracy and

turndown. Innately digital (measuring frequency and phase shift resulting from the Coriolis effect, the Coriolis meter requires no straight run, and diagnostics can immediately detect two-phase flow or blockage.

The Coriolis phase shift is directly proportional to mass flow, and the characteristic frequency of the meter tubes can repeatedly measure density to three or even four decimal places. For the optimum accuracy and turndown, a line-size reduction is not uncommon, and dual-tube meters will further reduce the effective line size as the fluid passes through the meter body—hence the pressure loss can be higher and might be a limiting factor. Different face-to-face dimensions will most likely require some piping modifications; and improper pipe alignment causing twisting or bending torque on the flow tube should also be avoided.

In recent years, Coriolis specialist Micro Motion has introduced a feature they call Smart Meter Verification. Especially useful in a blending application, it allows validation of a sensor in the line without having to remove it for recertification.

Especially in large line sizes, Coriolis meters are far from the least expensive solution. But their capabilities and features in a digitally-integrated blender have potential to justify the premium.



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Slurry flow measurement

Even ordinary process fluids can present problems due to suspended solids.

by Ian Verhappen

Flow measurement is important, especially when it's a custody flowmeter that's also the cash register. Obviously, there are many standards related to accurate flow measurement, including upstream and downstream straight-run rules to assure a nice, clean profile through the meter.

But very few process streams are 100% single-phase, with most having either small bubbles or low levels of solids. These are normally suspended close to homogeneously, so the fluid still behaves as if it were single-phase, therefore not affecting the measurement. Once they start having a noticeable number of solids—less than 200 microns primarily by accident, non-settling slurry with specific gravity less than 1.05, and less than 5% solids by weight—streams are considered a “light slurry.” Most of the time, until the second phase constitutes a significant percent of total fluid fraction, the fluid can be treated as a single phase.

Low levels of solids may be (and likely are) present in your process, even though you don't think so. If your flowmeter is downstream of a catalyst bed or some other process vessel with solids, chances are there will be some carryover, particularly during startup. Similarly, almost every well will contain some level of entrained solids, which normally continue with the liquid stream until they're removed in dedicated vessels. However, during different stages of plant operation, such as startup and shutdown, when the stream is at other than steady-state, even low levels of solids can have an impact.

Suspended solids at low levels that will not affect a single-phase measurement (other than perhaps higher wear) may not always stay suspended, especially if the flow is stopped. Without the fluid velocity to keep them in suspension, they will settle to the bottom of the pipe. This may affect a wide range of flowmeters, especially if they have some part of the sensor in this position. Therefore, if you suspect solids may occur, it's always a good idea to rotate your meter or impulse line by one bolt hole to keep sensitive parts of the instrument away from settling materials.

In many cases with a light slurry, some meters will no longer work and the application will require special meters to handle the solids. Typical flowmeters used for slurry streams are ideally non-intrusive or venturi because they have less sudden change in the flow path. When using a venturi meter to measure a slurry that's severe due to either the type or size of solids, the meter internals are often coated with a hardened material, which adds roughness at the sacrifice of accuracy, or is fitted with a hardened cast lining that can be replaced when the accuracy falls below what's acceptable. Fortunately, these meters are rarely used for custody transfer, but more for plant balance and simple regulatory control.

The above examples apply for light or even medium (5-20% solids) slurries.

However, in mining, "real" slurries with targets of close to 40% solids are often used in hydro transport technology where the solids are mixed with water and transported via pipeline relatively long (tens of miles) distances. One variable that needs to be controlled with hydro transport is the solids ratio, to prevent settling while still minimizing the amount of water being recycled.

Oil sands mining takes this concept one step further by going from two-phase, solid/liquid flow to four-phase flows of vapor(air), bitumen, water and solids (4-in. to micron size), where it's necessary to maintain both the solids content as well as the air content in the line. The good news is that with the help of industry and oil sands researchers, this has been done reliably for many years. The how is a story for another day, though I did enjoy working in this challenging environment.

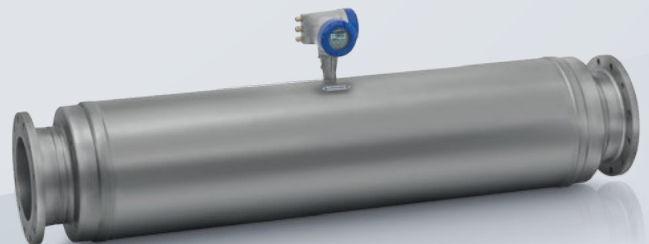
Like many other field sensor applications, flow may seem relatively straightforward. However, like many other parts of our industry, there are also many ways for the process to be "not as it appears," and as a result, the opportunity arises to excel or fail miserably. Small details, such as low solids concentrations, can have a significant impact on your measurement—even though the stream may not be considered a slurry.



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Knowing the best is the best

Understand the details to be sure you're specifying the right flowmeter.

by Greg McMillan

Greg: We often forget that the performance of equipment is in the care of the automation system that is the window into the process and the means of affecting the process. It starts with the measurement. You can only do as well as what the measurement tells you. Despite the process being in the critical care of the measurement, we may obsess over project budgets, losing sight of the bigger picture. The instrumentation is typically less than 10% of the cost of the equipment and piping, yet we see projects cut corners from misguided goals based purely on hardware cost.

Here, we look at flow measurement with the insight that the process is defined and manipulated by the mass flows as seen on the process flow diagram (PFD). While volumetric flows may be useful, mass flows define the material balance for changes in production rates and operating conditions, plus the process gains derived in Appendix F of my ISA books (e.g., 101 Tips for a Successful Automation Career).

There are many mass flow measurements, but most depend on adding temperature and pressure measurements, and assume a constant composition, often not realized by the user or in the process. A composition of each stream being exactly what's shown on the PFD is a rare occurrence. The fact that processes aren't perfect is reality, and is why process control systems are so valuable.

The Coriolis meter offers a true mass flow measurement with extraordinary accuracy and rangeability, particularly for liquid flow measurement, independent of chemical concentration, density and viscosity. The accuracy can be as good as 0.05% of rate for liquid flow with a rangeability of 200:1. Additionally, the density measurement offered is as good 0.1 kg/m³ for measurements between 300 and 5,000 kg/m³. For streams where a single component has a density that's quite different than the solvent or other component, the density provides a fast, reliable measurement of component concentration.

True mass flow measurements are critically important for control of many other types of process equipment besides reactors, such as crystallizers, evaporators and distillation columns. The Coriolis flowmeter provides this capability up front, and retains this capability, holding its calibration despite many adverse situations. There are no upstream or downstream straight run requirements and basically no maintenance requirements. While the upfront cost is higher, the lifecycle cost is typically less, particularly when you consider the cost of maintaining impulse lines. If you consider the impact on process efficiency, the extraordinary accuracy and rangeability, and a true mass flow measurement, translates into an incredible return on investment.

While the Coriolis flowmeter is far less susceptible to problems, it's useful to explore possible effects to gain confidence and justification for future applications and to alert the user to the special cases where this extraordinary performance is threatened. "Knowing the best is the best" is my goal. I'm impressed how technical advances seen in Smart Meter Verification (SMV) for smart meters can help us in this path. The following conversation is offered to gain insights on SMV capability and achieving the best by Tom O'Banion, director of chemical industry innovation for Emerson Automation Solutions.

Tom, what are effects of corrosion and erosion?

Tom: Although rare in practice, corrosion causes a thinning of the tube, which in the short term usually causes the meter to over-register (mass flow) and under-register (density). The thinner tube twists a bit more (so the flow reading is now biased high), and the frequency increases (so the meter thinks the fluid density has gone down). SMV can "see" this happening before the sensor tube integrity is affected. The goal is to get that meter out of service before a (very rare) tube breach could occur. Erosion also thins the sensor tubes with virtually identical effects as corrosion. In both examples, it's difficult to predict how uniform the corrosion or erosion is, so there's no 1:1 correlation to accuracy.

Greg: What is the effect of coatings?

Tom: Tube coating in general does not affect mass flow very much, but it does affect the density reading, and thus, concentration measurement and volume flow (Coriolis volume flow = mass/density). Coatings tend to be denser than the fluid, but it varies. It's more difficult to detect, but our new SMV Professional has a coating detection feature. If the coating is uneven, then it's relatively easy to see. If it's highly uniform, then we also examine other variables from the meter (drive gain, density trend) to ferret out what's happening.

Greg: What is the effect of freezing?

Tom: Freezing (water) will cause swelling of the tubes, and thus, an increase in stiffness. This will cause the flow reading to under-register (tubes twist less for a given amount of flow because they're stiffer). In addition, the effect on density is difficult to predict, but accuracy will be degraded. It should be noted that, in most cases, the meter is permanently damaged.

Greg: What is the effect of gas bubbles in liquids?

Tom: We've done a lot of research on two-phase flow over the past 15-plus years. It's a complex fluid interaction. Small amounts of gas and good mixing cause only small accuracy degradation. Larger amounts of

gas, whether it's well mixed, bubbles or actual gas slugs, cause more adverse effects on flow and density accuracy—the gas and liquid decouple from the tube vibration, causing larger errors due to a velocity of sound effect.

Improved two-phase flow measurement ability is a big subject in industry, and so our research continues. We have a few software options that help mitigate the effect. Advanced Phase Measurement is one prominent one. It reads the last “good” values for density, and uses that to “steer” through the chaotic and periodic periods of substantial gas bubbles.

Greg: What is the effect of liquid droplets in gases?

Tom: Liquid or “wet” gas has a somewhat similar effect as gas bubbles in a liquid stream. The liquid tends to stream down the tubes, dampening some of the vibration, causing density to over-read. Flow and density readings may become erratic and less accurate.

Greg: What's the effect of poor installation?

Tom: In the early days of Coriolis (pre-1990s), installation was more critical, as some designs were sensitive to pipe mount, stress and cross-talk. These have largely been eliminated. The most common field issue I've seen recently involves the meter

not staying full of liquid, or trapping bubbles, or trapping liquids in a gas application. It's a piping design challenge, usually easily rectified. Occasionally we see a meter under large axial or radial forces, and the meter zero is shifted.

Greg: Can we put Coriolis meters in series and parallel?

Tom: Absolutely! Two applications are safety instrumented systems (SIS) and large flow-rate applications. Large fiscal transfer



TOP 10 THINGS YOU DON'T WANT TO HEAR ABOUT FLOWMETERS

- (10) The stream composition, density and flow must be exactly what are on the PFD.
- (9) Meter sizing was so easy; we just went with line size meters everywhere.
- (8) We put flowmeters at the high point in the line to make sure they are empty for maintenance.
- (7) We put flowmeters in the pump suction to reduce the required pressure rating.
- (6) We standardized on the same materials of construction for all applications.
- (5) My impulse is to use impulse lines.
- (4) What is a Coriolis meter?
- (3) If we get a reading during water batching, we are all set.
- (2) Who needs turndown and ratio flow control?
- (1) We must minimize instrumentation costs.

stations often rely on multiple large Coriolis meters in parallel. I've seen applications in 30-in. crude oil lines require four or more large Coriolis meters. They're known for working well in high-accuracy, custody-transfer conditions.

Greg: Could we temporarily insert a Coriolis meter to verify the calibration of other meters, or to find the real density for their calibration?

Tom: Yes, our meters are often used in regulated industries such as food & beverage and life sciences, where master meters are installed on portable carts and moved around plants, calibrating other meters. These masters are available with full ISO-17025 NIST traceability. On a side note, customer needs still include a clamp-on Coriolis, to measure mass flow and hopefully fluid density. It's still a "gleam in our eye," but very challenging to do.

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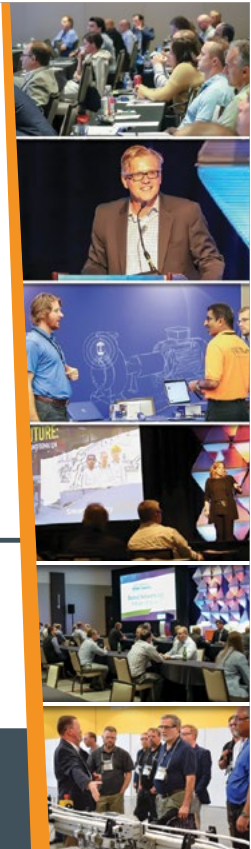
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When to use positioners in flow control

A positioner on an actuator that's too slow for the process can be worse than none.

by Béla Lipták

Q: I stumbled on www.ControlGlobal.com while searching for information about PID control of flow. This question may have been answered, but the couple of threads I found didn't seem helpful specifically for my problem. I'm controlling gas flow with a flow sensor and an electrically actuated (servo) valve positioner. The positioner is slow, taking up to 90 seconds for full travel.

I'm using a microcontroller to read the flow signal (F) and call out a control output of $c(t) = K_p + K_i[\Delta\{e(t)*\Delta t\}] + K_d*(\Delta F/\Delta t)$. The error is $e(t) = F_{sp} - F$.

The slow positioner has been causing constant position adjustment and overshoots. I'm able to get decent control only with a huge averaging of the input flow signal (over almost a two-minute time scale). I guess we can live with it, but is there a better way?

Murthy Tata

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A: This is a very basic and very important question. I'm glad you brought it up because, in my experience, the use and selection of positioners is the cause of the most frequent control problems. (The other error seen most often is usually caused by valve response.)

The answer to your question applies to all cascade systems. The slave controller in all

cascade control loops must be faster than the master controller. No exception! This is kind of self-evident from everyday life. After all, how could, say, a pilot do his/her job if the second pilot was still busy carrying out the previous order when the next was given?

People often don't realize that a positioner is a slave controller, with all its advantages and limitations. It can both help and hurt the performance of the loop. Therefore, I'll give a brief discussion of the subject of positioners before giving my advice concerning your specific question.

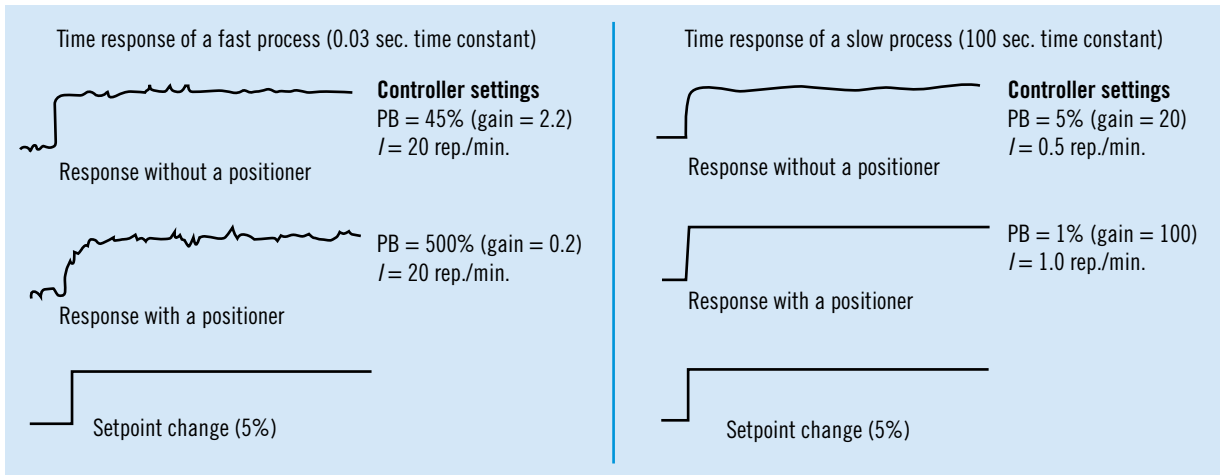
The purpose of a positioner is to improve the accuracy and response of control valves. This means it will help to have the valve position more closely approach the position commanded by the controller. A positioner can reduce the effects of many dynamic variations. These include changes in packing friction due to dirt, corrosion, lubrication or lack of lubrication; variations in the dynamic forces of the process; sloppy linkages (causing dead band); and nonlinearities in the valve actuator.

The dead band of a good valve/actuator is up to 5%. Large plug valves and ball valves with less than perfect linkages and inadequate actuators may be far worse. A better positioner with the proper actuator can often reduce the dead band to less than 0.5% of stroke.

A pneumatic positioner increases the actuator speed or thrust by increasing the actuator pressure and/or air flow volume, and can modify the valve characteristics through the use of mechanical links and cams or by electronic function generators. While these positioner capabilities are very important, some of these capabilities can also be obtained or approximated with other accessories.

The positioner/actuator combination is the secondary control loop in a cascade system, receiving its setpoint from the master controller. For a cascade secondary to improve control, it must respond more quickly than the primary loop. The ideal situation would be if the time constant of the secondary was one-tenth (open-loop speed of response 10 times as fast) of that of the primary (but certainly less than half). No process control response time can be faster than the slowest element in the control loop, therefore, the performance of a cascade system improves with fast secondary response.

It's clear that poor valve response reduces the quality of control much more than one would expect. If that's the case, the controller tuning must be modified (gain reduced, integral lengthened) to avoid oscillation due to dead band and response delay. In typical real applications, controller tuning is conservative and avoids any hint of oscillation, and therefore response is even worse than



WHEN POSITIONERS DON'T HELP

Figure 1: In slow processes (right), a positioner always improves loop performance, but in fast processes (left), particularly if the controller is pneumatic and the process is faster than the positioner, it can hurt loop performance..

it it could be. (Operators usually object to cycling processes.)

Figure 1 illustrates a fast flow process, where the loop without a positioner can be tuned more tightly (for higher gain and more repeats/minute). Such a loop responds better without a poor positioner. It might also be noted that after a new state is reached, the positioned installation gives better and noisier control because of increased speed of response.

Electric actuators are used where air isn't available and where their typically slow operating speed is acceptable. There are some specialized electric valve actuators that can provide very high position precision; others can provide reasonably fast response.

Sorry for taking so long to come to an answer to your question, but I believe it's

useful to understand the cascade nature of positioning, as described above. So, turning to your specific question, assuming that your valve is linear and you have no derivative in your controller, you can disconnect the positioner. Or if the positioner is an integral part of the actuator, insert a lag into the controller output to make its time constant at least double that of the positioner.

Another option is to use gap control, where as long as the flow is inside the gap, the controller stays inactive. Today's micro-processor controllers provide broad tuning adjustment ranges, so you can set the controller gain much lower (portional band wider) and leave the integral (reset) fast to match the time constant of your relatively fast flow process.

Béla Lipták

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A: I have few follow-up questions before I can guide you for a reasonably stable tuning. Which software PID block are you using? Is it PID_IND or PID_ISA block? Or are you doing your own logic? Have you done a step test? I've tuned liquid flow control, and we don't use D, but for gas, you'll need to use D gain.

Another problem I've seen is the range for the transmitter. What is the inherent dead-band of your positioner? Discuss it with the manufacturer of the positioner, and ensure that the setup/configuration is appropriate for your application.

Hiten A. Dalal PE

PMP Automation Engineer

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A: Yes, there is a better way to do flow control, but it would require that you replace the slow-acting electric control valve actuator with a pneumatic or a direct-acting, electric solenoid-type control valve actuator. What you describe is not a solenoid actuator but a reversible electric motor driving the control valve position through a screw-thread mechanical linkage. These have been in use for many years to control very large objects,

such as air dampers in boilers, but are not suitable for gas or liquid flow control.

If your actuator is more like a large air damper rather than a control valve, then you'd probably benefit from using a gap-action control algorithm or an error-squared control algorithm. These algorithms have a characteristic of taking little action when the measured value is close to the setpoint. Both algorithms are common variants of the PID algorithm you seem to be using, and are commonly found in the algorithms of most DCSs and even most PLCs used for closed-loop control.

Most process control textbooks also discuss these variations of PID control. The gap-action controller is simple: establish a zone around the setpoint and when the error is within this gap, don't change the controller output. The error-squared controller is more complicated, and you can find a discussion at this website: <https://pdfs.semanticscholar.org/921e/c98836dda49347d1d99f6a751b548b475283.pdf>.

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Custody transfer flow measurement

Why can a DP flowmeter be used for gas but not liquid?

by Béla Lipták

Q: I'm interested to know why orifice differential pressure (DP) flowmeters aren't used in liquid metering systems (for custody transfer purposes), whereas they're widely used in gas metering systems? What makes an orifice flowmeter a viable, cost-effective choice for gas metering systems only?

A. Rashimi

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A: The short answer is that orifices are used for both, but because custody transfer (fiscal metering) is such an important topic (see Chapter 2.20 in volume one of my handbook), I will give a more detailed answer.

Flowmeter selection can be based on government regulations, industry or national standards, and contractual agreements, and can also be subject to the approval of such organizations as API, AGA and ISO.

The acceptable uncertainty in the quantity of transferred liquid or gas determines meter selection. The uncertainty is the sum of the errors of all components of the metering system. In case of volumetric flowmeters, this includes errors by flow, pressure, temperature, density, composition sensors, their A/D converters, and in calculating the amount of energy (not mass, but energy) transferred. The hydrocarbon industry claims that cus-

TABLE I: FLOWMETERS USED IN CUSTODY TRANSFER

Features	Orifice and (Venturi)	Coriolis	Rotary PD liquid (gas)	Turbine dual helical	Ultrasonic, multipath
Chapter(s)	2.21-2.34	2.16	2.24, 2.25	2.31	2.32
Accuracy at max. flow	1% (0.25%)	0.15%	0.2% (1%-2%)	Liq: 0.25%, Gas: 0.5%	Liq: 0.25%, Gas: 0.5%
Accuracy at min. flow	2% (0.5%)	1%	0.1% (2%)	Liq: 0.5%, Gas: 1.0%	Liq: 0.5%, Gas: 1.0%
Rangeability	3:1-4:1	Up to 100:1	~ 15:1	Liq: 10:1, Gas: >20:1	>20:1
Reynolds (RE) limitations	>10,000 (>100,000)	Debated	Insensitive	Insensitive	< 2,000 and >8,000
Size range	0.5-24 in. (1-120 in.)	1.0 mm to 16 in.	1-18	Liq: 1-20, Gas: 2-12 in.	Liq: 2- >12, Gas: 2- >42 in.
Straight run up/downstream	20/5 (5/0-3)	None	None	15-20/5	20/5
Pressure Drop	High (low)	~ 10 psid	High	~ 5 psid	Low
Installation	Critical	Not critical	Not critical	Important	Important
Maintenance	High (high)	Low	High because moving parts	High because moving parts	Low
Mass flow or multiphase	No	Yes	No	No	No
Moving parts	No	Vibration	Yes	Yes	No
Bidirectional	Some w/2DP	Yes	No	Some	Yes

today transfer operates at an uncertainty of $\pm 0.25\%$ on liquid and $\pm 1.0\%$ or better on gas service, but I consider these numbers overly optimistic.

Table I lists flowmeters that can be used to measure hydrocarbon liquids and gases. The table also gives the chapter numbers where each is described in my handbook, their accuracies (if they're correctly sized, installed and maintained), and other main features. Table I doesn't list their first costs because, in larger transactions, the cost differences between meters are small in comparison to the cost of measurement errors.

For example, when oil costs \$60/barrel and we're unloading a 500,000-barrel tanker, each 0.1% uncertainty corresponds to \$50,000. In cases of smaller quantities, meter cost differences can be considered, and if accuracy is not critical, one can determine

the transferred quantity without flowmeters, just by measuring the level change of liquids or pressure change of gases.

A typical liquid custody transfer skid includes multiple flowmeters (master and operating meters), flow computers and meter provers. For pipe sizes below 42-in. diameter (1.07 m), onsite provers can be used and API requires prover accuracy to be 0.02%. The meter prover volume is calibrated against Seraphin cans, whose precise volume is traceable to NIST. Recalibrations should be performed frequently, typically before, during and after the batch transfer.

Béla Lipták
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A: Orifice meters are still widely used for liquid measurements and have been for many years. The orifice meter accuracy is

much affected by the details of installation, and comments about poor accuracy can usually be explained by poor installation.

The advantages and disadvantages of the various meter technologies are well known, and the available technologies have changed. One example is how Coriolis meters have become more popular as the technology has matured and competition has driven prices down. It's clear that meter selection is heavily affected by pipe size. I find it hard to imagine a Coriolis meter in a one-meter-diameter pipeline. And the cost?

National and international standards can affect decisions. Custody contracts may well have statements limiting options. It can happen that non-technical people write those contracts.

I'm prejudiced, but I have the impression that salespeople tend to suggest the more expensive choices in their catalogs.

In the decision process, it's common to underestimate the costs and details of installation for the various flowmeters. Accuracy is expensive.

I once developed a program to aid in flowmeter selection. The user entered information about the fluid and flows. The program then displayed a list of possible meter types with costs, accuracy and permanent pressure loss. This brought interesting com-

ments challenging estimated costs and accuracy. Support for this program went away as the costs of maintenance would be high as the data changed.

Good question, and we need to discuss these things.

Cullen Langford

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A: Orifice flow measurement is at best $\pm 4\%$ accurate. In spite of this, it was used for custody transfer of liquids for many years until better and more accurate instruments became available. Today, the Coriolis flowmeter is the standard for liquid flow custody transfer due to its high accuracy and often because it directly measures mass flow instead of volumetric flow. It's expensive, so sometimes if liquid is transferred from tank to tank, the before and after tank level measurements are used for custody transfer of liquids. However, that requires very accurate tank level measurement.

Measuring the flow of gases with an orifice flowmeter with compensation for temperature and pressure is typical for natural gas transmission, but that still doesn't make it accurate. In most cases, the low value of natural gas makes it uneconomical to spend extra money on more accurate gas flow measurement. For high-value gases, it's possible to use Coriolis flowmeters or a high-accuracy, positive-displacement meter. Sometimes, custody transfer of gases is

calculated from a change in pressure of the source of the gas, such as a cylinder.

Orifice flow measurement depends on Bernoulli's law that relates pressure drop through a sharp-edge orifice to volumetric flow rate. The pressure drop is between the upstream pressure (before the orifice) and the pressure at the vena contracta formed by the increased velocity of the liquid or gas as it passes through the orifice. Unfortunately, the location of the vena contracta varies with the flow rate, so there's no practical way to measure this pressure drop.

We do the best we can, and usually just measure the pressure drop at the flanges that hold the orifice plate in place, and depend on a correlation (approximation) to estimate the pressure drop at the vena contracta, or just assume that the pressure drop at the orifice is the same as that of the vena contracta.

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A: One of the biggest reasons why orifice plates are not used for liquid custody metering has to do with the following:

1. During startup, while the flow stabilizes, the error in measurement is generally unacceptable. The same happens when the system is shut down.
2. Sizing an orifice plate to guarantee custody transfer precision requirements generally requires the orifice plate to be designed and fabricated to extreme tolerances that not every company can do.
3. The turndown ratio for liquid orifice plates would require users to have too many orifice plates available for when flow conditions change.

To summarize, though custody transfer can be performed with orifice plates, it's not recommended due to the fact that signal instability can cause accounting errors; design and fabrication of orifice plates is very expensive; and finally, if the custody transfer is based on varying flow rates, then the need for additional orifice plates is increased.

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