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Flow Measurement

Improving Control, Management and Optimization of Critical Systems

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Table of Contents

Going with the Flow

Choosing the Right Flow Sensor for Various Applications

By Greg McMillan, Stan Weiner

Greg: Flow measurements offer opportunities for feed-forward, identification of valve backlash and stick-slip, on-line metrics and diagnostics, rejection of pressure disturbance, linearization, modeling and tracking down disturbances as outlined in “Secondary Flow Loops Offer a Primary Advantage.” Flow is by far the most manipulated process input for controlling process variables, optimizing process efficiency and setting throughput.

Stan: To get insights on what flow sensor works best in various applications we continue our interview with Ram Ramachandran the principal engineer at Systems Research Int’l. Inc.

Differential head measurements using differential pressure [DP] transmitters tend to have the lowest accuracy and rangeability due to the square root relationship; the highest noise due to sensitivity to velocity profile, and the highest maintenance cost due to impulse lines. If the velocity profile and density are constant (no opening and closing of valves or changes in composition), the repeatability is good. While the hardware cost may be low, the lifecycle cost is high from installation and winterization of impulse lines and maintenance to prevent line plugging, and to keep a constant phase and fluid composition in the lines. Furthermore, the increased process variability is a hidden cost. Most people don’t realize density affects even the volumetric flow through the Bernoulli equation. Then there is the poor turndown leading to loss of flexible manufacturing to minimize inventories, and match fluctuating energy costs and market demands. I stopped using them [differential head measurements] in the 1980s. Why are differential head meters used?

Ram: Many of these installations are legacy systems, still with us in large chemical plants and refineries in the United States. For high temperatures and large pipe lines in mature continuous processes (e.g., refining, chemical intermediates and pigments and dye manufacturing) with infrequent and relatively limited production rate changes, the differential head meters have been traditionally used. Elbow flowmeters with purged taps have been used when the process fluid is too hazardous, too corrosive or erosive, or pressure drop can’t be tolerated, and the accuracy required is only 5%. For much better accuracy and rangeability and less noise and sensitivity to piping configuration, Venturi tubes can be used with a minimal permanent pressure drop. Flow nozzles are a lower cost solution to Venturi tubes, particularly for large lines. The lowest cost flow sensor is an averaging pitot tube. Some manufacturers offer a retractable design.

Greg: If a wireless DP transmitter is used with an averaging pitot tube, the flow measurement is portable, enabling the exploring and prototyping of process control improvements, diagnostics and metrics. The rangeability can be extended to 10:1 if a second low-range transmitter is added, and measurement noise is incredibly low from strict attention to piping straight run requirements. These meters can justify a more permanent and accurate installation.

Stan: What can you do to achieve greater accuracy, rangeability and maintainability in large lines?

Ram: Turbine meters can provide incredible accuracy (e.g. 0.05%) and rangeability (e.g. 50:1). Bearing life is a problem for non-self-lubricating liquids, such as anhydrous ammonia. EMI has a sleeve bearing design that enables use in steam and gases. Insertion turbine meters and vortex meters are used for large pipelines. Vortex meters are the lower maintenance alternative, but at the expense of 5x deterioration in accuracy (e.g. 0.25%) and rangeability (e.g. 10:1) and greater straight run requirements. Repeatability stops at low flow. Improvements in bluff body and sensor design and temperature compensation have greatly increased vortex meter performance since their introduction. However, the meter coefficient is a still a function of kinematic viscosity.

Greg: Where is volumetric displacement used for flow measurement?

Ram: The oil and gas industry uses the technology of pulsating disc flowmeters for their huge pipe lines. The measurement of reciprocating pump stroke is used for toxic and lethal fluid flow measurement. Rotating disc flowmeters are used for natural gas and water flow measurement. Since these tend to read low as they age, there is an initiative to replace these with non-mechanical meters for large users.

Stan: Magmeters offer quite a performance advantage at low flows since their accuracy is a percentage of rate rather than a percentage of full scale like most other flowmeters. Magmeters also have a very short straight run requirement and can measure reverse flow. What do you see as some of the application considerations?

Ram: The main consideration is materials of construction and fluid conductivity. While newer meters have special low-conductivity capability, still some amount of water must be present. Oil companies will not entertain the possible use of magmeters due to previous failures.

There have been some spectacular failures of soft liners (e.g. Teflon) collapsing from a vacuum condition from condensation after steam cleaning or from tearing away from the wall due to poor liner installation. Thompson Equipment perfected the art of lining magmeters and is the choice for many manufacturers. For hot, dilute HCL glas-lined magmeters are used. Electrodes are available in a wide variety of corrosion-resistant materials, including gold and platinum.

AC magmeters had some initial problems when first introduced, but now predominate because of lower drift and less of an effect of solids. For huge changes in conductivity, a DC magmeter may be used.

Greg: My personal favorite is the Coriolis meter because it has no drift or installation effects (other than vibration), incredible accuracy (e.g. 0.02%) and rangeability (e.g. 100:1) independent of composition and velocity profile, low noise, no calibration or maintenance, plus an extremely accurate

Top 10 Reasons Not to Use Flow Measurements

10. Minimizing project costs are more important than minimizing operating costs.
9. Adaptive control will take care of everything.
8. I don't really want to know what the control valve is doing.
7. I want to do an academic paper on valve flow models.
6. I love process mysteries.
5. I don't want to disturb disturbances.
4. Operators say they don't change feed rates.
3. Feed-forward control is too complicated.
2. Online process metrics might show our mistakes.
1. We know the flows from the process flow diagram

density measurement that can offer an inferential measurement of concentration or percent gas or solids. Coriolis is the only true mass flow measurement. For liquid reactant feed measurement and ratio control, Coriolis meters are essential. Why isn't a Coriolis meter used?

Ram: The meter is expensive, particularly in large pipe sizes. The largest size is presently about 16 inches, but at quite a price. For slurries there must be no accumulation of solids. Straight-tube Coriolis meters are used to prevent erosion at a price of a 5x reduction in accuracy (e.g. 0.1%).

Stan: What about the measurement of flow in ducts?

Ram: Thermal gas flowmeters are predominantly used to measure refinery waste gas flow consisting of mostly ethane and methane. It is also common in material and energy balance controls in large furnaces by measuring air duct flow. Many of the emission reports to regulatory authorities are indirectly computed for total emission, based on plant throughput wherein air/gas flow measurements become critical besides direct composition analysis of stacks.

Greg: Thermal gas flowmeters depend on the thermal conductivity being constant. They are extensively used for measuring air, oxygen and carbon dioxide flow to bioreactors. For bench top and pilot-plant scale bioreactors, these flowmeters are integrated with a internal flow element and PID controller to become a mass flow controller (MFC) that gets its flow setpoint from the bioreactor control system. The tuning of these MFCs can be made fast enough to insure speed as a secondary loop is 5x faster than the primary dissolved oxygen or pH loop. What are some low-cost alternatives?

Ram: Fluidic Components Inc.'s flowmeters that measure the heat loss have a better accuracy and rangeability than thermal mass flowmeters, particularly if the stream has moisture. Two heaters are used to prevent condensation.

Stan: What is done for the flow measurement of solids?

Ram: The most accurate measurement of conveyor flow is by gravimetric feeders that are separate, specially designed sections of conveyors on load cells to measure speed and weight. Linear voltage differential transmitters (LVDT) offer an economical and fairly repeatable solution. Ultrasonic sensors are also used. Radiation sensors are more accurate than LVDT or ultrasonic, but require wipe testing every three years and permitting for maintenance by a radiation officer.

Flow out of a hopper is measured by a rotary valve in the hopper discharge. Measuring hoppers may be used at several points in a fluidized solids process, such as spar in hydrofluoric acid (HF) manufacturing. The same technique is used for cement kilns and bagging operations.

Greg: Flow can be computed from the rate of change in weight by load cells or level by radar as described last month. Centrifugal pump speed with temperature measurements for viscosity and pressure measurements for rise compensation have been used for computing polymer flow. A valve-flow model for equal percentage trim and a large valve to system drop ratio can extend the turndown of differential head and vortex meters, but should not be viewed as a replacement for flow measurements due to effects of shaft windup, backlash, stiction, composition and geometry.

Stan: How do you measure extremely low flow rates?

Ram: Coriolis meters as small as 1/8 in. are available. For even lower flows, capillary flowmeters with a DP measurement are used, keeping the system in temperature-controlled baths. Very small flow with high accuracy and resolution is achieved by using special turbine meters in pilot plants to measure 1 cc to 5 cc an hour or smaller.

Greg: Bench top bioreactors use peristaltic pumps for feeding seed cultures, amino acids, nutrients, reagents and glucose. The speed provides a volumetric flow measurement. If the choices seem too confusing, here is list of excuses to write the whole thing off. ■

Greg McMillan, Stan Weiner are frequent contributors to Control.

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Flow Instrumentation Solutions

Bidirectional Flow Measurement

The Right Flowmeter Is a Balance Between Technical Needs and Cost-Efficiency

By Ruchika Kalyani

Flow measurement plays a critical role in chemical and petrochemical, oil and gas plants. Criticality of flow measurement in the plants has become a major component in overall economic success or failure of given processes. Accurate flow measurements ensure the safety of the process and profits in plants. Better measurement can only be achieved by selecting the best/most suitable flow technology for each flow application. Sometimes, the accuracy required by the end users is the most significant factor for the specific application. The challenge is to find out the value of the product stream being measured, thus providing the most cost-effective and reliable solution to the end users.

Instrument engineers should convince the end user to not install a flowmeter that is more expensive than the yearly value of the stream and the potential loss of money caused by inaccuracies.

A diverse range of flowmeters along with the turndown factors is available for various flow applications, such as regular flow control (steam, gas, utilities, etc), process flow rates, fiscal or custody-transfer metering, and others. Most of these applications will be unidirectional, but some will be bidirectional.

The measurement of unidirectional flow rate is possible with all types of flow technologies, but the bidirectional flow measurement capability is required to measure the flow rates within the same flow loop in opposite directions. This sometimes creates difficult situations, challenges, process interruptions and/or measurement inaccuracies that can significantly affect the production and profitability of the plant.

We will further discuss the selection of the appropriate metering for bidirectional situations and applications, limitations, advantages and disadvantages, maintenance and installation cost.

Bidirectional Flow Measurement

Bidirectional flow lines are not very common in refineries and petrochemical plants, but if they are needed, they are always difficult. For bidirectional flow, the piping scheme uses the same line to accomplish delivery and/or control functions for flows moving in opposite directions (forward or reverse flow), depending upon the process conditions and objectives.

Examples of bidirectional flow are

- Raw water feed to two or more water treatment plants,
- Bidirectional steam lines supplying steam from one unit to another unit in the plant,
- Utility and circulating pumping of dielectric fluid into underground electrical cables in order to dissipate heat generated by high-voltage power lines,
- Gas injected or withdrawn from the gas storage field or reservoir, purging and blanketing of nitrogen in plants,
- Chilled water plant decoupling headers.

Bidirectional Flow Measurement Using Volumetric Flowmeter Options

The selection process of bidirectional flow metering is dependent on application requirements, process demand, end-user accuracy requirements and physical design constraints of the flowmeter itself. Various flowmeters are available with bidirectional flow capabilities, such as the DP transmitter with an orifice, the Venturi or wedge element, the Coriolis, ultrasonic, vortex, pitot, turbine and the magnetic flowmeter.

Instances where a bidirectional flow measurement is required include

- Possibility of having two different flow rates in either direction, due to the process and design conditions, and both flows need to be measured,
- Reverse-flow accuracy is required by end user or by the process.
- The need to measure reverse flow in the process.
- Bidirectional Flow Measurement Using Dual DP Transmitter Options

For bidirectional flow measurement between two process units in a process plant, two steam units linked to each other; i.e., at the time of deficiency of steam in one unit , the other unit will supply the required steam to the deficient unit and vice versa.

If reverse and forward flow rates are identical in both directions and precise accuracy is not required, then dual transmitters, one for each flow direction, are the best solutions for measuring the steam flows in/out of the plant. Two DP transmitters with an orifice plate, along with temperature compensation can be used for the bidirectional flow. In this case, a non-beveled, square-edge type orifice plate should be used, and the two edges of the orifice should comply with specifications for the upstream edge mentioned in ISO 5167 standard. It also is necessary to ensure of the full "upstream" straight lengths on both sides of flow instrument. This must be clearly communicated to the piping design team during design reviews, and before construction begins.

With this combination, do not expect high accuracy and turndown. This combination will provide the lowest installed cost with acceptable accuracy, as it is easy to maintain and replace. Also, this dual transmitter combination option will be ideal in cases where the transmitter will experience reverse flow once every four or five years for a four- or five- day period.

Bidirectional Flow Measurement with Single DP Transmitter Option

A single DP flow transmitter coupled to a primary element option, such as the special orifice plate mentioned above, can also be adopted for cheap reverse-flow measurement. This arrangement will cut down the installing expense of another (second) DP transmitter, orifice plate, additional hardware, meter installation requirements and the complexity of signal switching. The square root function is complicated with the single- transmitter option, as reconfiguration of the transmitter signal (4-12 mA and 12-20 mA) requires additional function blocks and, subsequently, corresponding function blocks or logic at the distributed control system (DCS) side.

In cases where it is only a matter of knowing the reverse flow direction and accuracy is not important, then existing the DP set without configuration can be used. At zero flow 4mA is shown, and an output less than 4 mA can be used to alarm for reverse flow even when the square root function is on.

With newer, smarter flowmeter techniques, transmitters are equipped with a feature that allows reconfiguration of the DP transmitter range; i.e., split-range output signal (4-20 mA) to system side (DCS, PLC). The bidirectional function (i.e. square root functions) can be directly applied to the transmitter by either just by installing special bidirectionality software from the flowmeter vendor at the control system side, or by using the inbuilt capability of the flowmeter to be used in both forward and reverse flow directions.

With equal or unequal flow rates, flow direction will be indicated as the output value (4-12mA = REVERSE and 12 -20 mA FORWARD). With equal flows, zero flow point is established based on DP range of forward and reverse flow, and for unequal flow rates, zero flow point will be a calculated value.

Bidirectional Flow Measurement with Vortex Flowmeters

The other option of two vortex flowmeters can also be used for steam bidirectional flow if higher accuracy is required than can be achieved using the orifice solution, but this application is limited to smaller line sizes, as vortex meters are more economical up to 4-in. (100 mm) pipe size. Beyond this size, orifice plates are more economical. In addition, the selection of a vortex-shedding flowmeter may increase the maintenance and installation cost.

Wherever higher accuracy is required, vortex flowmeters are not a good option, as vortices shed by both bluff bodies propagate really far beyond the pipe and may affect the other meters' readings. Another drawback is that the straight pipe run distance required between two vortex meters is unpredictable. For example, in the case of no obstructions, the meter required the run of 10 D to 15 D (diameters), and if there is a control valve in either direction, the meter may require the higher run of 25 D to 30 D, or even more. In comparison to the options of dual transmitters for bidirectional flow measurement between the two process units, DP flow measurement may be the most cost-effective solution.

Bidirectional Flow Measurement with Turbine and Magnetic Flowmeters

Bidirectional flow measurement is always a challenge when there are changes in process parameters, such as viscosity, conductivity, etc. It is always worth keeping these specific situations in mind while selecting any flowmeter technology but with bidirectional flowmeter applications, it is very important. DP type meters are usually not really well-suited to handle these process parameter variations.

An example is utility pumping and circulating plants pumping dielectric fluid into underground electrical cables in order to dissipate heat generated by high-voltage power lines.

This application requires flow rate monitoring upstream and downstream, as it involves dielectric fluid, therefore it requires viscosity compensation as the temperature of the dielectric fluid changes. In this application, turbine flowmeters can provide the solution for bidirectional flow measurement with moderate accuracy. Drawbacks associated with this technology include a poor response of the flowmeter at low flows due to bearing friction; lack of suitability for high-viscosity fluids because the high friction of the fluid causes excessive losses; and the requirement for regular maintenance and calibration to maintain its accuracy.

The magnetic flowmeter can also be used for bidirectional flow measurement. It has the advantages of no pressure drop, linear output, short inlet/outlet pipe runs (5 diameters upstream of the electrode plane and 2 diameters downstream), and good turndown. Magnetic flowmeters are relatively expensive, and are mainly limited to conductive fluid applications such as acids, bases, slurries as well as water. A pre-requisite for this type of flowmeter is that the fluid is electrically conductive with an absolute minimum conductivity of 2-5 µSiemens.

Bidirectional Gas Flow Measurement Using Ultrasonic Flowmeters

At gas storage fields or natural gas reservoirs, accurate gas flow measurements are required for tasks such as injection and withdrawal of gas from these reservoirs. Reservoirs are used as buffers between suppliers and consumers. In order to maintain the balance for the entire reservoir, it is necessary to monitor bidirectional flow at the wellhead.

For this purpose conventional DP flowmeters with an orifice are far from a suitable solution as they lack accuracy and reliability. Orifice plates are subject to wear and tear. Secondly, regular inspections and maintenance are required. While measuring the dirty gas, the pressure taps of the orifice plates are particularly exposed to clogging due to the solid particles which may be present in the dirty gas. These will definitely distort the accuracy of measurement. In these specific cases, an ultrasonic flowmeter may be a far better solution, since this type of flowmeter has no pressure drop, no flow blockage, no moving parts, is suitable for high-volume bidirectional flow and also for low-flow measurements where other types of flowmeters do not provide the required results.

The advantage of using the clamp-on gas flowmeter transducer on the outside of the pipe doesn't require any pipe work or any kind of process interruption. With this type of flowmeter even a little moisture content present in the gas cannot significantly affect the measurement.

The reliability, negligible maintenance with highest accuracy and long term cost of ownership are the major benefits of this technology.

Bidirectional Flow Measurement with Coriolis Mass Flowmeters

In the process industries, the Coriolis technology has set the standard for the flow and density measurements. This technology is used for various applications, such as mass balance, monitoring of fluid density and custody transfer, but also to reduce maintenance, and for bidirectional flow measurements.

In refineries, there are bidirectional applications, such as import and export of product, product transfer to storage and to petrochemical plants, and where the accurate measurement is more important than cost. Coriolis mass flowmeters can be used for accurate and reliable measurements of all streams in and out of the plant. This is critical for accounting and profitability. End users should take into account that inaccurate measurements sometimes may cause them to give away more product than they are being paid for. This can result in a significant loss of profit.

Conpared to the traditional use of volumetric flow technology for bidirectional measurements, the use of Coriolis mass flowmeters eliminates various well-known drawbacks of volumetric technologies, such as the requirement for significant upstream and downstream straight piping length and the reduction of potential errors that occur in compensation for temperature, pressure, viscosity or specific gravity. The Coriolis mass flowmeter technology does not require that compensation.

Coriolis meters measure mass flow. They do have their own inaccuracies, but these tend to be low relative to other types of flowmeters. The turndown of Coriolis meters is high compared to other types of flowmeters. Another advantage is that no recalibration is required when switching fluids or for changing process conditions.

Purchase Price v/s Cost of Ownership

It is very important for the control system engineer to evaluate the accuracy required for specific application before selecting any of bidirectional flowmeter technologies, as more accurate and precise flow measurement often results in higher cost of the flowmeter.

The control system engineer must understand that price is always the consideration. However, there are some important distinctions to be made in terms of price. A flowmeter can have a low purchase price, but can be very expensive to maintain. Alternatively, a flowmeter can have a high purchase price, but will require very little maintenance. In these cases, the lower purchase price may not be the best bargain. Other components of price include the cost of installation, the cost of associated software, the cost of training people to use the flowmeter, the cost of maintaining the meter, and the cost of maintaining an inventory of any needed replacement parts. All these costs should be taken into account when deciding what flowmeter to buy. This is should be the one reason for many users to look beyond purchase price when considering flowmeter cost. ■

Ruchika Kalyani is a control system engineer at Fluor Daniel India Pvt Ltd.

Getting to Know Insertion Flowmeters

Insertion Flowmeters Come in Many Varieties, but They All Share Similar Characteristics and Problems

By Walt Boyes

You can get flowmeters in insertion versions that are paddlewheel, propeller, turbine, magnetic, vortex and differential pressure sensors. Insertion flowmeters are popular in many industries, because they appear to be easy to install, inexpensive and come in technology variations that mimic full-pipe meters.

But with no exceptions, insertion flowmeters are not the same as their full-pipe counterparts. In fact, there is some evidence for David W. Spitzer's claim in his book Industrial Flow Measurement that insertion flowmeters are a type all of their own.

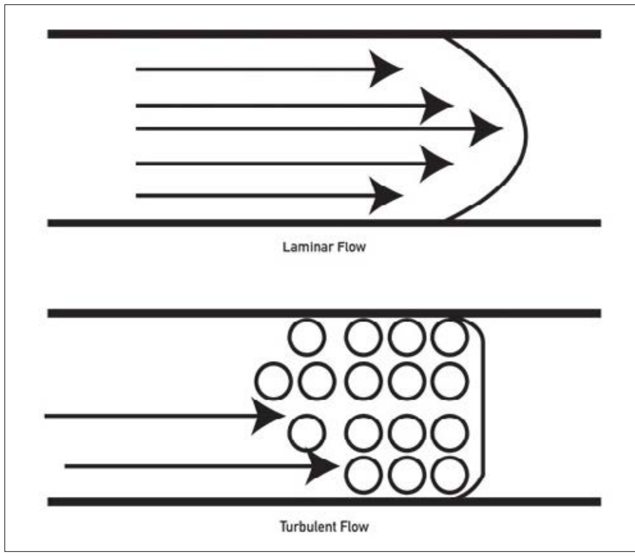
How Does This Work?

In Figure 1, you see turbulent flow and laminar flow. These are based on the concept of the Reynolds number, which is a dimensionless number relating to the ratio of viscous to inertial forces in the pipe. Laminar flow where the flow profile is straight and smooth occurs at Reynolds numbers of less than about 2500. Turbulent flow, where there are eddies, vortices and swirls in the pipe, occurs above 4500 Reynolds numbers. Transitional flow, which is neither fully laminar nor fully turbulent, occurs between about 2500 and 4500 Reynolds numbers. Laminar flow profiles are usually visualized as being bullet-nosed, while turbulent flow profiles are seen as plug flows.

Without getting too far into the math, flow studies have shown that in a pipe with a fully developed flow regime, either fully turbulent or fully laminar, the average velocity in the line can be found at a point somewhere between 1/8 and 1/10 of the way in from the side wall, depending on the flow study you read.

Insertion Paddlewheels, Propellers and Turbines

There are three very similar types of insertion flowmeter that use a rotor that spins with the velocity of the fluid.



FULLY DEVELOPED FLOW

Figure 1. Turbulent flow from 4500+ Rn. Laminar flow from 0 to 2500 Rn.

The first is a paddlewheel, because the rotor is parallel to the centerline of the pipe, just like a paddlewheel steamer. Paddlewheels range from very inexpensive to inexpensive, and are designed to be disposable. The least expensive ones use polymer bearings, which go out of round and cause the rotor to wobble before the rotor shaft cuts through a bearing and goes downstream. The best use jeweled bearings and ceramic shafts so that they have much more longevity and less drag.

The spinning of the rotor is sensed by either a magnetic pickup that generates a sine wave the frequency of which is proportional to velocity, or a Hall effect sensor that generates a proportional square wave.

The advantage of the magnetic pickup is that it generates the sine wave without additional power. The advantage of the Hall effect sensor is that it does not cause "stiction" (the momentary friction stop when the rotor sees the magnetic pickup's magnet). Hall effect sensors generally are able to read lower flow rates and are more accurate at lower flow rates as well.

Paddlewheel flow sensors are designed to be easily inserted into a small hole cut into the pipe using a custom fitting. Some paddlewheel sensors can be inserted into the pipe using a hot tap assembly, which allows the sensor to be inserted and retracted without shutting down the flow or relieving the pressure in the pipe.

Propeller meters use a prop shaped very much like an outboard motor's propeller and are generally connected to a mechanical or electromechanical totalizer with a cable very much like a speedometer cable. In fact, there is a legend that one very large manufacturer of propeller meters made a very inexpensive lifetime buy of Ford Pinto speedometer cables and used them for years. Some more modern propeller meters use embedded magnets and either magnetic pickups or Hall effect sensors. Like paddlewheels, propeller meters have a pulse output that is proportional to the average velocity in the pipe. Because propeller meter rotors are large and located at the centerline of the pipe, they are likely to be quite accurate, and even insertion propeller meters have been certified for billing purposes for decades.

Propeller meters, because their prop is significantly larger than a paddlewheel, are inserted using a flange that mounts into the upright member of a tee fitting.

Turbine meters come in both electronic and electromechanical styles, but the only insertion turbine flowmeters are electronic. They, like paddlewheels, use either a mag pickup or a Hall effect sensor to produce an output pulse that is proportional to the velocity of the fluid. Like paddlewheels, they must be inserted to the "average velocity point" that exists somewhere between 1/8 and 1/10 of the inside diameter away from the pipe wall.

Most insertion turbine meters have very small rotors, so they can be inserted through a small diameter fitting or through a small diameter hot tap assembly. Sometimes, especially in the municipal water industry, this is called a "corporation cock assembly," but it is essentially the same thing—a way of inserting a probe through a valve and still maintaining the pressure in the pipe without leaks. At least one vendor uses a larger turbine rotor and claims significantly better accuracy, especially at low flow rates. Your mileage may vary.

Propeller meters are almost always used for water service, either in potable water systems or in irrigation systems.

Paddlewheels and insertion turbines can be used in a variety of applications, with materials of construction varying based on the requirements of the applications, such as acids, bases, and hot or cold fluids.

Electronic paddlewheels and turbines can be set up to be bidirectional using quadrature detectors, which enable the signal to indicate either forward or reverse flow as well as flow rate. These are often used in HVAC applications where chill water and hot water flow through the same lines depending on the season.

The signal from the paddlewheel or turbine or electronic propeller meter is sent to a transmitter, which uses the pulse (or frequency) output to display flow rate and increment a totalizer (usually electronic). These transmitters generally have a pulse output, an analog output (usually 4-20 mADC), and often have one or two programmable relay contact closure outputs. These can be used as flow alarms, as diagnostic alarms or as a rudimentary dead-band controller.

Insertion dP Flowmeters

The most commonly used flow sensor in the world continues to be the differential pressure transmitter connected to a primary device such as an orifice plate or Venturi tube. In its insertion incarnation, the differential pressure sensor is connected to a pitot tube inserted in the flow stream, and just as a pitot tube measures velocity on the outside hull of an aircraft, the pitot tube measures the velocity in the fluid flowing in the pipe.■

Walt Boyes is a principal with Spitzer & Boyes.

Back to the Basics: Magnetic Flowmeters

Close to Being "Prince Flowmeter Charming," Magmeters Do It (Nearly) All

By Walt Boyes

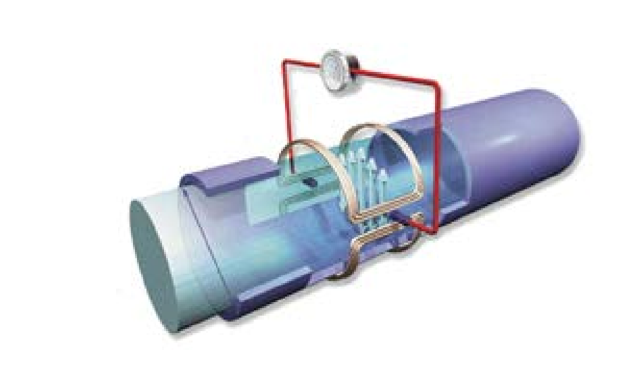
Ever since the invention in the 1790s of the Woltman-style mechanical turbine flowmeter, automation professionals have been looking for the one flowmeter that will work in every application. Unfortunately, there are 12 flow measurement technologies in common use for a very good reason. No single flow technology works well, or even acceptably, in all applications.

Of the more broadly based flow technologies, the one that works in the most applications, across most industries and with higher accuracy than even differential pressure is the electromagnetic flowmeter, or magmeter. According to Jesse Yoder at Flow Research, the total global market for flowmeters is roughly $4.7 billion, and magnetic flowmeters account for a little less than 20% of that total. There are a lot of magmeters shipped every year. Magmeters are used in every process industry vertical: water, wastewater, mining and minerals, utilities, food and pharmaceuticals. Magnetic flowmeters are designed for handling almost all water-based chemicals and slurries and are furnished with corrosion- and abrasion-resistant linings and even clean-in-place (CIP) designs for sanitary applications.

Magnetic flowmeters also are made in the widest size range of any flowmeter technology because they can be scaled up almost infinitely. The first use of the technology was in the huge sluices that drained the Zuider Zee in the Netherlands in the 1950s, and typically vendors supply a size range from ½ in. (12 mm) to 36 in. (914 mm), with several vendors supplying extended sizes up to 120 ins. (3048 mm). Several vendors sell sizes below ½ in. as well. How it is possible to scale up and down this broadly is directly related to the technology.

How a Magmeter Works

In 1831, Michael Faraday formulated the law of electromagnetic induction that bears his name. As used in an electromagnetic flowmeter, coils are placed parallel to flow and at right angles to a set of electrodes in the sides of the pipe, generating a standing magnetic field. The pipe itself must be non-magnetic and lined with non-magnetic material, such as plastic, rubber or Teflon. When the fluid (which must be conductive and free of voids) passes through the coils, a small voltage is induced on the electrodes, which is proportional to the deflection of the magnetic field. By Faraday's Law, this deflection is the sum of all of the velocity vectors impinging on the magnetic field.



FLOW TECHNOLOGIES

Figure 1. The velocity deflects the standing magnetic field and induces a voltage on the electrodes that is proportional to velocity.

Modern magmeters operate on a switched DC field principle to zero out noise that can be induced from RFI, EMI and electrical noise actually in the process fluid. They follow a regimen of turning the field off, measuring the voltage that is still induced on the electrodes, then turning the field back on and subtracting the off-state voltage from the on-state voltage. They do this several times a second, which reduces zero drift to almost nothing.

What this means for automation professionals is that the voltage induced on the electrodes is directly proportional to the average velocity in the pipe, and is therefore significantly more accurate than any other velocity-based measurement principle that only looks at a point or line velocity. In fact, the magnetic flowmeter is generally considered the most accurate wide-application flowmeter in current use.

Magmeter accuracy is remarkable, approaching the accuracy of positive displacement flowmeters. They're often used for custody transfer when the flow is of relatively long duration. Typical accuracy of a magnetic flowmeter is 0.5% of measured value from 0.3 ft per sec to 33 ft. per sec (0.1 to 10 m per sec) velocity. Some vendors indicate even higher accuracies over portions of the flow range, up to 0.1% of indicated flow rate.

Where Magmeters Won't Work

Magmeters have such a wide application that it's easier to say where they will not work than to list all the applications in which they will.

They will not work when the pipe is not full (with the exception of several versions designed specifically for this application). If the pipe is not full, there will be significant error. One of the most common application failures of magnetic flowmeters is on a gravity-fed line discharging to atmosphere in a tank. Very often, at very low flows, the pipe is actually not full, and the flowmeter will read in error. If the pipe fill drops below the line of the electrodes, the meter will not read at all. Sometimes, applications like this are designed with a u-tube in the line, which is supposed to keep the pipe full at all times. And, sometimes this actually works.

They will not work when the pipe is full of entrained gas or air. This changes the computed volume of the pipe and changes the volumetric flow through the meter in an uncontrolled fashion that's proportional to the amount of bubbles (or void fraction) in the pipe.

They will not work well where the flow starts and stops repeatedly because there is a lag between the time the flow starts and the correct velocity is read by the meter. This means that (again with the exception of some units that are specifically designed to be very fast) magnetic flowmeters don't work well in short-duration batching operations.

They don't read out in mass flow units, but when combined with an ancillary density measurement device (often, for larger diameter pipes a gamma nuclear densitometer), they can produce a high-precision mass flow measurement. This combination of devices is used regularly in any water-based fluid flow situation where the pipe size is larger than 12 in. (nominally 300 mm). This application is commonly found in the mining industry and in dredging applications in harbors and rivers around the world.

Most importantly, they will not work on non-conductive fluids or on gases at all. The minimum conductivity of a fluid is usually considered to be 5 μS (microSiemens) before a magnetic flowmeter will measure its velocity. In practice, it's not wise to use a magmeter on a fluid whose average conductivity is this low.

Finally, magmeters (except again for specially-designed units) have trouble working on fluids with extremely high or highly variable conductivity. Saline brine and seawater, are examples of this kind of fluid.

Using Magmeters

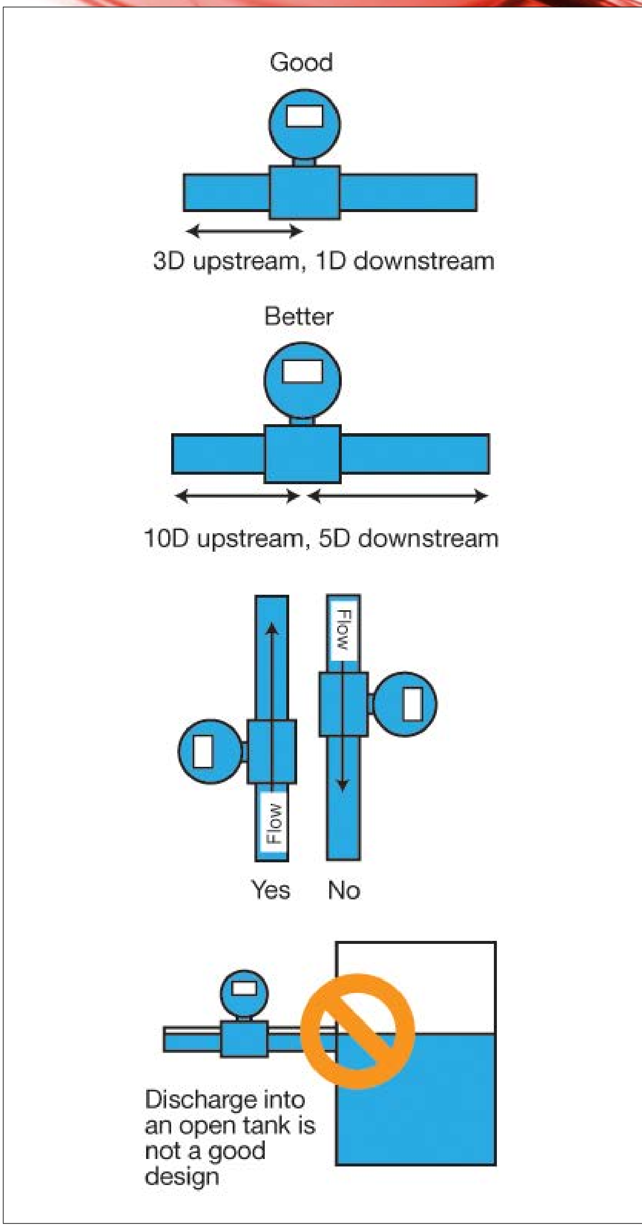
There are some simple rules for using magmeters, which, if you follow them, will produce a satisfactory application.

Straight Run

Magnetic flowmeters need less straight run than most flowmeters, often as little as three diameters upstream of the electrode plane (the centerline of the meter body, usually), and no diameters of straight run downstream. However, there are circumstances in which a better choice is to go with as much straight run as you can get. For example, spiraling flow (swirl in the pipe) can propagate for hundreds of diameters after a three-dimensional turn in piping. Spiraling flow causes severe inaccuracy in a magmeter, sometimes as much as 40% of measured value.

Vertical Mounting

One of the ways to make sure you have a fully developed flow profile moving through the meter is to mount your magmeter so that the flow is through the meter in the vertical



HOW A MAGMETER WORKS

Figure 2. Some basic rules of thumb for using magmeters.

direction. This helps in cases of spiraling flow and also helps reduce air entrainment.

Right Sizing

Although a magmeter will operate over the entire range from 0.3 fps to 33 fps (0.09 to 10 meters per second) velocity, it isn't wise to install a magmeter that's going to operate permanently at the lower end of that range. In applications where there are solids, this can cause buildup of solids inside the flow tube and sometimes on the electrodes themselves. If buildup occurs inside the flow tube, the calculated volume is now in error, and if buildup occurs on the electrodes, the insulating properties of the buildup can either reduce the voltage or break the circuit entirely. Either will cause inaccurate readings. It's better to size the flowmeter for a normal flow that is about 60% of maximum for that pipe size, and if necessary, install a properly designed meter run. Fortunately, for a magmeter, that meter run doesn't need to be as long as it does with some technologies for measuring flow.

Proper Grounding

Remember that the pipe section of the magmeter needs to be non-conductive for the circuit to work. The electronics that process the induced voltage, however, are susceptible to interference if they're floating above ground. Magmeter vendors all have grounding procedures, which you ignore at your peril.

Temperature and Pressure

Magnetic flowmeters are designed to work at moderate temperatures and pressures and should not be stressed above or below those specifications. Magnetic flowmeters should not be operated where a vacuum can be pulled inside the flow tube unless specifically designed for that service. This is so especially when there is a pressed-in polyurethane or Teflon lining, because the vacuum can pull the lining right out of the meter, causing potential hazard, as well as inaccuracy in reading. Both Teflon and polyurethane, which are the most common magnetic flowmeter liners, are de-rated for pressure at the upper end of their temperature range and will deform if overheated.

Magnetic flowmeters have become one of the most widely used flow technologies in the 50 years since their first introduction. They're simple, easy to maintain, and because they have no moving parts, able to operate for years without maintenance. ■

Walt Boyes is a principal with Spitzer & Boyes.

On site flow calibration is painful but necessary

Some new product introductions have raised doubt about what in-situ calibration for flowmeters is, and whether it can be duplicated with simulators and calibrators with expanded diagnostics.

By David W. Spitzer

THE TERM "in-situ calibration" means different things to different people. Calibration is a process by which the operation of an instrument is checked against a standard that is known to measure the desired parameter with a high degree of accuracy. A large amount of effort is expended to ensure that the standard achieves and maintains its accuracy. The extent of this effort may not be obvious to its user because off-the-shelf calibrators are engineered to be easy to use and maintain. In contrast, custom calibrators and calibrators manufactured in low volumes tend to require the user to pay more attention to detail.

Recently, especially in the process industries, some new product introductions have raised doubt about what in-situ calibration for flowmeters actually is, and whether it can be duplicated with simulators and calibrators with expanded diagnostics.

Flowmeters are functionally comprised of the flowmeter primary and the flowmeter secondary. The primary is physically involved with the fluid. The secondary, commonly called the transmitter, processes the signal(s) produced by the primary. Examples of primary/secondary pairs are given in Table 1.

These functional relationships exist even when the primary and secondary are packaged together. For example, a paddle wheel sensor and transmitter may be incorporated into the same housing and sold as a one-piece assembly. This construction reduces the cost of the flowmeter, reduces the electrical installation complexity/cost, and typically places fewer space requirements on the installation. Yet it still has primary and secondary functionality, just in one physical package.

TABLE 1: PRIMARY AND SECONDARY FLOW MEASUREMENTS

Primary	Secondary
Orifice Plate	Differential Pressure Transmitter
Magnetic Coil/Electrode Assembly	Magnetic Flowmeter Transmitter
Thermal Heater / Temperature Sensor(s)	Thermal Flowmeter Transmitter
Paddle Wheel Sensor	Paddle Wheel Transmitter
Oval Gear Assembly	Positive Displacement Transmitter
Vortex Shedding Assembly	Vortex Shedder Transmitter
Parshall Flume	Level Transmitter
Coriolis U-tube Assembly	Coriolis Mass Transmitter
Ultrasonic Sensor(s)	Ultrasonic Flowmeter Transmitter

In general, there are three components necessary to calibrate a flowmeter --- the flowmeter primary, the flowmeter secondary, and the calibration standard. By their nature, flowmeter primaries are exposed to the fluid flow. Note that even flowmeters with non-wetted sensors such as clamp-on ultrasonic flowmeters, are exposed to fluid via the ultrasonic energy that is transmitted/received to/from the fluid flow, and because the pipe itself becomes functionally part of the flowmeter primary.

In a flow laboratory, flowmeters can be calibrated by flowing the same fluid through the flow laboratory calibration standard and the "meter under test" (MUT) that is comprised of a flowmeter primary and secondary. This can be done by circulating the liquid (Figure 1), diverting the liquid to a weigh tank (Figure 2), and then circulating again (Figure 3). By comparing measurements from the standard and the MUT (while diverting), the MUT can be adjusted (calibrated) to provide measurements that mimic the standard.

Performing this type of calibration in the field (in-situ) is usually impractical or impossible, because flowmeter laboratories are typically relatively expensive, custom-designed installations that involve multiple valves and weigh tanks. One alternative method is to bring the MUT and its associated piping to a flow laboratory for calibration. Another alternative is to calibrate the MUT in the flow laboratory using piping that is identical to the piping in the field installation. In general, these methods are effectively impossible for the overwhelming majority of applications in process plants.

In contrast, in-situ calibration of a flow measurement system involves bringing the calibration standard to the instrumentation installed in the field. Key to this approach is the adequacy of the standard(s) to calibrate the components of the measurement system, and the ability to transport the standard to the field faithfully.

Custody Transfer Applications

The flow measurement derived from a custody transfer flow measurement system is used to calculate the amount of money that changes hands between the past and present owner of the material. Residential water and natural gas

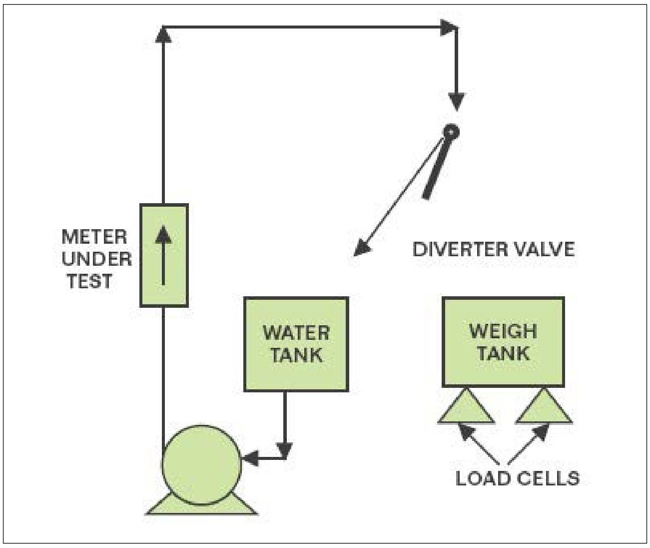


Figure 1.

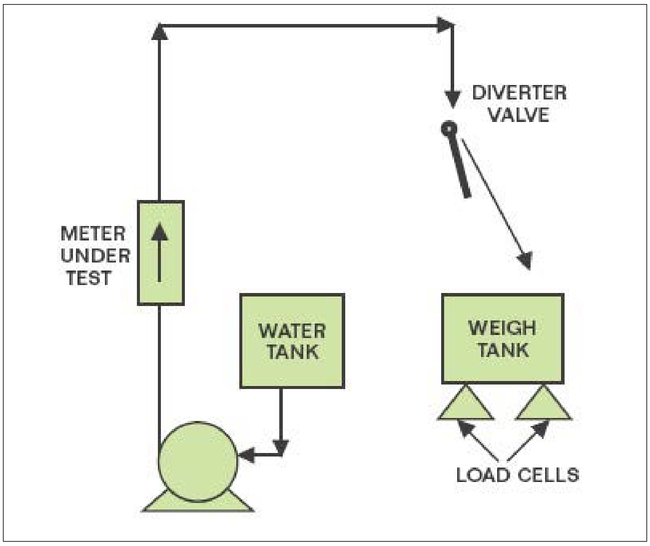


Figure 2.

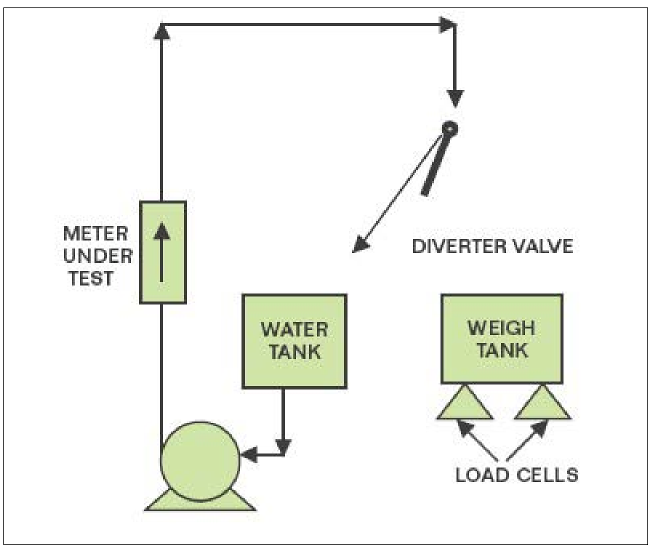


Figure 3.

meters that determine the homeowner's consumption are a commonly encountered type of custody transfer flowmeters.

In industry, custody transfer flowmeters are found in large numbers in the oil and gas industries. For example, flowmeters are used at the discharge of oil and gas wells to determine royalty payments and taxes thereon. Custody transfer flow measurement systems can also be used to determine the amount of petroleum products transferred between companies. Payments associated with some of these applications can involve the payment millions of dollars, so the ability to verify flowmeter performance is important. To put this in perspective, a calibration error of one percent of a $5,000,000 transfer is $50,000, so attention to detail and in-situ calibration can be important.

According to Zaki Husain, Senior Engineering Specialist, Chevron-Texaco, Houston, Tex., "Many custody transfer installations in the oil and gas industry are calibrated in-situ using a flowmeter proving system." A prover is a device that derives the flow rate by measuring the amount of time that an object, such as a ball or piston, travels through a known volume. Piping provisions are made to allow the prover to be installed in series with the flowmeter to measure the same flowing stream. Valves in the prover allow the flow to bypass the prover during the time that the prover is not measuring the flow rate. Due to the limited volume available in most in-situ provers, test times are relatively short and can be completed in just a few seconds.

"In North America, the equipment and methodology used to determine payment is usually dependent upon the agreement between the parties," Zaki adds. "Depending upon the agreement, the custody transfer measurement system could be implemented using such varied measurement systems as a 30-year old orifice plate with a circular chart recorder, or a precision positive displacement flowmeter with a microprocessor-based flow computer."

Depending on the agreement, these systems may or may not be calibrated using a prover.

Paolo Fiorletta, General Manager, Metroval, Nova Odessa, Brazil, works for a company that makes flowmeters for custody transfer applications. Fiorletta says, "Governmental constraints have been placed on installations in Brazil, primarily to ensure that the proper amount of royalties and taxes are paid and to ensure proper development of the reservoir. Compliance with Brazilian regulations requires that the flow measurement system be designed to meet certain performance requirements and be calibrated on a periodic basis by qualified personnel." As a result, in-situ calibration of the flowmeter system is virtually mandated in order to maintain performance during operation. Many other countries follow the same or similar regulations.

Non-Custody Transfer Applications

Most flow measurement systems installed outside the oil and gas industry do not involve custody transfer, but rather monitoring and controlling flow. Therefore, the in-situ testing procedures described above are generally relaxed for the majority of these installations. The degree to which they are relaxed is dependent upon the nature of the application and the sophistication of the end user.

In-situ flow calibrations of the entire flow measurement system (primary and secondary) are typically not performed for non-custody flowmeter applications. In many cases, only the secondary is calibrated because it is relatively expensive to perform an in-situ calibration of the primary. As a result, few flowmeter primaries are calibrated in-situ and it can be years until many of the primaries are even inspected.

Matt Otto, Engineer, Bayer, New Martinsville, West Va., takes exception to this, stating that Bayer's flowmeters are calibrated using a water source and a portable master flowmeter. "Piping connections to implement this type of calibration are routinely provided in new installations," he says. For high viscosity applications, material is allowed to flow to a portable tote bin that is weighed. The weight of the tote bin is then compared to the flowmeter measurement. Environmental audits generally incorporate in-situ testing of applicable flowmeters that is performed by outside contractors.

Roy Gregor, Component Engineer, Vermont Yankee Nuclear, Vernon, Vt., has mostly orifice plates and differential pressure flow transmitters to measure water flow rates. "The orifice plates are not routinely pulled for inspection because orifice damage would show up symptomatically as a low flow rate discrepancy when compared to other parameters monitored, such as differential pressure and temperature. The transmitters are calibrated using a 'water pot' onto which air pressure is applied." This procedure is an in-situ calibration of the secondary. However, it does not constitute an in-situ flowmeter calibration because calibration of the primary is not performed. It tells you whether the pressure sensor and transmitter are working, but gives you no information about the state of the orifice plate or venturi.

Juergen Amann, Instrument Supervisor, City of Tampa, Tampa, Fla., says, "Most of our magnetic flowmeters in sewage service are so large that wet testing them in-situ is impractical, so technicians can only calibrate the transmitters. In addition, the cost of returning primaries to the factory for calibration is excessive." Juergen added that most flowmeters cannot be removed from service so it is difficult to gain access to even inspect the primaries. In some installations, material balances and historical information are used to verify the reasonableness of the flow measurements.

Juergen and other flowmeter users in the water and wastewater industry have elected to purchase magnetic flowmeters with expanded diagnostic coverage. These flowmeters can monitor selected parameters in the secondary and primary, such as its associated electrical parameters. Variation from factory specifications would indicate a potential problem. The terminology vendors are using to describe these systems can be misleading. They provide in-situ verification of the parameters, the measurement of which may be traceable to a national laboratory such as NIST. However, these systems do not perform in-situ flowmeter calibration.

An engineer in a northern USA cement plant says that his plant has "a few magnetic flowmeters that measure water flows, but there are no calibration procedures for them. Our stack gas flowmeters are calibrated by the manufacturer's personnel, but I do not know if they are wet tested or not."

In-situ Calibration Equipment

With the exception of flowmeter provers, most in-situ calibration equipment is designed to calibrate the flowmeter secondary, or transmitter. Some of these calibrators are designed to transfer calibration information to/from other systems such as maintenance management systems. Automating these information transfers can speed the availability of information, improve worker productivity, and reduce the number of errors that inherently occur in a manual system.

John DuBay, Product Manager, Meriam Process Technologies, Cleveland, Oh., says, "Our calibrators address the calibration of the flowmeter secondary. The calibration procedures can be set up and scheduled using PC-based software and then downloaded to a handheld calibrator. The calibration can then be performed and automatically documented, yielding results which are then uploaded back into the PC-based software." Other vendors produce similar systems. Documentation of the calibration can be paperless, and depending upon the system details, integration with computerized maintenance management systems and messaging systems may be possible.

DuBay continues, "Electronic document control for the FDA can be implemented by associating a user with the handheld calibrator that performs the calibration." This is accomplished by means of a pass code and user ID that must be entered to invoke the rights and allow validation of the handheld operator's actions. This signing information, along with the calibration results, is stored in an audit trail that conforms to 21 CFR Part 11 requirements.

Unfortunately, suppliers do not always offer a clear distinction between in-situ calibration and expanded diagnostic coverage. Expanded diagnostic coverage can improve flowmeter availability by continuously monitoring certain parameters and comparing them with historical values to detect and diagnose certain flowmeter problems in a timely manner. Implementing expanded diagnostics can be beneficial to help justify an increase in the time between calibrations. However, performing expanded diagnostic coverage does not provide an in-situ flowmeter calibration (as some suppliers might imply), so it is not a substitute for an in-situ flowmeter calibration and should not be represented as such.

Expanded Diagnostic Coverage

Periodic flowmeter verification and/or calibration are commonly used to maintain the availability of flowmeters installed in operating facilities. These approaches typically detect flowmeter problems after they occur, and often only after the flowmeter had a detrimental effect on the process.

To detect potential problems before they occur, the transmitter often contains self-diagnostics that verify its operation. While this approach may provide significant diagnostic coverage for the transmitter, it generally provides only rudimentary diagnostic coverage of the flowmeter primary.

However, some flowmeter suppliers are embedding diagnostics that verify the integrity of the flowmeter primary. In general, certain parameters associated with the flowmeter primary are measured in the field and compared with measurements made at the factory. As long as the difference between the factory values and field measurements remain within tolerance, the calibration of the flowmeter primary is presumed to have not shifted. Some expanded diagnostics are continuously monitored, whereas others are performed periodically.

Note that this approach is not a flowmeter calibration, but rather an in-situ flowmeter verification check that implies (but does not definitively determine) that the calibration of the flowmeter primary has not shifted. It can be likened to checking to verify that the condition and dimensions of an orifice plate have not changed, thereby implying that its calibration has not changed. However, this orifice plate check would not detect an out-of-round pipe, coating, plugging, or an obstruction that could change the calibration of the orifice plate flow measurement system. Even using physical inspection of the primary cannot detect out-of-round pipes, welding slag and burrs, a glove caught on the valve upstream, or other serious problems. Only an in-situ flowmeter calibration can do all that and make sure the flowmeter system is accurate and reliable.

Despite its limitations, expanded diagnostic coverage is an in-situ flowmeter verification tool that can improve flowmeter availability and extend intervals between routine calibrations/verifications. It cannot completely replace the actual calibration of a flowmeter system, either in-situ or at the lab.

For example, Micromotion (Emerson Process Management) recently announced the availability of expanded diagnostic coverage for its Coriolis mass flowmeters. They have found that verifying the density calibration by periodically filling the flowmeter with known fluids (typically water and air) implies that the flowmeter calibration has not changed due to product build-up or corrosion.

Some flowmeter suppliers such as ABB, Krohne, and Siemens can provide portable equipment to periodically check their magnetic flowmeter primaries for insulation resistance and other internal electrical parameters that are indicative of flowmeter primary problems. Krohne offers a transmitter with embedded expanded diagnostics that can perform these checks continuously. ■

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Expanded flow diagnostics cast a wider net

Here's how to use several methods, such as element status checking, to improve flowmeter availability, increase consistency, and reduce costs in many applications and environments.

By David W. Spitzer

PERIODIC FLOWMETER verification and/or calibration are commonly used to maintain availability and proper operation of installed flowmeters. However, these approaches typically detect flowmeter problems after they occur, and usually only after the flowmeter has a detrimental effect on the process.

To detect and diagnose potential problems sooner, flowmeter transmitters often contain self-diagnostics that verify their operation. Integrating microprocessors into transmitters enabled development of software diagnostics that could verify operation of transmitter electronics. In addition, some technologies allow transmitters to perform limited diagnostics on parameters associated with the flowmeter primary.

For example, many microprocessor (and some analog) magnetic flowmeters can verify that the electrodes are part of a complete electrical circuit. An incomplete circuit is a condition that likely indicates that the pipe is empty, which could generate an alarm calling for operator or maintenance attention. In general, this particular diagnostic coverage is relatively straightforward, and has been offered for some time.

There is an underlying trend to reduce instrumentation maintenance requirements, while simultaneously increasing availability of the process. Fortunately, process availability often can be improved by increasing the instrumentation availability. One way to accomplish this is by identifying and fixing instrument problems before they affect the process.

However, a major difficulty in accomplishing this goal is that self-diagnostics typically verify transmitter operation, but generally don't provide extensive diagnostics relating to the flowmeter primary. If you want to confirm this, examine the list of diagnostic errors associated with one of your typical flowmeters. You likely will find many errors relating to transmitter electronic health and few or no diagnostic errors relating to the flowmeter primary.

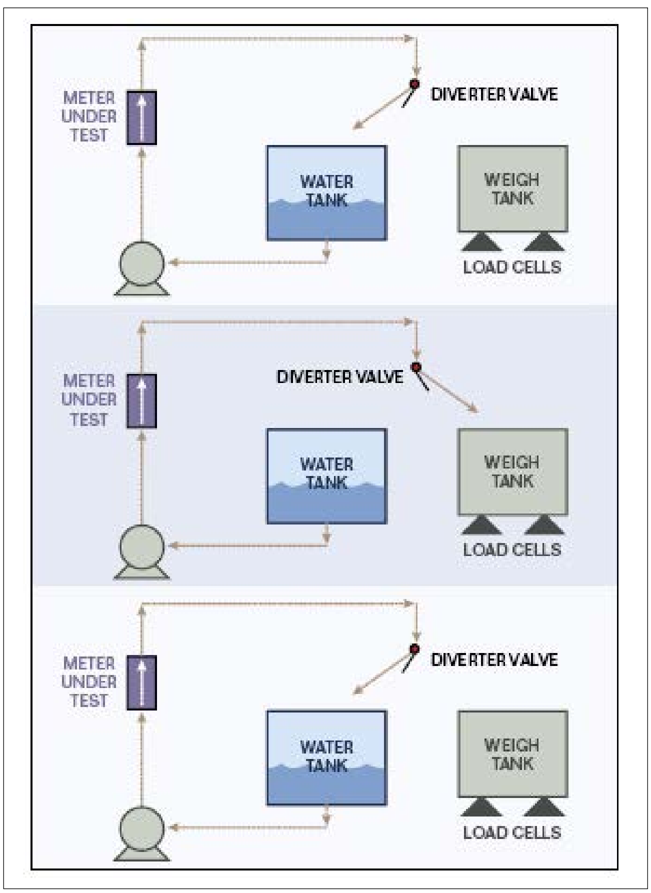
Status Checking

However, expanded diagnostics applicable to some flowmeter technologies are becoming available to check more of the status relating to the primary element. In some flowmeters, primary element status is used to infer that flowmeter calibration hasn't shifted. This inference isn't a substitute for checking calibration, but when properly designed and interpreted, this status information does increase the probability that the flowmeter is operating properly and that the flowmeter calibration hasn't shifted.

A brief review of calibration here may help clarify implications of information in the previous paragraph. Flowmeters can be calibrated by comparing measurements of the same fluid through a flow laboratory calibration standard and the meter under test (MUT). This can be done by circulating the liquid (See Figure 1, top), diverting the liquid to a weigh tank (middle), and then circulating again (bottom). By comparing measurements from the standard and the MUT (while diverting), the MUT can be adjusted (calibrated) to provide measurements that mimic the standard.

Calibration also can be performed by comparing measurements from the MUT with a flow laboratory with a master flowmeter in series with the MUT. In contrast, in-situ calibration is performed on the installed flowmeter in the field, where its measurements are compared with a standard such as a portable prover.

Note that these are wet calibrations because the actual



PRIMARY FLOWMETER LABORATORY

Figure 1. Calibrating flowmeters can be done by comparing measurements of the same fluid through a flow laboratory calibration standard and the "meter under test" (MUT). This is accomplished by first circulating the liquid (top), diverting the liquid to a weigh tank (middle), and then circulating again (bottom). By comparing measurements from the standard and the MUT (while diverting), the MUT can be adjusted (calibrated) to provide measurements that mimic the standard.

fluid flows through the MUT and the standard. Alternatively, dry calibrations are often used to infer that the flowmeter is calibrated. For example, differential pressure flow transmitters are often wet calibrated using a pressure source; however, its orifice plate flowmeter primary may be dry calibrated by measuring its diameter and visually inspecting it for damage. Many times, it is not examined at all, so it remains uncalibrated and unchecked.

On the other hand, using a calibrator to verify operation of a magnetic flowmeter performs a wet calibration on the transmitter, but doesn't check calibration of the magnetic flowmeter primary at all. This procedure is commonly called a calibration. Note that it's entirely possible that the magnetic flowmeter primary could be damaged or even non-functional before, during, and after this type of calibration.

Fewer Calibrations = Less Costs

Consequently, expanded diagnostics for the flowmeter primary are not a substitute for a wet calibration. However, performing expanded diagnostics does increase the probability that the flowmeter primary is still operational and functioning properly. Instruments with a higher probability of proper operation need not be calibrated as often as instruments subject to frequent calibration shifts or failure. Therefore, adding expanded diagnostics to a flow measurement system can increase the time between calibrations and can reduce the overall cost of calibrating the flowmeter.

Flowmeters that don't have expanded diagnostics generally require some human intervention to locate and diagnose problems. In many plants, the expertise needed to diagnose the problem may not be readily available. Expanded diagnostics can reduce labor costs by more clearly identifying the problem quickly without human intervention. In some cases, problems can be detected and identified, while the problem may still be intermittent and occur

INTO THE BLUE

Figure 2. An operator monitors the flow into the 300,000 lb. capacity weight and volumetric calibration water tank at Utah State University's Hydraulics Lab in Logan, Utah.

well before the process is affected. This can improve process availability and save significant amounts of money in some applications.

Despite limitations, some flowmeter suppliers are embedding diagnostics that verify the integrity of the flowmeter primary. In general, certain parameters associated with the flowmeter primary are measured in the field and compared with measurements previously made at the factory. As long as the difference between the factory values and field measurements remain within tolerances, the calibration of the flowmeter primary is presumed not to have shifted. Some expanded diagnostics are continuously monitored, while others are performed periodically.

This approach isn't a flowmeter calibration. However, it is an in-situ flowmeter verification check that implies (but doesn't definitively determine) that the calibration of the flowmeter primary hasn't shifted because there are other failure modes that may not have been checked.

Using expanded diagnostics can be likened to verifying that the condition and dimensions of an orifice plate hasn't changed, which implies that its calibration hasn't changed. However, this orifice plate check wouldn't detect an out-of-round pipe, coating, plugging, or an obstruction that could change the calibration of the orifice plate flow measurement system. These conditions could be detected using an in-situ flowmeter calibration.

Diagnostics Aid Consistency

Despite its limitations, expanded diagnostic coverage is an in-situ flowmeter verification tool that can improve flowmeter availability and extend intervals between routine calibrations and/or verifications. For example, Micro Motion recently announced the availability of expanded diagnostic coverage for its Coriolis mass flowmeters. It found that verifying the density measurement by periodically filling the flowmeter with known fluids (typically water and air) implies that the flowmeter calibration hasn't changed due to product build-up or corrosion. This is an example of a periodic diagnostic that can reduce calibration costs by increasing the time between routine reference device verifications.

Franki Parson, industry manager of life sciences at Micro Motion, says that, Many GMP-validated pharmaceutical manufacturing facilities must routinely verify field instrumentation to demonstrate process consistency. The ability to verify consistent performance, without external calibration laboratories or reference flowmeters, can reduce production interruptions, and can extend intervals between routine verifications. This generally requires less human intervention and can reduce labor costs.

Joseph LaFauci. associate director of automation technology at Merck & Co., adds that, The use of expanded diagnostics should be considered to reduce costs associated with maintaining flowmeter performance. He notes that hard data supporting the cost savings generally isn't available because flowmeters with expanded diagnostics have been on the market for a relatively short time.

Joseph adds the benefits of expanded diagnostics are amplified when used with fieldbus technology that allows faster and more accurate troubleshooting. However, the benefit received from expanded diagnostics depends upon the criticality of the instrument in the process, he says. For example, in critical applications, safety can be improved when transmitter diagnostic status is used to override potentially dangerous, fast-acting process events. Using advanced diagnostics coupled with control system interlocks provides predictable results and safeguards correct operator action.

Some flowmeter suppliers, such as ABB, Krohne and Siemens, can provide portable equipment to periodically check their magnetic flowmeter primaries for insulation resistance and other internal electrical parameters that are indicative of flowmeter primary problems. These are also periodic diagnostics that can reduce the cost of calibrations.

Meanwhile, Joe Incontri, sales and marketing director at Krohne, reports his company offers a magnetic flowmeter transmitter that can continuously perform expanded diagnostics on the flowmeter primary, such as checking for gas bubbles, electrode corrosion, low conductivity, liner damage, electrode fouling, external magnetic fields, partially full conditions, flow profile changes, and conductivity changes.

Incontri adds that Krohne also offers a separate, portable, handheld device that performs similar functions. An advantage of this approach is that the portable can be brought into a laboratory and calibrated, so it will be traceable to an external standard.

Availability Increases Safety

One measurement specialist at a multinational chemical company points out that the value of expanded diagnostics is more evident in Europe, where proof testing of Safety Instrumented Systems (SIS) has been common for more than a decade. Standards require proof testing of failure modes not covered by diagnostics. Therefore, high diagnostic coverage could reduce testing costs because fewer failure modes need to be tested. In addition, allowances for diagnostics might increase process availability in some applications. For example, a 1oo2D (1 out of 2 redundant decision, digital) installation using transmitters with expanded diagnostics might be able to replace a 1oo2 installation that uses conventional transmitters. Compared to the 1oo2, the 1oo2D would tend to reduce the number of false trips.

Another part of improving flowmeter performance is increasing the time that the flowmeter produces good measurements by pinpointing the cause of a problem and/or detecting the problem before it affects the flow measurement and the process. This is especially important when the flowmeter is difficult to access, according to Edgar Fajardo, senior instrument and electrical engineer at BASF in the Netherlands. Edgar works with instruments that have been installed for about a year on an unmanned platform that communicates to land via a fiber-optic link. Expanded diagnostics can help reduce costly helicopter trips to the platform by allowing some problems to be fixed from his office on land. If a trip becomes necessary, remote expanded diagnostics can help the technician select and bring the proper equipment and parts.

Flowmeters with expanded diagnostics have only been installed recently. The prospects for this technology look promising, but time will tell whether the use of expanded technology will take plant operation to a new level. ■

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