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November 2015

STATE OF TECHNOLOGY REPORT

Level & Flow

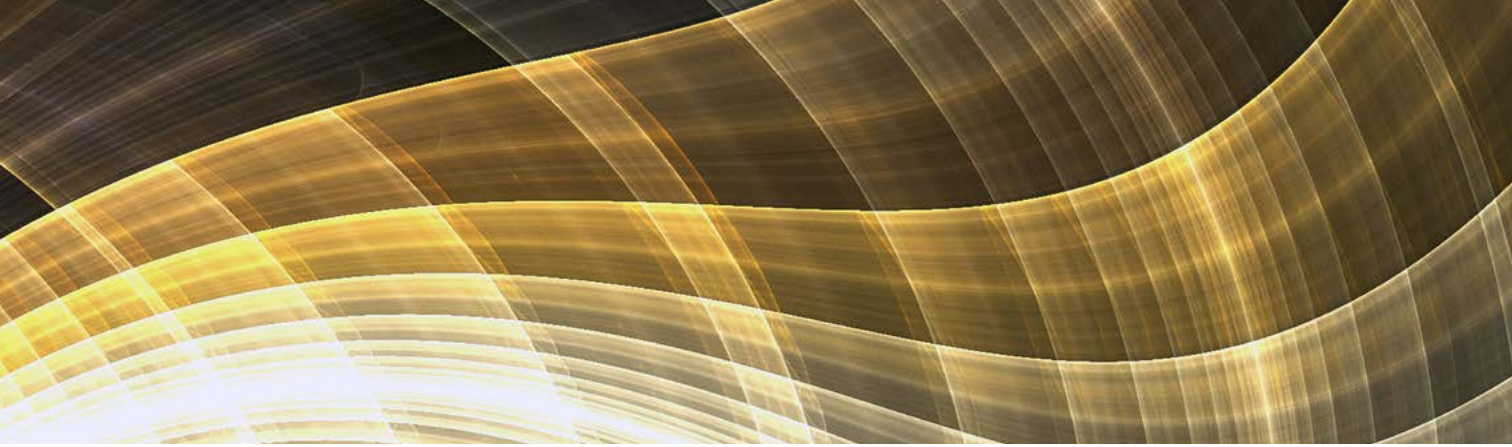


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Flow and level measurement present standing invitations for innovation

Advances in signal processing, networking methods and data management are increasing accuracy, reliability and ranges of applications.

Level and flow rank with temperature and pressure as the most fundamental of process control measurements, but being basic doesn't mean the technologies are standing still. Since last year's inaugural installment of Control's State of Technology Report: Level and Flow, we've seen several trends further mature and flower into real considerations for automation professionals who are installing and upgrading level and flow control systems. We also found some new developments that, while not measurement technologies themselves, promise to revolutionize how instruments are used.

Though the wide selection of basic technologies needed to accurately determine levels and flows haven't changed much in recent years, vendors have been combining capabilities for better measurement, joining them with microprocessors and software that make the sensors and transmitters smarter and more capable, and using networking methods and data management tools to increase their range of applications and help users make better decisions based on their assessments.

As examples, a level instrument that combines guided radar and capacitance is being used on fluids with an emulsion layer to detect interfaces where there isn't a clear separation between phases. For solids level measurement, laser scanners are being used to provide not just point levels, but 3D representations of the irregular surfaces of materials in vessels.

On the flow front, advances in digital signal processing are increasing the accuracy and extending the range of, among others, Coriolis flowmeters, which can now assess two-phase flows, such as a mixture of gas and liquids, more rapidly and in devices with diameters as small as 40 microns and up to 108 inches. Flowmeters of many types are being manufactured with better materials and standards of construction to improve corrosion resistance and to raise their temperature and pressure limits.

Ever more cost-effective, standardized, industrial-strength wireless technologies are allowing level and flow measurements in places where they were previously impossible or impractical, to help optimize inventory management, energy conservation, safety and labor efficiency. We're also starting to see proof that, with appropriate control strategies, wireless instrumentation and actuators can be used to safely and effectively perform a wide range of process control applications.

Of course, real safety systems still trend in favor of mechanical devices for safety applications such as pump protection or tank overflow prevention. Here, differentiated technology plays a role in establishing the independence of safety protection layers: A mechanical switch or magnetic level indicator provides assurance against common cause failures when used in conjunction with an electronic gauge.

The following pages present a compendium of the latest trends articles and application stories recently published in the pages of Control. We hope you find it useful.

The Editors

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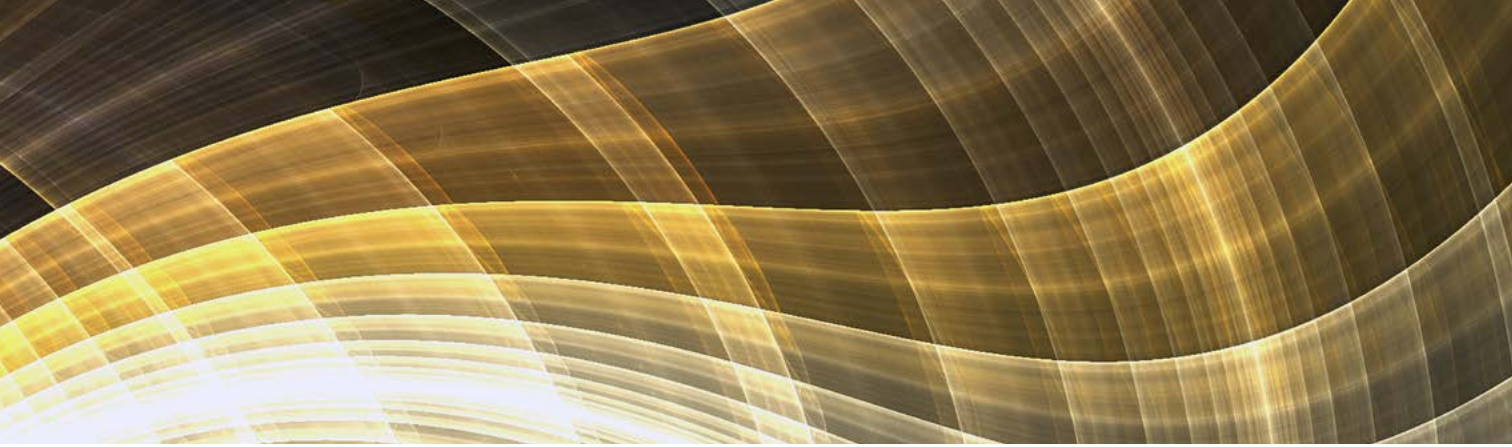
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People for Process Automation



Level technologies get faster and more precise

Level instrumentation, peripheral technologies, networking and software are being coordinated in efforts to obtain faster, more accurate readings.

By Jim Montague

“Level” measurement might be the wrong word. Changeable, dynamic or chaotic measurement might reflect reality better. This is because the contents of most tanks, silos and other process vessels are often anything but level. They’re typically pouring in, mixing with other substances, reacting chemically or draining out.

Of course, most process materials have enough time to settle before they’re measured, but users churning out increasingly complex products faster are pushing existing level devices to their limits. As a result, engineers, integrators and suppliers are helping users implement more sophisticated level technologies, combining existing level devices in new ways and also adding peripheral components and software that can help.

Guided by Radar

Two of the today’s most popular and frequently compared level solutions are through-air/non-contact radar and guided-wave radar (GWR). The first sends electromagnetic microwave pulses through the atmosphere, while GWR directs its pulses along a probe or, increasingly, flexible cable. As usual, the trick is to have the right level technology to fit the application.

For instance, Red Arrow Products Co. produces natural smoke condensates and food flavorings at its plant in Manitowoc, Wisconsin, and it stores wood oil in a 1.5-meter collection tank, which must maintain a constant level as part of its evaporation process. The company had been measuring the oil’s level with a capacitance sensor, but coating problems in the tank were causing unreliable measurements and hampering operations. Normally, capacitance devices work well with high-temperature, viscous and sticky substances.



Siemens

STORING SAND

Figure 1: Sibelco UK’s quarry uses flush-mounted, non-contacting Sitrans LR560 through-air radar level measurement transmitters from Siemens to avoid abrasive damage. They operate at a higher frequency of 78 GHz and use a narrower 4° beam angle to make sure their level measurements are accurate.

The wood oil tank was especially difficult because it operates with a vacuum, and its measurement device has to cope with vapor, mist and a tar-like buildup on its probe that could degrade signals. Consequently, Red Arrow’s wood oil tank was migrated to a Rosemount 5300



GWR transmitter with one rigid probe and Signal Quality Metrics (SQM) software from Emerson Process Management.

“In the past, occasional unplanned shutdowns due to probe failures or coating issues would upset our process, reducing product throughput and increasing energy use,” says Barry Schardt, Red Arrow’s equipment manager and electrical engineer. “Since we installed Emerson’s GWR transmitters a few years ago, we haven’t had premature shutdowns during a production run due to level probe failure.”

GWR isn’t affected by pressure and vapor-space changes, and SQM provides diagnostic information that relates directly to the coating on the probe and to changing surface conditions. These values can be assigned as process variables and tracked over time. This means Red Arrow’s staff can use their SQM data to maintain ideal operating conditions and improve product quality over extended, continuous runs.

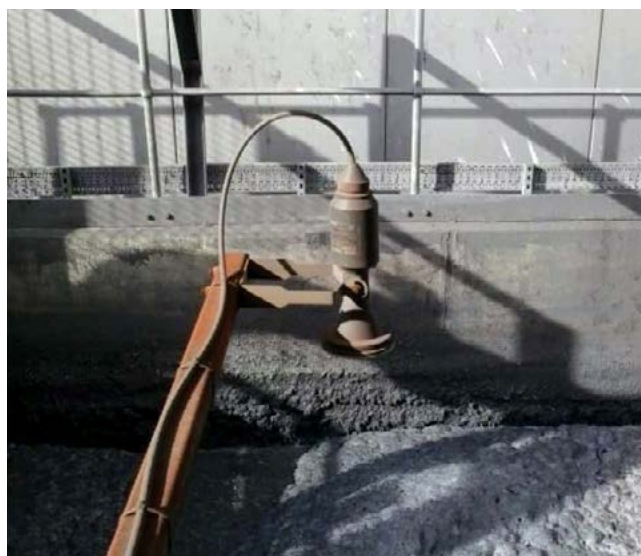
“We’re seeing more acceptance of radar technologies as they mature, and GWR is growing faster than other level technologies,” says Christoffer Widahl, senior product manager for new level programs at Emerson.

Fly Through the Air

As capable as GWR is in many applications, there are others where through-air/non-contact radar is indispensable for getting pulses through and securing accurate signals.

For example, Sibelco UK ships 750,000 to 800,000 tons of red and white silica sand per year from its 12-15-meter-deep quarry in Arelid, Cheshire, U.K. The white sand is used for making glass, and the red sand is used for playing-field drainage, animal bedding and other purposes. Once the sand is conveyed, cleaned, conditioned, graded and sorted, it’s stored in 20- and 49-meter silos.

These silos previously used GWR, but the abrasive sand was hard on the contact devices, and forced technicians to adjust them often to get accurate level readings. As a result, Sibelco recently switched to Sitrans LR560 through-air radar level measurement transmitters from Siemens. Operating at a higher frequency of 78 GHz and using a narrower



Vega

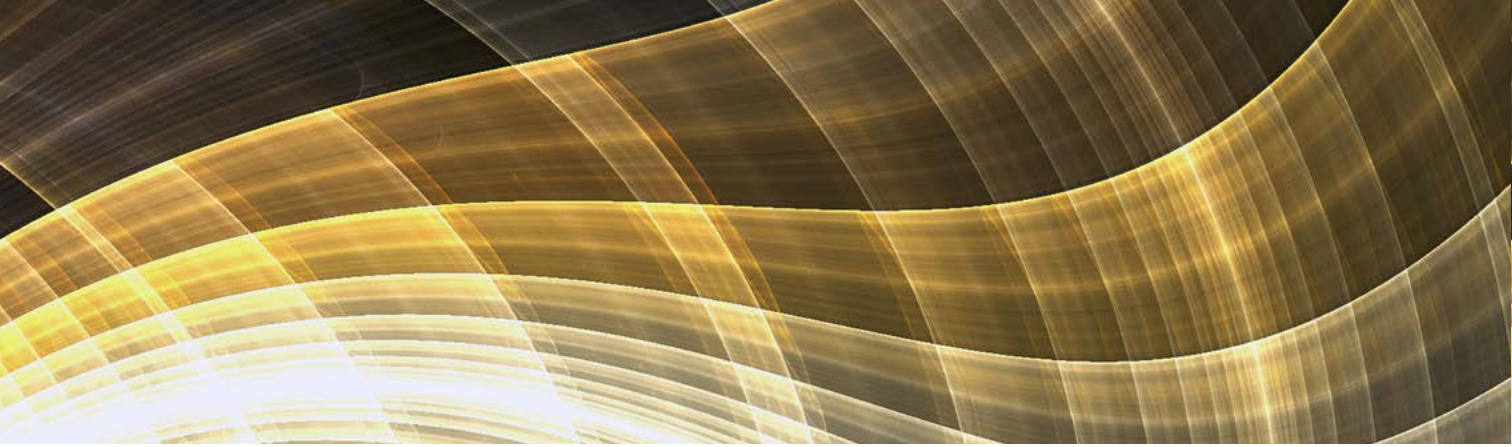
FOAM FIGHTER

Figure 2: The coagulation tank at Aston Martin’s paint shop uses a VegaPuls WL61 through-air radar sensor and its signal-focusing, 80-mm antenna to penetrate foam, secure millimeter level readings, maintain optimum water levels in the tank and prevent overflows.

4° beam angle, LR560 ensures that level measurements are consistently accurate. And, because the transmitters are flush-mounted and non-contacting, Sibelco’s technicians don’t need to worry about the abrasive sand affecting the instruments.

“The LR560 needs very little, if any, maintenance,” says Adam Daniels, Sibelco’s operations unit manager. “We’re pleased with the time savings we’ve gained from using these transmitters.”

Herman Coello, level market manager at Siemens, adds, “Ten or 12 years ago, you had to be an expert to set up a radar level transmitter, but today they’re super simple and can be set up in a couple of minutes. To avoid overflows and fines, radar solutions can also be combined with secondary



technologies such as mechanical floats, electronic capacitance devices or point-level switch for vessels needing alerts and alarms.”

Similarly, Aston Martin Lagonda Ltd. in Gaydon, Warwick, U.K., adds up to nine coats of paint to its auto bodies during a 50-hour process.

As a result, its paint shop must be carefully controlled. This includes its water recycling application and 3.5 x 5 x 8-meter coagulation tank with 140,000-liter/minute effluent flow, where entrained solids are removed (Figure 2). At the inlet, two transfer pumps force the incoming stream downwards, aerating the water to accelerate and improve the separation process. The coagulated solids settle at the bottom of the tank, and the clean, aerated water at the surface flows over a weir to be further treated and reused. The solids at the bottom are periodically pumped away for drying and disposal.

Because effluent treatment problems can quickly halt painting and production, Aston Martin’s engineers report it’s crucial to maintain optimum level and prevent overflow in the tank. However, this can be difficult because the water’s surface is turbulent, it foams readily and heavily, and buildup on any contact device quickly causes problems. In fact, after installing a GWR and trying point level switches, they found the heavy, unpredictable buildup and contamination on the probes was so severe that they caused false readings and needed frequent cleaning.

Consequently, a couple of years ago, Aston Martin’s engineers changed out its contact devices and implemented a contactless VegaPuls WL61 radar level sensor. It’s designed for water/wastewater applications, features an IP68 housing with an encapsulated antenna that’s ideal for harsh, effluent-plant environments, and is suited for them because the liquid density and substances contained in the liquid have no bearing on measurement accuracy. Most importantly, VegaPuls WL61 can cope with all reasonable levels of foam due to its signal sensitivity and 80-mm antenna that focuses its signal.

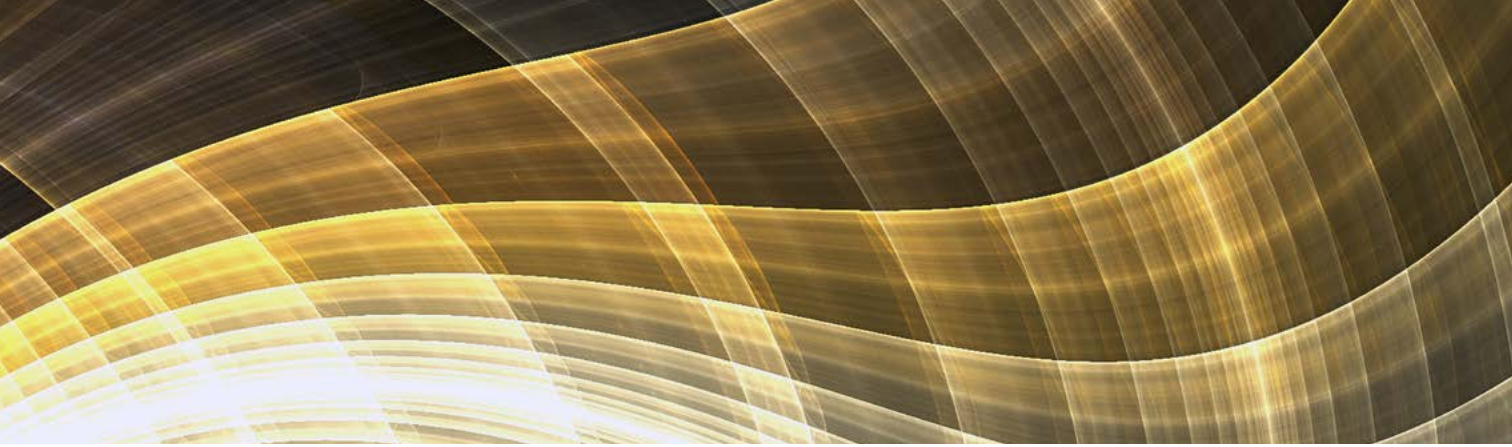
“The readings we now get are to the millimeter, which is extremely accurate, and allows us to have a greater level

of control, especially as this measurement also governs the water make-up valve, which operates to re-level the tank as water evaporates due to the process,” stated Aston Martin’s engineers. “All of the control strategy for the coagulation tank water system was rewritten after installation due to the radar level sensor’s greater level of accuracy, and so far we’ve enjoyed a 100% efficiency rate. The safety surrounding the tank has also been increased because we don’t have to enter the guarded area around the tank to clean off buildup. Being non-contact is ideal in this application, so if the pit is cleared out, we don’t risk any sensor damage either.”

Jeff Brand, product manager at Vega Americas Inc., reports that it’s improving performance of both through-air and GWR with more powerful, less costly microprocessors. “Better chips allow level measurement devices to send and receive more pulses quicker,” says Brand. “Those rates have doubled over the past five years, so we have much better resolution and signal processing, and we’re able to resolve levels faster and more accurately. The typical accuracy for our through-air products is ± 1 mm where it used to be ± 8 mm, and this means better inventory control and decision making for users.”

Beyond radar, some developers and users are implementing sonic scanners and laser-based devices to map material surfaces in vessels and help calculate their volumes and contents. For instance, Anglo Gold Ashanti’s (AGA) Moab Khotsong mine contributes 16.4% of the gold ore used by AGA’s South African operations. The ore is stored in 10 x 22-meter silos that can hold up to 10,000 tons, but grizzly bars across an aperture at the bottom of the silos must always be covered by enough material to avoid damage or blockages caused by rocks and gravel entering the silos.

As a result, AGA recently adopted Rosemount 5708 3D acoustic solids scanners in its gold ore silos to provide reliable content volume measurements. The resulting 3D graphical output of the mapped surface allows AGA’s site operations team to monitor if there’s sufficient gold ore for production and make sure it’s spread out enough to cover and protect the grizzly bars. They also enable the team to



see from a safe location if bridging or buildup is happening inside the silo.

“The 3D solids scanner provides us with accurate measurements in our large silo, which allows us to protect our equipment,” says Ernst Smith, C&I manager at AGA.

Similarly, ABB K-Tek recently released its VM3D volumetric measurement, 3D laser scanner that can form 3D maps of stockpiled solids in vessels. “Users can use VM3D to laser-trace profiles of chemical, fertilizers, coal, potash and other materials to more accurately determine their inventories,” says Charles Richard, ABB K-Tek’s global products manager for radar and magnetostrictive products.

Multitasking Measurement

Though level methods haven’t changed much at their roots in recent years, they have been combining technologies for better measurement, joining with microprocessors and software that make sensors and level transmitters smarter and more capable, and using networking and data management tools that help users make better decisions based on their analyses.

Gene Henry, senior product manager for level at Endress+Hauser, reports that E+H launched its Levelflex FMP55 multiparameter device a couple of years ago to combine guided radar and capacitance in one component. This cooperation is useful in level applications with an emulsion layer, and it’s even more helpful when there isn’t a clear separation between these layers.

“With a rag layer like this, the overall radar signal can get lost sometimes, and when this happens, our FMP55 can automatically switch to capacitance,” explains Henry. “Basically, the FMP55 provides two outputs. One is the overall guided radar, while the other can interface with capacitance or guided radar. Many products are separated by density, but now users no longer need to have two devices.”

Richard adds that ABB K-Tek’s Magwave solution combines magnetostrictive, GWR and local float components in one device with one set of process connections, and can add magnetically actuated switches to the float. “This is a dual-chamber device,” says Richard. “The GWR measures

FINDING THE RIGHT LEVEL

Several process control and automation suppliers offer online resources for learning about, evaluating, comparing and selecting the appropriate level measurement technologies based on the specific needs of each application. Here are a few of the most useful:

Endress+Hauser Applicator lets users input the temperature, pressure and other parameters they need, and narrow their selections to the most appropriate choices for level measurement and other technologies. It’s located at <https://portal.endress.com/webapp/applicator10>.

The Rosemount Library App from Emerson Process Management’s Rosemount Tank Radar AB division provides a series of easy-to-use engineering guides, which offer comprehensive information in the selection and installation planning of process components, including level measurement devices. Visit the library. “A Dozen Ways to Measure Fluid Level” is a white paper by ABB K-Tek that compares many of the most popular fluid-level methods.

liquid and produces a 4-20 mA signal; the magnetostrictive device detects the bullet float inside and has a 4-20 mA output; and the float and magnetic gauge have a local indicator. Having two independent and redundant transmitters and a local indicator is getting popular because they’re safer.”

Henry agrees that more powerful, less costly microprocessors, software and algorithms are enhancing level measurement capabilities and coordination. “The real innovations in level today are on the software side because we can use more of the data we’re getting from the same instrumentation,” says Henry. “So if we’ve got foam, and we’re monitoring the signal strength of free-air radar coming through it, we can now evaluate that signal with software, quantify how much foam is developing based on how much the output signal strength is diminished, and decide when and how much defoamer to add. Previously, defoamer was added periodically, which meant too much was used at too much cost. ■



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Advances in flow measurement and control

Current Industrial Instrumentation Measures More Parameters, More Accurately

By Leslie Gordon

The advent of more capable digital signal processing algorithms has resulted in an industry move toward electronic instrumentation such as mass, ultrasonic and magnetic flowmeters, while advances in traditional mechanical differential pressure, turbine and positive displacement devices are keeping them still the most appropriate technology for certain tasks. Let's take a closer look at developments taking place in the world of top flow measurement technologies and their applications.

Measuring Two-Phase Flows

Advances in Coriolis flowmeter technology now enable the meters to handle two-phase flows, such as a mixture of gas and liquids. These devices are also much faster to respond to changes in flow, thanks to newer digital techniques that let them respond in milliseconds.

At Chemtura Corp.'s Great Lakes Chemical facility in Manchester, U.K., technicians were having problems with a batch line that makes a variety of water treatment chemicals for heating systems and desalination applications. This process combines three feeds into a tank, blends and pH-balances the batch, and pumps it into a storage tank using a traditional Coriolis meter to measure flow. Sometimes the product needs filtering when it's pumped from the tank, which reduces the flow.

"We had large discrepancies between the metered inputs and output, and it was clear that the traditional Coriolis meters were not 'seeing' the entire product passing through," says Roger Marsden, director of Westmeade Services Ltd., which provides technical support to Chemtura. "Depending on the flow rate, up to 200 kg of product was 'missing.' When the product was filtered, as much as 1,000 kg went unmeasured."

The company tried using a digital Coriolis meter to see if

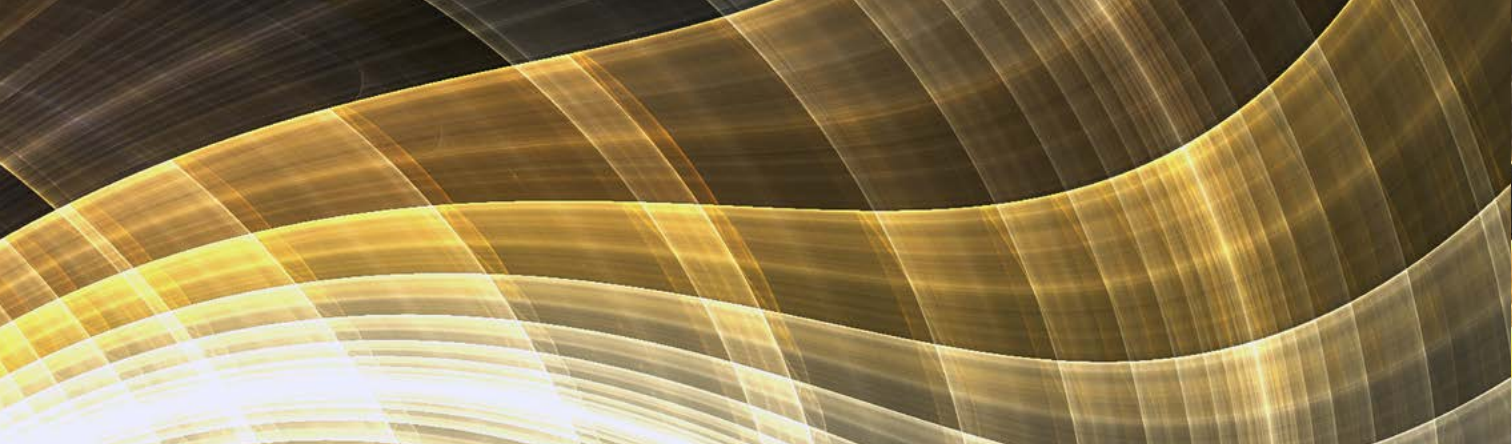


Schneider Electric

MEASURING MILK RUNS

Figure 1: Newer digital technology enables Coriolis meters to better read both mass flow and density, which is useful in applications such as loading and unloading milk trucks.

this would solve the problem. To test the meter, technicians installed a Foxboro CFT50 meter from Schneider Electric in series with the existing meter on the outlet to compare their performance. At the onset of flow, both meters had a zero reading, while the density reading indicated they were "wet and empty." Once the flow began, the CFT50 started to measure immediately, but the traditional meter took 16 seconds to register the flow, thereby allowing about 4 kg of material to pass through unmeasured. At full flow, the two me-



ters had the same readings. However, when the flow tubes drained, the existing meter stalled, failing to register the final blow-through of product. “We removed the old meter based on the CFT50’s good performance,” says Great Lakes instrumentation and evaluation manager Mark Wilkinson.

According to Wade Mattar, flow product manager, field devices for Schneider Electric, “Newer digital techniques have let the devices’ use expand into different applications such as that of loading and unloading milk trucks [Figure 1].” When a truck comes from a dairy to a processing plant and is emptied, a small amount of milk inevitably remains in the lines. If the milk sits too long, it will sour, so it’s necessary to completely clean the lines and tubing. “The changing flow conditions from full to empty typically mean gas gets mixed in with the liquid in the line. Older instruments would have shut down for several seconds trying to figure out how to deal with the gas, meaning the facility is missing lots of flow measurements, but digital Coriolis meters can easily handle these upsets,” continues Mattar.

Over the years, Mattar has seen a continual shift from the importance of just repeatability to accuracy for process control. “For example, due to a lack of accuracy, dairy processing plants in the past were losing 5-10% of the milk delivered from the truck, which they still had to pay for. More accurately metering the milk puts more money in the processor’s pocket,” he says.

Better Material Compatibility, Signal Analysis Techniques

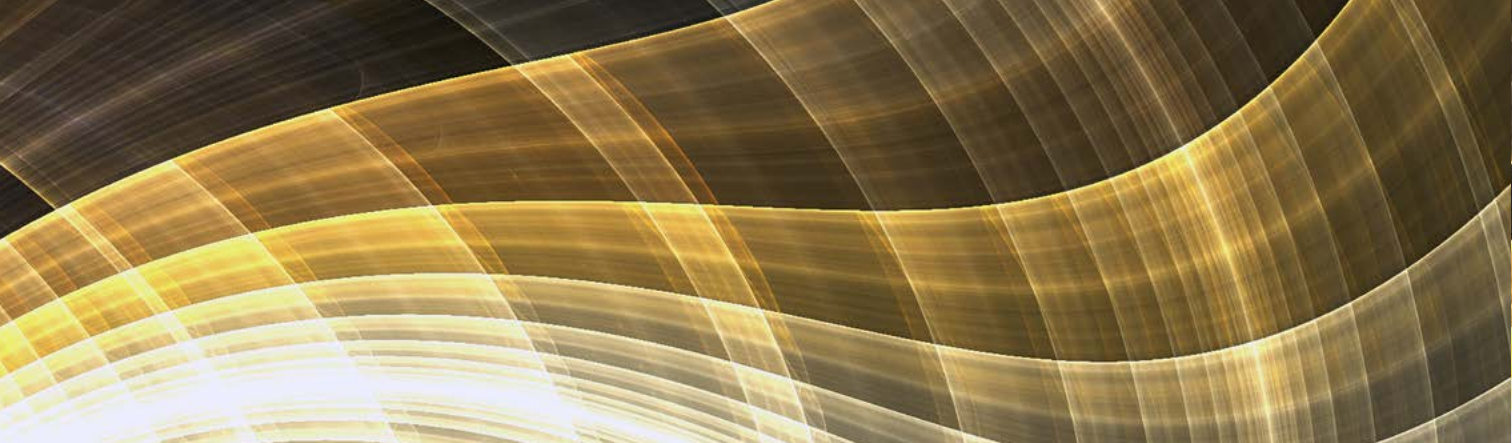
“The most popular and advancing technologies today center around Coriolis mass flow, electromagnetic magmeters, vortex technology, thermal mass and ultrasonic flowmeters,” says Jerry Stevens, product management team lead, flow products, Endress+Hauser. “While vortex, ultrasonic and electromagnetic technologies are inherently volumetric by their nature, thermal mass and Coriolis meters are con-

sidered traditional direct mass flow measurement devices. However, some of the volumetric devices do have the capability to generate a compensated output, maybe with the addition of temperature or pressure, or even fixed values, to output in mass engineering units.”

When it comes to recent enhancements to the performance in the flowmeter itself, Stevens says, “The best way to understand this is to look at the sensor, as well as the transmitter function and technology. The advent of new microprocessors and signal processing speeds have allowed better signal analysis techniques, which has improved all types of flow devices in general.” In addition, devices with diameters as small as 40 microns and up to 108 inches are demonstrating improved accuracy and stability with today’s digital signal processing.

Standards for better material compatibility for certain processes have also become a big factor for sensors. Examples include NACE-compliant materials for the chemical industry and NORSOK-compliant materials for the oil and gas industry, where super duplex stainless steel, a form of austenitic stainless steel, is now being used. Exotic high-nickel alloys as well as materials such as zirconium and tantalum, suitable for highly corrosive applications have also come into play. Current sensors can handle higher process pressures. “In fact, it’s not surprising to find flowmeters with the capability to match class 1500/2500 pressure ranges for many of the most commonly used flow technologies,” says Stevens.

The operating temperature range of sensors has also increased. “Industry demands for external ambient temperatures for most instrumentation used today in the highest percentage of applications is around -40 to 140 °F, but it’s not uncommon for process temperature requirements to mandate that the sensor technology must function from -328 to 842 °F,” says Stevens.



Improved vortex technology has increased the meters' suitability for measuring steam as compared to meters using traditional volumetric technologies such as differential pressure. "Additional measurement and input capabilities mean the device can eliminate the need for flow computers and directly output mass flow rates and calculated energy values to cover a wider range of process operating conditions, and refine end users' process capabilities," he says.

He gave an example of how vortex wet steam technology can even make better beer. Typically, a brewer heats a combination of milled grain and water with steam. Poor steam quality can impact the amount of heat or energy imparted in the process and the resulting produced wort. "Pressure changes from pipe reductions, as well as constricted flow through valves, tees and elbows, changes the steam type, superheating steam." This causes inaccurate monitoring of the used energy.

According to Stevens, using state-of-the-art vortex meters now solves the problem. "The meters 'know' the flow rate of steam regardless of changes in steam types because they can integrate temperature, pressure and, with innovative signal processing, obtain steam quality. This can ensure an accurate value of energy that's being used to control the process. This allowed a user to pinpoint inefficient areas in their plant operation, leading to process efficiency gains of over 20%," he says.

Flowmeters Help Measure Flare-Off

A recent trend in thermal dispersion flowmeters is the customer need for in-situ calibration checking and verification to meet environmental and safety regulations. "By that, I mean the capability to verify the flowmeter is still within calibration tolerances without physically removing it from the process stream," says marketing director Randy Brown of Fluid Components International (FCI). "In-situ calibra-

tion verification is an advantage because it's very expensive to remove flowmeters from the process, transport them to a lab, and wait for the lab to check their calibration, only to be told the meters are fine."

According to Brown, thermal dispersion meters operate by measuring the energy being shed by the sensors to molecules of the process fluid. "Our meter design features two thermowells. One is held at a constant temperature, and the other one is active and changing temperature with the flow. The differential temperature between the two thermowells is proportional to the direct mass flow rate. Thermal dispersion is therefore inherently dual-function, measuring both flow and temperature," he says.

Thermal flowmeters come in both inline and insertion configurations. The insertion style is more popular because it can be inserted with a single tap point, and the sensors are immersed directly into the flow stream. They can measure almost any kind of gas, including mixed-composition, moist and dirty gases.

With no moving parts to foul, break or wear, thermal dispersion meters are suitable for rugged, harsh applications. "We have a SIL-rated meter and global agency approvals on the entire instrument, from the sensor through the electronics and enclosure, for Class I, Div. 1, Zone 1 type explosive atmospheres, as well as NEMA 4X and IP67 ratings on the enclosures. Depending on the specific model, they include a local readout, multiple 4-20 mA analog outputs, and digital bus communications, including HART, Foundation fieldbus, Profibus and Modbus to communicate with operators and their control systems," says Brown.

While FCI's air/gas thermal flowmeters are found in a wide variety of industrial process and plant settings, including on-shore and off-shore flaring applications, they have recently become a good choice for flare gas monitoring applications at hydraulic fracturing sites.



Brown explains, “At fracking sites, it is natural gas that is being flared off, and the U.S. EPA and other regulators require measurement and reporting of the flared natural gas to determine if routine flaring can be continued or not. In the U.S., regulations stipulate that sites flaring off more than a certain amount of gas must instead recover it or pay fines equal to purchasing/consuming the gas.”

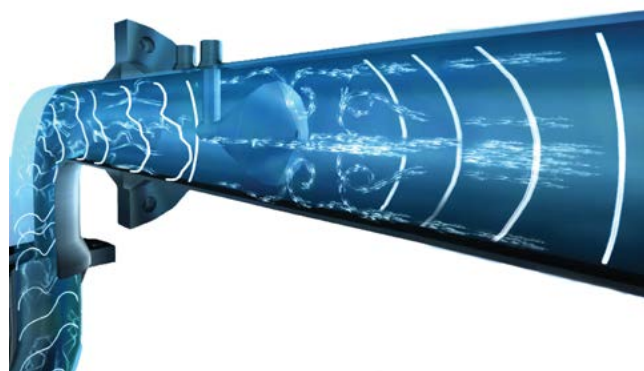
Eliminate Long Straight Runs

Also agreeing that accuracy is increasingly important, in this case for differential pressure (DP) meters, is Nick Voss, product manager of flow instrumentation designer and manufacturer McCrometer Inc. “DP meters are more accurate because of improved DP transmitters. For a long time, DP transmitters were the weak point in the measurement system because although they were accurate at the middle to high range of their full span, their low-range measurements were inaccurate. Over time, DP transmitter manufacturers have done a lot to improve the sensitivity of their equipment.”

For measuring fluid flow in closed conduits, the American Gas Association (AGA) or ISO 5167 require certain lengths of straight upstream piping to meter accurately, depending on the upstream disturbance. For instance, an orifice plate downstream of a double elbow in a 10-in. line needs 440 inches of upstream run. Even a Venturi meter needs about 220 inches for a 10-in. line, meaning that a lot of straight upstream run is required for an accurate measurement.

“In contrast, consider our V-Cone, a differential pressure-type meter similar to a Venturi or an orifice plate, but without the disadvantages,” says Voss. As the flow approaches the cone inside the device, the flow profile “flattens” into a well-developed profile, even in extreme flow conditions. When the flow passes the cone, the cone shape causes short vortices to form. The vortices create a low-amplitude, high-frequency and stable signal (Figure 2). “The design

lets users, for instance, bolt the device to a double elbow, requiring zero upstream run,” says Voss. “The V-Cone basically conditions out flow disturbances leading to the meter, thereby eliminating the need to use a conditioning plate.”



McCrometer

FLATTEN FLOW DISTURBANCES

Figure 2: As the flow approaches the cone inside a V-Cone meter, the flow profile “flattens” into a well-developed profile. When the flow passes the cone, the cone shape causes short vortices to form. They create a low-amplitude, high-frequency, stable signal.

Ultimately, regardless of the type of flowmeter, there is usually one element to be wary of, warns Voss. “In choosing a flowmeter, users must assess the environment it will work in. For instance, because Coriolis meters operate on vibration, they can be susceptible to vibration in the line. Most ultrasonic meters have to be specially designed to handle high-temperature steam and low-temperature cryogenic service. DP meters require ensuring the DP transmitters can withstand the temperature of the process fluid. And mag meters can be susceptible to electrical signal noise.” ■



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Looking Forward

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How to simulate wireless control

Modern systems support a modular approach that starts with the P&ID

By Terry Blevins and Mark Nixon

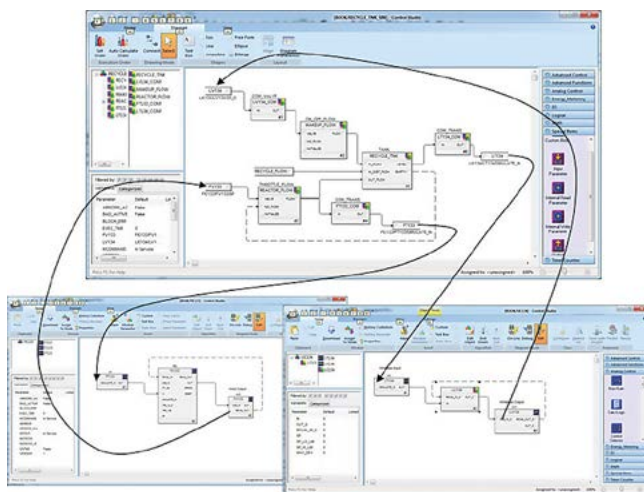
Dynamic process simulations may be used to demonstrate and test control that includes wireless transmitters and/or wireless valves and other final control elements. In most cases, the control system itself may be used to create a process simulation, including simulation of the wireless communication. Such a simulation can be used to check out or demonstrate a wireless control strategy without modifying the modules configured for monitoring, calculation and control.

The simulation can be used off-line with the existing distributed control system (DCS) monitoring and control modules and operator interface to explore and get familiar with tools for wireless control, such as PIDPlus for wireless control (May '15, p. 39) or wireless model predictive control ("Control Talk," June '15, p. 55). The capability also may be used to build comprehensive operator training systems.

How a modern simulation works

When a DCS is structured, for example, to allow control modules to be created using Foundation fieldbus function blocks, the analog output (AO) block is used to manipulate final control elements, such as valves, dampers or variable-speed drives. The analog output block's OUT parameter represents the current or digital signal to these final control elements and is the input to the process simulation. Similarly, in discrete process control, the OUT_D parameter of discrete output blocks may be added as input to the process simulation. Measured and unmeasured disturbances may be included in the simulation as adjustable discrete or analog parameters. When included, these parameters are also inputs to the process simulation.

The process conditions that result from the manipulated and disturbance inputs (e.g., monitored measurements of

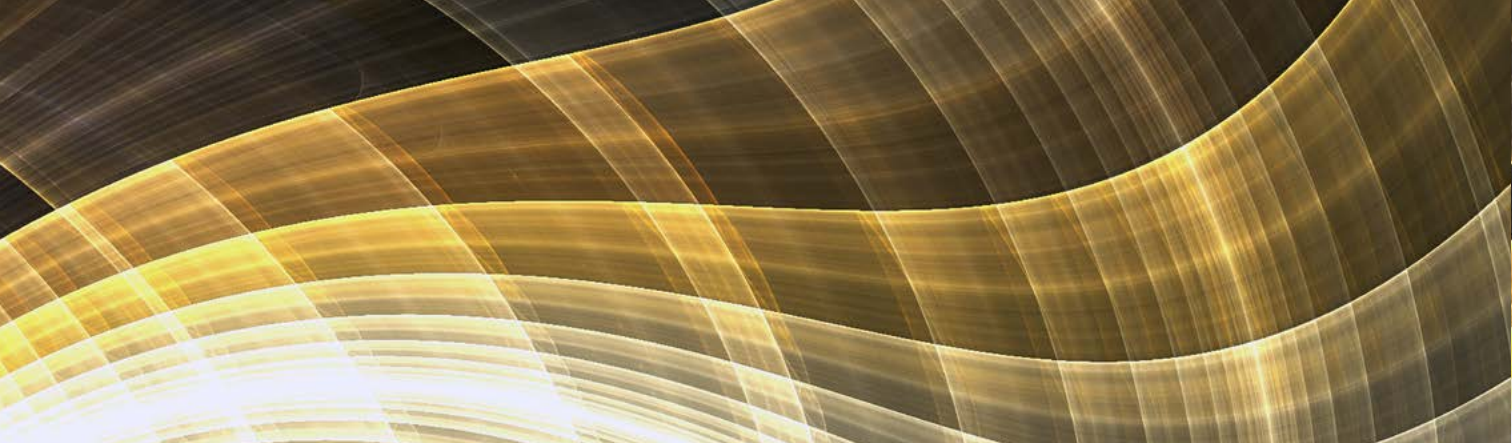


SIMULATION CONNECTIONS

Figure 1: Simulation modules may read the output value of analog and discrete output function blocks that are part of a control module. The results of the simulation modules may then be written back to the simulation input parameters of the analog and discrete input blocks of the existing modules.

process conditions, such as flow, pressure, temperature, level or composition, or the discrete state of a limit switch) are reflected in the process simulation outputs, and may be easily included in the simulation. Some of these process conditions may be measured in the field using transmitters or switches, and thus, the simulated values can be provided to the modules that access these field measurement values using analog and discrete input blocks.

The current or digital outputs of these transmitters and switches are normally accessed in a control system using



the analog and discrete input blocks. However, the normal processing of analog and discrete input blocks can be altered by enabling the Simulate parameter. When simulation is enabled in an input block, a Simulate parameter value is used in place of the field measurement. Thus, the simulated process output values may be used by analog and discrete input blocks in place of field measurements. Process simulation may be incorporated into the control system via this basic control system capability.

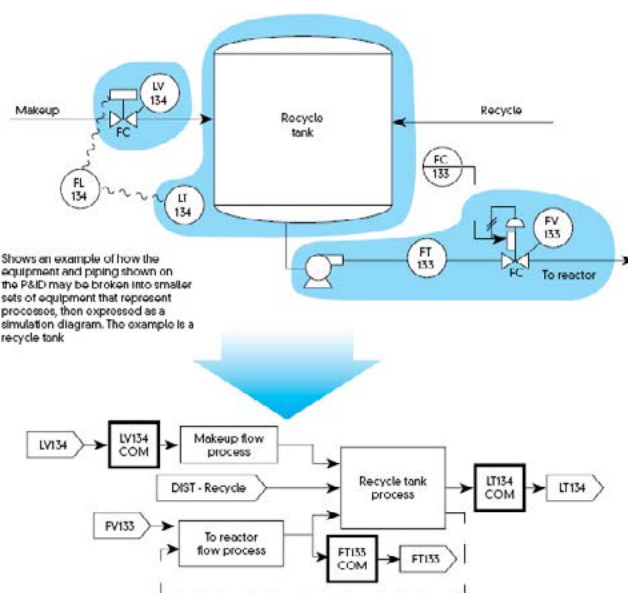
The most common way to add process and wireless communication simulation capability to a control system is to create new modules that contain only the process and wireless communication simulation. These simulation modules may be added without modifying existing modules because most modern control systems include the capability for a module to read and write parameters contained in another module (Figure 1).

The I/O blocks' Simulate parameter can be enabled in the existing modules to use the process simulation. When simulation is enabled, the normal operator control displays and engineering tools may be used to view the monitoring and control functions performed by the existing control system modules.

Develop the simulation from the P&ID

The plant piping and instrumentation diagram (P&ID) often serves as the starting point to develop a process and wireless communication simulation for control system checkout or operator training. In most cases, one process and wireless communication simulation module should be developed for the modules that support control or monitoring functions associated with each piece of equipment. Thus, a first step in developing a simulation is to break down the equipment and piping on the P&ID into multiple processes that may be simulated in one or more simulation modules.

Figure 2 uses the example of a recycle tank to show how the equipment and piping on the P&ID may be broken

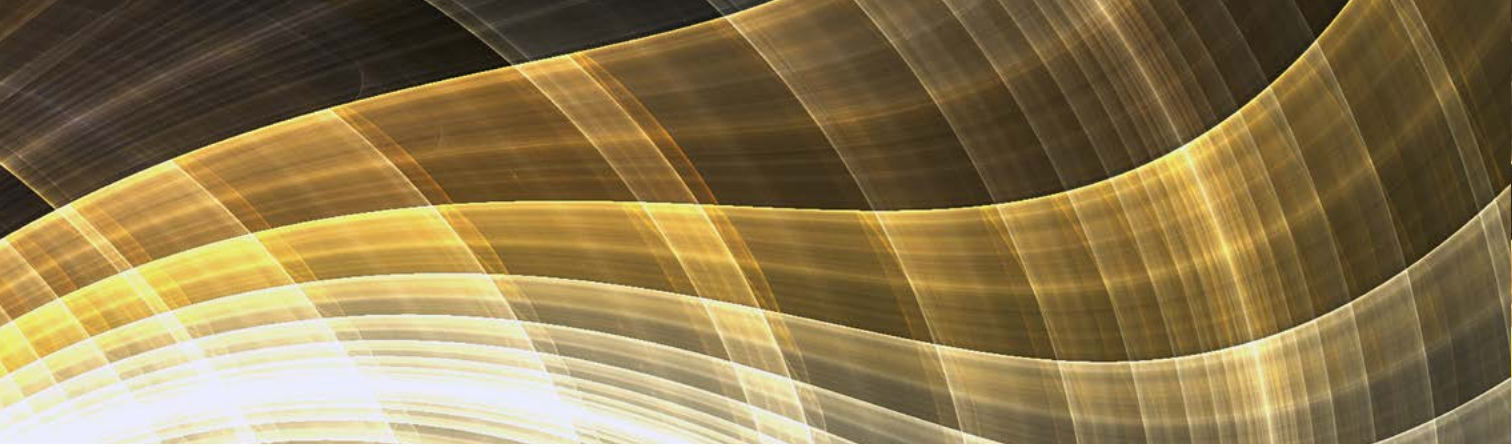


SIMULATION DIAGRAM OF A RECYCLE TANK

Figure 2: The highlighted areas of the P&ID will be simulated processes that are interconnected and can be documented along with the simulated wireless communications in a simulation diagram. Here, the makeup flow to the recycle tank is regulated by LC134 using a wireless on-off valve, FV134, based on the wireless level transmitter, LT134. The flow out of the tank, FT133, is regulated by LC134, using a wired throttling valve, FV133, based on a wireless flow measurement, FT133, and PIDplus for flow control, FC133.

into smaller sets of equipment that represent processes and then expressed as a simulation diagram.

The simulation diagram may be implemented as a simulation module that references the existing control modules. The processes and wireless communications on the simulation diagram are implemented as composite blocks in the simulation module. Process inputs from final control



elements are added as external references to the setpoints of the analog and discrete output blocks in the existing control modules. Unmeasured inputs to a process should be added as parameters. Process outputs and wireless communication simulations that represent field transmitter measurements are then implemented as external references that write to the Simulate parameter of the existing modules' analog and discrete input blocks.

Simulation implementation

When a control system is commissioned, the step response of a self-regulating process is often characterized as first order-plus-dead-time. Similarly, the step response of an integrating process is often characterized by the dead time and the integrating gain. It's appropriate to design a process simulation to duplicate the step response. For example, the simulation of a single input-single output (SISO) self-regulating process may be created using a filter block, a dead-time block and a multiplier block to simulate the process deadtime, time constant and gain. Process noise may be added to the simulated process outputs using a signal generator block.

Simulation of an integrating process should take into account the module execution period, and should support a varying number of inputs. In addition, the calculated value for the level should be limited to the vessel height. For example, a combination of standard function blocks and a calculation block may be used to implement the recycle tank level simulation.

The real-time dynamic response of the simulated tank and associated control modules will accurately reflect changes in flow to the reactor and in the recycle tank inlet flow disturbance input that is defined in the recycle tank simulation module.

A single composite may be created to simulate communication of a measurement value from a wireless transmitter to the gateway and its access by the control system. For example, the composite COM_Trans shown in Figure 3 allows either WirelessHART continuous (periodic) or window (non-peri-

odic) communication to be simulated based on the setup parameters of the composite.

Four parameters are provided in composite to define the communication setup:

- COM_DB – The percent change in the measurement valve from the last communicated value that will trigger a communication.
- COM_Default – The maximum time in seconds between communications.
- COM_Period – The period at which the transmitter wakes up, makes a measurement, and determines if the new value should be communicated based on the change in value and the time since the last communication.
- EXEC_Period – The execution period in seconds of the module that contains the COM_Trans composite.

By setting COM_DB to zero (0), the measurement value will be communicated on a periodic basis based on the update time specified in the parameter COM_Period. When COM_DB is set to a positive non-zero value, the measurement value is compared to the last communicated value on the period specified by COM_Period. If it exceeds the dead band specified by COM_DB, the value is reflected in the composite output to simulate communication of a new value. If the time since the last communication exceeds the default update time, COM_Default, the composite output is also updated to simulate the value that is communicated. If the measurement is used in control, PIDPlus detects communication of a new value by determining that the measurement value has changed.

Simulating non-linearity

Simulations based on duplicating the process step response may be effectively used to calculate a variety of self-regulating

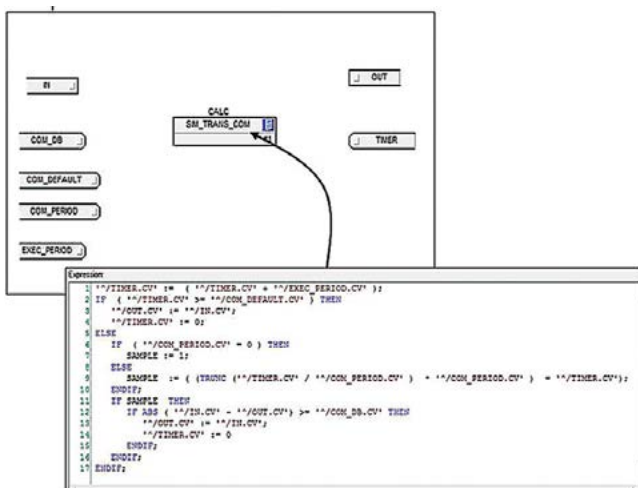


Figure 3: A single composite may be created to simulate communication of a measurement value from a wireless transmitter to the gateway and its access by the control system. Here, the composite COM_TRANS allows either WirelessHART continuous (periodic) or window (non-periodic) communication to be simulated based on its setup parameters.

and integrating process measurements. However, this simulation technique assumes that the process behaves in a linear fashion. When the simulation is used over a wide operating range, the step response may not accurately show the impact of process non-linearity.

A non-linear installed valve characteristic may be simulated by substituting a characterizer block for the gain multiplier block. Similarly, non-linear response often seen in analytic measurements, such as concentration after blending two streams or heater outlet temperature for varying inlet flows, may be accounted for in the process simulation. The corrections in process gain must be based on input/output relationships determined by performing energy and/or mass balance at steady state.

READ THE BOOK

For more information on control using wireless control simulation see Chapter 11 of the book, *Wireless Control Foundation—Continuous and Discrete Control for the Process Industry*. Workshops contained in the book are used to highlight key points. YouTube videos showing workshop solutions can be viewed at the book’s website. The book may be purchased through the ISA website and on Amazon.

Other considerations

Many excellent commercial simulation products may be purchased for process design. The simulation tools supported by these products are based on first-principle analysis of equipment, based on established laws of physics and chemistry, that does not make assumptions such as empirical model and fitting parameters. These simulations typically provide better results over a wider operating range than is possible using a step-response model. Though such tools have been successfully used for operator training, the cost of engineering a simulation with these tools is often prohibitive if the simulation is to be used only for control system checkout or operator training. Also, the expertise needed to update these types of first-principle simulations to reflect changes made at plant startup is often not available in process plants. ■

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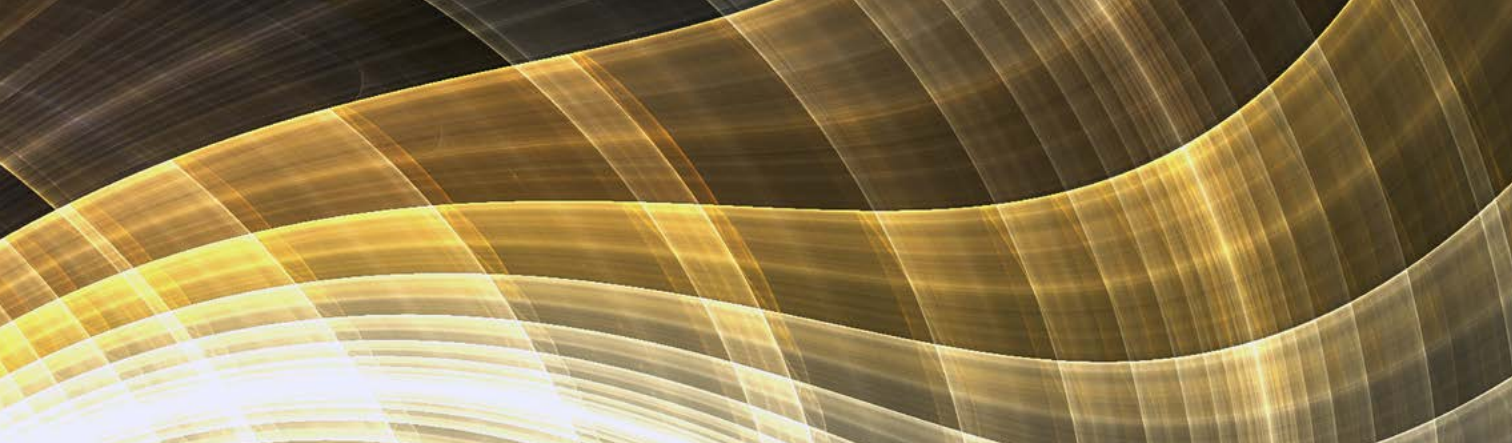
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Advances in Flow Instrumentation

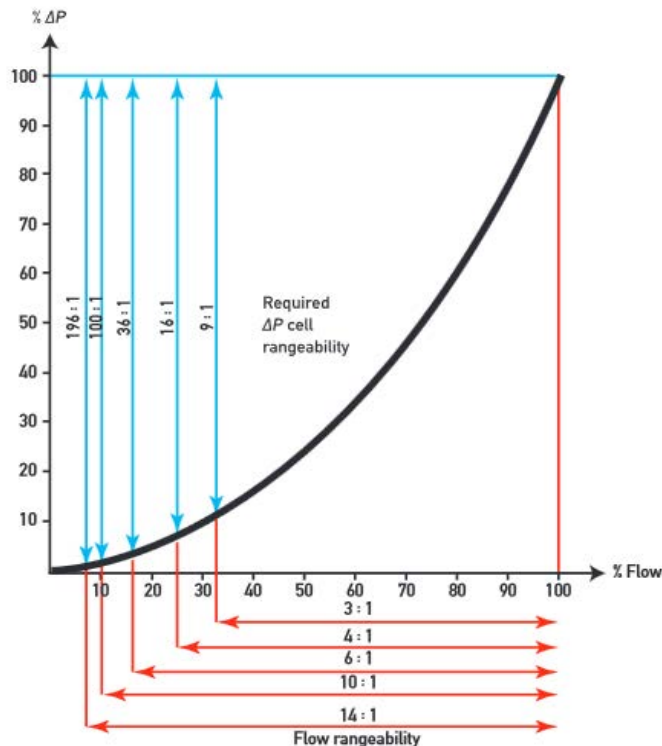
by Béla Lipták

In my May column, I described some new fiber-optic flowmeters used for subsea measurement of multiphase flows (oil, water, methane). Now I will describe some other, more recent advances in the field of flow instrumentation that have occurred partly because of the need for transporting and accurately metering large quantities of oil and natural gas.

Head-Type Flowmeters

When measuring flow by any differential pressure generating element, the measurement error is the sum of the sensor error, which is usually about one percent of actual flow (%AR), and the error of the d/p cell, which used to be around 0.25% to 0.5% of full scale (%FS). Therefore, in the past, if we wanted to keep the total error at minimum flow under 3%AR, the flow turndown (rangeability) had to be limited to about 4:1. Figure 1 shows the relationship between the turndowns in terms of flow and the corresponding turndown requirement of the ΔP transmitter.

Today, the maximum turndown capability of a smart, digital ΔP transmitter is nearly 200:1. Because of the square root relationship, this means that the flow rangeability is 14:1 ($14^2 = 196$). With a ΔP measurement error of 0.065%FS, the d/p cell error is 12.74% AR at the minimum ΔP ($196 \times 0.065 = 12.74\%$). Because of the square root relationship, this minimum ΔP error corresponds to a minimum flow error of $\sqrt{12.74\%} = 3.6\%$ AR. Adding to this ΔP error, the 1%AR error of the sensor (the precision of its discharge coefficient CD), gives us a total error of only 4.6%AR at minimum flow. Naturally, the full



DIGITAL ACCURACY GIVES HIGHER TURNDOWN

Figure 1: At a ΔP turndown of 196:1, the flow turndown is 14:1, and at the minimum flow ($100/14 = 7\%$), the total error is kept under 5% of actual flow (AR).



Emerson Rosemount

PLAYING IN THE HYDROCARBON SPACE

Figure 2: Wireless orifice flowmeters are appropriate for some hard-to-reach applications in oil-and-gas markets.

14:1 turndown can only be realized if at minimum flow ($100/14 = 7\%$ of full scale), the flow is still turbulent ($RE > 8,000$).

In addition to the tremendous increase in the accuracy of the state-of-the-art d/p cells, these smart units are provided with local displays, self diagnostics, alarms, memory boards for data acquisition and storage for hundreds of thousands of data points for displaying of trends, total flows, and to provide cell phone connectivity. They can be mounted to the sensor or connected wirelessly (IEEE802.11), allowing the sensor to be located in hard-to-access areas, while the d/p cell is in an easy-to-access location.

While the Venturi flowmeter is still the favorite when it comes to pressure recovery and accuracy, some of the other head-type flowmeter features also are competing on the hydrocarbon and other markets. For example:

- Conditioning orifice meters with wireless transmission (Figure 2);
- Regular and Venturi wedge meters for fluids containing sand or slurries;
- Averaging Pitot tube inside a flow nozzle combined with pressure/temperature sensors to calculate mass flow of natural gas;
- V-shaped cones. These cones require individual calibration, but their conditioning effect reduces the straight-run requirement; and
- Flow transmitters with pressure and temperature sensors can calculate mass flow of known molecular weight gases (Figure 3).

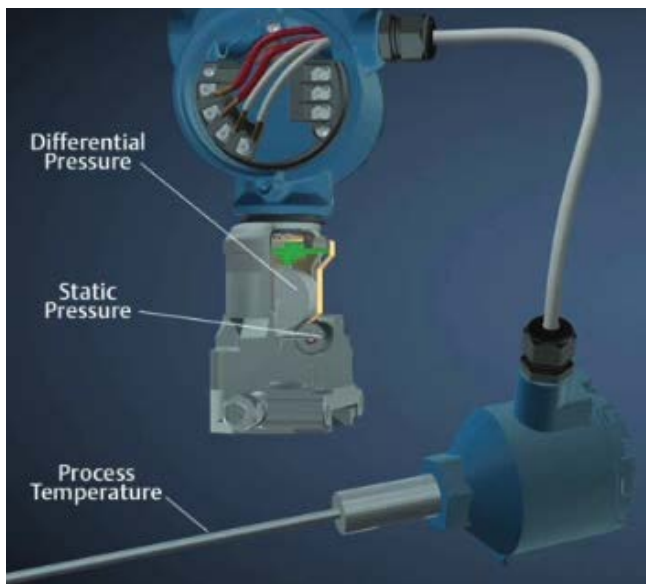
One should note that, in case of large flows, the unrecovered (permanent) pressure loss caused by the meter is an important consideration. This permanent loss is the worst in case of sharp restrictions (orifice $\sim 70\%$) and the best with smooth transitions (Venturi $\sim 15\%$), while something like the V-shaped cone causes an intermediate amount of permanent loss ($\sim 40\%$).

Other Flowmeter Types

In addition to head-type flowmeters, intense activity in the hydrocarbon industry has catalyzed advances in other flow-



meter families. In custody transfer applications, for example, the accurate and reliable Coriolis flowmeter is still the favorite, but other technologies are also competing for that market, for example, this bi-directional, multi-path, ultrasonic mass flowmeter for gas service (Figure 4). Similarly, at the drilling end of the hydrocarbon production process, a number of multiphase (oil, water, methane) flowmeters have been introduced, for example, the water cut meter, which uses five NIR wavelengths to distinguish



Emerson Rosemount

THE TEMPERATURE OF FLOW

Figure 3: Flow transmitter with pressure and temperature sensors calculates mass flow of known molecular weight gases.



Emerson/Daniel

TWO-WAY ULTRASONICS

Figure 4: Bi-directional, multi-path, ultrasonic mass flowmeter for gas service.

water, oil and gas and the undersea multiphase flowmeter, which calculates the total flow and its oil, water and gas content by simultaneous measurements of variables. These units are designed for operation at some miles of depth under the ocean. ■

Béla Lipták, PE, control consultant, is also editor of the Instrument Engineers' Handbook and is seeking new co-authors for the coming new edition of that multi-volume work. He can be reached at liptakbela@aol.com.



Instrumental in Sustainability



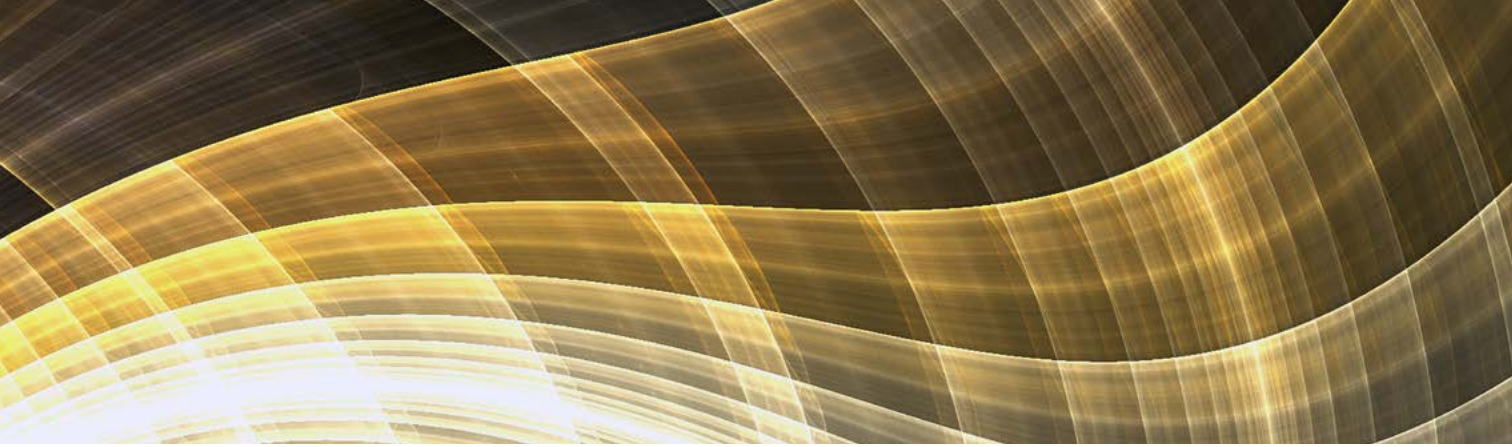
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Wireless level monitoring

Level instruments with wireless links to the cloud and Wi-Fi allow improved tank inventory management systems.

By Dan Hebert

Process plants and related facilities such as tank farms are filled with vessels, tanks and similar storage units, and most of these units could benefit from a system to measure, monitor and view inventory on a near real-time basis. “Logistical benefits of tank level monitoring include reduced emergency deliveries, better inventory management and labor productivity improvements,” says Michael Robinson, director of solutions, Endress+Hauser.

Wireless is a particularly good fit for this application, as most tank level instruments are installed at the top of a tank, a tough spot to access with wiring. Many tanks are located far from control rooms, requiring long home-run wiring. Wiring installed in the corrosive environments where tanks often reside has a tendency to fail at connection points, and conduit systems can rust and deteriorate. Finally, many tanks are installed in areas classified as hazardous, making it expensive to run and maintain wiring.

Available wireless level measurement technologies include differential pressure and radar, each of which can be made truly wireless with a battery-powered option. Relying on battery power could be a serious limitation in wireless instrument applications with rapidly changing process variables, but in the case of tank level monitoring, it’s feasible to have a very low update rate and correspondingly long battery life, up to 10 years in some cases.

But many tanks have existing conventional wired instruments, and others need to use level measurement technologies not available in wireless versions. For these instruments, a wireless adapter can be used to convert the wired instrument output to wireless. Although this isn’t a completely wireless solution, such as a wireless radar or DP level instrument, it does solve the problem of wiring back to an inventory management system.

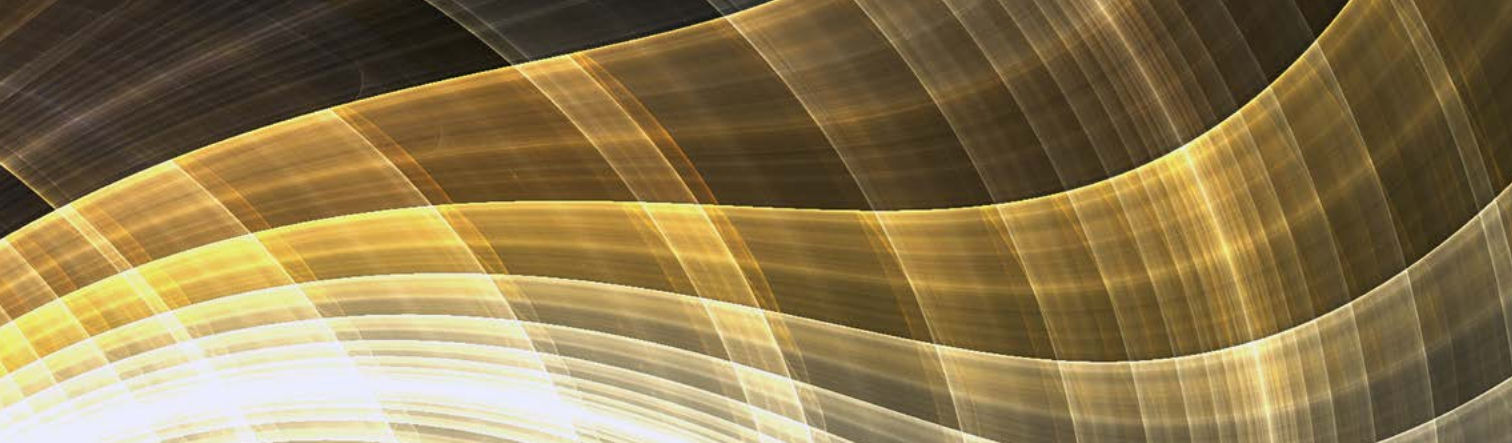
In either case, transforming level measurements into wireless signals is only one part of the equation, with the second being transmitting this information to a tank inventory monitoring and management system. The two main options for creating this data link are via the cloud or a local Wi-Fi network.

“Our wireless tank inventory monitoring solution can include an AC-, battery- or solar-powered cellular communication modem which transmits tank level information to our cloud-based service SupplyCare, which is hosted on secure Endress+Hauser servers. SupplyCare receives and stores the tank data and is configured to trigger visual notifications, email alerts and transaction information,” explains Robinson.

One could configure a system similar to SupplyCare by buying a modem, contracting with a cell provider, contracting with a cloud storage firm and installing appropriate tank inventory management software, such as an HMI with database storage capability, in the cloud. Once tank level data is sent to the cloud, it can be accessed for inventory management by any device with an Internet connection and proper login credentials. Typical devices used for accessing cloud data include PCs, laptops, tablets and smartphones.

Emerson Process Systems installed its Rosemount tank gauging equipment for inventory measurement of liquid storage tanks for St1, a Swedish petroleum refinery located in the Gothenburg harbor area. The plant has a mixture of wired and wireless equipment for level and temperature measurement, all connected to a wireless gateway.

Emerson’s local Smart Wireless Gateway collects tank data from the instruments and makes it available through a WirelessHART Wi-Fi network. Initially, instrument technicians could only perform monitoring and configuration by entering the tank farm area with a laptop PC. To improve access to the wireless network, St1 added a wireless connection from the

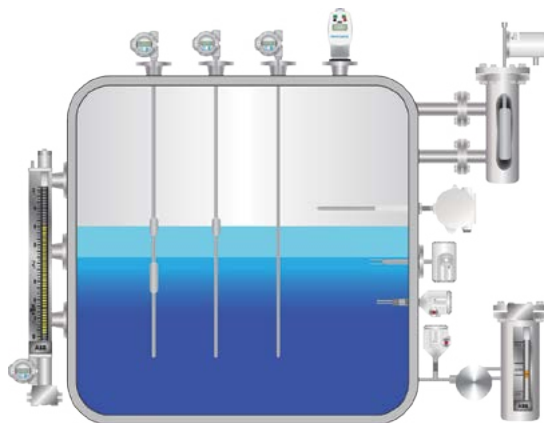


control room to the local gateway via the Wi-Fi based Pervasive Field Network (PFN) solution from Emerson.

The PFN link at St1 includes three industrial hotspot units. One hotspot is connected to the local gateway and to a remotely installed directional panel antenna. A second serves as a repeater to achieve line of sight. It is connected to two remotely installed panel antennas, one receiving and one transmitting, to relay data.

The third hotspot unit is installed in the control room area, and it's connected to a remotely installed panel antenna. In addition, it is equipped with an integrated antenna to create a Wi-Fi zone, enabling operators to access the wireless network from any place in the control room via a laptop equipped with the appropriate software. This data is also now available to any tank level management and inventory system with the Wi-Fi coverage area. ■

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Prevent Tank Farm Overfill Hazards

Catastrophic incidents have led to useful rules for systems that help avoid them.

by William L. Mostia, PE

Driving around petrochemical plants, oil fields or fuel distribution terminals or facilities, it's common to see large tank farms with vessels of various forms and shapes—cylinders, spheres, bullets and spheroids. These tanks can store feedstocks, intermediates and final products. For refineries, many of these tanks are used for what are called oil movements, which blend various products together to provide the many grades of gasoline, diesel and other refinery products required by the market and government regulations.

Process unit tank farms are typically a bit separate from the process units, located in bunds or diked areas, and spread over a large acreage. Fuel distribution terminals, which commonly straddle pipelines, are physically similar and may butt up against residential and light industrial areas, as can some plant tank farms. Many of these tank farms started out as remote sites, but plant expansions have sometimes met external industrial and residential sprawl to increase the potential consequences of a disastrous event.

It's safe to say that thousands of filling, emptying and transferring operations go on each month in these tank farms—maybe even every day. The overwhelming majority are done safely, but some result in overfills, which have led in a few cases to major incidents. Data compiled by a reputable operator in the United States estimated that an overfill occurred once in every 3,300 filling operations (“Atmospheric Storage Tanks,” Risk Engineering Position Paper 01, Marsh Ltd.).

Looking over the past couple of decades, we have had some notable tank overfill incidents: Laem Chabang, Thailand, in 1999 (seven dead); Buncefield, UK, in 2005 (43 injured), and the Cataño oil refinery in Bayamón, Puerto Rico, (three injured). All these involved spectacular explosions and fires with extensive damage to the facility.



UK Government

PRECIPITATING EVENT

Figure 1: In December 2005 a gasoline tank at the Buncefield oil storage and transfer depot, Hemel Hempstead, U.K., overflowed. The resulting unconfined vapor cloud explosion was the largest ever in peacetime Europe.

As it turns out, tank farm overfills that lead to a fire and explosion may not be considered common, but they're certainly not rare. A study of storage tank accidents for the period of 1960-2003 covered 242 tank farm accidents. Fifteen overfill incidents were reported, of which 13 resulted in a fire and explosion (“A Study of Storage Tank Accidents,” James Changa and Cheng-Chung Lin, *Journal of Loss Prevention in the Process Industries*, 19 [2006], p.51-59). The numbers of tank farm overfill incidents were probably under reported in this study, but still, tank farm overfill incidents in the study occurred on



average every three years. One interesting fact that arose while looking at overflow incidents is that they mostly occurred off day shift, which is very advantageous in regard to people occupancy/exposure, but where supervision is typically more relaxed, and there is less general oversight.

What really brought tank farm overfills to the forefront was an industry-changing incident that occurred on Dec. 11, 2005, at the Buncefield oil storage and transfer depot, Hemel Hempstead, UK. A gasoline tank overflowed, leading to an unconfined vapor cloud explosion that was deemed to be unprecedented—the largest ever explosion in peacetime Europe. It was fortunate that the explosion occurred in the early morning hours on the weekend, for while the damage was extensive, no fatalities occurred. However, 43 people were injured. Had the 6:01 a.m. blast happened during working hours on a weekday, it could have been far, far worse.

On Oct. 23, 2009, another large overflow event led to a fire and explosion at the Cataño oil refinery in Bayamón, Puerto Rico, injuring three and resulting in the Caribbean Petroleum Corp. having to file for bankruptcy. Another tank farm overflow also occurred in Kuwait, resulting in a fire and explosion (“Overflow + Ignition = Tank Farm Fire,” Presentation for HSE Moments/Alerts, bit.ly/1rHCPPrB).

While not due to an overflow event, but showing the potential consequences, a 2009 tank farm fire and explosion in Jaipur, India, killed 12 people, injured more than 200 and completely destroyed the tank farm.

Poor Instrumentation, Bad Practices

The Buncefield tank that overflowed had both a level gauge and an independent high-level shutdown, neither of which worked. Kuwait also had a level gauge and independent high-level alarm—neither functioned. In Puerto Rico, the liquid level in the tank could not be determined because the facility’s computerized level monitoring system was not fully operational. It seems there is a potential pattern: poor instrument maintenance, poor testing practices, lack of operational discipline—take your pick. Since tank farms do not “make

money,” many times they can suffer when maintenance budgets are constrained.

Another interesting thing to come out of the Buncefield U.K. Control of Major Accident Hazards (COMAH) report, “Buncefield: Why Did It Happen?” (COMAH, 02/11), was the practice of Buncefield operators “working to alarms.” Both API 2350-January 1996 and 2005 state that, “High-level detectors and/or automatic shutdown/diversion systems on tanks containing Class I and Class II liquids (2005 only) shall not be used for control of routine tank fining operations.” The 2012 version specifically prohibits this practice, but poor operational discipline always seems to trump standards and procedures.

The practice is not new in the process industries, but may deserve more looking into, as it may be more common than one might think, particularly where there are automatic shutdowns protecting transfers into a tank or other process operations. Trust in the protection systems is a form of faith-based risk-taking founded on prior experience, and generally represents normalization of non-conformance to procedures resulting from poor or slack operating discipline. How do your operators really operate your tank farm transfers?

The U.K. issued a number of comprehensive reports and recommendations regarding Buncefield that are worthwhile reading (www.buncefieldinvestigation.gov.uk/reports/index.htm under Reports). From a standards perspective, after Buncefield, the U.K. Health and Safety Executive (HSE) required the competent authority and operators of Buncefield-type sites to develop and agree on a common methodology to determine safety integrity level (SIL) requirements for overflow prevention systems in line with the risk assessment principles in BS EN 61511, Part 3. They should then apply the BS EN 61511, Part 1 for SIL-related systems that come out of the risk assessment. In 2009, the HSE issued the reports, “A Review of Layers of Protection Analysis (LOPA) Analyses of Overflow of Fuel Storage Tanks” and “Safety and Environmental Standards for Fuel Storage Sites.”

Meanwhile, on the west side of the Atlantic, API RP 2350 3rd Edition, “Overflow Protection for Storage Tanks in Petroleum Facilities,” which covers atmospheric tanks storing Class



I (flammable) and Class II (combustible) petroleum liquids, was issued in January 2005, the same year as Buncefield. The third edition of API 2350 was prescriptive in nature and a compilation of best practices that had over the years expanded its reach to these categories.

From an instrumentation perspective, API 2350 had minimal requirements for safety instrumentation and no requirement for evaluation of the safety risk, even though ANSI/ISA S84 (1996, 2003) and IEC 61511 (2004) were in place at that time. This standard divided facilities into attended and unattended operations. For attended facilities, there were no requirements for level detectors on the tanks, while unattended facilities required continuous monitoring, alarms and an automatic shutdown if the operator response time was not adequate, or the operation was fully automatic. This highlights a cautionary note that one should always remember: All standards provide minimum requirements, not maximum. Following good engineering practice and in most cases common sense (an old friend who some say has passed on, bit.ly/loRKeQZ) should not be hijacked by “minimum” safety requirements in a standard, particularly for cost reasons.

Because of the Buncefield explosion, the API 2350, 4th Ed., (2012) committee took the lessons learned to heart and introduced a number of new risk- and performance-based requirements, which brought it closer conformance to the SIS standards. (See sidebar, “Buncefield’s Legacy: API 2350’s New Requirements.”)

Technology Can Help

Placing instrumentation on widely geographically distributed tanks, particularly on existing tanks, can be a challenge both technically and in cost, but technology has advanced significantly in the past 10 years. We can easily digitally transmit multiple sensor inputs across a pair of wires, reducing wiring costs, using any one of the more than 50 fieldbuses available, a number which are third party-approved safety protocols (for example, Profisafe, Foundation fieldbus, ASIsafe).

Tank farm remoteness and geographical distribution often make them suitable for wireless monitoring applications,

BUNCEFIELD’S LEGACY: NEW API 2350 REQUIREMENTS

Because of Buncefield, the API 2350 4th Edition (2012) committee took the lessons learned to heart and introduced a number of new risk- and performance-based requirements, which brought it closer conformance to the SIS standards. Some of API 2350’s new requirements are:

1. A overfill management system is required;
2. A risk assessment shall be used by the owner and operator to categorize risks associated with potential tank overfills;
3. The definition of a set of operating parameters, including critical high level (CH), high-high level (HH), maximum working level (MW) and automated overfill prevention system (AOPS) activation level;
4. More emphasis on operator response time for level alarms;
5. Operators are required to categorize each tank under consideration for overfill prevention based on tank level instrumentation and operator surveillance procedures;
6. Emphasis on proof-testing of independent alarms and AOPS; When an AOPS is required, the standard provides two options for implementation, depending on whether the installation is existing or new. For existing installations, Appendix A of the standard provides an acceptable, essentially prescriptive approach that contains aspects of ANSI/ISA 84.00.01-2004 (IEC 61511 modified). For new installations, ANSI/ISA 84.00.01-2004 (IEC 61511 modified) must be followed.

which can be easily added to existing tanks. These can also be solar-powered. There are wireless applications for tank monitoring systems available using IEEE 802.15.4 (ISA 100.11a and WirelessHART), wireless cellular networks and global satellite networks. Another developing technology is mobile wireless applications, which allow tank farm field operators, in addition to the control room operator, to monitor tank levels.

Available automated safety shutdown systems geared to the tank farm environment range from local, high-reliability shutdown systems connected by Modbus to centralized systems



to using safety PLCs. Tank level and inventory management system technologies also have advanced.

Improvements have been made in guided-wave radar (GWR), through-the-air radar and traditional level measurement technologies. One of the main issues remains, which is how to proof-test these to meet API 2350 and ANSI/ISA 84.00.01 (IEC 61511 modified).

On June 10, the FAA authorized BP to use a commercial drone, supplied by Aerovironment Inc. (www.avinc.com), at its Prudhoe Bay, Alaska, site to fly aerial surveys over Alaska's North Slope. The same type of drone has been used in test flights by ConocoPhillips. It seems like a reasonable prediction that in the not-too-distant future, drones could be used to fly continuous circuits above a refinery or chemical plant, use visual and IR sensors, pattern recognition and analytical technology to detect abnormal conditions in the facility, and report them to the control room and field operators. This technology could easily be applied to tank farms.

Heed API 2350

API 2350 has been updated to be better in line with the industry standard ANSI/ISA 84.00.01-2004 (IEC 61511 modified), which is virtually identical to IEC 61511. To make our tank farms safe, we should apply the same safety rigor of assessment that we apply to our process units to our tank farms to ensure that a significant safety, environmental and/or financial incident does not occur in the future.

This API 2350 standard is listed as a "recommended practice," but do not be fooled. In the United States and in other countries that recognize API standards as recommended and generally accepted good engineering practice (RAGAGEP), if you have an incident in your refinery or fuel distribution tank farm, you will be held to this standard or the burden of proof otherwise. Chemical plants should meet NFPA 30, but may also be held to API 2350 overfill requirements as RAGAGEP.

One area that API 2350 does not address in tank farms is the use of combustible gas detectors and fire detectors. Open-path gas detectors could be particularly effective, as they can have a path length up to 200 meters, and point-source gas detectors



BP

SPILL SPOTTER

Figure 2. On June 10, the FAA authorized BP to use a commercial drone, supplied by Aerovironment Inc. (www.avinc.com), at its Prudhoe Bay, Alaska, site to fly aerial surveys over Alaska's North Slope.

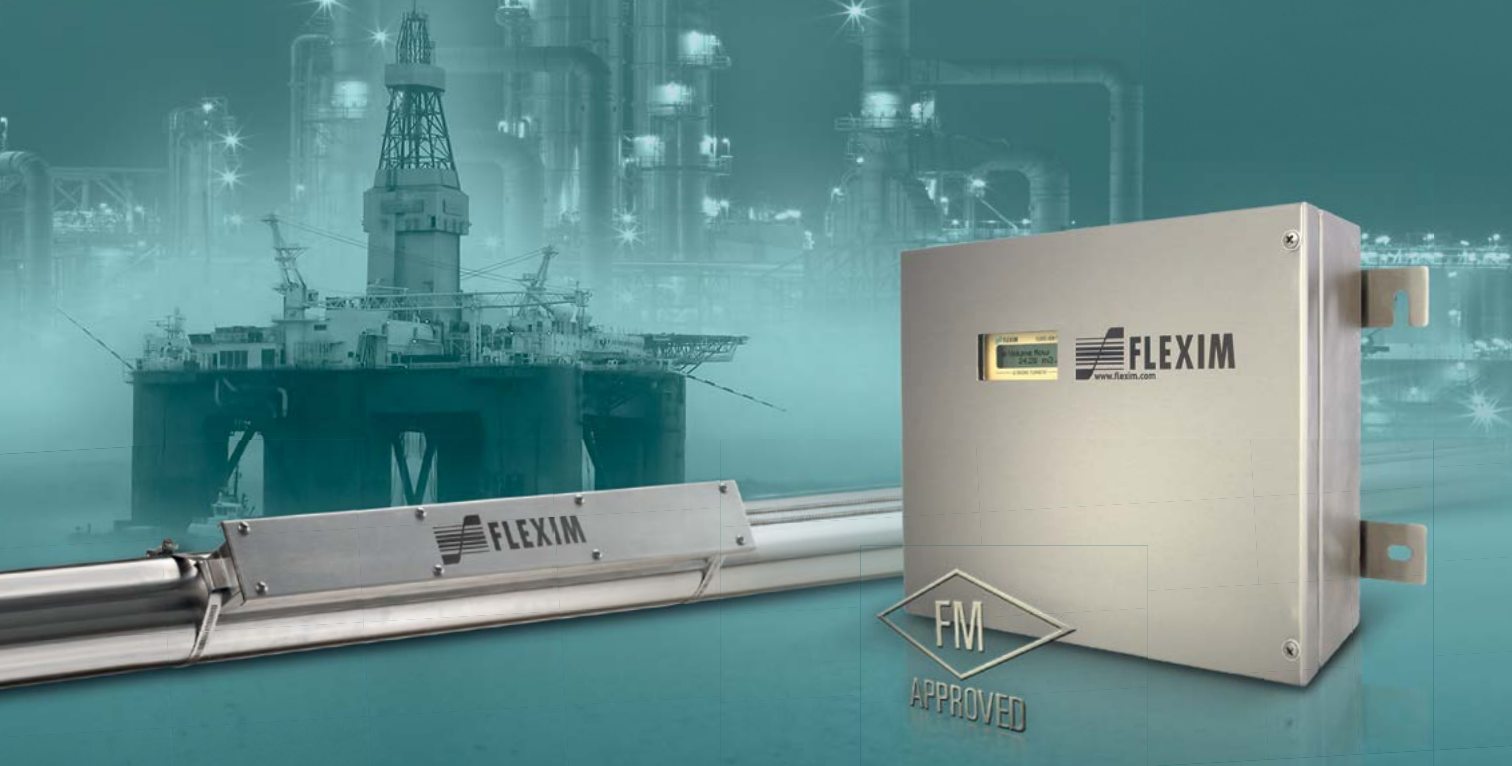
can be effective inside bunds, since many of the gases involved are heavier than air.

Fire detectors are not as effective for overfill situations, but can help prevent pool fires from spreading to other tanks by detecting rim fires and jet fires. While this seems to be a case of reaction rather than prevention, the sooner you can act to bring an developing incident to heel, even if you can't prevent it, the less the consequences will be.

It would seem important to minimize the potential of an electrical ignition source by properly, electrically classifying tank farm areas and ensuring that electrical equipment and instrumentation meet (and maintain) the classification.

This discussion only covered atmospheric tanks in tank farms, which obviously can create a hazard. One of the biggest hazards in a refinery tank farm typically comes from butane or other compressed gas spheres, which by some estimation can range up there with a hydrofluoric acid leak hazard in a refinery. But that is a discussion for another day. ■

William L. Mostia, PE, Fellow, SIS-TECH Solutions, is a frequent contributor to Control.



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Saving Steam Saves Money

Matt Brewing Co. reduced energy cost to brew beer by \$230,000 per year using mass flow instrumentation.

by Rich Michaels

The Matt Brewing Company is a family-owned business founded in 1888. We make the Saranac brand of specialty products. Nick Matt and his nephew, Fred Matt, currently head the management team at the brewery. Under the leadership of these third and fourth generations of the Matt family, the brewery continues to craft beer to the exacting standards set forth more than a century ago. The brewery currently makes up to 30 varieties of Saranac beer during the course of the year, with distribution to about 20 states.

The heart of a brewing operation is boiling the wort. Brewing starts with the addition of malted barley grain and water to the mash cooker. Mashing allows the enzymes in the malt to break down the starch in the grain into sugars, typically maltose, to create a malty, sugary solution. After mashing, the resulting solution flows to a filter press that separates out the grain. Matt Brewing Company sells the filtered grain byproduct to local farmers as animal feed.

From the filter press, the solution, now called wort, goes into one of two steam-heated, 500-bbl (15,000 gallon) kettles for boiling (Figure 1). One of the kettles boils the wort while the other is cleaned and prepared for the next cycle. A manually operated coil for steam at the bottom of the kettle preheats the wort.

The boiling operation continues for 90 minutes, evaporating about 5% to 10% of the solution. This operation, which includes the addition of the hops, sterilizes the wort and affects flavor, stability and consistency. The hops provide bitterness and flavor. Following wort boiling, the solution goes through a period in fermentation tanks and finally packaging in bottles and kegs.

Steam pressure management is crucial. Depending on the atmospheric pressure, we need to control the steam pressure to get more or less BTUs of heat into the kettle. A pound of

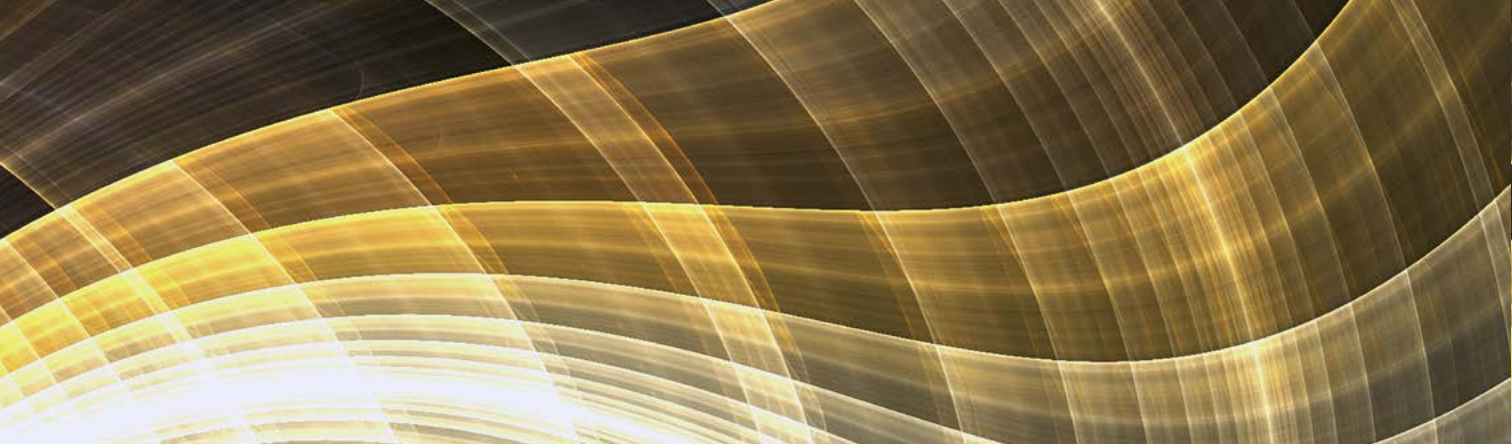


Boiling wort—malt, grain and water—and steam are at the heart of every batch of good beer.

steam represents a certain value of BTUs. Steam cost is one of the most important energy variables Matt Brewing deals with. We were looking for a way to improve steam quality and reduce steam use. We consulted with R.L. Stone Co. (www.rl-stone.com), Syracuse, N.Y., on instrumentation to optimize the wort boiling operation.

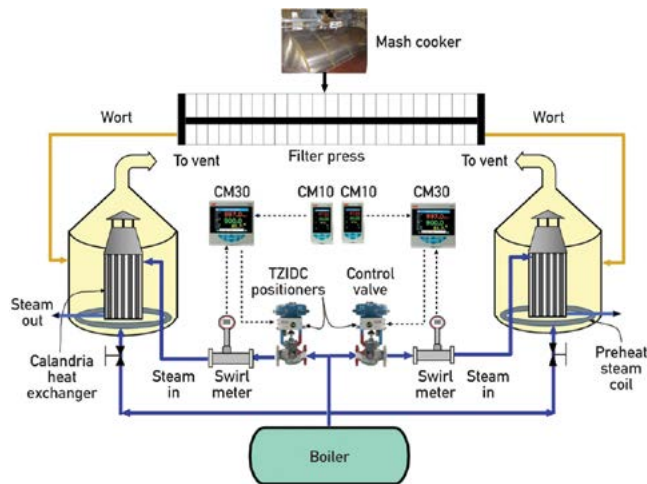
The new instrument system measures and computes mass flow rates of steam to control heat for boiling the wort. As the wort temperature reaches the boiling point, the steam in the bottom preheat coil shuts off, and the recently installed automatic steam heating system takes over. From the steam header, the saturated steam flows through a control valve and an ABB Swirl flowmeter before reaching the kettle. (Figure 2)

The Swirl meter is a “vortex precessing” meter, somewhat akin to a vortex-shedding flowmeter, except that the Swirl



COPPER KETTLES

Figure 1. Wort, the basic beer solution, goes into one of two steam-heated, 500-bbl kettles for boiling.

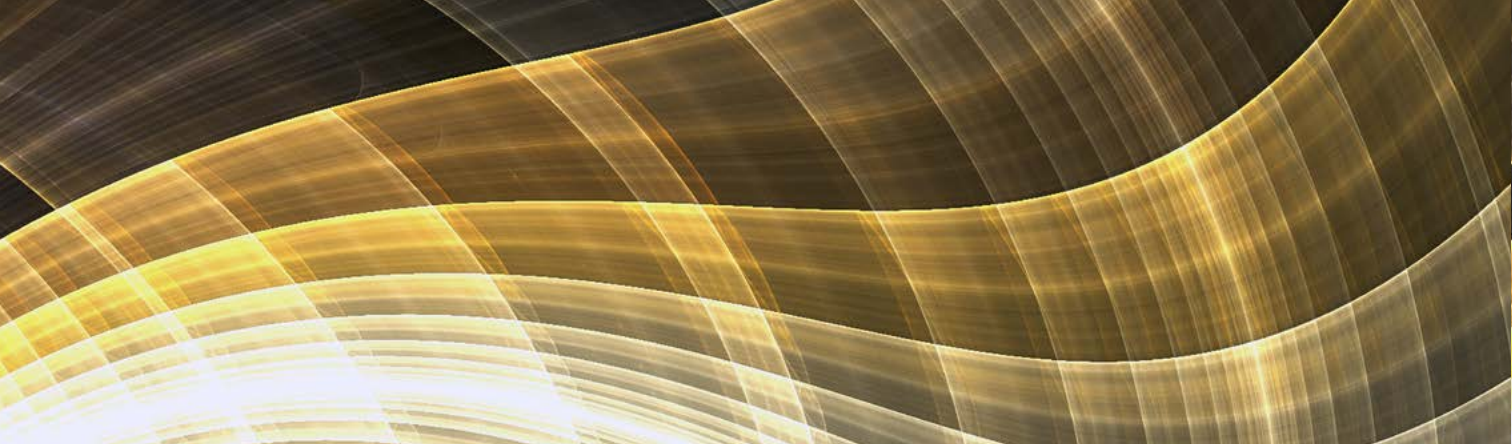


THE ENGINEER'S GUIDE TO BREWING

Figure 2. This schematic shows the flow of saturated steam through a control valve and a Swirl flowmeter.

meter has far better turndown at low flows and requires minimal upstream and downstream straight pipe, compared to other flowmeter types. We selected this type of meter because our piping geometry was tight, leaving very little space for straight pipe to condition the steam flow (Figure 3). The Swirl meter contains a built-in inlet flow conditioner and outlet straightening vanes, which saved the expense of re-piping the brewhouse.

From the flowmeter, the saturated steam flows to the top of an internal boiler in the kettle called a calandria (Figure 4, p. 48). The calandria is a shell- and-tube heat exchanger. Wort rises through the tube bundle in the calandria while heated by the down-flowing steam, which begins to condense. A deflector at the top of the calandria



A TIGHT SQUEEZE

Figure 3. Matt chose the Swirl meter because its piping geometry left little room for straight-run piping to condition the steam flow.

distributes the wort and prevents foam formation. The internal caldaria efficiently provides both heating and mixing of the wort.

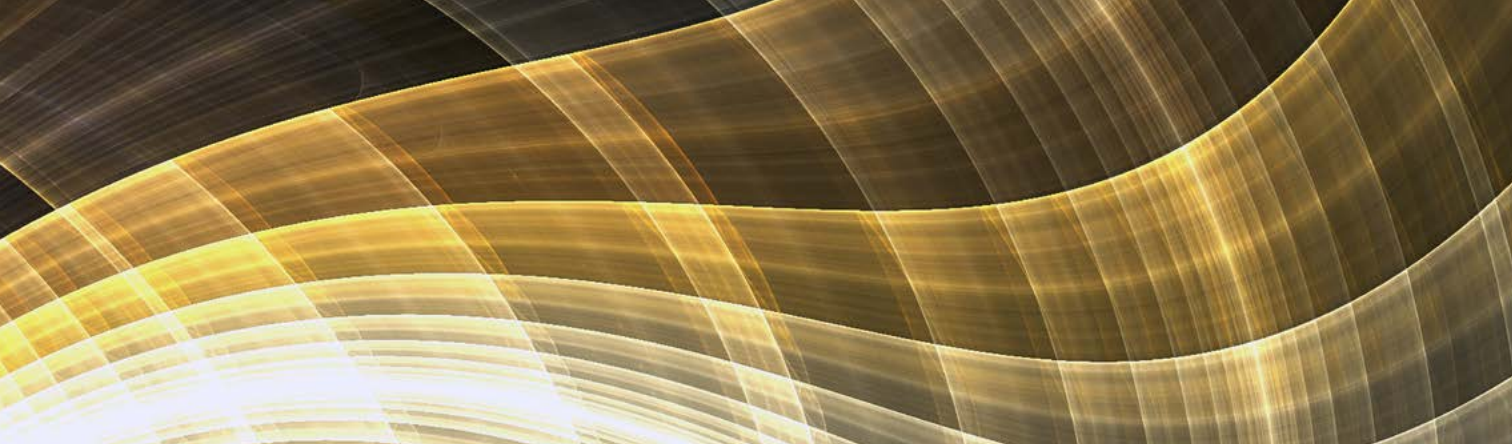
When starting a batch, the operator dials data representing the volume of wort in the kettle into an ABB ControlMaster CM10 flow computer. (Figure 5, p. 48) This unit calculates the optimum mass flow rate of steam based on wort volume and feeds that rate to the ControlMaster CM30 single-loop controller as a setpoint. The CM30 provides indication, recording, math functions and proportional/integral control of the steam mass flow.

The CM30s receive the steam mass flow rates from the Swirl meters and convert them to engineering units used in the brewing process. The CM30s compare the actual versus desired flow rate, and develop a control



DOUBLE DUTY

Figure 4. The caldaria, a type of heat exchanger, both heats and mixes the wort.



signal to maintain the predetermined setpoint. The 4-20 mA DC control signal goes to a set of ABB TZIDC intelligent electro-pneumatic positioners we installed on our existing Fisher control valves. An I/P (current to pneumatic) module within the TZIDC positioner precisely regulates air flow to pressurize and depressurize the valve while minimizing air consumption.

The displays for the CM30s indicate the desired steam mass flow rate (the control setpoint) based on the kettle volume, the measured steam mass flow rate in lbs/hr, and the percent control valve opening. The CM30 controller can also display steam flow rate trends. The CM10 displays wort volume in the kettle dialed in by the operator.

Prior to the installation of the new instruments, we collected three months of data for the wort boiling operation. Measured and calculated variables included kettle volume, steam pressure and temperature, percent evaporation, and necessary water additions. We compared the data we collected to what we believed to be optimum operating conditions and estimated possible savings.

Our savings have resulted from reduced natural gas costs and water usage. The new system for controlling steam pressure has generally reduced required steam pressures from 24 psi to 12 psi. The new system reduces steam use by approximately a third, depending on the brew volume and the operator. It also saves about 1200 gallons of water per brew cycle. We estimate the savings at approximately \$630 per day (about \$230,000 per year), and the payback time for the instrumentation project is about three to four months.

The results of the new control system are better quality and shelf life for our products with the added benefits of reduced energy and water use. We're considering adding a system to automatically send a signal value for wort ket-

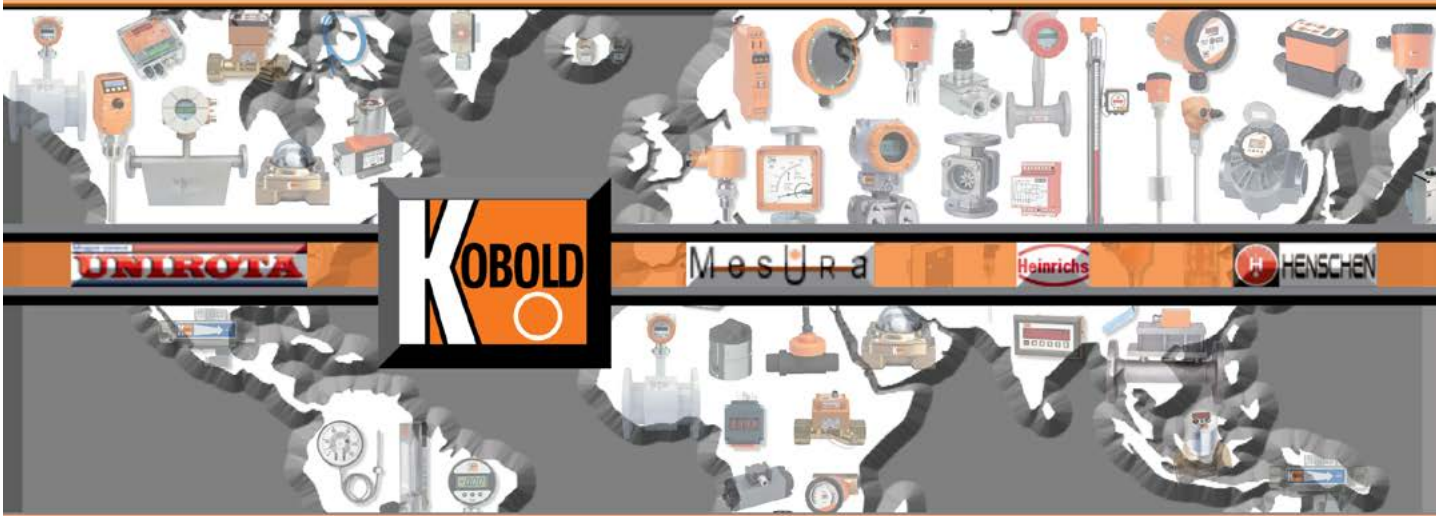


DIALING UP THE VOLUME

Figure 5. An operator sets the wort kettle volume on a flow computer prior to batch start.

tle volume to the CM10 controller. This would eliminate manual entry errors. We're also planning to add a system for reclaiming energy from plant wastewater to generate electricity for the plant. ■

Rich Michaels is brewing supervisor at Matt Brewing Company.

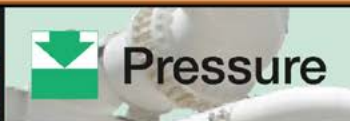


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Ultrasonic Flowmeters Make Chiller Control Easier

Clamp-on flowmeters are reliable and easily replaceable for maximum uptime

by Kevin H. Evans

For the Federal Aviation Administration (FAA), our most important product is the safety of the traveling public. Every single thing we do is focused on this one goal. We operate facilities that allow modern levels of air transport to occur. One of our Air Route Traffic Control Center (ARTCC) in the southwestern United States handles approximately 5000+ commercial flights a day. Locally, our part of the team effort is to provide the environment that allows the rest of the team to not worry about anything outside of their responsibilities. Power, water, computer support, communications and air temperature are things that need to be present, but invisible to the personnel working the screens.

More specifically to my facility, thousands of different items from mainframe computers to multi-hundred-ton chill water refrigeration units must work in coordination with each other. Providing support to the rest of our team makes the facility's task easier.

This coordinated effort is made possible by control automation. For the control automation to work well, it needs to have information, and, in part, this information is provided by flowmeters.

We have flowmeters on the water coming into facility, flowmeters on the natural gas that fires our boilers, flowmeters on our electricity, flowmeters on the air delivered throughout the ducts of the buildings, and flowmeters on the hot and cold water loops that move throughout the facility. We even have flowmeters on the air vented from the buildings.

The heart of the ARTCC facility is the high-powered computers that manage the flight control data. These aren't desktop PCs, but mainframes that generate consider-



MEASURING HOT & COLD

Figure 1. These meters are able to handle hot and cold water and indicate bidirectional flows.

able heat and must be kept cool. The HVAC air handling system is an essential part of the facilities I maintain.

Our main building depends on four chillers, each with a capacity of 350 tons of cooling. For the hot loop, we have three boilers which can transfer 3.5 million BTUs of heat into the water flowing through the hot-side piping. Another system is our humidifiers. Flowmeters are essential to avoid damage from a system running dry or water overflowing into other equipment.

The system design called for many Controlotron ultrasonic transit-time clamp-on flowmeters, now manufactured by Sie-



mens (www.industry.usa.siemens.com) that report directly to a distributed control system. These meters work especially well for us because they do not change the flow in the pipe where they are making their measurements.

The whole system depends on its flowmeters. The chiller and boiler control system must know how much hot and cold water is being used to create the discharge temperature supplied to the chill loop and the condenser. Without this data, the machinery could have a sudden and catastrophic failure.

In all of these situations, the flowmeters provide the information needed to control the system. Even if we are forced into manual operation, the flowmeters are responsible for giving the human operators the information they need to make the system work.

Our facility runs 24 hours a day, seven days a week, all year long. For heating and cooling purposes, this means two chillers and two boilers in operation.

Following the operation cycle from the point where new chillers and boilers are rotated into the system, the process looks something like this. The first operation is to bring on-line a new chiller. When the start command is given, the chiller repeatedly checks the output of the flowmeters in the condenser and chilled water loops in order to make certain that proper operating conditions, water flow and valve positions exist.

The transit-time flowmeters provide the fail-safe information to the control processor in the chiller, allowing each step in the starting routine to proceed by verifying that the valves are in the correct position, and that water really is moving through the piping loops for the condenser and chill water sides of the refrigeration unit. Additionally, reports from the flowmeters are sent to the control automation network and regulate the pumps to move the water through the system.

When the oncoming chiller is fully operational and is providing chilled water to the system, a previously oper-

HOW TRANSIT-TIME METERS WORK

Siemens Controlotron's founder, Joseph Baumel, designed the first transit-time ultrasonic flowmeter. The basic principle is simple. Transit-time ultrasonic flowmeters, sometimes called time-of-flight ultrasonic flowmeters, transmit ultrasonic energy into the fluid in the direction and against the direction of flow. At no-flow conditions, it takes the same amount of time to travel upstream and downstream between the sensors. Under flowing conditions, the upstream ultrasonic energy will travel slower and take more time than energy traveling downstream. When the fluid moves faster, there is an increase in the difference between the times required for the ultrasonic energy to travel upstream and downstream between the sensors. The electronic transmitter measures the upstream and downstream times to determine the flow rate. Sensors can be wetted, flush with the pipe wall or clamped on the outside of the pipe (Figure 1).



Figure 1. By measuring the difference in the speed of sound transmitted and received (transit time), these ultrasonic meters measure velocity and compute flow.

From The Consumer Guide to Ultrasonic and Correlation Flowmeters, 2004, by David W. Spitzer and Walt Boyes.



ating chiller is turned off and placed into reserve status. Again the flowmeters verify that the chiller is indeed off and the valves are closed. Proper optimization and careful programming can make the system a pushbutton operation, and significantly reduces the number of people needed to rotate fresh chillers into and out of operation. As the cycle continues, the second chiller is rotated into service, and the previously operating chiller is placed in reserve.

As all of the chiller rotations are happening, more transit-time flowmeters inside the chill water loop provide the information and feedback to ensure that the amount of water flowing to the air handlers' coils is the right amount for the building's heat load. Inside the air handlers, other flow-

meters confirm that air really is moving to the vents located within the various rooms of the facility. Finally, the exhaust fans from the rooms have flowmeters that verify the air is being removed from the room, ensuring sufficient number of air changes per hour in the facility.

Similar to the chill water system, the heating system cycles boilers in and out of service and maintains proper temperature inside the hot water loop. Boilers can be tricky systems. Improper start-up and improper shutdown can severely damage such systems.

Again the flowmeters are integral to the process, providing information for the boiler start-up and shutdown processes, and also verifying that water flow to the air handlers is correct.

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Often heat and cooling are required at the same time in an air handler. In such situations flowmeters can balance the demands on the system and reduce overall energy requirements. One of the reasons the Siemens Controlotron flowmeters were selected was their ability to handle both hot and chill water in the air handlers.

In our operation, we have multiple redundant flowmeters so that we can depend on having them when we need them. With good control automation, when the power goes

down, and you're on batteries, flowmeters can tell you when things have stopped.

Sometimes they provide the critical bit of warning in order to ensure that things like electronic devices do not overheat from cooling loss, or that pipes do not freeze from lack of heat in the building. ■

Kevin H. Evans is an Airway Transportation Systems Specialist, DOT FAA.

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