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Non-Contact Radar Level Meter Suits Bulk Solid Measurements

A drop form design eliminates need for an antenna aiming kit to amplify signals

THE OPTIWAVE 6300 C radar instrument is designed for accurate measurement of solids level, specifically the uneven surface of silo contents. The meter measures powder, granulates and bulk solids in buffer silos, hoppers, bulk storage containers and on conveyor belts. Its versatile design makes it suitable for a variety of industries.

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The OPTIWAVE 6300 C comes with a variety of options and users can choose a 3-in. diameter (DN 80) antenna made of Polypropylene (PP) or Teflon (PTFE) or a 6-in. (DN150) PP. Conventional stainless steel horn antennas up to 6 in. (DN 150) with a built-in horn purging feature also are available.

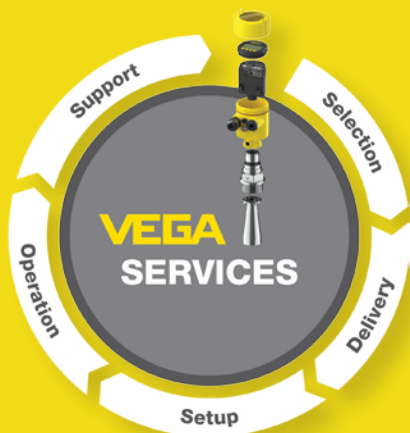
Start-up is easy due to the Quick Set-up wizard and a comprehensive help function. A large screen with a four-button keypad makes navigation easy, and the wizard displays information in nine languages, including Chinese, Japanese and Russian. ATEX, FM and CSA certifications are pending.



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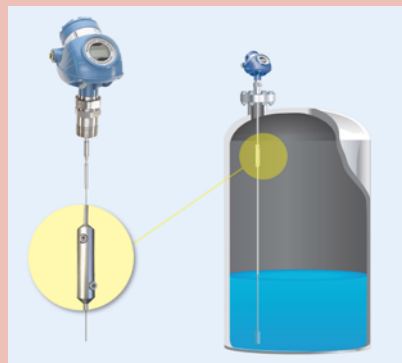
Transmitter Features Automated Integrity Testing

Test ensures the level measurement device functions correctly and improves safety

THE VERIFICATION Reflector function, now available with the Rosemount® 5300 Series guided wave radar (GWR) transmitters, is designed for applications requiring periodical transmitter integrity tests to ensure that the level measurement device functions correctly and overfilling will not occur.

The 5300 with Verification Reflector enables automated transmitter integrity tests without stopping the process or manually raising the product level in the vessel. This helps to reduce the risk of accidental spills and enables either device verification or proof-testing to be completed much faster. There is no need to climb the tank to remove the test measurement device or open the tank to monitor levels. This helps to reduce costs, increase plant uptime and improve staff safety.

Rosemount 5300 Series GWR level transmitters provide accurate and reliable direct level measurement. They are easy to install and are said to be immune to changing process conditions. With no moving parts, maintenance requirements are minimized. A wide choice of materials and process connections, and a broad range of accessories and probe styles make them suitable for a wide range of applications. They are capable of handling challenging applications including process vessels, control and safety.



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Cut Your Sensor Count But Not Your Data

Take advantage of multivariable devices to gain operating and maintenance benefits

By Ian Verhappen, Industrial Automation Networks

YOU LIKELY are spending more money than required on field sensors — not because you've selected the wrong sensors but because you have too many of them. "How can I have too many sensors when I barely have enough information now to monitor and control my process? What I really need is more not fewer sensors but I just can't afford them," you might argue. However, the fact is you're probably not fully using the capabilities of some of your sensors, and doing so would eliminate the need for other devices.

The majority of transmitters today are "smart" in one way or another and support some form of digital communication. It's well known in the automation industry that more than 80% of the installations with these devices aren't using this communication capability. Yet, digital communication provides the ability to share status and diagnostic information useful for improved maintenance of the devices, and enables them to transmit more than one process variable or, in the case of a control valve, to give feedback on actual versus output position. Earlier articles [1, 2] discussed the maintenance aspects of smart sensors, so this article will look at the opportunity lost only from a signal perspective.

The reason more facilities aren't using the multivariable capabilities of their installed equipment partly lies in the design process and partly stems from lack of knowledge by end-user engineers, something this article hopefully will start correcting.

DEALING WITH DISINCENTIVES

For new projects, taking full advantage of multivariable devices requires a conscious decision early,

preferably during front-end engineering design (FEED), to use digital communication and to address common roadblocks.

The majority of projects today are designed and built on a "time and materials" basis using either an engineering procurement contractor (EPC) or main automation contractor (MAC). Because compensation is based on the number of engineering hours and, in the case of the MAC, which also likely supplies the field devices, the number of devices and point licenses sold, the contract doesn't provide an incentive to use fewer devices.

For the EPC, each additional device means hours to design the necessary process connection, instrument specification and loop drawing, as well as the electrical work to connect it to the control system. So, even if the instrument discipline identifies an opportunity for a multivariable device, the mechanical and electrical disciplines will lose hours.

For the MAC, selecting a multivariable device will cost it the sale of a field device and the associated configuration time (although the configuration time difference between a soft and hard tag

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won't be significant). Depending upon the pricing model of the control system supplier, the point count license actually may increase if you start using soft tags and data available from smart sensors.

SMART FLOW METER



Figure 1. This vortex meter has an integral temperature sensor and an optional pressure sensor. Source: Honeywell.

On the positive side for both EPCs and MACs, with staff time at a premium going this route provides the benefit of increasing productivity.

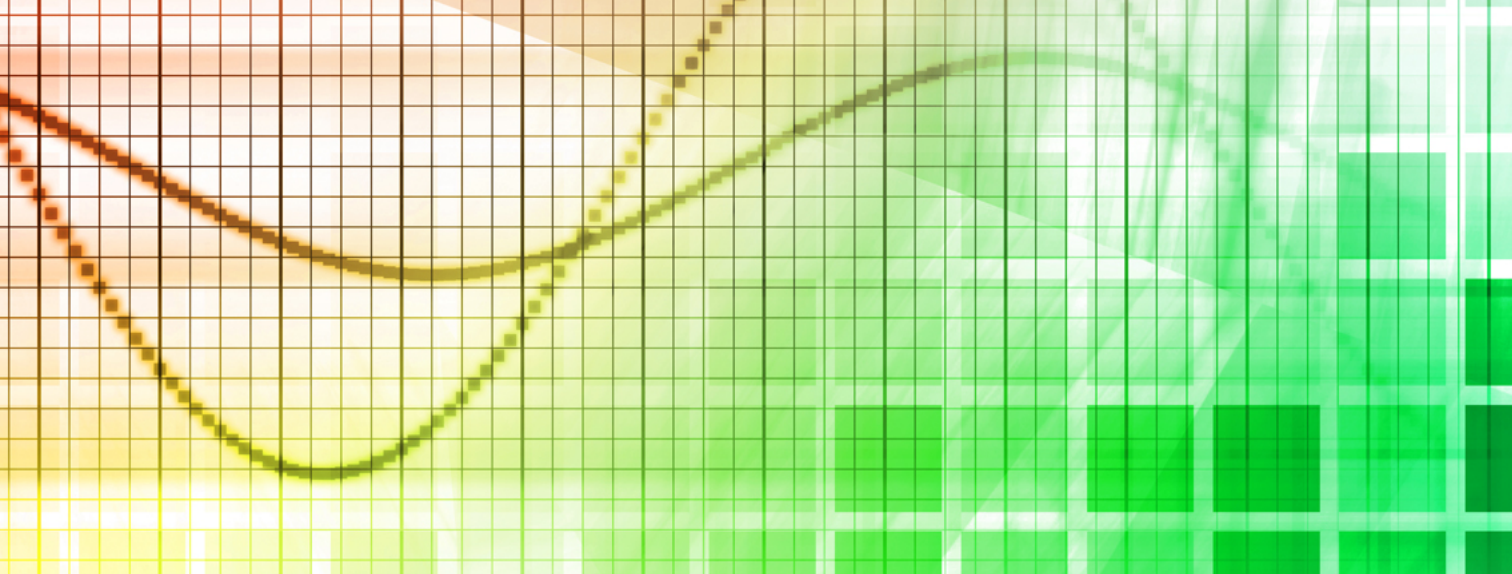
A typical smart device has upwards of 300 parameters available, so how to select the right information to transmit and capture can pose a challenge. This likely contributes to plants staying with the traditional one-to-one relationship of field device to signal. (Consultants can provide guidance on parameter selection as well as training to engineers on when to use multivariable devices.)

The best way to overcome some of the disincentives is to offer better incentives for shared success. For example, give the MAC incentives for every multivariable device it installs; because the savings to the project include the nozzle and connections, you're still ahead financially. This may not work as well for the EPC. So, consider framing the contract not as "time and materials" but as "cost plus." This provides an incentive to finish the project below a predetermined fixed cost and share the savings.

Many companies now incorporate value engineering reviews as part of the work flow. Because automation and control typically amount to about 5% of the total project cost, not too much energy is spent on them. However, if you have the right people in the room or break up the scopes of work appropriately, you likely will identify more opportunities for multivariable devices.

BROAD BENEFITS

Making the decision at FEED to use digital



signals opens up new opportunities to minimize engineering and field construction costs. The level to which you incorporate fieldbus technology also will impact the physical plant layout in a number of ways, including potentially increasing the degree to which you use panel prefabrication and modular construction.

Commissioning will be quicker — not only because there will be fewer physical devices to confirm but also because digital communications technology enables the work to be done faster and with fewer people. As we know, instrumentation and control groups always are the last ones finishing their commissioning, so any time saved here normally leads to an earlier startup and, hence, more production and faster return to positive cash flow.

Once the plant is operating, the savings and opportunities to use smart field devices continue — although realizing the full benefits may require changes in traditional work practices. For example, the ability to communicate to field devices means that a change in the device, such as altering a range, now is propagated through to the control system and vice versa. As a result, the risk of a range mismatch between the field and control system decreases. However, it also necessitates implementing appropriate policies around who has access to what form of changes in the device and control system.

Additional operating savings result because fewer nozzles also mean fewer possible leak points for EPA monitoring.

Being able to read the actual position of a final control element and compare it against the target

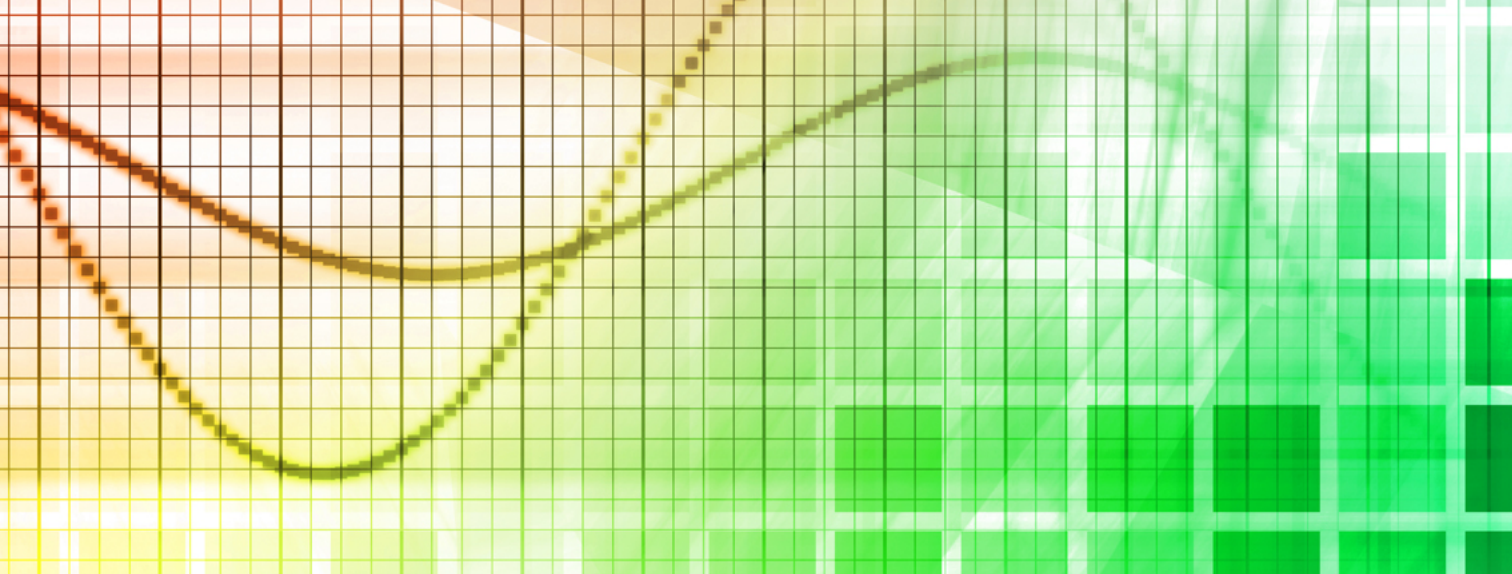
output value will assist in confirming proper process operation while also giving an indication of the actual loop response time and health of the control element as well.

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2. I. Verhappen, "Control Your Maintenance," p. 40, *Chemical Processing* (July 2006), www.ChemicalProcessing.com/articles/2006/092/
3. M. Bryner, "Smart Manufacturing: The Next Revolution," p. 4, *Chemical Engineering Progress* (Oct. 2012).

LOW-HANGING FRUIT

You likely already have a number of HART transmitters — and can take fuller advantage of them relatively easily and at minimal cost. An offline option is to capture information via your handheld or laptop-based HART communicators and then put those data into a central database. An online option is to transmit the data directly if you have a HART modem connected to each device. Check that your control system has cards that contain HART communications capability; modern analog input and analog output cards do. If need be, you can change out old cards to new ones during a plant shutdown. A second option for online data delivery is to install third-party HART "strippers" in your input/output cabinets to remove and retransmit the HART signal along a parallel system. A third option is to equip devices with WirelessHART so they can send data via a plantwide wireless network.



The HART data then can be used to confirm work history, allowing you to identify root cause problems and potentially modify your maintenance practices accordingly.

If you're restricted to staging your migration to using digital signals, the biggest return will come from diagnostic data on your control valves and, hence, your analog output cards. Because control valves have moving parts and contact process fluids that often are aggressive, they should get constant monitoring. Smart positioners not only can confirm the signal feedback but also can provide data on a suite of valve diagnostic parameters. The most commonly used parameter is "cycles," which indicates how many times the valve has changed direction and the distance traveled, i.e., how far the valve stem has moved (e.g., 0.25 in. in a down stroke and 0.5 in. in an upward direction for a total of 0.75 in.). A change in the ratio of cycles to distance traveled usually indicates packing or tuning problems, or some other actuator-related difficulty.

Myriad other diagnostic applications exist. Many microprocessor-based devices continuously check not only the health of their own electronics but also the sensor used to measure the process variables. For instance, differential-pressure-based flow meters monitor the frequency and amplitude of the pressure impulses in both legs and compare these over time to determine if one or both of the pressure taps are deteriorating (plugging). These data can identify when a problem is developing, allowing action to be taken at an opportune time before the measurement and, hence, control loop are affected.

Besides diagnostics, differential-pressure-based and other flow meters now are capable of measuring and reporting digitally multiple variables. Therefore,

it's possible to use a differential pressure meter to measure both the flow and the bulk line pressure to calculate a pressure-compensated flow, or with a vortex meter having an integral thermocouple to provide a temperature-compensated flow — in both cases increasing the accuracy of the measurement and, thus, enabling tighter control of the process.

There also are integrated differential pressure meters with the orifice directly connected to the pressure sensors, and a vortex meter with embedded pressure- and temperature-compensation sensors (Figure 1) allowing calculation of mass flow of vapor or steam from one device at a much lower cost than that of a Coriolis meter.

BE SMART ABOUT INSTRUMENTS

Various initiatives, such as the "Smart Manufacturing Leadership Coalition" and the "Advanced Manufacturing Partnership" [3] that bring together government, academia, suppliers and major end user companies, should foster increasing use of smart instruments. In addition, the International Society of Automation (ISA) recently formed a committee, ISA108, to develop standards and practices to assist in integrating smart device parameters into distributed control and maintenance systems and, hence, improving day-to-day operations.

Getting more value from your multivariable devices requires taking a different approach and understanding what those sensors can tell you. This can result in fewer instruments, better availability and improved return on your investment. ●

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Select the Right Liquid Level Sensor

It's important to consider a variety of factors when choosing the type of technology

By John E. Edwards, P & I Design

LEVEL MEASUREMENT, which is the detection of the phase split between vapor/liquid, liquid/liquid, vapor/solid and even liquid/solid, is a key parameter in the operation and control of modern industrial processes. A reliable outcome depends on the phase conditions being relatively consistent under all process conditions. Unfortunately, the importance of level control isn't always appreciated (see "Don't Underestimate Overfilling's Risks," <http://goo.gl/r7Fiu4>). Failure to measure level reliably has resulted in some of the most serious industrial accidents, including those at the Buncefield, U.K., fuel storage depot and BP's Texas City refinery.

The technologies to measure and transmit process level have evolved significantly since the 1960s. Impulse lines, used to connect instruments to the process, appear less frequently on new installations and are being replaced on existing ones. (Where used, they require specialist knowledge during design, installation and maintenance for reliable measurement.)

Today, sensor developments coupled with data transmission innovation offer reduced installation costs, simplified maintenance and enhanced plant performance.

DATA DELIVERY

Transmission technology development has allowed universal application of self-powered two-wire 4–20 mA dc signals. In addition, SMART transmitters provide bidirectional digital communication and diagnostics capability via the HART (Highway

Addressable Remote Transducer) protocol. The 4–20 mA and HART digital signals share the same wiring, offering a centralized capability to configure, calibrate, characterize and diagnose devices in real time, together with reporting capability. Data can be captured from multi-parameter devices without additional hardware, providing predictive maintenance capability.

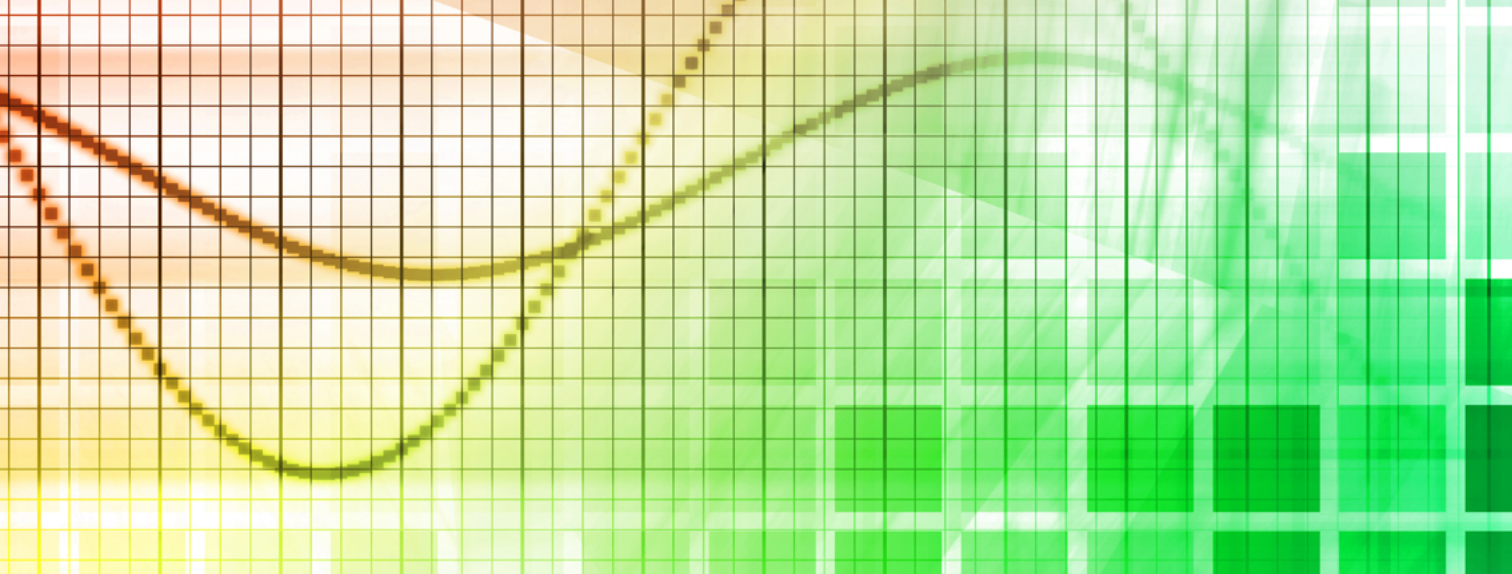
Meanwhile, development in fieldbus digital communication has enabled field devices to be connected using a single cable bus structure, reducing cabling, installation time and cost. Fieldbus is a device-level network that sacrifices speed for security. Several protocols are available, with Modbus, Profibus PA and Foundation being the most common. (See "Take Advantage of Fieldbus," <http://goo.gl/BxUbMQ>.)

Fieldbus technology is more complex and costly, requiring suppliers to provide sensor options to meet the different standards. Plant layout, sensor interface capabilities and data management infrastructure guide fieldbus selection.

MEASUREMENT TECHNOLOGIES

Here, we'll focus on liquid level measurement because it's usually the key to reliable and safe plant operation. Normally processors hold flows steady and let levels change within limits — this requires reproducibility. Accuracy is important for tanks used for stock and custody control.

A variety of mechanical and electronic technologies for level measurement are available:



Hydrostatic. This continuous indirect method measures the pressure due to liquid level and density plus over-pressure. The sensor measures the difference between this pressure and a reference one, normally atmospheric; so, it's not well suited for vacuum and pressure service. Instruments come in flanged-mounted or rod-insertion styles, the latter not being recommended for turbulent conditions. Typical accuracies claimed are $\pm 0.2\%$ of reading but this depends on process fluid properties and conditions.

Float displacer. Suitable for point or continuous applications, it measures the change in buoyancy via a torque tube, lever or servo arrangement. The continuous measuring range is set by the displacer length immersed in the tank's external cage, which is preferable for noisy applications, or servo mechanism. The point method uses a float, with the range being limited by the length of the float arm.

Nucleonic. Good for point or continuous duties, this non-contact method, which is independent of fluid density and viscosity, measures the signal strength of a radioactive source beamed across a vessel and has typical ranges of 0.24 m to 3.36 m. Accuracies generally claimed are $\pm 2\%$ of reading. It's the preferred method for monitoring level in flash vessels and reboilers under all temperature and pressure conditions.

Radar. Applicable to point or continuous applications, it measures the travel time of an impulse reflected from the liquid surface. Interference echoes from tank internals, and agitators are suppressed and signals can be characterized to give liquid volume. The sensor doesn't contact the liquid but is exposed to headspace conditions, which don't affect the measurement. Reflectivity requires the liquid dielectric constant, ϵ_R , to be at least 1.4 (hydrocarbons are 1.9–4.0, organic solvents are 4.0–10 and conductive liquids are over 10). Adjusting the antenna and signal conditions allows tailoring to the particular process, with guided radar used for low ϵ_R and turbulent conditions. The method can handle custody transfer because of its claimed accuracy of $\pm 0.5\text{mm}$.

Capacitance. For point or continuous service, it suits liquids that can act as dielectrics. Sensitivity increases with

the difference in dielectric constants, $\delta\epsilon_R$, between the liquid and the vapor space or between the two liquids. Special designs, involving coated and twin probes, are used when $\delta\epsilon_R$ is under 1.0, conductivities exceed $100 \mu\text{mho}$, or to overcome probe build-up effects, and when vessel material is non-conducting. Typical accuracies claimed are $\pm 0.25\%$ of span. However, fluid properties affect measurements, so the method isn't suitable for changing conditions. Maximum conditions are 200°C at 100 bar and 400°C at 10 bar.

Ultrasonic. Suitable for point or continuous use, it is based on the time-of-flight principle. A sensor emits and

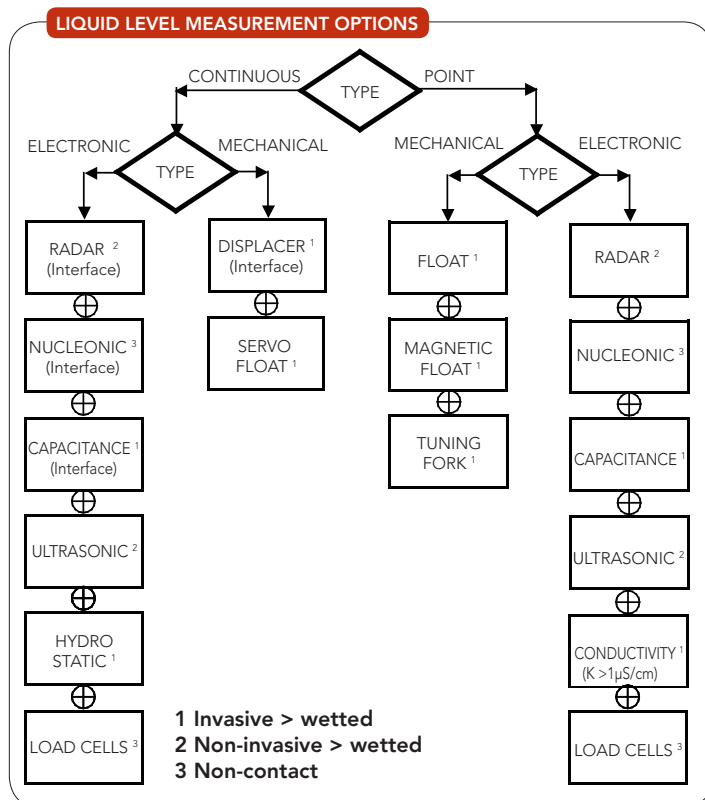


Figure 1. A variety of electronic and mechanical methods are available.

detects ultrasonic pulses that are reflected from the surface of the liquid. The method is non-invasive, with some types being non-contact, and isn't affected by ϵ_R , conductivity, density or humidity. Maximum conditions are 150°C at 4 bar.

Load cells. Appropriate for point and continuous applications, such devices, which can be based on strain gauge or piezoelectric technology, measure the weight of the process vessel plus contents. Individual load cell accuracy of 0.03% of full scale is achievable but overall performance depends on correct installation practices to exclude external forces due to associated piping and equipment. For vessels with jackets, agitation and complex piping, it's difficult to obtain an acceptable accuracy. When the container can be totally isolated, as in final dispensing and filling applications, precision weighing can be achieved.

Tuning fork. This method can detect point liquid level but isn't suitable for viscous and fouling applications. Maximum conditions are 280°C at 100 bar.

Conductivity. Good for finding point level, it requires a liquid conductivity exceeding 0.1 μmho and frequently is used on utility and effluent pump control systems.

Figure 1 summarizes the nature and applicability of these measurement technologies. Figure 2 gives more details on their use for continuous measurements. Impulse line applications have not been considered for main process applications but can still find use on general services and less critical installations.

Of course, besides technical suitability, it's important to consider economics. Typical comparative costs, from lowest to highest, are: conductivity → capacitance → tuning fork → hydrostatic → displacer → ultrasonic → load cell → radar → nucleonic.

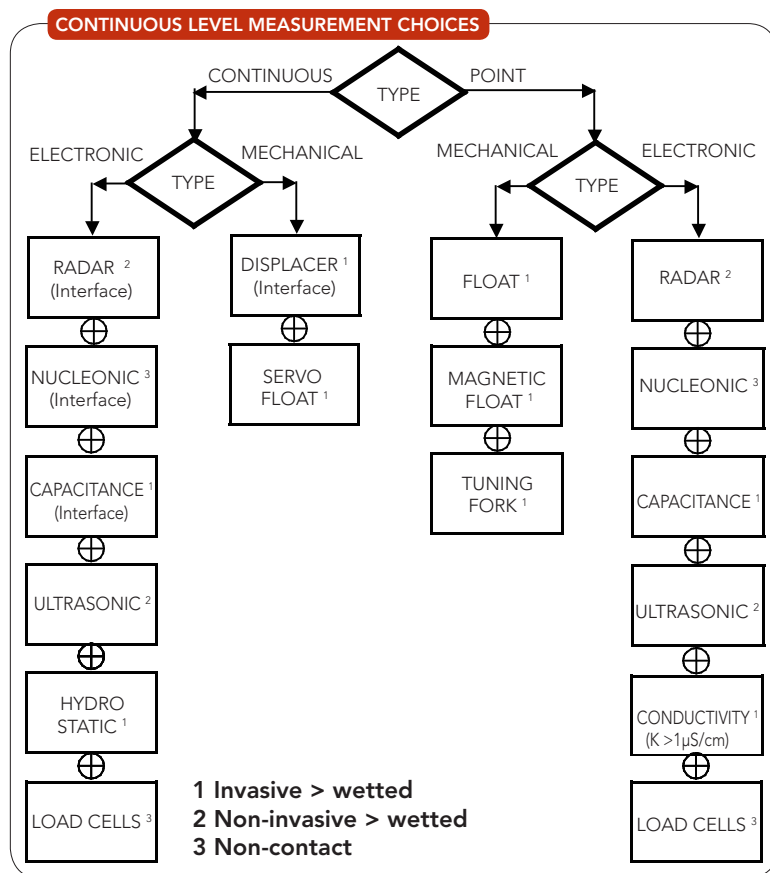


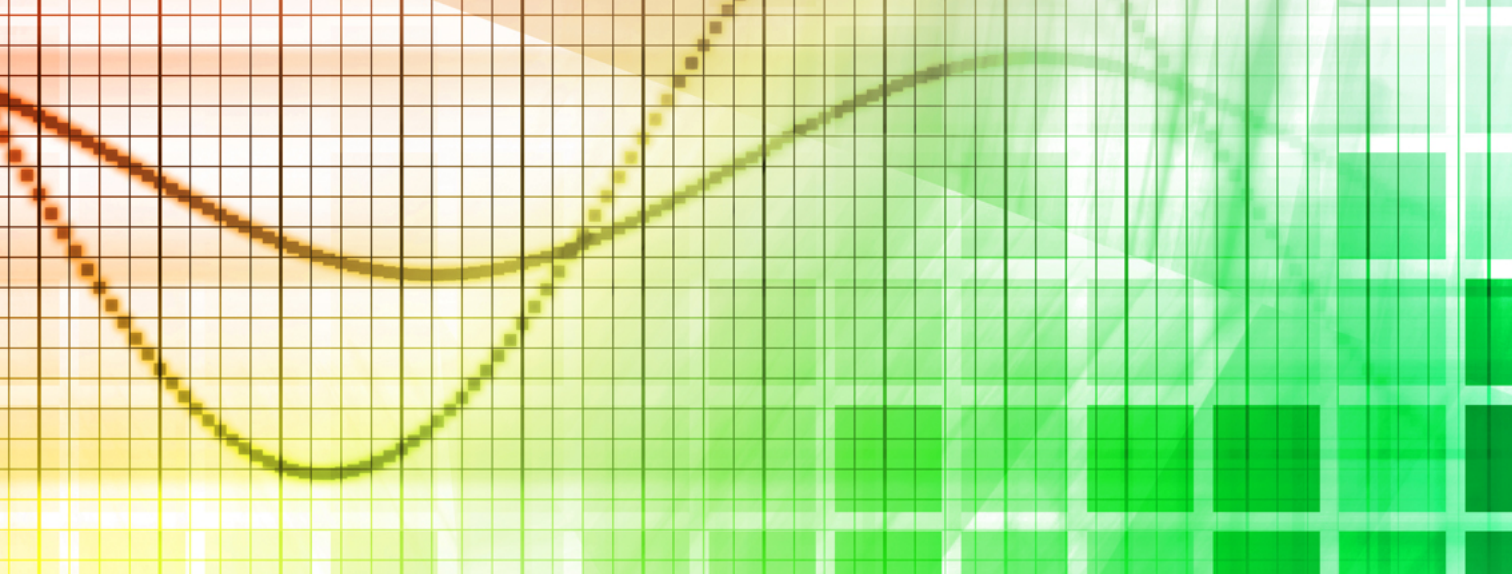
Figure 2. The nature of both the service and the fluid affect the selection.

APPLICATION CONSIDERATIONS

Selection also must consider both the process and its control.

Process. It's essential to understand the physical property variations of the process fluids and the phase changes that may occur within the process during normal and abnormal conditions.

Boilers, flash vessels and distillation column bottoms involve boiling liquids, resulting in noisy levels.



Displacers in external cages frequently are used on steam generators and flash vessels, provided the process fluids are of low viscosity and relatively clean. The non-contact nucleonic method will prove most reliable for distillation column bottoms, where reproducibility is more important than absolute accuracy. While expensive, it can be more than justified given its value in providing stable column operation and in preventing reboiler fouling due to loss of level.

Avoid the use of impulse lines in level systems if the process pressure varies and there's a tendency for solids' formation due to freezing, precipitation or polymerization. Purging the lines with inert gas or process compatible fluids will have limited success and is high maintenance.

Nucleonic level detection provides a powerful tool to perform on-line process diagnostics. Typical applications include monitoring level profiles in tray towers, distribution in packed beds, locating level build-up and blockages in vessels, and general flow studies.

Control. Let's consider a general equation describing the output, m , from a three-mode (proportional-integral-derivative) controller:

$$m = (100/P)[e + (1/T_i)\int e dt + T_d (de/dt)] + m_o$$

where P is proportional band, %; T_i is integral action time, min.; T_d is derivative action time, min.; m_o is steady-state controller output; and e is $\pm(X_{set} - X_{meas})$, the error between set point and process measurement.

Based on its form, we can predict the following behavior:

1. If there's no error the controller output will equal steady-state output, m_o .
2. Controller gain is $100/P$. So, increasing P decreases the controller gain with % change of output for same % error change reducing and vice versa.
3. The integral term, $1/T_i$, indicates that as T_i rises its effect falls. An increase in error results in an increase in rate of change of controller output. Slow processes can use higher T_i , provided the process isn't too slow to absorb the energy change — if it is, cycling will result.
4. Decreasing the derivative term, T_d , reduces its effect.

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Increasing error rate change increases % controller output change. In typical continuous process applications liquid level measurements are noisy; they present rapid changes in error with time, i.e., large de/dt . So, derivative mode never should be used — otherwise equipment damage may occur.

Continuous process applications often rely on surge vessels to minimize flow upsets to downstream units. The level is allowed to float between minimum and maximum values. Use proportional control mode alone with flow cutback override control.

Controlling level at a fixed point, such as for distillation column bottoms, requires proportional and integral control modes.

High integrity protection. For a level measurement deemed critical for plant safety it's common practice to install two or more redundant level systems. Redundancy implies elimination of the likelihood of a common mode failure, which can result when using identical methods, instrumentation and manufacturer.

Inherent in high integrity protection is the principle of fail-safe design. However, the total system needs in-depth study to determine the potential of fail-to-danger scenarios and to ensure testing facilities and procedures are acceptable.

Frequency of testing for satisfactory operation can dramatically impact system reliability. Unfortunately, conducting real on-line testing of level instrumentation generally is rarely possible because creating the process condition required, for instance, high level in a vessel, usually isn't feasible. ●

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Do Your Level Best

Level control with dP transmitters appears simple but really isn't

By Dirk Willard, Contributing Editor

I DIDN'T think I could solve the problem. I had to specify the level settings for a flanged and dished tank divided into three compartments with a bottom head as the third tank. It was a challenge but I met it. What do you know — integral calculus is actually good for something!

In a typical level problem, you must set high-high (HH), high (H), low (L) and low-low (LL), based on percent, for a standard two-element (wet, dry) differential pressure (dP) transmitter. Don't forget about full (100%) and empty (0%). All measurements normally are to centerline unless otherwise noted.

For a dP level transmitter, the upper range value (URV) and lower range value (LRV) are defined as:

URV = liquid specific gravity (SG) × the distance between 100% and 0% ($h_{100\%}$) + LRV; and

LRV = capillary fill SG × distance between the elements or pancakes × -1. The LRV distance should comfortably exceed the URV span.

The HH setting usually is at the lip of the overflow but sometimes is lower if process constraints dictate. Equating that with 100% full can cause problems. You may want to measure above HH in case the overflow fails. "Cameron Hydraulic Data" recommends a minimum spacing between settings of 3 in. or 2 min.

Establishing LL is simple for a cylindrical shape. Cameron suggests 1-ft submergence for every ft/sec velocity for the pump suction. So, for a 2-ft/sec velocity and a 6-in. nozzle, LL should be: $6/2 + 2 \times 12 = 27$ in. above the pump suction nozzle centerline. For saturated (boiling) liquids, use a safety factor or company standard.

The setting for H depends on the maximum fill rate. The material balance may be helpful. The L setting depends on the maximum withdrawal rate. It may make sense to set HH and H for the light liquid and LL and L for the dense liquid. However, here's where the calculation gets complicated.

To calculate a setting for a cylinder, first calculate the volume per inch. For a 10-ft-dia. tank this is 4.9 gal/in. If the fill rate were 50 gal/min, then for 2-min. minimum spacing the gap between HH and H would be $50 \times 2 / 4.9 =$

20 in. If the total span between 100% and 0% were 450 in. and HH were set at 95%, then H would be at $(427.5 - 20) / 450 = 91\%$. Change any gap less than 3 in. to 3 in. If you wanted H at 85%, the time between H and HH would be 4.4 min.

With other shapes such as cones and vessels where most of the volume is in the head, the calculation is more difficult. I've found it best to use the actual volume rather than the column change. In one vessel only 30% of the volume was in the cone. I've set LL based on liquid holdup and recirculation rate for such tanks. Also, you may want to confirm LL against Cameron's submergence recommendation.

Calibration introduces new problems. The density of ambient water used in testing probably won't match that of your process liquid. There's a simple correction. If water temperature during testing is 75°F, SG is 0.997. If process fluid at process temperature has an SG of 0.880, correct via a ratio. For example, if an H of 90% were desirable, then during calibration, the setting should be: $90\% \times 0.997 / 0.880 = 102\%$. The total inches of water column is the same but the height of the liquid is less for the heavier test water.

While geometry makes life difficult, SG causes real problems in dP level measurement. Sometimes a vessel contains more than one liquid, sometimes it changes during the process. Usually, it's best to set HH and H using the lighter liquid but not if the density ratio is more than about 1.2:1. Otherwise, your HH and LL alarms would be separated by only 20–40%, which is unworkable.

When this occurs, it's still possible to use a dP — but not alone. Consider a density measurement; a nuclear or dP cell in a still well may work. Calculate a new URV from the density: $URV_{new} = SG_{new} \times h_{100\%} + LRV$. Now, determine the true level: $\% \text{ level} = (dP_{new} - LRV) / (URV_{new} - LRV)$. In this way, URV and span are variables. ●

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