Level Measurement
PART I
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AN APPLICATIONS CONTEXT

The task of determining just how much material is in a tank, reactor or other container really doesn’t seem like it ought to be such a difficult task. But when faced with the question, the instrumentation engineer has at his disposal a surprising range of sensor technology options—all developed to overcome various application peccadilloes that confound a one-size-fits-all approach to the task.

A big part of the problem is that level instrumentation is necessarily an afterthought relative to the primary tasks of mixing, batching, storing and reacting that take place within a given vessel. For example, a process engineer considers first the conditions that need to exist inside a reactor vessel. If high temperatures, high pressures and vigorous agitation are needed, then the instrument chosen must bend to those conditions. Never mind the fact that agitation replaces any normal concept of level with a vortex. Similarly, if solids in a silo tend to pile or rat-hole, there may be no true “level” to detect. A tank’s

Level Instrumentation Application Considerations

- Can the level sensor be inserted into the tank or need it be completely external?
- Is a continuous measurement needed or will a point sensor be adequate?
- Can the sensor come in contact with the process fluid or must it be located in the vapor space?
- Is direct measurement of the level needed or is indirect detection of hydrostatic head (which responds to changes in both level and density) acceptable?
- Is tank depressurization or process shut-down acceptable when sensor removal or maintenance is required?
- Are the tank contents viscous, sludgy or foamy? Powdery, chunky or sticky?
head space may contain vapors or dusts that obscure a clear view of the surface. And sometimes the level of interest is actually that of an interface between two immiscible liquids.

Another important application consideration is whether absolute accuracy or reproducibility is of primary importance. High absolute accuracy typically characterizes tank gauging applications where level measurements are used for custody transfer applications. Reproducibility and precision, on the other hand, typically carry the day for in-process tank and reactor applications where stability of process control and overall operations is the central aim.

Sometimes, too, a continuous level reading isn’t necessary and a discrete level switch will do. When safety or environmental impacts are at risk, for example, a redundant level switch based on a different sensor technology than the primary level gauge may provide an independent layer of protection to reduce the risk of overflowing a tank—or running a pump dry.

TECHNOLOGY OVERVIEW

Level instrumentation works by leveraging a variety of underlying physical operating principles. Some having moving parts; some do not. Some don’t come in contact with the tank contents itself; others require an immersed probe or at least a wetted surface. Some are designed to pinpoint the actual position of the tank level in space; others infer it from secondary measurements.

A mechanical float may move up or down based on fluid level, or a buoyant displacer may exert a varying force, depending on how much of it is submerged. The measured capacitance between an electrical probe and the tank wall may vary based on the amount of intervening material. Radiation may be timed during its roundtrip from the top of the tank to the surface, or differentially absorbed by tank contents during a trip across. The measured difference in pressure, too, between the bottom of the tank and the vapor space (the hydrostatic head) provides an inferential indicator of tank level.
Each of the technologies summarized here comes with its own advantages and limitations.

- Capacitance/RF Admittance devices include both continuous gauges and point-level switches. Changes in the electrical properties of the space between two electrodes on a switch or between a long probe and the tank itself (due to intervening material) indicate changes in level.
- Differential Pressure devices measure tank level based on the pressure difference between the bottom of the tank and the head space (for pressurized vessels) or atmospheric pressure for vented tanks.
- Floats and Displacer devices are similar in concept. A mechanical float moves with changing level, and a complementary detection technology is used to determine the position of the float Displacers, meanwhile, feature a cylindrical float that is partially submerged and constrained from moving; the apparent weight of the displacer varies with level.
- Laser level gauges are top-mounted, non-contact devices that project a laser beam toward the surface. Time-of-flight is used to calculate distance of the material level from the top of the tank.
- Magnetostrictive level gauges are a variation on the float level gauge. A float containing a permanent magnet moves freely up and down a magnetostrictive waveguide/probe. A low current interrogation pulse travels down the waveguide, and when it reaches the float a torsional twist and reflection are created, indicating the float position and level.
- Nuclear level gauges infer level in even the harshest reactor conditions by passing radiation through a tank’s walls—and its contents—to a detector on the opposite side. Attenuation of the radiation is proportional to the amount of material traversed, and the liquid level in turn.
- Radar gauges come in two variations: top-mounted, non-contact devices that use an “open beam” reflected radar signal to determine liquid level. Guided-wave radar devices are similar, but the radar signal follows a probe waveguide down to the material, the surface of which partially reflects the signal and allows level calculation.
- Ultrasonic gauges operate similarly to open beam radar gauges (above), but calculate level based on the time required for an ultrasonic signal to be reflected from the liquid surface.
- Vibration level switches detect the presence of surrounding liquids or solids based on the shift in resonant frequency of a vibrating probe.
THE LEVEL MEASUREMENT CONTINUUM
Level measurement technologies and applications can be arrayed along a continuum from the cheap and relatively easy to the dear and difficult.
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Twenty years had passed, and the manufacturer’s ionization-chamber-based detector for level measurement was no longer manufactured or supported. This distillation column bottoms application was uncommonly unfriendly to floats, displacers and differential pressure methods (DP) due to its viscosity and tendency to polymerize, so a nuclear level device was an attractive choice.

The site was already licensing and maintaining nuclear instruments for other applications, so adding new nuclear sources to its existing license was less intimidating. Lacking any additional level instruments—a gauge glass, for example, which had plugged up and was effectively abandoned many years ago—the tower control was extremely reliant on this single, obsolete solution.

What was the level, really? Nuclear or radiometric level instruments function by directing a carefully sized and focused beam of gamma radiation through the vessel containing the substance of interest. The beam is electromagnetic radiation, like X-rays, microwaves (or light, for that matter), and one can imagine the receiving instrument is detecting the “shadow” cast by the process fluid. But for most detectors, it’s really the total radiation that’s correlated with level—the instrument doesn’t really “see” the progression of a shadow per se. Modern detectors are designed to function with increasingly smaller (and hence safer and easier to license) radioactive sources, so in this case, the entire span of the ionization cham-
ber would be used in capturing and quantifying the gamma rays that made it through the vessel and the fluid. When the level is high (or the nuclear source holder’s shutter is closed), the least radiation is collected or counted, and when the vessel is empty, the most radiation gets through.

The source of gamma rays in this application was a tiny quantity of cesium 137, a byproduct of nuclear fission and the decay of other radioactive isotopes. The gamma radiation produced by the 275 millicurie source was itself produced by the decay of the 137Cs. The cesium isotope therefore decreased in quantity (and “power”) over the years, and with a half-life of about 30 years, would be measurably diminished in the 20 years since its installation. How might this be reflected in the level measurement? Since the aging detector was commissioned on the new source, the gradual decay of would reduce the base radiation, and would look like a higher level than was actually present.

Rather than risk an emergency repair (possibly a futile hunt on eBay), the site elected to determine if a modern level transmitter could use the old source and provide a reliable level measurement. Detector technology has improved and even the 20-year-old source was more than adequate to support a new level measurement. The other feature one gets with modern devices is improved access to diagnostics using HART or fieldbus. Field strength or “counts” can be tracked live in a HART- or fieldbus-capable host system.

Like DP or displacer measurements, the boiling liquid will have a lower density, which will tend to make the level read low as the boiling liquid not only weighs less, it absorbs less radiation, making all three methods potentially read low if they were benchmarked against pre-startup conditions.

But how precise does a distillation column bottoms level need to be? Unlike a boiler steam drum, where short residence times and dire consequences from low level (boiler trip) and high level (liquid carryover) compel us to compute precise compensation for density, chances are tower level can tolerate much greater uncertainty. In the example case, ensuring the level was high enough to prevent pump cavitation, maintained enough ullage to absorb disturbances, and staying below the tower’s reboiler return meant an uncertainty as great as ±0.25 feet (0.1 meter) would suffice.

Modern radiometric instruments are not only capable of exceeding requirements with existing sources, the option for using digital integration with HART or fieldbus affords additional insight and diagnostics to ensure applications add value for another two decades. End users are encouraged to be alert to cases where obsolete technology could be a threat to future reliability.
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Guided-wave and other radar-based methods have been the fastest evolving of the primary level measurement technologies in recent years, but they can’t do it all on their own.

Similar to any of today’s process control and automation solutions, they require a growing cast of supporting devices and systems to achieve and maintain their advances, most notably onboard microprocessors to process data and Ethernet ports to communicate it. In the case of level measurement, specific technical gains mean seeing further, deeper and more accurately through vapor, steam, foam, intermediate layers, sediment buildup and physical obstacles to determine precise amounts of substances in tanks and other vessels.

“Level instrument performance has improved in the past few years, but their costs haven’t ramped up at a similar rate. In some cases, technologies like radar have become more affordable compared to when it was first introduced, but its economic benefit isn’t limited to return on investment (ROI) because the expertise required to set up newer level technologies has decreased,” says Herman Coello, level marketing manager at Siemens (www.siemens.com). “Taking into account the changing demographics and the drain in expertise leaving the industry, one can see that when level technologies are simple to set up, this represent a real economic value since training is virtually not needed. Furthermore, apps are being used for setup and in some cases for diagnostics, and this can be a real time saver.”

Radar pierces barriers
Guided-wave and other innovations penetrate foam, steam, intermediate layers and more.

By Jim Montague
NON-CONTACT VS. GWR

Level technologies don’t generally change quickly, but radar has been moving rapidly. “This growth has been driven by high-speed processing chips and falling sensor prices as more suppliers make pulse radar components for backup and side-sensing devices in cars,” says P. Hunter Vegas, project engineering manager of the Process Automation Group at system integrator Wunderlich-Malec (www.wmeng.com) in North Carolina. “In the late 1980s and early 1990s, radar level meant crazy-expensive, big parabolic dishes and were mostly installed in the huge storage tanks that could justify the cost. In the mid-1990s, newer, lower-cost radar level sensing technologies were introduced including non-contacting pulse radar and contacting or GWR.”

<table>
<thead>
<tr>
<th>Application</th>
<th>Characteristics</th>
<th>Selection and best practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryogenic applications</td>
<td>Clean fluids with low viscosities and low dielectric values such as LNG, LPG, ethylene, propylene, R22 and other refrigerants, carbon dioxide, nitrogen, argon and xenon.</td>
<td>NCR (if dielectric is high enough) or GWR: use radar with a dedicated cryogenic tank seal High-precision tank gauging system for storage tanks, custody transfer, or full containment LNG tanks</td>
</tr>
<tr>
<td>Separators</td>
<td>• This is commonly an oil and water application. Depending on the fluid separation, an emulsion layer could be present • Dirty or paraffin-laden hydrocarbons could cause some coating, so a single-lead probe is recommended</td>
<td>GWR: use a single-lead rigid probe</td>
</tr>
<tr>
<td>Distillation columns</td>
<td>• Wide temperature ranges, can be as high as 750 °F (400 °C) • Fluids, especially at the lower end, can be dirty and cause coating and plugging of equipment • Important to insulate chambers and piping to minimize risk of plugging and to maintain lower viscosity</td>
<td>GWR: use a single-lead probe</td>
</tr>
<tr>
<td>Blending tanks</td>
<td>• Blending tanks are used for mixing fluids or solids into fluids, usually at ambient conditions • Level measurements are needed to monitor fluid additions • May be corrosive, vapors, turbulence, foam • Usually has an agitator for mixing.</td>
<td>NCR</td>
</tr>
<tr>
<td>Reactor vessels</td>
<td>Reactor vessels are similar to blending tanks except that a reaction is required to produce the final product. While the components can create an exothermic or endothermic reaction, sometimes external heat is required • Vapors, foam and turbulence are often present • Density can change as part of the reaction • Pressure can vary from vacuum to positive pressure</td>
<td>NCR</td>
</tr>
<tr>
<td>Steam generation</td>
<td>• High-pressure/high-temperature equipment required • Density and dielectric of steam increase as pressure and temperature increase • Density and dielectric of liquid decrease as pressure and temperature decrease • Dielectric changes in the steam require compensation for the guided wave radar measurement • Control range is over small span</td>
<td>GWR: use dynamic vapor compensation</td>
</tr>
<tr>
<td>Solids</td>
<td>Solid products have different properties/challenges depending on if they’re powder, pellets or big particles, and whether it’s dry or humid. Also, different products tend to pile up differently. Dust is very common.</td>
<td>NCR: use for heavy materials GWR: use for low-dielectric, lightweight materials. Note: This is generalized</td>
</tr>
</tbody>
</table>

Vegas reports non-contact radar initially used a frequency-modulated, continuous-wave (FMCW) radar signal aimed at the surface of the product. The return signal echo was sensed, and the difference in frequency allowed the transmitter to determine the time of flight, and thus the height of the level. As high-speed processing chips became available, pulsed radar was introduced that used a fixed-frequency pulse of radar to measure the time of flight of the echo to detect the level. The performance of both types depends on the reflectivity of the product, frequency of the radar, and size of the antenna horn.

“There are significant tradeoffs between these components,” explains Vegas. “If material contact is allowed, GWR can be a better choice because all of the radar energy is focused down the probe. This allows it to operate with lower dielectric materials, and it can even measure level and interface simultaneously in some applications. The significant increase in signal strength and efficiency allows GWR to be used in boiler-level applications. Whether you use non-contacting or contacting radar, significant improvements in digital signal processing and radar component design have allowed radar to handle a broader range of applications even as the price has dropped.”

Siemens’ Coello adds, “Instruments have become more compact and easier to use. In the case of some radar level transmitters, the operating frequency has moved to the W band. Within this frequency spectrum, instruments operating from 78 GHz to over 80 GHz are now popular. To an end user, the focus shouldn’t be the operating frequency because some level applications are better suited for lower operating frequencies. Nevertheless, the higher frequency provides

TO-DO LIST FOR LEVEL
To determine the most appropriate, accurate, best-performing solution for a level measurement application, users and experts alike must follow several steps, according to P. Hunter Vegas, project engineering manager of the Process Automation Group at system integrator Wunderlich-Malec Engineering’s (www.wmeng.com). These include:
- Understand the process and obtain the dielectric properties of the material. Is the tank agitated? Could foam build on the surface? Is material contact allowed?
- Get a detailed drawing of the tank, and ideally work with the radar vendor to determine the best size/location of the nozzle before the tank is built. Internal baffles, fill pipes, agitator blades, recirculation nozzles, bottom shape, etc. can all impact the performance of the unit.
- Work with the radar vendor to determine the best radar solution. The best radar technology (FMCW vs. pulse vs. GWR) can be selected along with the best frequency, antenna/probe type, and nozzle location to maximize the chance of success.
- If an application has a tank with an existing nozzle, options may be somewhat limited. In this case, give the vendor the tank details and process data, and see if a solution can be found. It may be necessary to install a new nozzle to allow the radar to operate successfully.
- Once installed, use software provided with most radar transmitters to commission them. This involves mapping tank internals when it’s empty to teach the transmitter to ignore echoes from fixed components. Mapping software can even mask and ignore spinning agitator blades.

“It’s really important to work with your vendor to carefully evaluate your application and determine the right radar solution,” adds Vegas. “It’s also important to size and position the nozzle to suit the transmitter, rather than selecting a transmitter to fit an existing nozzle. The latter might work, but it will probably never give optimal performance.”
an unprecedented flexibility in terms of installation. Thus, the need to retrofit the process connections where instrument are installed has decreased. Another benefit of higher frequency is the instrument signal is much narrower than the signal from instruments operating in the C band. Again, this is why process connections are now less challenging. But at the same time, a narrow signal means there’s less interference from any obstructions inside a tank or silo. The overall result is faster commissioning with a new level of dependability."

Despite these gains, non-contact just can’t penetrate some process conditions, which is where contacting or GWR comes in because its probes and wires physically reach the substances users want to measure. “Radar can have a hard time in applications with different dielectric constants that cause electric reflectivity,” adds Vegas. “If you have material with low conductivity like propane or LNG, signals can bounce back weak. This is where GWR can help because its focuses energy down a rod, which shows changes in the dielectric constant, and allows readings that couldn’t be seen before. GWR started to gain ground in the early 2000s, and has come a long way in the past 10 years as its data processing and other costs came down.”

HANDLING THE HEAT

While high-temperature applications used to rely on pressure devices to indicate level, gradual improvement in radar and GWR are allowing them to also serve in these environments. Thomas Kemme, global strategy manager at Magnetrol (www.magnetrol.com), reports, even with GWR, the aggressive nature of steam vessels make them a difficult environment to work in. For example, condensation on the probe naturally occurs, which can result in GWR level measurement errors due to delays in signal transmission down the probe. “Our Eclipse steam probe has an innovative probe design that includes new Condensation Control Technology

STEAM AWAY CONDENSATION

Figure 1: Eclipse guided-wave radar (GWR) steam probe has an innovative design that includes Condensation Control Technology (CCT) coupled with its original, patented Automatic Steam Compensation (ASC) to eliminate inaccuracies caused by condensation. Source: Magnetrol
(CCT) coupled with our original patented Automatic Steam Compensation (ASC). The new steam probe with CCT eliminates inaccuracies caused by condensation so that optimal performance can be achieved. There are already users showing improved performance of their GWR in steam applications. Installation of the new Eclipse steam probe with CCT directly solved a customer measurement issue in the Netherlands by eliminating condensation on the probe.” (Figure 1)

CHOOSING WISELY

When implementing a level measurement application, Wunderlich-Malec’s Vegas reports there are many technical aspects that must be considered. “Some users think a radar transmitter is just purchased, installed, and it works, but unfortunately there’s a lot more involved,” he explains. “A radar’s performance is determined by a combination of process characteristics, tank internals, size/type of antenna and the frequency. Process and tank dimensions limit options and selections of antenna and frequency require tradeoffs.

“For instance, low-dielectric materials or foams can reduce the strength of the echo in non-contacting applications. Larger antennas can increase signal strength, but the size is usually constrained by the size of the nozzle. Higher frequencies have more signal strength for a given antenna size and tend to focus the beam to a smaller area, but high frequencies are absorbed by foams and scattered by turbulence. Meanwhile, low frequencies can handle foam and turbulence, but have a larger beam size, usually require bigger antennas, and tend to pick up reflections off internal tank components. If contacting radar is an option, then the tradeoffs of various probe designs must be considered and in difficult applications, a stilling well may be required.”

Vegas adds that seeking expertise during the instrument selection process is critical to success. “The industry is moving rapidly and new improvements are being introduced all the time,” he says. “Work with your vendor to make certain you get the best combination of frequency and antenna type for your application, and find out the right nozzle size and location before you buy the transmitter. Many users just slap a nozzle on the tank, and then try to find a radar device that fits. This greatly reduces your equipment selection options and virtually ensures a less than optimal result.”
RADAR IS THE BETTER ULTRASONIC

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The five non-contacting level measurement technologies are radar, nuclear, laser, weight and ultrasonic. Each of them has both good points and bad. Radar, for example, is relatively expensive in the more accurate versions (frequency-modulated, continuous-wave, FMCW), while nuclear level is limited to relatively small vessels, and there are licensing and safety considerations. Lasers appear to have developed an application niche, especially in the measurement of bulk solids and powders. Weighing systems can be used in some vessels, but it is, again, a relatively niched application solution. Of all of these, ultrasonic level measurement is the most widely used non-contact technology. Ultrasonic level transmitters are used in most industries and are very widely used in open-channel flow measurement systems, sited atop a flume or weir.

HOW DOES IT WORK?

Ultrasonic level sensors work by the “time of flight” principle using the speed of sound. The sensor emits a high-frequency pulse, generally in the 20 kHz to 200 kHz range, and then listens for the echo. The pulse is transmitted in a cone, usually about 6° at the apex. The pulse impacts the level surface and is reflected back to the sensor, now acting as a receiver (Figure 1), and then to the transmitter for signal processing.

Basically, the transmitter divides the time between the pulse and its echo by two, and that is the distance to the surface of the material. The transmitter is designed to listen to the high-
est amplitude return pulse (the echo) and mask out all the other ultrasonic signals in the vessel.

Because of the high amplitude of the pulse, the sensor physically vibrates or “rings.” Visualize a motionless bell struck by a hammer. A distance of roughly 12 in. to 18 in. (300 mm to 450 mm), called the “blanking distance” is designed to prevent spurious readings from sensor ringing. This is important for installation in areas where the distance above the level surface is minimal.

**PHYSICAL INSTALLATION ISSUES**
There are some important physical installation considerations with ultrasonic level sensors.

1. Make sure the materials of construction of the sensor housing and the face of the sensor are compatible with the material inside the vessel. Most ultrasonic sensor vendors provide a wide selection of sensor materials of construction in case the standard sensor housing isn’t compatible. Most sensors come with a PVC or CPVC housing. PVDF, PTFE (Teflon) and PFA (Tefzel) are usually available. In some cases, a housing of aluminum or stainless steel with a polymer face can be provided.

2. Make sure that the operating temperature range of the sensor is not exceeded on either the high or low temperature end. The materials of construction may deform or the piezoelectric crystal may change its frequency if the temperature range is exceeded. The change in ambient temperature is usually compensated, either by an embedded temperature sensor, a remotely mounted temperature sensor or a target of known distance that can be used to measure the ambient temperature.

3. Locate the sensor so that the face of the sensor is exactly 90° to the surface of the material. This is especially important in liquid and slurry level measurement. In some bulk solids measurements, this can be modified (and this will be discussed in a later section of this article). If
you do not do this, your echo will either be missed entirely by the sensor, or it will use an echo that is bouncing off the vessel wall or a vessel internal structure instead of the real level.

4. Make sure that the vessel internals do not impinge on the pulse signal cone from the sensor. If they do, you may get a spurious high amplitude echo that will swamp the real return echo from the surface of the material.

5. Make sure you avoid agitators and other rotating devices in the vessel. Sometimes you can do this with an additional waveguide. If you can't, make sure you purchase a transmitter that can compensate for the effects on the echo of the agitator blade moving in and out of the signal cone.

6. Mount your sensor where it can't be coated by material or condensation inside the vessel. Coatings attenuate the signal, sometimes so much that there is no longer enough power to get through the coating to the surface and back. If it isn’t possible to avoid coatings, try to provide some means of cleaning the sensor face. Some transmitters provide a signal “figure of merit” that can be used to detect coatings or other signal failures and activate an alarm function.

7. Always use the vendor-supplied mounting hardware for the sensor. Hard-conduit-wiring an ultrasonic sensor can increase the acoustic ringing and make the signal unusable.

APPLICATION CONSIDERATIONS

Because ultrasonic level sensors and transmitters are inexpensive and usually easy to install, they’re often used at the outer edge of the application envelope, and erratic or erroneous signal and signal failure often result.

1. Try to avoid agitated tanks even when the agitator is below the surface of the material. Agitation can produce whirlpools or cavitation, which may attenuate the signal or cause it to bounce off a vessel wall. In some cases, the agitation may be so extreme that the measurement you are trying to make is “what the vessel level would be if the agitator was turned off” (Figure 2). This is not a real measurement, and it may not be possible to make it with any degree of confidence or accuracy.

Figure 2. Sometimes the measured value is “what the level would be if the agitator were turned off.”
2. Sparged tanks, where air or another gas is introduced into the vessel by means of diffusers or spargers, can cause bubbles or foam to form on the surface of the material. It is good to avoid this application. A layer of bubbles or foam can attenuate the signal either entirely or partly. If it attenuates the signal entirely, there will be no echo return. It is more insidious if it only attenuates the signal partly. A false echo can occur from somewhere in the foam layer, rather than either the surface of the foam or the surface of the liquid below the foam (Figure 3).

3. Avoid foam. Foam can do three things to the accuracy of the level measurement, and all of them are bad. 1. It can attenuate the signal so that there is no echo or only an intermittent echo. Intermittent echo can sometimes be dealt with using a sample-and-hold circuit or algorithm in the transmitter so that the level doesn’t change until the next good echo. Sometimes, however, that can be dangerous, as in the case of a vessel where the level is quite near the maximum fill point. 2. Foam can provide a false reading of the true level. You can get a reading from inside the foam layer, instead of the actual level. 3. Foam clumps can cause the echo to be deflected away from the vertical, and the sensor may receive an echo that has made one or two hops against the side of the vessel, yet still be a high enough signal to fool the transmitter.

4. Avoid volatile liquids. Back when I was in sales, I sold an ultrasonic transmitter to a major northeastern United States utility for the measurement of level in huge bunker oil tanks. The sensor was installed in early November, and it worked acceptably well until mid-May of the following year, when the customer reported that the sensor was insisting that the level in the tank was several feet higher than it actually was. This “ghost level” phenomenon is a function of the volatile liquid in the tank. As the ambient temperature rose, the vapor blanket on top of the bunker oil began to become more dense and increased in height. The ultrasonic sensor picked up the top of the vapor layer, instead of the actual oil level in the tank. By late June, the sensor was regularly reading 80% to
100% because the early summer heat had caused the vapor blanket to fill the tank. We replaced the ultrasonic sensor with an FMCW radar sensor, which worked correctly, and I learned something.

5. In solids and powders, you may have to aim the sensor at a point that is not 90 degrees to the level surface (perpendicular to the vertical axis of the vessel). You may want to aim the sensor because of rat-holing and angle-of-repose issues at the top, midpoint or bottom of the angle of repose. Try to have the transmitter calculate what the actual level might be. At least one vendor has developed a multiple sensor array that can scan the angle of repose and determine what the actual filled volume of the vessel is.

6. Avoid pressurized tanks. The speed of sound changes with temperature and density, and pressurizing the vapor space above the level can affect the density of the vapor space and, therefore, the speed of sound.

ULTRASONIC OPEN-CHANNEL FLOWMETERS

One of the most important applications for ultrasonic level sensors and transmitters is measuring open-channel flow (figure 4).

Most of the same caveats apply to ultrasonic level sensors used as flowmeters as apply to ultrasonic level sensors used as tank level measurement devices. There are a few more:

1. Avoid wind and sun. Wind can blow through the vapor space and attenuate the signal or blow it off course. Sun can raise the temperature of the sensor housing itself beyond the operating temperature range of the device-and higher than the ambient temperature.

2. Make sure that there isn’t foam on the surface. This can happen often in nitrifying wastewater discharges.

3. Make sure that there is not too much turbulence or ripples (or if the flume or weir is large enough, wave action) on the surface.

4. Above all, make sure that the flume or weir is installed correctly. Many problems blamed on the ultrasonic transmitter are actually problems that are caused by the flume not being installed level both hori-
zontally and vertically, as well as front to back through the measurement zone.

5. Make provisions to keep ice from forming on the sensor in the winter or dripping condensation in the summer.

THE ONE-TRICK PONY – NOT!
Ultrasonic sensors are simple to understand, easy to install and inexpensive. It's easy to go to them as the unthinking sensor of choice for level applications, just as many people go to differential pressure level sensors. Yet, as many users have found, ultrasonic sensors and transmitters are tricky beasts. As with any other field instrument, applying an ultrasonic level sensor too far outside the manufacturer’s recommended application envelope is destined to fail, and sometimes fail spectacularly. But, if you follow these basic guidelines, you will have successful ultrasonic level installations.
Greg: Instruments provide the view into the process and means of controlling it. If they’re not telling the truth, we’re in serious trouble. If you can’t measure it, you can’t control it.

Mike Laspisa offers his insights as to where we are now and where we should be with instrumentation specification based on 37-plus years working in the instrumentation and control (I&C) discipline, including 32 years as a lead I&C engineer or manufacturing plant staff I&C engineer. I spent most of the 1970s in instrument and electrical (I&E) design and construction, and to this day, the performance of instrumentation is foremost in my mind. Mike’s goals are very similar to mine in terms of wanting to share our knowledge often learned the hard way to help automation engineers do what’s best.

Mike, what were the original intents and methods for I&C specification from the late 1970s to the late 1980s?

Mike: Field device importance was held in high regard. Measurement and control device specification was a science, and could only be learned on the job. I&C engineers were considered an important asset by both the company and the client. Instrument engineers specified measurement devices, and selected and sized control valves, regulators and safety relief devices using process data, process and instrument diagrams (P&IDs), and pipe specs. A control valve outside sales engineer would review the engineer’s selection and discuss dif-
ficult applications. Valve sizing calculations were always done by the engineer doing the valve specification.

Device selection took into account both application requirements and device cost. However, performance was the primary selection criteria. Process data was analyzed by the I&C engineer for each measurement and control application, including control valve sizing pressure drop, flow measurement turndown and multiple case studies, if applicable. Accuracy, advanced control strategies, ratio blending, batch addition resolution and many other requirements were discussed with process engineers during joint P&ID development.

However, mass flow measurement choices were limited (e.g., load cells, weigh belt, and volumetric flow with pressure and temperature compensation by remote electronics or computational module).

**Greg:** How would you describe our current situation?

**Mike:** Project bottom line focus has led to cost-effectiveness becoming almost more important than performance in instrumentation and control device selection. In addition, I&C device vendors are being asked to select/size field devices more often based solely on the data provided on a datasheet. A reduced budget for I&C specification work is now expected for projects and by some clients. Unfortunately, I&C device vendors are using a younger inside sales force that seems to rely mostly on software for quotations without the experience to ask the right questions or quote needed accessories.

Fast-track engineering has almost become the standard. This sometimes leads to preparing I&C device specifications without the necessary information to specify them completely. Also, process data is usually provided late, and is furnished incomplete or in partial installments. I&C engineer value or project early involvement is questioned by project management. Process or sometimes even project engineers think they can make the early decisions on required I&C devices, or assist the client in P&ID development.

Relying on vendors to select and/or size I&C devices has negatively impacted development of I&C specifying engineers. This has led to I&C engineers not questioning process data and issuing incomplete datasheets. Reduced budgets and fast-track engineering have also compromised the datasheet checking process. The focus now appears to be more on checking tags against P&IDs rather than application information (sizing, materials of construction, end connections/rating, pipe specs, etc.) and the completeness of the critical process data required to support the sizing and selection of the device.
On the other hand, there are some bright technology developments that have made I&C device applications easier (and more forgiving), such as mass flowmeters, smart transmitters with wide rangeability, multi-variable transmitters, radar level transmitters and digital valve positioners.

**Greg:** I&C engineers should ask process engineers what accuracy is required. In my experience, the accuracy they want is aggressive and was often not achievable until recently.

Mike, how does this history or commentary relate to instrument specification work at engineering, procurement and construction (EPC) firms?

**Mike:** When I was reviewing project work before I retired, I observed a number of specification deficiencies that included incomplete or incorrect datasheets. Calibrated ranges didn’t always take into account the minimum, normal and maximum process requirements and sensor rangeability. I’ve seen datasheets where the vendor was to select the device size, model, trim, etc. from limited or possibly unintentionally skewed information (e.g., all globe valves with 5 psi valve drop for sizing, regulators using pilots where they weren’t required, etc.) Some specific application requirements (e.g., magmeters missing ground straps/rings/ground electrodes; flow primary element selection not compatible with process pipe/duct; analytical probe connection requirements not considered during specification; level measurement selection not compatible or practical for application) were not specified correctly. Is this a checking issue, a philosophy issue (i.e., leave it up to the vendor whenever possible), or a misunderstanding of what is required?

The interface with piping designers, including in-line installation detail preparation, is more after-the-fact than timely to the piping design effort. Packaged system instrumentation is a shared responsibility, but process design usually is in the lead. Historically, I&C does not get involved with the measurement requirements, only the hardware preferences, control system choices, and device signal levels.

**Greg:** We have to be especially careful to make sure packaged equipment suppliers use the latest and best technology consistent with plant standards.

**Mike:** The package instrumentation, control devices and control system (including the interface with the plant control system) must meet the equipment specification expectations/requirements (e.g., manufacturer or equal, type or series, and control system preference). There have been many examples where the plant standards or even preferred vendors were ignored to save money by accepting OEM devices well after the specification phase.
Greg: What’s needed for a much better future in the specification of I&C devices?

Mike: Better use of appropriate instrumentation and control device learning opportunities (courses, exhibitions, free vendor/manufacturer seminars, lunch-and-learns, asking a lot of intelligent questions and mentoring). Provide internal or external technical resources to discuss device-type applications during datasheet preparation. Develop the preferred role of vendors and I&C engineers in selection and sizing of I&C devices. Discuss the expectations for instrument process data analysis. Determine the critical data fields or notes for the different I&C devices. Datasheet checking must cover technical content as well as device checks against P&IDs for tag and service.

In addition, see the “Instrument Datasheet Preparation Flowchart” for the recommended approach to specifying instrumentation and control devices. Develop a standard naming convention for instrument package workbooks, worksheets and archiving. Discuss vessel connection responsibilities, requirements and impact on device specification. EPC firms need to get I&C engineers more involved in the packaged equipment system specification process and bid review. Process engineers commonly use vendors to create their package specifications, but they rarely have an I&C engineer involved in any conversations or meetings.