

The Big 6 level measurement technologies

Where to use them and why

—
MS Sreekanth
 Global Product
 Manager, Level
 Measurement
 Technology

ABB Measurement
 & Analytics

Anyone who's ever worn a tool belt knows that sometimes you have to use a tool for something it's not designed to do. If you don't happen to have a hammer, a heavy wrench will work in a pinch. But of course, the job will be done more effectively when you use the right tool.

When it comes to measuring the level of materials in a tank or other vessel, there are many tools you can choose from. Some are clearly better suited to certain applications, but in many cases the best level measurement technology for the job can be hard to identify. Understanding the most-common types of fluid-level-measurement technology will help you make a good choice and select the right measurement tool for the job.

Level-measurement applications

Knowing the amount of liquid contained in a tank is an essential piece of data in almost every process and production operation. That information is primarily needed to fill one of five requirements:

- **Inventory control:** Ensure purchasing and stocking the optimum volume of material
- **Process efficiency:** Maintain appropriate levels of materials to optimize production processes and use storage options most efficiently.
- **Safety:** Avoid overfills/overflows to prevent injury, environmental issues and need for cleanups.
- **Consistent supply:** Have the required volume of materials to meet production or customer demands without interruption
- **Custody transfer:** Meet commercial and legal requirements for accurate measurement of transferred materials.



Technology considerations

When choosing the potential technology for an application, the first question to answer is “Are you measuring solids or liquids?” There are some meter types able to work with both types of materials, and others uniquely applicable to one medium or the other. We will focus only on liquid-measurement application.

The second question is “Do you need continuous or point-level measurement?” We will narrow the focus for our exploration to only continuous-level technologies.

Within the universe of continuous-level measurement of liquids, there are six commonly-used meter types:

- Differential pressure
- Ultrasonic
- Guided Wave Radar
- Laser
- Magnetic level gauges
- Magnetostrictive

Let’s look at each of them, how they work, and what applications they’re best suited to.

The Big 6 fluid-level measurements



Differential pressure

This is probably the oldest, most trusted, and commonly used, level-measurement method for liquids and liquefied gases in both open and closed tanks, including pressurized tanks. The meter typically includes a stable body and a diaphragm with a sensor to measure the pressure exerted by a column (or head) of liquid in the vessel. The diaphragm is deflected by the pressure differential, changing the electrical property of the sensor and creating a proportional electrical signal. The sensor could be one of many different types.

Calculating the value of the signal requires a bit of math that includes three variables: pressure, density (specific gravity) which must be entered as a constant, and the measured product height or level.

In open tanks, the meter calculates the differential between atmospheric pressure and fluid pressure. In closed tanks, it calculates the difference between the low-side, blanket pressure and the fluid pressure. In both cases, accurate level calculations depend on knowing the fluid density.

In applications where density changes, more sophisticated meters must be used. These “multivariable” meters accommodate dynamic liquid



density by compensating the calculated density based on a fourth variable. For liquid and wet-leg applications, the meter includes a temperature probe, decreasing the calculated density as the temperature increases. For steam applications, the fourth variable is determined based on static-pressure tables. Multivariable sensors may require multiple penetrations points in the tank.

Advantages

- Most versatile and widely used technology
- Indirect, contact measurement
- Simple design with low purchase cost
- Configurable with a variety of options to suit application
- Externally installed or retrofitted to existing vessel

Limitations

- Measurement affected by changes in specific gravity/density
- Mounting constraints / limited flexibility compared to other technologies
- Higher total cost of ownership considering periodic calibration and maintenance
- Require two vessel penetrations in closed tanks, creating leak potential



Ultrasonic

This technology relies on sound waves to determine material level by gauging the distance between a top-of-tank transducer and the surface of the material, whether liquid, solid, or slurry. The transducer emits short ultrasonic impulses (sound waves) that represent mechanical energy. The waves bounce off the top of the material like an echo and return to the transducer which calculates the “time of flight” to determine the height of the material in the tank. The transducer emits a relatively narrow beam, so obstructions in the tank typically don’t impair its applicability or accuracy.

Like the differential pressure meter, ultrasonic technology has been in use for decades and is another old and proven technology. Due to inherent limitations of ultrasonic measurement, this technology is used primarily in water/wastewater and aggregate applications.

Unlike the differential pressure gauge, there is no bottom penetration in the tank, and therefore no risk of leaks. The ultrasonic meter is also unaffected by changes in material density or specific gravity. However, because sound waves can’t travel in a vacuum, ultrasonic meters can’t be used in vacuum or reduced-pressure vessels. And accuracy can be affected by the dispersion and absorption properties of the liquid. Foam, for example, can create false reflections.



Laser

This is one of the latest advancements in level-measurement technology. It’s really only in the last five or six years that it’s become a mature, reliable technology.

Like the ultrasonic meter, a laser is also mounted at the top of the vessel pointing down. But instead of emitting a sound wave, the laser emits a flash of light. The light is reflected back from the surface of the material to the meter where it is detected by an optical receiver. The distance is calculated based on the time it takes for the light to travel to the surface and back to the instrument.

Compared to the sound pulse of an ultrasonic meter, the laser beam is significantly narrower. With virtually no beam spread (0.2 degrees), it’s possible to find an appropriate mounting location that will ensure consistent, reliable readings even in tanks with many obstructions. The laser emitter can be mounted anywhere on the tank lid, including along the tank wall. Ultrasonic and radar systems work best when centered at the top of the tank. Laser technology also works well in narrow tanks, something else that gives ultrasonic and radar meters trouble.

There are two general types of ultrasonic meters. The integrated version encompasses both the sensor and the electronics in a single, compact instrument. There is also a remote version that separates the two components, enabling remote level monitoring.

Advantages

- Proven, widely used
- Indirect measurement
- Acoustic, non-contact with no moving parts
- Simple and cost-effective
- Unaffected by changes in product density, composition, moisture content, electrical conductivity, or dielectric constant
- Narrow beam angle minimizes effect of obstructions
- Lower-cost alternative to radar / laser
- Not affected by material dust

Limitations

- Dirt, irregular and sloped material surface affect measurement accuracy
- Affected by many interferences
- Doesn’t provide high repeatability
- High pressure and/or temperature affects meter accuracy
- Weak echo, and reduced accuracy, due to dispersion and/or absorption of material (e.g. foam)
- Vapor and condensate can create false echoes

This is a universal measurement technology, used for both liquids and solids. It can also be used for positioning applications and on conveyor belts. Its versatility makes it applicable in many applications and industries. That versatility comes at cost, though. Compared to ultrasonic, laser is significantly more expensive.

Advantages

- Indirect measurement
- Non-contact
- Very high update rates are achievable; no “lock-in” issue sometimes experienced with ultrasonic meters
- Effective in both very narrow (down to 2”) and deep tanks (330 ft. for liquids, 650 ft. for solids)
- Not affected by material density
- Works with solid or liquid materials

Limitations

- Costlier than ultrasonic
- Not suitable for interface measurement
- Not applicable for environments where dust or other suspended material will interfere with laser beam
- Doesn’t work with shiny materials or when foam is present



Guided wave radar (GWR)

With this technology, also called time-domain reflectometry (TDR), the meter is mounted on the top of the tank or chamber with a probe that usually extends the full depth of the vessel. A low-energy pulse of microwaves is sent down the probe. When the pulse reaches the liquid level (the air/liquid interface), a significant amount of the microwave energy is reflected back up the probe to the transmitter. As with most other meter types, the time delay between the transmitted and received echo signal is used to calculate the distance to the liquid surface.

This reflective action depends on the liquid's dielectric value. High-dielectric liquids reflect the entire pulse, providing reliable, accurate measurement. Low-dielectric material doesn't adequately reflect the pulse, resulting in inaccurate readings. Some advanced meter designs can overcome this issue.

This lack of complete reflection can be capitalized on to provide interface measurement in tanks containing two liquids with different dielectric properties. That makes it possible to measure both total level and the interface with a single meter.

Emulsion layers create an indistinct boundary between atmosphere and liquid, making GWR a poor

choice in these applications. However, instruments supported with appropriate algorithms can overcome some of these challenges.

Unlike laser meters, which simply assess the speed of the beam return, GWR meters actually assess both the speed and the waveform of the reflected signal. The signal must therefore be properly tuned during commissioning to ensure accuracy.

Advantages

- Unaffected by changes in pressure, temperature, density, conductivity, etc.
- Contact type
- No moving parts
- Unaffected by dense fog, dust or steam, and by high pressure or temperature
- No beam-angle issue: Works even with difficult tank geometry or interfering obstacles
- Can be used with liquids, sludges, slurries, and some solids

Limitations

- Commissioning requires special expertise
- Sensitive to build-up on the probe
- Challenging to measure interface with emulsion/rag layer



Magnetic level gauge (MLG)

Aside from putting a graduated stick in the top of a tank to measure fluid level, the sight glass is probably the oldest and simplest of all level-measurement approaches. The major drawbacks to using a sight glass are safety and maintenance concerns. The MLG mimics the approach of a sight glass in a safer, more reliable way that provides a simple but powerful approach to measure liquids.

An MLG system includes a sealed float enclosing a magnetic ring housed in a non-magnetic float chamber. The float moves up and down in the tank as the liquid level rises or falls. Outside the vessel, a highly visible magnetic "shuttle" is contained in a separate, sealed glass tube. As the tank level increases and the float rises, the shuttle moves in unison. This provides a continuous, highly visible indication of liquid level.

Compared to a sight glass, this gauge has fewer potential leak points and lower maintenance. There are no tank penetrations required. While the basic design provides only local, visual indications, a transmitter can be added for remote monitoring.

Advantages

- Requires no power
- Simple design and purchasing, with piping drawings reduced to equipment specification schedules
- Often used in high temperature, high-pressure or toxic/corrosive environments.
- Longer life compared to electronic measurement techniques
- Low total cost of ownership

Limitations

- Affected by changes in specific gravity
- Movement of the in-tank float can be affected by high-viscosity or sticky liquids
- Completely customized solution, increasing purchase cost



Magnetostriuctive (MR)

This is a relatively unknown technology compared to the others discussed above, but it offers some unique benefits, including the highest accuracy (1mm) and resolution. It also provides four measurements: level, interface, temperature, and ullage.

An MR gauge can be configured in two ways.

- A probe is directly inserted in the tank with a magnetic floating ring that moves up and down on the probe. (Intrusive)
- A vertical, metal column or chamber is attached to the tank with connections at the top and bottom, configured like a sight glass but without the ability to directly view the liquid in the column. Instead, a magnetic float moves up and down in the column. The probe is positioned outside and parallel to the column. (Non-intrusive)

In both designs, the meter generates low-energy pulses of current through the probe. These pulses create a magnetic field that interacts with the float. The resulting torsional waves travel through the sensor wire at a known velocity, enabling calculation of the liquid level.

It's possible to include multiple floats, enabling measurement of both the upper level and interface

layer. Compared to other technologies, this provides superior interface measurement. The second float can be designed specifically to the application providing accuracy even with emulsions.

While the non-intrusive mount requires additional components and engineering, the payoff is both higher safety and lower maintenance, making it the most common and attractive solution.

Advantages

- Only moving part is the very low maintenance float
- Unaffected by process conditions: foam, emulsion, mist, gas layering, dust, dielectric value, temperature, etc.
- No maintenance or calibration
- Best technology for interface measurement
- Lower total cost of ownership

Limitations

- Float movement affected by high-viscosity or sticky liquids
- Length limited to 75ft (22m), less than other technologies.
- Floats designed for specific application



Making the right technology choice

This overview of level measurement provided you with a good foundation for selecting the right technology for your application. Still, it's obvious that this can be a complicated selection process. It's typically prudent to contact vendors offering these technologies to gain further insight into their specific product capabilities, measurement accuracies, pricing, etc. to ensure you have all the facts as you make your decisions.

[Click here for a pre-recorded webinar on this topic.](#)

Selecting the right level technology

Feature	Magnetostrictive (non-intrusive)	Magnetostrictive (direct mount)	Guided wave radar	Laser	Ultrasonic
Non-Intrusive/Non-contact	Yes	No	No	Non-contact	Non-contact
Fast Response Time	10 updates /second	10 updates /second	10 updates /second	2 updates /second	2 updates /second
Accuracy	± 1.27 mm	± 1.27 mm	± 2 mm	± 11 mm	± 2 mm
Simple Start-up	Yes	Yes	Know-how required	Know-how required	Yes
Simple Maintenance	Yes	Yes	Yes	Yes	Yes
Adjustable insertion depth	Non-invasive	Yes, with compression fittings	Special probe	Non-contact	Non-contact
Probe Exchangable/Cuttable	No	No	Yes	Non-contact	Non-contact
Top or Bottom Mount	Excellent	Can be done	Theoretically !	No	No
Certified for use in SIL2/3	Yes	Yes	Yes	Yes	No
Integral RTD in Sensor	Yes	Yes	No	No	No
Vessel type	Magnetostrictive (non-intrusive)	Magnetostrictive (direct mount)	Guided wave radar	Laser	Ultrasonic
Storage Vessels	Good	Good	Good	Good	Good
Process Vessels	Good	Good	Good	Consult Factory	Consult Factory
Stilling Well/EC	Excellent	Consult Factory	Excellent	Good	Consult Factory
Horizontal Cylinder	Good	Good	Good	Good	Good
Small Vessels	Excellent	Consult Factory	Consult Factory	Excellent	Good
Tall vessels	Up to 50ft	Up to 75 ft	Up to 217ft	Up to 330ft	Up to 33 ft
Tall or unusual nozzles	Consult Factory	Good	Use Coax or SW	Excellent	Consult Factory
Internal obstructions	Excellent	Consult Factory	Consult Factory	Consult Factory	Consult Factory
Process conditions	Magnetostrictive (non-intrusive)	Magnetostrictive (direct mount)	Guided wave radar	Laser	Ultrasonic
Turbulent Surface	Good	Consult Factory	Good	Good	Consult Factory
Foam	Excellent	Excellent	Good	Consult Factory	Consult Factory
Steam	Good	Good	Good	Consult Factory	Consult Factory
Vapors	Excellent	Good	Good	Consult Factory	Consult Factory
Flashing Service	Excellent	Consult Factory	Consult Factory	Consult Factory	Consult Factory
Sparging Service	Good	Consult Factory	Consult Factory	Consult Factory	Consult Factory
Slurries	N/A	Consult Factory	Good	Consult Factory	Consult Factory
High Viscosity	Consult Factory	Consult Factory	Consult Factory	Good	Good
Coating Service	Light Coatings Okay	Light Coatings Okay	Light Coatings Okay	Good	Good
Interface Applications	Excellent	Excellent	Good	N/A	N/A
Pressures Swings	Good	Good	Good	Good	Good
Temperature Swings	Good	Good	Good	Good	Consult Factory
Extreme Pressures	Vacuum to 5000	Vacuum to 2400	Vacuum to 5000	Consult Factory	Consult Factory
Extreme Temperatures	Excellent	Good	Good	Consult Factory	Consult Factory
Specific Gravity Swings	Consult Factory	Consult Factory	Excellent	Excellent	Good
Dielectric Swings	Good	Good	Good	Good	Good
Vibration	Good	Good	Good	Good	Consult Factory
With Agitators	Consult Factory	Consult Factory	Good	Good	Consult Factory
Sump	Consult Factory	Good	Good	Excellent	Excellent