LEVELLING UP

Julian Yeo, United Electric Controls, and Dr. Parimal Joshi, Potence Controls Pvt Ltd, discuss the role of pressure instrumentation in providing accurate and dependable level measurement in tank storage and terminal environments.

Reliable level measurement is critical in bulk liquid storage facilities. Ineffective or inaccurate measurement can lead to inventory mismanagement, product miscalculations and losses, environmental violations, or even hazardous overfills. Various level measurement technologies exist in the industry today such as radar, ultrasonic, guided wave, and pressure-based methods. While radar and ultrasonic systems are often the default choice for non-contact applications, pressure-based sensors remain essential due to their robustness, cost-effectiveness, and consistent performance across a range of tank configurations. This article focuses on the role of pressure instrumentation in providing accurate and dependable level measurement in tank storage and terminal environments. It will also examine advantages and disadvantages of pressure-based level measurement and review how pressure sensors can be effectively applied to augment level control capabilities.

Types of level measurement technologies

There are different types of level measurement technologies. Depending on application, one type may be more suited over the other. Facilities often deploy diverse level measurement technologies. Table 1 shows a high-level comparison of existing technologies.

Pressure-based level measurement

The principle of pressure-based level control in tank storage applications relies on the relationship between the hydrostatic pressure at the bottom of a liquid column and the height (level) of the liquid.

Hydrostatic pressure principle

The concept is that the pressure at the bottom of a tank is directly proportional to the height of the liquid above it.

Formula: $P = \rho \times g \times h$, where P = pressure at the sensor, ρ = density of the liquid (kg/m^3), g = acceleration due to gravity (9.81 m/s^2), and h = height of the liquid (m).

By measuring the pressure at the bottom of the tank and knowing the density of the liquid, the level h can be calculated. This is suitable for open tanks.

Differential pressure principle

This is a variation of the hydrostatic pressure principle that measures the difference between pressure at the bottom of the tank and at the top (vapour space). This compensates for pressure exerted by vapour above the liquid in pressurised or closed tanks.

Formula: $\Delta P = P_{bottom} - P_{top} = \rho \times g \times h$, where ΔP = differential pressure between bottom and top of tank, ρ = density of the liquid (kg/m^3), g = acceleration due to gravity (9.81 m/s^2), and h = height of the liquid (m).

The high pressure side of the differential pressure instrument is connected to the bottom of the tank while the low pressure side is connected to the top of the tank. The difference in pressure is solely due to the liquid column as the vapour pressure is accounted for. The level h can be calculated since the density of the liquid is known.

Certain compensations on the instruments are necessary to account for changes, such as liquid density due to temperature or composition changes. Users must also keep all units consistent in order for the formula to be valid.

Advantages and limitations

There are several advantages to pressure-based level measurement:

- Cost-effectiveness: pressure-based instruments are generally lower cost than radar or guided wave radar technologies. This is the case especially for simple, large tank applications.
- Robust and reliable: pressure-based sensors are not affected by dust, foam, or condensation, which would otherwise affect non-contact sensors.
- Simple to install and maintain: easy to retrofit into existing tanks with threaded or flanged ports.
- Works with irregular tank shapes: tank shape does not affect hydrostatic pressure. Pressure-based instrumentation is not dependent on reflection or signal path and can thus be used in non-standard tank geometries.

On the other side, there are also limitations to pressure-based level measurement:

- Density dependent: the formula for hydrostatic pressure measurement is dependent on fluid density. This means that level measurement accuracy has to be compensated for, especially when there are temperature or composition changes. That means that calculations may not be straight forward.
- Risk of clogging and fouling: for pressure-based level measurement to work, the media has to be in contact with the pressure sensor. If the impulse line or pressure connection is clogged with sludge or particulates, the reading on the pressure sensor will be inaccurate. This also adds to additional maintenance efforts.

Pressure-based level measurement is cost-effective and easy to install but may require careful consideration of process conditions or extra device maintenance to prevent risk

Table 1. Comparison between types of level measurement technologies

Technology	Accuracy	Contact/ non-contact	Cost	Maintenance	Density/ temperature sensitvity	Use case
Float-based	Low-moderate	Contact	Low	Medium-high	High	Backup, visual indication
Capacitance/ conductive	Moderate	Contact	Low-medium	Medium	Medium-high	Small tanks, clean stable media
Ultrasonic	Moderate	Non-contact	Low-medium	Medium	Medium-high	Water tanks, open top tanks
Hydrostatic pressure	Moderate	Contact	Low	Low	High	General-purpose liquid tanks
Radar (non-contact)	High	Non-contact	High	Low	Low	Tall, volatile, or corrosive tanks
Guided wave radar	High	Contact	High	Low	Low	Tall tanks, foaming/ liquid-vapour mix

of clogging. There is no perfect technology, and the user needs to balance the considerations at hand.

Case study

A client in the midstream oil and gas industry operates a terminal in Asia with many cylindrical aboveground storage tanks. The site previously relied on ultrasonic sensors for level monitoring but started to face several challenges leading to frequent alarms. The challenges included:

- Inaccurate level readings from vapour interference and foam.
- High maintenance on ultrasonic sensors from condensation build-up.
- Risk of overfill and spills.
- Lack of instrumentation diversity, as ultrasonic devices were often offline during cleaning cycles.

Solution

The client's engineering team added pressure instrumentation to the mix of level control technologies. In some tanks, the user installed United Electric Controls' (UE) HART-enabled differential pressure (DP) hybrid transmitters (316 stainless steel diaphragm) and configured it for hydrostatic level measurement. These hybrid transmitters have an inbuilt relay that allows for local alarming.

As these were closed tanks, the high pressure side of the DP devices was connected to the bottom of the tank while the low pressure side was connected to top of the tank. Resistance temperature detectors (RTDs) were installed so that temperature compensation can be made to account for density changes.

With the implementation of the DP devices, there was better accuracy of level measurement and control because the instruments were unaffected by conditions such as foam and vapour. There were no maintenance issues arising from condensation build-up. These hybrid transmitters were able to provide an analogue output so that level measurement could be trended. More importantly, because of the integrated relay, early warning alarms could be triggered locally without the need for a programmable logic controller (PLC). This helped to reduce risk of an overfill situation and streamlined inventory for intermediary devices like PLCs.

Conclusion

Pressure-based measurement is a cost-effective method for level control and there are advantages and limitations to this technology. Users who know how to deploy diverse instrumentation technologies create enhanced capabilities for level measurement and control because they know how to capitalise on the unique advantages offered by various technologies. In some cases, like the midstream application outlined in this article, the client's augmentation of pressure instrumentation enabled it to achieve enhanced operational accuracy, reduce maintenance requirements, and improve safety with less likelihood of a hazardous tank overfill. T&T