Intelligent Buoyancy Level Measurement, Part 1:

Rethinking the Design of High-Precision, Buoyancy Level Measurement Instruments

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Introduction

How next-generation design innovations can advance the capability and accuracy of a vital class of process measurement instruments

It is no surprise that capable managers and skilled personnel find ways to maximize the performance of measurement instruments despite their inherent limitations. But not even the best of them can overcome the most basic limitation of a traditional buoyancy level measurement transmitter.

The basic technology of buoyancy level measurement dates from the ancients, when Archimedes of Syracuse observed that "any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object."

Buoyancy level measurement remains crucial to the management of fluids in a range of process industries—oil, petrochemicals, chemicals, and more—because it offers a precise means of measurement that is *unaffected by key process variables* like fluid pressure and temperature. Yet, these *variables* are the factors on which most other methods of level measurement depend. Take hydrostatic level measurement, for example. The accuracy of hydrostatic level measures are reduced due to the influence of increased pressure. A similar influence can result at high temperatures, which can change the density of fluids being measured.

Another common form of level measurement utilizes radar or ultrasonic waves. This form of measurement literally bounces electronic or sound waves from a sending unit down through a vessel to the surface of the measured fluid, which reflects the waves back for measurement. The degree of reflection for each fluid depends on its dielectric constant—a measure of the free electrons available in the molecules of that fluid. When single fluids, or fluids with widely varied dielectric constants, are being measured, the differing reflections show the fluid interfaces, or levels, clearly.

However, achieving precise level measurement using radar or ultrasonic methods can be much more difficult when measuring the interfaces of two fluids with similar dielectric constants within the same vessel. These include two of the most common constituents of petroleum and petrochemical processes: oil and water. As a result, obtaining radar and ultrasonic level measurements can be problematic, often requiring additional time during which the fluids can more thoroughly separate into layers. But even then, a very shallow layer of oil atop a layer of water can be extremely difficult to detect. This is where buoyancy interface measurements can come into play.

Why buoyancy level measurement is different

Unlike these other fluid measurement technologies, buoyancy level measurement is a measure of force—buoyancy. For a particular fluid, buoyancy remains consistent based on the density of the fluid despite process changes that may affect process and fluid temperature or pressure.

Typically, buoyancy level measurement instruments employ a displacer, suspended in a tube or directly into the vessel and the fluid. Displacers can be vertically suspended from measurement sensors in top-mounted configurations, or linked by way of a horizontal torque arm/torque tube assembly when the sensor is side-mounted.

As the liquid level in the vessel changes, the buoyancy force on the displacer changes, resulting in a change to the "apparent" weight of the displacer. In traditional buoyancy level transmitters, the change in weight is captured indirectly in the form of distance (via mechanical or rotational movement), or in the form of voltage changes related to the movement of elements within linear-displacement or Hall-Effects sensors.

As a technology, traditional buoyancy level transmitters are well proven. But, their accuracy and ultimately, their efficiencies of operation are limited by several factors. The first is their reliance on mechanical linkages and moving parts. These introduce immediate concerns about hysteresis. Longer term, the need to adjust traditional buoyancy level transmitters to compensate for the wear of moving parts makes the time and effort of repeated calibration a necessity.

These instruments cannot directly measure liquid levels and interfaces. What they do is to capture a secondary indicator of buoyancy force change—namely, motion—then calculate what the proportional change in the fluid level should be.

But what if there were a more accurate way to do a buoyancy level measurement? What if there were a technology available that could directly measure buoyancy force change—and do it with greater accuracy and repeatability? What if this technology could eliminate the moving parts that cause hysteresis and add to the costly challenges of maintenance and periodic calibration?

Rethinking the measurement challenge

Several years ago, engineers at Foxboro were asking these questions. And, in time, they devised a new answer, resulting in the first really new technical solution to the problems of buoyancy level measurement in a long, long time. The questions that they asked, and the answers that they found, clustered around a number of big ideas:

- Measuring buoyancy force directly, with precision
- Eliminating hysteresis
- Ensuring repeatability
- Reducing ownership costs, from selection and commissioning to long-term operation

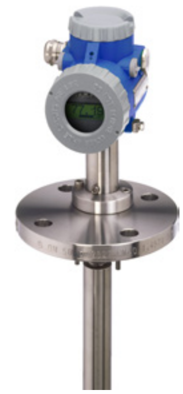
The solution they developed, like the buoyancy principle first proposed by Archimedes, proved to be simple. And today, this solution is found in the latest line of buoyancy level measurement devices from Foxboro—a collection of devices trade-named LevelStar™.

Like traditional buoyancy level measurement transmitters, the new LevelStar devices start with a displacer element whose length is suited to the distance being measured, made of materials that are appropriate for use with the liquid. But that's where the similarity with traditional devices ends. The LevelStar design eliminates mechanical linkages and moving parts, along with associated hysteresis, by linking the displacer directly to a custom-designed force sensor, housed in a load cell.

The unique load cell design of the LevelStar captures precise buoyancy level measurement for even the tallest vessel given maximum movement of about 30 microns (0.03 mm), or about half the width of a human hair. Thus, for all practical purposes, the LevelStar design accomplishes direct buoyancy level measurement without the use of moving parts. The design eliminates virtually every element of mechanical linkage that could contribute to hysteresis in measurement.

But the benefits of this direct-measurement approach go further. The innovative LevelStar design also enables a fundamentally more accurate measurement: 0.2% of full span, a far more precise measurement of liquids than the 0.5% accuracy typical of traditional devices. Thus, the LevelStar device can identify liquid units in minimum quantities that are essentially invisible to inherently less accurate instruments.

This precision extends to interface measurement and density measurement as well. Precise interface measurement is possible with the LevelStar instrument because it directly measures the buoyancy force difference between the two liquids in which the displacer is fully immersed. This makes it one of the rare buoyancy transmitters that can be considered suitable for accurate and reliable process interface measurement. The same design lends itself to precise density measurement when the precision-made displacer is fully immersed in a single-phase liquid.



The absence of moving metal parts and complex linkages in the LevelStar instrument makes the process of measurement more repeatable over a wide range of temperatures, since even minute variances in the behavior of linked components due to temperature or pressure changes are eliminated. A high-temperature variant of the LevelStar product, the 244LD, can provide precise and repeatable level measurement at pressures from vacuum to 500 bar (7,250 psi) and at temperatures from –196°C to 500°C (–320°F to 932°F), ranges far beyond the capability of traditional buoyancy level measurement devices.

In operational and cost terms, the expanded operating range, together with the improved accuracy, performance, and repeatability of this technology, can pay big dividends by dramatically reducing or eliminating the need for personnel to access, maintain, or recalibrate level measurement instruments in processes that involve dangerous substances or extreme operating conditions.

To meet a range of application and operating needs, the LevelStar instruments may be installed on top of a vessel or in a side-mounted displacer chamber. Displacer chamber configurations include top, bottom, or side mounts, while transmitters may be either flange or sandwich-mounted. A full range of displacer sizes and wetted materials are also available.

Conclusion

The next generation of intelligent buoyancy level measurement devices set new standards for accuracy, repeatability, and cost-effectiveness, but not by changing any of the fundamental requirements of buoyancy level measurement. Instead, these devices, typified by the Foxboro LevelStar, leverage the capabilities of advanced sensor design with the power of software-driven configuration and diagnostic tools to redefine the challenges of buoyancy level measurement and to meet them in a fundamentally simpler, more elegant, and far easier-to-manage way.

The simple, direct-measurement design of LevelStar instruments eliminates virtually all of the complexity, variability, and motion associated with the mechanical linkages of traditional buoyancy level instruments while improving not only repeatability, but also accuracy from a typical 0.5% to 0.2% or better of full span measurement.

Learn more about Foxboro buoyancy level sensors and software-based tools by visiting our website.

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