

Fundamentals of hydrostatic level measurement

A guide to the most important level measurement technology



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The user of industrial level measurement sensors finds himself exposed to an almost unmanageable number of measurement principles and alternative products in the instrumentation for level measurement. For many years, hydrostatic pressure measurement has been the most important measuring principle in continuous level measurement. This trade article presents the fundamentals of hydrostatic level measurement in a practical and understandable format.

The importance of hydrostatic level measurement

In continuous level measurement, hydrostatic pressure (also known as hydrostatic level measurement) is the principal sensor technology and measuring principle, with a market share of approximately 40 %¹ by sales volume. Still considerably ahead of ultrasound and radar technologies, hydrostatic sensors for level measurement are installed in more than every second measuring point. Thus, the immense importance of this technology is reflected in its steady growth from US\$ 650m in the pre-crisis year of 2008, to around US\$ 770m in 2013¹.

What is meant by hydrostatics?

Hydrostatic pressure sensors are used for the measurement of level or filling height of a liquid. Hydrostatic pressure measurement is suited for level measurement due to the hydrostatic effect of non-flowing fluids. This physical principle describes the effect of the weight force of a stationary, meaning non-flowing, liquid on a measuring point. This weight force is usually described as "hydrostatic pressure".

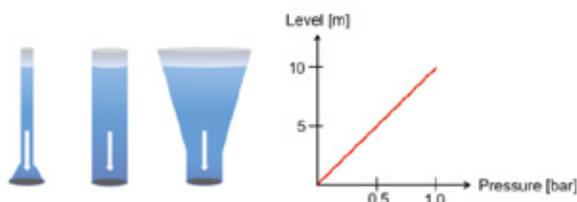


Figure 1: Illustration of the hydrostatic paradox

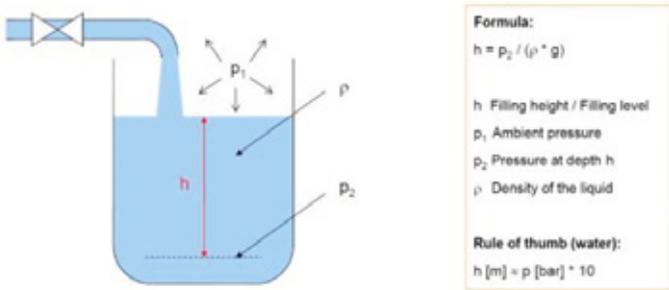
The most important condition for hydrostatic level measurement is what is called the "hydrostatic paradox". This means that, regardless of the shape and volume of a vessel, the hydrostatic pressure at the measuring point of a tank or vessel is proportional only to the filling height (Fig. 1).

Level measurement in open, vented vessels

In hydrostatic level measurement in open or vented basins or vessels, a continuous pressure compensation of the ambient air with the gas phase above the liquid takes place. Thus the ambient pressure that acts on the medium as an additional "force" always resembles the ambient pressure acting on the whole system, including the level sensor. If one therefore uses a pressure sensor with a relative pressure measuring cell, a pressure sensor that is compensated or vented (just like the tank) to the ambient pressure, it "automatically" compensates for the effect of this ambient pressure on the level measurement. This means that a relative pressure sensor in vented vessels and tanks completely "cancels out" the atmospheric pressure overlying on the liquid from the level measurement. Thus, the hydrostatic pressure corresponds only to the filling height of the liquid (Fig. 2).

Level measurement in sealed, gas-tight vessels

The level measurement in sealed, gas-tight vessels, which is frequently found in the chemical industry, requires a compensation of the pressure of the enclosed gas phase above the liquid. The enclosed pressure of the gas phase acts as an additional force on the liquid and distorts any hydrostatic pressure measurement at the base of the vessel. Thus, this distorting influence must be compensated through an additional pressure measurement of the gas phase. Frequently, a second pressure sensor is used for the measurement of the gas pressure. This application effectively represents a differential pressure measurement, where the two separate pressure measurements are offset against each other (Fig. 3). This offset calculation can be made either by two individual sensors or via an integrated differential pressure sensor. In this application, the sensors



Formula:
 $h = p_2 / (\rho \cdot g)$

h Filling height / Filling level
 p_1 Ambient pressure
 p_2 Pressure at depth h
 ρ Density of the liquid

Rule of thumb (water):
 $h [m] = p [\text{bar}] \cdot 10$

Figure 2: Level measurement in open, vented tanks and vessels

used can either be relative (sensor with ambient pressure compensation) or absolute pressure variants (sensor with sealed vacuum reference).

Types of hydrostatic level sensors

In hydrostatic level measurement, one can differentiate three types or designs of level sensors: conventional pressure transmitters, process pressure transmitters and submersible pressure transmitters, available in relative, absolute and differential pressure variants. For application in tanks and free-standing vessels, conventional pressure transmitters or process pressure transmitters are particularly suitable, either with a conventional pressure port or a flush diaphragm design.

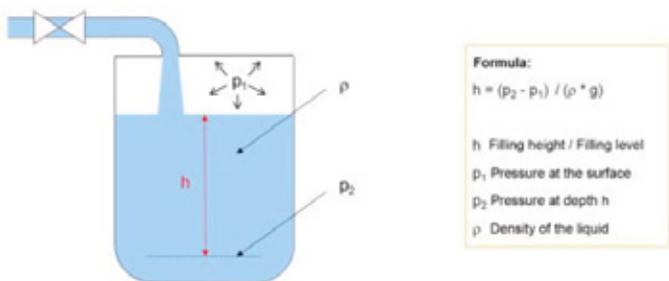
Specifically in the water and wastewater industry, submersible pressure transmitters ('level probes' or 'submersible probes') are frequently used to measure the level in reservoirs, wells or other open bodies of water (Fig. 4). Submersible pressure transmitters are specifically designed to operate while continuously submerged in liquids. They mainly differ from conventional pressure sensors in their media resistance, pressure tightness, cable quality and ingress protection.

Advantages and limitations of hydrostatic level measurement

Hydrostatic pressure and level measurement enjoys a consistently high popularity due to its high robustness, high reliability and simple installation of this technology. The following characteristics constitute the greatest advantages and limitations over other measuring principles:

Advantages:

- Proven and established measuring principle with high reliability, field-tested millions of times
- Robust measuring process, uninfluenced by disruptive factors such as dust, foam, vapour, buildup, contaminants, etc.
- Reliable measurement unaffected by many physical characteristics such as conductivity, dielectric coefficient or viscosity
- Level measurement unaffected by vessel geometry and existing installed equipment



Formula:
 $h = (p_2 - p_1) / (\rho \cdot g)$

h Filling height / Filling level
 p_1 Pressure at the surface
 p_2 Pressure at depth h
 ρ Density of the liquid

Figure 3: Level measurement in sealed, gas-tight tanks and vessels



Figure 4: Product, WIKA LH-20: Design – submersible pressure transmitter

- Simple installation and operation of submersible pressure transmitters and conventional pressure sensors without the need for calibration or adjustment
- Direct contact with the medium
- Numerous alternative design variations and sensor technologies for almost every application

Limitations:

- Unsuitable for bulk material
- Accurate measurement requires either media with constant density or continuous density measurement of the medium

Hydrostatic level measurement in practice

The great popularity of hydrostatic sensors lies in their simple application, a low susceptibility to problems from installation through to their continuous operation, their high tolerance to disturbances and the suitability of the technology for almost all application conditions. Nevertheless, it is also important here to avoid a few pitfalls in order to use this measuring method effectively and safely for level measurement.

The influence of temperature, especially its influence on the density of the specific medium, must always be incorporated into the calculation of the level for a correct level measurement. An increase in the process temperature may lead to a lower density of the medium and a correspondingly increasing level, however, not always in the same proportion as the increase in the hydrostatic pressure. This leads to an inaccuracy in the calculation, e.g. to a lower reading of the level. Therefore, various pressure sensors with additional, integrated temperature sensors, are available which enable the measurement of the medium temperature for density compensation.

The medium and its characteristics, in particular its viscosity and solids content, will decide between using a pressure sensor with a traditional design with pressure port or one with a flush diaphragm.

A pressure sensor with a pressure port should always be used when the medium has a low viscosity and is free from coarse-grained contaminants. However, if a medium has a tendency to build-up, is highly viscous or contains a lot of particulates, then one should select a sensor with a flush diaphragm. In contrast to a flush diaphragm sensor, a sensor with a pressure port can become blocked or the media in it can harden or crystallise. Submersible pressure transmitters (Fig. 4), as a specific design variant of a pressure transmitter, are used in contaminated media, such as wastewater, as well as in clean media, such as fuel or groundwater.

Outlook

Hydrostatic level measurement technology has, in recent years, gained an exceptional market importance as a result of its simple and easily understood usage. Through its high durability and its tolerance to a large number of disturbances and unsteady process conditions, this technology will, for the foreseeable future, maintain its status as the most important sensor technology principle for level measurement.

Please find further information on the information platform www.wika.com/hydrostatic-level

Source:

1. VDC Research Group, Inc.: What's driving the process level measurement & inventory tank gauging markets, 2011