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Sensors & Controls

Level sensor technologies - an overview.

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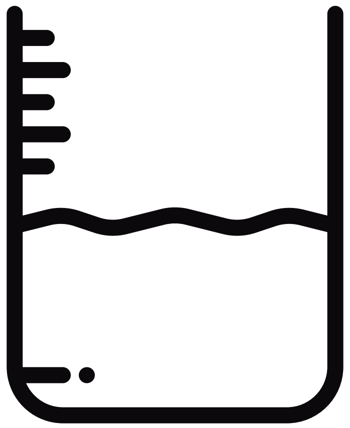
1. Level measurement. How hard can it be?



In the level measurement chapter of the Instrument Engineers Handbook, there are 22 technologies described with numerous variations of each. In this White Paper we will only be presenting an edited overview of those technologies, primarily for the process, water and wastewater industries.

There are few things as ubiquitous in process control as measuring the levels of process materials. Whatever the material, liquid or solid, level measurement accuracy can be a determining factor in safety, regulatory compliance, operational efficiency and profit margins.

With so many options, it can be daunting selecting the correct level measurement technique for a particular application. To specify the appropriate method – or methods - it is important to understand the fundamentals behind each technology and how their advantages and disadvantages inter-relate with the characteristics of the process material, such as density, capacitance and temperature, for example.

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2. Back to basics

The first step in identifying the right technology for your applications are categorising them into two broad groups – contact and non-contact. Then break it down further by the types of material they can measure.

To determine whether contact or non-contact is the correct method, the nature of the measured material– such as available power, pressure, temperature, container geometry and materials, agitation levels – must be taken into account.

Is it corrosive or tacky, possibly damaging the measurement device? What is the installed environment and variations within it? With volatile materials would a contact sensor create a safety hazard? Could the process attributes – temperature, pressure or agitation, for example – affect the reading or damage the sensor?

Non-contact technologies may exceed the financial constraints of the project or not provide the level of precision necessary.

Whole life cost is also a consideration. It is a fact of our economic lives that nearly every capital budget is divorced from the maintenance budget. Downtime cost resulting from a low cost or misapplied sensor is generally not factored into project purchasing decisions.

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3. Getting to know you

The materials in process control can be classified as liquids, granular solids, slurries and interfaces.

The types of level sensor used with liquids are influenced by density variation, processed under a wide array of temperatures and pressure.

Interface level, the point at which liquids of different densities meet – water and sludge, for example - requires special consideration beyond typical level measurement.

Many of the technologies for liquid measurement will be unusable or onerous for measuring granular solids. Slurries pose specific challenges with suspended solids content and higher viscosities.

For all of these points and many more not covered, understand the material to be measured at all process stages, when narrowing down technologies optimised for your application.

As previously mentioned, the number of technolog options means this is an overview, providing a high level summary of some available technologies and how each one fares as a measurement device.

For more in-depth information, look at manufacturer's websites. The objective here is to give a head start in conducting your measurement search.

So let's make a start with contact measurement and the simplest – the level sight gauge.

4. Level Sight Gauge

Typically a tube connected to openings at the top and bottom of a container it has, as a minimum, a transparent face for the operator to see the level of process material. Technically, this is non-contact measurement as no sensor is contacting the material.

The level sight gauge is possibly the most trustworthy method of measurement - because the level can be seen by operators and engineers.

Because of potential damage or obscuration of the viewing area or markings, many of the concerns of contact sensors – agitation, corrosiveness, tackiness, temperature, pressure, etc. – should be considered. Additionally, pressure or temperature differentials between tank and viewing window can affect accuracy.

If using a sight glass to measure interface level, remember that the top opening point must be submerged at the top liquid level and the lower opening at the level of the denser liquid, or you will get an incorrect level measurement.

Perhaps an obvious point, but a sight gauge can only be used with liquids, as slurries and granules do not move fluidly. Also, if you want automation with your level measurement, then a sight glass is not suitable.

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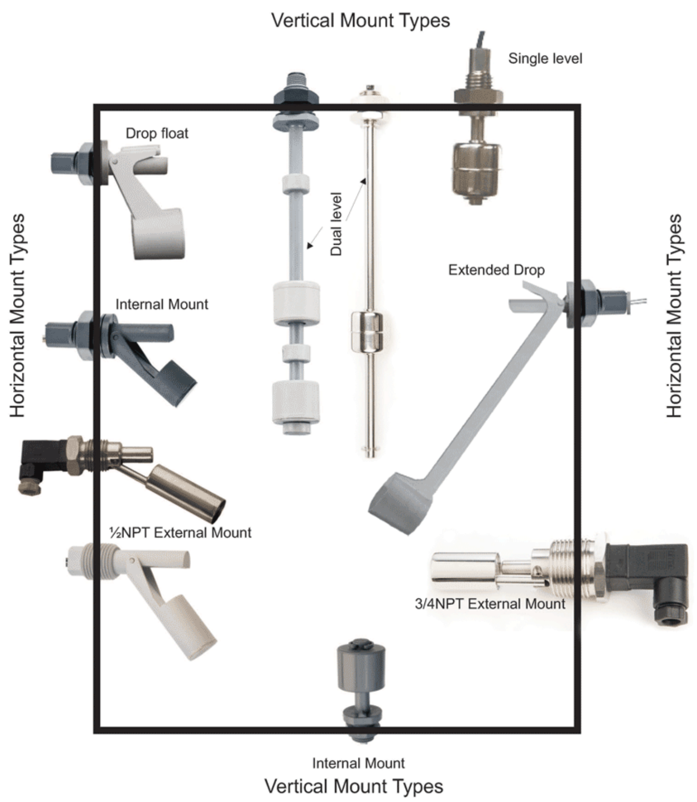
5. Float Sensors



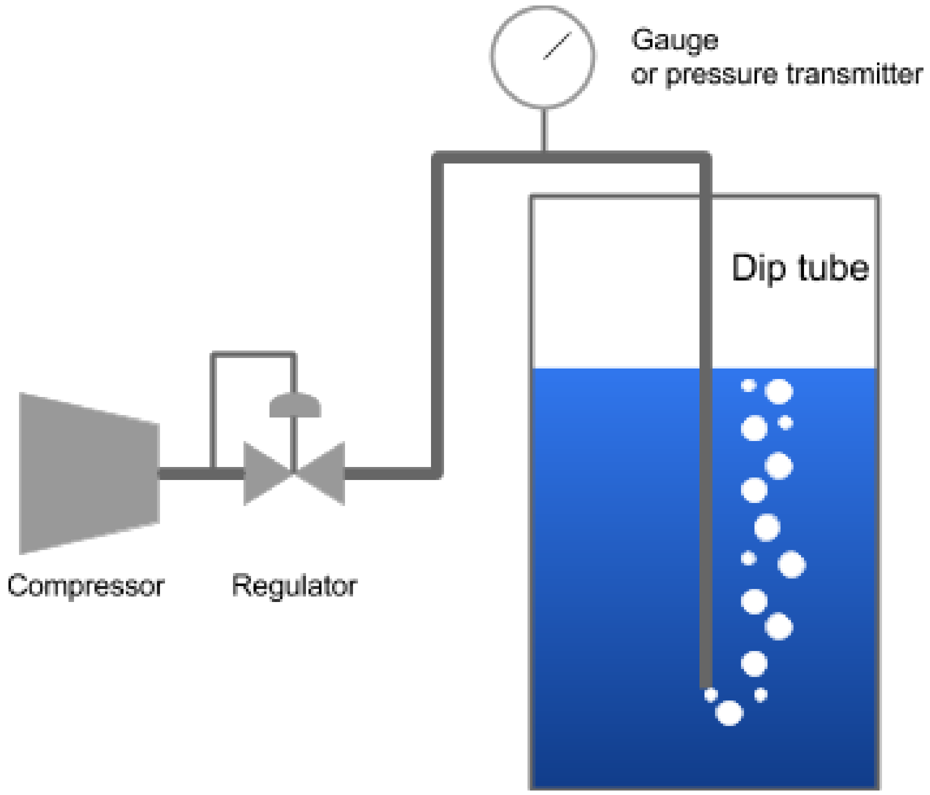
This can be a device that relies on the material's specific gravity to raise and lower a float, measuring the level. Often used in a gauge similar to sight glasses, they can have a rod projecting from the top of the float that has a pointer on the end, reporting against a gauge board or tripping high or low level switches.

Magnetic floats use reed relays placed lengthwise inside a guide tube. When the float passes, the magnetic field trips the relays giving a level indication. Accuracy of these sensors is determined by the number of reed relays inside the guide tube.

Cable float switches have a buoyant, sealed chamber suspended on a cable. As the level rises the chamber tilts and triggers a switch; other types of float sensor use a pivot, just like a ball cock. Both give a point level switch output, although cable float switches can offer up to four switch points in one device.

Float devices are simple to understand, relatively low-cost and can measure large level ranges. They can be susceptible to wear, corrosion or contamination build-up which leads to the float jamming or clinging. Regular cleaning is required to alleviate this.

6. Bubble Tubes



Bubbler-type level detection has been used since compressed air became available and operates like blowing air into a glass of water with a straw. The more water there is - the harder you need to blow.

Bubble tubes rely on the specific gravity of the material. A tube is submerged into the fluid and air or nitrogen is pumped through the opening, near the bottom of the tank. The resulting back pressure is proportional to the liquid level and density.

If it is impractical to submerge a tube, air can be pumped in through a port on the side of the tank, which makes access and mechanical support easier, as well as mechanically cleaning accumulated deposits.

Simple, inexpensive and flexible, the bubbler tube is unaffected by foaming and variations in the pressure or composition of vapour above the liquid. However, if processes change the density of the liquid – bubble formation or boiling, for example – this results in 'understated' level outputs, as drops in density reduces the hydrostatic head.

Only used for measuring liquids – although they tackle more difficult fluids such as tars - the bubbler tube is often installed as an inexpensive overflow back-up, or if other level sensors could fail to function properly. A dependable and consistent air or gas supply is essential for reliable operation and the open end of the tube can become blocked, necessitating regular cleaning.

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7. Capacitance Sensors

A powerful method of level detection is Capacitance, which uses the same principle as electronic capacitors, to measure the level of liquids, granules and liquid-liquid interfaces. Consisting of two conductive metal plates separated by insulating material, capacitance is the measurement of the amount of energy a capacitor can store.

By using a method very similar to that of electronic capacitors, the capacitance of a process material can be measured which corresponds to the level of material.

When measuring a non-conductive material it is used as the insulator part of the capacitor; the tank wall acts as the second conductor plate. For conductive materials, the probe body is insulated and the material acts as the other conductive plate.

In either case, a rise in the level of material corresponds with increases in the measured capacitance – over that of air. Capacitance technology can be used for continuous measurements or point-level measurement switches.

With the solid, no-moving parts construction, there is little to deteriorate or fail. Material compatibility is the most obvious obstacle to satisfactory life spans, along with probe failure in heavily agitated tanks.

Fatigue failure from eddies exerting rapidly alternating loads on the probe can be overcome by a support with an insulated bush near the tip of the sensor probe. Consideration must be given to coating build-up around the support giving rise to errors.

With particularly abrasive materials, consider if the probe material itself, or its coating, is sufficiently abrasion resistant to take advantage of the prolonged service life offered by this technology.

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8. Resistance Tape

Invented in the early 1960's for continuous liquid level measurement, Resistance Tape uses the mechanical force of the liquid to measure level.

A flat, coilable strip up to 30 metres in length, it is suspended from the top the tank, with a cross section small enough to be held within a perforated pipe, which supports the sensor and acts as a stilling pipe in turbulent processes.

Two wires, one attached to a voltage source and one to a precision resistor, are enclosed in a shielded, flexible sleeve. Hydrostatic pressure on the sleeve shorts out the submerged length of tape, generating a change of resistance which equates to the level.

Although delicate, resistance tapes measure liquid and slurry levels with one moving part. This movement is caused by the liquid, providing a stable resistance output independent of most liquid properties.

Suitable in liquid storage tanks, sumps and streams if the pressure is near atmospheric and the temperature is near ambient, it is compatible with corrosive and slurry type materials.

Because of limitations caused by actuation depth variation, pressure equalisation and dryer maintenance, they should be chosen with care and selectivity.

So far we have been looking at contact sensor technologies. Now we come to a technology that bridges between contact and non-contact – Ultrasonic.

To finish with contact sensors, let's first consider contacting ultrasonic.

9. Contacting Ultrasonic

Typically point level switches, working on the principle of the sensor vibrating at its resonant frequency when not submerged in process material. When the frequency becomes dampened, the material has reached sensor level providing an accurate point level measurement.

This works with liquids, slurries and granules, although be aware of coating of the probe and corrosion. Some sensors are like a tuning fork; if used with granules or materials which includes large solid particles, then 'bridging' may take place between the two fork tines which affects the sensors functionality.

Similarly, if the sensor probe is installed under a tank fill point, it is possible for process material to deposit on the probe, providing false measurements. Deflectors can be installed above the probe element. Some probes are shaped to prevent this along with the 'tuning fork' design to remove the bridging problem.

Probably most people are more familiar with ultrasonics as a non-contact sensor, which is what we will now look at.

10. Ultrasonic

Put simply, ultrasonics transmit sound waves and use the time-of-flight principle to determine the distance of a surface from the sensor, from which a level can be derived.

The primary advantage of ultrasonic transmitters is elimination of moving parts and measuring the level without contacting the process material. In some specialised variations, tank penetration can also be avoided.

Measurement reliability is unaffected by changes in the process material composition, density, moisture content, electrical conductivity and dielectric constant. With temperature compensation and automatic self-calibration, readings can be accurate to within 0.25% of full scale.

Limitations are that an ultrasonic sensor is only as good as the echo it receives. The echo can be weakened as a result of dispersion and absorption. The strength of the echo will reduce further if the tank is tall, the vapour space is dusty, or if it contains foam or other sound absorbing materials such as water vapours or mists.

In addition to weak echoes, another problem is the reflective property and density of the process surface. If it is sound absorbing, sloping or irregular – causing a diffused reflection of the ultrasonic pulse – the result can be an error, as the time of flight may not equate to the vertical distance between transmitter and process material.

Speed of sound is also temperature dependant, so unless the sensor can measure and compensate for temperature variation – particularly important in open to environment installations- then performance variations could occur. Condensation, dust build-up and additional objects within the tank can also cause measurement unreliability.

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11. Radar

Similar to ultrasonic is Radar, which also uses time-of-flight for level measurement but uses the speed of light rather than speed of sound. Radar sensors can be non-contact and, through the use of a probe acting as a waveguide, a contact sensor.

Radar works by transmitting electromagnetic pulses onto a surface and measuring the time it takes for those pulses to bounce off and return. Just like ultrasonic, a level is calculated as the product of one-half the time-of-flight and the speed of light.

As a non-contact sensor, radar has the advantage of being unaffected by the process materials condition – such as agitation, corrosiveness, tackiness, temperature, pressure, etc. - and used to measure liquids, slurries and granular solids.

Materials with high conductivity tend to be better suited for radar measurement because they reflect more of the radio signal. Conductive fittings within a tank, such as agitators, can cause interference with the radar signal.

The latest generation of sensor has a very narrow radar beam cone, down to 6°, which makes it easier to align the beam without getting interference from other equipment within the tank.

There is no ideal measurement technology. In a perfect world, all measurement would be non-contact and even non-invasive. Non-contact radar comes close, but it does have some weaknesses that can be overcome by using contact radar.

12. Load Cells

Normally used to measure weight they can be used to determine a tank level.

Attached to the support structure, they measure the downwards force from the weight of the vessel above. By subtracting the empty tank weight from the measurement, and assuming the tank has straight sides, changes in the measured weight correlates with a change in level.

Being located externally, they can be used to measure solid or liquid, but do require the material to be a consistent density. Diaphragm detectors work on a similar principle, except that the force exerted by the process material is detected against a diaphragm.

The essential difference is diaphragm detectors contact with the process material and are located at the bottom of the tank where sludge and deposits can accumulate. This means if the diaphragm face becomes coated or blocked, it requires a full drain-down to remove the sensor for cleaning.

However, their relative simplicity and lack of moving parts offers reliable measurement. They can often be seen installed as a back-up to other sensor technologies.

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13. Radiation Sensors

Radiation level sensors use radioactive isotopes to transmit gamma radiation into and through a tank to receiving sensors on the other side, measuring the attenuation of that radiation.

When Isotope atoms decay, they emit three different types of radiation which can be picked up and measured by special sensors. For level measurement, Gamma radiation is used, being best at penetrating materials.

It can be used for both point and continuous level measurement.

In point applications – such as high and low level alarms – a receiving sensor is installed parallel to the radiation source on the opposite side of the tank. Any change in frequency modulation over a pre-set threshold triggers an alarm.

For continuous measurement, sensors need to be installed along the height of the tank on the opposite side. This is because radiation is released in all directions from a radioactive source. By referencing the attenuation detected through an empty tank as datum, changes detected by a sensor are attributed to the level being at or above that sensor.

Radiation detection is appealing for hard-to-handle, toxic and corrosive processes. It does not require vessel wall penetration and is unaffected by the physical state and properties of the process material.

Costs and licensing requirements limit the number of applications and despite the improvement of alternative technologies, radiation sensors continue to solve critical process applications when other options have been exhausted.

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14. *"There's a way to do it better – find it"* Thomas A. Edison.

The technologies described above barely scratch the surface of those available to industry and engineers, not to mention variations of these technologies.

With the almost countless number of process materials and conditions in industries requiring level measurement for their processes, a virtually equal number of methods for measuring level exist. It offers a daunting number of options available to plant designers and engineers. There is certainly not a 'one sensor fits all' solution.

By understanding the limiting factors of contact and non-contact sensors, combined with knowledge of the operating principles of the more common level sensor technologies, will help when determining which technique is best suited to an application.

Because of the importance of dependable and cost effective level measurement in maintaining safe and accurate process control, new technologies and refinements are continuously coming to the market. These developments can challenge pre-conceptions of how best to measure process materials.

With such choice available to specifiers, it can be easier to stick with technologies you have experience of, accepting the shortcomings those technologies exhibit for non-optimised applications.

Following this path, will not do your operating expenditure and profits any favours. With the pressures on all organisations for higher quality and environmental standards while reducing operating expenditures to ease squeezed margins, it is essential to source the best solution for each application.

Don't worry though – you are not alone. Speak to companies that understand your needs and have the knowledge and capability to offer level sensors to answer your needs. You may need to collaborate with more than one supplier and leave your comfort zone, but that investment in time and research will be rewarded with a long-term, cost-optimised solution for dependable performance.

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