CHOICES IN AUTOMATED LEVEL DETECTION

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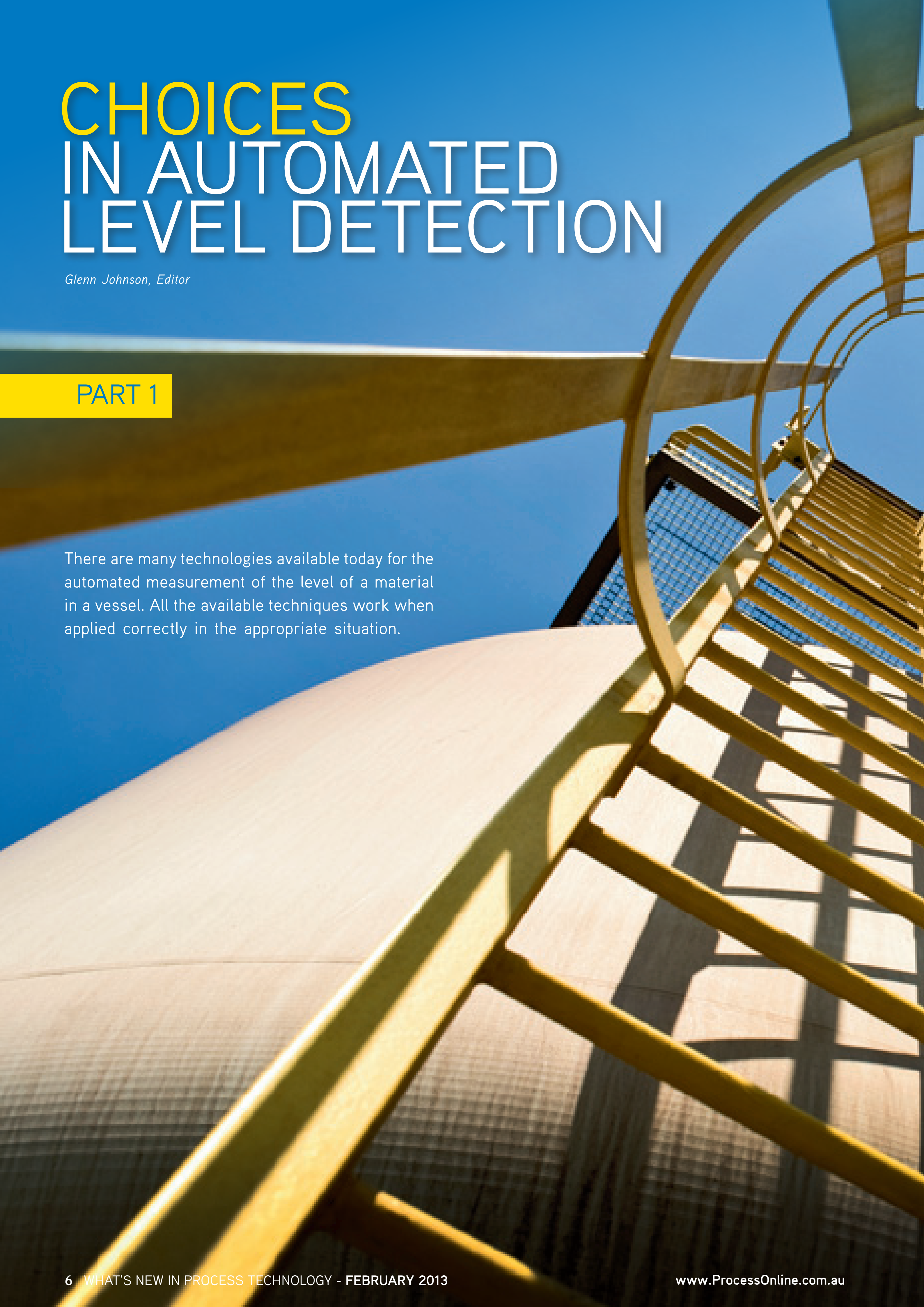

PART 1

There are many technologies available today for the automated measurement of the level of a material in a vessel. All the available techniques work when applied correctly in the appropriate situation.

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There are many level measuring situations in which virtually any measuring technology will work, but there are also many cases where some technologies will work while most others will not. Generally speaking, it is a case of the more difficult the process environment or material, the more costly and complex the level technology.

This article is an overview of those common technologies and techniques that can be considered 'automated' instrumentation. Manual level measurement gauges are not covered.

Head versus height

Level measurement techniques can be categorised into two broad categories. One is 'head measurement', which is based on the force of the process material pushing down on a measuring device, and 'height measurement', which is based on measuring the distance to the upper surface of the material.

Head measurement

For head measurement, there are two basic categories: one is the measurement of the weight of the process vessel or tank and the other is the measurement of the pressure applied by the material in the tank. Of these, measuring the weight of the vessel (usually performed with load cells under the tank supports) can give an accurate measure of how full the tank is, given that the density of the material is known - and it works for both solid and liquid measurement. The only risks of error here are electrical interference with the load cells, and vibration - the vessel needs to be shielded from vibrations, which may be transferred to the load cells, leading to spurious measurements.

Measuring the pressure exerted by the contents of the tank is generally only suitable for liquids, but there are various methods of doing so, depending on the measuring conditions and material.

Height measurement

Height measurement means measuring the distance of the top surface of the material (liquid or solid) from either the top (most common) or bottom of the vessel. Various forms of contact-based and non-contact methods are used, and some permit the detection of multiple levels simultaneously (liquid interface level measurement) where two materials of different density are present, one floating on the other. All methods have their pros and cons, and the correct method must be chosen based on the conditions of the process and the properties of the process material.

Point level versus continuous

Sometimes we want to know the fill level of a vessel at all levels, to measure the quantity of material available. In other cases we are only interested if the level falls below a certain point, perhaps to trigger refilling, or if it exceeds a certain point, to prevent overflow, or to stop a filling process. The first is called continuous level measurement and requires a method that is constantly seeking or following the top surface level of the material. The second is called point level measurement and uses instruments or sensors located at appropriate heights in the vessel that are triggered when the material level passes that point - in other words there is a change of the conditions surrounding the sensor.

Challenges

Depending on the liquid or solid to be measured, the design of the vessel and the conditions of the process, various challenges may be encountered.

The design of the vessel must be taken into account, not only for its shape (in some cases the geometry of the vessel affects the level calculation), but also for internal structural features such as seams, supports and ladders, which may obstruct certain types of measurement.

In some cases, the material may be so corrosive or flammable, or the vessel may be so hot or cold that no form of instrument can enter the vessel. In these cases, nuclear level measurement may be the only solution.

Solids

For solids, the nature of the solid and the way it behaves in the vessel affect the measurement. Obviously, using head measurement by measuring the weight of the vessel eliminates all issues of the material properties, but this is not always practical, such as in the case of very large silos. Surface height measurement of solids presents various challenges:

- **Surface dynamics** - The filling and emptying of the vessel results in a sloping top surface (the material has an 'angle of repose'), that makes it difficult to determine the 'average' top level (Figure 1). Also, particle size has an impact on the

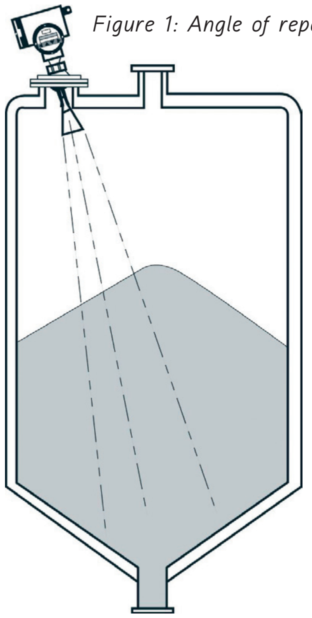

Figure 1: Angle of repose.

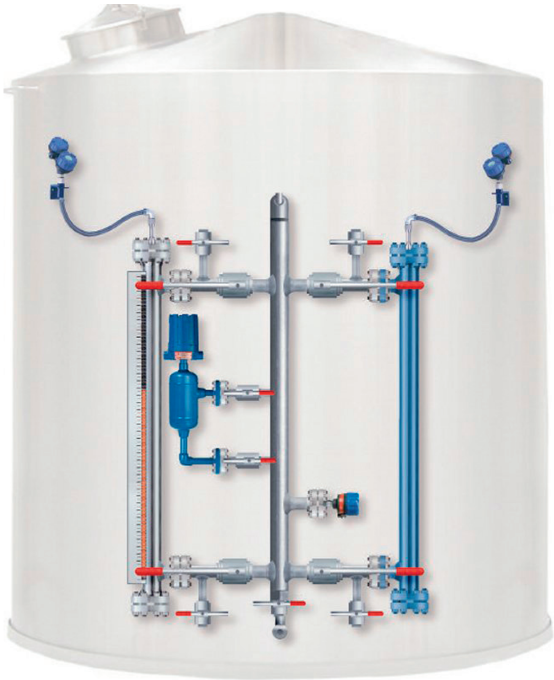

Figure 2: Examples of tank bridle use. (Source: Magnetrol)

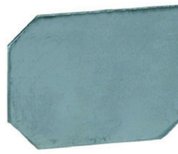

Figure 3: Rotary paddle switch. (Source: Monitor Technologies)

effectiveness of non-contact methods of measurement, due to uneven reflection of sound or radio waves.

- **Tensile forces** - Forces in tall solids silos can reach many tonnes. As the vessel is filled or emptied, the material can cause damage to measurement devices.
- **Dust and noise** - Dust filling the space above the material, as well as sound and electromagnetic noise, are common in solids vessels and can have detrimental effects on various types of measurement methods.
- **Material build-up** - Some instruments are particularly sensitive to material build-up that can interfere with radio or electronic measurements or clog up moving mechanisms.

Liquids

While liquids usually provide a nice flat surface for surface measurement, there may be other challenges surrounding the particular liquid that will affect what type of level measurement is used.

- **Corrosion** - Some liquids are highly corrosive so contact methods of measurement may not be appropriate, since the liquid will damage the instrument. Corrosive vapours may also be present above the liquid, so non-contact instruments need to be protected.
- **Agitation** - In some processes, the liquid is agitated in the vessel, or agitation occurs during filling and emptying, giving a moving level, as well as having impact on some types of measuring instrument.
- **Density change** - Measurement methods that depend on a steady material density may be affected by the change of density caused by temperature fluctuations.
- **Foam** - Surface foam on a liquid (which may be there for various reasons, including agitation) can cause some non-contact methods to be inaccurate by presenting multiple interfaces.
- **Vapour** - In closed vessels, vapour build-up above the liquid can cause interference with non-contact methods, and for some pressure-based head measurements, can cause increased pressure, resulting in a level reading that is too high.
- **Multiple interfaces** - Some vessels will contain immiscible liquids of different densities, so that one tends to float on the other. Some methods of measurement are useful for detecting the interface level as well as the total level, but this depends on the properties of the liquids and the measurement method.
- **Material build-up** - As for solids, some instruments are particularly sensitive to material build-up that can interfere with electronic and radio measurements or clog up moving mechanisms. For liquid applications, this can be a problem when the liquid is viscous or sticky.

Methods of interfacing

With the exception of vessel weighing methods and nucleonic measurement, most methods of measurement involve some form of connection with the inside of the vessel, if not with the material itself.

Tank bridles

One more traditional way of attaching instruments in the case of liquid measurement is the same way that visual level indicators have traditionally been configured. A bridle (also known as an isolating column or bypass pipe) is a vertical pipe connected to the side of the vessel, typically with two connections to the side of the vessel (high and low), or with one high on the side and one at the bottom (Figure 2). Because under most circumstances the fluid inside the bridle will rise and fall equally with the level of the fluid in the vessel, the bridle can be used as the location to apply the level instruments, although in most cases instruments are placed in their own bypass pipe or nozzle attached to the bridle. There are many advantages in using a bridle:

- **Fewer connections** - The tank, once built with a bridle, need never be tampered with to add instrumentation.
- **Simpler changes** - Changes to the instrumentation on the bridle do not affect the vessel.
- **Avoids obstructions** - Internal structures in the tank have no effect on instruments attached to the bridle.
- **Overcomes turbulence and foam** - In an agitated vessel, the bridle provides a calm surface for level measurement.

It should be remembered that tank bridles do not always reflect the actual level. Examples may be where the level has exceeded the upper end of the bridle, or where two fluids are present, in which case the interface level in the bridle will probably not match the actual interface level, or may not appear in the bridle at all.

Direct connection

While non-contact methods of continuous level measurement such as radar can be

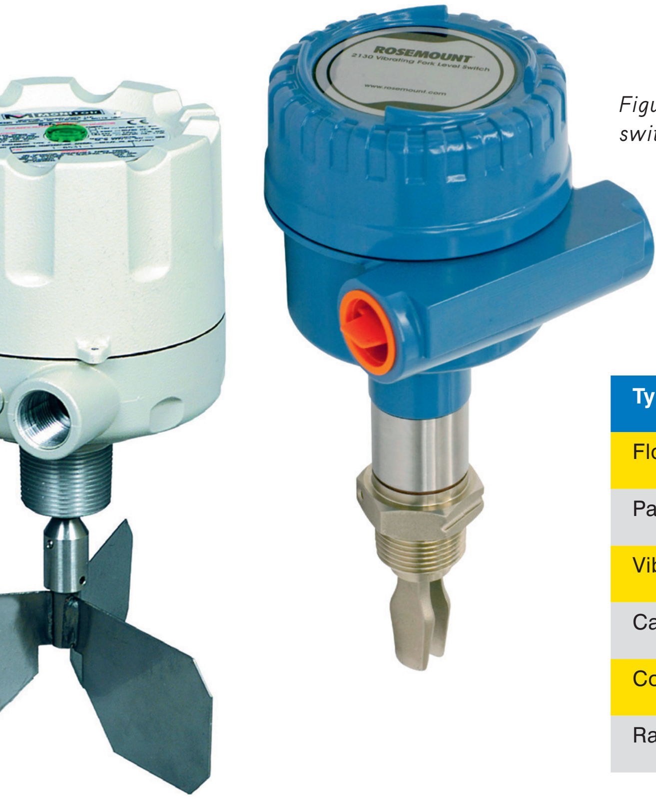

Figure 4: Vibrating fork level switch. (Source: Rosemount)

Type	Point detection for liquids	Point detection for solids
Float	Yes	
Paddle		Yes
Vibratory	Yes	Yes
Capacitance	Yes	Yes
Conductive	Yes	
Radiometric	Yes	Yes

Table 1: Summary of point level switch applications.

used with tank bridles, in the case of solids measurement (and also many liquid measurement applications) an instrument may be mounted directly through an opening in the tank. In the case of liquid head measurement, this may involve the direct connection of one or more pressure instruments directly to the side or bottom of the tank. In this case, valves may be interposed for maintenance purposes.

In the case of continuous height measurement for both solids and liquids, this will involve inserting the instrument though a hole in the top of the vessel. In this case, the risk of the detrimental effects listed above needs to be taken into account in each case.

Point level instruments

The simplest application of level sensing is for detection of levels at fixed points for simple applications such as preventing overfill or run-dry, and to start and stop filling operations. All the point level instruments described below involve some element which protrudes into the process material and comes into contact with it.

Float switches

Float switches use a float and magnetic switching action to switch when the float rises or falls with a liquid level. They are only suitable for liquids, and usually only for overfill detection, and come in vertical and horizontal orientations and can be top or side mounted. Their main advantage is their simplicity, but their disadvantage is the use of moving parts that can wear out, and the risk of seizing if they are not operated frequently. For this reason, they are not suitable for critical level detection, especially for hazardous liquids.

Rotary paddle switches

Rotary paddles rotate a small paddle and the movement is disrupted when it comes in contact with the process material. They are only suitable for solids. Their main advantage is their simplicity, but their disadvantage is the use of moving parts that can wear out, and the risk of damage from forces exerted by some types of material.

Capacitance point level switches

Capacitance type limit switches are static level sensors, use a sensing rod insulated from a ground sleeve. A capacitance is formed by the sense rod and earth extension, or the metal wall of a vessel. When no material is present, the capacitance is directly proportional to the probe dimensions and dielectric constant of air ($\varepsilon_0 \approx 1$). When material is present, the capacitance gets multiplied by dielectric constant of the material. This variation in capacitance is then translated into switching output by the device.

The main advantage is that there are no moving parts, but the material being detected must have a dielectric constant different from air, and liquids must be non-conductive. They can also be detrimentally affected by static charges in silos.

Conductive point level switches

Conductive limit switches work by inserting a rod into the vessel and applying an alternating voltage. In the simplest design, when an electrically conductive liquid contacts the probe it makes a circuit between the probe and the vessel wall. When the vessel is non-conductive, a version with an integral ground probe can be used. Some designs have multiple probes with different lengths so that if suspended vertically they can detect multiple levels.

Using alternating voltage prevents corrosion of the probe rods and electrolytic destruction of the product. They are only suitable for use with conductive liquids.

The main limitations of conductive level switches are that contamination of the probes can prevent detection, and they may not be reliable if the conductivity of the liquid varies.

Vibrating fork level switches

A pair of blades (or 'tines') is inserted into the process vessel and made to vibrate by a piezoelectric crystal oscillator. When the process material comes in contact with the forks, the resulting change in resonant frequency is detected. Their main advantage over a paddle switch is that there are no moving parts and they also work with liquids. Compared with capacitive or conductive sensors, the conductivity of the liquid medium is not relevant. However, some versions have very long forks that may be prone to being bent by heavy solids. They are not suitable for some very light materials such as ashes and build-up of material on and between the forks can cause inaccuracy, so the type of material is important in deciding whether to use them.

In Part 2

In Part 2 of this article, we will look at various technologies for continuous level measurement.