Level measurement: the basics

The sensing and control of product levels in containers involves a wide range of materials-liquids, powders, slurries, and granular bulk. All level measurement involves the interaction of a sensing device, element, or system with material inside a container. You can use a wide variety of physical principles to measure level-sight, pressure, radiation, and electric and sonic principles.

Three sight-type level sensors are glass gauges, displacers, and tape floats. Glass gauges are the most widely used instruments for measuring process tank level. Two types of level glass gauges measure liquid level in process tanks: tubular and flat gauges. The tubular type works on the same principle as a manometer. As the liquid level in an open tank rises or falls, the liquid in the glass tube will rise or fall. The gauges consist of glass, plastic, or a combination of the two materials.

Tape float

One of the most simple, direct methods of float level measurement is the tape float gauge. A tape connects to a float on one end and to a counterweight on the other to keep the tape under constant tension. The float motion results in the counterweight riding up and down a direct-reading gauge board, thereby indicating the level in the tank.

Standard floats are normally cylindrical for top-mounted designs and spherical or oblong for side-mounted designs. Small-diameter floats see use in higher density materials. You can use larger floats for liquid-liquid interface detection or for lower density materials.

Pressure-type instruments

Another common example is closed-tank level measurement. If the pressure in the closed tank changes, an equal force applies to both sides of the differential pressure (dP) transmitter. Because the dP cell responds only to changes in differential pressure, a change in static pressure on the liquid surface will not change the output of the transmitter. Thus, the dP cell responds only to changes in liquid level when the specific gravity of the liquid is constant.

Bubblers

The air bubbler is another pressure-type level sensor where you install a dip tube in a tank with its open end a few inches from the bottom. A fluid forces itself through the tube; when the fluid bubbles escape from the open end, the pressure in the tube equals the hydrostatic head of the liquid. As liquid level (head) varies, the pressure in the dip tube changes correspondingly.

For tanks that operate under pressure or vacuum, installing a bubbler system becomes slightly more complex, because the liquid level measurement is a function of the difference between the purge gas pressure and the vapor pressure above the liquid. Because differential pressure is now involved, the transducer used is normally a dP cell.

One disadvantage of using a bubbler is limited accuracy. Another is bubblers will introduce foreign matter into the process. Liquid purges can also upset the material balance of the process, and gas purges can overload the vent system on vacuum processes. If the purge medium fails, not only do you lose the level indication on the tank, but you also expose the system to process material, which can cause plugging, corrosion, freezing, or safety hazards.

Capacitance probes

A variety of instruments and sensors use basic electrical principles to measure and detect level. A capacitor consists of two conductors separated by an insulator. We call the conductors plates and refer to the insulator as the dielectric. The basic nature of a capacitor is its ability to accept and store an electric charge. When a capacitor connects to a battery, electrons will flow from the negative terminal of the battery to the capacitor, and the electrons on the opposite plate of the capacitor will flow to the positive terminal of the battery. This electron flow continues until the voltage across the capacitor equals the applied voltage.

You measure capacitor size in farads. A capacitor has the capacitance of 1 farad if it stores a charge of 1 coulomb when connected to a 1-volt supply. Because this is a very large unit, we commonly use one millionth of it, noted as a microfarad. The electric size in farads of a capacitor is dependent on its physical dimensions and on the type of material (dielectric) between the capacitor plates.

Resistance tapes

The resistance tape spirally winds around a steel tape. This instrument mounts vertically from top to bottom on a process tank. The pressure of the fluid in the tank causes the tape to short-circuit, thus changing the total resistance of the measuring tape. An electronic circuit measures the resistance; it's directly related to the liquid level in the tank.

Ultrasonic level measurement

Ultrasonic level sensors measure the time required for sound waves to travel through material. Ultrasonic sound waves generally have frequencies above 20 kilohertz. Ultrasonic instruments operate at frequencies inaudible to the human ear and at extremely low power levels, normally a few thousandths of a watt. The velocity of a sound wave is a function of the type of wave transmitted and the density of the medium in which it travels.

When a sound wave moving in a medium that transmits sound strikes a solid medium, such as a wall or a liquid surface, only a small amount of the sound energy penetrates the barrier, reflecting a large percentage of the wave. The reflected sound wave is called an echo.

A generator and transmitter produce the sound waves, and a transducer sends out the sound. The measured material or level reflects the sound waves. A transducer senses the reflected waves and converts the sound wave into an electrical signal, which it amplifies and sends to a wave-shaping circuit. A timing generator synchronizes the functions in the measurement system. The instrument measures the time that elapses between the transmitter burst and the echo signal. This elapsed time is proportional to the distance between the transducers and the object being sensed. The instrument is easily calibrated to measure fluid or material level in a process vessel.

Radiation-type instruments

Nuclear radiation instruments have the ability to sec through tank walls and can be mounted on the outside of process equipment. This reduces installation and repair costs. These systems can detect the level of liquids, bulk solids, and slurries.

Nuclear systems use a low-level gamma-ray source on one side of the vessel and a radiation detector on the other side. You can obtain a more accurate level measurement by placing several gamma sources at different heights. The material in the tank has a transmissibility different from that of air, so the instrument can provide an output signal proportional to the level of the material in the container.

Intrinsic safety defined

Hazardous locations are present in industries such as munitions, petrochemical, auto (paint spray booths), grain, wastewater, printing, distilling, pharmaceutical, brewing, cosmetics, mining, plastics, and utilities.

ISA-RP12.6 defines intrinsically safe equipment as "equipment and wiring which is incapable of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture in its most easily ignited concentration." You can achieve this by limiting the power available to and generated by electrical equipment in the hazardous area to a level below that which will ignite the hazardous atmosphere.

The European standards define the general specifications and the detailed guidelines for methods of protection against explosion. The national requirements primarily contain installation requirements.

In the past, the U.S. and Canada have classified hazardous areas by classes, divisions, and groups. Although this system is still in use, North America is gradually beginning to adopt a classification system based on zones as standardized in many countries of the world.

Common instruments in hazardous areas

Switches-Include push buttons, selector switches, float switches, flow switches, proximity switches, and limit switches.

Thermocouples-Inexpensive temperature sensors constructed of two dissimilar metals that generate a millivolt signal varying with temperature.

I/P converters-Convert a direct current milliamp signal to a proportional pneumatic output signal, which usually positions a control valve.

Transmitters-In control systems, they convert a process variable to a proportional electrical signal. The electrical output is a 0/4-20 mA, 0/1-5 volt (V), or 0/2-10 V signal.

RTDs-Resistance temperature detectors (RTDs) convert temperature into resistance. A resistance change could be 0.385 ohms/°C for a 100-ohm platinum RTD.

Light-emitting diodes (LEDs)-Don't use standard incandescent bulbs in explosive areas because of radiant heat, current requirements, and the susceptibility of the bulb to breakage.

Solenoids-Electrically actuated valves allow full flow or no flow of gases or liquids. Don't use standard 24 volts direct current solenoids in the hazardous area due to the coil's energy storing capacity.

IS solenoids-To design for IS certification, one common procedure is to embed two diodes connected in parallel to the coil. These diodes eliminate the potential arcing if a wire were to break. They suppress the arc and provide the solenoid with a low inductance rating.

Strain gauges-Measure stress, force, weight, and pressure in load cells, scales, and transducers.

Potentiometers-Adjustable resistors with resistance value (ohms) that changes with mechanical wiper movement.

Audible alarms-Horns or buzzers signal a hazardous event has occurred. Typically, barrier choice would be the same for audible alarms as it is for solenoids.

Serial communications-Transferring data in a sequence of bits, generally in the form of a low voltage signal (0-15V), the most common serial communications protocol is RS-232.

Fire detectors-Detect flames in a hazardous environment. In the normal state, a low current (4-6 mA) passes through the detector circuit

A level experience

If you want to control your level problems, you need to understand which level technique to use in a particular application. While there is no perfect level control for all applications, reviewing the weaknesses of a technology and comparing to specific application parameters will yield insight into its potential for success.

A popular choice for high alarm or spill protection, on-off type devices or switches only indicate the presence or absence of product at a certain point, shutting off a pump or triggering an alarm if the fluid level in a tank gets too high. These usually go by the name of dumb switches with no self-diagnostics and no way of communicating if they are working. You must physically test them. One example is a simple mechanical float switch.

On one hand, you need to check level devices regularly if they don't have a self diagnostic. On the other hand, a contact ultrasonic or gap switch is your best choice in smart switches, which monitor themselves, sending an alarm if they wander out of specification. Proportional devices or transmitters reveal exactly how much product is in a tank. With them, information can transmit to other devices. You can use them for control or inventory.

Buoyancy

Some ancient technologies are still valid today, such as the simple principle of a float; as the fluid level rises, so does the buoyant float. The variable is merely how the, motion of the float translates into a control action. Some applications find the mechanical linkages converting the float's up-and-down motion into a contact closure or opening. Look at the float in a toilet tank. In applications requiring isolation of the stored fluid, you can use magnetic coupling to seal the liquid.

These magnetically linked devices see more use in industrial applications with high pressures or hazardous fluids. The displacer method, a variation of float technology, uses heavier-than-liquid displacers where an upand-down motion actuates a switch. Here, displacers connect in line to a spring using a suspension cable and position themselves to rise at a force proportional to the displaced volume of the liquid. Magnetic coupling to the switch is also possible, allowing the liquid to isolate from the controls.

Floats and displacers are easy to use and don't require power to operate. Floats need no calibration while you can calibrate displacers without level movement. Floats provide an accurate, repeatable set point. Displacers can have a number of on/off ranges within a single vessel if you need control of multiple levels. Because displacers are heavier than the liquid they control, they don't bob with wave or surge action. Switch short-term cycling is not a problem. Surface turbulence and foam don't impede displacers or floats. Displacer units can be continuous level transmitters or switches. Buoyancy methods are usable in applications up to 5000 psi and 1000 Ĩ°R

Buildup and deposits are a problem and can impede performance. Floats and displacers work only with low viscosity liquids; viscous and dry media require other methods. Liquids with the potential for buildup or those with suspended solids can cause hang-up in the sensors' moving parts.

Magnetostrictive

Magnetostrictive transmitters detect level by transmitting an electromagnetic pulse down a wire. A donut-shaped float with an internal magnet moves with the level. A magnetic field creates a twist on the wire at the point of the level. When the electromagnetic pulse encounters this magnetic field, a pickup in the transmitter propagates and reads an acoustic pulse. This allows you to use the float as a transmitter rather than just a switch. The cost is reasonable, and the device has a high accuracy, but only for clean fluids. Similar devices use a chain of reed switches instead of a magnetostrictive element to save cost, but it reduces accuracy.

Magnetic level indicators

Magnetic level indicators (MLIs) consist of a float with a magnet dropped into an isolating pipe or bridle connected to the side of a tank. The bridle can be any plastic or non-magnetic metal. Fluid will rise and fall in the bridle, matching the level of fluid in the tank. Highly visible magnetic flags go outside the pipe to indicate the fluid level. These devices are safer and easier to read than a sight glass. They also can easily retransmit the signal by adding switches, or transmitters, which clamp on to the outside of the pipe and pick up the magnetic field from the float.You can remove the magnetostrictive transmitter float and clamp it on to the outside of the MLI, creating a transmitter that doesn't have to be inserted into the vessel. You can also install a guided wave radar (GWR) transmitter directly into the MLI for increased integrity due to its redundant measurement.

MLIs can see use in temperatures up to 1000°F and are easier to read and safer than a glass sight tube. You can add alarm switches and transmitters by simply clamping them on to the outside of the bridle any time. MLIs are a piece of pipe you can build in many configurations. You don't need power for local indication. They are suitable for cleaner, low solids applications where there is little risk of the float building up or getting stuck in place.

Capacitance

Capacitance (RF or admittance) is a flexible level measurement technique that works for liquids, solids, corrosive materials, high temperatures, and pressures. However, some application sensitivities and calibration issues exist. Cumbersome calibration, dielectric shift, and buildup on the probe are key issues.

In all cases, the devices measure a change in pico farads (pF), a unit of capacitance. A simple metal rod, coated with insulation when used in electrically conductive fluids, turns the storage vessel into a large capacitor. Any material added to the tank will have a higher electrical dielectric than the air it displaces, so increasing the level of the product increases the amount of capacitance. You can make on/off or continuous measurement any-; where on the probe.

Ultrasonic

Ultrasonic level measurement techniques include sending a sound wave through air (air sonar), or liquid (liquid sonar). A sound pulse (usually ultrasonic) is transmitted, and you can time the return reflection (or echo) from the surface of the liquid to determine distance. Liquid sonar devices (gap switches or contacting ultrasonics) typically see use as a switch to detect the presence or absence of fluid in a notch in the probe. Both types use a piezo crystal to generate the pulse. Non-contact ultrasonic measurement is especially suitable for corrosive and dirty applications, as well as for liquids, slurries, and bulk, solids.

Contact ultrasonics are useful in high alarm and overfill applications as they have diagnostics to self-check and ensure reliable operation and are relatively inexpensive. Ultrasonic non-contact units are limited to applications under 50 psi, 300 °F and are not reliable in the presence of heavy surface foam. Interference from falling liquids, steam, dense vapors, and dust can affect the signal propagation, as can obstructions in the vessel. Gap switches need to avoid build-up of material in the sensor gap and are typically limited to 325 °F and 1500 psi.

Radar

Radar level measurement is based on measuring the transit time of high frequency (GHz) electromagnetic energy transmitted from an antenna at the top of the tank and reflecting off the surface of the level medium; the higher the dielectric of the medium, the stronger the reflection. Radar is robust, reliable, and becoming popular as prices decline. Line-powered and loop-powered products now offer a wide range of flexibility to the user in hazardous and non-hazardous areas.

Today, radar comes in two forms: non-contact (through air) and contact (guided wave). The transmitted energy travels freely over long distances (greater than 200 ft) and is unaffected by changes in temperature, pressure, of vapor density above the medium. Non-contact radar measures effectively in applications of varying process media conditions like dielectric or specific gravity, and you can use it in corrosive environments. High temperature (750ĭ°F) and high pressure (5000 psig) are possible.

Reliably picking the level signal out of the background noise (false targets) is a difficult and often unreliable process. Performance can deteriorate significantly in the presence of mixing blades.

Contact or GWR uses a probe or waveguide to conduct the signal to the surface and back. GWR can measure in almost any application less than 100 ft and will work in many situations through air radar and other technologies; cannot. This is due to the increased transmission efficiency the metal waveguide offers.

You can install GWR and get it working with little or no calibration because the signal does not spread away from the antenna at launch; false target rejection is not an issue with GWR. It is easy to handle extremely low dielectric (e >1.4) media, turbulence, foam, tank obstructions (false targets), and fast-moving levels. High temperature (750ĭ°F) and high pressure (5000 psig) applications are common. In many applications, coating/buildup on the probe causes no significant error. GWR can measure accurately and reliably up to the very process seal of the probe. It's excellent for applications where overfill is a problem. Further, GWR has the ability to measure fluid/fluid interface applications of low dielectric over high dielectric media. Using contact and non-contact radar judiciously can be effective in most process level measurement applications.

Differential pressure

Differential pressure (DP) is a popular choice for clean liquids with a constant specific gravity. DP transmitters do not measure level directly; they instead infer level by the downward pressure or weight of the liquid against a diaphragm. If the temperature or specific gravity of the medium changes, significant error will occur. If the vessel is pressurized, you need to add a second connection to the vessel above the liquid to measure and allow for correction of this variable, hence the term differential pressure, which measures the difference between these two points. You can use DP for flow measurement by inserting a device into the line to create a pressure drop proportional to flow. DP devices connect to the vessel below the liquid surface, increasing the likelihood of leaks and making it difficult to remove if it needs service or cleaning.

Transmitters aid interface level measurement

Many processes use water as a means of transporting product from one point to another For example, in oil production, water or steam is often used to lift oil out of a well.

In chemical production, water is sometimes a byproduct or a tool used to clean a vessel.

In these situations, the water and hydrocarbons will mix together.

At some point, it will be necessary to remove the hydrocarbon from the water.

If allowed to settle undisturbed in a tank, the mixture will separate into its two components, with the heavier, denser material sinking to the bottom and the lighter, less dense material rising to the top.

This principle is exactly the same as the way in which oil and vinegar separates in an Italian salad dressing.

One example of this in a real application is a separation tank.

A control valve regulates the ingress of a liquid mixture of water and hydrocarbon into the vessel.

Eventually, the lighter material in the mixture finds it way up to the separation stack, where a water/hydrocarbon liquid interface forms - effectively a dividing line between the two liquids.

The position of this liquid interface is critical - too little or too much either way will end up with either water being drawn out with the hydrocarbon, or hydrocarbon remaining in the tank.

In either situation, the end result is reduced product quality and process efficiency, adding to the product cost.

When the mixture gets to the critical interface point, a pump will pull out the hydrocarbon from the stack while a continuous amount of new mixture is pumped into the tank.

The hydrocarbon is then sent on for processing, free of water.

For this process to operate at optimum efficiency, it is vital that the interface level is measured and controlled properly.

A range of different technologies exists for interface level measurement applications.

Many of these technologies can encounter problems when either the interface level becomes too small or the process involves sticky solids.

Substances that can coat or leave residue can also present a problem when using these devices.

Here, we will look at the advantages and disadvantages associated with the three main methods most commonly employed for interface level measurement, namely: displacers,

capacitance probes and differential pressure transmitters.

Displacer type transmitters rely on the principle of buoyancy and consists of a large chamber flanged to the separation stack.

A float or element of a known specific gravity will float at the point of interface.

A series of moving part linkages attached to the float indicate the float's position to a transmitter, informing it of where the interface is.

Although relatively straightforward, this technique has a number of key disadvantages.

First, petrochemical and chemical applications are often characterised by aggressive conditions, demanding the use of exotic materials, which can add substantially to the cost of the transmitter system.

The mechanical linkages can also stick, fouling the measurement and requiring frequent maintenance.

The overall accuracy of these devices is also often questionable - in some cases, customers have reported accuracies of just 10% at best.

Capacitance probes comprise a long metallic probe, which normally enters the top of the separator vessel and extends to its lowest point.

Liquid level and interface are detected by measuring the capacitance value between the wall of the vessel holding the liquid and the probe itself.

Again, the aggressive nature of most chemical and petrochemical applications will require the use of exotic materials, adding to the cost of the installation.

Another complication associated with this technology is the measurement of sticky substances, which can coat the metal, resulting in measurement uncertainties and poor readings.

Other factors such as foam on the liquid surface or vibration of the tank can also conspire to reduce measurement certainty or even render the probe inoperable.

Remote seal differential pressure transmitters probably offer the best solution for the measurement of liquid interface levels.

With this technique, when the distance between the taps on the separation stack is filled only with the lighter liquid, the differential pressure is minimum value or the lowest range value (LRV) of the transmitter.

When it is filled with the heavier liquid, the differential pressure is at its maximum value, or the upper range value (URV) of the transmitter.

Although this technique overcomes many of the problems associated with the previously described methods, particularly with respect to corrosion, it does have one main drawback.

The small difference in both the specific gravity of the two liquids and the distance between the taps on the separation stack results in a very small differential pressure span.

In many cases, the size of this span is often lower than the recommended minimum span for most remote seal transmitters.

One way of overcoming this problem is to use remote seals and transmitters which are sensitive enough to detect very low span changes.

An example is ABB's own remote-seal based 2600T interface level transmitter, which has been specifically designed for use at very low differential pressures.

These transmitters use a remote seal with a highly sensitive diaphragm available with a range of fill fluids for a variety of applications.

Protection against leakage of the fill fluid is ensured by an all-welded construction, which offers a significantly extended service life than seals using a conventional gasket or thread construction, particularly in vacuum applications.

A chemical plant wanted an interface level transmitter for use in a chemically aggressive hydrocarbon reprocessing application.

In this application, a mixture of process hydrocarbons cleaned from the plant's tanks and reactors, and water used for cleaning the reactors, was piped into a holding tank where it was allowed to settle.

The customer wanted to be able to pump the hydrocarbon back into the process for reclamation without also pumping any of the water.

In designing a solution, several obstacles had to be overcome.

First, the application involved a very low differential pressure span impossible for most remote seal transmitters to measure.

A second challenge was the location of the application, which was subject to considerable swings in ambient temperature.

Such inconsistent conditions can often pose a potential problem when measuring very small pressure differentials.

To solve this problem, the entire transmitter, with remote seals connected, would have to be temperature characterised together in an environmental chamber.

A microprocessor-based ABB 2600T draft range differential pressure transmitter was installed because of its small upper range limit, suitable for the close requirements of the application.

The temperature characterisation data from the environmental chamber was stored in the transmitter's memory.

The transmitter's onboard temperature sensors monitor the ambient temperature.

Accurate pressure measurement is ensured by the transmitter's microprocessor, which compares the data from the environmental chamber with the ambient temperature conditions and adjusts the transmitter's output accordingly.

A major concern at the outset was the risk of any pressure imbalance inside the capillary system due to changes in ambient temperature, which would cause the fill fluid to expand or contract.

The effect of this potential change was calculated under laboratory conditions, with the uncertainty of the system being predicted to be less than 0.5% of span.

Since this new interface level transmitter was installed, the interface level control has greatly improved.

The customer has also reported that downtime has been eliminated, saving over GBP 30,000 per year on the cost of maintenance alone.

Before this, monthly maintenance was required to clean the previously installed buoyancy transmitter system to prevent shutdowns.

Despite this, the instruments would frequently foul up anyway, resulting in the process being shut down.

Selecting the right solution for an interface level measurement application requires consideration of many factors, including accuracy, aggressiveness of the application media and the level of maintenance deemed acceptable for the application.

Opting for a remote seal differential transmitter system provides an ideal solution for aggressive applications and can help to eliminate maintenance whilst delivering greatly enhanced measurement accuracy.

Displacer transmitters in the hydrocarbon industry

The displacer transmitter for liquid level measurement is based on Archimedes principle, that the buoyancy force exerted on a body immersed in a liquid is equal to the weight of the liquid displaced

Archimedes' principle states that the buoyancy force exerted on a body immersed in a liquid is equal to the weight of the liquid displaced This is the principle on which the displacer transmitter for liquid level measurement is based If the cross sectional area of the displacer and the density of the liquid are constant, then a change in level brings about a corresponding change in the apparent weight of the displacer.

Displacer transmitters have provided highly reliable level measurement in difficult hydrocarbon applications for many years.

The measurement technology is simple, reliable, accurate and adaptable to a wide range of needs, including the measurement of an interface between two immiscible liquids.

Importantly for hydrocarbon applications it can be used at very high temperatures and pressures, when most other technologies fail.

There are two types of displacer transmitter in common use today; torque tube and spring operated.

Both have a cylindrical displacer element of a length corresponding to the range of the level measurement required and weighted to sink in the liquid being measured.

In both the maximum change in effective weight of the displacer element is equivalent to the weight of the liquid displaced when the displacer is completely submerged in the liquid.

It is important to also take into account the effect of the upper fluid which, even if a vapour, will have an effect on the buoyancy force, particularly if the vapour space is at a high pressure.

The difference between the two types of displacer transmitters centres around the mechanics of transmitting the displacer movement because of the buoyancy force from the wetside of the instrument to the dryside where it can be translated into an electronic, or in earlier designs, a pneumatic, signal proportional to the liquid level change.

With a torque tube design, the displacer element is suspended on a knife edge hanger at the end of a cantilever arm, the other end of which is welded to the torque tube.

The torque-tube is a hollow tube welded at one end to the instrument flange which is put in torsion by the weight of the displacer element on the cantilever arm.

A rod, welded to the torque tube at one end but free at its other end, sits inside the torque tube and is thus caused to rotate axially as the torque tube rotates.

When the displacer rises or falls, the corresponding angular displacement of the torque rod is linearly proportional to the displacer movement and therefore to the liquid level.

The knife-edge bearing support minimises friction and a limit stop on the torque arm is used to prevent accidental over-stressing of the torque tube.

With regular maintenance, this type of design is proven to measure reliably.

There is a huge installed base in the hydrocarbon and other industries and the technology is well understood.

It is suitable for use in very high pressures - up to about 17Mpa/170bar (2,465psi) and in process temperatures from 200C (-328F) to more than 450C (842F).

However, it is a bulky instrument which can be awkward to install.

As a mechanical device with a critical knife edge bearing, it requires constant, careful maintenance to ensure continued accuracy.

And finally, because the design relies on a welded pressure joint at the flange end of the torque tube, regular inspection for signs of fatigue or corrosion is essential.

The newer spring-operated displacement transmitter is a more elegant design that overcomes many of the problems associated with torque-tube devices.

Just as reliable as the torque-tube, it is smaller, lighter and more robust.

In a spring-operated instrument, the change in apparent weight of the displacer is transmitted directly, through a spring or coil from which the displacer weight is hung.

When the displacer rises or falls with changing liquid level the spring will relax or extend accordingly as dictated by the formula: Spring extension (contraction) = Force/Spring Rate.

A core piece is located on top of a rod attached to the spring and is thus caused to rise or fall inside the pressure tube.

A precision linear variable differential transformer (LVDT) is situated outside the pressure tube, totally isolated from the process pressure and vapour.

Movement of the core within the fields of the LVDT causes an imbalance which the instrument electronics detects and is able to convert into a signal proportional to the liquid level.

It should be understood that the spring is a heavy duty coil made from typically three or four mm (0.125ins) gauge specially selected alloy wire.

The coil is always selected such that it is operating at about 10% of its yield stress, ensuring maximum sensitivity to changes in the force on it, without the possibility of over-stressing.

Mechanical stops prevent over extension or coil bound operation.

The best instruments on the market are those with coils made from Nimonic, a nickel alloy which gives the spring a perfectly linear expansion over the full operating temperature range of the instrument giving highly accurate level measurement.

Key advantages of the spring operated transmitter are that it has a much smaller mounting envelope than a torque-tube, it is lighter and much easier to install and does not have critical welds under stress.

However, the operating range is not quite as wide; spring-operated devices are typically suitable for use in pressures up to about 25Mpa/250bar (3,600psi) and in process temperatures from 260C (-436F) to about 300C (572F), although specifications do vary between manufacturers.

Whichever transmitter technology is chosen for the application, the size and weight of the displacer is crucial, since it determines the relationship between the change in the apparent weight and the liquid level.

The optimum displacer diameter for any one application depends on the density of the process liquids, the process operating conditions, and the level measurement span.

It is important at the ordering stage to give the manufacturer the correct data so that the instrument can be sized correctly and be calibrated to give the correct level reading at the process operating conditions.

The inclusion of powerful microprocessor electronics and digital communications in modern displacer transmitters does however give the user the facility to trim, re-calibrate or re-range the instrument very easily on site.

As mechanical devices, displacer transmitters have traditionally needed regular maintenance, cleaning and checking of the calibration.

If you are thinking of investing in this sort of instrumentation then it is worth looking into this aspect thoroughly, since some instruments need significantly more work than others.

The best spring-operated displacement transmitters offer very stable operation with long maintenance intervals, while the maintenance investment required with some torque-tube instruments may be considerably higher.

Might TDR radar be an attractive alternative? In the last two to three years, time domain reflectometer (TDR) radar has been put forward as an alternative to mechanical displacer transmitters for level measurement in difficult applications.

TDR radar makes its measurement by sending a radar signal down a guide rod or wire and monitoring the time taken for a portion of the transmitted microwave energy to be reflected from the liquid/air interface.

The position of the liquid level surface is identified because the change in dielectric which occurs in the transmission line at that point causes reflections.

The time it takes for the reflections to get back to the receiver provides an indication of the distance between the transmitter and the surface of the liquid in the tank.

With no moving parts, this technology is attractive in clean non-viscous liquids because it requires much less maintenance than mechanical devices.

It is starting to be used in hydrocarbon applications and is said to be capable of operating in conditions up to 200C (392F) and 34Mpa/345bar (5,000psi) but because it has not yet established a track record its long term reliability in difficult level measurement applications is not yet proven.

Displacement transmitter technology is a tried and trusted method of level measurement for high temperature and high pressure environments.

The evolution from torque-tube to spring-operated instruments and the addition of high accuracy LVDTs, sophisticated electronics and digital communication options has made significant gains in functionality and operability in the field.

The introduction of TDR radar as a non-mechanical alternative suitable for all but the harshest applications offers the possibility of reliable measurement with much lower cost of ownership.

Although it is starting to make an impact on the market, TDR radar has a long way to go to catch up with the huge installed base of displacer level transmitters in demanding hydrocarbon processing applications on and off-shore.
