Various Technics of Liquids and Solids Level Measurements (Part 5)

In the four previous parts of this series of articles, level measurement using a floating system, using pressure instruments, using radar waves and using ultrasonic waves were discussed. The instruments offered by Indumart company applicable for each method were also recommended. In the final part of this article, level measurement using capacitance, conductivity probes, vibration forks, thermal dispersion and optical technics are discussed.

CAPACITANCE LEVEL MEASUREMENT BASICS

Capacitance level instruments operate on the basic principle of the variation of the electrical capacity of a capacitor formed by the sensor, the vessel wall and the dielectric material. A capacitor is made of two conductive plates which are isolated from each other by a dielectric. The storage capability of a capacitor is directly dependant on the plates areas (A), their distance (d) and the dielectric constant of the material between the plates (ε).

$$C = k\varepsilon A/d$$ Eq. 4. Capacitance Calculation

Where,
C is the value of capacitance, expressed in Farad.
k is a constant with a value of 0.225 or 0.0885 depending on the units used.

As an example, the dielectric constant of air is 1, while the dielectric constant of water at 20°C is 80. When a vessel is being filled with water, the probe is exposed to a more conductive material than air and thus the capacitance value of the probe will increases due to a higher dielectric constant of water.

The dielectric constant of the process material is the most important aspect of this level measurement application and this must be taken into account that temperature, moisture content, humidity and density can change the dielectric constant of the process material. The higher the dielectric of the process material, the easier and most reliable would be the level measurement. Materials with low dielectric constants, such as, plastics, glass, sand and mineral oil are not very good candidates for capacitance level measurement application. Light density materials with large particle size which have a large volume of air between the particles also have low dielectric constants and not suitable for this technique.

Figure 25: Capacitance Level Sensor

Sensitivity of the measurement can increase by exposing a greater area of the probe and by decreasing the distance between the plates. Moreover, it is important that the entire probe be covered with the process material, and not just the tip of the probe. Typical insertion lengths of standard capacitance range from 20 to 40 cm.

Wet and sticky materials cause permanent coating and build-up to the probe and can introduce errors in the level measurements. As the liquid level drops, the probe remains wetted, providing a conductive path between the probe and the vessel wall. The faster the level drops, the larger would be the false reading of level measurement. Also materials that are very conductive (water and water-based liquids) can cause a short circuit between the bare stainless steel probe and the vessel wall. It is recommended to use Teflon insulator on the conductive probe, when the dielectric constant of the process material is high.

Installation of the probe must be such that it does not contact the vessel wall or any structural element of the vessel. The probe should not be mounted where the process material can form a bridge between the probe and the vessel wall. If a probe is installed through the vessel's wall and the weight of the process material acting on the probe is considerable, a protective baffle should be installed above the probe. Additionally, the probe should not be mounted at an upward angle to avoid material build-up. In applications where the vessel is made of a non-conductive material, a second probe parallel to the active probe or a conductive stip can be installed.

CONDUCTIVITY LEVEL MEASUREMENT

Conductivity level measurement is very similar to the capacitance technique. Conductivity level sensors detect the medium's resistance when their electrodes are covered by the process material. This method is normally used for water vessels and also in processes such as water & wastewater treatments, chemical, pulp & paper, food, wine, biological, etc. They may be mounted as a multi-point sensors that can be with up to four probes (by Indumart) or three probes and one reference electrode. Electrical conductivity of the liquid between each probe and the reference electrode in non-metal vessels, or between each probe and the case in metal tanks will count as the measured signal.

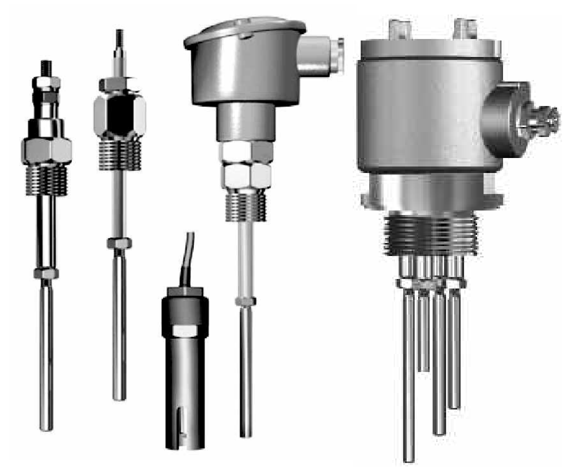

Figure 26: Conductivity probes

They can be mounted on various open or closed vessels (suitable for pressurized tanks) or ordered as the submersible version for level detections in wells or very deep tanks. They can control the differential of minimum and maximum level, with an adjustment for sensitivity. Indumart *SSC series* of Conductivity Sensors are mostly applied in combination with *LSC11 Series* switch/indicator for ON/OFF level control of liquids with relatively high conductivity.

It allows monitoring of up to 3 levels. When each level is reached, the corresponding relay is activated or deactivated (drainage/supply control). The operator can program the direction of relay action at the level reached as well as connection (dependence) between two levels.

In addition to controlling the level, the *LSC11 Series*, indicates the level reached with the aid of a light indicator.

Figure 27: LSC11 Conductivity Level Controller

VIBRATING FORK LEVEL MEASUREMENT

Vibration Fork Level Switches are designed to vibrate at its frequency by a pair of piezoceramic discs. By coming into contact with the medium, the frequency and amplitude of vibration changes. This change is detected, processed and converted into a switch signal. They can be used for liquids with specific gravity greater than 0.7. They may also be applied on light and medium density free flowing granules and powders. They cover a large variety of applications such as: overfill or dry run protection, pump controls, high/low fail safe limit switch, dry/wet indication in pipes.

A good vibration fork sensor has high excitation frequency which ensures interference-free operation and enables applications in turbulent liquid surfaces and high vibrating vessels. This measurement technique is very well suitable for high viscosity liquids (response time will be longer) and the operation will not be affected by foam and gas content of the process.

Vibration fork can be used in liquid, solid and slurry level detections. When used on wet powder, the vibrating paddle has a tendency to create a cavity in the granular solids. If this occurs, false reading will result, because the sensor will confuse the cavity with empty space.

Figure 28: Vibration Fork

THERMAL DISPERSION LEVEL MEASUREMENT

The principle of thermal level sensors is to differentiate between the temperatures of the vapor above the liquid and the liquid itself or, more commonly, the increase in thermal conductivity as a probe becomes submerged in the process liquid. One of the simplest thermal level switch designs consists of a temperature sensor heated with a constant amount of heat input. As long as the probe is in the vapor space, the probe remains at a high temperature, because low-conductivity vapors do not carry much heat away from the probe. When the probe is submerged, the liquid absorbs more heat and the probe temperature drops. The switch is actuated when this change in temperature occurs.

Another type of thermal sensor uses two resistance temperature detectors (RTDs), both mounted at the same elevation. One probe is heated and the other provides an unheated reference. The outputs of both sensors are fed into a Wheatstone bridge. While the sensor is in the vapor phase, the heated probe will be warmer than the reference probe, and the bridge circuit will be unbalanced. When both probes are submerged in the process liquid, their temperatures will approach that of the liquid and their outputs will be nearly equal and the bridge will be in balance. This level switch is actuated when a change in bridge balance occurs.

Since all process materials have a characteristic heat transfer coefficient, thermal level switches can be calibrated to detect the presence or absence of any fluid. Therefore, these switches can be used in difficult services, such as interfaces, slurry, and sludge applications. They can also detect thermally conductive foams if spray-cleaned after each operation.

Thermal level and interface switches have no mechanical moving parts and are rated for high pressure. They work best with non-coating liquids and with slurries having 0.4-1.2 specific gravity and low to midium viscosity.

A third type of thermal switch also uses two sensors inside the same vertical probe. One is mounted above the other and both are connected to a voltage source. When both are in the vapor or both in the liquid phase, the current flow through the two sensors is the same. If, the lower one is in liquid and the upper in vapor, more current will flow through the lower sensor and a current comparison can detect this difference and actuate the switch. One interesting feature of this design is that the sensor capsule can be suspended by a cable into a tank or well, and the sensor output can be used to drive the cable take-up motor. In this fashion, the level switch can be used as a continuous detector of the location of the vapor/liquid interface.

OPTICAL LEVEL MEASUREMENT

In level measurements, the optical sensors rely upon the light transmitting, reflecting, or refracting properties of the process material. A refracting sensor relies on the principle that infrared or visible light changes direction (refracts) when it passes through the interface between two media. When the sensor is in the vapor phase, most of the light from the LED is reflected back within a prism and when the prism is submerged, most of the light refracts into the liquid, and the amount of reflected light that reaches the receiver drops substantially. Therefore, a drop in the reflected light signal indicates contact with the process liquid.

The optical level switch can be either of a contacting or non-contacting design. In a non-contacting, reflecting optical sensor, a beam of light is aimed down at the surface of the process material. When the level of this surface rises to the setpoint of the switch, the reflected light beam is detected by a photocell. Both the LED light source and photodetector are housed behind the same lens. By adjusting the photocell or the detection electronics, the sensor can be calibrated to detect levels at various distances from the sensor. These reflective switches can measure the levels of clear as well as translucent, reflective, and opaque liquids. This technique also has applications for some solids level measurements such as molten metals, molten glass, glass plate, or any other kind of solid or liquid material that has a reflecting surface. However, a refracting sensor cannot be used with slurries or coating liquids, unless it is spray-washed after each submersion. Even a few drops of liquid on the prism will refract light and cause erroneous readings. A sludge level sensor of this design uses an LED and a photocell at the end of a probe, located at

Ithe same elevation and separated by a few inches. To find the sludge level, a mechanism (or an operator, manually) lowers the probe into the tank until the sensors encounter the sludge layer.

By using multiple photocells, a sensor can detect several levels. Refracting sensors are designed to be submerged in liquids; therefore, any number of them can be installed on a vertical pipe to detect a number of level points. If the receiver module is motor driven, it can track the reflected laser beam as the level rises and falls, thereby acting as a continuous level transmitter.

Other transmission sensors rely on the refraction principle utilizing an unclad, U-shaped fiber optic cable. A light source transmits a pulsed light beam through the fiber cable, and the sensor measures the amount of light that returns. If liquid covers the cable, it will cause light to refract away from the cable. The use of fiber-optics makes the system impervious to electrical interference, and some designs are also intrinsically safe. Optical level switches are also designed for specific or unique applications. For example, a level switch that combines an optical with a conductivity-type level sensor to detect the presence of both water (conductive) and hydrocarbons (nonconductive).