This discussion of buoyancy, capacitance, and ultrasonic level sensing techniques includes a quick reference guide in chart form that cross-references methods, media, and media characteristics.

A Look at Level Sensing

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Understanding level sensing techniques is only part of the answer to level control problems. Understanding which technique to use in a particular application is the rest of the solution. Here is a brief review of three level measurement methods, their advantages, and their limitations. Included too is guidance that should help in selecting the right method for the job: In the "Quick Reference Guide to Level Sensing Systems," each cell lists the level sensing methods of choice as a function of system requirements and type of medium (two left columns) and characteristics of the medium (top row).

BUOYANCY

Archimedes defined the principles of buoyancy some 2200 years ago. Level sensors based on the phenomenon he described might seem somewhat dated, but they remain the device of choice for many applications where more sophisticated instruments would constitute overkill.

Simply put, as the fluid level rises, so does the buoyant float. What varies from manufacturer to manufacturer is how the motion of the float is translated into a control action. In some applications, mechanical linkages convert the float's up and down motion into a contact closure/opening. In approaches that require isolation of the stored fluid, magnetic coupling permits the liquid to be completely sealed, as in applications where the fluid is stored at high pressure (see Figure 1).

The displacer method, a variant of the float approach, uses heavier-than-liquid displacers whose up and down motion actuates a switch. Here, however, the displacers are connected in line to a spring by means of a suspension cable and are positioned to rise at a force proportional to the displaced volume of the liquid. Magnetic coupling to the switch is also possible, allowing the controlled liquid to be isolated from the controls.

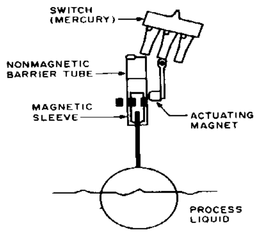

Figure 1. *Buoyancy level sensors may be isolated from the stored fluid by magnetic linkage to the output device.*

Buoyancy Advantages. Floats and displacers are easy to understand and use. Calibration is not required for floats, and displacers can be calibrated without level movement. Floats provide an accurate, repeatable setpoint. Displacers can have a number of off/on ranges within a single vessel if control of multiple levels is required by the application. Because displacers are heavier than the liquid they control, they do not bob with wave or surge action and switch short-term cycling is not a problem. Surface turbulence and foam do not significantly impede displacers or floats. Displacer units permit continuous level transmission. Buoyancy methods are usable in applications up to 5000 psi and 1100°F.

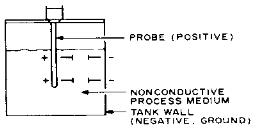

Figure 2. *In noncontact media, the capacitance probe and tank wall serve, respectively, as the positive and negative plates.*

Buoyancy Limitations. Build-up and deposits may impede performance. Accuracy is typically limited to ± ¼ in., so the application requires more precise control. Floats and displacers work only with low-viscosity liquids; viscous and dry media require other methods. Liquids with the potential for build-up or those with suspended solids can cause hang-up in the sensors' moving parts.

CAPACITANCE

Using capacitance to measure level turns the entire storage vessel into a giant capacitor (see Figure 2). As is the case with a circuit-size capacitor, the important parameters are the area of the conductive plates (A), the distance between them (d), and the dielectric constant of the stored material (ε). The capacitance (C) of a parallel plate capacitor is thus:

$$C = \frac{\varepsilon A}{d}$$

In industrial applications, the entire

tank wall serves as the negative, or ground, plate of the capacitor. The probe serves as the positive plate. The material between the tank wall and the probe, i.e., the material stored in the tank, becomes the dielectric material. When the tank is empty, the dialectric material is air, with its dielectric value of 1. Because all other substances have dielectric constants greater than 1, capacitance increases as the tank fills with material.

This change in capacitance, which corresponds to a rise or fall in the level of the stored material, can be measured with an invasive probe connected to capacitance based electronics. Level change may be indicated by a switch for on/off point level control or a level transmitter with a continuous output, such 4-20 mA.

The capacitive method of level detection requires one approach when the stored material is nonconductive and another when the material is conductive. In the nonconductive, or insulating, case, a metal rod may be used as the positive plate. As previously noted, the stored material between the rod and the tank wall serves as the dielectric material. If the material is conductive, the effect is one of moving the tank wall into contact with the probe, and an insulated rod is required (see Figure 3). The insulation becomes the dielectric material, while the fluid and tank wall together function as the ground plate. Thus, the "capacitor" is re-established. If there is doubt as to whether or not to use an insulated rod, current practice suggests using one.

Capacitance Advantages. RF capacitance level measuring techniques have been in use for a long time, and they represent a well-known, time-tested approach. This method may be used with a wide range of liquids, powders, granular solids, and slurries, and on either conductive or nonconductive materials. Setpoints are adjustable and multilevel measurements can be made. Outputs may be on/off or continuous. Because capacitance measuring devices have no moving parts, maintenance is minimized. Corrosive materials may be measured using probes made of corrosion resistant materials. The interfaces of conductive and nonconductive liquids may also be monitored. Measurements are made at low energy levels that are harmless to operator, process, and environment. Various models of capacitance probes (rods) can fit contoured and tall tanks. Pressure and temperature capabilities reach 5000 psi and 1000°F.

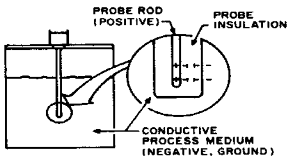

Figure 3. *Where conductive liquids are measured by capacitance methods, an insulated probe re-establishes the capacitor.*

Capacitance Limitations. Changes in the dielectric constant of the stored material will result in erroneous measurements; because the dielectric constants of some materials change with temperature, a dielectric compensated detector must be used. Capacitive systems usually require field calibration. Vessel level must typically be varied in order to calibrate the system. If extremely conductive materials are being measured, any build-up of material on the probe can affect accuracy or repeatability.

Because of the possibility of improper probe capacitance, the need for correct probe selection in complex applications, and the possibility that help will be needed in determining grounding configurations, the user should contact the level control system supplier early in the design process to ensure that the system is correct from the start and thus avoid the delays and added expense of an improper configuration.

ULTRASONIC

Although some references state that ultrasonic methods should be used only in point level measurement, this method works for continuous level measurement as well. There are two approaches: sending a sound wave through air, and sending a sound wave through liquid.

The level of the medium can be calculated by measuring the transit time for a pulsed sound wave to travel from a transducer downward through air and echo off the surface of the process medium (see Figure 4). This is called noncontact measurement because the transducer is mounted above the highest level of the medium. The technology is a good choice for media with shifting density, specific gravity, and conductivity, as well as for slurries, bulk media, and corrosive liquids. Transducer limitations, however, restrict applications to low pressure/low temperature.

In a variation of this method, a transducer is submerged in liquid and a pulsed sound wave is transmitted up through the liquid to echo off the liquid/air or liquid/liquid interface. The wave travel time is measured and converted to a liquid depth output (see Figure 5). Transducers may be top or bottom mounted. Higher pressures and temperatures may be monitored than is the case with the noncontact method, but applications are limited to clean liquids. In each approach, the transmitter output can track the level continuously or select predetermined setpoints for alarms and/or pump control.

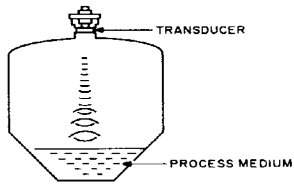

Figure 4. *Ultrasonic waves are reflected from the surface of liquids or solids, and the travel time is converted to a level output.*

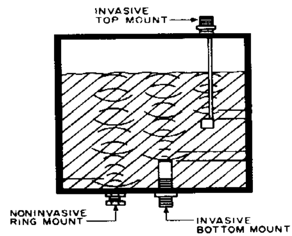

Figure 5. *Ultrasonic transducers may be submerged in the fluid. The liquid/air or liquid/liquid interface between liquids or differing densities reflects the waves.*

When only level alarm and/or pump control is required, a less expensive technique using different ultrasonic transducers can be substituted. As shown in Figure 6, a high-frequency sound wave is generated by a transmitting crystal positioned and focused at a receiving crystal mounted across a gap. When the gap is filled with liquid, the receiving crystal will generate an output at a level 200-400 × higher than it will with air in the gap. The presence or absence of liquid in the gap can thus be detected.

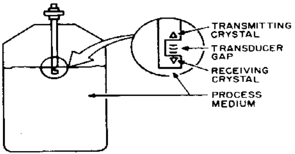

Figure 6. *A transmitting crystal generates a high-frequency sound wave to a receiving crystal mounted on the other side of a gap. Changes in the receiving crystal's output indicate the presence or absence of liquid in the gap.*

Time delay circuitry can be used to eliminate switch chatter caused by turbulence. Effervescent liquids can be monitored by means of transducers with built-in signal averaging circuitry. Sensing units are available for single and multiple set points.

Ultrasonic Advantages. Noncontact ultrasonic measurement is especially suitable for corrosive and dirty applications, as well as for liquids, slurries, and bulk solids. Continuous and multipoint measurement and control are possible. Accuracy is 0.25% of F.S. on transmitters and repeatable setpoints are obtainable with point sensors. Chemically compatible sensors are available. Ultrasonic operation is harmless to the process, operators, and environment, and Nema 7 housing can permit operation in hazardous atmospheres. Applications with a high degree of aeration or with suspended solids can be monitored with either noncontact sensors or devices incorporating signal averaging circuitry.

Ultrasonic Limitations. Ultrasonic noncontact units are not reliable in the presence of surface foam. Interference from falling liquids, steam, dense vapors, and dust can interrupt the output from noncontact transmitters. Bulk solids prone to bridging, ratholing, or shifting will impede the accuracy of noncontact transmitters. Crystalized build-up in the sensor gap will prevent point sensors from functioning reliably. Fluids must also be drained from the gap to reset the alarm relay.

SUMMARY

Textbook information must be teamed with experience and direct observation to select the right equipment and make the best use of it.

Special thanks to Magnetrol for this article. For more information contact local representative Provincial Controls.