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# Unraveling The Complexities of Level Detection

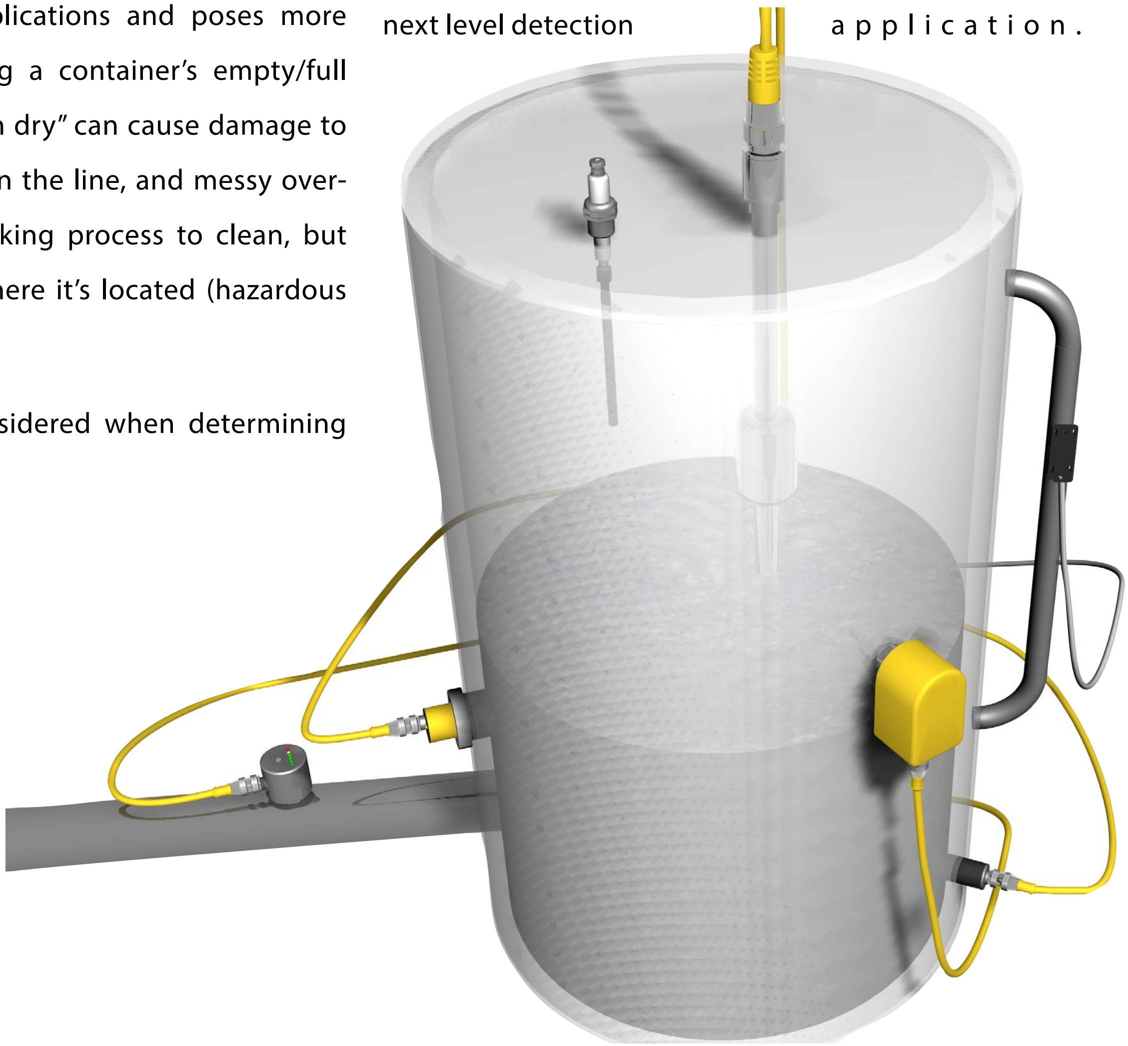
White Paper - W1015

# UNRAVELING THE COMPLEXITIES OF LEVEL DETECTION

When considering using sensors for level detection it is important to understand that no two applications are the same. This is essentially due to the wide-ranging amount of applications that require level detection. From food and beverage products like cookie dough, pancake batter and seasoning mix, to rocks and gravel, hot wax and glue. Practically all products produced during an industrial process application need to be monitored to determine level.

For many applications, accurately gauging level in a container has more implications and poses more risks than merely reporting a container's empty/full conditions. Medias that "run dry" can cause damage to other parts and processes in the line, and messy overfills are not just a pain-staking process to clean, but may pose risks involved where it's located (hazardous materials and locations).

Many factors must be considered when determining an application's sensing needs. The material used for the container, the media being sensed, and the environmental conditions the application consists of, merely touch on the variety of issues that must be taken into consideration. Only after careful examination can one determine the best sensing option and there are many options: from probe to capacitive to ultrasonic, sensors have been consistently finetuned and redesigned to encompass more and more application requirements. This variety of sensing options enables users to choose the sensor most appropriate per application. Making this choice is not often easy, and can easily become confusing. This paper will help you through the basics of what sensors are commonly used for level detection and considerations you should be aware of for your next level detection application.



# SENSORS FOR LEVEL DETECTION

Generally, there are two sensor categories for level detection: single point level detection and continuous level detection. Single point level detectors determine one point of the level of a media, whereas continuous level detection provides constant evaluation of the contained media.

### *Capacitive*

Capacitive sensors (Figure 1) can "see through" lower dielectric materials such as plastic or glass to detect higher dielectric materials, such as liquid. This allows capacitive sensors to detect the level of many materials directly through the wall of a plastic container, or by utilizing a sight glass or tank well for metal tanks

***Figure 1***

Capacitive sensors are also used to detect a wide variety of materials, for instance plastic pellets in a hopper for injection molding processes. Further, intrinsically safe NAMUR capacitive sensors are used in hazardous areas such as grain elevators, to detect materials ranging from rice and barley malt, to corn and soybeans.

Capacitance is a function of the surface area of two electrodes, the distance between the electrodes, and the dielectric constant of the material between the electrodes. Capacitive sensors work when two metallic electrodes (A and B) are placed in a feedback loop of a high frequency oscillator (Figure 2). When no target is present, the sensor's capacitance is low and the oscillation amplitude is small. When a target approaches the face of the sensor, it increases the capacitance and the amplitude of oscillation. The amplitude of oscillation is measured by an evaluating circuit that generates a signal to turn the output ON or OFF. Generally, the larger the dielectric constant of a material, the greater the achievable operating distance of the sensor.

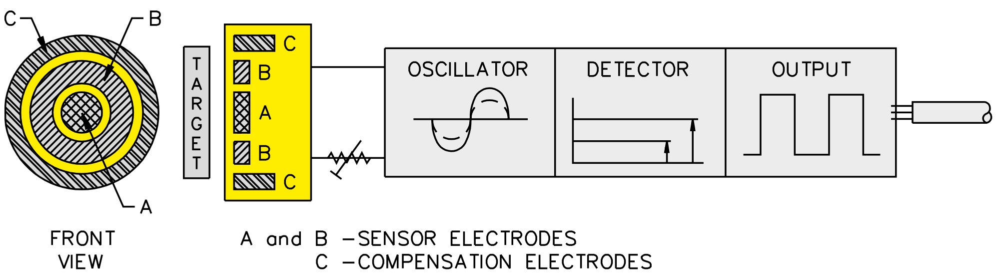



***Figure 2***

### *Ultrasonic*

Ultrasonic sensors (Figure 3) emit an ultrasonic pulse that reflects back from any object entering the sonic cone. Since sound has a constant velocity at

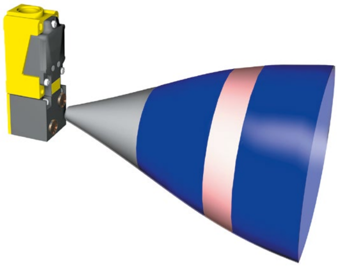


*Figure 3*

a given temperature and humidity, the time taken for this echo to return to the sensor is directly proportional to the distance of the object. The sensor's output status is dependent on the comparison of this time with the setting of the detection zone.

| | Continuous Level Monitering | Point Level |
|---|---|---|
| Capacitive Sensor | | ● |
| Hydrostatic/Pressure | ● | ● |
| Ultrasonic Sensor | ● | ● |
| Conductive Probe Sensors | | ● |
| R16/Float | ● | |

**Point vs Continuous Level**

| | High Viscos-ity | Low Viscos-ity |
|---|---|---|
| Capacitive Sensor | | ● |
| Hydrostatic/Pressure | ● | ● |
| Ultrasonic Sensor | ● | ● |
| Conductive Probe Sensors | ● | ● |
| R16/Float | | ● |

**High Viscosity vs Low Viscosity**

Ultrasonic sensors are typically mounted above a container and emit the pulse downward to detect the level of the contained media. Solids, fluids, granular and powdery targets can be detected by ultrasonic sensors. Both air temperature and humidity influence the pulse, and consequently change the sensor's rated operating distance. Note that hot surfaces reflect sonic waves less than cold ones, and ultrasonic sensors may not be suitable for use above turbulent areas.

### *Probes*

Magnetostricitive linear displacement transducers (LDT) provide continuous, absolute position detection. LDTs, (Figure 4) detect the position of an external magnet along the active stroke of a sensor without causing any wear on the sensor parts, providing longer and (potentially) better performance. Multiple LDT probe sensor variations increase level detection possibilities, including models with sanitary and intrinsically safe ratings for food, beverage and pharmaceutical applications.

*Figure 4*

Conductive probe sensors (Figure 5) detect empty and full conditions by extending two probes into a container and sensing the continuity between each rod and a reference point in the tank to determine the level of media in the container. In order for this single point detection to work, the media in the tank must be conductive. Conductive probes can also be used in applications to control the filling and draining of a container, or as high and low level alarms.

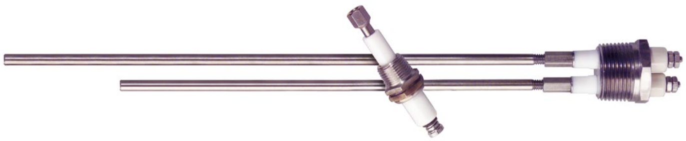


*Figure 5*

***Pressure***

Pressure sensors detect the level of media as it exerts pressure on the sensor. Generally used for liquid level detection, the sensor is able to continuously output this pressure reading that is easily converted to a liquid level. Pressure sensors can be externally mounted and therefore do not interfere with the internal contents of the container.

Pressure sensors are also available in submersible form. These submersible pressure sensors (Figure 6) feature a weighted cone or cage allowing the sensor to remain on the bottom of the container it is placed in. Submersible pressure sensors can be used in applications such as wastewater, pond levels, and fuel tanks.

*Figure 6*

# LEVEL SENSING CONSIDERATIONS

***Container***

This paper uses container as a generic term for anything used to hold a medium, whether it is a tank, cylinder or anything else used for this purpose.

MATERIAL

Containers can be made from plastic, glass, metal, steel and stainless steel, among other things. There is no real standard for the materials containers are made from, though the material used influences decisions affecting what mediums can be contained and what type of sensor can be used per container. For example, a capacitive sensor cannot sense through containers made from stainless steel.

SIZE

The size of a container is based on the application it is being used for. The size can range from very tall/short in height to very large/small in diameter, and includes cylinders, funnels, and other shapes designed for specific applications. The size greatly influences the types of sensor used, as well as the reaction time of the sensor and the rate of fluid change. Tall (height) and small (diameter) containers also have a faster rate of change than shorter/larger containers, which affects the sensor's reaction ability.

A sensor's applicability can also be affected by the size of the container. For instance, if a container is very tall with a small diameter some sensors will not work to sense levels within this container. Probes will not fit inside the container but many other sensors would work for this application.

SHAPE

A container's shape can also vary greatly depending on the application. From very tall/short in height to very small/large in diameter, the type of sensor used is totally dependant on the shape of the container and the user's demands. Shapes include cylinders, silos, funnels, and just about anything you can imagine to be used to contain something.

SPECIAL PROPERTIES

This includes instances where atypical container types are used to accommodate certain industry or medium (material being sensed) considerations. One such instance is double-jacketing containers for the food and beverage industry. This method is similar to a double-broiler, where a pressurized "jacket" is built around the actual container and is used to heat, cool and control the conditions of the liquid contained inside. It is extremely expensive to retrofit an existing container to do this. Note that industrial pressurized containers also entail extremely expensive retrofitting associated with recertification and downtime.

### *MEDIA PROPERTIES*

The gamut of materials being sensed is nearly insurmountable. Basically, if you can imagine a material, it is being sensed. From fine powder like flour and makeup [powders], to large broken rocks and boulders in a quarry, the type of media sensed has a profound impact on the type of sensor that can be used. Instances that produce a large charge of static electricity may render run-of-the-mill sensors inoperable. Media, like dust, can also permeate the sensor causing damage, and in some cases, extreme environmental wear can harm a sensor.

DRY

Grain elevators produce fine dust particles in the air that can result in explosive conditions. To function in this volatile environment, a sensor must be designed for explosion proof and/ or intrinsically safe environments. These sensors must be extremely rugged and able to resist extreme temperatures and flammability, in addition to being specified for hazardous locations.

Fine powders can also affect a sensor's operation. False outputs are possible if the powder permeates the sensor's housing. If fine powder accumulates on the outside of the sensor and is somehow affected by moisture (water, condensation, etc.), the ensuing buildup can inhibit the sensing field and prevent a sensor from properly functioning.

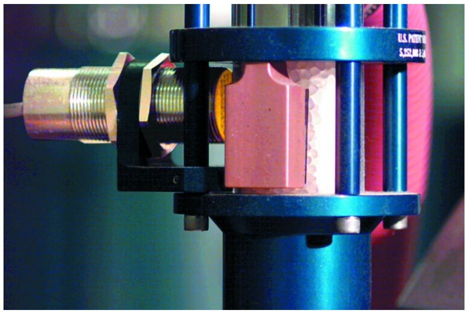


*Figure 7*

Elaborating on the quarry scenario, the size and weight of the media being sensed may also pose issues for the common sensor. When gravel, rocks or large stone (even boulders) are dumped and poured into a container, the sensor can be damaged by mere contact. It's easy to imagine media of this nature destroying or rendering a sensor in this environment useless. Sensors must be designed for extreme wear and harmful environments, in addition to careful placement (mounting), to withstand these conditions. Further, these conditions may also produce dust that, as previously mentioned, can harm the sensor.

The rapid transfer of plastic pellets in hoppers can cause high static electricity. When the transfer occurs for extended periods of time, as often found in said applications, a high amount of static electricity causes electromagnetic interference with the internal components of the sensor resulting in sensor failure. High static electricity in these applications can also cause the plastic to stick together, generating a false reading by the sensor, i.e. pellets "clumping" together can cause error in level detection.

*Figure 8*

LIQUIDS

Perhaps liquids produce the most adverse and challenging conditions for sensors. The term liquid is not an accurate statement to encompass all the media needed to be measured in this category. The better phrase? Anything that is not dry. From fruit cocktail to honey, to wax and liquid nitrogen, there is simply no norm. Stemming from that fact, there is really not a norm for sensor application in this realm, though there are ways to help one determine which is best suited per application. The viscosity of the media has a large impact on the type of sensor able to be used per application. Depending on the viscosity, the media may cling to the sides of the container or, when using a probe, cling to the actual probe and prevent the sensor from providing an accurate reading. Depending on the thickness of the media, some sensors will work better than others. For instance, probes work better for sensing honey, as the honey "pulls" off a probe more quickly than the sides of container.

Foamy media or those that produce foam when agitated also require special consideration when choosing a sensor. Not only is it extremely difficult for a sensor to detect foam through a container wall, the foam may also build-up on the container sides potentially causing sensor malfunction (i.e. foam dries on the container's sides). If using an ultrasonic sensor positioned over the container to detect liquid level, foam can easily flow over the container because the sensor is programmed to sense the liquid, not the foam level.

Product build-up is also a large consideration in these applications, as wax, glue and other adhesives can build-up on the sides of the containers and interfere with the flow and the sensors reading. Non-homogenous liquids, for instance fruit cocktail, can lodge and jam floats on probes and also cause sensor failure. Note that some capacitive sensors are designed to ignore this buildup.

Media that is allowed to change states will also pose issues for sensor reading. For example, a sensor that is programmed to detect hot wax will not necessarily detect wax that has been allowed to cool. Further, media that is hot enough to produce vapors may also pose problems and false reads for some [ultrasonic] sensors, as the vapors impede on the pulse and/or range of the sensor.

### *APPLICATION CONDITIONS*

The environment where an application is located is vital to consider prior to choosing sensors for level detection. Rugged and sanitary environments, temperature variables, and hazardous areas all require uniquely designed devices to withstand the rigors associated with each area.

#### SANITARY

Sanitary and hygienic environments, like those found in food, beverage and pharmaceutical industries require absolute cleanliness. These environments must maintain sanitary standards, for instance the 3A standard for dairy applications. Some of these environments, like breweries, are also subject to frequent washdowns by high-pressure and possibly caustic liquids to ensure cleanliness.

Sensors must be capable of operating in these applications, in addition to being rated for use in sanitary locations. Sensors are made from material compliant with these locations, and are sometimes fitted with special mounting mechanisms for increased usability.

#### TEMPERATURE

All sensors have temperature ratings; therefore a particular sensor's feasibility for an application is dependent on its rating and the temperature within the environment. Some sensors are better for extreme cold/heat better than others. As previously mentioned in this paper, ultrasonic sensors are affected by heat waves, therefore an ultrasonic sensor would not be effective if mounted above a media producing heat waves.

*Figure 9*

Some applications entail requirements that make sensor use unfeasible, for instance when frying potato chips in 400 degree oil. The oil produces heat waves that prevent ultrasonic sensors use, the sides of the metal container are too hot for capacitive sensors to be used, and the agitation caused by the dipping/frying action prevents accurate detection by other sensors. Another example includes a liquid being held at the freezing point actually freezing. Once frozen, the sensor will no longer be able to detect the liquid, as liquid and ice are measured (detected) differently.

#### AGITATION

Many level detection applications involved some measure of mixing and/or agitation to the media, and a sensor in this environment must be able to function around said disturbances.

Different processes negate the use of different sensors in these applications. If air is brought into the liquid at a high speed, for instance when mixing bread dough, air pockets will form within the media and potentially cause a sensor's misread. Further, low/high speed mixing may cause agitation that will cause [probe] sensors to false output.

Filling and mixing simultaneously can make nearly every sensor produce a false reading, for example when large/aggressive filling cause vortex formation. Further, when large quantities of fill cause spray, the sensor may pick up the spray and begin to measure the spray rather than level.

### *CONCLUSION*

Selecting the correct level detection sensor is a crucial decision for your application. These devices are used to ensure reliability of processes and prevent potential errors that could be caused from the former method of level detection: a person visually monitoring the operation. The time that must be dedicated for human monitoring in these applications can be inefficient and costly. Not to mention, the monotonous action or a simple distraction can lead to errors, making the use of sensors to detect level a cheaper and more reliable alternative.

This paper has begun to identify the numerous sensing tools used to detect level and potential instances where they may be implemented along with many of the considerations that need to be thought of before choosing which sensing tool is right for you. This should serve as a general guide for sensor's use in these applications and inform one about the complexities involved therein. The sheer variety of applications and materials being sensed requires close examination to make an informed decision in regard to sensing options. It is good practice to consult a sensing specialist, if on-staff, or other persons/resources well versed on this subject prior to sensor purchase.

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