Technology Review
Point Level Monitoring of Powders & Bulk Solids

Monitor Technologies, LLC.

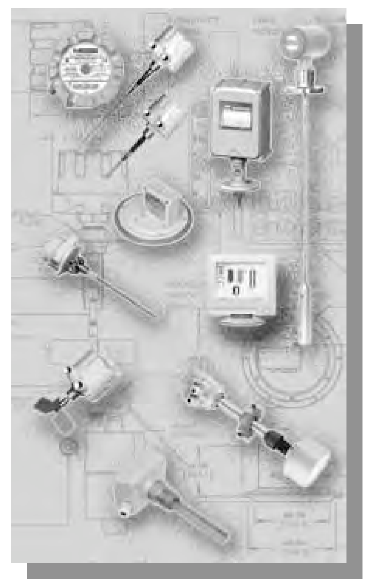
November 2005

Technology Review
Point Level Monitoring of Powders & Bulk Solids

Introduction

Point level monitoring is the detection of the presence or absence of material at a predetermined point in a bin, silo, hopper or any other type of vessel. This can be a liquid or bulk solid material, such as powders or granules. Most point level monitors are used to detect either a low or high level condition, though they can be used anywhere within the vessel.

The objective of this white paper is to educate the reader on the selection of point level monitoring technologies for specific applications to improve process efficiency, reduce up-front costs and minimize overall cost of ownership. This white paper will serve as a source of introductory training for the novice, as well as being an education update and refresher for the experienced engineer. The subject matter and discussion within this white paper is not designed to be industry specific. A variety of industry application examples may be provided.



Detecting the presence or absence of bulk solids requires knowledge of the target material to be detected and knowledge of the various sensor technologies available to address your specific applications. To aid in better understanding point level monitoring, we will:

1. Identify the characteristics of the "process" and "target material" that can influence sensor technology choice.

2. We will review the available sensor technologies discussing the principle of operation and "Pros and Cons" of each technology.

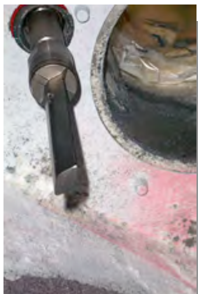
Process Characteristics Affecting Technology Choice

"Process characteristics" include details about the process that could impact the choice of a point level sensor technology as well as environmental details that might do the same. Let's review them individually, but they can also interact with each other or with "target material characteristics" to further impact our choice.

Flow of Material

The flow of the target material into and out of the vessel can impact sensor choice and create installation considerations. The usual issue in regards to the flow of material is whether or not the sensor can be mounted out of the material flow. Material falling onto invasive sensors can create false signals or even damage certain sensors.

In addition, the inlet and discharge locations impact the material "angle of repose", which is the shape of the material surface during filling or discharging. This may impact the chosen location of the sensor dependent on your objectives and process control needs.



Knowledge of your material flow inside your vessel and the contour of the material surface (angle of repose) as the vessel fills and empties is an important consideration. You should plan on choosing a sensing location based on your process control need and the flow profile of your vessel. In some applications you may not be able to mount the sensor at the monitoring point. Sensors that can provide extended lengths so that you can reach a monitoring point several feet below the installation location may need to be considered.

<u>Speed of Response</u>

How fast the material level changes in the vessel can impact the choice of sensor technology. Fast changing levels, typically present in continuous manufacturing processes where bins and hoppers are used for short-term material storage or accumulation, require fast responding sensors. This means electronic sensor technologies may be best suited.

For example, let's consider the hopper on a plastic injection molding or extrusion machine. A level sensor may be used to detect a low-level condition in order to trigger filling the hopper with raw material. Conversely, a sensor might be used to detect a high level condition (such as in a blending hopper) to provide an alarm and emergency shut-off if the material level gets too high in order to prevent material back-up and spills.

In these examples the speed at which the machine draws material out of the hopper, the hopper size and the hopper fill rate all determine how quickly the sensor and process control system must respond. Many times machines must run as part of a continuous process and the hoppers and feed system must not run out of raw material, or create back-ups and spills. The level sensors must be very reliable and respond accurately and quickly to a definitive change in material level. Delay of even several seconds could impact the process.

In addition, the speed of response of your filling system can impact sensor location. If a point level device is being used for high-level detection and controlling the filling of a vessel, the amount of material remaining in the fill pipeline after flow is stopped needs consideration when determining sensor monitoring location.

Surrounding Processing Equipment

Process equipment in the vicinity of the desired sensor mounting location may impact sensor choice and mounting. A bin vibrator or pneumatic hammer of some type may be used to assist with the flow of material out of a vessel. This is usually associated with powders in a storage condition.

When being filled pneumatically the flow of material into the vessel is a combination of air and material. As the material settles in a stored condition the air is forced out and the powder particles compact. The material becomes virtually like one solid mass. While we disagree with the solution employed in some situations, many industry applications will use a pneumatic, hydraulic or electric vibrator to impact the outside of the bin and shake the material into a flowing condition. It seems more plausible to inject air back into the packed material to place it in a natural flowing condition. However, many choose vibrators.

Vibrators too close to a proposed mounting location for a level sensor can create reliability and life problems for the level sensor and impact the appropriate choice of technology and product. This vibration can be violent in nature when too close to the level sensor and can literally shake the sensor or its components apart. Level sensors that must be mounted in these installation conditions necessitate remotely mounting electronics in a split-architecture scheme to remove the sensor electronics from the area of violent vibration.

Access

The location of the monitoring point should be considered. This includes the location of the vessel, the predetermined monitoring point, sensor mounting location as well as the surrounding obstructions at the desired mounting location. If the level sensor will be mounted in a very difficult to reach location this may warrant a sensor with extremely high reliability and long life. Tight clearances and surrounding obstructions may necessitate compact sensor technology.

Process Control

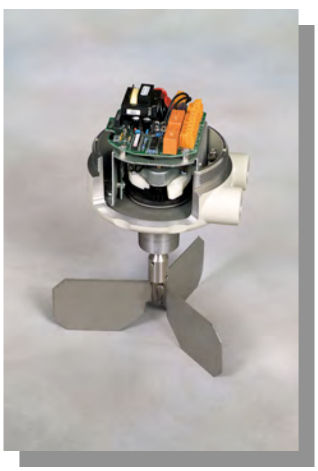
In this area there are three topics that come to mind. The “Output” required, the “Critical Nature” of the level sensing, and requirements for “Local Indication”.

Output: What you will be doing with the sensor signal when material presence or absence is detected should be determined. In fact, is it material presence or absence in which you are interested? Most point level sensor output is a relay or electrical switch capable of passing current of at least 5 amps through its contacts. What form of contact closure do you need? Most sensors will provide a SPDT output with a normally open and a normally closed contact. Other sensors will provide an electronic solid-state closure capable of passing <500mA of current.

Choosing the N.O. or N.C. contact (relay, electrical switch or solid state) will depend on your need. Relay contacts can typically be used to pull in other control relays, motor starters, or simply provide a digital input to a PLC or other control system. Solid-state electronic closures are just used as digital input to a control system.

Critical Nature: The critical nature of the level detection is important to assessing the level sensor technology and even the specific brand. The more critical the level sensing application, the more important sensor performance and reliability becomes. If a sensor failure substantially impacts your profit, creates extensive maintenance expenses, significantly degrades your product or process quality, then this will likely influence the sensor technology you choose, such as the need for a "fail-safe" device. It also can determine the price range you can expect to pay for the sensor.

Let's briefly explain what "fail-safe" means. A "fail-safe" level sensor is one in which the output of the sensor will be placed in a "safe" condition or state in case of sensor failure. There is a varying degree of fail-safe sensors. The vast majority of point level sensors that claim to have a "fail-safe" output simply mean that the output will change state into the "alarm" or "activated" condition should power to the sensor fail. However, this provides limited protection, as it will not necessarily help you should the level sensor fail for any other reason.



Some technologies lend themselves to providing a more complete "fail-safe" design where sensor functionality is monitored along with providing "fail-safe" output in the even t of power supply failures to the sensor. One such example is the fail-safe rotary paddle bin level indicator shown here. In this sensor one of the primary elements in the sensing scheme is continuously monitored for proper functionality by using Hall Effect sensors in a patented manner. The condition of the primary element is analyzed by a microcontroller and the health status of the unit is determined. This unit is capable of providing a separate relay output and local indication of a detected sensor failure, not just failure of the input power supply.

In addition, performance and reliability is somewhat related to the sensor technology and also related to brand. Applications requiring the highest degree of reliability may lead to a solid-state device rather than a mechanical or electromechanical sensor. However, don't forget to consider the fail-safe nature of the device as mentioned previously. The ability to detect a sensor failure and provide an immediate warning can provide high value in your process.

The cost of process problems or lost profit due to a sensor failure may far outweigh the initial expense for the highest possible degree of level sensor performance and reliability.

Local Indication: If the level sensor is being mounted in an area where local indication is feasible then this may be a good idea. Some level sensors today are available with high intensity LED indicators that will provide information at a glance, i.e. power is on, material is detected or absent and whether or not the unit is functioning properly. This type of local indication can be advantageous and inexpensive. Many level sensors include this as a standard feature.

Environment

The environment that a level sensor will find itself in has an impact on the choice of technology to be used. This includes evaluating the planned location of the sensor, the temperature and pressure inside the vessel, the ambient environmental temperature the unit is expected to work in, as well as the electrical area classification for safe operation.

Location: The physical location of the level sensor can dictate the type of sensor to be used. Top or side mounting, amount of access, physical space and the type of process connection are all aspects of the "location" of the sensor and should be considered.

Internal Vessel Temperature: The range of temperature expected within the vessel is a critical parameter that needs to be considered. Most level sensors are going to be mounted such that they are invasive. This means that the internal vessel temperatures will be in direct contact with the exposed sensor mechanism, such as the sensor probe on a RF capacitance sensor.

Internal vessel temperatures, such as those found in asphalt hot mix silos, will conduct through the probe material and also through the vessel walls and the sensor mounting connection. The internal vessel temperature can radiate off the vessel wall and impact the surrounding ambient operating temperature of the external sensor components such as their electronics mounted within the sensor housing. All sensors will have a range of internal process temperatures that can be tolerated and these must be closely evaluated. Problems can occur at the extremes of these process temperature ranges (the extreme hot and cold), primarily because of the impact of these temperature extremes on electrical and electronic components. Temperature extremes may also conflict with ratings for various materials use in the manufacture of the level sensor.

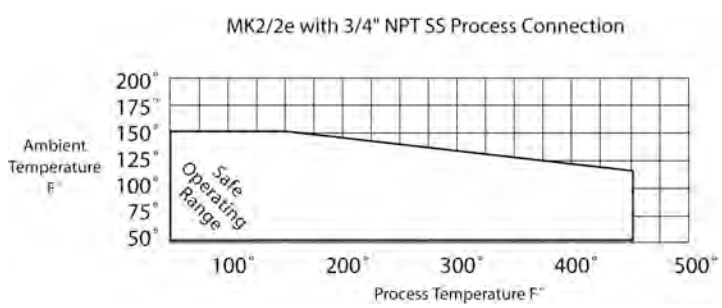
The internal vessel temperatures and the external ambient operating temperatures of the sensor must be assessed together as they are interdependent and impact each other. Refer to "Ambient Operating Temperature".

Internal Vessel Pressure: Internal vessel pressures can impact the choice of level sensor. In most powder and bulk solids applications this is not a concern. Most vessels are vented or are only periodically under pressure, such as when in a filling or discharging condition.

Pressures in powder and bulk solids applications tend to be very low, i.e. <30psi (2 bar). However, higher pressure can exist and this process parameter should be checked and considered during the level sensor selection process to ensure that the sensor is suited to the process environment and will perform accurately and reliably for a reasonable lifetime.

Ambient Operating Temperature: The ambient operating temperature is a concern usually when the vessel is located outside a controlled environment, such as outdoors, or when the internal vessel process temperature effects the ambient condition for the sensor. In many geographic locations extreme environments can exist, both hot and cold. Level sensors must be capable of operating accurately and reliably as specified for a reasonable life expectancy within the installed environment.

Environments can produce ambient operating temperature highs of >100°F (38°C) and also <0°F (-18°C). A single level sensor can easily be subjected to both extremes within the span of a year. In addition, ambient air temperatures can be deceiving. A temperature high of 110°F (44°C) during the summer in southern Arizona, USA could actually produce ambient temperatures seen by the sensor electronics in excess of 125°F (52°C) in the direct sun. In addition, the critical nature of process and ambient operating temperatures can be seen even more dramatically as they are considered together.



Choosing level sensor technology must consider the combined effects of process internal vessel temperature and external ambient operating temperatures. This chart illustrates the safe operating range of a level sensor, considering the effects of both ambient operating temperature and internal vessel (process) temperatures. It is obvious and critical that brand and technology requires close evaluation to ensure that the selected sensor is properly matched with the application.

Electrical Classification: The environment in which the level sensor is installed must be examined as to its electrical area classification in accordance with the NEC or other governmental regulations that control and dictate this type of issue. In the USA, area classification is determined by the National Electric Code (NEC).

Areas are generally classified as Ordinary or Hazardous. Most all sensors can be installed in areas classified as Ordinary, however, sensors that are required for installation in Hazardous areas require special electronic and enclosure designs and must be tested and certified to meet NEC standards for the specific type of Hazardous area.

Careful examination of product specifications, agency approvals and specific application requirements is necessary to ensure plant and personnel safety when dealing with any hazardous area. Hazardous areas in the USA are categorized by "Class", "Division" and "Group" as follows:

- ❖ Class I or II; Class I environments exist where the explosive material is in gas or vapor form. Class II environments deal with explosive dusts.
- ❖ Division I or II; Each Class environment is separated into Divisions. The Divisions indicate how likely or prevalent the hazardous gas, vapor or dust is prevalent. Division I environments are those where the hazardous gas, vapor or dust is present during normal operation and ignitable concentrations are likely to exist. Division 2 environments are where the hazardous gas, vapor or dust is not necessarily present during normal operation but may exist in flammable or explosive concentration due to equipment failure or maintenance. Consult the NEC or other regulatory information for further definitions.
- ❖ Groups A, B, C, D, E, F and G; The Group designation defines the MESG (Maximum Experimental Safety Gap) for various hazardous materials. The MESG is the maximum dimension in which an explosion on the inside of an enclosure will not propagate flame to a flammable mixture on the outside of the enclosure. The more hazardous the material, the less the MESG and the lower the Group letter (A is the lowest letter with the smallest MESG).

Physical Vessel Attributes

There are a few aspects of the vessel that need to be considered as they can impact the selection of the sensor. These include internal obstructions, insulation jacketing, concrete vessel walls, a liner of ceramic or glass and non-metallic vessels. The impact from some of these is obvious. Mounting concerns need to be thought of before choosing an appropriate sensor technology.

Material Characteristics Affecting Technology Choice

"Material characteristics" include details about the target material that could impact the selection of a point level sensor technology. These characteristics include Particle Size, Bulk Density, Dielectric Constant, Corrosiveness, Abrasion and Packing/Clinging. We'll review them individually, but remember that they can also interact with each other or with "process characteristics" to further impact our choice of technology.

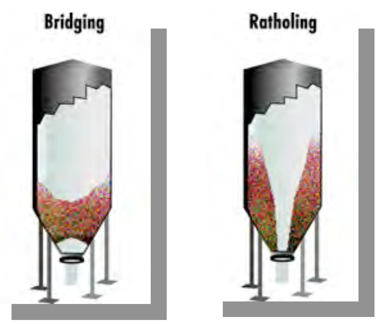
Particle Size

The primary concerns in regards to the particle size of the material to be detected has to do with:

- Physical damage or deformation of the sensor.
- Sensor surface contact, which can affect the sensor's ability to detect the material (overall dielectric constant).
- Flow of the material around the sensor (will the material pack or bridge in proximity to the sensor).
- Dust

Physical Damage: Large aggregate material, such as coal, can be heavy and also have ragged sharp edges. Some sensor technologies can suffer damage by heavy aggregate material, especially if the material collides with the sensor during filling.

Surface Contact Area: Some sensors' ability to detect material is based upon the dielectric constant of the material (discussed later in more detail). The amount of physical contact between the material and the sensing element can effect the overall dielectric constant and the ability of the sensor to detect this type of material.



Material Flow: The ability of the material to flow around and away from the sensor is an important characteristic for most sensors. Mechanical diaphragm, vibratory and RF capacitance sensors all have some limitations in this area. In addition, even the most common electromechanical sensor may provide a false detection if material bridging and packing occurs around the sensor. One other consideration is the ability of the target material to flow and discharge readily. Conditions such as "ratholing" and "bridging" can occur and create false readings and other problems. These situations may require a solution to the flow problem before reliable level detection can occur.

Dust: Many materials with very fine particle size (powders) create dust during filling or discharging. The level sensor will need to suffer no ill effects from this dust and must be capable of operating within this environment and with dust coatings on the sensor surface. Cement powder and flour are two good examples. Both can leave a coating on the sensor and can also have flow problems during discharging from the vessel. These materials, and other fine particle powders, contain a large amount of air mixed in with the material during filling of the vessel. As the material settles, the air is displaced by the heavier material and the material packs, becoming virtually a solid mass.

Bulk Density

The bulk density of the material is related to its volume and weight. Typical bulk density values are in terms of lbs/ft^3 (pounds per cubic-feet), kg/m^3 (kilograms per cubic-meter) or g/cm^3 (grams per cubic-centimeter). The material bulk density affects sensor choice in the following ways:

- Physical damage or deformation of the sensor.
- Mechanical or electromechanical sensing limitations.
- Dielectric constant.
- Damping effect.

Physical Damage or Deformation: As with the particle size, some sensor technologies can be damaged or impaired by the weight of the target material. This includes impact damage during filling and also the stresses associated with side loading on top mounted extended probes as material moves and shifts during filling and discharging.

Mechanical/Electromechanical Limitations: Sensors activated by mechanics may have limitations in regards to the tolerable weight of the target material, such as standard diaphragm switch units. In addition, the bulk density of the material and the particle size affects the choice of paddle for rotary paddle units due to the requirement of the material to stop the rotation of the paddle.

Dielectric Constant: The dielectric constant and material bulk density are sometimes related. A general rule of thumb employed is that the lighter the material, the lower the dielectric constant. The reason for this is that light materials tend to have more entrained air per cubic foot/meter/centimeter. Therefore, very-light materials can be difficult to sense for technologies that are affected by the dielectric constant of the material such as RF capacitance.

Damping Effect: Some technologies require the weight of the material to actuate the sensor. The diaphragm switch is a pressure-activated switch. There is a minimum bulk density or weight to activate the unit and a maximum value (over the maximum may damage the switch). Solid state vibratory type sensors use the damping effect of the material to change the frequency of the probe vibration, thereby allowing the electronics to sense the material. Typical vibratory sensors have low-end density limits and are not typically used with heavy materials (>50 lbs/ft^3 / 800 kg/m^3) unless top mounted.

<u>Dielectric Constant</u>
The ε_r (epsilon r), or dielectric constant, of a material has impact on the choice of technology, specifically in regards to RF capacitance sensors. The dielectric constant also can have affect on radar technologies. However, this technology is used for continuous level measurement and not point level detection.

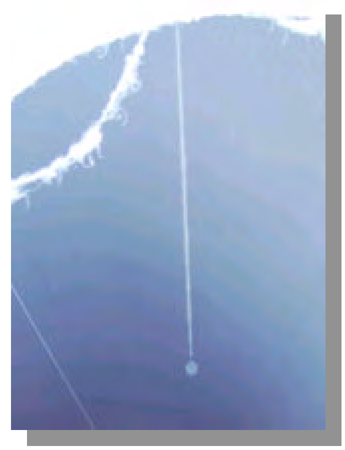
The dielectric constant determines the ability of a RF capacitance sensor to detect the material. State-of-the-art grade sensors will be able to detect a change in capacitance value as small as 0.5pf (picofarads). The amount of capacitance change created by the presence of a material is dependent upon its dielectric constant.

Each material has a different dielectric constant and it can vary depending on moisture content. Any variation in dielectric constant can affect the sensor's ability to perform, based upon its calibrated state, which is tied to the specific dielectric constant at the time of calibration. RF capacitance sensors must contain enough sensitivity to allow them to be calibrated to deal with materials having low dielectric constants (many powders and plastics), or if the dielectric constant varies frequently (such as with changes in moisture content).

While radar (microwave) technology is not applied in point level detection sensors, it is used for continuous level measurement. The dielectric constant of the target material impacts a continuous radar sensor in the ability of the material to reflect the radar pulse or signal. The lower the dielectric constant is, the less reflection will occur.

Corrosiveness & Abrasion
These two material attributes primarily effect the sensor choice of materials of construction. They somewhat effect technology universally. However, some sensor technologies may have more limitations than others may, and one may not be suitable for a material considered generally to be abrasive or corrosive. Chemical compatibility with materials of construction must be considered to ensure proper operation and reasonably long-term reliability.

Packing/Clinging
Many materials, especially powders and other solids with high moisture content, can pack or cling to invasive sensors creating a build-up of material on the sensor probe element. This can create a challenge for the level sensor to distinguish between the material build-up and the presence of material level. Some plastics applications can also create stringy "angel air" within the internal environment of the vessel that can become attached to probes, extensions and cables.



Sensors operating in these types of environments where build-up can occur require proper selection. The technology needs to be able to either ignore the build-up or not be effected by it at all.

Other Characteristics (Process and/or Material) Affecting Technology Choice

I feel it worthwhile to highlight one other characteristic that exists in certain applications that can affect the choice of sensor technology. This characteristic is "static discharge". Static discharge can exist in certain applications, especially those dealing with plastics.

Plastic material conveyed via pneumatic medium builds up substantial static electricity. This potential energy can discharge to probes and extensions of sensors extending into a vessel.

It is critical that electronic sensors be properly grounded to the vessel and that the vessel be properly grounded to a good earth ground. RF capacitance sensors in particular are sensitive to static discharges. However, good design eliminates this as a cause of failure. If you have this type of environment, consult with your supplier about the design of their RF unit and whether there is adequate static discharge protection.

Available Sensor Technologies

There are generally six technologies used for detecting the presence and absence of powders and bulk solids. We will review the principle of operation and application guidelines of each of these:

- Pressure Sensitive (Diaphragm Switch)
- Tilt Switch
- Rotary Paddle
- RF Capacitance
- Capacitance Proximity Switch
- Vibratory

LEVEL MONITOR QUICK REFERENCE CHART

PRODUCT TECHNOLOGY	MATERIAL			DENSITY				TEMP		
	Solids	Slurries	Liquids	1.5 - 5 lb/ft³	5 - 15 lb/ft³	15 - 35 lb/ft³	35+ lb/ft³	Low	to 300°F	> 300°F
Rotary Paddle	▼			●	▼	▼	▼	▼	▼	▼
RF Capacitance Probe	▼	▼	▼	●	●	▼	▼	▼	▼	▼
Proximity Switch	▼	●	●	●	●	▼	▼	▼		
Vibratory Probe	▼	●	●	▼	▼	▼	●	▼	▼	
Diaphragm	▼				●	▼	▼	▼	●	
Tilt Switch	▼				●	▼	▼	▼	●	
Ultrasonic	●	●	●		●	●	●	▼	●	
Cable-Based Smart Sensor	▼	▼	▼	●	▼	▼	▼	▼	▼	●

▼ = Applicable ● = Consult Factory

Pressure Sensitive Diaphragm Switch

These level sensors are fairly low in cost and do not require any power supply in order to function. They have a fairly long life expectancy in simple applications where the material is not abrasive, corrosive, sharp or extremely heavy.

Operating Principle: A diaphragm switch bin monitor provides level indication by detecting pressure applied by the bulk solids material to the sensing diaphragm. The unit is installed to a vessel wall so that the diaphragm is exposed to the material to be sensed. As material contacts the diaphragm, a force is exerted through the diaphragm to a pressure plate within the diaphragm switch. Physical deflection of the pressure plate activates an internal switch, which is user accessible for signaling alarms, lights or PLC inputs. When material recedes from the diaphragm, a light duty spring returns the pressure plate and internal switch back to their original positions.

Application: The diaphragm switch is used in feed and grain applications for low-level indication, screw-conveyor back-up protection, plugged chute detection, low level detection in aggregate bins and many other applications.

Pros
- Low profile mounting is unobtrusive.
- No power required for operation.
- High current rating (15A) of switch contact
- Low cost and very economical.
- Easy to install and setup.
- Relatively long life when properly applied.
- Hazardous location designs available.

Cons
- Material must be dry and free flowing.
- Sensitive to abrasion.
- Mechanical, moving parts.
- Not used for light materials (<15 lbs/ft^3 / 240 kg/m^3)
- Use in non-pressurized vessels only.
- Typical internal bin temp <200°F (94°C) max.

<u>Tilt Switch</u>

Tilt switches are also fairly low in cost and do not require any power supply in order to function. They have a fairly long life expectancy, depending on installation practices and the material to be detected. They are suspended from the top of the vessel by a chain, cable or some other means. They are used solely for high-level detection.

Operating Principle: A tilt switch provides level indication by detecting the angular position of the tilt switch enclosure. Typically the unit is suspended above the material to be sensed. Internally, some brands use a mercury-filled microswitch mechanism. However, another method of detection available is the use of a steel ball centered over a switch resulting in switch closure when not tilted by the material. As rising material contacts the tilt switch (or the extension actuator) the enclosure begins to tilt. When the enclosure body is tilted at an actuating angle, typical around 17°, the steel ball rolls off center, reversing the switch contact state. As material falls away from the switch enclosure body (or the extension actuator) and the unit becomes upright, the ball returns to its original centered position, once again causing a change of state in the switch. The change in the state of the internal switch is user accessible for signaling alarms, lights, or interfacing with a PLC.

Application: Tilt switches are used for high-level detection only. This is due to the fact that the target material must build up underneath the switch and tilt it in order to actuate the switch mechanism. Tilt switches can be used in a variety of applications and with many different types of materials, including those in the density area from >15lbs/ft_ (>240kg/m_). Typical applications include high-level detection in aggregate piles, under or over loading on mechanical belt conveyors and high-level detection of grains within elevator silos.

Pros
- Low cost and very economical.
- No power required for operation.
- High current rating (10A) of switch contact.
- Rugged with low maintenance.
- Easy to install and setup.
- Hazardous location designs available.

Cons
- High-level detection only.
- Mechanical, moving parts.
- Not used for light materials <15 lbs/ft^3.
- Use in open piles or non-pressurized vessels only.
- Typical internal bin temp < 200°F (94°C) max.

Rotary Paddle

The most commonly used technology for powder and bulk solids applications is the rotary paddle or “bindicator”. Many users attach the term “bindicator” to all bin level indicators for powders and bulk solids, however, the rotary paddle especially. This relates to the Bindicator® brand recognition levels (Bindicator® is a registered trademark of The Bindicator Company and Venture Measurement). However, over the decades the name has become generic and synonymous with bulk solids bin level indicators.

Rotary paddle level sensors are electromechanical devices that today are reliable, virtually universal in application and still fairly cost effective. Life expectancy and maintenance is brand dependent as some major design and quality differences do exist. Applications include both high and low-level of virtually any powder and bulk solid material.

Operating Principle: The operation of a rotary paddle level sensor is fairly simple. The unit is installed through the wall of the vessel, so that the paddle protrudes inside the vessel. A small electric motor drives the paddle, which rotates freely in the absence of material. When the paddle is impeded by material a switch is activated signaling that the material is present. When the material falls away the switch changes state and indicates an absence of the material once again.

There are differences in operation between the brands available, most nuances in design. However, one significant difference in the operating principle is in regards to the shut-off of the motor during times when the material is present and the paddle is impeded. Most units installed today stall the motor under power and rely on the motor gearbox to withstand the stalled torque to protect the motor. However, some brands will disconnect power to the motor when the material is present and impeding the paddle from rotating, and then reconnect power when the material is absent thereby allowing the paddle to rotate again. Vendors claim advantages in both designs, however, it appears that the motor shut-off approach is by far the most reliable in the long-term.

Application: Rotary paddle technology is as close to being a universal point level technology for powders and bulk solids as you can get today. These devices are used on powders as light as 5lbs/ft^3 (80 kg/m^3) and with heavy aggregate and powders over 100lbs/ft^3 (1600 kg/m^3). The principle of operation is simple and a wide variety of paddles, extensions and even high temperature designs allowing the unit to be used in applications up to 750°F (399°C) are available. Rotary paddle units are used for both high and low-level detection in a wide range of industries including plastic processing, chemicals, feed, grain processing and storage, food processing and baking, minerals, aggregates processing to name just a few. They can also be used in hazardous areas with explosive or flammable vapors and dusts.

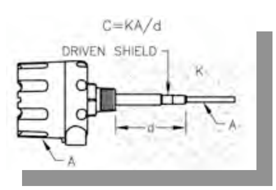
Pros
- Simple operation.
- Wide range of applications.
- Rugged construction.
- Variety of accessories and options.
- Low cost and economical.
- Easy to install and setup.
- Wide range of power supply options.
- Hazardous area ratings.

Cons
- Electromechanical, moving parts.
- Not good for materials <5lbs/ft^3 (80 kg/m^3)
- Some prone to frequent motor failures.

<u>RF Capacitance</u>

These sensors are solid-state devices and are in wide use today in a variety of powder and bulk solids applications. State-of-the-art designs offer a high degree of reliability and offer features to simplify setup and improve universal applicability. Their primary limitation is based on the dielectric constant of the target material. RF capacitance sensors are mid-range priced starting around $330 (US). High-end RF capacitance sensors can cost >$700 (US).

Operating Principle: A radio frequency is applied to the probe and is continuously analyzed to determine the influence caused by the surrounding environment. As material contacts the probe, the radio frequency shifts resulting in an increase in capacitance (C).



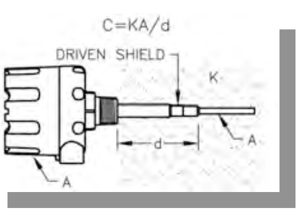
The sensor's active probe and the vessel's wall makeup the two plates (A = area) of a capacitor which are separated by a fixed distance (d). The probe's insulator and surrounding air provide the dielectric material (with dielectric constant "K"). As the air (K = 1.0) is displaced with any other material (K > 1.0), the capacitance effect (C) is enhanced, thereby changing the application's impedance.

The changing impedance is measured within the sensor's electronic circuitry and compared to a reference established by the sensitivity setting. The setting determines how much influence must be present before the output changes state.

Application: The use of RF capacitance sensors has become somewhat universal. They are used on a variety of powders, liquids and slurry materials. Application limitations have primarily been related to the dielectric constant of the target material. As can be seen from the discussion on the operating principle, if the material changes the sensor's ability to detect the material could change as well.

RF units are calibrated to the specific application thereby "tuning" the device to the actual dielectric of the target material. However, dielectric constant can change with changes in moisture content, humidity levels, etc. In addition, some applications require detecting different materials within the same vessel (Day 1 = Material A; Day 5 = Material C, etc.). In these applications an RF sensor could be calibrated to the material with the lowest dielectric constant in order for it to work with all materials.

Another application consideration is material build-up or coating on the probe. Material build-up typically occurs at the vessel wall where the sensor protrudes inside, but some materials can cling or coat the entire length of the probe. RF capacitance technology cannot necessarily differentiate between build-up of material and the actual presence of material level. This means that build-up can create a "false" detection and signal of material presence. However, an adaptation to the probe and electronics has been employed by some brands to deal with this problem and provide automatic immunity to material build-up. This adaptation is generically known as a "driven shield". Here's how it works:



The driven shield section of the probe enables the electronic circuitry to ignore product build-up on the probe that would otherwise cause false sensing. The driven shield is activated with the same radio frequency potential as the sensing probe. Since current cannot flow between identical potentials, the driven shield blocks current flow from the active probe to the vessel wall through the material build-up, thereby eliminating the sensing of the material build-up.

Pros
- Solid-state operation, no moving parts.
- Proven technology and reliable.
- Wide range of applications.
- Rugged construction.
- Variety of accessories and options.
- Easy to install and setup.
- Wide range of power supply options.
- Hazardous area ratings.

Cons
- Requires tuning to applications.
- Dependent on dielectric constant.
- Review use on light materials.
- Some require frequent re-calibration.
- More expensive than rotary paddle.

Technology Review
Point Level Monitoring of Powders & Bulk Solids

Capacitance Proximity Switch

These level sensors offer the advantage of being very compact and low in cost. They are solid state devices operating similarly to a RF capacitance sensor. They are used in applications where the material is dry, free-flowing and require a solid-state output.

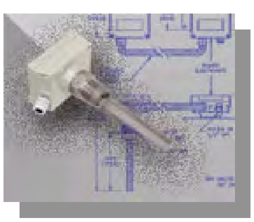
Operating Principle: Capacitance proximity switches operate by detecting the electrical effect of the material surrounding the sensor inside the vessel. A radio frequency is applied to the proximity switch sensing region and is continuously analyzed to determine the influence of the surrounding environment. Since all materials have dielectric constants and conductance values that are different from that of air (material absent condition), the resultant impedance seen by the radio frequency changes whenever material approaches or contacts the sensing region. This influence is measured within the circuitry and compared with the reference point set by the sensitivity adjustment, which determines how much influence must be present before the output changes.

Application: Proximity switches are solid-state devices used to detect the presence or absence of a variety of powder and bulk solids. They are used in applications where the target material is dry and free-flowing, as the switch cannot tolerate build-up or much of any dusting on the sensing part of the switch. They are used in applications where their compact design is an advantage, such as in small hoppers and bins.

Pros
- Solid-state operation, no moving parts.
- Proven technology.
- Compact, fits in tight spaces.
- Low cost.
- Easy to install and setup.

Cons
- Requires tuning to applications.
- Dependent on dielectric constant.
- Review use on light materials.
- Cannot tolerate build-up.
- Only solid-state output, no relay.

Vibratory



These level sensors are solid-state and operate on a wide range of powders and bulk solids, as well as liquids and slurries. However, units designed for solids will not necessarily operate on liquids or slurries. The sensors typically provide relay output and do not require any calibration to tune the unit to the application. They are priced moderately, more than other level sensors.

Operating Principle: These level sensors use a mechanism to vibrate their probe at some frequency and then look for the effect of the target material on the frequency or amplitude. Many of these sensors use piezoelectric technology. Here's how this works:

Two piezoelectric crystals are located in the probe, typically at the base near the mounting connection. A signal is applied to one of the crystals at the frequency corresponding to the probe's self-resonance. The electrical signal applied to the crystal results in a physical deformation of the crystal, which causes probe vibration. With no material present in the vessel and in contact with the probe, the second crystal feels the vibration. This vibration causes the physical deformation of the second crystal, which generates a voltage to be analyzed by the electronics. With material present and around the probe the vibration is dampened, thereby minimizing the voltage generated by the second crystal. The output voltage is analyzed by the electronics, and the relay output status changes accordingly.

Application: Vibratory probes have the advantage of not requiring tuning or calibration and being able to sense a wide variety of materials, including materials as light as 1.5lbs/ft^3 (24kg/m^3). However, build-up and coatings can be a problem depending upon how heavy they might be. Generally, any application where the solid may build-up on the probe should be avoided. Applications range from polystyrene beads to heavy clay. Vibratory probes are ideal where changes in vessel contents is common since these sensors don't require calibration.

Pros
- Solid-state operation, no moving parts.
- Proven technology.
- No calibration required.
- Easy to install and setup.
- Handles light weight, low dielectric material.
- Easy to install and setup.

Cons
- Not tolerant of material build-up.
- Moderately expensive.
- Sensitive to mechanical deformation.

Conclusion

The choices of technologies for point level sensors abound. They include older mechanical and electromechanical devices, as well as newer solid-state electronic technologies designed to overcome the problems of the old technology. However, the older units are still out there performing well and being consumed by users in large numbers. Vendors have continued to invest in evolving the older product lines, as well as developing and evolving newer solid-state devices.

There are several application parameters to consider in order to ensure a proper selection. We reviewed these parameters. We also reviewed each available technology. The review of each technology included a listing of Pros and Cons. Once we identify the available technologies that will work in an application, how do we make a final decision?

Technology Review
Point Level Monitoring of Powders & Bulk Solids

It is a buyer and users market. There are numerous suppliers and multiple technologies for most applications. Is price the only way to make a final selection? No. Here's what is suggested. First, create a short list of possible suppliers. Next, evaluate these suppliers and their products for whether they offer a solution to your application. Check specifications carefully, and verify. Look for the highest value.

Your decision is likely to be based upon the following:

- Personal Preference: Each of us is influenced by the previous experience we may have had with a specific technology and brand. Keep in mind that there can be a wide range of performance and quality differences amongst brands and in some cases a problem may not be associated with the technology but rather with the brand. Keep an open mind.

- Perceived Durability: We all want a device that is easy to install and setup, never requires maintenance and lasts forever. This is not necessarily a realistic expectation, but you should expect a reasonable warranty of two years and you can examine a vendor's commitment to quality by reviewing their quality certification. Those that are ISO 9001 certified have invested time and money, and have developed a culture of quality in design and manufacture. These vendors may also be far more committed to customer satisfaction as well, due to the requirements of the ISO standard.
- Lowest Cost: Cost can also be a major driver in the decision process. This is usually the initial purchase and installation cost. Once the Pros and Cons have been evaluated and the vendors have proven their products through presentation and possibly a trial in your application, there is no other criterion besides cost. You should choose the most economical option that fits your application and your most important needs.

Regardless of which technology you finally select, remember to closely follow manufacturer's guidelines and recommendations to avoid problems and frustrations.