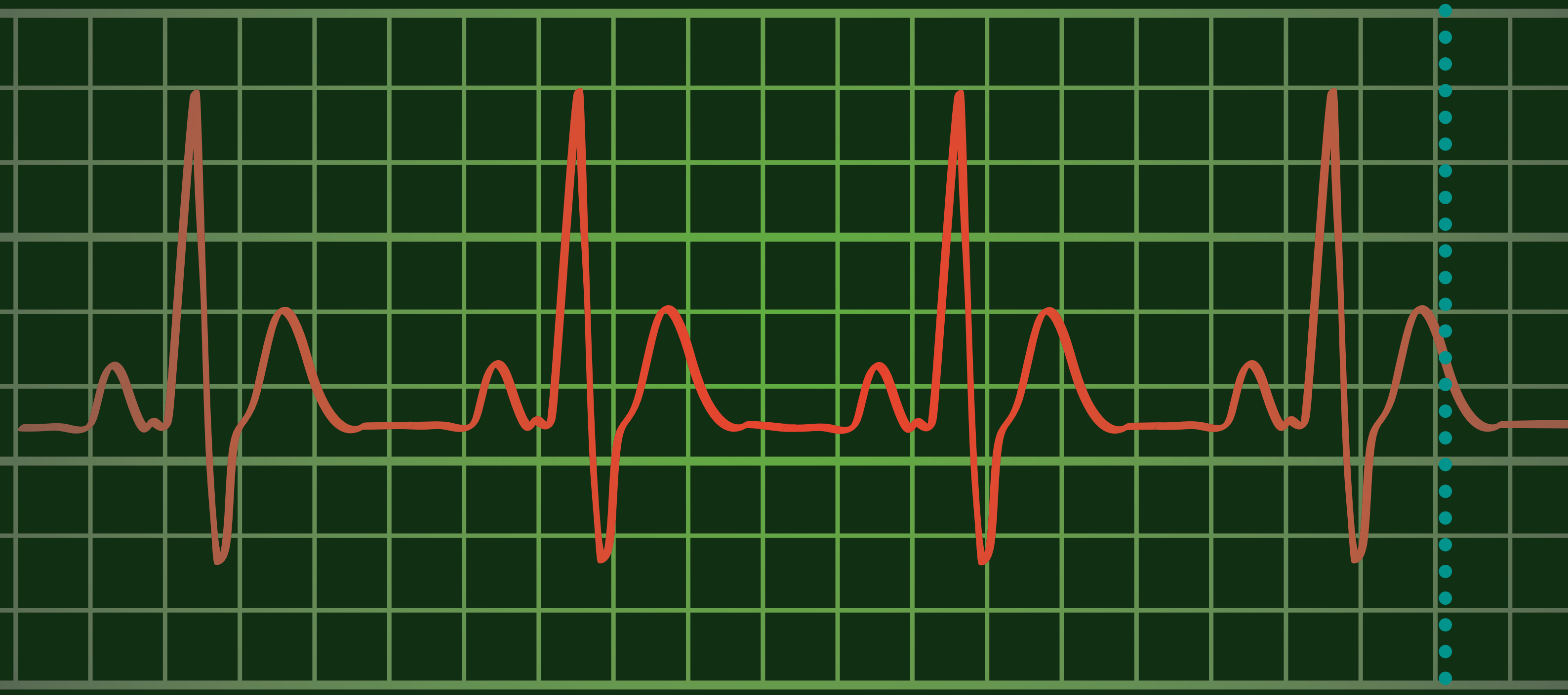

Beyond Failsafe Monitoring

Joe Lewis, Monitor Technologies, USA, presents recent directions in bulk solids level monitoring.

Recent directions

The human heart pumps 80 thousand times or more each day. That is more than 31 million times each year, and more than 2.5 billion times over an 80 year lifespan. For such a small organ, the heart plays a critical role: we die if it stops. Many people take care of and maintain their heart so that it performs its function for as long as possible. To make sure our heart lasts for 80 years or more, we have to check its health. Visits to the doctor at least once a year and periodic blood work to monitor lipid protein (cholesterol), triglycerides, and even fasting blood sugar levels, are measures many of us take to ensure our heart remains healthy. Without these diagnostic checks we can be surprised with a major catastrophic failure event. However, by monitoring the functioning of

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the heart and evaluating key indicators of its health, we can take immediate action to prevent a catastrophe, even if there is a failure. The warning signs need to be visible to us, and acted upon.

A level monitor used to detect a high level condition is similar to the heart in that, if it fails, a catastrophic event usually occurs as it is most often used to shut down the filling process of the bin or silo upon which it is installed. The catastrophic event in this instance is an overfilled silo. Failures of high level indicators can be very costly as they are leading causes of overfilled silos. For this reason, one recent direction in high level monitoring is the move towards "self-validating bin level monitors". The worldwide cement industry uses thousands of high level monitors to help control their processes and manage inventories: it is thus crucial that they operate – and keep operating – effectively. Any failures must be detected immediately.

Figure 1. Roof of flyash silo.

The top ten ways to tell if the silo has been overfilled	
10	Pneumatic tubing is cascading to the ground as the pressure blows the fill lines off the silo.
9	The baghouse on top of the silo is no longer visible, as it is now covered by the material that was in the silo.
8	A "creaking" sound is heard coming from the roofs of any buildings near the silo as material spills onto them.
7	The truck driver filling the silo suddenly looks very sheepish as he prepares to make a run for it.
6	Flocks of pigeons suddenly go airborne.
5	It sounds like it is hailing outside even though the sun is out.
4	There is a loud clanking sound as the silo railing hits the pavement.
3	A sherpa asks if a guide is required to climb the mountain of material now piled next to the silo.
2	Your maintenance manager is in a panic because he cannot find a shovel.
And the number one way to know your silo has been overfilled:	
1	**All employees are scrambling to move their cars!**

Level monitoring

Level monitoring is different than level measurement. Level monitoring is concerned with monitoring a particular point for the presence or absence of a material. This is also referred to as "point level" because of the specific type of monitoring. Detecting the presence of material in a silo at a "high level" is a very common application, but the point for detecting material presence or absence could be elsewhere in the vessel, such as "low level", or at a material re-order point for inventory management purposes. The primary monitoring objective in a "high level" application is to look for the presence of material, which indicates the rising level of material in the vessel. Conversely, in "low level" monitoring applications, it is the absence of material from the point of monitoring that is indicated.

In level monitoring of bulk solids there are five principle technologies, including: rotary paddle, RF capacitance, vibratory, as well as the diaphragm and tilt switches. All of these technologies are contact type devices in that they detect the contact of material on the sensor. Non-contact devices include those of the ultrasonic, nuclear, and microwave beam-breaker types, but together they make up less than 20% of the level monitoring market for bulk solids. The most commonly used technologies for point level monitoring of bulk solids are the rotary paddle, RF capacitance, and vibratory devices.

Level monitoring devices have an average selling price of less than US$400, and a third sell for an average of only US$200. How long can one expect an industrial instrument to last that cost only US$200? What if it fails?

When level monitors fail

Most facilities that process bulk solid materials have suffered the failure of a level monitor. In such circumstances, if the level monitor is used for presence detection or high level and the unit has failed, it is usually only discovered when the silo is overfilled! This results in catastrophe. One cement and flyash user indicated that it costs about US$5000 every time a silo is overfilled. Experiences may differ, but lost material alone is not the only cost. There is also the clean up. For many people, air quality is monitored closely and overfilling a silo results in an increase in emissions and a decrease in air quality, which may lead to fines associated with non-compliance to air quality regulations. These can sometimes be significant. Then there is the physical damage to things like filters and vents on the silo that get clogged with material as it continues to pump into the vessel until someone realises that the system did not shut down the fill process. And finally there is the cost of lost production that can occur when the silo is shut down in order to get everything back to working order. This might be temporary, but lost production time still has a cost if operating a continuous process operation.

In the "executive corner" editorial in the September 2007 issue of *InTech* magazine, Dr Peter Martin of Invensys states that "engineers must step up and assume a leadership role within their companies by helping drive new levels of business performance". He goes on to state that the reason many companies do not understand the true value of engineering is "because most financial systems cannot measure the improvements it generates".

This is a good point. The business systems and models within most companies consider "engineering" and even its close cousin "IT" as a cost, perhaps as an "investment". As part of his conclusion, Dr. Martin argues that engineers "first need to carefully select focused improvement projects that can clearly demonstrate the bottom-line improvement". With that in mind, the opportunity to excel, whether as an engineer in a consulting position or at a facility, will be presented here. Saving money by avoiding costs and keeping production running has value. This one is a "no-brainer".

Self-validating level monitors

The number one way to prevent overfilling silos is the use of a self-validating level monitor.

This is not a new concept. In fact, the introduction of the first self-validating level monitor for bulk solids dates back to the 1960s. However, even today, some 40 years or so later, it is estimated that less than 5% of high level monitoring applications use this type of device. Lack of awareness and the short-sighted bottom line attention to "purchase cost" is the reason.

What is a self-validating level monitor? It is vastly more than a simple "failsafe" device. In fact, the term "failsafe" has been misused for decades: by definition, it means that if the device was to fail, the output that is tied to some final control element would move into a "safe" condition.

This is all well and good; however, with level monitors this term has been misapplied by relating it only to power system failure and not the internal failure of the level monitor to perform its intended function. The reason this convention developed is because of the use of relays as the output device. Prior to using relays, level monitors used simple switches, and some (like the diaphragm and tilt type) still do. However, with the use of electromechanical relays, the level monitor could energise the coil of the relay under "normal" conditions and de-energise the coil upon "alarm" condition. This allows the level monitor's relay output to proceed into the "alarm" condition if power to the monitor were to fail. However, this approach is really only partially "failsafe".

Figure 2. Self-validating point level sensor using Hall-effect technology.

A self-validating level monitor is "beyond failsafe", as the conventional use of the term failsafe is understood. It continuously evaluates its health and ability to perform its intended function and will thus continuously confirm its functional status. The output from such a monitor is also different from that of a simple fail-safe unit. The output from the self-validating level monitor provides assurance by indicating *both* material presence/absence, as well as the unit's functional status. These indications are transmitted simultaneously through the use of multiple relay outputs and, for most units, also local visual indication.

The characteristics of a self-validating level monitor are summarised below:

- Continuous diagnostics of critical internal functions.
- Independent multiple outputs that indicate material presence/absence, as well as the health status of the level monitor.
- Premium price.

Today's monitor for bulk solids

The five primary level monitor technologies that were previously mentioned have limitations that narrow the scope of their bulk solids application use. However, one technology has a far broader base of application than all others, and this is what today's self-validating bulk solids level monitors are based upon.

Rotary paddle technology is the most universal level monitoring technology exclusively for bulk solids. In addition to universal applicability in bulk solids, rotary units are cost effective: in most applications, a standard rotary level monitor can be purchased for US$200, nearly 50% lower than the average price for a level monitor. In addition, rotary level monitors are available from a wide variety of sources and manufacturers around the globe. First introduced in 1956 and refined over the decades, the rotary level monitor is the best choice for bulk solids level monitoring.

Today's self-validating level monitor for bulk solids applications will use rotary technology, but the standard device will need some way to monitor its internal functions. This means that the drive shaft rotation has to be monitored, and logic needs to be introduced to determine whether the monitor is doing what it is supposed to be doing, when it is supposed to be doing it. For example, if shaft rotation stops and the primary presence detection is not sensing material presence then there is a problem with the level monitor. Conversely, if shaft rotation stops but the primary presence detection is also indicating material presence, then it is functioning correctly.

Two technologies are available today for sensing shaft rotation in rotary type self-validating bulk solids level monitors. These are the use of optical and Hall-effect sensors. However, the early version of self-validating level monitors introduced in the mid-to-late 1960s used a mechanical means to trigger a relay that indicated whether shaft rotation was occurring or not.

The reliability of the method of sensing shaft rotation is critical to the functioning of the self-validating bulk solids level monitor. Units that are equipped with the optical method of sensing shaft rotation monitor pulses from an optical encoder system that is attached to the rotating shaft have been used for a decade or so in this application. However, units operating in bins and silos where the internal environment is very dusty, such as cement and flyash, may develop problems as dust works its way through the shaft seal. Dust can foul optic elements and prevent pulses from being generated and thereby indicate false information. This may not occur often, but it is possible.

Enter Hall-effect sensors: these sensors have been used in self-validating bulk solids level monitors since the early part of this decade. Hall-effect sensors are based on the principle discovered in 1879 by Edward Hall. A voltage is created when a small current flows through a magnetic field. By monitoring this voltage, as a magnetic element rotates with shaft rotation, shaft rotation can be monitored. Sensing shaft rotation by using Hall-effect sensors is not sensitive to the possible presence of dust inside the housing and they will not foul.

Once there is a means of monitoring shaft rotation, a method of comparing this rotating state to the detection of material absence or presence is required. Early units did not include a logic comparison function and users had to compare the state of the basic presence/absence output to the state of the shaft rotation output in the control system. Today, the required logic and diagnostic functions are implemented using a microprocessor or microcontroller within the monitor. No matter how shaft rotation is monitored, a microprocessor or microcontroller is used to perform the comparative logic. These devices are extraordinarily common and low cost.

Compared to the fail-safe convention of manipulating relay output state into the alarm mode upon power failure to the level monitor, the self-validating bulk solids level monitor is truly safe. In fact, it is “failsafe+”, as it detects internal functionality health, as well as power supply status. In addition, the self-validating level monitor provides an output that differentiates between material presence/absence detection and the health of the level monitor. Most self-validating bulk solids level monitors also provide local visible indication of material detection and sensor health without removing the monitor’s cover.

Conclusion

Here is a chance for engineers to show one example of their worth within a company or to clients. Use self-validating bulk solids level monitors in all high-level applications to prevent spills and overfilling that result from unknown level monitor failure. While the cost of a self-validating bulk solids level monitor is only US$300 – 400, the value of avoiding costly overfilling and spills is many times more. The small premium price is justified by ROI: cost savings flow to a company’s bottom-line and improved cash-flow.