The gas phase reactor is central to any polyethylene or polypropylene plant.

A comparison of level measurement solutions for the gas phase reactor

In many polyethylene and polypropylene plants, the gas phase reactor is an important vessel. Depending on the process, either ethylene or propylene enters a reactor through the bottom. Next, feedstock mixes with a catalyst to form a powdery polymer. This powder forms a bed that becomes less dense the closer it is to the top of the vessel. Converted gas that reacts with the powder leaves the reactor quickly, and the unconverted gas travels to the top of the vessel until it reaches the disengaging zone. Here, it separates from the powder, leaves the reactor, and is recycled back into the process.

To achieve maximum efficiency and produce an optimal throughput, operators want to run the process at the ideal level. Running too low will decrease the amount of throughput and potentially lead to chunk formation, and if the process is run too high, the fines of the powdery polymer bed can get carried out at an excessive level with the unreacted gas through the gas outlet at the top and into other applications downstream. This poses a major threat to the exchangers and those other applications, eventually leading to a shutdown and shortening the production cycle.

Operators often run this process at a lower level to avoid these costly shutdowns and extend their production cycle. That's because traditional measurement sensors have a difficult time both monitoring the fines and getting a true level measurement due to the changing density of the material bed. This paper will discuss the current solutions available for these measurements, weigh their pros and cons, and allow the user to determine which solution works best for them.

The traditional approach: Differential Pressure

Differential pressure—either electronic or traditional—is most commonly used to measure and control the reactor bed level. The mass of fluidized product bed exerts a hydrostatic pressure on the diaphragm of the lower sensor. The sensor on top of the vessel accounts for any head pressure. Using this method requires careful calibration, and operators must input two known data points: a density and the measuring range of the level. As mentioned before, the density is constantly changing in this reaction, but a fixed density is used for calibration.

As the density of the material bed changes, the reading for the level will change accordingly, giving a level measurement error. The differential pressure sensors can only provide an "average level" because it's using an average density to calculate the level. When the product is more dense than the original input, the level measurement will appear higher than it is, and when the product is less dense, the level measurement will appear lower than it is.

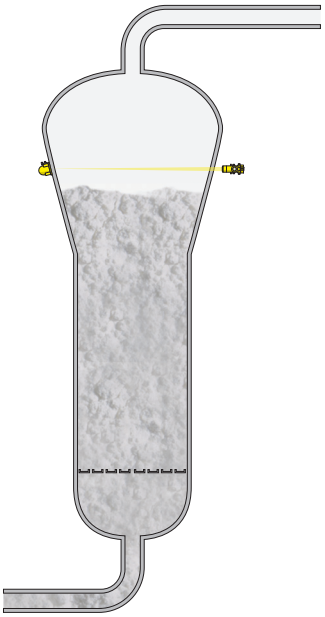
Compared to the measurement errors from the changing density, the greater issue for operations is the amount of maintenance differential pressure sensors require. Small chunks of polyethylene and polypropylene sometimes form, which can strike and damage differential pressure transmitter seals leading to maintenance-related errors. More commonly, buildup can occur where the sensor is installed, leading to intermittent clean-outs, leaving operators without any measurement control variable during this time. Because of the multiple possible errors, operators eventually lose faith in their measurement, and they begin to operate at a lower than optimal level.

Another approach to level: Radiometric

Radiometric technology is a reliable and accurate technology used in critical applications where standard measurements fail. A radioactive isotope emits gamma radiation from a source holder, and the radiation attenuates as it passes through the vessel and the material inside. A detector on the other side of the vessel measures the radiation reaching it. Using the amount of gamma radiation reaching the sensor, radiometric sensors can calculate a number of measurements, including point level, density, and continuous level. With all of these measurements, both the source holder and the sensor are mounted externally, leaving nothing to interfere with the process within the vessel. Knowing the properties of the material being measured and the vessel construction allows engineers to properly size the radiometric source and the sensitivity of the sensor ahead of time.

Radiometric point level switch

Radiometric point level switches provide an on or off signal to inform operators whether or not product is present. When product is below the switching point, radiation from the source reaches the detector, and once product reaches the switching level, the gamma radiation either no longer reaches the detector or is significantly less. This type of setup can notify operators of a full point, or conversely, an empty point.



With a radiometric point switch, a beam of radiation is emitted from the source, through the vessel walls to the detector. The switch changes output when material breaks the beam.

Gas phase reactors domes have large diameters and thick walls, so the path between the source and the detector is a long one. Over this vast distance through thick walls, a certain percentage of radiation will be lost before it even reaches the sensor. As the level climbs in front of the switch, the radiation is partially blocked by the fines, and then it's further blocked by the fluidized bed.

Knowing the optimal level for maximum throughput and minimum carryover is a valuable piece of information. However, the user would need to know that exact level of fines or the fluidized bed at which optimal operation occurs. Plus, the radiometric switch could only be calibrated to measure the level of either the fluidized bed or the fines, two products of differing densities, each of which requires slightly different source sizes and setups. To make this process as efficient as possible, operators must be able to track a certain amount of fines and control the level throughout the vessel, making this a possible, yet partial solution.

Radiometric density for carryover measurement

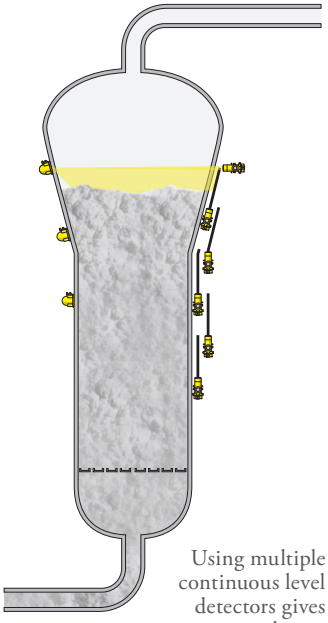
At first glance, a radiometric density sensor looks similar to the point level switch. The sensor and the source are mounted near the beginning of the dome on a gas phase reactor, so as the fines travel up the center closer to the gas outlet, the radiation is partially blocked. But instead of measuring the

presence or absence of product, the densitometer is designed to measure the percentage of fines at a higher accuracy. That's because the densitometer is capable of detecting small changes with a high resolution.

The amount of radiation reaching the sensor slowly decreases as more fines cross between the source and the sensor, and this change is provided as a continuous 4-20mA signal. Measuring the fines rather than detecting them provides the big advantage of preventing carryover. Unfortunately, this by itself doesn't allow the operator to view the continuous level and can lead to operating at low levels due to the lack of information.

Radiometric continuous level

Using a radiometric continuous level sensor works under the same principle as the other radiometric measurements previously mentioned. The main differences are the larger span of the radiation field and the area the sensor is detecting the incoming radiation. The radiation field spans straight across the vessel and downward at a 45˚ angle, and the sensor extends downward along the opposite side of the vessel to detect the entire radiation field. Depending on the vessel shape and size, a source or multiple sources are sized to penetrate the vessel and reach the sensor or sensors.



Using multiple continuous level detectors gives operators a better picture of the continuous level inside the gas phase reactor while monitoring the fines.

Calculations are made prior to installation that account for product density, which determines how much radiation will be able to pass through the product. A denser material will block more radiation than a less dense material. As the product level rises, a corresponding amount of detected radiation decreases and vice versa.

In the gas phase reactor, a single radiometric detector cannot accurately detect level for the same reason differential pressure cannot accurately detect continuous level – varying densities. Radiation from the source isn't equally attenuated throughout the vessel. The fines near the top block very little radiation while the fluidized bed at the bottom blocks a significant portion. This large gradient delivers a poor measurement resolution. Even as the reliability is improved, the accuracy is nearly the same as differential pressure. This option brings a small added value, but more can be achieved from a variation of this solution with the addition of another.

A complete gas phase reactor solution

The varying densities throughout the gas phase reactor require a finer resolution than a single continuous level detector is able to achieve. Using multiple detectors to segment the measurement throughout the vessel can give operators a continuous level measurement and monitor the fines. Each sensor simultaneously acts as an individual level measurement for its designated section of the vessel while providing a portion of the total level for the entire vessel.

The total level sensor will provide a 4-20 mA signal for controlling the leading edge of the fluidized bed. At the same time, the segmented detector model can individually indicate any fines floating above. That's because each level sensor is simultaneously acting as individual densitometers. The level sensors can provide a density output for the fines while also providing a level reading of the fluidized bed. This solution gives operators the control and the resolution needed to optimize the process inside the gas phase reactor.

Conclusion

Providing an accurate continuous level measurement with carryover detection to operators can give them the confidence needed to run the gas phase reactor at its full potential. Today's users are all too familiar with the shortcomings of using differential pressure for this difficult measurement. Using radiometric technology and different types of detectors allows operators to optimize throughput, monitor carryover, and reliably control their process.

Multiple radiometric sensors mounted externally on the vessel can simultaneously measure continuous level of the fluidized bed while monitoring fines at the top of the vessel. These sensors can provide a more reliable and accurate measurement without interfering with the process, and their performance can be calculated in advance by factoring in the dimensions of the vessel and the type of product being produced.

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