Beginner's Guide to Differential Pressure Level Transmitters

The not-so-straightforward basics of this measurement technique

by David W. Spitzer

GIGO means "garbage in, garbage out." This phrase applies in industrial automation because using faulty measurements can fool even the best control system. One remedy that can help avoid a GIGO scenario is to understand the measurement technique and its limitations to the extent that its application can be reasonably evaluated. Differential pressure level measurement is one of those key measurements you need to understand to avoid the dreaded GIGO.

The importance of level measurement cannot be overstated. Incorrect or inappropriate measurements can cause levels in vessels to be excessively higher or lower than their measured values. Low levels can cause pumping problems and damage the pump, while high levels can cause vessels to overflow and potentially create safety and environmental problems. Vessels operating at incorrect intermediate levels can result in poor operating conditions and affect the accounting of material.

The level of a liquid in a vessel can be measured directly or inferentially. Examples of direct level measurement include float, magnetostrictive, retracting, capacitance, radar, ultrasonic and laser level measurement technologies. Weight and differential pressure technology measure level inferentially. All have problems that can potentially affect the level measurement.

Differential pressure level measurement technology infers liquid level by measuring the pressure generated by the liquid in the vessel. For example, a water level that is 1000 millimeters above the centerline of a differential pressure transmitter diaphragm will generate a pressure of 1000 millimeters of water column (1000 mmWC) at the diaphragm. Similarly, a level of 500 millimeters will generate 500 mmWC. Calibrating this differential pressure transmitter for 0 to 1000 mmWC will allow it to measure water levels of 0 to 1000 millimeters.

Note that this example presumes that the liquid is water. Liquids with other specific gravities will generate other differential pressures and cause inaccurate measurements. Continuing with the previous example, the same 500-millimeter level of another liquid with a specific gravity of 1.10 at operating conditions in the above vessel will generate 550 mmWC of pressure at the transmitter. As such, the differential pressure transmitter calibrated for water would measure 50 millimeters higher than the actual 500 millimeter liquid level. Conversely, if the liquid has a specific gravity that is lower than that of water, this transmitter will measure lower than the actual level. This example illustrates that differential pressure technology does not measure level, but rather infers level.

Three Calculations

All is not lost because the calibration of the differential pressure transmitter can be modified to compensate for a dif-

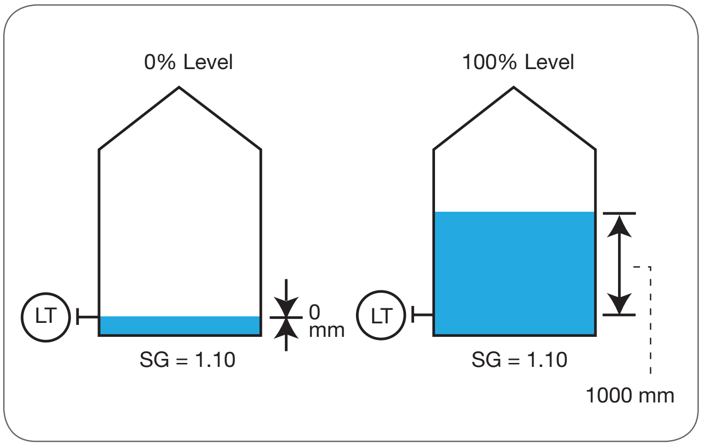

Figure 1. The level transmitter for these vessels should be calibrated 0 to 1100 mmWC to measure liquid levels of 0 to 1000 millimeters.

ferent specific gravity. This technique used to calculate the new calibration is useful for both straightforward and more complex installations.

Figure 1 shows the vessel both at 0% and 100% level. The pressure generated by the liquid at the level transmitter diaphragm is the liquid height times the specific gravity. The pressure is 1.10*(0 mm) when the vessel at 0% and 1.10*(1000 mm) when the vessel at 100%. Therefore, the transmitter should be calibrated 0 to 1100 mmWC to measure liquid levels of 0 mm to 1000 mm.

A somewhat more complex application is illustrated in Figure 2. In this application, for process reasons, we need to take the measurement from 200 mm to 1000 mm above the nozzle. In addition, the transmitter is located 500 mm below the nozzle. Note that the technique of sketching conditions at both 0% and 100% level is the same as performed in Figure 1. At 0% level, the pressure at the transmitter is 1.10*(500 +200 mm), or 770 mmWC. At 100% level, the pressure at the transmitter is 1.10*(500+1000 mm) or 1650 mmWC. Therefore, the transmitter should be calibrated 770 to 1650 mmWC to measure liquid levels of 200 mm to 1000 mm above the nozzle.

Figure 3 illustrates the use of a differential pressure transmitter with diaphragm seals to sense the pressures at the nozzles in a pressurized vessel. In this application, the low-pressure diaphragm is located above the liquid to compensate for the static pressure in the vessel. Other complications include the densities of liquid and capillary fill fluid and 0% and 100% levels that do not correspond to the nozzle positions.

Using similar techniques as in the previous examples, at 0% level, the pressures at the high and low sides of the transmitter are {1.10*(200 mm) + (3 bar)} and {1.05*(1300 mm) + (3 bar)} respectively. Therefore, the differential pressure transmitter will subtract the high side from the low side and measure {1.10*(200 mm) + (3 bar)} minus {1.05*(1300 mm) + (3 bar)}, or -1145 mmWC.

At 100% level, the pressures at the high and low sides of the transmitter are {1.10*(1000 mm) + (3 bar)} and {1.05*(1300 mm) + (3 bar)} respectively. Similarly, the differential pressure transmitter subtracts the high side from the low side to measure {1.10*(1000 mm) + (3 bar)} minus {1.05*(1300 mm) + (3 bar)}, or -265 mmWC. Therefore, the transmitter should be calibrated -1145 mmWC to -265 mmWC to measure liquid levels of 200 to 1000 millimeters above the lower nozzle.

Note that the static pressure in the vessel does not affect the calibration because it appears on both sides of the differential pressure transmitter where it effectively cancels out. Further analysis also will reveal that locating the differential pressure transmitter at different elevations does not affect the calibration.

These same techniques can be used to determine the calibrations for interface level measurements. Note that these techniques involve applying hydraulics to the installation and application. Nowhere do we use terms such as elevation, suppression and span. The use of these terms can easily confuse and mislead the practitioner.

What Ifs

What if the liquid density changes during operation? What if the change is due to changes in the composition of the liquid? What if the change is due to temperature changes? What if the vessel is filled with a different liquid that has a different specific gravity? These are important questions that should be asked (and answered) when considering the use of differential pressure level measurement instruments. Repeating, differential pressure measurement does not measure liquid level—it infers liquid level—so specific gravity changes can affect the perfor-

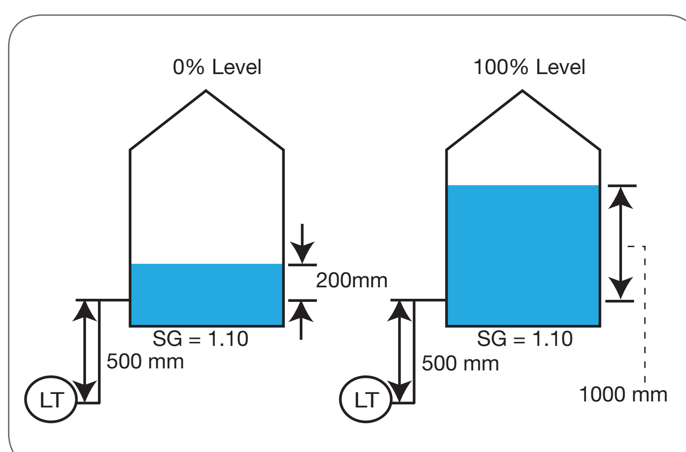

Figure 2. This transmitter should be calibrated 770 to 1650 mmWC to measure liquid levels of 200 mm to 1000 mm above the nozzle.

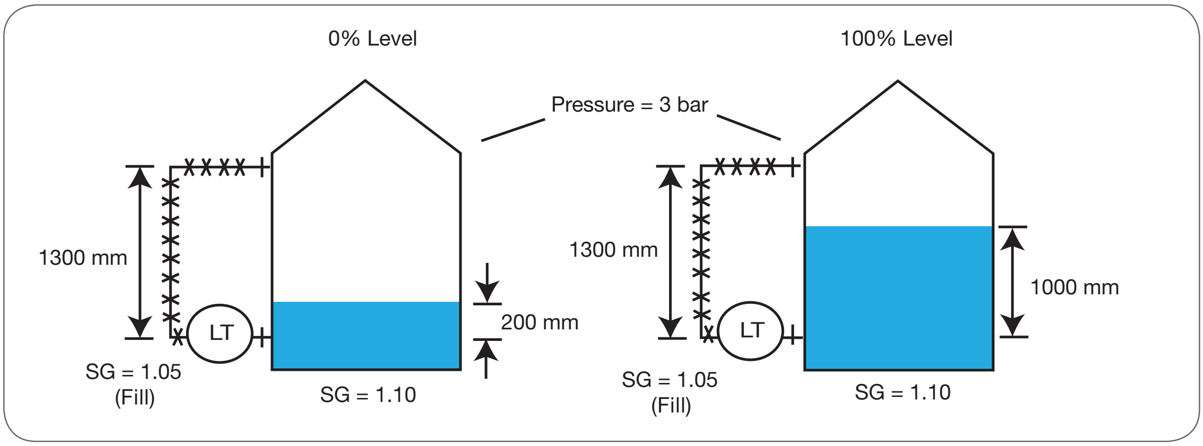

Figure 3. In this case, the differential pressure transmitter subtracts the high side from the low side, so it should be calibrated -1145 to -265 mmWC to measure liquid levels of 200 to 1000 millimeters above the lower nozzle.

mance of the level measurement. In practice, the specific gravity of many liquids is known and relatively stable, so that differential pressure techniques are commonly applied to many liquid level measurement applications.

Spanning Specifications

The differential pressure transmitter should be operated within its published specifications to maintain accuracy. The span of a transmitter is the difference between the 100% and 0% calibration values. Differential pressure transmitters have specified minimum and maximum spans. For example, a given differential pressure transmitter may be calibrated with spans between (say) 400 mmWC and 4000 mmWC. In addition, the transmitter zero may also be raised or lowered by up to, for example, 4000 mmWC. Calibrations that do not meet the transmitter specifications are potentially subject to significant error. The calibrations in the examples were 0 to 1100, 770 to 1650, and -1145 to -265 mmWC, respectively. Each has a span greater than 400 mmWC and less than 4000 mmWC. In addition, their zeros are not raised or lowered by more than 4000 mmWC. Therefore, all of these calibrations are within the transmitter specifications.

However, the calibrated span specified for another transmitter model of the same manufacture may be between 100 mmWC and 1000 mmWC, and allow the zero to be changed by 1000 mmWC. This transmitter would not be applicable to the first and third examples where the span is 1100 mmWC, and the zero is lowered by 1145 mmWC, respectively. However, it could be used in the second example where the span is 880 mmWC, and the zero is raised by 770 mmWC. Using this lower range transmitter (1000 mmWC) will usually be more accurate because of the smaller absolute errors associated with other specifications such as temperature, pressure and ambient temperature affects. Therefore, all being equal, it's generally desirable to use the lower range transmitter to reduce measurement error.

The maximum flow rate of flowmeters is often specified to be significantly higher than the design flow rate to allow for transients and increased plant throughput over time. In level measurement, the vessel size is fixed, so using a higher range differential pressure transmitter provides no similar benefit and typically results in additional measurement error that can be avoided by using a lower range transmitter.

Using the available information properly is another potential problem. Some years ago, distributed control system inputs were incorrectly configured to correspond to the maximum transmitter spans. Aside from using incorrect values, the levels should have been expressed in percent. Using absolute level measurement units such as inches, feet, millimeters or meters increases the potential for error because operators must remember the height of each vessel to put the level measurement in context with the vessel. This can easily become overwhelming and cause operator errors because plants often have hundreds of vessels. For example, a vessel operating at 2.8 meters does not readily indicate a problem to the operator even though the vessel overflows at 3.0 meters. On the other hand, the operator can easily determine that a vessel operating at 93% level might warrant attention and that a vessel operating at 97% may need immediate attention.

Differential pressure measurement is a workhorse of industrial level measurement that's been used for decades and will continue to be used for decades to come. ■

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