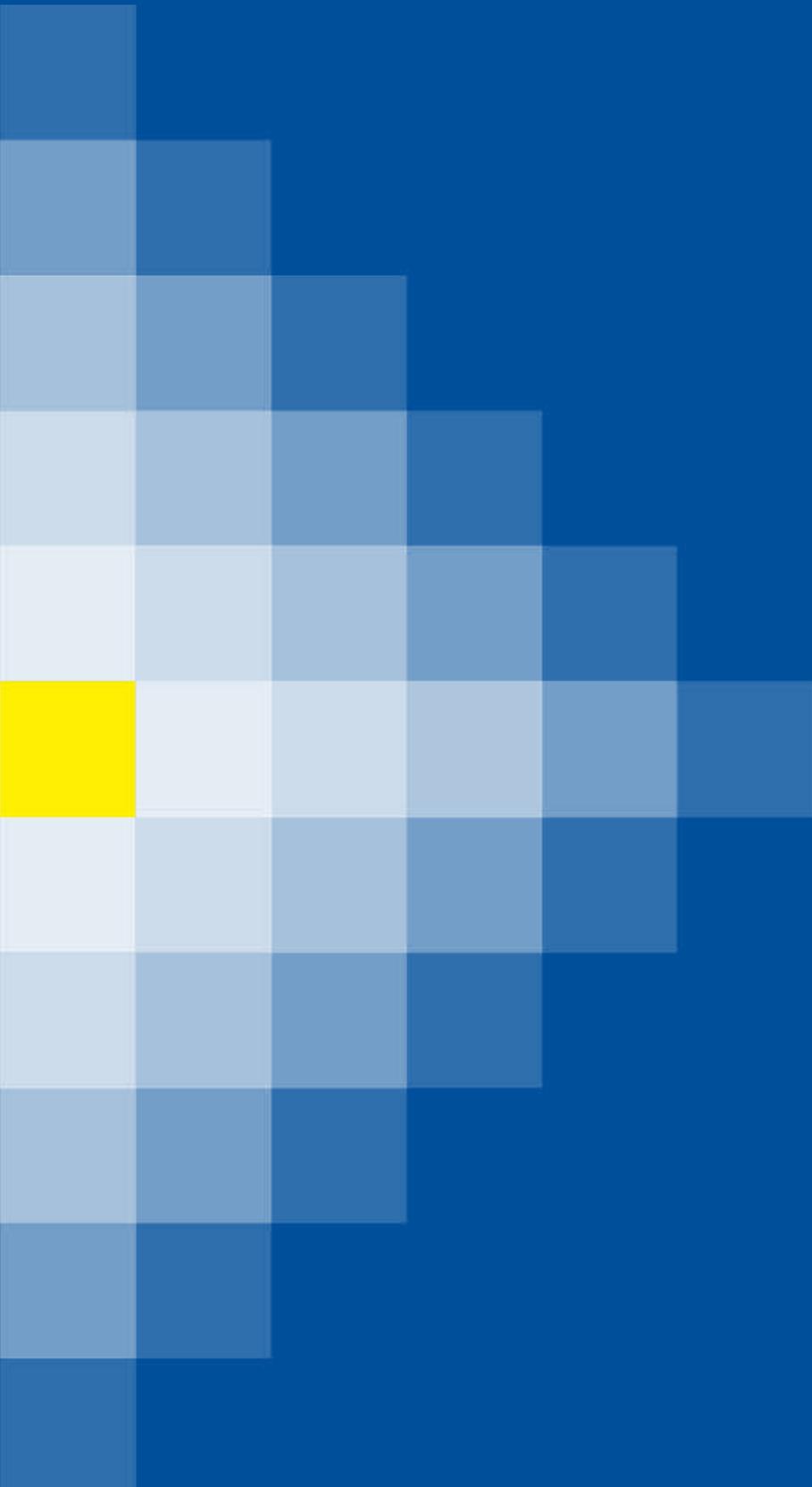YOKOGAWA ◆

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Level Measurement

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Level Measurement

Level measurement is one of the more essential measurements in a process. Incorrect measurements can cause tanks to overflow creating potential safety or environmental problems; or, low levels can cause pump damage. Even incorrect intermediate levels can result in an inferior quality product. Whether the application is for monitoring or control, the level measurement needs to be accurate and repeatable. Today there is a host of different measurement technologies designed to track the level in a tank. There are direct measurement technologies such as ultrasonic, radar, or float; and indirect measurement technologies such as weight and differential pressure. All of these technology groups have contact and non-contact devices. There is not one 'silver bullet' technology; all have their advantages and disadvantages. So, there is a lot to consider when selecting a level measurement device.

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Introduction

This paper covers one of those technologies: differential pressure (DP) level transmitters. A DP level transmitter uses the head pressure and specific gravity of the media to infer the level in the vessel. It is a widely-used level technology having the advantage of being based on a well-understood principle. It is an excellent selection for clean liquids but also works well with viscous liquids and slurry/sludge; but, is not recommended for solids. The disadvantage is the limited temperature operating envelope of the transmitter. Adding a remote diaphragm seal system to the DP transmitter overcomes this limitation.

DP Level Measurement

Level is a measure of the position of the boundary surface between a liquid and gas. The DP level pressure transmitter can measure the height from a reference surface to the boundary surface if the density of the liquid remains constant. The relationship can be expressed mathematically using the formula:

Level = pressure measured / specific gravity of the liquid

Diaphragm Seal System

One solution for the installation and corrosive questions is to add a diaphragm seal system to the transmitter. This system introduces different wetted materials that are more resistant to a corrosive liquid. The system can also help with installation with large tanks. However, diaphragm seals attached via capillaries use fill fluid to transmit the pressure from the process to the sensor; the fill fluid causes ambient and process temperature effects to be higher. Ambient and process temperature drift are two ways temperature changes can affect the unit.
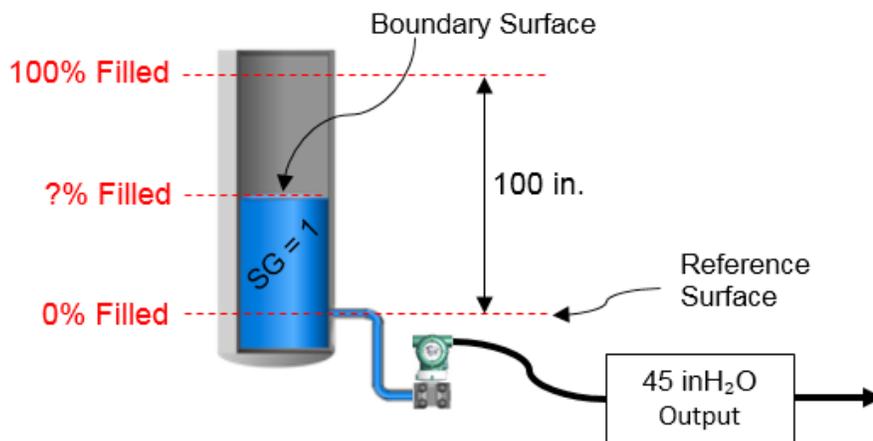
Fig. 1: *A simple open tank configuration. However, in practice, there are many application characteristics to consider when designing a DP level system. How will it be installed? Is the liquid corrosive? What is the temperature of the liquid? Process temperature? Ambient temperature?*

Ambient Temperature Drift

Ambient temperature is the temperature around the process. With a tank located outdoors, the transmitter and capillary system could see temperature swings day-to-night, season-to-season, or even shady-to-sunny. This change in temperature affects the fill fluid just like any liquid. The fluid contracts and expands within the capillary with the change causing inaccuracy in the reading. The reading reflects a change in the fill fluid instead of an actual change in the level.
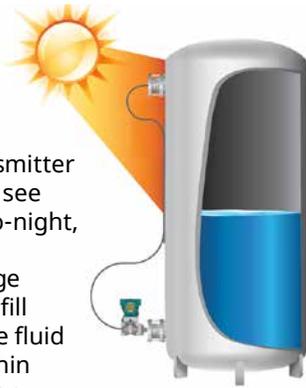
Fig. 2: An example of a tank with direct sun on the top connection point and the transmitter in shade (Sunny-to-Shady). This causes a temperature imbalance yielding what appears to be drift in the level measurement.

Process Temperature Drift

Process temperature drift is similar to the ambient temperature drift except that temperature influence comes from the process itself. The temperature of the process conducts through the metal diaphragm into the fill fluid, thus, causing the same contraction/expansion as ambient temperature changes - again causing inaccuracy in the reading. The reading reflects a change in the fill fluid instead of an actual change in the level. This effect is especially prevalent with unbalanced systems (one capillary is longer than the other). The longer capillary equalizes to a specific temperature, while the shorter would not be able to equalize at the same temperature. The unbalanced temperature causes level measurement inaccuracy.

Yokogawa Solutions

Compensating Capillary Design

Much like a compensation leg of a 3-wire RTD, this design has a compensating capillary 'leg' to help balance the volume and temperature of the fill fluids between the high-pressure and low-pressure side in an unbalanced design.

This design is unbalanced because the high-pressure side seal is directly mounted to the transmitter and the low-pressure side seal is mounted to the transmitter via a capillary. The compensation capillary is attached to the high-pressure side of the transmitter and bundled along with the low-pressure capillary. The compensation capillary equalizes the volume of fill fluid between the two sides of the transmitter; thus, allowing for ambient temperature balance between them.

This solution reduces the influence of ambient temperature drifts whether caused by swings day-to-night, season-to-season, or shady-to-sunny; but, where the influence of process temperature drift would not exist or is at a minimum.

Fill fluid expansion due to ambient temperature change
Conventional product:

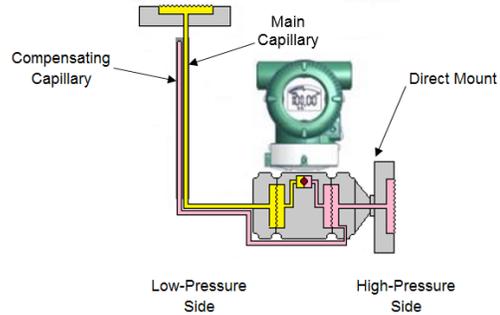$$V_H \times \beta \times (\Delta T\text{-}RT) < V_L \times \beta \times (\Delta T\text{-}RT)$$
$$\div\ V_H < V_L \quad V_L - V_H = \text{Error}$$

Ambient temperature correction via compensating capillary design :

$$V_H \times \beta \times (\Delta T\text{-}RT) = V_L \times \beta \times (\Delta T\text{-}RT)$$
$$\div\ V_H = V_L \quad V_L - V_H = 0(\text{zero})$$

β: volume change rate
VH: volume of fill fluid (high pressure side)
VL: volume of fill fluid (low pressure side)
ΔT: temperature difference

Dual Compensating Capillary Design

This design balances the volume and ambient temperature of the fill fluids between high and low-pressure side capillaries just like the design mentioned above; but, the compensation capillaries also connect into a compensation chamber that is the same volume as the main chamber in each diaphragm seal. A temperature conductive plate between the main chamber and compensation chamber exposes the same process temperature changes to both chambers balancing the entire system - reducing the influence of process temperature in the level measurement.

This solution reduces the influence of ambient temperature drift and process temperature drift. Apply this design to applications where the influence of both impacts the ability of the DP pressure transmitter to measure level accurately.

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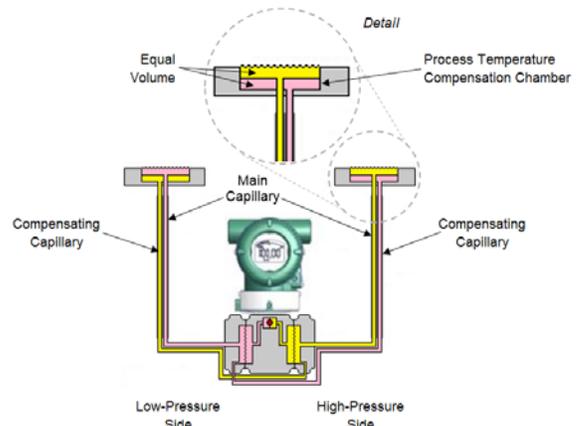
Conclusion

Whether the application is for monitoring or for control, the level measurement needs to be accurate and repeatable. Differential pressure level transmitters are a well-understood technology for getting this done. However, temperature influence can make the reading seem to drift.

Yokogawa has introduced two compensating capillary designs to minimize this influence in extreme conditions.

Although the explanation of the technology was simplified here, these designs and manufacturing techniques make the Yokogawa compensating capillary level transmitters a distinctive solution in the market.

At Yokogawa we continue to listen to customers' concerns to strengthen and develop our ability to respond to their diversifying application needs.

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