

## New Measurement Practices for Cold Climates Part 2: Electronic Remote Sensors for Liquid Level Measurement

Electronic Remote Sensor (ERS) technology eliminates capillaries. In a cold climate, benefits include reduced cost, no need for heat tracing, improved performance, reduced spares and simplified maintenance.

### Traditional Pressure-Based Level Measurement

A “bottom-up” pressure measurement can be used to infer level because the pressure exerted by the fluid is proportional to the fluid height – above the tap – and the fluid density. So, for a known fluid density, the measured pressure gives level. In severe or plugging applications, or with special process connections, remote seals are used to isolate the transmitter from the process and “repeat” the pressure signal.

In a closed tank, the fluid above the liquid level is pressurized, and the level is actually proportional to the *difference* in pressure between the top and bottom tap, obtained with a differential pressure (dP) transmitter. The transmitter is typically located at grade near the low-side (high-pressure) process connection. The high-side (low-pressure) seal is normally near the top of the vessel, so must be connected to the transmitter via oil-filled capillaries that hydraulically repeat the pressure signal from the seal to the transmitter.

Although the low-side seal is normally physically close to the transmitter, users traditionally specified equal length capillaries – with the excess lower seal capillary coiled up at the transmitter. The rationale for including this extra capillary is to “balance” the impact of fill fluid expansion. An increase in ambient and/or process temperature causes the fill fluid to try to expand – in the fixed volume of the capillary this mimics an increase in pressure, hence inferred level. In this **Balanced System** temperature changes will have an equal impact on both high and low side capillaries, with zero net error.

Unfortunately, there is another significant error – the head temperature effect. As the ambient and/or process temperature increases, the fill fluid specific gravity decreases. This causes the force on the transmitter from the upper seal to decrease, since head pressure is the product of specific gravity and height, so the inferred level is reduced. There is no effect on the lower seal, since it is at the same elevation as the transmitter (height is zero). This means that in a Balanced System, the impact of fill fluid expansion is zero, while the head temperature effect is not. A better approach is to **Direct Mount** the lower seal with no capillary. Since the two effects act in opposite directions, the non-zero effect of expanding fill fluid will counteract the head temperature effect, minimizing net error. As an additional benefit, eliminating the lower seal capillary dramatically speeds response time, since changes in liquid level do not need to travel through the entire capillary before being sensed at the transmitter. And of course, Direct Mount also reduces cost, since it eliminates one length of capillary.

Since fill fluids have known coefficients of thermal expansion, and since diaphragms and capillaries have known stiffnesses and volumes, it is possible for the supplier to quantify these effects in advance. Given application details and expected ambient and process temperature variation, the supplier can optimize seal and capillary design (fill fluid, diameter, thickness) so that, in the real installation, the two effects will almost exactly cancel each other out over the widest possible range. Today, this optimization is done with sophisticated software by suppliers, to provide a **Tuned System**.

## Challenges in Cold Climates

One drawback of using a Tuned System is that it creates a unique solution for each application, possibly leading to a large number of unique spare parts. Most users choose to sub-optimize individual applications, balancing the need to achieve acceptable performance while maximizing commonality. Even so, if any component of the system is damaged during installation or operation, the entire assembly must be removed and returned to the supplier for repair. This is a particular problem in cold climates, where working on these devices in the field is uncomfortable and unsafe. Also, most cold climates are remote from repair facilities; so long return shipping times can lead to days or even weeks without a working measurement.

Another problem observed in cold climates is that the viscosity of the fill fluid in the capillaries can change dramatically with temperature. The user must choose a fill fluid that will not vaporize under worst-case vessel conditions – the highest temperatures and lowest pressures – to avoid oil boiling and seal rupture. Figure 2 shows a vapour curve for a common fluid, Dow Corning DC200. At atmospheric pressure, DC200 is stable to 205°C (400°F). If the vessel ever operates under vacuum conditions – common with distillation columns, for example – the temperature limit will be much lower.

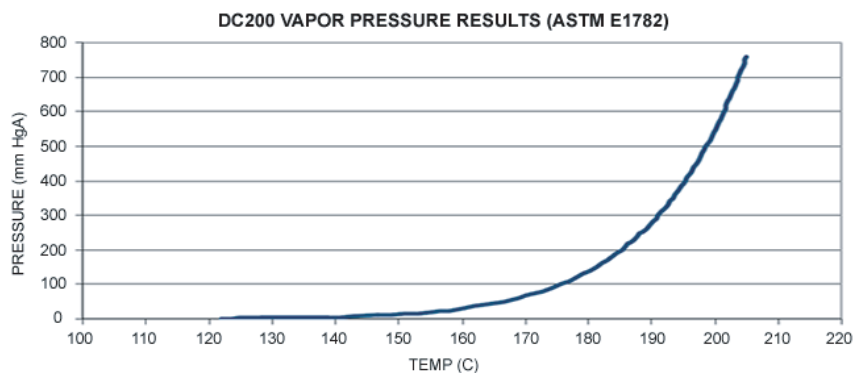


Figure 2

Unfortunately, fill fluids suitable for higher temperatures suffer from very high viscosity as temperatures decrease. Table 1 shows maximum and minimum

temperatures at atmospheric pressure, as well as viscosities at 25°C, for some common fill fluids.

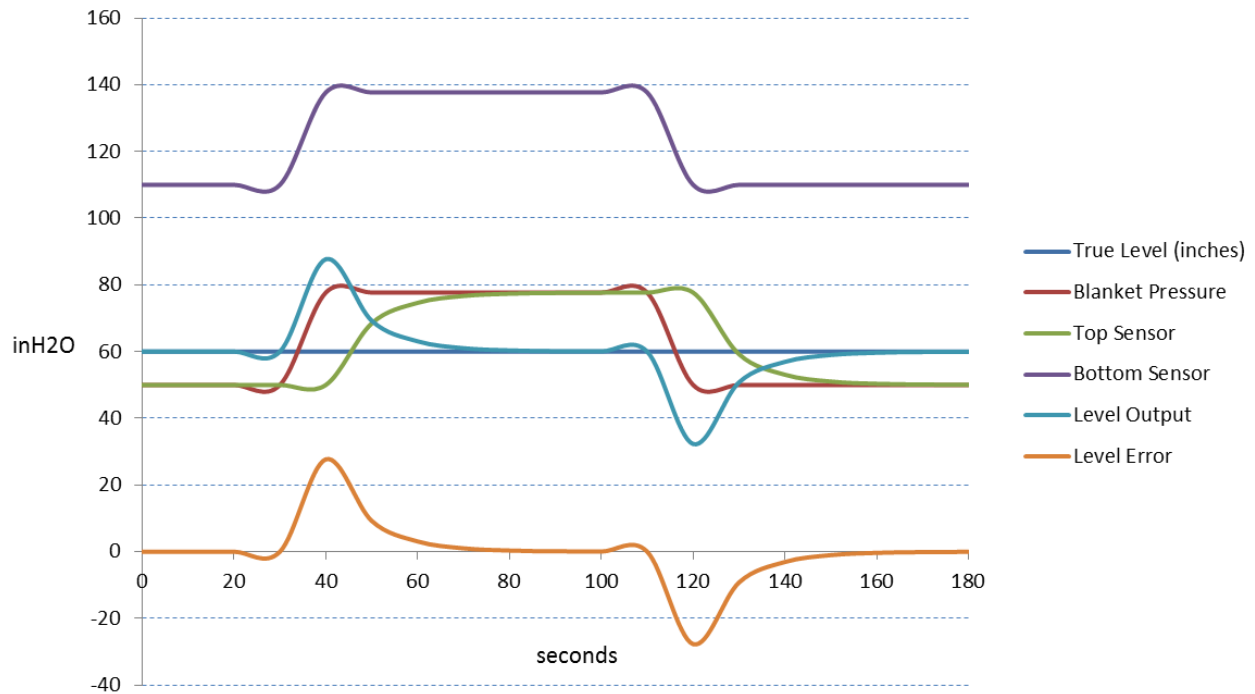
Table 1 – Common Fill Fluids (Dow Corning)

Silicone Fill Fluid	Temperature Range °C	Temperature Range °F	Viscosity at 25°C (cps)
DC 200	-45 - 205	-49 - 400	9.5
Syltherm XLT	-73 - 149	-100 - 300	0.85
DC 704	20 - 350	68 - 662	<b>175</b>

In an application with process temperatures exceeding 205°C – or even lower with vacuum conditions – the user would likely choose DC 704. If the vessel were tall, with a long capillary connecting the upper seal (which measures blanket pressure) to the transmitter, in a cold climate its oil could cool significantly by the time it reached the transmitter. In an extreme case, its oil could freeze and stop responding entirely at 20°C; even at higher temperatures, response would slow.

If the lower seal (which measures liquid head + blanket pressure) were directly connected to the transmitter without capillary – which provides best performance to changing process level – its oil would remain hot, with low viscosity and fast response. As a result, in a cold climate the high and low measurements could become **desynchronized**. Changes in blanket pressure would immediately affect the lower seal, but only affect the high seal after some lag time. As shown in Figure 3, a relatively small change of ±1 psi in blanket pressure causes a level swing of up to ±27.7 inches in measured level until the top sensor measuring blanket pressure ‘catches up’.

Figure 3 – Impact on Measured Level of  $\pm 1$  psi change in Blanket Pressure  
(Vessel @250°C, Ambient =20°C, DC704)



Unlike with water, silicone oil does not expand when it freezes. This avoids physical damage to the system and allows full recovery when ambient temperatures rise in the spring. Unfortunately, since the system recovers fully every spring the user may not notice these problems, except as poor measurement stability when temperatures fall again next winter. To prevent this problem, users in cold climates will usually heat trace their critical capillaries. While effective, heat tracing is very expensive to procure, install, operate and maintain.

## Electronic Solutions

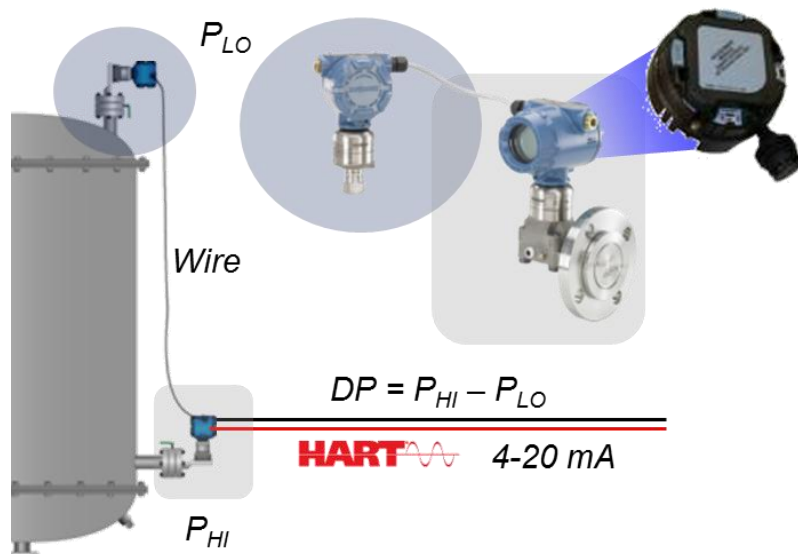
In theory, a better solution would be to install separate high and low pressure transmitters, and subtract the signals to obtain a level. Since the two transmitters are connected electrically instead of hydraulically, capillaries – and their attendant cost, reliability and response time problems – are eliminated. Unfortunately, while this approach can work well with a digital bus like FOUNDATION fieldbus, it's not as effective if the user is using a more common HART or 4-20 mA connection. Not only must the user double the transmitters, field wiring and DCS inputs, but relatively small errors in the calibration of the transmitters and the analog inputs –

and rounding errors in the DCS – lead to relatively large errors in the measurement. This is because the ranges of the individual pressure transmitters must often be greater than the range of the *difference* in pressures which yields the level. Consider the case of a vessel operating with a maximum pressure of 200 psig, and with a maximum level of 200 inches of water. In a traditional capillary system, the user would probably select a single dP transmitter with a range of 250 inH2O – the line pressure is not relevant since only the difference is being measured. Each error of  $\pm 0.1\%$  in the transmitter, in the analog input calibration, or in the math block of the DCS would cause an error of 0.25 inches H2O in the level measurement, relatively trivial in most process applications.

If using separate transmitters, the user must select two transmitters, each with a range of say 300 psig. Each  $\pm 0.1\%$  error in the system would cause a non-trivial error of  $\pm 0.3$  psig or  **$\pm 8$  inches** in the level measurement. For this reason, users have only used two-transmitter, all-electronic solution solutions with the lowest line pressures, and when high accuracy is not needed.

New **Electronic Remote Sensors** – shown in Figure 4 – eliminate these problems. Two high-accuracy sensors communicate digitally, and a single HART/4-20 mA output provides the subtracted level. No additional wiring or DCS input is required, though a user with HART DCS inputs can access both of the measurements independently, for process variable as well as setup and diagnostic information.

Figure 4 – Electronic Remote Sensors Used in Level



This new type of Electronic Remote Sensor provides much better accuracy at low or vacuum pressures, and comparable accuracy up to about 300 psig of line pressure.

Response time is much faster, with no synchronization problems. Other benefits include:

- **Easier installation**, typically by a single technician – instead of a sealed system with two heavy flanges connected to a transmitter via long inflexible capillaries, the user simply installs two pressure transmitters, and then connects them with standard Belden cable.
- **Reduced spare parts** – instead of a complete spare system for each unique level system, the user would need only a spare transmitter for each range and connection type in the plant. This also allows the user to optimize each individual application without increasing spare parts.
- **Easier maintenance, greater uptime** – instead of removing and shipping the complete system back to the supplier, having it repaired and then reinstalling, the user would simply replace any single failed component with a replacement from stores.

In a remote, cold climate – these benefits would be magnified, plus the user could significantly reduce life cycle cost by **eliminating the need for heated capillaries**.

## Conclusions and Recommendations

dP-Level continues to be the dominant level measurement technology used in the process industries. Users choose dP-Level because it is proven and well understood, and suitable for wide range of applications. Some implementations are better than others:

- A Tuned System, where the supplier uses sophisticated modeling software to optimize diaphragm and capillary sizes, thicknesses and materials as well fill fluid to the specific application, is usually better than ....
- A Direct Mount system, in which the lower seal is directly connected to the process without capillary, so that the head effect can at least partially cancel out the seal temperature effect, is usually better than ...
- A Balanced System, in which the user specifies a capillary for the lower seal matching the upper seal to attempt to 'balance out' the seal effects

The newest approach – Electronic Remote Sensors, now available for both HART/4-20 mA and fieldbus – is usually best of all, providing better performance in most applications, and much lower life cycle cost, particularly in a cold climate.

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