Technical Note
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Rising to new levels with ERS™ Systems and Tuned-System™ Assemblies

1.1 Executive summary

Differential pressure (DP) technology has been used for many years to measure tank level. Internal tank architecture, agitation, corrosive or viscous processes that may cause challenges for alternative level technologies are ideal applications for DP level technology, which delivers a repeatable, stable and accurate measurement when utilized correctly.

Traditional DP technologies such as wet leg and dry leg systems, which utilize impulse piping as well as capillary based solutions, are well understood and reliable technologies. Impulse lines benefit from clean processes as they are prone to plugging and may freeze in extreme cold ambient temperatures. Capillary solutions continue to give excellent measurements when capillary lengths can be minimized. However, these traditional DP level systems can be difficult to use in areas and applications with wide ambient and process temperature shifts.

Improvements to traditional measurement technology, such as Tuned-System Assemblies, have been developed to increase response time and reduce measurement error and are considered best practices for indoor applications and shorter spans and tanks with high pressure vessels.

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Another DP level instrumentation innovation is Rosemount® 3051S Electronic Remote Sensors or ERS Systems. This technology builds upon the proven DP technology and is suited to distillation towers, tall vessels and other applications with long spans or widely varying temperature. The Rosemount 3051S ERS System (Figure 1-1) replaces mechanical impulse piping and long lengths of capillary with two pressure transmitters that are linked together electronically. Differential pressure is calculated in one of the two sensors and is transmitted to the DCS or PLC using a standard two-wire 4- 20mA HART® signal.

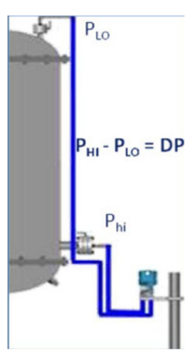
Figure 1-1. With a Rosemount 3051S ERS System, a digital signal replaces impulse lines and capillary to increase measurement reliability and performance on tall towers and vessels.

1.2 Overview of traditional DP Level technology

1.2.1 Vapor pressure (vessel static pressure) is subtracted in DP measurement

Conventional DP transmitters are used in level applications by measuring the amount of pressure exerted by the liquid level in a vessel. For example, a 500 mm column of water will exert 500 mmH20 of pressure. However, in many applications, there is additional vapor pressure above the liquid. Since vapor pressure is not part of the liquid level measurement, it must be subtracted from the overall pressure measurement (Figure 1-2). The use of impulse piping or a remote seal with capillary is required to measure the presence of vapor pressure at the top of the vessel.

Figure 1-2. Tank vapor pressure must be subtracted from the overall pressure to calculate tank level.



1.2.2 Using impulse piping to measure vapor pressure

In an impulse piping configuration, the low-side reference leg is filled with either a column of liquid (wet leg), or with a suitable dry gas (dry leg). Wet legs are used when the vapor blanket in the tank will condense into a liquid form. Likewise, dry legs are used when the vapor will not condense. While relatively simple in concept, impulse piping installations can be difficult to maintain. Evaporation often occurs in wet legs and condensation can occur in dry legs. Both conditions will cause measurement error in the DP transmitter as evaporation and condensation will cause fluctuations in the low-side reference pressure. Impulse lines can also leak, plug, and may require insulation or heat tracing to prevent freezing or excess vapor condensation. Additionally, rigid impulse piping can complicate installations in dense plant infrastructures.

1.2.3 Capillary systems reduce the challenges associated with impulse piping

Capillary and seal systems eliminate many of the issues with impulse piping installations; such as plugging caused by viscous processes and suspended solids. A remote seal system consists of external sensing diaphragms mounted to the process and connected to the DP transmitter with oil-filled capillaries. Changes in pressure cause the diaphragm membrane to deflect, and the pressure is propagated through the oil-filled capillary and ultimately exerts the force on the transmitter sensor resulting in a measurement. Oil-filled capillary systems are carefully welded and manufactured so that the systems are hermetically closed for reliable performance. Careful construction and manufacturing eliminate leak points and plugging as well as any evaporation or condensation issues that can occur with impulse piping. Additionally, the capillary simplifies installation of the measurement point. Capillary is not rigid like impulse piping, making it possible to easily install around permanent structures. This allows measurement points in locations previously deemed too difficult to instrument with impulse piping.

1.2.4 Balanced systems do not eliminate all temperature induced error

A common capillary seal configuration is the “balanced system”. A balanced system consists of two identical remote seals and equal lengths of capillary on both the high and low side of the DP transmitter (Figure 1-3). This type of system is traditionally specified because it supposedly compensates for all temperature induced errors. For example, as the outdoor temperature changes, whether from night to day or season to season, the oil volume in the capillary will expand and contract causing fluctuations in the internal pressure of the capillary system. These changes in pressure will result in measurement error, commonly referred to as “temperature induced volume effect” or “seal effect”. A balanced system was initially thought to cancel out this error because the same expansion / contraction of oil volume will occur on both the high and low sides of the transmitter due to the symmetrical construction. While the volume does expand and contract equally within a balanced system, there is another source of temperature induced error that does not affect the high and low pressure sides of the transmitter symmetrically.

Figure 1-3. A balanced system has identical diaphragm seals and equal lengths of capillary on both the high and low side of the DP transmitter.

Figure 1-4. A change in process temperature induces the fill-fluid density to change within the capillary. This change in density causes a measurement shift due to the head pressure varying.

A change in process temperature induces the fill-fluid density to change within the capillary. This change in density causes a measurement shift due to the head pressure varying.The second source of temperature induced measurement drift occurs when a capillary seal system is installed with a vertical separation between the two seals. This measurement drift occurs on most vessels and distillation towers, and there is a "head pressure" exerted on the low side of the transmitter from the weight of the fill-fluid within the capillary. If ambient temperature conditions change, the fill-fluid within the capillary will also experience a subsequent temperature change. The density of the fill-fluid within the capillary will fluctuate with the change in temperature and cause the amount of head pressure force that is measured by the transmitter to vary. This source of error is called "temperature induced density effect" or "head effect". While balanced systems can cancel out the changes in volume within the system due to equal lengths of capillary, they do not compensate for this change in density as the low pressure side is generally mounted at a higher elevation than the high pressure side (Figure 1-4). Balanced systems also require the use of a pipe stand or other mounting hardware to facilitate the installation of the transmitter. In addition, balanced systems result in excess capillary on the high side of the transmitter that is often coiled up and adds unnecessary costs.

Figure 1-5. A tuned-system assembly minimizes fill -fluid volume on the high pressure side of the transmitter to increase performance and response time.

1.3 Tuned-system assemblies

1.3.1 Reduced temperature errors

A better solution, when compared to balanced systems, is a Rosemount Tuned-System Assembly by offering improved performance and easier installations at a lower cost. Tuned-System Assemblies consist of a chemical seal mounted directly to the high-side of a DP transmitter. A single length of capillary connected to another seal is welded to the low side of the transmitter (Figure 1-5). The asymmetrical design purposely minimizes the fill-fluid volume on the high side in order to counteract the temperature induced density effects that will always be present on any vertical installation. For example, when ambient temperatures increase, the fill-fluid expands (negative shift in Tuned-System Assembly, no shift in balanced system) but the density decreases (positive shift in both systems). The total cumulative temperature effects will lower the total error in a Tuned-System Assembly as the temperature induced effects shift the measurement in opposite directions (Table 1-1).

Table 1-1. Tuned-System assembly has less total error compared to the balanced system.

28 °C ambient temperature increase	Balanced system (6m capillary total)	Tuned-system assembly (3m capillary total)
Temperature Induced Volume Effects	0 mbar shift	-4.2 mbar shift
Temperature Induced Density Effects	+9.0 mbar shift	+9.0 mbar shift
Total Error	+9.0 mbar shift	+4.8 mbar shift
% Increase in Performance		47% improvement

Tuned-System Assemblies can be directly mounted to the vessel without the need for additional transmitter mounting hardware, and thus installation costs are often reduced by 20% by eliminating this hardware as well as the unnecessary length of capillary on the high side of the transmitter.

1.3.2 Limitations of tuned system assemblies

While Tuned-System Assemblies are a proven and reliable technology, tall vessels and towers have posed a significant measurement challenge. In particular, long vertical tap-to-tap distances require extended lengths of capillary to facilitate the installation. As the tap-to-tap distance grows, the resulting head pressures within the capillary become too great to “tune” out. For example, an installation that requires 15 meters of capillary will experience as much as 383mmH20 (37.6mbar) of measurement drift for a 28 °C change in temperature. This is five times the capillary length of the Tuned-System Assembly cited in Table 1-1 (above), but almost ten times the measurement drift. Additionally, time-response can be sub-optimal on tall vessels and towers as the distance the pressure signal propagates through is substantially greater. Overall, as the length of capillary attached to the transmitter low side increases, an accurate measurement becomes increasingly more difficult to achieve.

1.4 Electronic Remote Sensor (ERS) technology

Electronic Remote Sensor technology solves many of the problems that are traditionally seen when making a DP measurement on tall vessels or towers. Rather than using a single DP transmitter with mechanical impulse piping or capillary, the Rosemount 3051S ERS System uses two direct mount gage or absolute sensors that are connected with a non-proprietary electrical wire. One of the two sensors calculates the DP and transmits it back to the host system/DCS using a standard two 4-20mA HART signal.

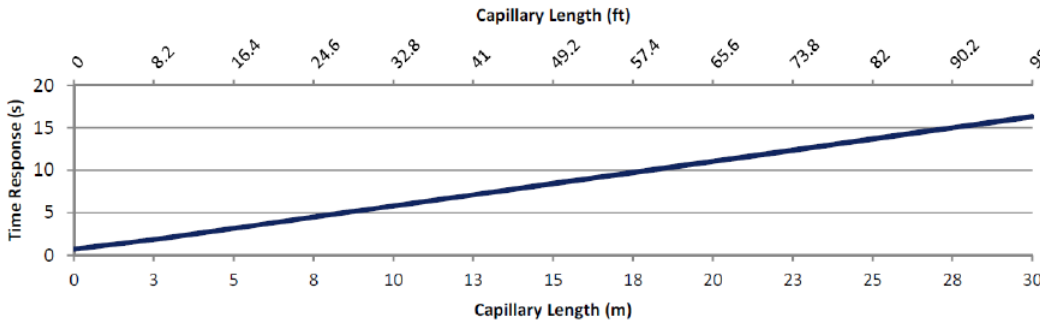
The unique digital architecture of the Electronic Remote Sensors enables many benefits when used on tall vessels and distillation towers that traditional systems cannot achieve successfully.

1.4.1 Electronic remote sensors improve performance

Electronic Remote Sensors replace the long lengths of oil-filled capillary and impulse piping with an electrical wire that is immune to temperature induced effect. This means the operating engineer will be able to get an accurate measurement over a large range of ambient temperatures without fill-fluid density or volume changes affecting the reading.

As stated, time response is suboptimal in traditional installations with long measurement spans. The more capillary required, the longer it takes for a change in process conditions to traverse through the capillary to the DP transmitter. The digital architecture of Electronic Remote Sensors improves time response by removing the mechanical connections. As can be seen in Figure 1-6, the time response can become a critical issue with long lengths of capillary and impulse lines. The 3051S ERS System improves time response by over 500% when compared to a 5 m (16.4 ft) balanced system and over 3000% when compared with a 30 m (98.4 ft) balanced system.

Figure 1-6. The time response of 1.092 mm (0.040 inch) capillary with Silicone 200 fill-fluid at 24 °C (75 °F) ambient. System is balanced with equal lengths of capillary on the low and high reference connection of the transmitter.



Any temperature induced measurement drifting issues can lead to serious problems. A drifting measurement causes reduced confidence that the process is operating at capacity or safely. For example, measurement drift caused by plugged impulse lines or wet leg / dry leg failure could lead the operator to believe that a distillation tower is weeping or has liquid / vapor entrainment. The cost of maintaining a proper measurement adds up quickly when the operator is making frequent trips from the control room to the field to verify measurements and instrument failures.

Consider an application at Chevron Phillips Chemical in Texas using a traditional magnetic float device with heat tracing to monitor tank level for a chemical holding tank. When the heat tracing failed during large downward swings in ambient temperatures, the bridle would freeze and Chevron Phillips would experience an inaccurate level measurement. This event posed a significant environmental risk, if spilling were to occur, it would expose the company to potential large fines from environmental agencies. Chevron Phillips replaced the entire bridle assembly with Electronic Remote Sensors and has eliminated any risk of tank spill- over. The process has been continuously running without any unplanned shutdowns for over four years. Process engineers have commented that because of the increase in accuracy and reliability, they are able to better control the process in the vessel and have experienced better on-stream operation since installation.

1.4.2 Cleaner installations and less maintenance

Installation time is drastically reduced as difficult to install impulse piping has been replaced with an electrical wire. The electrical wire can be fed through floor grates and wound around plant obstacles further simplifying installation. Additionally, cold weather installations of impulse piping and capillary often require heat tracing or insulation in order to prevent freezing, however because these fluid-filled mechanical parts have been replaced with an electrical wire, heat tracing or insulation is required. These advantages effectively make installation a one-person job, saving the end-user substantial installation costs.

Impulse lines are maintenance intensive as well. Piping needs to be checked for leaks, condensation, evaporation, and plugging frequently to insure that the measurement seen in the control room is accurate. The digital architecture of Electronic Remote Sensors eliminates these clipboard rounds, resulting in cleaner installations with less maintenance and upkeep. Additionally, massive storerooms may be necessary to stock all necessary repair parts for traditional systems whereas the 3051S ERS System eliminates the need for various lengths of capillary required to span multiple distances. Spares inventory can be reduced to a standardized transmitter and a spool of wire reducing plant instrument investment costs.

Solvay Chemical in France has already realized the maintenance benefits of Electronic Remote Sensors. While operating a brine evaporator instrumented with impulse piping Solvay would frequently lose measurement due to plugging the impulse piping with crystallized salt. A complex flushing system was installed without any success. The evaporator consequently needed to be taken off line so maintenance staff could remove the salt buildup. A 3051S ERS System was installed with a tank spud remote seal eliminating all the headaches that Solvay was previously experiencing. In fact, because Solvay has not lost measurement due to plugging, a higher level of efficiency has resulted by reducing operations and maintenance costs.

1.4.3 Additional process insight maximizes throughput and product quality

The 3051S ERS System is a MultiVariable™ solution that provides additional process information for optimized control. In addition to the DP calculation, operating engineers have real-time access to the measurements from each pressure sensor and a scaled output for tank level or volume measurement.

Electronic Remote Sensors MultiVariable capabilities has software that allows the end-user to program linear functions for strapping tables of both standard and irregular shaped tanks to further enhance the accuracy of volume, mass, density and interface measurements. Non-linear functions can be used for horizontal flow applications as well.

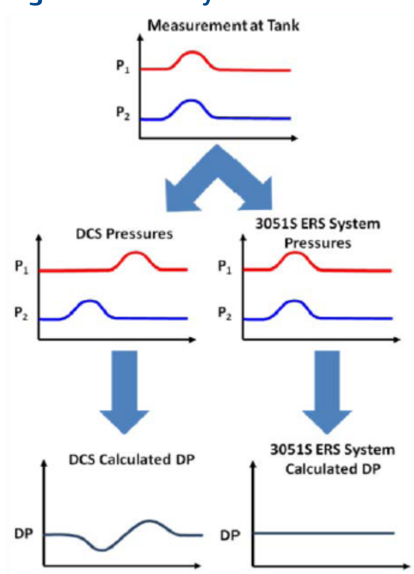
While this MultiVariable capability is a huge advantage across many industries, no one is realizing the benefits more than those who have Electronic Remote Sensors installed on distillation columns. Foaming, entrainment, weeping and flooding are major concerns and prime contributors to dangerous conditions, poor quality and low throughput. These distillation tower challenges occur when the process engineer has a lack of insight into the operating conditions. Generally speaking, the more process information the engineers have about the distillation process, the greater control they have in increasing profits and reducing operating costs.

Because two transmitters are installed, the operator gains access to both PHIGH and PLOW measurements as well as the differential pressure measurement. Having access to PHIGH and PLOW measurements, along with a temperature measurement, allows the process engineer to know the exact location of the distillate on the vapor-pressure curve. Once the operating engineer knows where the distillate lies on the vapor pressure curve, they can alter the tower parameters to increase throughput and quality. This is easily done as all the process information and variables are easily accessible by viewing the device dashboard (Figure 1-6). This reduces instrumentation costs as these additional pressure measurements eliminate the need for supplemental pressure instrumentation.

Figure 1-7. Gain access to more process variables such as PHI, PLO, DP, mass, density and interface.

In addition, because the operator has access to the PLO measurement point as well as the system DP, vapor pressure can be actively monitored. This is particularly beneficial when dealing with gas-blanketing systems such as nitrogen blanketing. Since some fuels require oxygen to combust, an inert gas such as nitrogen is often “blanketed” across the surface to reduce the risk of ignition. Some blanketing gases are also non-breathable substances and sudden loss of vapor pressures could lead to hazardous situation for operating personal.

Figure 1-8. Do-it-yourself systems have an inherent “polling rate error” as the PHI and PLO signals are not synchronized.



1.4.4 A fully synchronized measurement with no polling error

High and low pressure measurements are fully synchronized by specialized software to ensure that the differential pressure measurement is accurate. DP measurement error can occur in do-it-yourself solutions. Do-it-yourself solutions consist of two independent transmitters sending independent 4- 20mA signals to the DCS for calculation. Because of the DCS polling rate, there is a time synchronization error between the two signals. The timing gap provides the DCS with asynchronous transmitter signals and therefore an erroneous DP is calculated. The 3051S ERS System solves the polling rate error by synchronizing the measurements and calculating the DP prior to sending a 4-20mA signal to the DCS (Figure 1-7). A further advantage of the digital architecture over do-it-yourself installations is that only one I/O connection is required, whereas the do-it-yourself version requires two I/O points, doubling the cost in wiring.

1.5 Complimentary technologies

While the 3051S ERS System is great for tall vessels and towers, there are applications where a Tuned-System assembly will continue to be the preferred technology. The sensors in a 3051S ERS System are specified and sized based on the combined static pressure and the DP column from the liquid level, where as a Tuned-System assembly is sized just on the DP column. Because of this, Tuned-System assemblies will continue to be the optimal solution for smaller, higher pressure vessels, and Electronic Remote Sensor technology will enable new success on tall vessels, distillation towers, and other similar applications.

Balanced systems will continue to be the configuration of choice when the remote seals are installed on horizontal applications, such as across a DP flow element such as a wedge meter.

Additional information on the Rosemount 3051S ERS System including more detailed success stories, videos, and product specifications can be found online at http://www.rosemount.com/3051SERS.

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