ABB MEASUREMENT & ANALYTICS - WHITE PAPER

Tank level measurement using Digital Diaphragm Seal systems

Refinery plant
at Europort harbor, Rotterdam

The perfect solution for reliable measurement of the filling quantity in containers, silos, tank systems where ambient temperature effects and fast response are critical to customer.

Measurement made easy

Introduction

When we think about level measurements, the first installation that comes to mind is a tank.

In order to perform an accurate tank level measurement, there are different factors that need to be taken into consideration and different options to execute the measurement from a technical point of view. The most appropriate is the differential pressure (DP) measure where not only shape and use of the tank are considered, but also the properties of the medium inside the vessel itself (i.e. corrosive, viscous, in motion, etc).

DP levels are historically executed using predominantly capillary-based remote seal devices, such as ABB´s pressure devices 266MRT or 266DRH, which have proven in time the suitability for the majority of applications. Thanks to repeatable and stable measurements, ABB models deliver in fact, accurate data that can easily be read either from the local displays or from the DCS control room.

There are nevertheless applications and installation conditions which affect performances of the standard oil-based capillary systems. From an application standpoint, it might be required to have faster response times to ensure process valves are controlled appropriately, while we might face environmental conditions (e.g. thermal excursion) from the installation side that could lead to errors which are expensive to sustain or prevent.

A typical error is the one generated by the so-called “head effect”: it is the influence of ambient temperature variation on the filling fluid column inside the capillaries themselves: in other words, the heat-tracing capillaries need to be removed, is to ensure that the capillary temperature is kept on a constant level.

Let's consider an application for a DP measure of 500 mbar in a 10-meter pressurized tank level measure installed outdoor in the north of Germany: the challenges that a standard capillary remote seal device must deal with are multiple:

- Ambient temperature might vary from -15 °C up to 25 °C
- During winter there might be ice formation on the capillaries
- If the device is installed at the bottom of the tank, high side will be direct mount while low side will have a capillary of 10 mt
- A 10-meter oil-filled capillary has mechanical properties for which pressure on a diaphragm will take time to be transmitted to the device sensor to be then elaborated.

Some of the above challenges are somehow addressed with regular remote seals (i.e. equalizing the high and low sides lengths to minimize impact of unbalanced systems or heat tracing), but in case accuracy and speed are key to success then a different solution must be sought, especially if the minimization of the total operating costs is even more significant.

Keeping your measurement quality and saving costs with digital diaphragm seals

And here's where ABB Digital Diaphragm Seals (DDS) makes the difference!

DDS in fact have been designed to address the issues that conventional remote seal systems already address, plus many of the problems that traditionally require high costs or performance compromises, especially when devices are to be installed on tall vessels or distillation towers.
DDS is in fact designed as two direct mount gauge or absolute sensors that are connected with a non-proprietary electrical wire. One of the two sensors, specifically the one to be installed on the high side of the DP measure, is defined as "Primary" and embeds all the functions necessary to calculate the DP. It's the "brain" of the system which transmits signals back to the DCS/control room leveraging a standard two-wires 4–20 mA HART signal.
The other device, defined as "Secondary" has the function to collect independently the pressure on the low side and transmits it to the Primary for elaboration. Such digital architecture has multiple advantages if compared against a traditional oil-based capillary system.

DDS is a specific configuration of the 266 gauge or absolute models like 266HSH/GST when ordered with standard process connections like 1/2 NPT male thread but can also be configured as a version of 266HRH/GRT.
In these latter models, DDS features the well-known direct mount remote seal models from the S26 catalog, all manufactured using the All-Welded technology unique to ABB pressure devices. Additionally, DDS can feature a variety of materials (e.g. AISI, HC, Diaflex, H-Shield, etc) and a wide number of sensor ranges, from the low ones up to high pressure ones.

As we have anticipated, DDS delivers key benefits to customers, such as:

1 Higher performances

a. Ambient conditions do not influence anymore the accuracy of the system.

Given the immunity of the electrical wires to temperature variation, there are no more risk of drifts and wrong data, which would otherwise require additional verification methods on the installation working at capacity or set.

b. Faster response in case of process control actions.

DP measure is not derived from mechanical transmission of pressure and it is not conveyed through the capillary but is electronically and real-time provided to the Primary device reducing up to 95% the response time

2 Lower cost of ownership

a. Lower installation costs.

Heat-tracing capillary is not something to be considered anymore, even in installations where ice formation is a risk. Additionally, since the high and low side transmitters can be installed separately and cable-connected later, the related workforce time and efforts are reduced.

b. Lower cost of maintenance and replacement.

The modularity of the system allows to act independently on each unit without recalibrations of the system. Additionally, more space around the vessel is freed up since there's no need to have equal capillary lengths (required to minimize performance impacts in the standard remote seals).

All the above benefits shall be considered "on top" of the already embedded advantages that the 266 models deliver already, such as the modularity of the electronics and displays.

Installations where Digital Diaphragm Seals expresses its biggest potential:

- Boiler Drum Level, condenser and any pressurized tank in Power plants
- Distillation towers and tall vessels in Oil and Gas plants
- Evaporators and distillations vessels in Chemical plants

Digital Diaphragm Seals architecture is modular and flexible and to ensure customers can extract the best out of the technical solution. Now, let's deep dive a bit more into how to order and configure the system.

Get the most out of your measurement

Here below some guidelines and tips:

- Primary and Secondary devices shall always be codified with the same model type (e.g. 266HSH) and sensor range to enable DP calculation. Always consider that Primary device sensor range shall be able to measure the entire column of the vessel. For example, to measure a 400 mbar DP in an 8 mt pressurized tank with a static pressure equal to 1 bar, the correct sensor for a 266HSH Primary is 1600 mbar / 642 inH2O range (code H).
- Primary is the unique device that shall be calibrated. Secondary unit shall be always delivered at full span.
- Secondary device is always delivered without display.
- Connection cables are not delivered with the devices in the standard offering. Customers have full freedom to mount the most appropriate ones during installation as per their convenience.
- It's a good practice to order Primary and Secondary with the same tag number to ensure proper coupling during installation. Primary device in fact performs a compatibility check on serial number of the Secondary unit during initialization but from a user perspective Tag is much more recognizable.
- In case of re-order of a spare unit, a single Primary or Secondary device can be ordered but the tag number or the partner device shall be kept the same as the original model and transferred to the new/spare unit.

Now that rules for codifications have been explained, let's make a performance comparison of a conventional differential pressure remote seal solution and a DDS system composed by gauge models with direct mounted remote seal.

In both cases, the simulation will be considering a silicon filling and a 2 in stainless steel flush flange.

The installation conditions are:

- 8 mt pressurized tank (Static pressure = 2 bar)
- DP level: 250 mbar
- Ambient temperature: -10 °C to +10 °C
- Distance between the taps: 4 mts

The traditional solution (equipped with a 400-mbar sensor calibrated at 250 mbar) can be executed either with a direct mount (image A) or capillary solution (image B) on the high-pressure seal side.

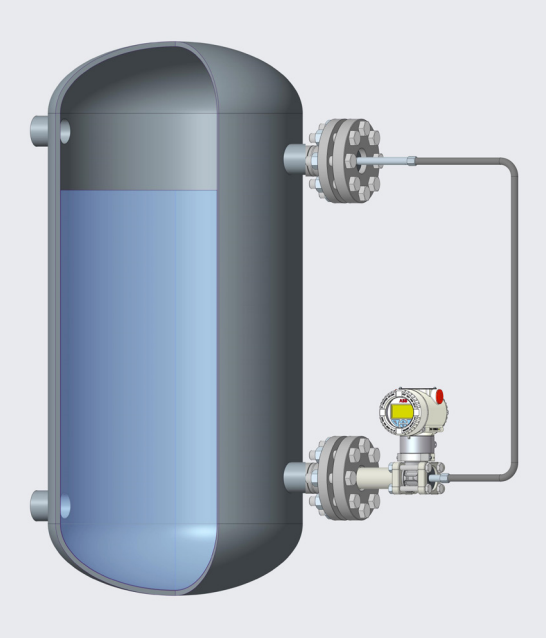

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Image A
Direct mount solution

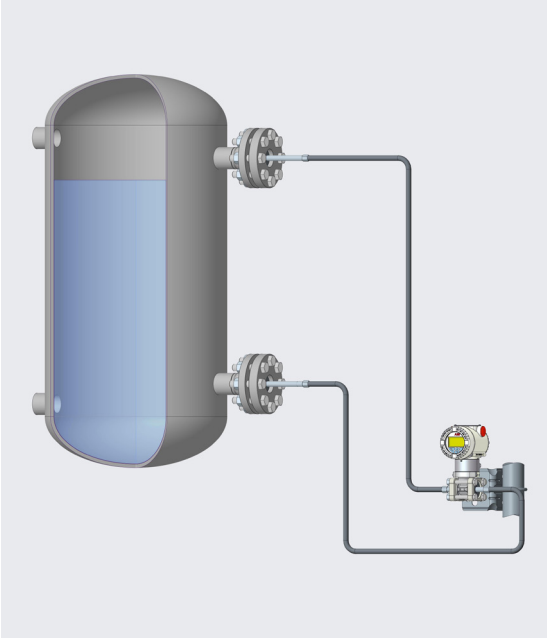

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Image B
Capillary solution

For sake of understanding, let's use theoretical conditions like:

- 8 mt pressurized tank (Static pressure = 2 bar)
- DP level: 250 mbar
- Ambient temperature: -10 °C to +10 °C
- Distance between the taps: 4 mts

to define performance levels.

In the installation with the direct mount seal the TPE is approximately a value of 0.470%, coupled with a response time of 1840 milliseconds (image A).

In the case of the two-capillary system instead, we have a lower TPE approximately 0.163% with a response time of 3110 milliseconds: this is driven by capillaries being both 4 mt long and hence leading to a more balanced system (image B).

In both cases anyhow, we must consider the so-called "head effect", which in these specific application conditions is around 3% of the calibrated span and cannot be zeroed without heat tracing.
This factor shall be summed up to TPE to obtain a more comprehensive Total Error in between 3-3.5% depending by the type of installation.
It is important to say that head effect is fully dependent on the installation conditions and mounting, which means that only customers have visibility of its peculiarities.

The calculate of the TPE (Total Probable Error or Total Performance) is a method calculating an hypothetical "worst case scenario" for each device (similar DIN16086).
The calculation is performed by using the "Sum of Squares" method, where three metrics are squared, and the result has its square root taken.
A general Total Probable Error formula looks like:

$$E_{perf} = \sqrt{(E_{\Delta Tz} + E_{\Delta Ts})^2 + E_{\Delta Pz}{}^2 + E_{\Delta Ps}{}^2 + E_{lin}{}^2}$$

E_{perf} = TPE Total Probable Error
$E_{\Delta Tz}$ = Effect of the ambient temperature on zero
$E_{\Delta Ts}$ = Effect of the ambient temperature on span
$E_{\Delta Pz}$ = Effect of the static pressure on zero
$E_{\Delta Ps}$ = Effect of the static pressure on span
E_{lin} = Base accuracy rating

Let's look at the DDS solution instead: as per image C, we can see how the 2 direct mount models work independently.
Both the Primary and Secondary are equipped with the same sensor, where the Primary is calibrated according to the span to be measured (250 mbar) while the Secondary at full span. The selection of the sensor is particularly critical since the Primary shall be able to "sustain" both the static pressure and the DP measure to be performed: in this case sensor shall have a range capable of at least 2250 mbar.

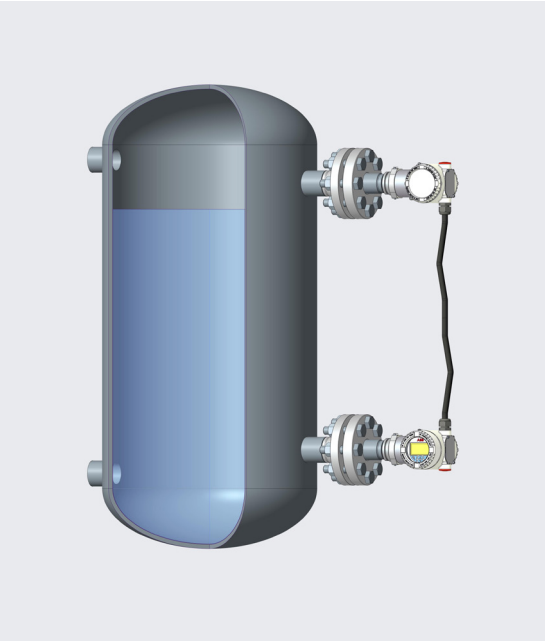

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Image C
DDS solution

With the above configuration, the TPE can be assessed as approximately 0.655%, while the response time is around 830 milliseconds.

At a first glance the accuracy of the DDS may look worse than a standard remote seal, but we shall remember that the most important factor to be considered is the absence of the head effect. Considering hence the TPE and the head effect together, DDS can deemed a more accurate and efficient measuring solution when compared to standard remote seal on tall vessels and temperature-influenced installations.

Differential Pressure transmitter with Direct and Remote seals mount installation (image A)
Total Error: 3.569%

Differential Pressure transmitter with two Equal Remote seals mount installation (image B)
Total Error: 3.262%

Digital Diaphragm Seal DDS (image C)
Total Error: 0.655%

On top of this, there's another couple of tips: knowing the static pressure behavior, a wet & in-field calibration of the device or a PV bias removal could increase even more the accuracy. This is particularly relevant for the Secondary unit, for which the accuracy error could be almost zeroed. Being the dynamics of static pressure variation very peculiar to the installation, ABB suggests having the Secondary trimming operation executed during commissioning via PC-based tools or by an authorized ABB Service representative.
In order to have a flavor of such improvement, supposing that the 2 bar of static of the example are constant across the entire behavior of the DP measure, the Secondary could be calibrated at 250 mbar too (2000 to 2250 mbar), resulting in a TPE of the DDS system close to the Differential Pressure transmitter with two Equal Remote seals mount installation (image B).

Each installation has challenges and specific attention points for which traditional remote seal systems are and will remain a valid solution in many applications, but what can be definitively stated is that DDS represent the technological evolution in case faster and more accurate measurements are required by a process.

Discover the DDS from ABB, available in a variety of connections, materials and ranges!

ABB Measurement & Analytics

For your local ABB contact, visit:
abb.com/contacts

For more product information, visit:
abb.com/measurement

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