

Pressure measurement

Applying remote seal, isolation diaphragms between process fluids and transmitters



Remote seals protect transmitters when measuring difficult fluids and expand the applications for pressure measurement solutions

Measurement made easy

—
Quick and accurate measurement while maintaining transmitter protection

Introduction

Remote seal systems protect transmitters while faithfully conveying pressure signals. They enable the measurement of not only pressure and vacuum, but also of derived variables, including flowrate, level and density. At extreme temperatures and with challenging process media, the use of remote seal transmitters is widespread throughout industrial and municipal processes.

Although the typical transmitter has a metallic isolation diaphragm to help protect it from exposure to the media being measured, many difficult applications make this protection ineffective. In such cases, the measuring system must include some way to keep the measured fluid from directly contacting the transmitter sensor, while responding quickly and accurately to changes in the measured variable.

If extreme high or low process temperatures exist, these may cause damage to the sensitive electronics at the sensor if they are in direct contact with the diaphragm. Remote seals mitigate these extreme temperatures by using a small cross-sectional area coupling and fill fluids with low thermal conductivity.

Remote seals

The most practical method of protecting the transmitter from the process fluid is the use of remote seals – also known as chemical seals and isolation seals, see Figure 1, page 2. Remote seals enable the transmitter to be located up to 24.3 m (80 ft.) from the point of measurement.

An isolation seal has two main components:

- a flexible seal diaphragm that is exposed to the measured fluid and reflects its pressure
- a liquid-filled capillary – the capillary connects the remote seal to the transmitter and its liquid hydraulically transmits the process pressure from the isolation diaphragm to the sensor diaphragm.

...Remote seals

Depending upon the measured variable and mounting considerations, the remote seal connection can be assembled to either the **High** or **Low** pressure side of the DP pressure transmitter, or both. Flow measurement, for example, requires two separate seal systems, each connected to one of the DP transmitter's inputs.

Instead of being remote, the seal system can be close-coupled to the transmitter, see Figure 2. When feasible, close coupling has the advantage of being especially responsive to pressure changes and less subject to effects of ambient temperature changes.

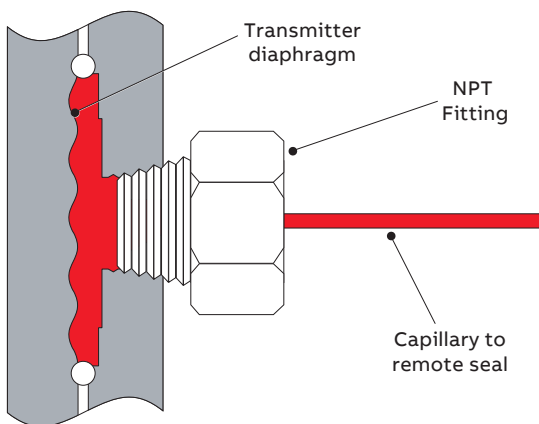


Figure 1 Common Competitor's threaded/gasketed design – inferior



Figure 2 Close-coupled, direct mount remote seals, also known as 'Pressure level transmitters'

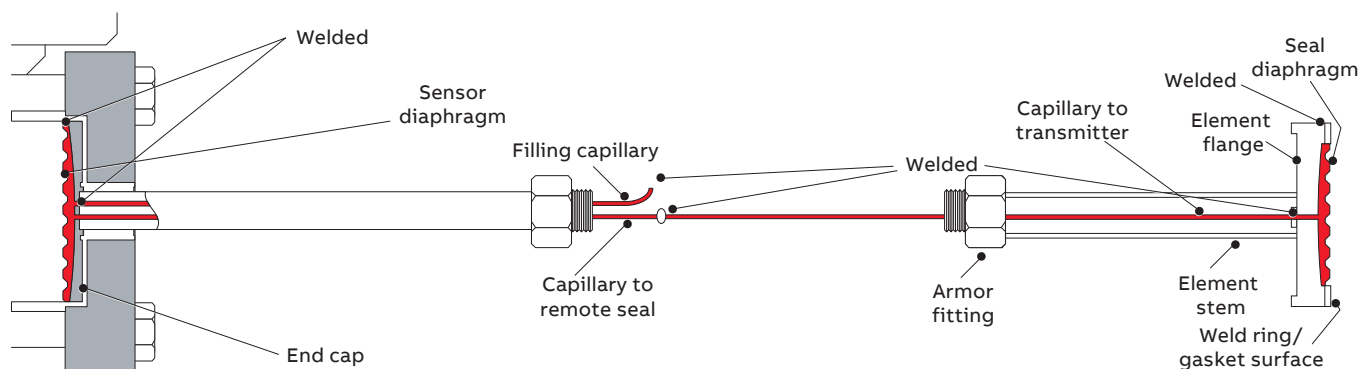


Figure 3 All-welded ABB's Standard Design – superior

Seal system integrity

An important construction feature of a remote seal system is that it prevents in-leakage of air or other ambient gases, and it prevents the leakage of fill fluid out of the system. The integrity of the hydraulic circuit is critical to the system's performance. Even a tiny air or gas bubble entrained in the fill fluid will cause adverse effects to the pressure measurement. This is especially vital for operation under vacuum conditions where the differential between the sub-atmospheric pressure in the system to the outside environment will attempt to pull the smallest gas molecules through any flaw, indefinitely.

The use of all-welded, hermetically sealed construction at key points helps to assure reliable performance over a wide range of temperatures and absolute pressures (Figure 3). This is in contrast to "repairable" gasketed and threaded seal systems where the reliability of the transmitter measurement depends on a combination of gaskets, bolting hardware and the quality of machined threads over time and temperature cycles (Figure 1). Another weakness is that these designs are prone to tampering after installation.

The effect of temperature on performance can be markedly lessened by sealing the system under full vacuum, minimizing the presence of entrained air or other gases. The thermal expansion of air is 1,000 times greater than that of a typical silicone fill fluid; thus, an air bubble of only 0.812 mm (0.032 in.) diameter can cause, in terms of pressure, a system error greater than 25.4 mm (1 in.) of water per 37.7 °C (100 °F).

Why use a remote seal?

Typical examples of where remote seals are selected over impulse lines:

- The process fluid is highly corrosive. Seal diaphragms come in a wider choice of corrosion-resistant materials and coatings than do the isolating diaphragms of ordinary transmitters.
- The measured fluid contains particulates or is viscous, so as to foul the impulse lines leading to the transmitter in a conventional installation.
- The process fluid exceeds the maximum or minimum recommended temperature for the transmitter.
- The measured liquid can solidify in impulse lines and the transmitter body.
- The transmitter must be located away from the process to be more accessible for maintenance.
- The measured fluid is too hazardous to allow conventional field calibration and service at the point of measurement.
- An interface-level or density measurement is involved. These applications require a signal-transfer fluid of equal and constant specific gravity on both the **Low** and **High** connections to the transmitter body.
- Isolate transmitter from high vibrations of the process line.
- An industry specific process connection is required. For example, 3-A sanitary type seals for food and beverage, dairy, pharmaceutical and biotech, and machine connections for pulp & paper and polymer processing.
- Simplify maintenance on wet / dry leg impulse lines.

Capillary fluid and diameter

The choice of fill fluid for a seal system can affect the safety of certain processes, as well as the accuracy and response time of the measurement. What's more, if a fault condition causes the fill fluid to leak, a poorly chosen fluid could affect the quality of the process stream being measured.

Four considerations apply when choosing the fill fluid

- 1 Temperature** – the operating temperature ranges for a fill fluid depend on the measured pressure. A given grade of silicone oil, for example, can operate at –90 to 80 °C (–130 to +176 °F) under vacuum conditions, but instead at –90 to 180 °C (–130 to +356 °F) when the pressure is above 1.03 bar (15 psia). A fluid exposed to temperatures outside its recommended range may solidify or vaporize.
- 2 Expansion coefficient** – the various fill fluids in use have different coefficients of thermal expansion. Wide fluctuations in ambient temperature can cause the fill fluid to expand or contract significantly. This effect becomes particularly important in unbalanced systems where capillaries of the **High** and **Low** connections have lengths that differ or they are exposed to different ambient temperatures. The smaller the expansion coefficient, the less the measurement will be affected.
- 3 Compatibility with measured fluid** – because the seal diaphragm is usually thin, there is always the chance that it could be damaged and the fill fluid could leak into the measured medium. This possibility should particularly be considered if contamination of the measured fluid is covered by government regulations (as with foods processing) or where inert fluid is required in a combusive process like wet chlorine or oxygen service.
- 4 Viscosity** – the fill fluid's viscosity can significantly influence the response time of the measurement. The less viscous the fluid, the faster the response. Remember also that if the temperature around the capillary decreases, the viscosity increases. Kinematic viscosities of fill fluids range widely – from 4 mm²/s (4 cSt) for silicone oil to 1,130 mm²/s (1,130 cSt) for glycerin, both at 20 °C (68 °F) – glycerin is usable down to the extremely low temperature of –274 °C (–462 °F).

Response time

Before the capillary fill fluid can hydraulically convey to the transmitter a change in the pressure of the measured medium against the seal diaphragm, a finite amount of time must elapse. Often overlooked, this response time can significantly affect the performance of the seal system and measurement.

The major design considerations with respect to response time are the capillary diameter and length as well as the viscosity of the fill fluid. The smaller the diameter, the longer the response time. The typical diameter of the capillary is 1 mm (0.04 in.) In applications where response time is important, consider a larger diameter. As for capillary length, it is often dictated by installation needs, but response times are improved by keeping the capillary as short as feasible.

Although low fill-fluid viscosity favors a fast response, a low viscosity may not be consistent with the requirements for thermal expansion and operating temperature range. The trade-off varies on a case-by-case basis.

Fluctuating temperature effects

A common problem with using remote seals is the inaccuracies that can result from fluctuating temperature conditions. Each change of ambient temperature around each seal capillary will expand or contract the fill fluid by an amount dictated by the fluid's thermal expansion coefficient.

The system designer has four options to minimize the error caused by temperature effects:

- Keep a balanced system of equal high-low seal types and capillary lengths
- Reduce capillary diameter and length to decrease the volume of fill fluid (at the risk of increasing the response time).
- Choose a fluid with lower expansion coefficient (subject to viscosity and temperature-range limitations).
- Specify a relatively large diameter for the seal diaphragm. The comparative stiffness of small diaphragms tends to magnify errors related to temperature fluctuations.

Installing a seal system

Proper installation of the transmitter and its remote seal system depends basically on the variable being measured. In general, flow and gage-pressure applications allow the most flexibility. Conversely, when the process vessel operates under vacuum, a liquid-level measurement entails restrictions on the relative elevations of the transmitter and the seals. For measurements of absolute pressure, there are similar restrictions when the lower range value is less than 1 atm.

Basically, transmitters linked to remote seals respond not only to process pressures, but also the head pressure caused by the liquid column in the seal system itself. The latter is a function of transmitter and seal locations. Dealing with this complication depends on the type of measurement being made.

With most installations for measuring flow, gage-pressure or absolute-pressure, the head-pressure effect is minor and can be canceled out by a zero adjustment in the transmitter. When measuring liquid levels, however, head pressures can have a bigger effect on configured measuring span because of a substantial difference between the elevations of the high- and low-side seals (Figure 7).

Measuring pressures

A gage-pressure transmitter with a remote seal can be used for measurement on either a process pipe or a tank. Figures 4 and 5 show gage-pressure installations on pipe, respectively for pressure service and vacuum service. The seal diaphragm should be on the top or the side of the pipe as shown to keep sediment from collecting on the seal diaphragm. For single capillary remote seal transmitters, consider also that for the head pressure affect will begin to consume the pressure measuring range of the sensor the farther it is mounted from the seal datum line.

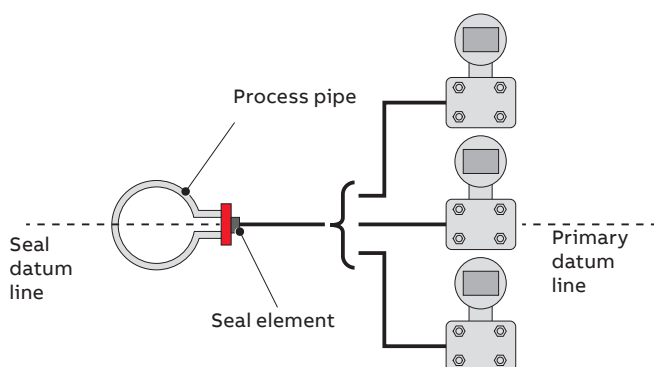


Figure 4 Transmitter can be located above, below, or at the same level as the seal for pressures above 1 atm

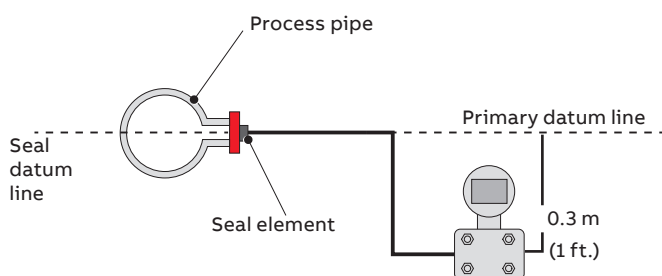


Figure 5 For measuring pressures that can fall below 1 atm, the transmitter should be placed so that its datum line is at least 1 ft. below the level of the seal

Pressure service

When the low end of the operating- pressure range is above 1 atm (0 psig), the transmitter can be placed in any convenient location – at the same level as the remote seal diaphragm, above or below it, see Figure 4.

Vacuum service

When the operating-pressure range includes pressures below atmospheric, the transmitter must be below the elevation of the seal element, see Figure 5. This ensures that the pressure in the transmitter body is always above 0 psia, because of the positive head effect of the capillary fill fluid on the sensor. The recommended minimum vertical distance between transmitter datum line and seal datum line is 0.3 m (1 ft.) .

For absolute-pressure measurements, follow the recommendations for vacuum service.

Flow Measurement

Differential-pressure transmitters with two remote seals can measure flowrates in horizontal or vertical lines. Figure 6 shows a horizontal installation, the transmitter connected across the differential-producing (wedge) flow element. The upstream seal links to the transmitter high side (HP), the downstream one to the low side (LP).

Whether the pipe is horizontal or vertical, the transmitter can be placed in any convenient location (except in vacuum applications, where it must be below the datum line of the lower seal). For accurate measurement of liquid flow, the flow restriction must be in a pipe section that is always full. In a horizontal setup, as shown, the seal elements are at the same elevations, so head pressure of capillary fill-liquids are the same on the high and low sides of the transmitter. Accordingly, the transmitter calibrations can be zeroed out. If the process fluid contains suspended solids, the seal elements should be at the top of the pipe, to avoid collection of solids on the seal diaphragms.

In a vertical setup, the elevation difference between the seals induces a differential head pressure even with no flow. When the pipe is full at no flow, the initial differential depends on the distance between the two seals, and the difference in density between the process liquid and the fill liquid. A zero adjustment in the transmitter can compensate for this condition.

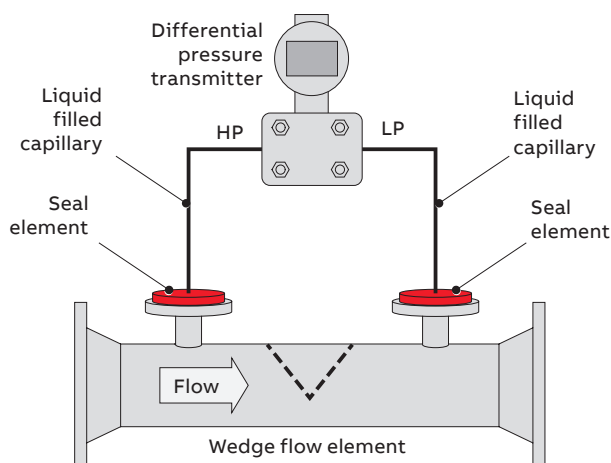


Figure 6 Flow measurement – placing of seals upstream and downstream of a flow restriction

Liquid-level measurement

A DP transmitter with either one or two isolating seals can measure liquid level whether the tank is open or closed and, in the latter case, whether it is operating under positive pressure or vacuum. For closed tanks, given the choices of using one or two seals, and dry-leg or wet-leg connections, the installation options multiply.

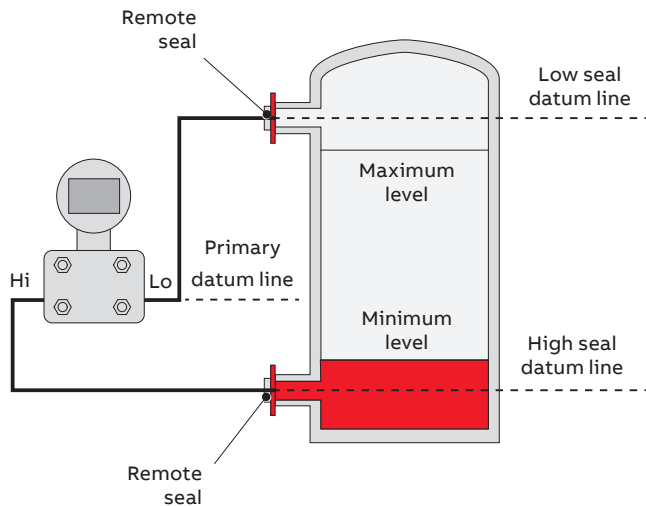


Figure 7 Measurement in a closed tank using 2 seals (the transmitter placement acceptable only for tanks in pressure service)

Open tank, one remote seal

The seal element is typically located close to the bottom of the tank (see Figure 8) so that its datum line is at or below the minimum process fluid level. As shown, the seal connects to the high side of the transmitter, with the low side vented to atmosphere. The transmitter can be located either above (as shown) or below the seal element. The head effect can be corrected accordingly by the zero adjustment.

The vertical distance of the transmitter seal above the datum line should not exceed 9m (30 ft.). The distance would cause the head pressure effect of the capillary to apply a full vacuum to the transmitter sensor, thus causing damage.

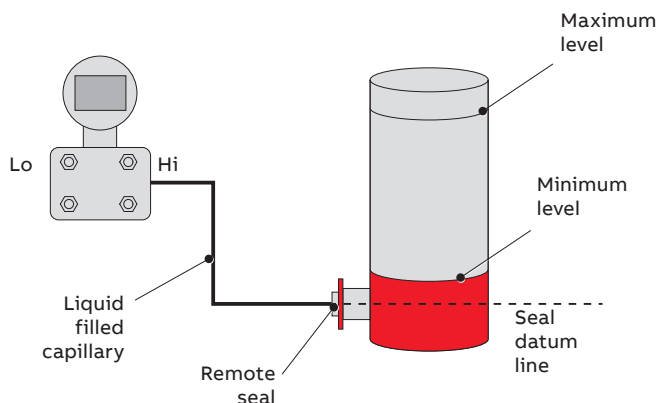


Figure 8 Measuring liquid levels in an open tank using a single seal

Closed tank, two remote seals with pressure service

When two seals are used (see Figure 7) the lower one, located at or below the minimum level, is connected to the high side of the transmitter. The other isolation seal must be at or above the maximum level and connected to the transmitter low side. This arrangement cancels out the effect of vessel pressure, and the instrument measures only liquid level.

When measuring liquid level in pressurized vessels, the transmitter can be located between the seals, as shown in Figure 7, or it can be either above or below both seals.

For closed tank service involving vacuum pressures, the transmitter must be located below the high side seal datum line regardless of whether one or two seals are being used. The recommended minimum distance between the primary datum line for the transmitter and the high side seal datum line is 0.3 m (1 ft.)

Dry leg with remote seal

If the process vapor is not readily condensable, or if the compensating leg is at a higher temperature than the tank interior, a dry leg can be used – see Figure 9. A condensate trap at the bottom of the leg minimizes the chance of condensate collecting in the transmitter body and affecting the low-side reference pressure measurement.

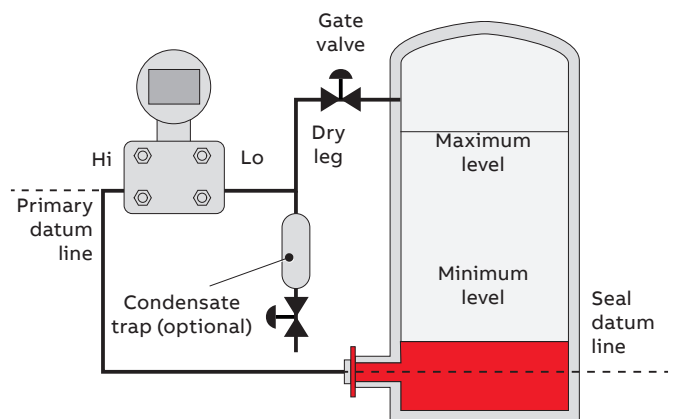


Figure 9 This setup for level measurement uses only one seal (low side of transmitter is connected to the vapor space by a dry leg)

Wet leg with remote seal

If the process vapor is condensable, a wet leg can be used; the leg is filled with a suitable liquid of higher specific gravity, to maintain a constant pressure on the low side of the transmitter. This arrangement avoids the problem of process vapor condensing and collecting in the compensating leg, which would lead to serious measurement error. An alternative is to locate the transmitter near the tank top, so that condensate drains back into the tank – see Figure 10.

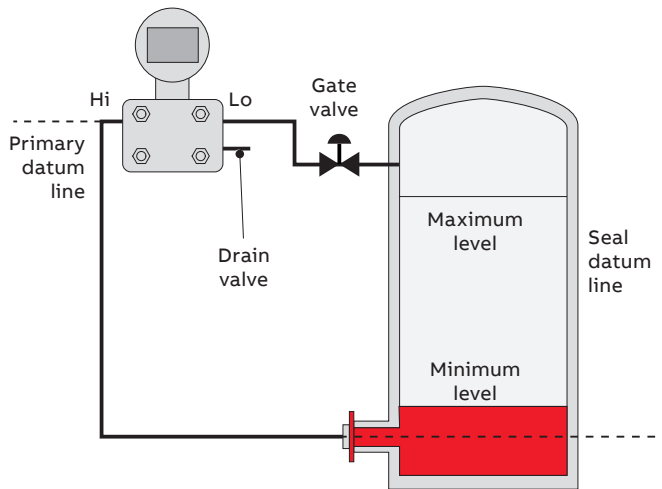


Figure 10 Level measurement – elevating the transmitter to ensure condensate drains back into tank (when readily-condensable liquids are present)

Interface level and density measurement

Using two seal systems, the interface level between two liquids in a process vessel can be measured with a DP transmitter (Figure 11). The same concept can be used to measure liquid density or specific gravity. The high-side seal element is located near the bottom, with its datum line at or below the lowest interface elevation. The low-side seal is at or above the highest interface elevation. Under all interface conditions, the minimum level of total liquid in the vessel must be above the low seal element near the top of the vessel.

When the vessel is open or under positive pressure, the transmitter can be between the two seals, or above or below both. The preferred site is midway between them. This minimizes the capillary length required and usually provides the most uniform distribution of ambient temperatures. If, instead, the operating-pressure range includes pressures below 1 atm, the transmitter must be below the high-side seal, as with vacuum service.

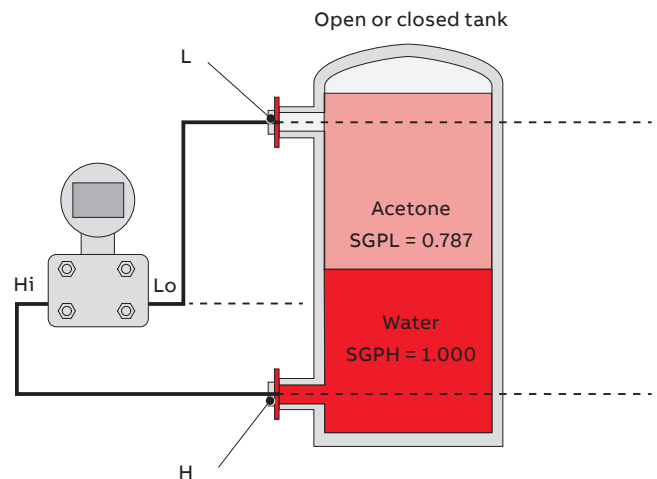


Figure 11 Interface level and density application – applying DP remote seals across a fixed volume

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