The Versatile Differential Pressure Transmitter

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Abstract

The differential pressure transmitter is the most versatile of all the pressure sensors having the broadest measuring capability and application exposure. This document is intended to give the reader a better understanding of the fundamentals of differential pressure measurement and its applications. Battery-powered wireless differential pressure transmitters add the dimension of increased flexibility for installations where wiring costs or the absence of available power have limited the use of traditional wired differential pressure transmitters.

Pressure Fundamentals

Pressure devices are typically categorized into three types of pressure measurement: GAUGE pressure, ABSOLUTE pressure and DIFFERENTIAL pressure. Fundamentally, they are all differential pressure measurements.

A gauge pressure device is one that measures pressure relative to atmospheric pressure. The process side of the pressure sensor is exposed to process pressure while the non-process side is left exposed to the atmosphere. Essentially the sensor has atmospheric pressure force on the non-process side of the sensor and process pressure force on the process side of the sensor. The gauge measurement is the difference between atmospheric pressure and the process pressure. If the non-process side of the sensor was sealed off from the atmosphere then any trapped volume of gas would expand and contract with temperature changes and impart a pressure change on the non-process side of the sensor. This would create a gross error to the gauge pressure signal. As a rule, all gauge pressure sensors must have an internal passage from the non-process side of the sensor to atmospheric pressure.

An absolute pressure measurement device is similar to a gauge pressure sensor in that only one side of the sensor diaphragm is exposed to process pressure. The non-process side of an absolute pressure sensor is designed to contain a near perfect vacuum. With the non-process side of the sensing diaphragm at full vacuum the absolute pressure reading is obtained by measuring the differential pressure force between it and the process side of the sensor. Any applied pressure to the process side would be a positive differential and referred to as an absolute pressure reading.

The description of gauge and absolute pressure types has shown that they are inherently differential measurements and to that end Differential pressure transmitters can be more broadly applied than any other type of transmitter.

A differential pressure measurement is typically performed by subjecting a diaphragm-type sensor to two independent pressure inputs. The pressures are applied to opposite sides of the sensor with the forces counteracting each other to result in a sensor response that is equal to the net difference of the two pressure inputs (Figure 1). Both the high side (blue) and the low-side (yellow) pressures are independently transmitted to the sensor in order to determine the “differential pressure”.

Leaving the differential pressure transmitter's low side pressure port open to atmosphere allows the transmitter to be used for a gauge pressure measurement as the applied process pressure will be a positive differential from atmosphere. Applying a full vacuum to the low pressure port will allow the differential pressure transmitter to respond in a manner similar to an absolute pressure transmitter.
To measure a vacuum where atmospheric pressure is to be the zero starting point, the vacuum is applied to the low pressure port while the high pressure port is left vented to the atmosphere. The increasing differential value (the increase in vacuum) is shown as a positive output change.

### Applications

#### Flow

The most popular application for differential pressure transmitters is to measure the pressure drop across an orifice plate for measurement of flow (Figure 2). There are many books written on this subject so it is not the objective of this article to go into the details necessary to engineer a full solution. The objective here is merely to support increased opportunity awareness.

An orifice plate, pitot tube, venturi, V-cone, etc. are examples of primary flow elements that create a pressure loss as a fluid flows past their restriction. The amount of restriction is tailored to meet the process considerations of piping, pressures and flow. The pressure loss is proportional to the size of the restriction, the fluid properties e.g. density and the velocity of the fluid. By measuring the pressure drop through differential pressure created across the primary element it is possible to calculate the fluid flow. Pressure taps located upstream and downstream of the flow element are connected to the high and low input ports of the differential pressure transmitter. The pressure in the line maybe upwards of 1,000 psi but the pressure drop is usually very small. Using two separate gauge pressure devices and subtracting the readings would result the combined error of two devices having wide measuring spans. The result would be a very poor measurement seldom suitable for control. Utilizing a differential pressure transmitter allows the measurement to be made with one device over a much smaller span resulting in greatly improved precision. It also serves to reduce the amount of field wiring by eliminating the need for a second transmitter.

The differential pressure value is generally expressed in “inches H₂O”. This value is then run through an equation to convert the pressure reading to a flow value. A simplified approach to convert from pressure to flow is to take the square root of the pressure reading, express it as percent flow and calculate the flow value from the percentage.

Example: Flow element has been engineered to represent full flow being 1,000 gallons per minute at a pressure drop of 100” H₂O. The square root of 100"H₂O would be 10 which is expressed as 100% of flow. Under operating conditions if the pressure reading was at 49"H₂O the square root would be 7 which would represent a 70% flow reading. 70% of flow equals 700 GPM.

The function of performing the square root calculation is very frequently performed at the transmitter so that the local display can be configured to read out the flow value instead of the pressure reading.

**Note:** Applying a wireless DP transmitter with an averaging pitot tube can be a very inexpensive approach to adding flow measurement points at a plant that wants to achieve better energy balance measurements.

#### Filter Screen Quality

Many processes require filtering of a fluid to assure large particle sizes are separated out and not allowed downstream. Filters come in many shapes and sizes depending upon the needs of the user. It may be a wide mesh screen across the water intake at a power plant to a micron sized mesh filter at a paint pigment plant. Regardless of the type of customer the approach to filter cleanliness quality is very similar. As a filter traps particles it reduces the free space for the fluid to pass through. The restriction in free space causes the pressure on the upstream side of the filter to increase. By measuring the upstream and downstream pressures a determination of filter cleanliness can be obtained. An increasing differential pressure is indicative of filter clogging. As with the flow measurement application described earlier, the upstream pressures will often be much larger than the amount of the
pressure drop. So here too differential pressure measurement provides much greater precision and reduces the number of devices required to perform the measurement.

**Note:** Some filters such as bag houses are often at areas outside of the building structure and frequently lend themselves to wireless solutions.

**Level**

Liquid level in vessels is a very popular application for differential pressure transmitters. They are often the most cost effective solution. Fluid within a tank develops a head pressure that is able to be measured at the bottom of the tank. Head pressure is a function of the height of the fluid and the fluid density.

If the tank is an open vessel then the measurement could be performed with a gauge pressure device but as is typical with most tanks the amount of pressure produced is often very low. Head pressures of less than 400”H2O are often the norm. Gauge pressure transmitter spans are usually much larger. Better precision to the measurement is obtainable by using a more sensitive DP transmitter and venting the low pressure port to atmosphere.

If the tank is a closed vessel then the DP transmitter is an even more cost effective solution. Volatile fluids will release vapors when left vented to atmosphere and as a result they must be contained to avoid harming the environment. When kept in a sealed tank they will release vapor will until pressure equilibrium is achieved. The vapor pressure rests on top of the fluid and adds to the head pressure reading that is measured at the bottom of the tank. To properly calculate fluid level the vapor pressure needs to subtracted from the total head pressure. Here again rather to using two independent gauge pressure transmitters, a single DP transmitter can be applied to receive both the total head pressure and the vapor pressure. The differential pressure is representative of the net head pressure or the height of the liquid level.

There is much more that goes into tank level applications than the simple description provided here. Isolation diaphragms, filled capillaries, physical mounting i.e. flanges, etc. have to be taken into consideration. Alternate technologies also warrant consideration such as ultrasonic, radar and load cells.

**Note:** Tanks and vessels are often in remote areas and frequently lend themselves to wireless solutions. A battery powered wireless DP transmitter eliminates the need to bring power to a tank resulting in substantial installation savings.

![Figure 3. Typical level measurement application](image-url)
Density
With tank level applications that contain expensive materials it is desirable to measure the level as accurately as possible for inventory purposes. Changes in temperature typically cause fluid density changes which in turn affects the head pressure value at the bottom of the tank. A technique that has been used in the past to measure the density change is to place a fixture on the side of the tank with taps that are a fixed distance apart. By mounting a differential pressure transmitter off of the two taps a measurement of the fluid density can be calculated. If the tank were filled with a fluid having a density of 1.0 and the transmitter taps were separated by 10” then the transmitter would read 10”H₂O all the time. But if the fluid were to drop in temperature and have a density change of plus 3% then the reading of the transmitter would increase by 3% to 10.3” H₂O. The value of 0.3” of level can easily equate to thousands of gallons of miscounted product in large diameter tanks. Having the density reading available allows for corrections to be applied to the level value.

Note: There are several existing approaches to obtain accurate tank level measurement, the first and foremost of which is the Honeywell Enraf product line. The FlexLine Radar Level Gauge is available with the Honeywell OneWireless radio solution to simplify and reduce wire costs.

Leak Detection
During startups and often times during operation and maintenance it is necessary to perform leak testing on piping and vessels. While there are several approaches to it, some involving sniffing for the presence of specific gases such as Helium or watching for the migration of dyes or fluids viewable under ultraviolet light, a low cost simple alternative is to perform a pressure decay test. Pressure decay can be as simple as applying test pressures to a vessel and monitoring for a pressure drop over a period time. Larger vessels are usually tested at lower pressures than smaller ones due to the greater force that pressure applies over a wider surface area. Low pressure changes are usually more readily observable with a DP transmitter as the span on of differential transmitter tends to be lower than that offered on gauge pressure instruments.

Another approach to picking up pressure decay faster is to have a reference chamber of a volume similar to the chamber to be tested. The reference chamber would be one that has been previously qualified as being leak free. Pressure or vacuum is applied to both chambers simultaneously with a differential pressure transmitter connected between them. When the test pressure value is reached the chambers are then isolated from each other. The narrow span range of the DP transmitter will quickly detect any differential pressure change occurring between to two tanks which would indicate a leak if one were to exist.

Note: Leak detection on tanks and vessels is often a temporary test and performed where there is no easy access to power. A battery powered wireless DP transmitter provides local display for immediate feedback while the test is in progress but also offers the means to capture and document the test results without having to pull wires to data logging equipment.

Viscosity
Coriolis meters today are widely accepted for mass flow, density, % solids, brix, Baume and temperature measurements. A less frequently performed measurement is the measurement of fluid viscosity. To accomplish this requires the addition of a differential pressure transmitter with taps located upstream and downstream of the coriolis meter. By utilizing the data flow, density and temperature data from the coriolis meter a calculation can be performed with the addition of the differential reading to derive the fluid viscosity.

Note: The viscosity calculation is usually executed at the host controller and running additional wires to bring back the DP measurement can be cost prohibitive. Wireless DP transmitters solve that problem.
Summary

Differential pressure transmitters account for roughly two thirds of the pressure transmitters sold. As previously shown, they are the most versatile of the pressure sensing technologies, adaptable to provide the broadest application coverage. Special materials of construction, broad selection of installation and process mounting configurations and a performance unsurpassed for over 20 years have earned Honeywell’s ST 3000 Smart Pressure Transmitters a reliable reputation. That same level of performance and quality is now available in XYR 5000 and XYR 6000 wireless transmitters, further positioning Honeywell transmitters as industry leaders.

More Information

For more information about Honeywell’s versatile Differential Pressure Transmitter, visit our website at www.honeywell.com/ps/hfs or contact your Honeywell account manager.

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