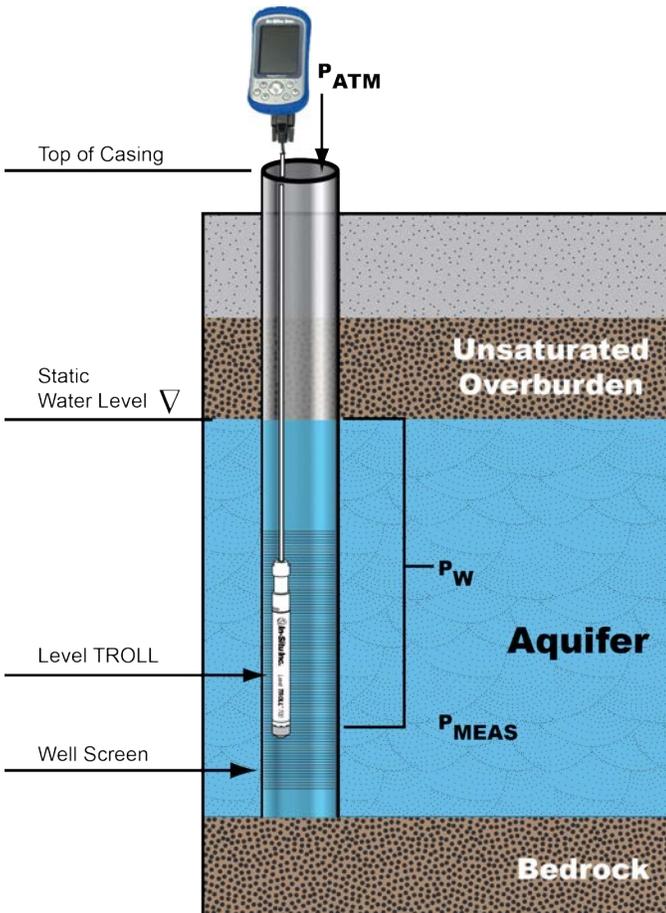


## Comparing Vented and Non-vented Pressure Sensors

### Overview

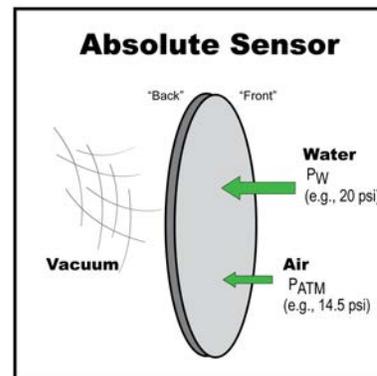
This describes the difference between non-vented (absolute) and vented (gauged) pressure sensors and explains the proper use of each type of sensor in different applications. It also describes how to calculate the accuracy of a pressure sensor and determine the usable depth. The illustration below provides a general illustration of the forces measured by a pressure sensor's internal strain gauge.



### Non-vented Pressure Sensors

A non-vented (or absolute) pressure sensor measures all pressure forces applied to the strain gauge, including atmospheric pressure. The back of an absolute pressure sensor is sealed from the atmosphere, and thus the front of the pressure sensor responds to both the pressure head of the water above the sensor and the atmospheric pressure above the water. This is shown by the following equation and illustration:

$$P_{\text{MEASURED}} = P_{\text{WATER}} + P_{\text{ATM}}$$

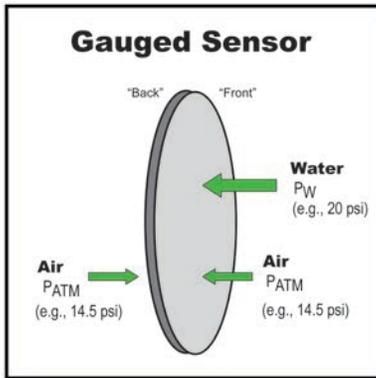


The unit of measure is PSIA (pounds per square inch absolute), measured with respect to absolute zero.

### Vented Pressure Sensors

A vented (or gauged) pressure sensor measures only the pressure head of the water above the sensor. Vented sensors eliminate the effects of atmospheric pressure because the sensor's vent allows atmospheric pressure to be applied to the back of the sensor. The forces applied to a vented sensor are shown in the following equation and illustration:

$$P_{\text{MEASURED}} = P_{\text{FRONT}} - P_{\text{BACK}} = (P_{\text{WATER}} + P_{\text{ATM}}) - P_{\text{ATM}} = P_{\text{WATER}}$$



The unit of measure is PSIG (pounds per square inch gauge), measured with respect to atmospheric pressure.

### Which Sensor Should I Use?

Atmospheric pressure fluctuations will cause water level changes at a monitoring location if the location is open to the atmosphere, such as open wells and surface water. Locally, barometric effects can change significantly from location to location as a result of topographical and micro-meteorological changes. Therefore, it is important to compensate for the barometric pressure changes when monitoring water elevation. Vented sensors automatically compensate for barometric pressure (except in confined aquifers), while non-vented sensors must have their data post-corrected to accurately reflect water level in any situation. Vented sensors are more accurate due to a smaller total maximum error, which is discussed later.

### Confined vs Unconfined Aquifer

Confined aquifers require barometric post-correction regardless of if a vented or non-vented pressure sensor is used. However, vented sensors are more accurate due to a smaller total maximum error. In general, barometric effects do not cause changes in water level in unconfined aquifers. A gauged sensor will work well in this situation. Again, absolute sensors need to be corrected with barometric data to obtain accurate water level elevations.

## Gauged Pressure Sensors

A gauged pressure sensor measures true water level elevation. Post correction is not needed, but the user must ensure that the vent tube of the cable is venting properly. In order to maintain proper venting and to protect the cable connector from moisture and corrosion, In-Situ recommends using a desiccant cartridge at the surface connector of the vented cable.

## Absolute Pressure Sensors

An absolute pressure sensor needs to be post-corrected with barometric data. Ideally, a BaroTROLL Data Logger should be used to monitor barometric data when using an absolute pressure sensor. Therefore, the post-corrected data for true water level has a cumulative accuracy because the error of the absolute pressure sensor and the BaroTROLL Data Logger is a combination of both instruments.

## Usable Depth

The useable depth of a pressure sensor is the maximum depth of submersion below the surface of the water that you can expect to collect accurate data, within specifications, and not stress or damage the pressure sensor. This is also the maximum range that the sensor is calibrated.

To determine the maximum usable depth for a given pressure sensor, simply look at the engraving on the transducer housing that states the range in feet/meters for the sensor or refer to the useable depth, listed in parenthesis, on the specification sheet for each specific sensor range.

An absolute pressure sensor of the same pressure range as a gauged pressure sensor cannot be submerged as deep as a gauged sensor because approximately 12 PSI to 14 PSI (8.44 m to 9.85 m; 27.7 ft to 32.3 ft) of atmospheric pressure is already being exerted on the absolute pressure sensor.

## Accuracy and Resolution of Absolute and Gauged Sensors

### Accuracy

Accuracy is defined as the degree to which an instrument reading approaches the true value. Accuracy is the proximity of a measurement to the true value and precision is the repeatability of measurements.

### Resolution

Resolution is the smallest amount of change that can be detected by the sensor before the measured value is recognized.

Because there are several different pressure sensor ranges to satisfy required accuracy and resolution specifications, it is important to relate the maximum usable depth for each range of sensor to make sure that the sensor operates properly. Refer to the tables below to determine the maximum usable depth and accuracy for each pressure sensor range.

In-Situ Inc. offers instruments with pressure sensors that are available in several PSI ranges and as either gauged or absolute (see Table below). Instruments with either gauged or absolute pressure transducers include: Level TROLL 500 and 700 Data Loggers, Aqua TROLL 100/200 Data Loggers, Aqua TROLL 600 Multiparameter Sonde, and TROLL 9500 Water Quality Instrument. The Level TROLL 400 is an absolute-only instrument.

PSI Range Full Scale	Gauged Usable Depth (Meters   Feet)	Absolute Usable Depth (Meters   Feet)	0.1% Full Scale Accuracy (PSI   Meters   Feet)
5	3.5   11.5	N/A	0.005   0.004   0.012
15	11   35	N/A	0.015   0.010   0.035
30	21   69	11   35	0.030   0.021   0.069
100	70   231	60   197	0.10   0.070   0.231
300	210   692	200   658	0.30   0.211   0.692

500	351   1153	341   1120	0.50   0.352   1.153
1000	NA	693   2273	1.00   0.703   2.307

In-Situ Inc.'s instruments are available with different accuracy specifications:

- Level TROLL and TROLL 9500 Instruments have an accuracy specification of  $\pm 0.1\%$  full scale (FS) from  $-5^{\circ}$  to  $50^{\circ}$  C for both gauged and absolute sensors.
- Aqua TROLL 100/200 Instruments have an accuracy specification of  $\pm 0.1\%$  FS from  $0^{\circ}$  to  $50^{\circ}$  C for both gauged and absolute sensors.
- Full scale (FS) is defined as the PSI range for the sensor installed on the transducer. In-Situ Inc.'s Level TROLL and Aqua TROLL Instruments have an accuracy specification of  $\pm 0.05\%$  at  $15^{\circ}$  C because this is the average temperature of groundwater and creates stability for the pressure readings.

An accuracy specification of  $\pm 0.1\%$  FS represents a deviation from 100% accuracy; therefore, accuracy should be specified as 99.9%. However, convention dictates that  $\pm 0.1\%$  is an accuracy specification rather than an inaccuracy (tolerance or error) specification.

In-Situ Inc.'s Rugged TROLL 100/200 Data Loggers, Aqua TROLL 400 Multiparameter Instrument, and smarTROLL Multiparameter Handheld include absolute pressure sensors (see Table below). Rugged TROLL Data Loggers are available in various ranges, while other instruments have one standard pressure range.

Pressure Range in Meters   Feet Full Scale	Absolute Usable Depth (Meters   Feet)	Full Scale Accuracy (Meters   Feet)
9   30	9   30	0.027   0.09
30   100	30   100	0.09   0.30
76   250	76   250	0.23   0.75

In-Situ Inc.'s Rugged TROLL, Aqua TROLL 400, and smarTROLL Instruments have an accuracy specification of  $\pm 0.1\%$  FS typical and  $\pm 0.3\%$  FS maximum from  $0^{\circ}$  to  $50^{\circ}$  C. Full scale (FS) is defined as the pressure range in feet/meters for the sensor installed on the transducer.

An accuracy specification of  $\pm 0.3\%$  FS represents a deviation from 100% accuracy; therefore, accuracy should be specified as 99.7%. However, convention dictates that  $\pm 0.3\%$  is an accuracy specification rather than an inaccuracy (tolerance or error) specification.

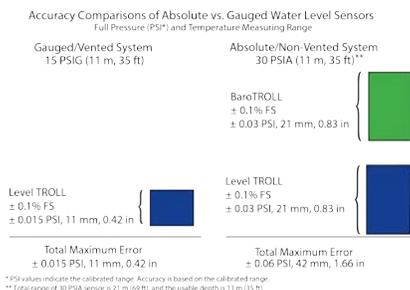
## Determining the Accuracy of a Pressure Sensor

To calculate the accuracy of any given pressure sensor, simply multiply the pressure rating of the sensor by the accuracy specification (0.1% or 0.3%) and it will give the accuracy range ( $\pm$ ) you can expect from this sensor. See the following examples (note: 1.0 PSI = 0.703 m = 2.307 ft).

- A transducer with a 30 PSI sensor ( $0.1/100 \times 30 = 0.03$  PSI) has an accuracy of  $\pm 0.03$  PSI.
- A transducer with a 30 foot sensor ( $0.3/100 \times 30 = 0.09$  feet) has an accuracy of  $\pm 0.09$  ft.

## Comparing Accuracy of Absolute vs. Gauged Sensors

The figure below compares a gauged Level TROLL 15 PSIG sensor to an absolute Level TROLL 30 PSIA sensor. This illustration demonstrates how the output from an absolute level instrument has an additional error of  $\pm 0.1\%$  due to the cumulative error of post-correction. The total cumulative error is  $\pm 0.2\%$  when using an absolute Level TROLL Instrument and a BaroTROLL Instrument compared to  $\pm 0.1\%$  when using a gauged Level TROLL Instrument. (Note: 15 PSIG and 30 PSIA sensors are compared because they have the same usable depth.)



## Conclusion

Absolute sensors work for all applications if a barometric record is kept for applications that need to be compensated for barometric pressure changes, especially during long-term monitoring. However, post-correction of the data introduces cumulative error into the final results, which makes the data less accurate than the data from a gauged sensor. A gauged sensor is more accurate because the vented system eliminates barometric effects on the sensor, which eliminates post processing for water levels in unconfined aquifers. Well water levels in confined aquifers are indeed sensitive to barometric pressure. Post correction of water level for barometric effect is needed for both absolute and gauged sensors.