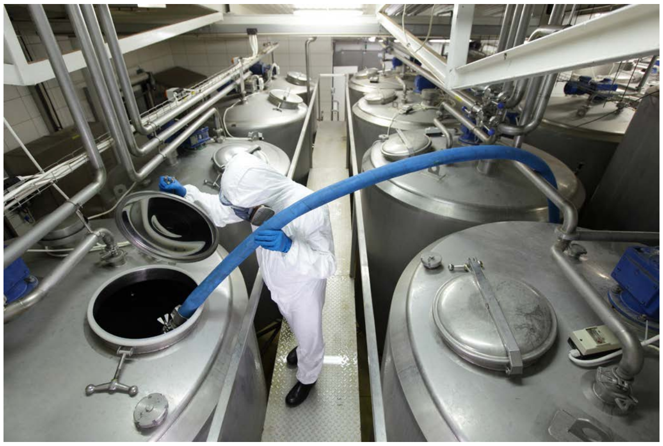
BEST PRACTICES IN MEASURING TANK LEVEL
What to Know About Measuring Tank Level

WHITEPAPER



Whether you are looking for a solution to solve a water supply issue to a building or trying to monitor a process tank within your factory, the proper tank level is extremely important to the success of your project. There are countless applications across many industries that with a few simple steps can ensure that you can meet the needs of your project.

What type of tank do you have? There are two main types of tanks that are used in the HVAC and Industrial markets; vented and sealed tanks. This simple question of the type of tank will drive the entire decision making process of your application, so the decision is crucial.

A vented tank is any tank, regardless of size or shape, which has a liquid in which atmospheric pressure (approximately 14.7 PSI) is the only force on top of the liquid in that tank. One of the most recognizable vented tanks is an elevated water tank. An elevated water tank can be used to supply the proper water pressure to a factory or neighborhood that may not have adequate pressure to service the application. Other applications include oil tanks, stand pipes, sewerage wet wells, fire prevention tanks in remote communities and food and beverage manufacturing.

Measuring the liquid level in a vented tank can be completed in a variety of ways, with many different levels of accuracy. The first thing you need to know is if your vented tank is above ground or if your tank is buried in-ground. An above ground tank will typically have a process connection external near the bottom of the tank as well as a way to access the tank from above. A tank that sits in-ground will typically have an access hatch that you can access to install your sensor.

1. Methods of Tank Level

The simplest and least expensive form of tank level measurement is the glass or clear plastic sight glass mounted on the side of the tank. The sight glass is installed so that it has a pressure connection where the media can travel up the sight glass, so that the liquid level can be seen without having to look inside the tank itself. With this method, since there is no alarm or electronic feedback loop, a sight glass setup requires periodic inspection and manual refilling. If your application doesn't call for high accuracy and automation, its a reliable

What's Inside

method that requires little to no maintenance. As a result of its limitations, float or liquid level switches have replaced sight glasses in many applications to help reduce human error in your liquid supply. Typically, two float switches are used to measure tank level, and both are mounted inside of the tank, indicating low or high level. As the liquid level falls or rises to a predetermined set point, a rod closes a contact to complete a circuit that notifies maintenance or sounds an alarm. Float switches are reliable, inexpensive and ideal for non-critical applications (± 6”), such as sewerage systems.

Capacitance, resistive, ultrasonic and hydrostatic methods are more commonly used in critical applications. Even though all methods transit the liquid level in real time, they work on different principals.

Capacitance level sensors detect a change in the capacitance that occurs between two conductors when a fluid is present. An empty tank has a lower capacitance in comparison to a filled tank. Unfortunately, as levels drop, some liquid remains on the sensor that can cause false readings. As a result, there is a lag in the response time, especially with liquids with a high viscosity. This type of sensor isn’t ideal for tanks that encounter rapidly changing liquid levels.

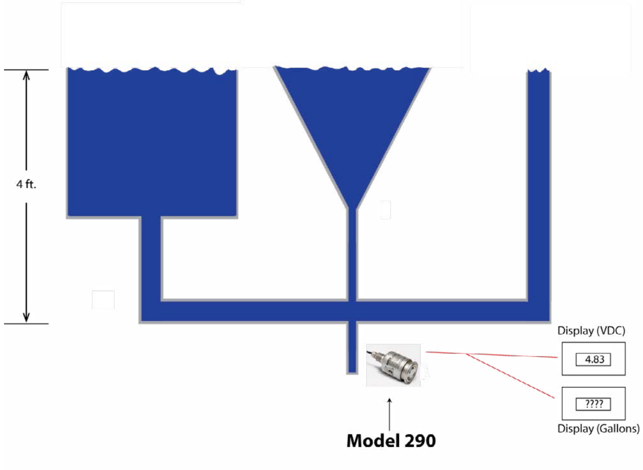
Resistance measurements are often made with a series of sensors that have been submerged into the filled tank. This process is similar to a dipstick in a car’s oil reservoir, but with sensor probes along the length of stick. These sensor probes are connected to circuitry that ties back to a control panel to alert when to fill, alarm or drain in the application. The drawback to this method is that the accuracy is dependent on the amount of probe sensors, the more installed the better the measurement, but initial price increases.

Ultrasonic sensors are mounted at the top of the tank and emit high-frequency acoustic waves that reflect against the process media below and return to the transducer. The sensor then measures the signal’s transit time to determine liquid level height within the vessel. One advantage of this type of sensor is that it does not come in contact with the liquid and may make a good choice for more corrosive media. Conversely, if the media foams, these units will measure the top of the foam rather than the liquid level, giving the user false data of liquid in the table. In addition, their accuracy can be affected by moisture, temperature and pressure.

2. Hydrostatic Method (Vented Tank)

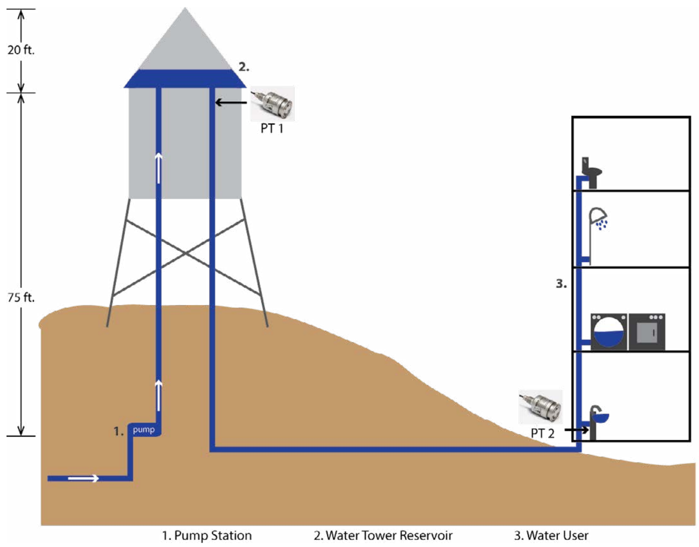
Considering both cost and accuracy requirements is something every system designer faces when starting a project. One of the most preferred methods to combat cost vs. accuracy is the hydrostatic method. The hydrostatic method utilizes simple physics to yield great results for tank level applications. By using a liquid’s specific gravity (See Table 1 for common Specific Gravity values) and column height, a pressure is generated by the liquid and can be measured. Utilizing a gauge (vented to atmosphere) pressure transducer, a user can get real-time tank level even in the most rapidly changing tanks. A pressure transducer will read any height above the diaphragm of the sensor (regardless of the shape of the tank, see Figure 1), so the mounting location is extremely important.

Figure 1



For example, in Figure 2, you have a water tower located up on a hill supplying water to a house below. A water tower is one of the most common above ground vented tanks that people are used to seeing. In Figure 2 there are two mounting locations depicted, one right below the tank and the other right at the incoming location of the house.

Figure 2



3. Above Ground Application

Selecting the Range

Knowing the column height above the sensor helps determine the right pressure range for the application. As shown in the calculation below, the required range of sensor is based on the mounting location. In this example there is a difference of 75 ft depending on the sensor's location. This difference in elevation will need to be factored in when selecting a pressure range, as shown in the equation.

$$PSI_{range} = SG \times CH \times 0.433$$

PSI_{range} = The range of the sensor required to meet application
SG = Specific Gravity of the liquid (see Table 1)
CH = Column Height of the liquid in feet
0.433 = Conversion factor of liquid height into PSI

Table 1: Specific Gravity and Viscosity of Liquids

Liquid	Specific Gravity		
	Temp		
	°F	°C	H_2O at 60°F
Water, Fresh	60	15.6	1
SAE 30 (Oil)	60	15.6	0.88-0.94
Beer	60	15.6	1.01
Benzene (Benzo) C_6H_6	60	0	0.899
Castor Oil	68	20	0.96
Cola	68	20	1.03
Corn Oil	60	15.6	0.924
Diethylene Glycol	60	15.6	1.12
Diethyl Eter	68	20	0.714
Ethylene Glycol	60	15.6	1.125
Gold	60	15.6	19.3
Isopropyl Alcohol	68	20	0.787
Machine Lubricants			
#8			0.88-0.94
#10			0.88-0.94
#20			0.88-0.94
#30			0.88-0.94
Kerosene	60	15.6	0.78-0.82
Jet Fuel (av)	60	15.6	0.62-0.88
Mercury	60	15.6	13.57
Milk	60	15.6	0.02-1.05
Propylene Glycol	68	20	1.038
Quenching Oil	60	15.6	0.86-0.89

In the water tower example above, this will give you two different pressure ranges for your sensor depending on the mounting location. Pressure transducer accuracies are typically rated in percentages of full scale, or example, ±0.25% FS. As the full scale range increases the level of accuracy will decrease, as a result of the longer range change.

By using the PSI range calculation, mounting the sensor in Location 1 or 2 equates to:

Location 1: PSI_{range} = 1 x 20 x 0.433 = 8.66 PSIG
Location 2: PSI_{range} = 1 x 95 x 0.433 = 41.14 PSIG
Note: Specific Gravity of water is equal to 1

Mounting Location 1 requires a 0 to 10 PSIG sensor with an accuracy of ±0.69"W.C. Mounting Location 2 requires a 0 to 50 PSIG sensor with an accuracy of ±3.46"W.C. While that may not seem like a drastic difference, depending on the geometry of the tank, the 2.77" could mean a difference of hundreds of gallons of water or more.

Table 2: Water Tank Level to PSI Conversion using ±0.25% FS Accuracy Transducer

Full Scale Pressure Range	Tank Level (Water)	Accuracy of Level
0-1 PSIG	0-2.307 ft	±0.07"W.C.
0-10 PSIG	0-23.07 ft	±0.69"W.C.
0-50 PSIG	0-115.3 ft	±3.46"W.C.
0-100 PSIG	0-230.7 ft	±6.92"W.C.

Now that the height of the liquid is known, how much water does that equate to? To make that conversion you must first know the volume of the tank. The two most common shapes are cylindrical and rectangular tanks, which are also the easiest shapes to calculate.

For a Cylinder:

Volume = π x r^2 x h
π = 3.14159
r = radius of the tank
h = height of the tank

For a Rectangle:

Volume = L x W x H
l = length of the tank
w = width of the tank
h = height of the tank

In the water tower example we have a cylindrical tank with a radius of 10 ft and a height of 20 ft.

This gives a volume of:
Volume = π x 10^2 x 20 = 6,283.18 ft^3

There are 7.48 gallons of water/ft^3, which means that the water tower has 46,998.19 gallons of water. By taking the total number of gallons and divide it by the height of the tank, we get 195.83 gallons of water per inch of height in the tank. So when you are talking about those 2.77 inches of accuracy difference in the example above, it equates to over 540 gallons of water.

Depending on the application, the amount of water could be crucial to the residents who depend on the water tower for drinking water and fire protection.

Note: For Location 2, add of the volume of your piping to the volume of the tank itself.

4. In-Ground Application

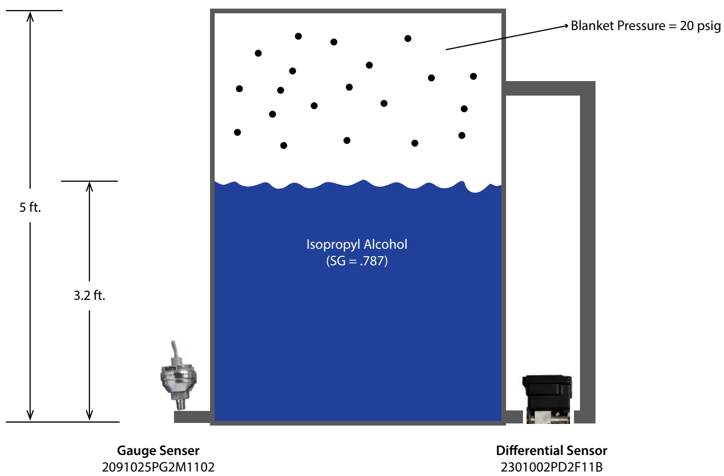
For in-ground applications, all of the same methods and principles still apply, except there's no ability to connect a sensor externally to tank in most cases. In this type of application the tank can be assessed through an access hatch or drilled hole in the top of the tank. All methods, other than the common sight glass, of tank level measurement can still be viable options even in a in-ground installation. The main change is when utilizing the hydrostatic method, use a submersible pressure transducer or mount the sensor in a submersible enclosure. Typical in-ground applications include oil tanks, sewerage wet wells, water storage tanks and lake and pond water depth.

5. Hydrostatic Method (Sealed Tank)

Just as in the vented tank application the basics of tank level will still be in play. The key difference is that in a sealed tank there is often a blanket pressure (of an inert gas) that resides on the liquid you are trying to measure. Sealed tanks are used when dealing with a fluid that either has a rapid evaporation rate or the fluid gives off a dangerous byproduct. An example would be a plant that manufactures acetone; if the product was stored in a vented tank the product would eventually evaporate completely.

Another example involves a plant that manufactures isopropyl alcohol. If the product was stored in a vented tank, the product would eventually evaporate completely. In these kinds of applications, if a gauge style pressure transducer was mounted at the bottom of the tank. The sensor will measure both the liquid level and the effect the blanket pressure is causing on that liquid will be measured. This will give a substantial difference in liquid level measurements and false inventory measurements. In order to make sure only the liquid inside of the tank is being measured, exclude the blanket pressure from the equation. The simplest way to measure just internal liquid is to utilize a true differential pressure transducer (DPT). A DPT has two pressure ports; a high port and a reference port. The location of these two pressure ports will help determine the liquid level. The high port will be pumped into the bottom of the tank and reference port will be pumped into the top of the tank, where the blanket pressure is located (See Figure 3).

Figure 3



In Figure 3, the pressure at the bottom of the tank, caused by the Isopropyl Alcohol, is 1.704 PSI (0.787 x 5 x .433 = 1.704). However, if a single gauge sensor was mounted at the bottom of the tank, a 0 to 25 PSIG range (1.704 PSI from the liquid + 20 PSI from the blanket pressure) would be required. This would only give the overall pressure, and not liquid level. A differential sensor, would give a 21.704 PSI reading at the bottom of the tank, but the 20 PSI blanket pressure will act on the back side of the sensor. The blanket pressure will result in a net of 1.704 PSI (21.704 PSI – 20 PSI = 1.704 PSI), which is the pressure caused by the liquid level.

6. Helpful Hints

There's a wide variety of tanks and transducers to measure liquid tank level, sometimes causing the wrong sensor to be selected for the application. Here are a few of the most common mistakes that system designers make when selecting and installing a transducer:

- Selecting a sensor with the wrong pressure range
- Not knowing what the liquid height is going to be
- Choosing a transmitter that cannot be submerged for an in-ground application
- Mounting the transducer at the wrong height/location
- Not selecting a NEMA 4 sensor for an outside application
- Making a purchase without consulting a transducer supplier when it's unclear which sensor is best for the application
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Questions to Ask

To help ensure the best sensor is selected, ask the following questions:

- Is the tank vented to atmosphere or is it sealed?
- What is the tank height?
- What is the liquid height that will be measured?
- What accuracy is to be maintained at that height?
- What type of liquid is it?
- What is the specific gravity of that liquid?
- Does the tank already have fittings?
- Does the tank have external pressure points?
- Is it an above ground or in-ground tank?
- What is the excitation voltage?
- What is the desired output, 4 to 20 mA, 0 to 5 V or 0 to 10 V?
- Is it an indoor or outdoor application?
- What are ambient and media temperatures?

Selecting the optimal method to measure liquid tank level is an extremely important decision when starting a project. Making the right choice helps ensure that both aboveground and in-ground vented and pressurized tanks work properly. This means that homeowners will receive water for drinking, water will be available to fight fires in remote residential areas, manufacturers will maintain their industrial processes, and food and beverage companies will have less down time. To accomplish this, system designers must take into account many variables to properly measure the liquid in their tanks. What first sounded like a simple question has many considerations, so make sure to contact a sensor supplier with any tank level questions.

Author Bio:
Tom Lish is the Industrial Product Manager at Setra Systems, Inc. As part of the Product Management Team, Tom is responsible for assisting with new product development initiatives, marketing collateral support and supporting existing product lines for the HVAC/R, Critical Care, Industrial, Calibration, Barometric and Test & Measurement markets.

Prior to joining Setra, Tom was working in the technical support and engineering group for Blake Equipment Company, an industrial/municipal pump solutions provider. He focused on proper selection and troubleshooting of pumps as well as working on designs for larger community lift stations for sewerage and clean water applications. Tom holds a Masters of Science in Engineering Management as well as a Bachelors of Science in Mechanical Engineering from Western New England University.