Whitepaper

Best Practices in Measuring Tank Level

What to Know About Measuring Tank Level

OVERVIEW

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 tanks and sealed tanks. This simple question 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, but are not

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Sections

limited to oil tanks, stand pipes, sewerage wet wells, fire prevention tanks in remote communities, food and beverage manufacturing, etc.

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-grade will typically have an access hatch that you can access to install your level sensing solution.

Methods of Tank Level

The simplest and often 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 constant feedback loop, a sight glass setup requires periodic inspection and manual refilling. This method will give a rather rudimentary level of accuracy, but if your application does not call for high accuracy and you do not want to pay for any automation, it is a reliable method that requires little to no maintenance. Because 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. One indicates low level, the other 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 fairly reliable, inexpensive, and ideal for non-critical applications (+/- 6”), such as sewerage systems.

Capacitance, resistive, ultrasonic, and hydrostatic methods are used for more critical applications. While ultimately they perform a similar action - they 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 while a filled tank has a higher capacitance. 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 is not ideal for tanks that encounter rapidly changing liquid levels.

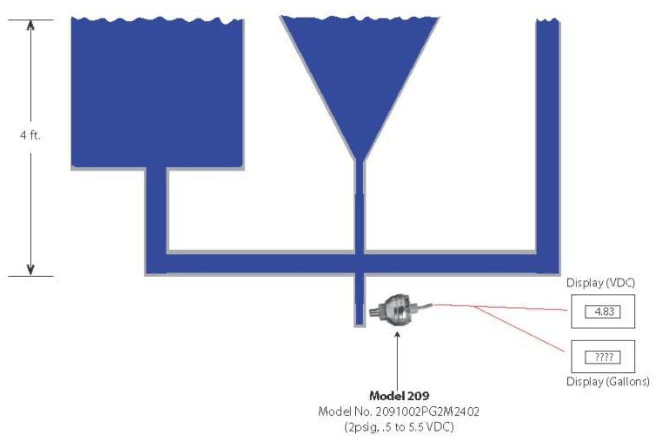
Resistance measurements are often made with a series of sensors being submerged in the liquid down into a tank. If you picture the dipstick in your cars oil reservoir, but with sensor probes along the length of stick, resistive devices are used in the same manner. These sensor probes are connected to circuitry that ties back to your alarms or to your control panel to let it know when to execute an action; fill, alarm, drain for example. The drawback to the resistive method is that your level is only as accurate as how many sensor probes you have. The more you have the better your measurement.

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. In addition, their accuracy can be affected by moisture, temperature, and pressure.

Hydrostatic Method (Vented Tank)

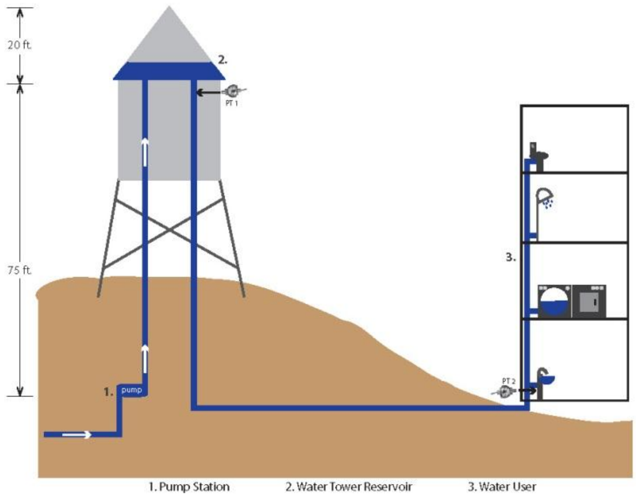
Walking the fine line between cost and accuracy is something every system designer faces when they begin a project. One of the most preferred methods to use to achieve that cost vs. accuracy battle is the hydrostatic method. The hydrostatic method utilizes simple physics to yield great results for tank level applications. Using a liquids specific gravity (see Table 1 for some common Specific Gravity values) and column height you can determine pressure caused by that liquid. 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



Above Ground Application

Selecting the range

When you are selecting the range of your transducer it is important to know the column height above the sensor to ensure that you have a large enough pressure range to cover your application. Using the calculation below you can see the required range of sensor based on the mounting location and better decide on which works best for you. In this example there is a difference of 75 feet depending on the sensor's location. This difference in elevation will need to be factored in when selecting your pressure range.

$$PSI_{range} = SG \times CH \times .433$$

Where: PSI_{range} = The range of the sensor required to meet application

SG = Specific Gravity of the liquid (see Table 2)

CH = Column Height of the liquid in feet

.433 = Conversion factor of liquid height into PSI

Specific Gravity and Viscosity of Liquids			
Liquid	Specific gravity		
	Temp		
	°F	°C	H2O at 60°F
Water, fresh	60	15.6	1
SAE 30 (Oil)	60	15.6	.88-.94
Beer	60	15.6	1.01
Benzene (Benzol) 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 ether	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			.88-.94
#10			.88-.94
#20			.88-.94
#30			.88-.94
Kerosene	60	15.6	.78-.82
Jet Fuel (av)	60	15.6	.62-.88
Mercury	60	15.6	13.57
Milk	60	15.6	1.02-1.05
Propylene glycol	68	20	1.038
Quenching oil	60	15.6	.86-.89

Table 1

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, i.e. +/- 0.25% FS. As your scale increases your level of accuracy will decrease as a result of the range change. Using the calculation above, mounting the sensor in location 1 gives you:

Location 1: $PSI_{range} = 1 \times 20 \times .433 = 8.66$ PSIG

Location 2: $PSI_{range} = 1 \times 95 \times .433 = 41.14$ PSIG

Note: Specific Gravity of water is equal to 1

Using mounting location 1 you can use a 0 to 10 PSIG sensor that has an accuracy of +/- 0.69 inches of water ("WC), while using mounting location 2 you now will need to use a 0 to 50 PSIG sensor that has an accuracy of +/- 3.46" WC. While that may not seem like a drastic difference, depending on the geometry of your tank, the 2.77 inches could mean a difference of hundreds of gallons of water or possibly 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 Reading
0-1 PSIG	0-2.307 feet of water	±0.07 inches of water
0-10 PSIG	0-23.07 feet of water	±0.69 inches of water
0-50 PSIG	0-115.3 feet of water	±3.46 inches of water
0-100 PSIG	0-230.7 feet of water	±6.92 inches of water

Now that the height of the liquid is known, just 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 is good because those shapes are the easiest to calculate.

For a cylinder:

$$\text{Volume} = \pi \times r^2 \times h$$

Where: π = 3.14159
r = radius of the tank
h = height of the tank

For a Rectangle:

$$\text{Volume} = l \times w \times h$$

Where: l = length of the tank
w = width of the tank
h = height of the tank

In the water tower example we have a rectangular tank with a radius of 10 feet and a height of 20 feet. This gives us a volume of:

$$\text{Volume} = \pi \times 10^2 \times 20 = 6{,}283.18 \text{ ft}^3$$

There are 7.48 Gallons of water per cubic foot, so that means that in our water tower we have 46,998.19 gallons of water. If we take that number 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 that amount of water could be crucial to the residents who count on the water tower for their drinking water or in some cases even fire protection.

Note: If you choose mounting location 2 you would need to add the volume of your piping to the volume of the tank itself.

In-Ground Application

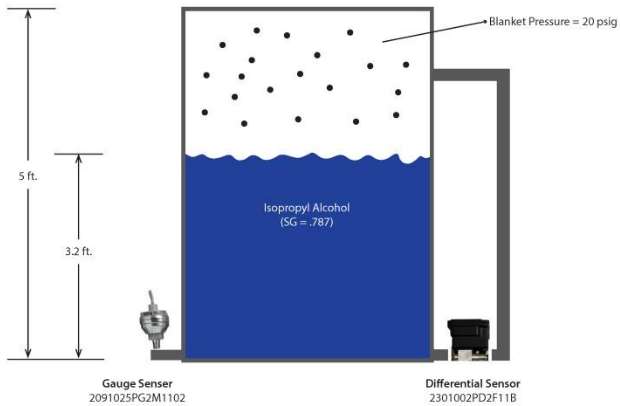
For in-ground application, all of the same methods and principles still apply, but the unique aspect is that you no longer have the ability to connect a sensor externally to thank in most cases. In this type of application you will be accessing the tank through an access hatch or drilled hole in the 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 that when you are utilizing the hydrostatic method, you will need to use a submersible pressure transducer or mount the sensor in a submersible enclosure. Some typical application for in-ground applications are oil tanks, sewerage wet wells, water storage tanks, and even in the non-traditional sense lake and pond water depth.

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 you are dealing with a fluid that either has a rapid evaporation time or the fluid gives off a dangerous byproduct. An example would be 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 you were to use a gauge style pressure transducer mounted at the bottom of the tank, not only will you be measuring the liquid level, but you will also be measuring the effect the blanket pressure is causing on that liquid. This will give you a substantial difference in your liquid level measurements. In order to make sure you are only measuring the liquid inside of the tank you want to subtract the blanket pressure from the equation. This can be accomplished in multiple ways, but the simplest way is to utilize a true differential pressure transducer. A differential pressure transducer has two pressure ports; a high port and a reference port. Where these two pressure ports are located will help you determine your liquid level; the high port will be plumed into the bottom of the tank and reference port will be plumbed into the top of the tank (where the blanket pressure is located). (See Figure 3).

Figure 3



In the example above, 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 you used a single gauge sensor mounted at the bottom of the tank you would need to go to a 0 to 25 PSIG range (1.704 PSI from the liquid + 20 PSI from the blanket pressure) and even then you do not know the liquid level, just the overall pressure. If you choose a differential sensor, you would still see the 21.704 PSI at the bottom of the tank, but the 20 PSI blanket pressure will act on the back side of the sensor and give you a net of 1.704 PSI (21.704 PSI – 20 PSI = 1.704 PSI), which is the pressure caused by your liquid level.

Helpful Hints

With such a wide variety of tanks and transducers to measure liquid tank level, it's understandable that sometimes the wrong sensor is selected for an 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
- Purchasing a sensor without knowing if the tank is vented to atmosphere or is pressurized
- 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

Questions to Ask

To help ensure the best sensor is selected, the following questions should be asked:

- 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 or 0 to 5 V or 10 V?
- Is it an indoor or outdoor application?
- What are ambient and media temperatures?

Selecting the optimum method to measure liquid tank level is an extremely important decision when starting your project. Making the right choice helps ensure that both vented aboveground and in-ground tanks as well as 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 continue to produce with 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 twists and turns, so if you have any questions please consult with your sensor supplier.

About the Author:

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Tom holds a Masters of Science in Engineering Management as well as a Bachelors of Science in Mechanical Engineering from Western New England University.

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