Technical Article

Liquid Level Measurement

A pressure transmitter can be used to determine the liquid level in a tank, well, river or other body of liquid. The pressure at the bottom of a liquid filled container is directly related to the height of the liquid. The transmitter measures this hydrostatic head pressure and gives the resulting liquid level. To get an accurate reading, the measurement device needs to be located at the lowest point you want to measure; typically mounted or laying on the bottom of the container.

When measuring liquid level, specific gravity must be taken into account. Consider the following equation:

$H = \frac{P}{SG}$ or $P = SG \cdot H$

H – Height of the liquid being measured (typically in inches, feet, centimeters, meters, etc.)
P – Hydrostatic head pressure at the bottom of the tank (typically in inches of water column, feet of water column, psi, bar, Pascal's, etc.)
SG – Media's specific gravity (a dimensionless number calculated from: Density of media being measured ÷ Density of water at 4° C. For example, the density of Kerosene equals 0.82 g/cm^3. Therefore, the SG of Kerosene is 0.82 g/cm^3 ÷ 1.00 g/cm^3 = 0.82

For example, suppose we have a container of water 8 inches deep. Water has a specific gravity of 1.00. To calculate the hydrostatic pressure at the bottom of the container consider:

H = 8 inches of water
SG = 1
P = x PSI
P=1 • 8 inches = 8 inches W.C.
So the hydrostatic pressure (P) at the base is equivalent to 8 inches of water column.

1 inch of water column = 0.03613 PSI (27.678 inches of water column = 1 PSI).
8 inches WC • 0.03613 = 0.289 PSI
So 8 inches WC = 0.289 PSI of hydrostatic pressure at the bottom of this container.

As you can see, a higher or lower specific gravity can have a considerable impact on your level measurement. Other variables such as device location, temperature and/or the gas pressure acting on the media in a sealed tank are also important when making an accurate liquid level measurement.

The following are different suggestions for taking accurate liquid level measurements.

Vented / Open Tanks

This is the simplest case to consider in level measurement. Vented/open tanks include elevated, above ground and inground tanks that have open vents or expose the media to local atmospheric pressure.

Typically the instrument can be mounted to the side of the tank (as shown in Diagram 1) or a liquid level probe can be dropped directly into the media in the tank (as shown in Diagram 2). The force of hydrostatic head pressure will allow you to take an accurate level reading.

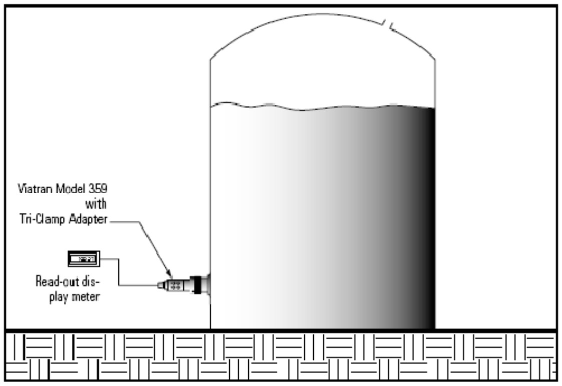

Diagram 1 – Vented/open tank with a Tri-clamp mounted transmitter.

Let's assume you want to measure the liquid level in a vertical tank 20 feet high. A full tank would exert a maximum hydrostatic head pressure of 20 feet of water column. (Assuming this is water at 4° C.) Since one foot of water column is equivalent to 0.43356 PSI, the maximum hydrostatic head pressure exerted on the base of the tank and the pressure transmitter is 8.671 PSI.

Viatran
3829 Forest Parkway
Suite 500
Wheatfield, NY 14120

Hotline: 1-800-688-0030
Int'l: 1-716-629-3800
Fax: 1-716-693-9162
Email: solutions@viatran.com
Web: www.viatran.com

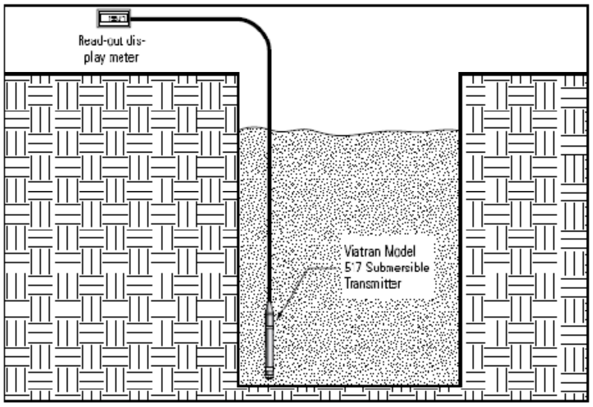

Diagram 2 – Open tank with a submersible transmitter.

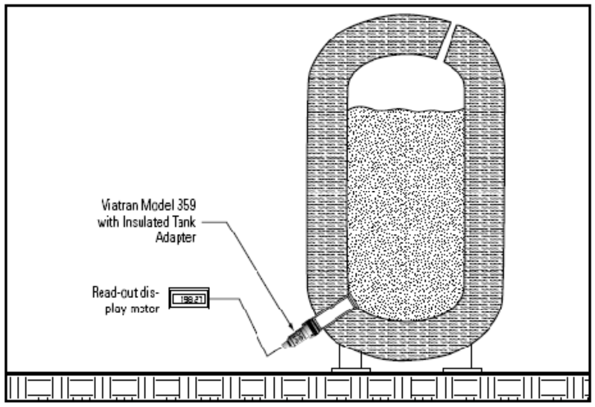

Diagram 3 – Insulated tank with adapter.

Now assume this same tank is full of Kerosene. Since Kerosene has a specific gravity of 0.82, utilizing the equation noted we have:

P = 0.82 • 20 feet = 16.4 feet water column or
16.4 feet • 0.43356 = 7.11 PSI.

In this example there is a difference of 1.561 PSI or 3.6 feet WC between water & kerosene. This demonstrates the importance of knowing the specific gravity of your media in order to get an accurate level measurement.

When selecting a transmitter to measure liquid level in vented/open tanks there are some elementary factors that should be considered in regards to installation. Can the bottom of the tank be tapped? What type of fitting can be inserted here? Can a weld-in adapter be used? If the bottom of the tank cannot be tapped, can a level probe be inserted from the top of the tank? Is this a sanitary application where an approved product is required or contamination issues are a concern? Is the media compatible with the standard materials or are optional wetted parts required?

If this is a sanitary application or the instrument can be mounted from the exterior of the tank, Viatran's Model 359 can be utilized. Viatran offers many different receivers for the Model 359 to either match your existing design or weldin adapters for your new installation.

If this is not a sanitary application, Viatran's Model 517 can be inserted from the top of the tank and lowered to the bottom or Viatran's Model 244, 344 or 544 can be plumbed via a pipe fitting to the tank base. The Model 517 is the easiest, most non-intrusive way to take a liquid level measurement. No holes or adapters are needed in the tank wall and the transmitter can be easily removed without draining the tank.

Viatran
3829 Forest Parkway
Suite 500
Wheatfield, NY 14120

Hotline: 1-800-688-0030
Int'l: 1-716-629-3800
Fax: 1-716-693-9162
Email: solutions@viatran.com
Web: www.viatran.com

If an insulated style tank is utilized, the pressure measurement is the same as mentioned in the above example, except a special adapter will be required. The adapter is welded flush on the interior of the tank and extends through the insulation to the exterior of the tank where the transmitter is inserted (see Diagram 3).

Sealed / Pressurized Tanks

A sealed tank often has a higher than atmospheric pressure gas blanket on top of the liquid. There is an additive effect of the hydrostatic head pressure (pressure exerted by the liquid level) and the pressure of the gas blanket on top. The hydrostatic pressure and gas pressure together give a total pressure exerted at the bottom of the tank and on the level instrument.

Knowing this relationship, it is impossible to get an accurate liquid level measurement using the methods as demonstrated in the open/vented tank example. The addition of gas pressure would indicate a higher liquid level, which is false.

One method and the most accurate, is to utilize a differential pressure transducer (DP). This device will accurately measure the liquid level while negating the gas blanket pressure effect. A DP with the high side (leg) running to the base of the tank and the low side plumbed to the top of the tank above the liquid (as shown in Diagram 4) will measure the difference between the gas pressure and the combined gas and liquid level pressure. This leaves the liquid level measurement only (barometric pressure is not an issue with this scenario).

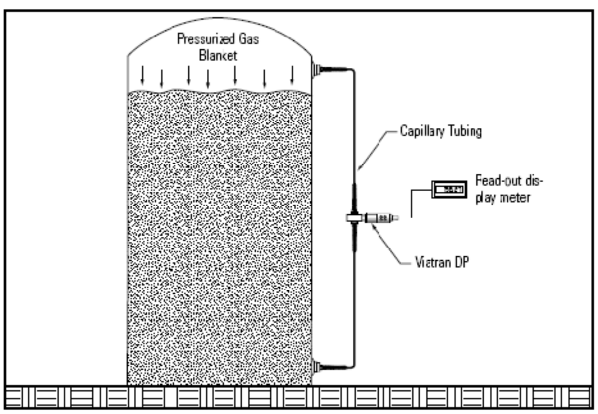

Diagram 4 – Sealed tank with a differential pressure transducer.

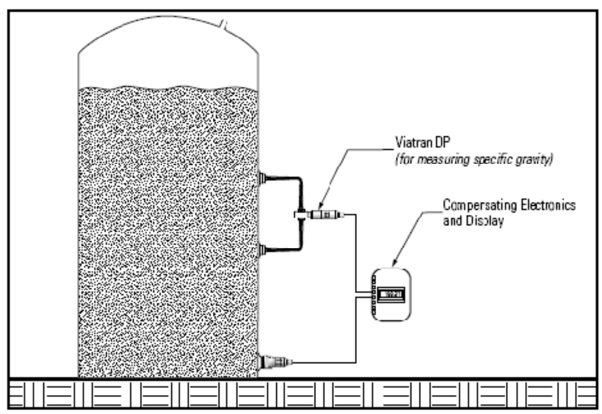

Diagram 5 – Vented tank with changing media density.

However, there are many precautions and variables to consider when performing this measurement. Where can the transmitter be mounted? Will the leg of each side be exposed to different temperatures? How long should each leg be? Is this system indoors or outdoors? What are the minimum and maximum temperatures of the media and gas? Does the tank see vacuum?

Viatran
3829 Forest Parkway
Suite 500
Wheatfield, NY 14120

Hotline: 1-800-688-0030
Int'l: 1-716-629-3800
Fax: 1-716-693-9162
Email: solutions@viatran.com
Web: www.viatran.com

Viatran
A Dynisco Company

To demonstrate measurement principles only, the following example will assume that optimum conditions exist. Let's assume your tank was 30 feet high, had 20 feet of water (20 feet of water = 8.671 PSI) and has a pressurized gas blanket of 5 PSI on top. Recalling that water has a specific gravity of 1.00, the hydrostatic head pressure and gas pressure reading at the base of the tank would total 5 PSI + 20 feet WC = 13.671 PSI or 31.539 feet WC.

As shown in Diagram 4, we utilize two remote seals via oil filled capillary tubes. We mount the low side seal of the DP above the 20 feet of water and into the gas blanket area. The high side of the DP would be mounted as close to the base as possible. The low side of the DP would sense the 5 PSI gas blanket. The transmitter subtracts the low side pressure of 5 PSI from the combined high side of 13.671 PSI or 31.539 feet WC and leaves a resulting 8.671 PSI or 20 feet WC.

Another method, not as accurate, is to utilize Viatran's Model 517 and drop this into the sealed tank. The cable end should exit the tank via a sealed feed through. A breather on the Model 517 is not required since changes in local atmospheric pressures are irrelevant. A second transmitter, Viatran's Model 570 for example, would get mounted on top of the tank to measure just the gas blanket. The two signals would then be fed into a circuit that is capable of subtracting the two. The resultant would be the liquid level reading only. This method is not as accurate as using a DP, but where space and installation is a problem this will typically yield acceptable results.

Vented or Open Tank with Changing Media Density

Some manufacturers use a single tank to process multiple medias with different densities or they have a media that changes density with temperature. This is very common in the food & beverage industry where different ingredients are blended & mixed in the same tanks. An accurate liquid level measurement in these conditions utilizing a gage type instrument mounted in the base of the tank is impossible.

Utilizing a DP coupled with a gage type transmitter will provide an accurate liquid level measurement even if the density is changing. As shown in Diagram 5, mounting the two legs of a DP a known distance apart will measure the hydrostatic head pressure between these 2 points and help you determine the specific gravity of the media. The specific gravity can then be multiplied by the level reading from the gage transmitter to obtain an accurate level reading in the system.

Let's assume you have a tank 30 feet tall filled with 20 feet of water. As shown in Diagram 5, if you mounted a DP on the side of this vertical tank with the low side exactly 12 inches above the high side, the output would be equivalent to 12 inches WC or 0.43356 PSI. Understanding this, we can now calculate the specific gravity of a liquid other than water.

For example, let's assume you have a tank with 20 feet of an unknown media. Your DP is hooked up as described above, with each leg 12 inches apart. The output from the DP corresponds to a water column reading of 9.84 inches. Remember, the two legs are 12 inches apart.

Consider the following formula:

$$SG = \frac{DP}{D}$$

DP – Reading from the DP of the distance between DP legs (9.84 inches of water column)
D – Actual distance between DP legs (12 inches)
SG – Specific gravity

So:

$$SG = \frac{9.84 \text{ inches}}{12 \text{ inches}}$$

SG = 0.82

Here we find that the specific gravity of this media is equal to 0.82.

To determine the corrected level measurement of the media at its present density, we take the output from the gage type transmitter (Viatran's Model 359) mounted at the base of the tank and multiply it by the specific gravity we determined above. In this example we have 20 feet WC multiplied by the SG of 0.82 or 20 feet WC • 0.82 = 16.4 feet WC.

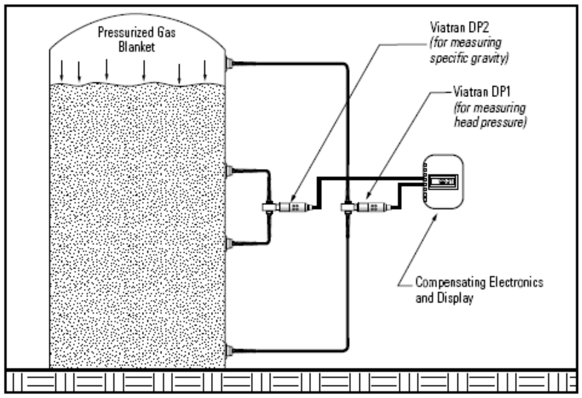

Diagram 6 – Sealed tank with changing media density.

There are many different input devices available today that can take the two 4-20 mA outputs, multiply these and give a resultant 4-20 mA equivalent to the proper level we just demonstrated.

This example demonstrates that even with density fluctuations, you can still obtain an accurate liquid level measurement.

Sealed Pressurized Tank with Changing Media Density

Here we have a combination of both a changing specific gravity and a pressurized sealed tank. Diagram 6 shows two DP units utilized to take an accurate liquid level measurement in this situation.

The first DP is set up like the example in a pressurized sealed tank. The low side senses the gas blanket and the high side senses the liquid level and gas blanket pressures combined (DP1). The resultant from this DP is the static pressure measurement only. However we also have a changing specific gravity.

As shown in the previous example we mount a second DP (DP2) with its two legs 12 inches apart on the side of this vertical tank. We can then calculate the specific gravity. Once the SG is known, we multiply it by the static pressure utilizing a math board and both DP signals. We should now have an accurate liquid level measurement in a pressurized tank with changing specific gravity.

These were just a few general examples of the different methods available to solve your liquid level measurement needs.

Viatran offers many differential pressure transmitters that can accomplish liquid level measurement accurately; Models 274, 374, 276, 376, 571, 574 or IDP10 with ranges from 0.5 inches WCD to 3000 PSID, along with capillary tubing, remote seals, and a variety of fill fluids to meet your needs. Viatran also offers products such as the Model 517 that are easily installed and provide high accuracy results. For sanitary applications the Models 350, 351, or 359 can be utilized. For more information, contact Viatran today.