New Level Measurement Technologies for Liquids

Clint Cowan,
Industrial Sensors Product Manager

May 2019

Contact versus Non-Contact Sensors

> **"Initially, laser sensors were not viewed as effective liquid sensors, but that has all changed."**

Contact sensors come in a wide variety of product configurations: pressure sensors, float sensors, bubblers and hydrostatic, just to name a few. But whatever the configurations, they all have one thing in common: they must contact the material they're designed to measure.

This particular attribute of a contact sensor can also be its downfall. Contacting materials can prove problematic—leading to high maintenance costs, frequent down times, or sensors simply not working at all. Depending on the material and how the sensor needs to contact it in order to do its job effectively will determine the maintenance costs and possible degree of risk using one of these sensors.

While contact and non-contact sensors will co-exist in the industrial world for many years to come, it's clear the trend is for more non-contact sensors to be installed. Non-contact sensors hold the promise of reducing maintenance costs and improving reliability of level measurement sensors.

Different Types of Non-Contact Sensors

Non-contact sensors fall into three general categories: Ultrasonic, Radar and Laser. Ultrasonics have been around the longest, are the most mature technology, and generally the least costly. Like its name implies, Ultrasonics are based on sound waves.

Ultrasonics come with a lot of inherent limitations. Chief among these are:

- the speed of sound through air varies with the air's temperature.
- debris, extreme turbulence or wave action can cause the ultrasonic sensor to report fluctuating readings.
- maximum distance to the water level is usually restricted to 30 feet or less.
- high concentrations of fine sediment in suspension can scatter and absorb the sonic pulse.
- ultrasonics can't be mounted near walls, ladders or other obstructions.
- any noise present in the tank could throw off the sensor readings.
- ultrasonics require air to operate; if the medium is in a vacuum (no air is present), they will not work.
- ultrasonics are very limited with the use of stilling pipes.

For some applications, ultrasonic sensors will prove to be the ideal sensor, both cost-effective and meeting your application requirements. For other applications, however, their limitations will come into play and could pose major problems. Ultrasonics manufacturer's have designed ways to mitigate some of these limitations, for example, by adding a temperature sensor or dampener to compensate for these conditions. Exactly how well they perform in your specific application will vary.

Through-air radar is another non-contact technology. It is newer than ultrasonic, generally more costly but with higher performance. Radar works similarly to ultrasonics but uses radio waves instead of sound waves to return a signal back to the sensor. Radio waves have some advantages over sound waves. For example, they can operate at much faster speeds (the speed of light versus the speed of sound), aren't affected by a vacuum, or ambient noise.

Through-air radar comes with disadvantages, as well. In addition to costing more, it can be more complex to setup, and it is dependent on the material's dielectric constant. Like ultrasonics, its beam width is wide, do shooting next to walls or through narrow passageways can be an issue.

Ultrasonics and radar have developed more sophisticated methods for dealing with the intrinsic shortfalls of their technologies. Sometimes, these techniques have been successful in mitigating their disadvantages to a certain degree. But they have also added cost and complexity in many instances. Whether these techniques and their associated costs will prove advantageous for you and your application are a matter of on-going debate.

Laser sensors are a recent addition to the list of non-contact liquid sensors. Initially, laser sensors were not viewed as effective liquid sensors, but that has all changed. Advances in technology have given laser sensors the ability to detect liquid levels under a variety of conditions, and they now can address some of the issues experienced with other types of non-contact sensors.

Advantages of Laser Sensors

Laser sensors have several major advantages over ultrasonic and radar sensors. First, the beam of the laser sensor is much narrower than the beams of ultrasonics and radar. This allows the laser sensor to range further to distant targets, be installed next to walls or other structures, guided through or around obstructions that would be problematic for ultrasonic or radar sensors. Second, lasers are an optical technology, and in that regard work very similar to the human eye. The laser beam cannot penetrate opaque surfaces like radar and ultrasonics can. In many cases they will reflect off of a surface more easily than other non-contact sensing technologies. Third, they can be mounted next to walls, in narrow spaces, or where obstructions exist. The narrow beam width of the laser allows for more mounting flexibility, and usually results in a simpler install (see Figure 2, below).

Beam Spread of Laser over 360° Radius

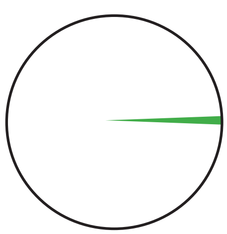
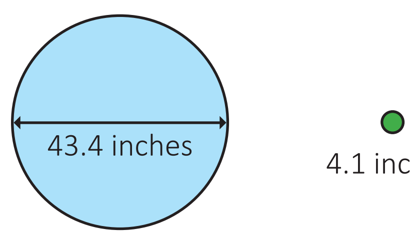


Figure 1

Beam Spread at 100 Feet



This narrow beam width makes lasers ideal for measuring down stilling pipes. Stilling pipes are common methods for gaining a more accurate measurement, particularly in challenging environments. Stilling pipes can "calm" the liquid material down, making it easier to measure. They can also reduce or eliminate foam and other particulates that float on the surface, making for a cleaner, easy spot for measuring to the liquid material layer.

Laser Sensor Ultrasonic Sensor

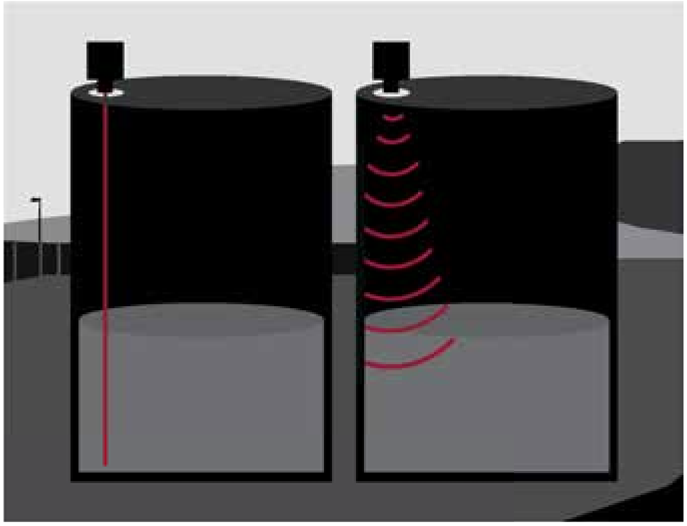


Figure 2

Two identical vessels have the same aperture available to install a non-contact sensor, located near the left wall of the tank.

On the left, the laser sensor's narrow beam can reach the entire length of the tank, accurately reporting the level throughout its entire range.

On the right, the ultrasonic sensor's wider beam width starts hitting the left wall about 2/3 the way down, making measurements beyond that point inaccurate.

Stilling pipes are problematic for ultrasonics and radar. First, they must be sufficiently wide enough for the wider beam to penetrate the length of the stilling pipe without hitting its walls. Second, the pipe cannot contain any obstructions that might trigger a false target, such as exposed bolts, seams, etc. Third, the stilling pipe must be made of a material that will not interfere with the beam of the ultrasonic or radar sensor. Generally, PVC will not work, because being made of a type of plastic that will absorb their waves, thus producing bad readings for these types of sensors.

The bottom line is, when using or wanting to use stilling pipes, laser sensors are much more forgiving and allow you to have more flexibility with installation and more reliability in operation.

Disadvantages of Lasers

Like every other type of measuring sensor on the market, laser sensors come with some disadvantages too. Laser sensors do not perform well in environments with heavy fog, steam or mist. If the mist is so thick, for example, that the human eye cannot see the material layer from the point where the sensor will be mounted, it is likely the sensor will not be able to detect it either. This "eye test" is a general rule-of-thumb for a quick test, but it is not always an absolute test.

The human eye operates in what is commonly referred to as the visible spectrum, from about 390 to 700 nanometers (nm); laser sensors typically operate at 905 nm, in the infrared (IR) spectrum outside the visible spectrum. Consequently, what the laser "sees" at 905 nm may not be exactly what the human eye sees in the visible light spectrum. For example, the human eye could not see a water level in complete darkness, but operating at 905 nm, the laser sensor would not have any problem seeing the water level and measuring accurately to it.

Other disadvantages of lasers are direct sunlight into the lens of the sensor. Direct sunlight can oversaturate

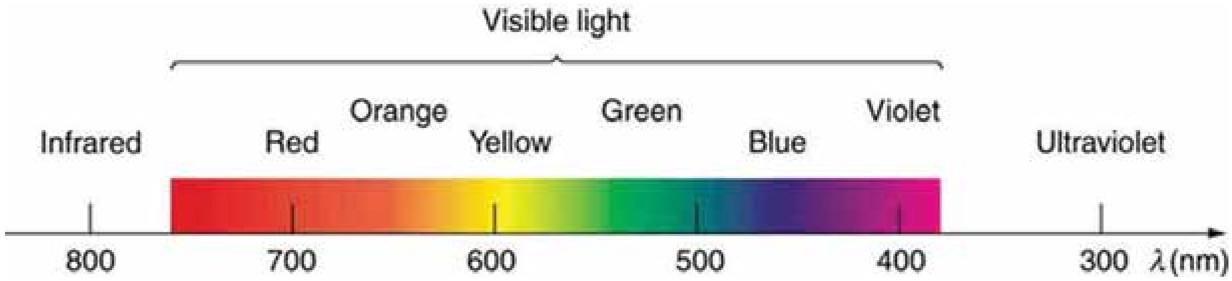


Figure 3

the lens and give false readings or take the sensor off-line. If the sensor is mounted outdoors and direct sunlight is a possibility, you should make sure the manufacturer has a sunshade option that would eliminate this phenomenon.

Finally, the lenses of the laser sensor need to be kept relatively clean. The lenses can take some build-up, but if there's so much dust that is begins to prevent the laser beam from penetrating through the lenses, the sensor can go off-line. Fortunately, being a non-contact sensing technology with a lot of mounting flexibility, the laser can be mounting far enough away from dust sources that it can usually mitigate this problem to a large degree.

	Laser	Ultrasound	Radar
High Accuracy	✓		✓
Used in Stilling Pipes	✓		
Used in Narrow Spaces or Next to Walls	✓		
Wide Temp Ranges	✓		✓
Ease of Installation	✓		
Low Cost	✓	✓	

Figure 4

Cost of Sensor Versus Total Cost of Ownership

From a financial analysis approach, the up-front cost of the sensor is an important consideration but even more important is the total cost of ownership (TOC). Many operators have come to understand a pressure sensor may be an inexpensive device, relative to a non-contact sensor, but if the down time and maintenance costs are included in the overall cost equation, it becomes the costlier proposition. In today's world, the consequences of down-time, possible liabilities, damaged equipment, government fines, and high maintenance come at a steep cost, and these must be factored into any purchasing decision. Many times, the TOC of the non-contact sensor makes the decision to purchase one a no-brainer.

How do You Know if Laser Sensors are Right for You?

There is no single sensing technology that is right for every application, in any environment. Each technology has its own inherent strengths and weaknesses, and understanding these within the context of your application will go a long way in choosing the right one for the job.

If you've been using a contact sensor and are ready to try a non-contact sensor to replace it, understanding the strengths and weaknesses of the different technologies will point you in the right direction.

If you've been using a non-contact sensor and it isn't working out for you, determine if you're running up against one of the limitations of that technology. Switching to a laser sensor may be the answer if it's not impacted by anything else.

If you're going directly from a manual process to an automated one, it makes since to explore all the potentially successful sensing technologies, and choose the one that best fits your application and budget.

How Do You Know Which Laser Sensor You Should Purchase?

There are few choices when it comes to a laser sensor to measure liquids across a variety of materials and applications. You want to choose a company that has a strong reputation for designing laser sensors since this task is not an easy one. There is a market for cheap laser sensors, and suppliers that build for this market, but these products are not intended for measuring liquids, and should not be considered here.

Even among quality laser sensor manufacturers, features can vary. There is one vendor that produces a very good product, but its not ideal for dynamic conditions. For example, its update rate is rather slow, meaning that's fine for static conditions, but if it's a dynamic environment where your tank could overflow in five minutes, waiting ten minutes for an update would be unacceptable.

You should understand your requirements in detail and make sure the laser sensor you choose has the best feature set to accomplish how you intend to use it.

Finally, there's no substitute for testing the sensor you've chosen to implement. If you've never installed a laser sensor and are unsure how it will perform relative to other sensors, you should consider testing one before buying many of them.   Testing will allow you to evaluate the sensor in your specific application and determine its true value to you. Once you are reasonably convinced it will work satisfactory in an application, the decision to purchase more becomes an easier one. At the same time, becoming familiar with this new technology can also give you ideas where you might be able to use it next, sometimes in applications you hadn't even considered before.