Tank-nically Speaking

by Marcel Moreau

Marcel Moreau is a nationally recognized petroleum storage specialist whose column, **Tank-nically Speaking**, is a regular feature of LUSTLine. As always, we welcome your comments and questions. If there are technical issues that you would like to have Marcel discuss, let him know at **marcel.moreau@juno.com**

Making Sense of Sensors

Sensors are old hat to regulators in states where secondary containment has been required for a while, but implementation of the secondary-containment provisions of the 2005 Energy Act will introduce sensors in greater numbers to many more regulators, tank owners, and operators. So this seems like a good time to provide a primer on how the most common kinds of sensors used in UST systems today work. Along the way, I'll also touch on some the reasons why they may not work as well as they should.

In the late 1980s and early 1990s, there were many different types of UST sensors—dissolving strings, proximity switches, wires with dissolving insulation, vapor-sensing adsistors, and metal-oxide semiconductors. Most of these have gone the way of the dodo, although some still survive in isolated pockets of the country. In the interests of brevity and relevance, I'm going to limit this discussion to the technologies that I believe are most commonly used today.

What Is a Sensor?

In the UST world, sensors are devices that act as remote eyes to alert us to conditions of interest in the interstitial spaces of UST systems. These interstitial spaces include those between the walls of double-walled tanks and the insides of tank-top and under-dispenser sumps. Sensors are basically switches that are designed to automatically complete, interrupt, or modify an electrical circuit when certain conditions are present. In the UST world, these conditions most often boil down to the presence of product or water in the interstitial space where the sensor is located. Other conditions, such as the loss of vacuum in a sealed interstitial space, can also be monitored.

The change in the circuit produced by the sensor triggers an audible and visual alarm that is typically in a separate location such as an adjacent building. These days, the alarm may also be transmitted to a remote location that could be the company's head office, a dedicated 24/7 monitoring center, or even a distant land anywhere else on the planet. Most often, the alarm is a component of an automatic tank gauge (ATG).

Sensors are intended to provide constant, unobtrusive vigilance. Like obedient bird dogs, their job is to hunt quietly and point clearly when the prey is present. In the UST realm, the prey is most often liquid—rainwater, groundwater, gasoline, diesel, or some related petroleum product. There are also a handful of vapor sensors and vacuum sensors out there, but they are not included in this article.

A Word About Compatibility

In these days where ethanol in fuel has become almost as pervasive as ethanol in taverns, compatibility of sensors with ethanol fuels is a factor that must be considered. A brief and unscientific survey I conducted of manufacturers' literature indicates that most sensors are compatible with E10 fuels, but only a few are rated for use with higher levels of ethanol. For any new facility or for a facility where a conversion to ethanol-blended fuels is planned, owners should verify the compatibility of any sensors with the product to be stored.

Types of Sensors

Discriminating Versus Nondiscriminating

The two main categories of liquid sensors are discriminating and nondiscriminating. Discriminating sensors are able to tell the difference between product and water and typically issue different messages on an ATG display, depending on the liquid that is detected. Non-discriminating sensors merely indicate the presence of a liquid, without indicating whether the liquid is product or water. Most discriminating sensors combine two separate sensor technologies, one that indicates that a liquid is present and a second technology that either responds only to product or can tell the difference between product and water.

It is important that facility operators know whether the sensors present at their facility are discriminating or nondiscriminating, because the alarm messages associated with nondiscriminating sensors often err on the side of caution and indicate a "fuel alarm" even when only water is present. The all-too-frequent intrusion of water into tank-top sumps thus produces "fuel alarms" that turn out to be "only" water.

Alas, the frequent reoccurrence of these "nuisance" alarms often results in a rather nonchalant attitude toward ALL alarms on the part of facility personnel. Facility operators with nondiscriminating sensors must understand that "fuel alarms" responding to water intrusion are not happening because of some defect in the sensor. They must understand that each "fuel alarm" requires immediate investigation to determine the real nature of the liquid that is present. Operators who are not willing to do this should invest in discriminating sensors.

Discriminating sensors produce alarm messages that differentiate between product and water, allowing for a two-tiered response to an alarm—immediate and urgent response for product alarms and a more measured response for water alarms. While this seems like a very valuable distinction to me, the great majority of tank owners have chosen the cheaper nondiscriminating sensors over the more expensive discriminating ones. The exception to this is California, where regulations have encouraged the use of discriminating sensors.

Float Sensors

By far the most common sensor technology used in UST systems is the float sensor, which does not discriminate between product and water. This technology is very simple. Two parallel, flexible strips of metal that act as switch contacts are encased in a small, liquid-tight tube. When the two strips of metal touch, an electrical circuit is completed. When the two strips do not touch, an electrical circuit is open or incomplete.

Outside the tube, there is a donut-shaped float that contains a magnet. The tube containing the switch contacts fits loosely inside the hole of the float/magnet. When liquid is not present, the magnet is positioned away from the switch contacts. The switch contacts are normally closed (touching) so that when liquid is not present, the electrical circuit is complete. When liquid is present, the float/magnet rises up on the tube and the magnetic field of the magnet in the float separates the two switch contacts, opening the switch. The opening of the switch is the signal that liquid is present.

Float sensors can be packaged in many different ways. One very common way is in a gray cylinder about 12 to 22 inches long and about 2 inches in diameter. The float switch is actually located near the bottom of this cylinder, and the rest of the cylinder is empty.

There are a couple of variations on this theme. While the normally closed sensor described above is common today, some of the earlier sensors were normally open, which means that the switch contacts were separated when liquid was not present and came together (completed the circuit) when the float/magnet moved upward to indicate the presence of liquid. The disadvantage of this type of circuit is that if a wire is broken or disconnected, the sensor is not able to sound an alarm, but there is no indication at the ATG that anything is wrong.

The normally closed sensor solves this problem by having the "normal" condition be that the circuit is complete. So if a wire is broken or disconnected, the alarm sounds to indicate that there is a problem.

Some sensors go a step further and include a resistor (an electrical component that has a fixed amount of electrical resistance to electrical current) in the circuit near the switch contacts. Thus, the "normal" condition is to have very little electrical resistance in the circuit because the switch contacts are closed or touching.

If the float moves and separates the switch contacts, the circuit will have a resistance equal to that of the resistor. This reading is the alarm condition that indicates to the ATG that liquid is present. If a wire to the sensor is disconnected or broken, the resistance of the circuit will be infinite, and the ATG will interpret this as a trouble condition rather than a detection of liquid. This type of sen-

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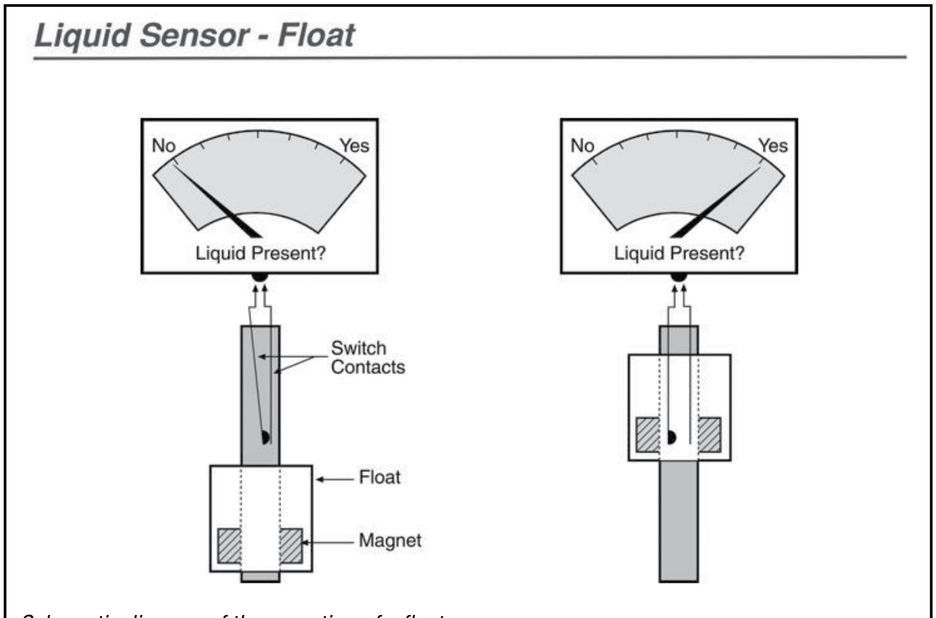
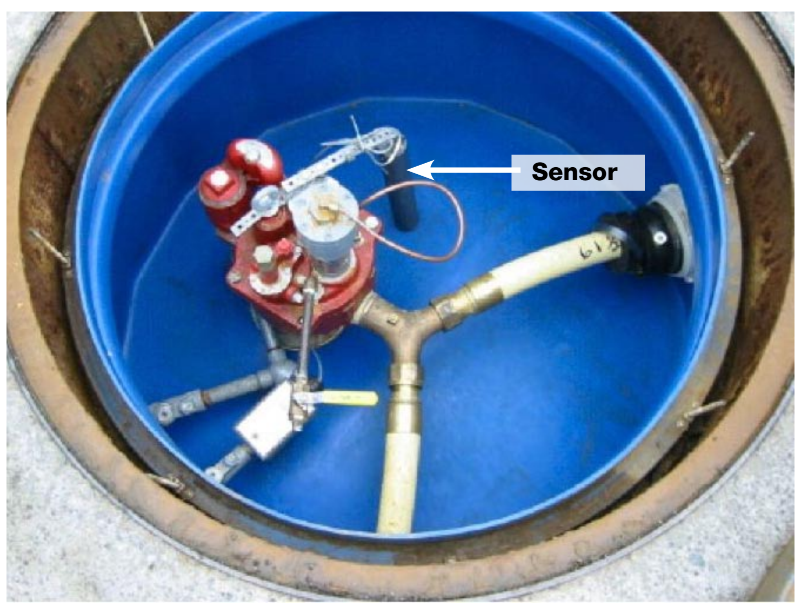


Schematic diagram of the operation of a float sensor.



A properly installed float sensor.

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sor is sometimes referred to as a "tri-state" sensor because it can indicate three conditions: normal (very low resistance), liquid present (when the resistance of the circuit is equal to the resistor value), and trouble (open circuit).

Float Sensor Issues

Float sensors have three big issues:

- They must be properly located (an issue with all sensors)
- They must be positioned vertically so that the float can move with minimum friction
- The float must be free of dirt and debris or anything else that can prevent the float from moving freely.

While the ATG can effectively monitor the integrity of the float-sensor wiring, this is not sufficient to verify that the sensor is operational. Because the sensor has moving parts, the ability of these parts to move must be verified to ensure that the sensor is operating properly. There is no way that the ATG can know whether the sensor is properly located, vertically oriented, or whether the float is moving freely. Float sensors must be physically inspected and tested to verify that they are operating properly.

Testing the operation of float sensors is typically just a matter of submerging the lower part of the sensor in a container of water to ensure that the alarm is triggered at the ATG. There may be a delay of several minutes between the time the sensor is immersed in water and the time when the ATG alarm sounds.

Electrical-Resistance Sensors

These sensors consist of a rubberlike strip of material that has carbon particles imbedded within it (the technical term for this rubberlike strip is "conductive elastomer"). These carbon particles conduct electricity, and there are enough particles imbedded in the strip that the electrical conductivity of the strip is relatively low.

The sensor works because the material swells when it comes in contact with petroleum products. As the material swells, the carbon particles move farther apart so they do not touch one another, and the electrical resistance of the strip increases substantially. This increase in electrical resistance is the signal that petroleum is present. The strip only swells in the presence of petroleum, *not* water.

This type of sensor is often packaged in a gray plastic cylinder, very much like the float sensor. Careful inspection is often required to distinguish this type of sensor from a simple float sensor.

Electrical-resistance technology is almost always used in conjunction with float switches so that the sensor is a discriminating sensor. In a typical configuration, the petroleum-sensing strip is oriented vertically inside a gray plastic cylinder with a float switch located at the bottom of the cylinder and another float switch at the top.

The function of the float switch near the bottom of the sensor is to indicate that water is present. Even if water is present, the sensor will still be able to respond to petroleum because the strip of elastomer extends a foot or so vertically (assuming the sensor is properly oriented) and will respond to the presence of petroleum anywhere along its length.

Once the fuel-sensing strip is completely submerged in water, however, it cannot be directly exposed to petroleum and will not swell. To alert the facility operator of this condition, the second float switch located at the top of the sensor sounds an alarm when the water level is so high that the presence of petroleum can no longer be detected.

This combination of float-switch and electrical-resistance technologies makes this discriminating sensor capable of multiple alarms and warnings—water present (but not so much that the sensor will not detect fuel), fuel present (anywhere along the length of the sensor), water too high (water above the sensor so fuel will not be detected), and open circuit (broken wire).

Electrical-Resistance Sensor Issues

The float-switch portions of this type of sensor share the same issues as the plain float switches noted above. The product-sensing portion of the sensor has no moving parts, so it has few maintenance issues other than proper location and orientation.

Testing the operation of the fuel-sensing portion of the sensor requires exposing the sensing strip to a petroleum-based liquid that will cause it to swell. A common complaint is that it then takes a while for the test liquid to evaporate and the sensing strip to return to its normal state. Testing the float switch components of these sensors is merely a matter of submerging the sensor in a bucket of water.

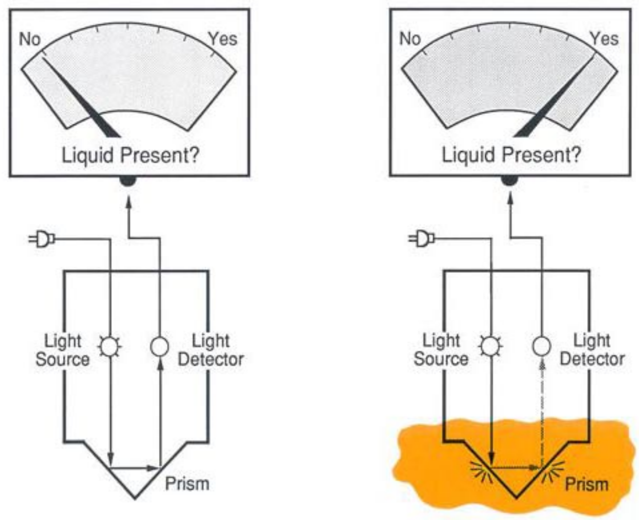
Optical Sensors

Optical sensors work by having a small electric eye that changes electrical resistance, depending on the amount of light it is receiving. The sensor also includes a small light-emitting diode (LED) that provides a source of light. These two components are separated so that the light must travel inside a clear plastic prism and reflect off the sides of the prism to reach the electric eye. Most of the light is reflected at the edge of the prism because of the large difference in density between the plastic and the air (remember your high school physics?).

The normal condition is for the LED to be on and the light to reach the electric eye. When liquid is present, the difference in density of the plastic and the liquid at the surface of the prism is much less, and a substantial portion of the light is refracted outward into the liquid. The amount of light now reaching the electric eye is reduced, and this causes a change in the electrical resistance of the electric eye. This change in resistance is detected and interpreted as the presence of liquid. This type of sensor technology will respond to any liquid and so is nondiscriminating. Failure of the LED or any broken wires will also be detected because the light signal will be lost.

Optical sensors are sometimes combined with a simple electrical-resistance sensor to turn them into discriminating sensors. Note that this is *not* the same type of electrical-resistance sensor that is described above. This resistance sensor works by measuring the electrical resistance across two electrical contacts that protrude slightly from the sensor into whatever liquid is present. Keep in mind that water is a pretty decent conductor of electricity but petroleum products are not. Once the optical

Liquid Sensor - Optical



Schematic diagram of the operation of an optical sensor.

part of the sensor indicates that liquid is present, the device checks the resistance across the two electrical contacts. High resistance indicates petroleum, and low resistance indicates water.

Optical Sensor Issues

The advantage of this type of sensor is that there are no moving parts to become stuck, and the orientation of the sensor is not critical to its function. A potential issue in humid climates is that condensation or frost on the surface of the prism can cause an alarm. Testing the sensor is simply a matter of submerging it in water. This may require the use of a dark-colored container to minimize the amount of ordinary daylight that reaches the light sensor. If too much daylight is reaching the sensor, it may not go into alarm.

Discriminating versions of this type of sensor can be tested for operation by submerging the sensor in both water and product.

General Sensor Issues

In many ways secondary containment with continuous interstitial monitoring is the simplest form of leak detection. It is very much a black and white method – liquid is either present in the interstitial space or it is not. There are no grays as there are with volumetric methods, where small volume changes due to temperature, evaporation, or tank deflection must be distinguished from actual leaks. While simple in concept, however, there are several factors that confound secondary containment as well.

While sensors are based on sound mechanical and electrical principles, there is no lifetime guarantee provided by any manufacturer stating that their sensor will work forever. The sump environment is not pristine. Sumps are most often dirty, subject to wide swings in temperature, high levels of moisture, and sometimes high levels of fuel vapors. As a result, moving parts tend to get stuck, moisture and dirt can cloud surfaces that should be clean, and components tend to degrade over time.

The "bury it and forget it" mentality that is pervasive in the tank world does not apply to sensors any more than it does to any other storage-system component. Unless sensors are inspected and tested on a periodic basis, their reliability will deteriorate over time.

The other issue that vexes secondary containment is the nuisance infiltration of water, especially into tank-top sumps. Many sensors fall prey to the "crying wolf" syndrome and end up being ineffective because they are repositioned, disconnected, or simply ignored when they sound an alarm. While keeping water out of sumps is a challenge, it is a challenge well worth taking on, otherwise the effectiveness of sensors and secondary containment is severely compromised.

Discriminating sensors that tolerate a limited amount of water without compromising the ability to detect product have some advantages here, as long as facility personnel know how to distinguish a fuel alarm from a water alarm and respond appropriately to each kind of alarm.

Sumps that are not liquid-tight pose a somewhat opposite problem. I personally know of several substantial releases where the product escaped into the environment from a leak in the containment sump before it could reach a sensor and be detected. Leaky sump piping penetrations, electrical conduit penetrations, and the connection point between the containment sump and the tank seem to be the prime locations for these types of leaks. The solution here is in careful installation of quality components to begin with, and periodic evaluation of the integrity of the secondary containment over time.

Perhaps the most pervasive sensor issue is the personnel who ignore alarms. There are many excuses for this—ignorance of the significance of the alarm, being too busy to pay attention, having previously responded to too many "false" alarms. Operator training requirements may help with this issue somewhat, but my gut feeling is that this will only be a small improvement.

As big oil leaves the retail arena and the number of small owners proliferates, each one of these issues is only likely to grow in magnitude. We have made great strides in the last 20 years in improving the integrity of storage systems. We have picked the low-hanging fruit of bare-steel tanks and galvanized pipe. As we move into the era of secondary containment and sensors, we must keep in mind that better technology is only part of the answer. Proper operation of UST systems and appropriate response to UST alarms requires the active participation of tank owners, operators, and regulators. ■