Level interface sensing for water dump control in the oil and gas industry

Accurate and reliable detection of the interface between oil and water in a water dump tank improves the separation process

By William Sholette, Level Products Business Manager, Endress+Hauser

About the Author

William Sholette is the Level Products Business Manager for Endress+Hauser in the Northeast USA regional office (500 Horizon Drive, Suite 502, Chalfont, PA 18914).

William has been involved in level measurement for the past 33 years in virtually all aspects of process level measurement instrumentation - from manufacturing and sales, to his present position in product management. He is currently responsible for level products in Northeast United States. William attended Villanova University and has certification in management and marketing.

In a fracking operation at oil and gas wells, water and oil both come to the surface, and must be separated. Oil and gas can be filtered from the water fairly easily, but the remaining water, called "produced water", is contaminated and must be treated before being released into the environment.

Fracking is becoming widely used in the oil and gas industry. As it grows in popularity, treating produced water coming from wells is becoming a major challenge, especially because the cost of cleaning produced water is about 300 times that of cleaning municipal waste water.

A similar problem exists at oil refineries, where incoming crude oil contains water that must be removed prior to refining. At refineries, crude may contain anywhere from 3% to 5% water.

The volume of water produced is dependent on a number of factors including source of the oil, age of the well, type of separator, and location in the refining process. Volumes ranging from several hundred to millions of gallons a day are possible.

Whether the separation is done at the well site or at the refinery, one of the most critical parts of the process is measuring the level of the interface between oil and water in the separation vessel. A correct measurement ensures that the maximum amount of oil is drawn off for refining purposes, and a minimum amount of oil and hydrocarbons are sent to the water treatment process.

Separation Processes Oil in production fields contains varying amounts of water depending on the specific oil reservoir, the age of the well, and the methods used in extracting the oil from the ground. Some separation of water from the oil is done in the field to reduce the amount of water that is transported to the refinery.

At a well site, especially one that uses fracking, the separated water must be treated on site or at a nearby water treatment facility before the water can be returned to the environment.

Endress+Hauser
People for Process Automation

Refineries take in crude oil from production fields with varying levels of Basic Sediment & Water (BS&W) measurements. The higher the BS&W measurement, the more water is in the crude. The refineries separate the water and other impurities through various separation processes including, but not limited to: gravity separation, desalter vessels, and skim tanks.

In all these processes, water separates from the oil and must be evacuated from the bottom of the vessel, while the hydrocarbons typically are removed on a continuous basis by flowing over a baffle at one end of the separation vessel (Figure 1).

Figure 1: In a separation vessel, oil and water separate, with oil moving to the top and water to the bottom. Capacitance level switches are used to detect the oil/water interface.

Essentially, all the various separation processes involve a tank where oil and water co-exist, with oil on top and water on the bottom. As the separation process continues, the water must be removed.

Water Dumping The process of removing water from the separation vessel is referred to as a "Water Dump." The water is "dumped" to a treatment plant for processing, while the oil is removed from the top for further refining. Because of the high cost of treating the water, it is critical to know when the interface between the water and oil reaches a low point, to prevent dumping oil to the water treatment facility.

The main purpose of water dump control is to prevent excess hydrocarbons from being sent to the water treatment facility. There are two reasons for this: first, in some cases there are fines for dumping hydrocarbons to the water treatment plant; second, the idea is to maximize the hydrocarbon throughput to the refining process, not dump it down the sewer.

A number of methods can be used to measure the interface between water and oil. These include everything from manual sampling to sophisticated continuous level measurement instruments, such as: guided wave radar and gamma radiation transmitters.

But for water dump control, an on/off capacitance level switch inserted near the water outlet is almost always the preferred alternative, for reasons delineated below.

Inside Capacitive Switches A capacitor is made up of two conductive plates separated by a non-conductive "dielectric" material, Figure 2.

Dielectric materials are categorized by their "Dielectric Constant" or "DK" which is a number that is related to the material's ability to store a capacitive charge. The higher the dielectric number, the more capacitance it can store.

Capacitance is equal to the DK (Dielectric Constant), times the Area of the conductive plates, divided by the Distance between the two plates, or:

$$C = (DK * A) / D$$

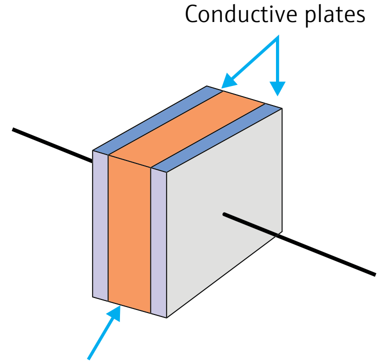

Figure 2: A capacitance sensor can be used to detect the presence of conductive fluids.

Capacitance sensors for level measurement use these basic capacitance concepts, with the vessel becoming one plate of the capacitor (Figure 3) in point level applications. That is, the probe becomes one conductive plate, the vessel or a ground reference becomes the second conductive plate, and the material being measured is the dielectric material. In the case of conductive materials such as ground water, the plates are essentially shorted out, providing a large change in capacitance.

A bridge circuit in the sensor's electronic unit is balanced to null out the capacitance generated by an uncovered sensing element. As material covers the probe, an increase in capacitance is generated on the probe side of the bridge, which causes the bridge to become unbalanced. This change is converted to a switch command to allow a relay or other output to indicate the status of the switch, either covered or uncovered.

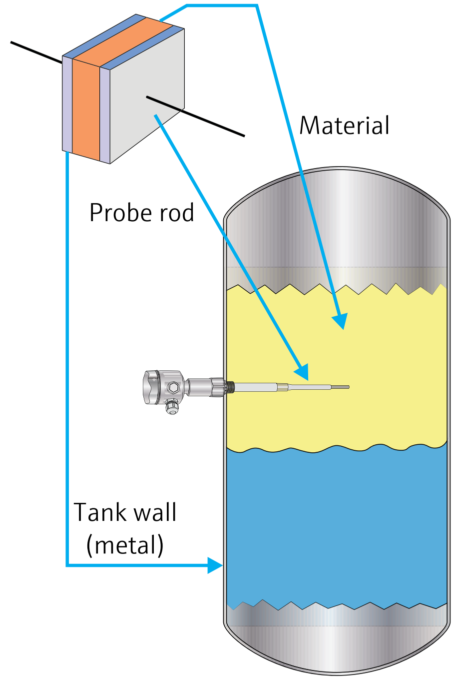

Figure 3: In a capacitive level sensor, the vessel itself becomes one plate of the capacitor, and the oil/water mixture is the dielectric material.

In the case of materials that leave a coating on the probe, active buildup compensation in the electronic unit provides a means to compensate for the coating and continue to provide reliable measurement.

Water Dump Applications Knowing where the interface between the water and oil occurs is important to prevent dumping oil to the water treatment plant, **resulting in loss of product, extra cost for treatment, and potential environmental fines**.

Using a capacitance switch to identify the interface between the oil and water is very effective because of the dramatically different electrical properties of the two fluids. Ground water is very conductive and acts to short the two plates of the capacitor, causing an almost infinite change in the measured capacitance. The oil phase is not conductive, and the low dielectric constant of oil (around 2DK) causes a small change in the measured capacitance. This results in a very clear electrical definition between the two phases.

In a water dump tank, the sensor is covered with a mixture of oil and water until the separation process proceeds, when oil moves to the top and relatively clean water moves to the bottom. The separated water will still contain some oil, grease, iron, polymer additives, paraffin wax and other contaminants that will be removed in the ensuing water treatment process. The sensor will probably never see pure water. However, even with the contaminants, the water phase will be conductive making it electrically different than the oil phase.

The capacitance switch is mounted at a point where the low interface between the oil and the water needs to be detected. This could be a horizontal installation just above the water dump outlet line (Figure 4). The capacitance switch could also be mounted directly into the water outlet piping.

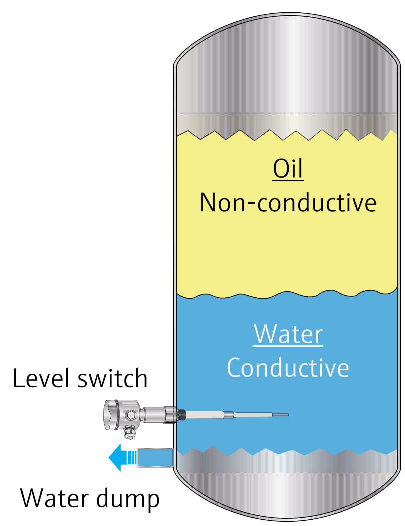

Figure 4: A capacitance level switch mounted just above the water dump outlet line can detect the presence of oil and send a signal to shut off the pump, thus preventing oil from reaching the water treatment process.

In some cases, the vessel has no openings to mount the sensor horizontally at the required point of control. In these cases, a capacitance sensor can be mounted from the top of the vessel extended down to the control point. Since the capacitance sensor will see a large change between the water and the hydrocarbon, vertical mounting is often feasible, but a horizontal installation at the control point is preferred.

The capacitance switch is set with a large preload on the bridge circuit to make it less sensitive. This allows the switch to detect the water because of the large change in capacitance due to water's conductive electrical properties. The low dielectric constant and non-conductive properties of the oil phase will not generate a large enough change in capacitance to exceed the large preload on the bridge circuit.

The result is that the switch will change states as soon as the water drops below the tip of the probe. This provides an extremely reliable indication of the water/oil interface that can be used to stop dumping.

Other Point Level Methods for Detecting Interface Several other methods are available to detect the water/oil interface, but all have significant disadvantage as compared to capacitive level sensors:

Manual sampling The manual sampling method is somewhat archaic, but is still used in many facilities. A number of valves are spaced vertically on the side of the vessel. An operator opens the valve briefly and pulls a sample. By observing the sample visually, it can be determined which valve yields water and the next closest valve where oil is present, thereby identifying the interface is between the two valves.

Manual sampling has a number of flaws. First, it only gives an idea of where the interface is located - that is, somewhere between two valves. Since the samples are taken manually, the location of the interface is only as accurate as the last sample. It also relies on a manual visual interpretation of what is water and what is oil. This interpretation is arbitrary and inconsistent with different operators. Last, it is an operator's judgment to decide when to stop dumping, which adds to the human error factor.

Sight glass A sight glass located in the water dump outlet line can be used to visually discern the change from the water phase to the oil phase. As in the manual sampling method, it relies on a visual interpretation of what is water and what is oil. Also, because the sight glass is in the outlet line, some oil will inadvertently be dumped. As this is a manual function, human error is introduced.

Conductivity switch Conductivity switches operate by passing an electrical current from one electrode to a second electrode through a conductive liquid. In an oil/water interface application, the current passes through when water is present. When the liquid changes to non-conductive oil, the current no longer passes between the electrodes and the switch indicates a change of state.

Conductivity switches can and do provide reliable interface detection in many installations. However, if the electrodes become coated with a non-conductive material such as heavy crude oil or paraffin wax, the electrode will no longer be able to pass current. This will indicate a false reading until the electrodes have been cleaned. For this reason, conductivity switches should only be used in separation processes where the phases are free of heavy material or contaminants.

Float switch Float switches can be used for measuring the interface between water and oil. The float is calibrated for the specific gravity of water, which is 1.0 or slightly higher. The oil has a lower specific gravity, generally between 0.7 and 0.9. As the water level drops the float arm moves down, providing an indication of the low water control point.

Floats can be problematic in water dumping applications for several reasons. The moving parts of the float switch are susceptible to wear and damage. The float can be compromised causing it to sink. Heavy crude and wax can build up on the float and float arm, causing hang-up and failures. Finally, the specific gravities of both the ground water and the oil are variable, requiring calibration "tweaks" on a regular basis.

Conclusion There are a number of point level approaches to measure the interface between water and oil for water dump control. Manual methods, such as sampling valves and sight glasses are still widely used in these applications. Using level instrumentation to determine the interface removes both the manual aspect and human error from the procedure.

When comparing point level instruments that can detect the water/oil interface, the capacitance sensor stands out as the best choice. Capacitance level switches are simple to calibrate and can be installed horizontally or vertically. There are no moving parts to wear out or hang up. Because capacitance has the advantage of active buildup compensation, materials that coat such as heavy crude or paraffin are not a problem.

Capacitance level switches provide reliable water oil interface detection, and help to automate the water dump control process.

WP01002A/24/EN/01.13

Endress+Hauser, Inc.
2350 Endress Place
Greenwood, IN 46143
Tel: 317-535-7138
Sales: 888-ENDRESS (888-363-7377)
Service: 800-642-8737
Fax: 317-535-8498
inquiry@us.endress.com
www.us.endress.com

Endress+Hauser
People for Process Automation