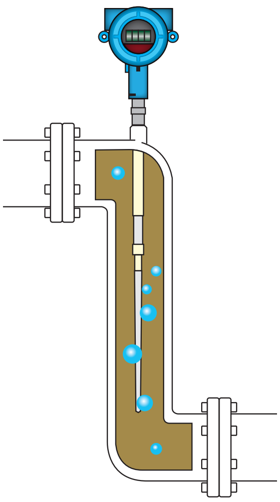
Capacitive Sensors for Water Cut Measurement

Separation operations, automated well testing and lease automatic custody transfer (LACT) are, but three of the oilfield applications for which capacitive analysis has a record of reliable, cost-effective performance

Measuring the amount of water in oil, or 'water-cut', is a key process control and production management variable in today's oilfields. It is also a central factor in determining just how much of those royalty-bearing fluids actually become available for sale.

Because water-cut is such a critical measurement, a number of technologies have been developed over the years to measure the composition of oil-and-water mixtures. Coriolis densitometers, microwave analysers and infrared spectrometers all have application strengths in certain niches; however, none equals the cost-effective, broad applicability of capacitance analysis to the water-in-oil mixtures most common to the oil patch.



The probe of an insertion-style capacitive watercut analyser forms a concentric capacitor with the surrounding pipe, allowing it to calculate the average composition of the entire stream

What is Capacitive Analysis?

The capacitive analyser is, in effect, a concentric inline capacitor that utilises the relatively large difference in dielectric constant between oil (k 2.3) and water (k 80) to infer stream composition. The system transmits a radio frequency voltage to the sensing element and measures the capacitance between the probe and the surrounding pipe. The more water there is in the intervening fluid, the higher its capacitance.

From the measured capacitance, the percentage of water in oil can be calculated based on a predictable relationship between the properties of the materials. Furthermore, while water's dielectric constant varies little with temperature, system electronics can compensate for temperature-dependent changes in the oil-phase dielectric constant. While this conceptually elegant approach does have limitations, it is simple, relatively inexpensive and requires little maintenance relative to other options. Additional advantages of capacitive water-cut analysers include:

- ***Unrivalled high temperature and pressure capabilities (up to 450°F and 1,500-psi)***
- ***Non-epoxy coatings that are resistant to even erosive, sand-bearing mixtures***
- ***Relative immunity to paraffin build-up***
- ***Insertion probe assemblies that are easy to install and clean, as well as, typically, being straightforward to calibrate***

The most significant drawback of the capacitive analyser is that the underlying physics limit it to oil-continuous mixtures. As water content in an oil-continuous mixture increases, there comes an inversion point after which the oil is dispersed in water rather than the water dispersed in oil. At this point, the fluid becomes conductive and the capacitor is effectively 'shorted out'. From a practical standpoint, this limits the capacitive analyser's range to 0-50 per cent water with light oil, and 0-80 per cent with heavy oil.

Other technologies can measure over the full 0-100 per cent water range, but they are more complex, require more maintenance and typically cost three to four times as much. Fortunately, most oilfield applications do not operate on the water-continuous side of the spectrum.

Separator Control and Optimisation

Among the common applications of capacitive water-cut analysis in oilfield operations is the thermal separator, or 'heater treater'. This uses thermal energy in combination with chemical injection and/or high-voltage electrical fields to break oil/water emulsions. Residence time in these normally horizontal units allows the relatively dry oil and relatively oil-free water to settle into two parallel streams for further processing or storage.

For final oil-phase quality assurance, a capacitive water-cut analyser is used in conjunction with another radio frequency probe to detect the level of the electrical interface between the oil and water phases within the tank. (This electrical interface within the emulsion layer is, in fact, the same relatively sharp transition between oil-in-water and water-in-oil phases that renders capacitive water-cut analysers unsuitable for determining the composition of water continuous mixtures). Together, these measurements provide the basis for optimal control of a well-behaved separator, meaning one with a predictably consistent emulsion thickness.

The water-cut monitor dictates the level at which to maintain the electrical interface (to provide necessary oil dryness). The interface gauge, in turn, determines the position of the water-dump valve necessary to maintain the interface level at the position prescribed by the water-cut monitor. Less well-defined emulsion layers might include a high-level interface gauge or switch to increase chemical injection, reduce throughput, or take other measures to reduce emulsion thickness.

Automated Well Testing

While the production separator described in the previous section might be used to continuously process the combined output of many wells across an oilfield, automatic well testing (AWT) systems are an important tool for assessing and managing the productivity of individual wells. An AWT, in contrast to a production separator, consists of a small, batch-oriented vessel that is used to sequentially test the productivity and qualitative output of dozens of wells per day.

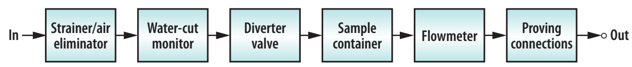
In short, the output of a particular well is metered to the test vessel until full to a given level. Once allowed to separate, net oil is calculated by a combination of capacitive water-cut analysis of the oil phase, measurements of the water level, oil-water interface level, mass flow rate (typically measured using a Coriolis meter) into the tank, and associated temperatures and pressures. Net oil is the amount of oil produced excluding its 'basic sediment and water' (BS&W) content. A very large oilfield might contain as many as 100 AWTs, each testing 20-50 wells in scheduled rotation.

The data collected by AWTs provide crucial insights into geological conditions underground and can help in the development of strategies for optimal oilfield lifecycle management.

Lease Automated Custody Transfer

The movement of oilfield production to pipelines, trucks, railcars or storage tanks often represents a custody transfer - a change in ownership or allocation that signals an exchange of currency. In larger facilities, oil typically is sold through a Lease Automated Custody Transfer (LACT) unit that measures the flow rate and composition of the crude as it changes hands. LACT units, or skids, are designed to API standards and to satisfy any additional measurement and sampling standards required by the purchaser. The value received for the crude will depend on its density, water cut (BS&W content) and volume transferred.

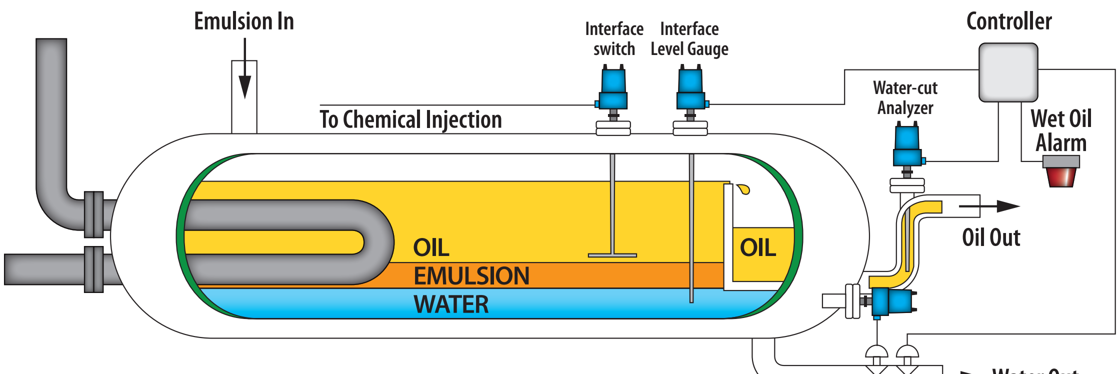
Accuracy of the volume measurement is assured by periodic validation of the flowmeter against a ±0.2 per cent accurate prover. Water content and density for compensation purposes is calculated by analysis of a continuously collected sample diverted from the primary stream. (The sample flow rate is calibrated to always be proportional to the total flow, so sample composition will accurately reflect the average stream composition).



Simplified functional diagram of a LACT unit

In this application, a capacitive water-cut analyser can calculate the value of the transferred crude while policing the upper limit of the allowable water content. If the water content gets too high, it shuts down the transfer and diverts the oil back to its source for further processing.

Separation operations, automated well testing and lease automatic custody transfer are, but three of the oilfield applications for which capacitive analysis has a record of reliable, cost-effective performance. In many other situations where oil meets water, capacitive cut monitors are proving their worth as well.



Together with an RF interface level gauge, a capacitive water-cut monitor can provide effective control of a thermal separation unit

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