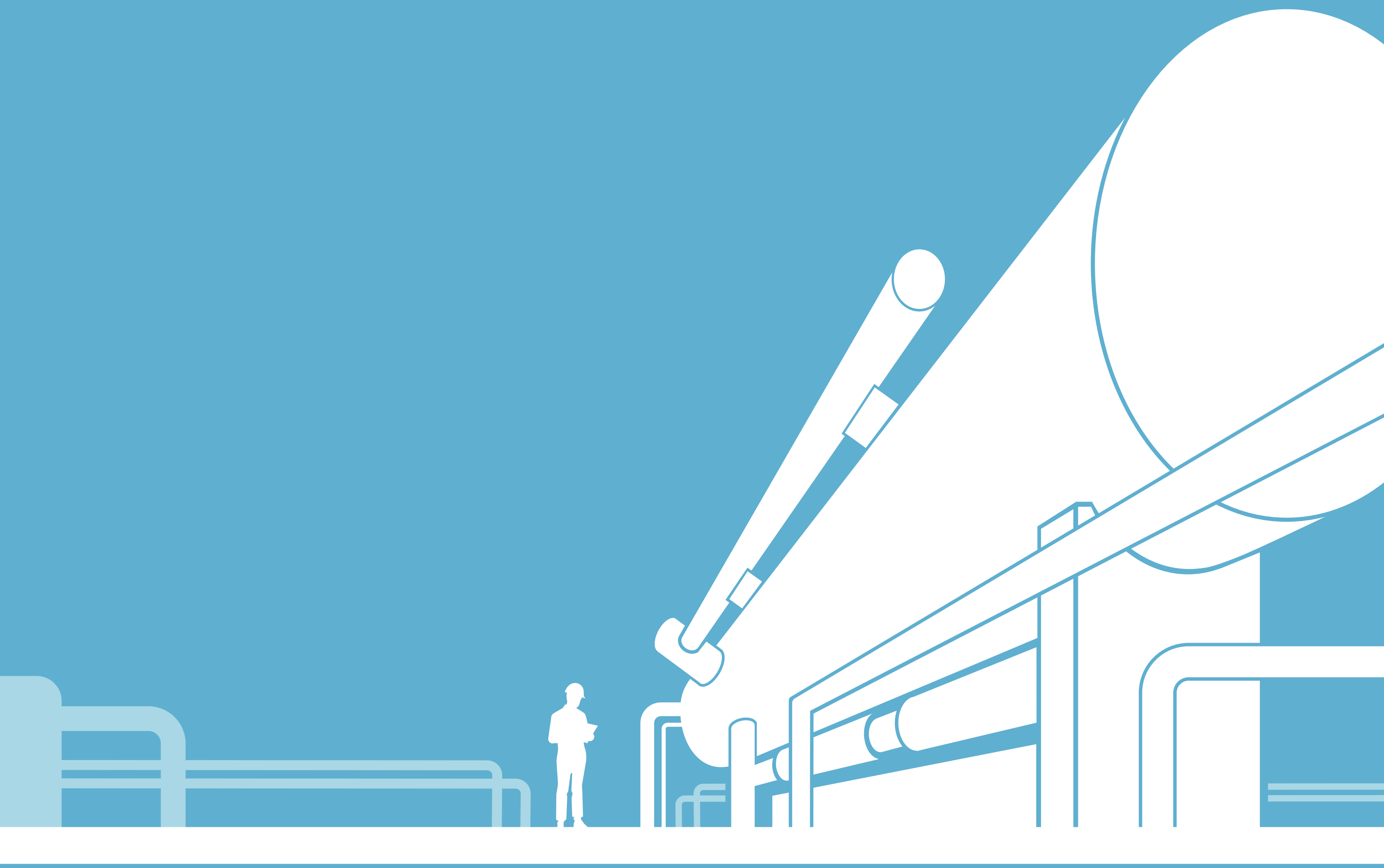
INTERFACE IN THE FIELD

Achieving Reliable Interface Measurement to Optimize Process and Increase Uptime



A Magnetrol® **Level Matters** Series White Paper

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Achieving Reliable Interface Measurement to Optimize Process and Increase Uptime

Objective

Interface or multiphase level measurements exist throughout the Oil & Gas streams as well as Petrochemical. While level measurement technologies have come a long way in effectively measuring liquids and solids, multiphase level measurement continues to be the biggest challenge and opportunity that exists today to which there is no perfect technology.

However, experience has shown that process optimization and increased uptime can still be achieved in many separator applications through reliable, best-in-class, level technology.

The objective of this paper is to review interface challenges, the current technologies being utilized for interface, field experience in various applications to achieve process optimization and increased uptime, and the future of reliable interface measurement.

Figure 1: Various types of upstream separators

Overview

This white paper will examine:

- Interface Challenges (Emulsion)
- Current Level Technologies Utilized for Interface Measurement
- Field Experience for Process Optimization and Increased Uptime
- The Future of Reliable Interface Measurement

Interface Challenges (Emulsion)

In the Oil & Gas and Petrochemical industries, the need for interface measurement arises whenever immiscible liquids, those incapable of mixing, reside within the same vessel. The lighter medium rises to the top and the heavier settles at the bottom. In oil production, for example, water or steam is used to extract oil from a well. Well fluids then route to production separators where they settle into their primary constituents as a hydrocarbon over water interface.

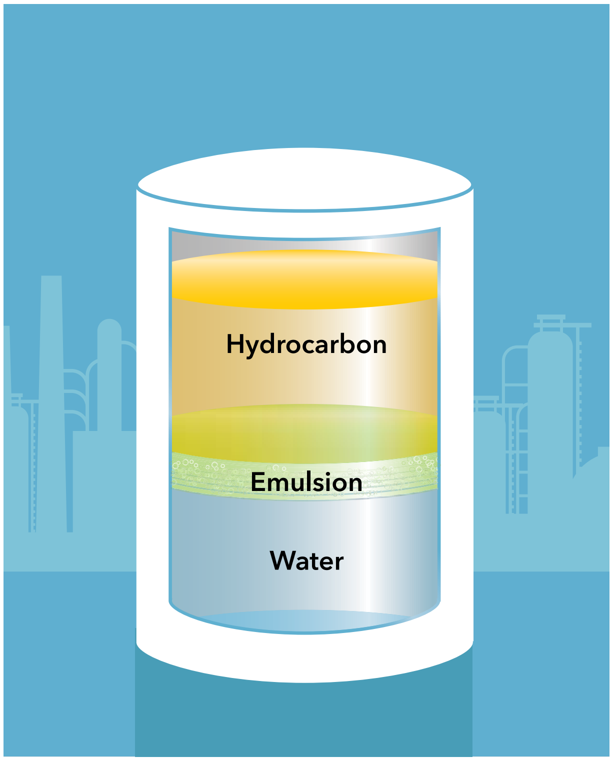

Figure 2: Multiphase level often includes hydrocarbon top, emulsion (rag layer) middle and water bottom

Interfaces can form between liquids and solids, liquid and foam, and liquid and gas; but the emphasis here will be concentrated on liquid-liquid interface (often with a vapor space above the top/lighter liquid). Immiscible liquids meet along an interface layer where they undergo some amount of emulsification. This emulsion layer (also referred to as a “rag” layer) may form a narrow, distinct boundary, but more frequently it is a broader gradient of the mixed liquids. Generally, the thicker the emulsion layer, the greater the measurement challenge.

While monitoring the top, or total level, is critical for safety and overfill prevention, knowing the level of an interface is necessary for maintaining product quality and operations efficiency. If there is water in oil that is not separated effectively (water carryover), then this can induce processing problems, equipment failures and unplanned shutdowns. If there is oil in water (oil extraction), then there can be production loss, environmental fines, penalties and forced shutdowns.

Of all the level switches and transmitters available, only a handful are suitable for reliable interface measurement. The leading interface measurement technologies include guided wave radar (GWR), buoyancy-based displacers and magnetostrictive, RF capacitance, nuclear/ gamma radiation and thermal dispersion. Ideally, the technology utilized for interface applications does not have to differ from other level instruments installed at the facility in order to maintain familiarity with users. Standardizing on a technology helps reduce training, installation & commissioning, maintenance and downtime. Of course all of these have an associated cost.

Current Level Technologies Utilized for Interface Measurement

There is no perfect, one-size-fits-all technology for interface applications. Outside of considering reliability and price points, familiarity often plays a pivotal role in determining the level measurement solution. This is particularly true for established technologies such as differential pressure (DP) and displacer-based products.

DP is still the most widely used level measurement technology, as seen in the *Control* Market Intelligence Report in March 2017,[1] where over 40% of instrumentation users / respondents advised that they prefer and use DP in approximately one-third or more of their applications as a percent of all instruments. However, DP is not a preferred technology for interface measurement. Extensive calibration is required along with assumptions that density and total level are constant.

Utilizing this technology typically results in one inferred interface measurement near the middle of the emulsion layer as opposed to both total level and interface measurement. Variation in the thickness of the emulsion layer affects density, and can therefore induce significant inaccuracy.

Of all the level switches and transmitters available, only a handful are suitable for reliable interface measurement.

Referencing that same *Control* report, the second most preferred technology as a percent of all instruments and applications is GWR. Over 25% of respondents preferred GWR in approximately one-third of their applications.

The ability to use GWR for total level (potential overfill prevention) and interface applications greatly increases user familiarity, allowing the technology to be applied correctly while decreasing training and commissioning time. GWR may also have limitations for interface but these are often mitigated with demulsifiers or increasing process temperature to assist the separation of heavier oils.

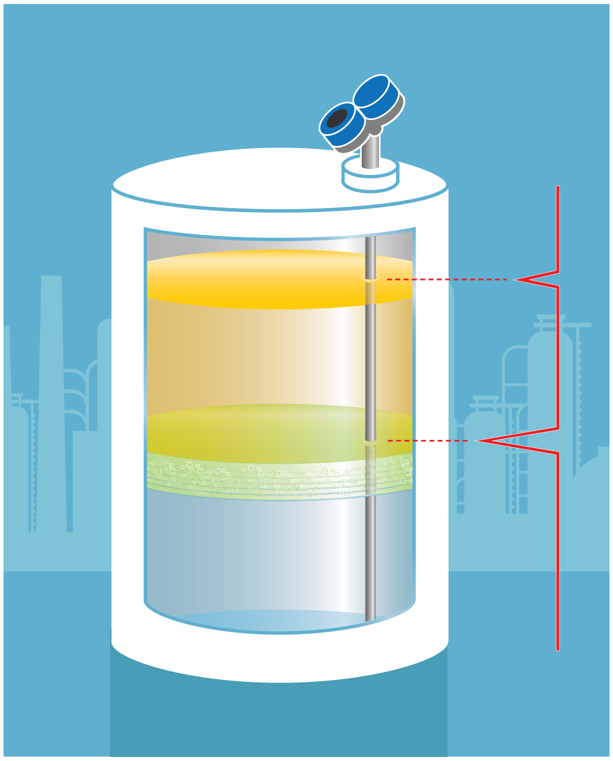

Figure 3: GWR with signal reflections down probe

Magnetostrictive technology is also used for interface measurement. It is based upon buoyancy principles, therefore specific gravity-related drawbacks exist, but it has advantages particularly in applications with large or swelling emulsion layers. Consideration must be taken for solids buildup, such as paraffin or asphaltene adhesion, due to moving parts.

> **Heavy oils may present major inaccuracies when coating probes or building up on floats, which can also increase maintenance intervals.**

Other interface technologies, such as displacers (mechanical) and RF capacitance, are preferred by only 12.6% and 8.2% of respondents respectively in one-third of their applications.

Heavy oils may present major inaccuracies when coating probes or building up on floats, which can also increase maintenance intervals. However, there is a comfort level with these technologies for Oil & Gas sectors in particular.

To summarize, Table 1 on the following page displays a condensed look at the primary technologies used in interface, along with their strengths and limitations.

A figure is also included to highlight the importance of addressing density, or API gravity, for technology consideration. High specific gravity (low API) heavy crude oils impact the emulsion layer and can potentially add to the maintenance requirements.

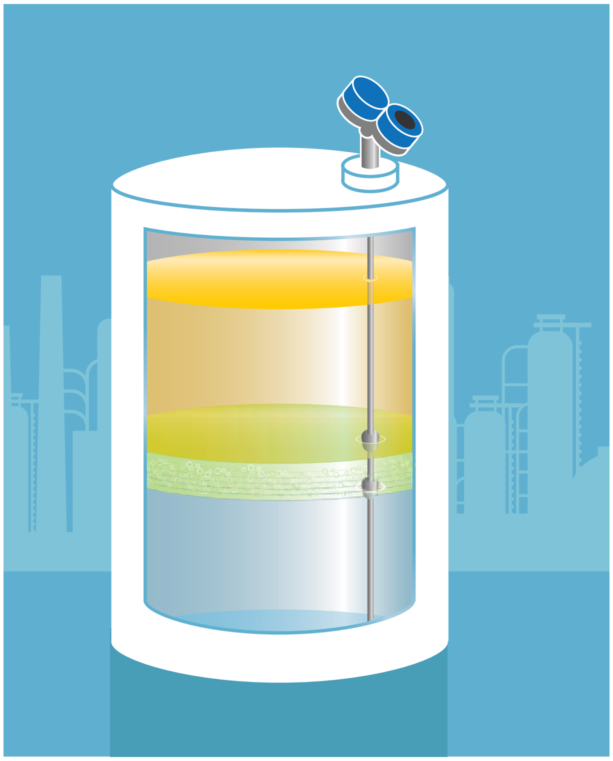

Figure 4: Direct-insertion magnetostrictive transmitter measuring emulsion layer

Interface Level Technology Comparison *Table 1*

Technology	Measurement	Strengths	Limitations
Guided Wave Radar	-Tracks top level and near top of emulsion layer -Low dielectric top level and high dielectric bottom level -Direct level measurement, even in low dielectrics, versus inferred (some GWR and other technologies)	-No calibration -No density dependency -Buildup detection and diagnostics -Less maintenance (no moving parts) -Overfill prevention (total level measurement) -Familiar across applications	-Thick emulsion layers and energy lost before bottom -Manufacturer performance variation such as those inferring or bottom following -Plugging potential for coaxial probes
Displacer	Tracks near middle or average of emulsion layer -Buoyancy forces change with liquid type -Capable of measuring interfaces with higher dielectric liquid on top	-Historical familiarity across applications -Switches and transmitters	-Moving parts to maintain -SG dependent -Only interface level or total level and range may be fixed
Magnetostrictive	-Buoyancy-based floats weighted for different levels, including total level and particularly bottom of emulsion -Capable of measuring interfaces with higher dielectric liquid on top	-Multi-float (SG) configurations for total level and emulsion layer -Thick or growing / swelling emulsion layers -No calibration typically required	-Moving parts to maintain particularly due to coating -SG dependent -Minimum separation required by physical float dimensions
Capacitance	-Measures near bottom of emulsion layer -Capacitance changes between low/ high dielectrics	-Historical familiarity for interface -Less maintenance with no moving parts -Switches and transmitters -Economical price point	-Calibration required -SG / dielectric / viscosity performance variation -Less usage in other applications -Buildup on probe / coating
Nuclear (Gamma/Radiometric)	-Nuclear radiation variation through different SGs -Profiles emulsion	-Inferred profile of emulsion layer including thick rag layers -Some types are non-contact to process -Can profile sand and foam for contact-type devices	-Expensive upfront price with additional regulation, maintenance and safety costs -Wall buildup and SG variation can cause errors -Non-contact only on smaller diameter vessels
Thermal Dispersion	-Switch point dependent on calibration -Thermal conductivity differences between liquids	-Economical -Less maintenance with no moving parts or plugging -Foam detection possible -Analog output emulsion tracking	-Switches only -Calibration required -Less familiarity

Transmitter Comparison by Oil SG/API *Figure 5*

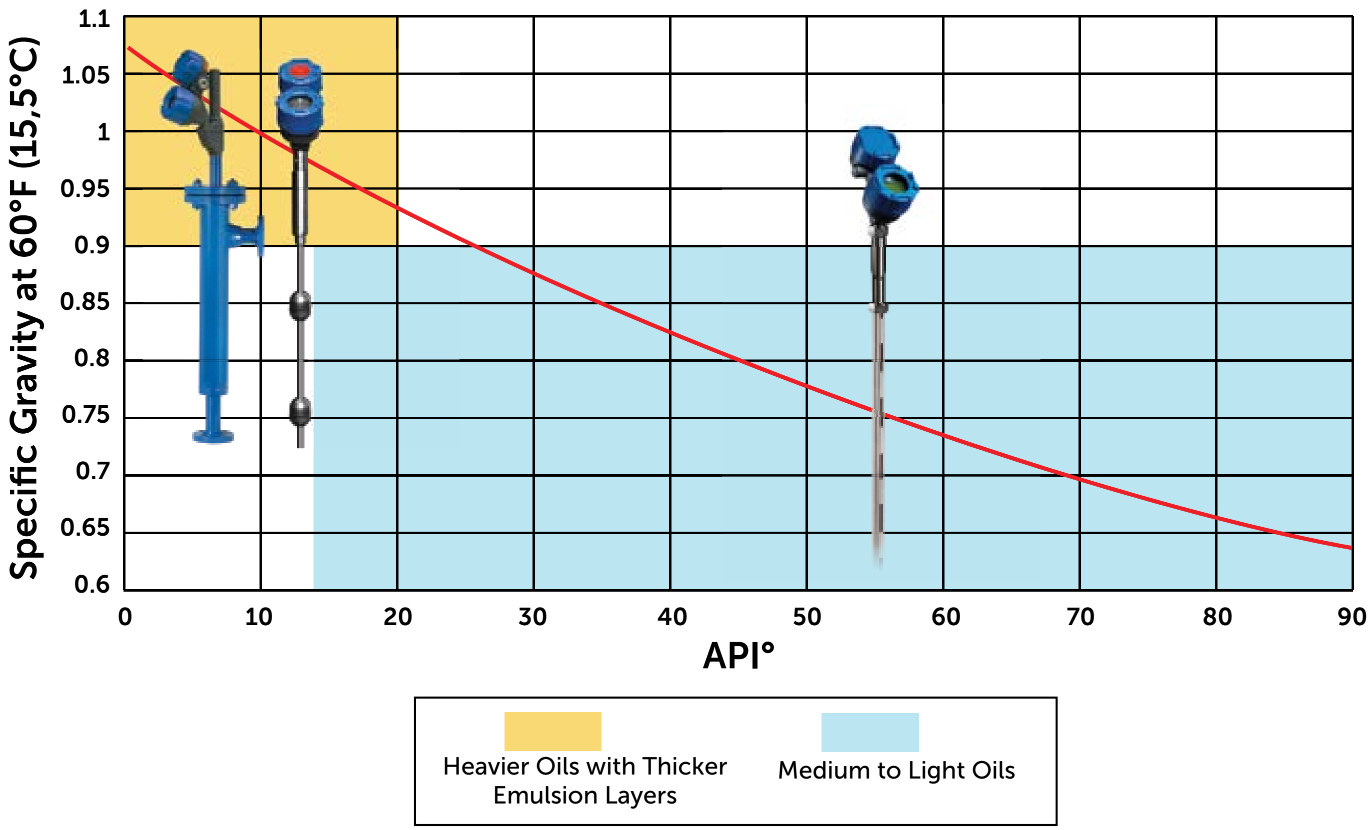

Figure 5: Magnetrol recommendations with buoyancy-based technologies (displacer and magnetrostrictive) on the left for heavier oils with thicker emulsion layers, and GWR on right for medium to light oils.

Note that these are general guidelines and there is overlap between technologies that may vary from this illustration. Consult Magnetrol for best technology-to-application match.

Field Experience for Process Optimization and Increased Uptime

In the Oil & Gas and Petrochemical industries, there are numerous interface applications that potentially produce an emulsion layer. Having a reliable level measurement will help optimize processes while increasing uptime. The following are applications and case studies highlighting the challenges faced for level technologies and the importance of this measurement.

It should be noted that no matter the technology, optimal installation conditions will assist in maximizing device performance. For instance, when inlet crude oil from a well enters a separator, retention time may be the most important factor to allow for the desired instrumentation performance, and therefore, process optimization. In other words, if the feed comes into a horizontal separator, the optimal installation location of the level measurement device is further away from the inlet (closer to the weir) where separation of the crude and water becomes more uniform. Demulsifiers assist with emulsion breakdown but can be reduced (estimated $1.5-2K USD per ton) when working in concert with reliable interface level measurement.

When device performance is maximized, a tighter control of the top of the emulsion layer is possible. The top of the emulsion is an indicator of water present in oil. With the primary goal of the separator to remove water from the oil, the level measurement can now allow operation closer or further away from the weir to optimize separator efficiency and retention time. If the separator-type is primarily for water storage, with a thin layer of oil on top, then tighter interface control will also provide a more accurate representation of how much water (only) is present in the vessel. This allows improved truck utilization, ensuring full truckloads during water extraction from storage vessels.

This ideal installation may not always be possible on a retrofit, but ideally instrumentation location is taken into account during separator design.

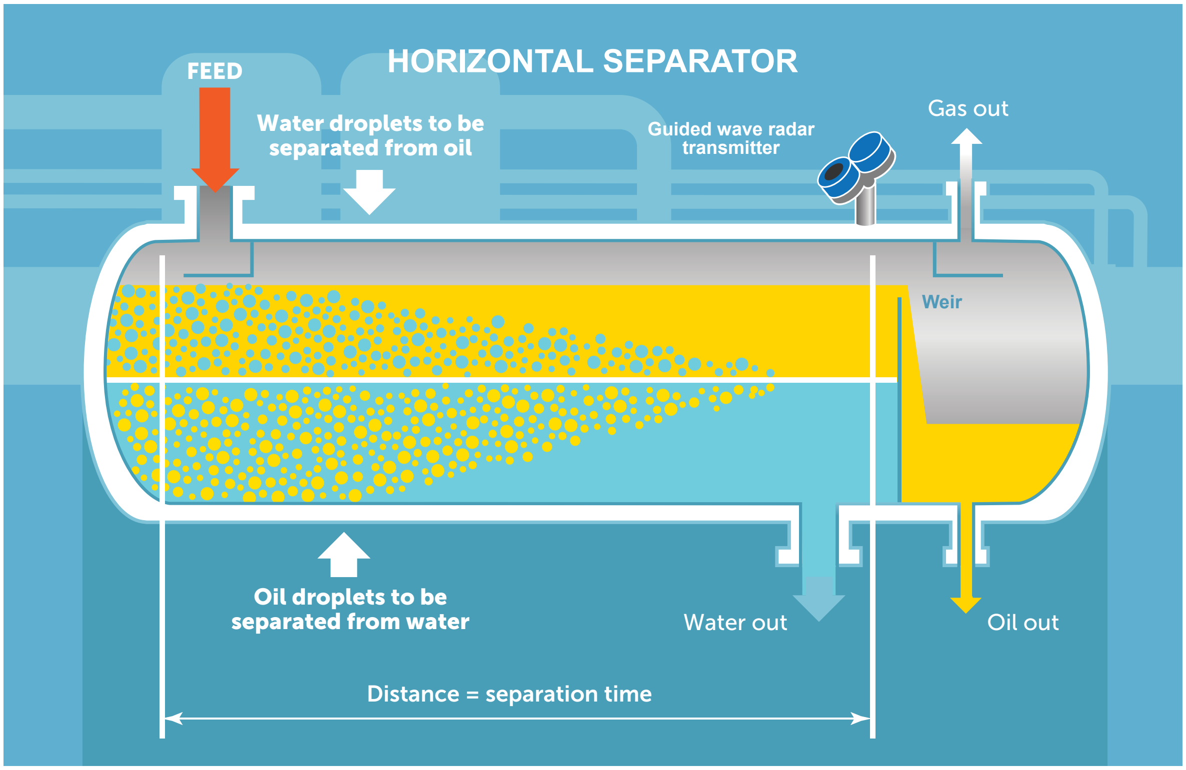

Figure 6: Retention time allows for improved separation and instrumentation performance. Note the installation location of the dark blue guided wave radar transmitter.

What is important to consider in any application, regardless of whether it is interface or total level, is what can occur during upset conditions or start-up and shutdown.

Most devices may work fine in normal interface operation; however, reliable measurement is required in those upset cases as well:

- When only one liquid exists (only water or only oil)
- When chamber is flooded (only oil and water – no gas phase exists)
- Multiphase oil, water and gas including overfill prevention

The first industry that comes to mind when discussing interface is upstream Oil & Gas or exploration and production (E&P). The initial challenges begin at the wellhead separators and resonate through the remaining hydrocarbon streams. Aside from this initial separation, an increasingly influential interface measurement for unconventional plays utilizing hydraulic fracturing is at saltwater disposal (SWD) facilities.

What is important to consider in any application is what can occur during upset conditions or start-up and shutdown.

These types of interface challenges exist through midstream tank farms and storage terminals, into downstream boots and desalters at refineries, and even petrochemical quench towers in the quench settlers/quench water separation drums.

INTERFACE APPLICATION CASE STUDY #1

Upstream Saltwater Disposal (SWD) Facility

Situation

In a SWD facility, frac trucks deliver saltwater and frac flowback from the field which is fed into a disposal well through a treatment plant. The wastewater unloaded from the truck immediately goes into a gun barrel separator (battery) where water and remaining oil are naturally separated. Additional heavy oil downstream in the facility is eventually fed back into the gun barrel separator, creating a dynamic emulsion layer. It is imperative that the oil is separated from the saltwater prior to injection into the spent well.

Figure 7: Truck unloading into tank battery for salt water / oil storage and separation

Figure 8: Location of injection well

Cost

The oil-water separation in the gun barrel separator and any downstream unit is critical. If oil carries over into the disposal well then it can damage or plug the well, requiring rework costs and downtime as well as an increase in chemical costs used in the treatment process.

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Having a clearer understanding of the day-to-day storage of "unwanted" liquids in the tank battery (pending disposal) versus production capacity allows for better management and utilization of resources, such as trucks getting dispatched to remote sites with sufficient capacity. Wellsite automation becomes imperative with instrumentation that can communicate through the desired protocols, are faster to commission and require little power to cycle up and down quickly.

In addition to the saltwater disposal fee, the separated oil represents additional revenue for the company. Since the injection well is porous by nature, any residual oil in the saltwater limits its capacity and eventually the well must be reworked at a significant cost.

Solution

After the gun barrel separator, the oil-water emulsion is passed into a treatment unit while the top layer of oil is sent to a separate holding tank. The Eclipse® Model 706 guided wave radar (GWR) transmitter effectively measures the oil level in the gun barrel tank, as well as the top of the oil-water emulsion, ensuring that the different products are routed to the appropriate units. This in turn prevents potential downstream plugging of the disposal well and reduces chemical treatment costs. Additional GWR transmitters or Non-Contact radar devices can then be utilized for the standard total level measurements.

INTERFACE APPLICATION CASE STUDY #2

Separator Boots (Refinery)

Situation

In refineries, "boots" are gravitational separation devices commonly found among, but not limited to, alkylation units, hydrotreaters, cokers and amine units. Extending off of the bottom of these horizontal vessels is a boot where interface can occur between the process hydrocarbons and heavier density liquids, such as residual water, HF acid, glycol or amine.

Residual water is often present in many refinery applications, with one refinery approximating that 25% of their level applications may involve some type of interface. The boot is a last step separator to prevent particular liquids from reaching downstream processes.

Figure 9: Boot for separation in a refinery (GWR transmitter installed in blue chamber at right)

Cost

The result of ineffective boot interface measurement can range from reduced productivity and process efficiency to catastrophic failures in downstream equipment.

If trace water particles arrive downstream it may only cause minor maintenance or clean-up over time. Conversely, if a slug of water is not separated and eventually enters distillation columns or other high temperature units, then the water will rapidly flash due to thermal expansion, potentially causing excessive vibration and damage to trays or other parts of the distillation column. This of course draws major concerns over safety and productivity lost, as it can cost $550K USD per hour to have a tower down; and, it may take days to bring back up depending on severity of the damages.

The result of ineffective boot interface measurement can range from reduced productivity and process efficiency to catastrophic failures in downstream equipment.

In the example of HF acid being knocked out through the boot, if the HF acid level is not controlled and it proceeds downstream, then it will corrode stainless steel piping, valves, fittings and instrumentation.

In the other direction off of the boot, if hydrocarbon process liquids exit the boot with residual water, then it will diminish efficiency of the water treatment processes. Wastewater streams that have hydrocarbon particulates may cause downstream problems, such as plugging of screens or filters.

Solution

The ECLIPSE Model 706 GWR transmitter is an ideal solution for boots, often accompanied by a magnetic level indicator (MLI) for visual indication. Sight glasses and MLIs are prevalent in refineries for manual inspection and walk through.

With the Aurora® design from Orion Instruments®, a Magnetrol company, users can benefit from the redundancy of a GWR and MLI through a single external chamber. This can prove beneficial in tight spaces and smaller vessels, such as boots, where a user will receive two technologies while utilizing a single process connection (typically an existing set of mating flanges).

If the emulsion is too thick, users can externally strap on to the chamber a Jupiter® Model JM4 Magnetostrictive transmitter (also an Orion Instruments product).

Figure 10: GWR with MLI for redundancy

INTERFACE APPLICATION CASE STUDY #3

Petrochemical Loss of Primary Containment (LOPC)

Situation

One of the world's largest oil & gas and petrochemical companies headquartered in Europe was having issues with multiphase level measurement involving a hydrocarbon with water bottoms and a gas vapor space. GWR was being utilized, but the existing device did not produce a reliable signal throughout the length of the probe and the interface made it difficult to distinguish between the upper level and water bottom.

> Direct cost of a work-related death is $1M USD and indirect costs are approximately four times greater.

Cost

Because of the error induced from the water bottom, the GWR in service threatened loss of primary containment (LOPC). Stringent environmental, health and safety practices did not allow this type of hazard to continue knowing the impact of overfill in terms of personnel safety, cleanup, fines and reputation.

According to the National Safety Council's "Injury Facts" via *Chemical Processing Magazine,* direct cost of a work-related death is $1M USD and indirect costs are approximately four times greater.[2]

Solution

In this case the user was interested in staying with GWR due to the many applications throughout the facility currently utilizing it, therefore different manufacturer's devices were tested side-by-side.

The Eclipse Model 706 was found to be best-in-class, tracking top level up to the device's flanged process connection (above 100% level point) even with water bottoms present. The Eclipse Model 706 eliminates any dead zones or blind spots at the top of the probe allowing direct measurement to be made and preventing LOPC. The superior signal strength also allowed for measurement through the hydrocarbon to detect the water level below.

It was determined that one Eclipse Model 706 GWR transmitter could be used regardless of whether the chamber had a gas phase, was completely flooded with liquid, had one level on the probe, two levels on the probe or no level present.

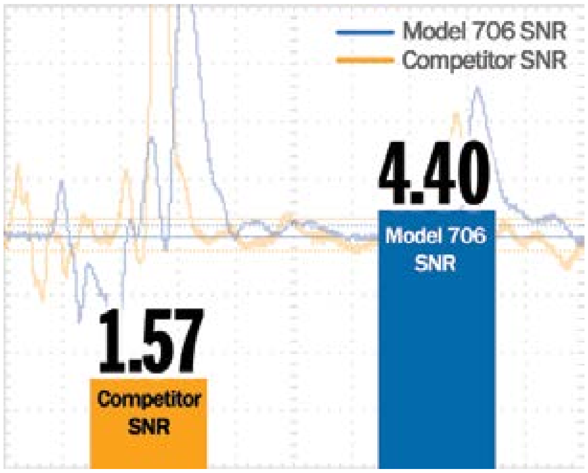

Figure 11: GWR signal-to-noise ratio (SNR)

INTERFACE APPLICATION CASE STUDY #4

Petrochemical Water & Benzene

Situation

One of the largest polyolefin producers in Germany has a vessel with a mixture of benzene and water. Benzene, an aromatic hydrocarbon that is an important constituent in gasoline, has a very low dielectric (low conductivity) which can be problematic for certain technologies.

The level technology in this case was a GWR transmitter mounted in a chamber on the side of the vessel. The chamber had the potential to fill completely and there was a tendency for the GWR to lose signal near the top of the probe due to the low dielectric benzene.

Figure 12: Benzene and water

Cost

Outside of a sight glass, the GWR was the only level technology in the vessel. The existing GWR signal was being lost at different times of the day, including in the middle of the night, allowing zero remote visibility into the process and causing safety concerns due to potential overfill. Sometimes the signal was lost for hours and the only method of reacquiring signal was to disconnect the power supply and restart.

During these times of lost signal, it was required to send a technician out to the vessel, no matter the time of day or night, in order to physically view the sight glass.

This occurred many times over an 18-month span, as the GWR manufacturer could not resolve their issues related to the impedance mismatch, adding substantially to the total cost of ownership of the device.

During these times of lost signal, it was required to send a technician out to the vessel, no matter the time of day or night.

Solution

Because of the failed GWR, this user considered moving to a displacer due to the historical reliability of the technology. However, one last opportunity was given to GWR by installing the Eclipse Model 706.

The Model 706, with its specifically designed impedance matched probe, has been performing flawlessly. The impedance matching allows for level measurement up past the process connection, or 100% level point, allowing for overfill prevention or measurement in full chambers.

It has eliminated maintenance and service time at the vessel and those inconvenient times when signal was lost. Supporting proof of reliability is provided through Safety Integrity Level (SIL) documentation, such as certificates and FMEDA reports.

INTERFACE APPLICATION CASE STUDY #5

Petrochemical Quench Settler

Situation

Feedstock comes into the ethylene plant and goes through the ethylene furnaces (pyrolysis). Once cracked into a variety of hydrocarbons and hydrogen, it immediately begins to recombine into larger molecules. To prevent these reactions, the cracked vapor goes through the quench towers to cool using oil or water.

The heaviest hydrocarbons are carried with the water into the quench settler or the quench water separation drum (QWSD). An interface is created in the quench settler and possibly an emulsion layer if too much caustic is added.

Figure 13: Quench towers

Cost

Keeping control of the interface is important in the quench settler for multiple reasons:

- Water recirculation back into the quench tower. Carrying over hydrocarbons reduces productivity and causes potential fouling of equipment.
- As feedstock is increased, more cooling fluids are required which increases the importance of water recirculation.
- Loss of interface control will ultimately reduce efficiency of the quench tower operation leading to reduced productivity.
- If fluid composition negatively changes in the quench tower, less ethylene is produced from the feedstock.
- Regulating interface can also aid in using less caustic keeping these costs down.

Loss of interface control will ultimately reduce efficiency of the quench tower operation leading to reduced productivity.

Solution

Depending on the size of the emulsion layer, GWR or magnetostrictive technologies are options to keep tighter control of the liquid separation in the quench settler. If the emulsion layer has a tighter window, then GWR is typically recommended, but if the emulsion layer is thick then it may be best to utilize magnetostrictive with a float designed to follow the bottom of the emulsion.

The Future of Reliable Interface Measurement

These field experiences present acceptable solutions for many of the challenges that exist today, but productivity has yet to be maximized in applications with thicker, ever-changing emulsions layers. This includes desalters in refineries and even the applications highlighted above under certain conditions.

Now, imagine a future where…

- Downstream equipment requires minimal maintenance
- Production is maximized with lower costs and less downtime
- Safety and time are not sacrificed due to lack of instrumentation reliability

The key to optimization for interface is solving the emulsion factor. No economical technology accomplishes all three level measurements: the top of the hydrocarbon level (total level), while simultaneously measuring the top of the emulsion (water in oil) and bottom of the emulsion (oil in water). For the level device, this becomes a multiphase (or three-phase) application.

Other technologies have attempted to solve multiphase measurement, but often have been uneconomical in doing so. For instance, multiphase flowmeters in upstream oil & gas are positioned against three-phase separators that cost around $1M USD depending on size, while a multiphase flowmeter has a price on average of over $250K USD.[3]

Nuclear technology can effectively measure the emulsion layer, but this has a similar purchase price along with additional radiation-based regulations and costs. Another option in the market, outside of level, is a multi-probe array based on water percent concentrations. This probe array is costly and requires up to four installation points (including one upstream of the separator).

It is easy to find problems, less simple to solve them. The aforementioned success with GWR, specifically for extremely challenging applications, may lead to future enhancements within the technology. GWR effectively measures interface due to the impedance changes created as the signal goes through the hydrocarbon level into the emulsion. However, as it does not take a great deal of water within a hydrocarbon to make it conductive, this results in an interface measurement near the top of the emulsion only, without detection of the bottom of the emulsion as there is no distinct impedance change through the layer. It is important to state that even basic applications with a fairly clean interface can be problematic for some GWR manufacturers that rely on software tricks or inferred measurements in low dielectric hydrocarbons (due to inadequate signal strength).

Tackling this multiphase measurement is at the forefront of technology development as interface level is the most effective means of optimizing separator processes and increasing uptime in the Oil & Gas and Petrochemical industries.

References:

1. “Market Intelligence Report,” *Control Magazine,* March 2017.
2. “National Safety Council’s Injury Facts,” *Chemical Processing Magazine*, 2017.
3 “Module E—The World Market for Multiphase Flowmeters,” *Flow Research*, March 2012.

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