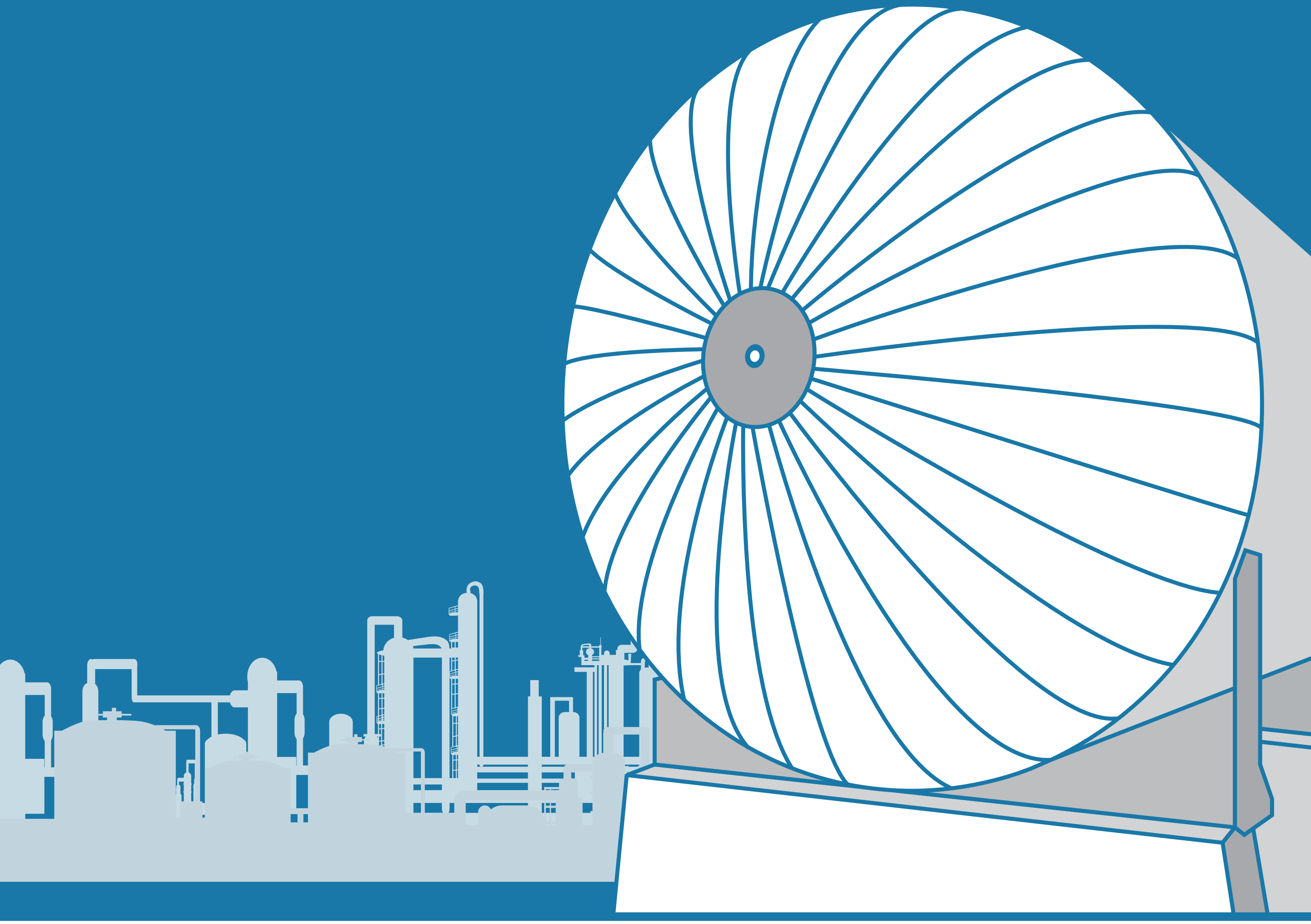
EMULSION IN THE FIELD

The Genesis of TDR Multiphase Level Measurement

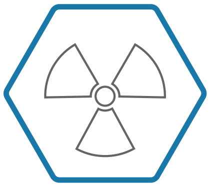


A Magnetrol® **Level Matters** Series White Paper

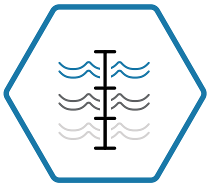
INTRODUCTION

Multiphase level measurements exist throughout the process industries and are particularly relevant in the Oil & Gas and Petrochemical sectors due to the value derived from effective water and hydrocarbon separation. While level instrumentation has come a long way in measuring liquids of all varieties, multiphase level measurement is often considered the greatest challenge and opportunity that exists today. This is evidenced by over half of separator failure modes being attributed to level instrumentation per Offshore Reliability Data (OREDA, 2002).

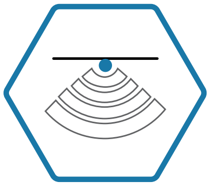
Many technologies attempt to tackle multiphase measurement but all have direct and/or ancillary limitations:



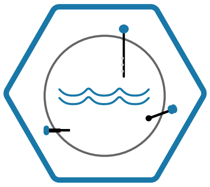
Radiometric and nucleonic technologies can profile multiphase media conditions, potentially without intrusion into the process vessel; however, they come with high upfront costs, regulatory burdens and increased safety requirements.



Multi-technology approaches using Guided Wave Radar (GWR) and Capacitance may be able to provide total level and interface measurement, but there are still limitations within the technologies; such as capacitance calibration shifts, buildup concerns and emulsion thickness limitations.



Sensors measuring discrete segments (tomography) are limited in resolution by the dimensions of those segments along with other limitations based on the technology utilized (e.g., conductivity).



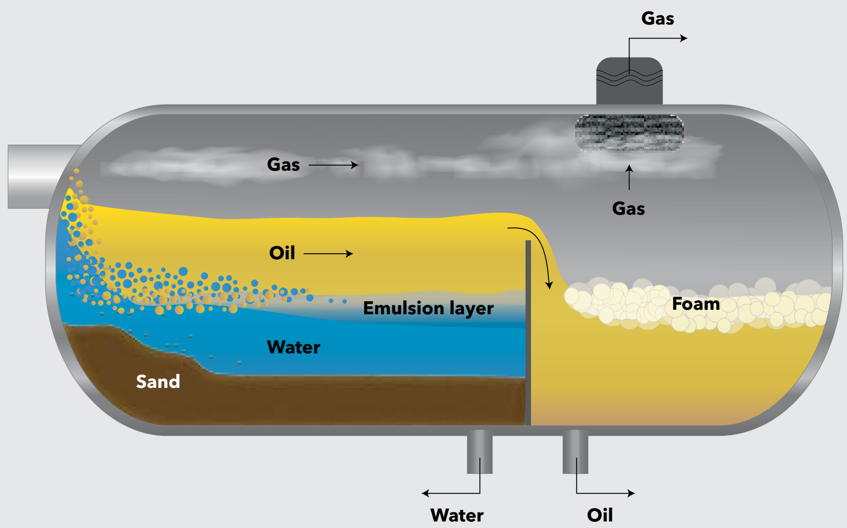
Multi-probe arrays are available that measure oil/water percentages but require multiple points of entry into the process vessel and surrounding piping; often complicating maintenance, increasing costs and adding potential leak points.

Solids detection (i.e., sediment or sand) often requires separate instrumentation from the interface level transmitter.

While this proves there has been considerable effort by instrumentation manufacturers to measure multiphase levels, only now is there a cost-effective TDR-based multiphase level detector capable of widespread adoption.

EMULSION CHALLENGES

When immiscible liquids reside in the same vessel, eventually the lighter liquid rises to the top and the heavier settles to the bottom. This is the case with oil and water, where effective separation is critical to the productivity of upstream wells, processing plants and refinery/petrochemical complexes.



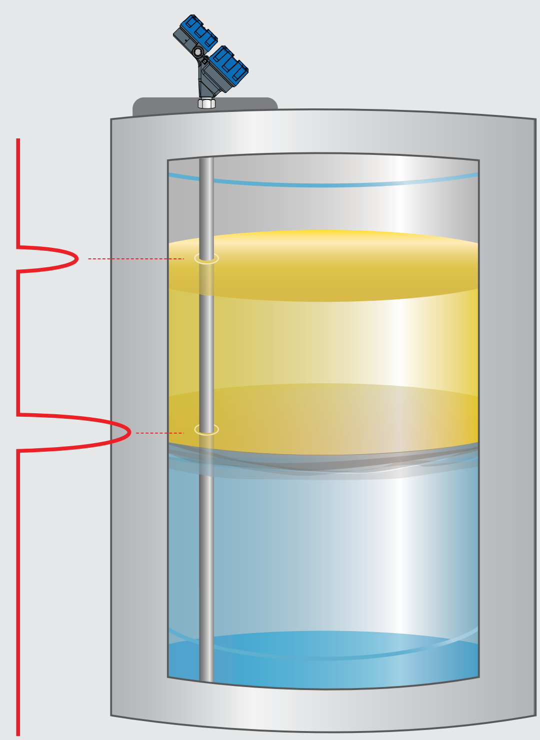
Horizontal separator

Oil and water that undergoes emulsification is widely seen as the most difficult type of interface to control.

A thick or dynamic emulsion layer creates challenges for one of the most widely utilized level technologies: Guided Wave Radar (GWR).

GWR is a microwave radar device combining time domain reflectometry (TDR) and equivalent time sampling. The synthesis of technologies creates a high-speed GWR transmitter that is extremely effective at tracking total level and interface in separators; particularly when there is a relatively distinct boundary between the liquids. However, as the emulsion layer grows, GWR tends to measure near the top of the layer. Even a small amount of water in the oil (top of the emulsion layer) makes it conductive enough to produce an impedance change detectable by the transmitter. This leaves little remaining energy to be transmitted through the rest of the emulsion layer.

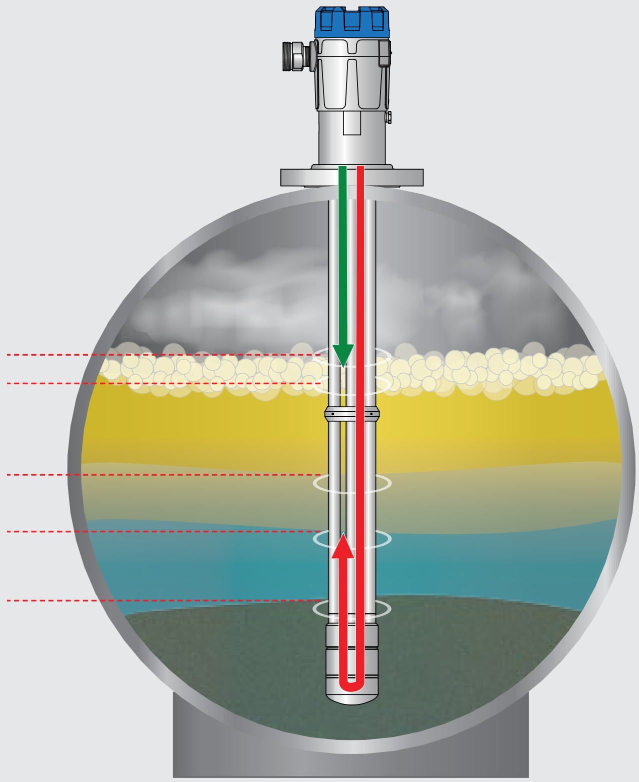
With the growth of TDR based level instrumentation, there is an emphasis on expanding the use of TDR into multiphase applications where mainly high-priced profilers or multi-probe arrays exist today.



Vertical separator with cleaner interface

GENESIS OF MULTIPHASE TDR

An innovative approach was required to take advantage of the strengths of traditional TDR-based transmitters while improving upon the design to compensate for thick emulsion layers and potential sediment levels.

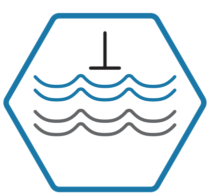


Genesis Multiphase Detector

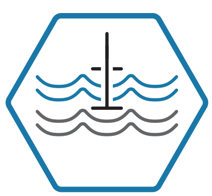
A new TDR Multiphase Detector, aptly named Genesis®, was invented to dynamically measure thick emulsions and sediment levels. The measurement is accomplished by sending high frequency energy down the probe to detect upper level(s) while simultaneously sending energy back up the probe to detect various other levels that may be present.

This unique (and patented) combination of "Top-Down" and "Bottom-Up" measurements, along with sophisticated software algorithms, make it possible to measure total level, top of emulsion, bottom of emulsion and sediment through a single opening in the vessel.

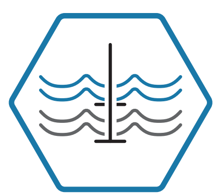
There are inherent differences from a user standpoint between this new multiphase detector and traditional loop-powered TDR-based instrumentation; one of them being higher power consumption to accomplish up to four measurements.



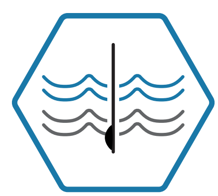
Total level



Top of emulsion



Bottom of emulsion

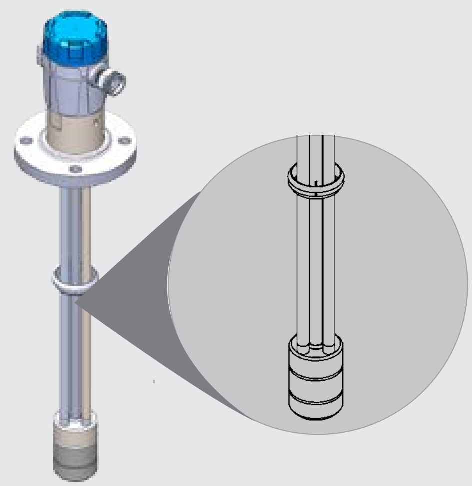


Sediment

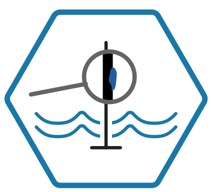
As with other technologies that contact the process, the probes are a critical element to maximizing the performance of Genesis. Probes will range from a large diameter coaxial to a completely new Pentarod design. The Pentarod is a five-conductor probe with four reference rods surrounding a PFA coated active center rod.

The concentrated signal yields coaxial-like performance; yet it has an “open” design that is less susceptible to measurement errors due to media buildup or bridging. The PFA coated center rods, aside from improved resistance to heavy coating, allow the pulse to travel in water with less absorption.

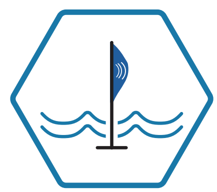
Genesis builds upon the proactive diagnostics found in GWR today in order to actively monitor buildup on the probe; enabling operators to streamline maintenance and reduce downtime. These buildup diagnostics capabilities include:



Genesis Pentarod probe design

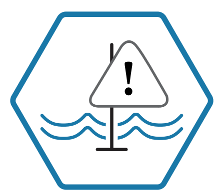


Location on the probe where buildup has occurred



Relative measure of buildup on the probe; indicating that buildup could potentially interfere with the actual level measurement

Rate of buildup as a percent per time period



A diagnostic warning when buildup may affect the level measurement

Furthering on these capabilities and of particular importance in upstream separators, an alarm can be configured when sand/sediment reaches an identified level on the probe to proactively eliminate unplanned shutdowns.

Due to the growing number of interface level transmitters and significance of this measurement, a technology breakdown is provided in Table 1 highlighting strengths, weaknesses and recommended uses in applications with thick/dynamic emulsion layers where a profile of the total level, top of emulsion, bottom of emulsion and sand/sediment is desirable.

TABLE 1: LEVEL TECHNOLOGIES IN INTERFACE SERVICE WITH THICK EMULSIONS

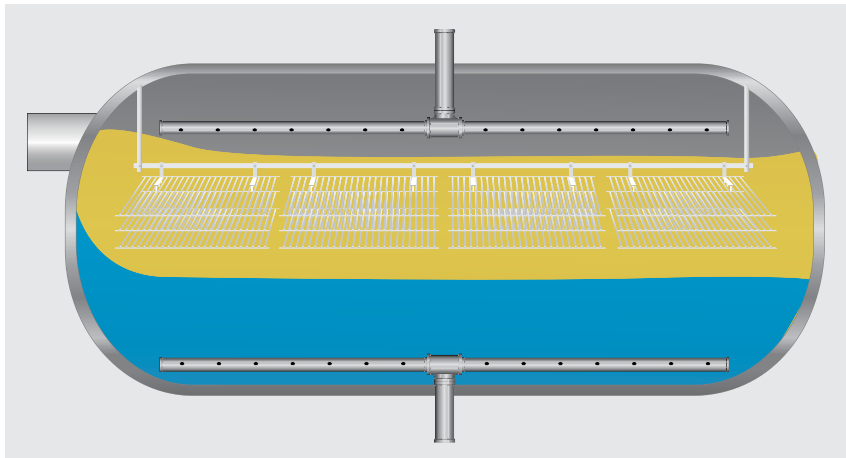
TECHNOLOGY	MEASUREMENT	TOTAL LEVEL	TOP OF EMULSION	BOTTOM OF EMULSION	SAND / SEDIMENT	STRENGTHS	WEAKNESSES
TDR MULTIPHASE DETECTOR (GENESIS)	TDR-based with concentrated top-down and bottom-up signals for multiphase measurement	Recommended	Recommended	Recommended	Recommended	Thick emulsion layers No calibration or density dependency Lower upfront cost relative to profilers Buildup detection	Higher power consumption and price point compared to GWR
GUIDED WAVE RADAR	TDR-based with signal concentrated down the probe reflecting off the liquid level(s) when impedance changes are detected	Recommended	Recommended	Not Recommended	Not Recommended	Low total cost of ownership Clean, distinct interfaces No calibration or density dependency Buildup detection	Thick and dynamic emulsion layers Heavy buildup
DIFFERENTIAL PRESSURE	Inferred interface measurement near the average density of the emulsion layer	Not Recommended	Review	Review	Not Recommended	Most widely used level technology / familiarity in total level applications Relatively economical upfront price	Thickness of layer affects density causing inaccuracy Total level assumed constant in interface service
NUCLEONIC (GAMMA/ RADIOMETRIC)	Provides density profile or level outputs by detecting the amount of radiation through the varying specific gravity (SG) emulsion layer	Recommended	Recommended	Recommended	Recommended	Non-contact options depending on vessel size Thick rag layers with non-uniform densities Can potentially profile sand	Most expensive upfront price Additional regulations and maintenance costs Potentially wall buildup Radiation safety concerns
DISPLACER TRANSMITTERS	Buoyancy-based capable of tracking interface of two immiscible liquids when displacer is fully submerged	Not Recommended	Review	Review	Not Recommended	Historical familiarity Steady output Capable of measuring interfaces with higher dielectric on top	Density dependent Moving parts Tracks near middle / average of emulsion layer Interface or total level
MAGNETO-STRICTIVE	Buoyancy-based floats weighted for different liquid SGs; particularly useful for bottom of thick emulsion layer	Recommended	Review	Review	Not Recommended	Thick emulsion layers Capable of measuring interfaces with higher dielectric on top Multi-float configurations	Density dependent Moving parts Minimum separation required by physical float dimensions
CAPACITANCE	Detects level based on capacitance changes between low and high dielectric liquids	Not Recommended	Review	Review	Not Recommended	Historical familiarity for interface measurement Economical upfront price No density dependency	Calibration required for total level or interface Recalibrations or errors due to dielectric shifts Buildup / coating
TOMOGRAPHY	Detects conductivity differences using electrodes at various segments down a probe	Recommended	Recommended	Recommended	Recommended	No density dependency Tolerant of buildup Can potentially detect sand/solids for full profile	Expensive upfront price

● Recommended ● Review ● Not Recommended

REALIZING OPERATIONAL IMPROVEMENT

Liquid-liquid separation is fundamental throughout the Oil & Gas value chains. Level measurement is the primary method of tracking fluid interface and the following are a few core applications with thick/dynamic emulsion layers where enhanced multiphase measurement improves productivity, safety and ultimately profitability.

DESALTERS



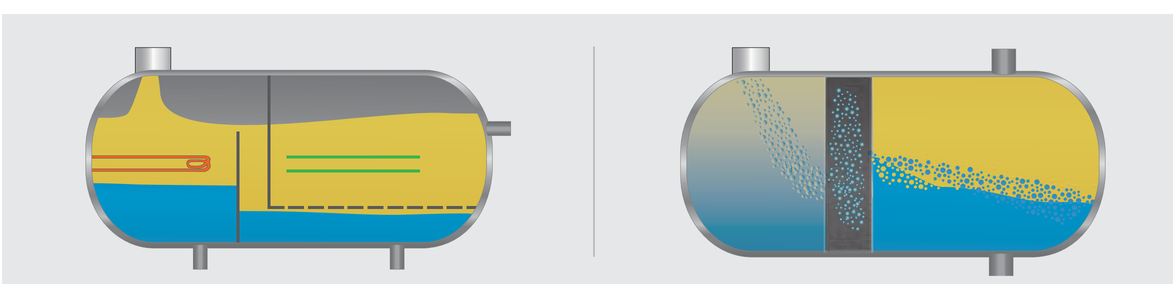
At the early stages of a refinery, a desalter separates water and salts/chlorides/sediment from crude oil to mitigate effects on downstream equipment—particularly corrosion caused by chlorides. If water is carried through to the distillation column, there is the potential for entrained water to flash to steam during heating, which can damage trays or other parts of the tower (crude unit). On the water/brine outlet, if oil gets into the wastewater stream, then it may result in fines or diminish the efficiency of the water treatment process as particulates plug screens or filters.

It is imperative that desalters run at optimal levels relative to the electrostatic grid to maintain productivity and assist in balancing the inlet crude, outlet crude, outlet water/brine and chemicals for emulsion control. The key to bringing this balancing act together is controlling and optimizing the emulsion layer.

ELECTROSTATIC COALESCERS

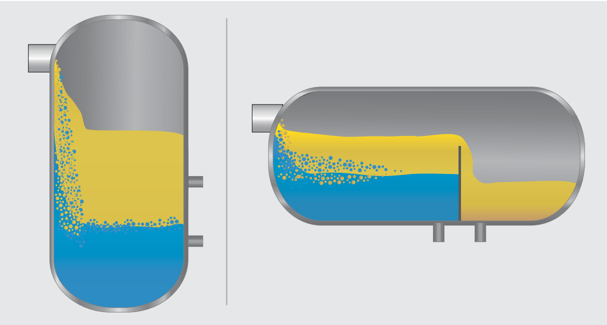
With the same principal of operation as a desalter at a refinery, electrostatic coalescers are utilized upstream for dehydration and desalting; commonly found on floating production storage and offloading vessels (FPSOs).

Monitoring the separation of water, crude and the associated emulsion layer is of primary importance with emphasis again on preventing too much water from contacting the grid and oil from leaving with the effluent water. Proper removal of soluble salts/chlorides also prevents downstream pipes from rotting out.



SEPARATORS

Most upstream liquid-liquid separators are designed to separate immiscible liquids by *gravitational force* as the higher density liquid falls to the bottom while the lighter liquid rises to the top. These can be two-phase or three-phase separators in a variety of shapes.



As with any separation process, particularly upstream Oil & Gas, it is imperative to maximize profitability by recovering as much of the oil as possible while limiting oil removal mixed in with the water. Better visibility into the thickness of the emulsion layer helps accomplish this.

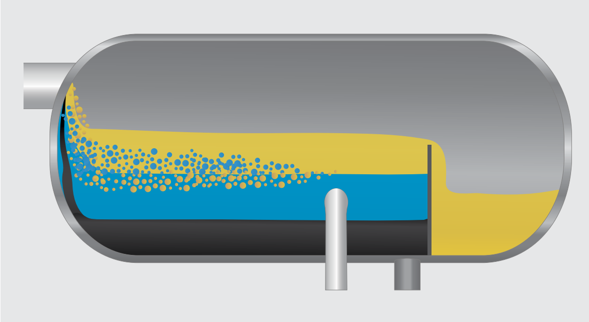
Another difficulty often found in upstream operations is sand or sediment accumulation at the bottom of separators. Oftentimes, a separate instrument is required to identify when sand reaches a certain level. A multiphase detector can reduce the necessary openings in the vessel by providing a sand measurement in addition to the various interface levels.

QUENCH WATER SETTLERS

In ethylene production, feedstock is cracked into a variety of hydrocarbons and hydrogen. This effluent from the furnaces will attempt to recombine into larger molecules unless it is immediately cooled in the quench tower. Historically, direct cooling using quench water or oil is an effective method to prevent unwanted reactions from occurring.

Quench tower operation is critical to efficient production/throughput and product quality. Because of the constituents of the effluent, fouling is of primary concern and will result in high operating and maintenance costs. Caustic water and heavy hydrocarbons accumulate at the bottom of the tower and into the quench settler (or quench water separation drum).

Based on the residence time in the settler and properties of the liquids, an emulsion can form while the liquids separate. Understanding the top and bottom of the emulsion layer mitigates fouling concerns by reducing the hydrocarbons being recirculated back into the quench tower (gas crackers) while increasing the efficiency of the dilution steam system which assists the cracking operation. This ultimately increases productivity by maximizing ethylene production from a given feedstock.



CONCLUSION

Measuring dynamic conditions in the most difficult types of separators is now achievable with the Genesis TDR Multiphase Detector. Genesis is a powerful, yet cost-effective, solution capable of measuring total level, top of emulsion, bottom of emulsion and sediment from a single instrument.

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