

White Paper

# In-Line Mass and Watercut Metering Enables Crude Visibility and Improves Desalter Process Efficiency



## In this White Paper

*The oilfields of Bohai in the west and Dagang in the north – producing 310,000 barrels a day – are conveniently linked by land and sea transport to the largest refinery and petrochemical company in China, which produce various petroleum products (including clean gasoline for automobiles, kerosene, light diesel, LPG, petrol coke) as well as petrochemical and chemical fiber products. This large refinery in Tianjin, has put a lot of emphasis on differentiating itself by using integration strategies, as well as focusing on green and low-carbon emission development. This is a refinery that practices dedicated scientific principles in streamlining and improving the efficiency of its refining operations and management practices.*

*“How can we know, in real-time, if there is water in the crude oil that we purchase?” This was the first question from the Plant Manager that led to today’s successful implementation of in-line mass and watercut metering solutions (as check metering) on the incoming crude oil that we see today at the facility. It’s understood that the crude oil price depends heavily on the quality of the crude, and some of the key parameters are water content, API gravity and density of the crude. Opportunity crudes (also known as spot crudes, advantage crudes or discount crudes) are lower in cost, however they are often lower in API gravity, can contain high concentrations of salts and solids, unstable asphaltenes and other contaminants such as paraffins, tramp amines, calcium naphthenates and other metallic contaminants, compared to normal crude feed slate. Therefore, any crude that is shipped or transferred via pipeline must meet strict regulations in regard to crude quality and this is also critical in determining optimum refining formulations and processes to ensure the quality of various petroleum outputs, which, in turn, determine the price of the oil products.*

## Customer Pain

Since this refinery has limited crude tank storage available, the purchased crude is transferred from the supplier's storage tank directly into the desalting unit by pipeline (via two buffer tanks), which is the key challenge for this refinery. This setup has been problematic for decades. In the past there was no meter check at the site, which meant they could only rely on the supplier's metering data on the quantity and quality of the crude being transferred. There were times when this process cast doubt on what and how much was transferred. The national trade regulation allows for a +/- 0.5% water content (averaged over a set period of time) which has always been a disadvantage for refineries as buyers, both in terms of commercial trade and for crude quality control for the subsequent refining process. In other 2 refineries across China – as well as Asia as a whole – they have been doing both manual sampling and auto-sampling on water content analysis. Not only is this not a continuous or real-time method of sampling, but the limitations of the sampling circuit pose other problems, such as, representative sample taken, intermittent sampling, sampling tube clogging, human influence factors, etc. As crude switching and crude variability increases, the refinery has to deal with a wide range of frequently changing crude composition and water content which are fundamental and critical parameters to monitor. For example, a difference of 0.1% of water content could cost 8 million dollars a year (based on USD 75/barrel).

When the refinery tried other in-line measurement technologies such as capacitive, infrared and microwave absorption, the results were not satisfactory in meeting their high accuracy and reliability performance requirements because of significant errors, unstable readings and unreliable measurements due to compensation issues.

Additionally, processing issues with the crude unit (such as fouling and corrosion) can frequently be traced back to poor efficiency of the contaminant removal in the desalter, which is why the desalter often becomes the primary focus when solving the problem. Basically, desalting is a water-washing operation where the salt and water content are reduced to limit their negative effect (scale formation, corrosion and catalyst deactivation) in the downstream process. But, since emulsions can be formed during this process, there is a risk of water carryover into the organic phase. To overcome this problem chemical de-emulsifiers are added to break up the emulsion, this reduces the water and salt content. Desalter performance is typically measured by the efficiency of salt removal, oil dehydration and chloride control. However, a recent influx of opportunity crudes has introduced great variability in the quality of crude, where the quality of that crude can impact the stability of emulsions in the desalter, as well as corrosion control in the overhead system. Other configuration problems can arise, such as, accelerated preheat train, furnace fouling, degraded desalter temperatures, plugging of cold train exchangers and more difficult phase separation downstream.

In the past, they have had limited visibility into the quantity and quality of the crudes they purchased which has caused process problems that threaten the reliability, efficiency and mechanical integrity of their equipment. Therefore, it is important to have clear insight into the quality of the different crudes, especially as it impacts the amount of chemical de-emulsifiers that will be used as that directly affects the optimum formulation to ensure complete emulsion breaking in the desalting process. Based on experiences with opportunity crude, they were able to determine a correlation between API gravity in the crude and the tendency to form strong emulsions in the desalter. From this observation they were able use the API gravity measurement to improve the desalter process efficiency. It is important to note that in order to optimize operating costs, a reduction in demulsifier concentration in crude oil desalting will generate savings of many thousands of dollars. Additionally, excessive demulsifier can cause issues in the downstream process, such as catalyst deactivation. This is why measuring, monitoring and analysis of water content, API gravity and density of crude oil are some of the fundamental and important parameters for the refinery to note when improving their optimum formulation via various programs (e.g. crude pre-treatment, chemical treatments, mechanical solution, engineering practices, etc.).

## Emerson Solution

“Are you sure you (Emerson™) can solve this and meet our requirements?” This was the next question from the Plant Manager. The solution shown in the below picture is what has been running at the site since last year. Standing in front of the 9 x 10 x 6 meter stainless steel skid, it appears to be an ordinary metering system mainly with pipes, junction boxes and skid framework support (refer to [Figure 1](#)).



**Figure 1.** Mass and Watercut Metering System installed at refinery site in Tianjin.

However, the capability and performance of this system is far beyond what other systems have achieved. Since commissioning, programming and fine-tuning this best-in-class performance solution, the refinery completely relies on this system to measure, monitor and analyze the crude variability to overcome the challenges described above.



on this system to measure, monitor and analyze the crude variability to overcome the challenges described above. This metering system utilizes two top-notch technologies that are the key drivers in delivering the superior performance of the system, namely the Roxar™ Watercut Meter and the Micro Motion™ Coriolis Meter. The setup of this metering solution includes:

- One 20 inches Full bore and In-Line Roxar Watercut Meter unit for high accuracy and sensitivity of water in oil measurement
- Three 10 inches MicroMotion Coriolis Flowmeter (CMFHC3) units for high accuracy of direct mass flow, density and temperature measurement
- One 10 inches MicroMotion Coriolis Flowmeter (CMFHC3) unit for high accuracy proving
- Other: Valves, Flow Computer, Sampling System Some photos of the setup are shown below (refer to [Figure 2](#)).

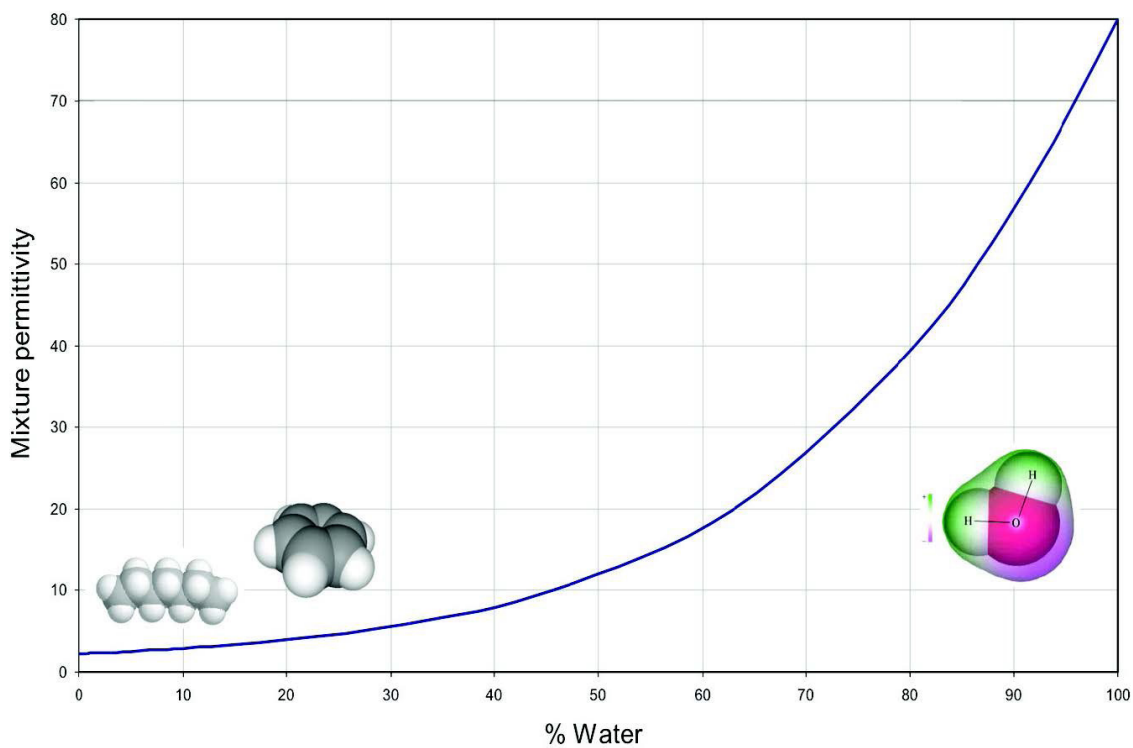


**Figure 2.** Main component and setup of the Mass and Watercut Metering skid.

## Roxar Watercut Technology

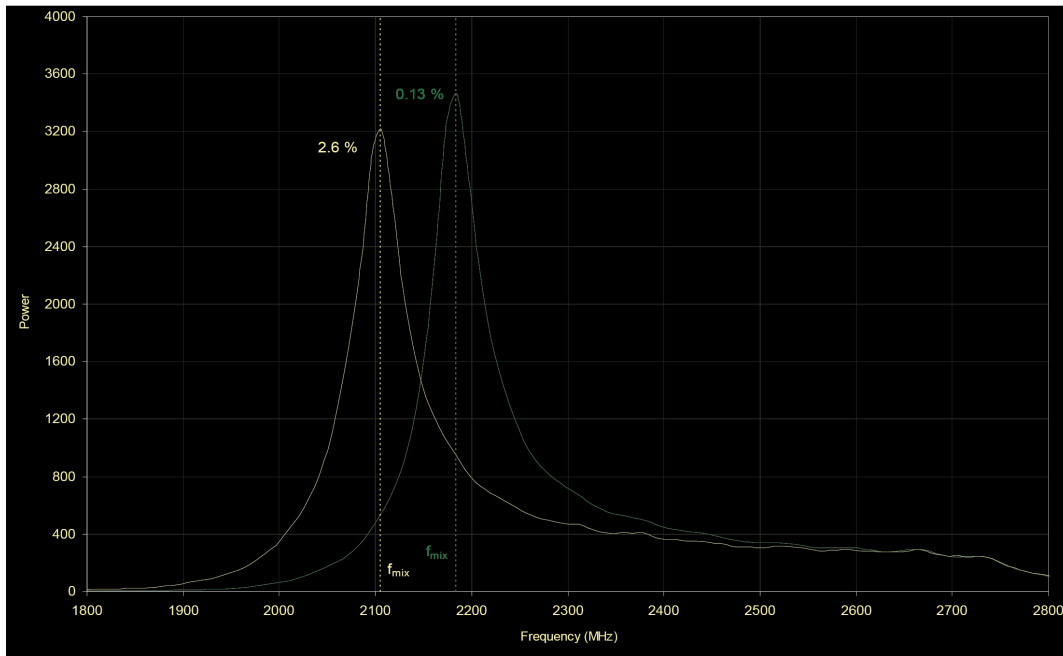
Since measuring, monitoring and analyzing crude and water content to desalter is the key concern here, it is important to acknowledge that microwave resonance technology is one of the key technology differentiators for this success. The unique and patented technology from Roxar in the watercut meter is capable of measuring the permittivity of an oil/water mixture with an extremely high level of accuracy and sensitivity.

The permittivity of water is typically 70+, depending on salinity, while the permittivity of condensates/oil may range from approximately 1.8 to 2.4, depending on the density of the hydrocarbon. The percentage of water is calculated by relating the permittivity of the mixture to the permittivities of dry oil and water, respectively, thereby ensuring accurate measurements across all watercut ranges (refer to [Figure 3](#)).



**Figure 3.** Roxar Watercut Meter percentage calculation by mixture permittivity.

Basically, the measurement principle for this technology is where the meter scans the entire frequency range and locates the microwave resonance frequency ( $f_{mix}$ ) (refer to [Figure 4](#))



**Figure 4.** Roxar Watercut Meter scan and locate microwave resonance frequency.

From there the permittivity of the mixture ( $\epsilon_{mix}$ ) is calculated as per the equation below. Vacuum frequency is a unique value to each meter calibrated in the factory.

$$\epsilon_{mix} = \left( \frac{f_{vac}}{f_{measured}} \right)^2$$

Upon knowing the permittivity of the mixture ( $\epsilon_{mix}$ ), the watercut is calculated using the Bruggemann equation ( $\beta$ ) as shown below.

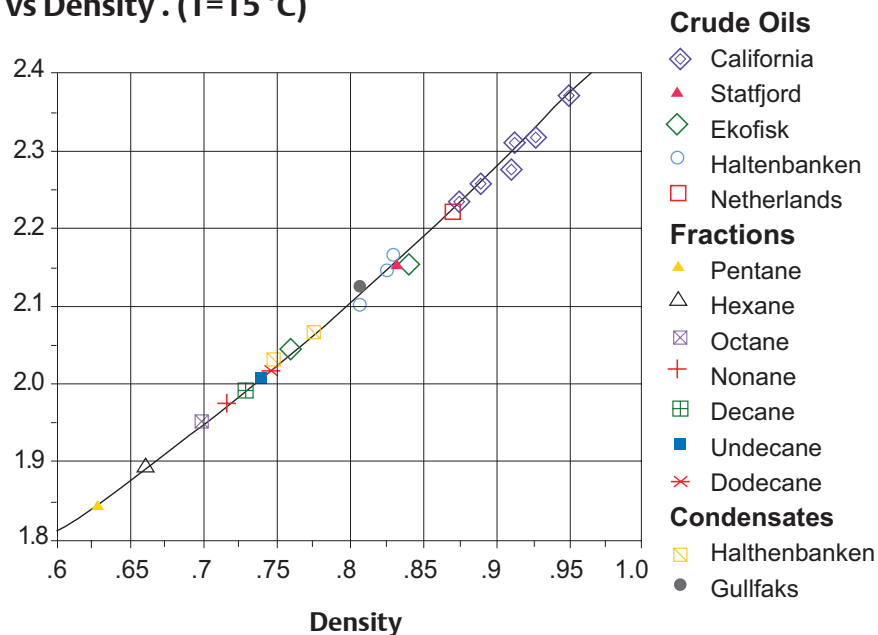
$$\beta = 1 - \frac{\epsilon_{mix} - \epsilon_{water}}{\epsilon_{oil} - \epsilon_{water}} \cdot \sqrt[3]{\frac{\epsilon_{oil}}{\epsilon_{mix}}}$$

With the microwave resonance technology, Roxar Watercut Meters are able to achieve the highest accuracy in the market at  $\pm 0.05\%$  (absolute for 0-1% water) for low cut and high cut measurement, and with a sensitivity of 0.005% (equates to 50ppm) which can detect small changes which is required for very low-cut measurement.

Another important capability of the meter is automatic density correction to ensure the measurement accuracy and consistency as the crude quality changes/shifts. Typically, such shifts occur on a continuous basis where it will affect the meter zero and such zero shift is in the range of 0.027% water absolute per  $1 \text{ kg/m}^3$  change in density (approximately 0.03% water if the oil's density changes from 980 to 981  $\text{kg/m}^3$ ). That means if the density increases, the percentage of water measurement will increase, and vice versa.

There is a very exciting feature of the high frequency based Roxar technology and that is the patented relationship between the dielectric constant of oil and its density. Roxar has collected hydrocarbon samples from a variety of operators and fields worldwide and found the relationship between a dielectric constant and density (refer to [Figure 5](#)). We use the input in an iteration loop (calculations) in order to compensate for variation of dry oil density at variable temperatures.

#### Dielectric Constant vs Density . (T=15 °C)

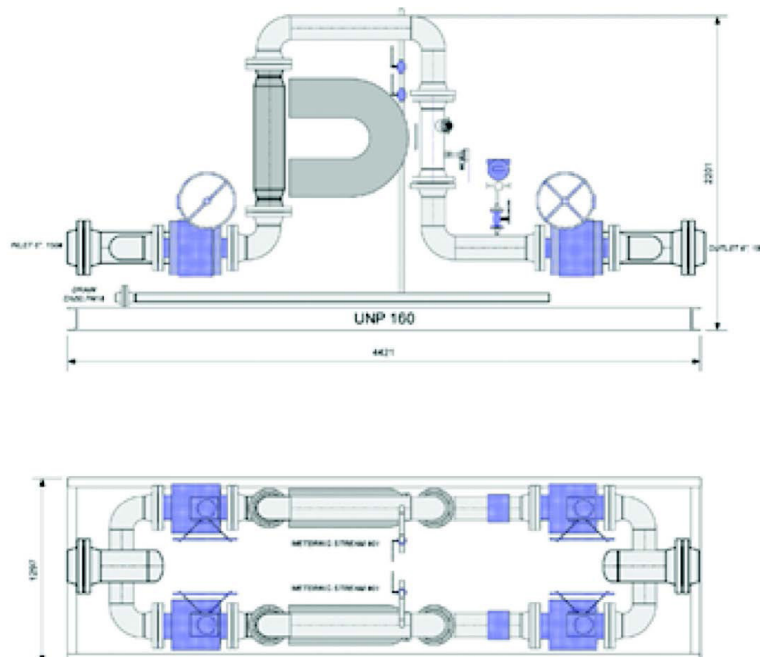


**Figure 5.** Roxar Watercut Meter patented AutoZero enables automatic compensation for changes in fluid density.



## Micro Motion Coriolis Technology

The Micro Motion Coriolis Meters were installed (immediately upstream from the watercut meter) to measure the real-time crude density and input to the watercut meter automatically to perform AutoZero. By feeding a continuous live density signal to the meter (density of oil and water mixture at line pressure and temperature), the meter can automatically compensate for any changes in the dielectric constant for the oil, as a function of the measured mixture's density. Alternatively, a densitometer can be used to perform AutoZero, however they used this opportunity to fully optimize the performance of this metering system by measuring mass (direct), gross volume, corrected net volume, and API gravity at the same time. This kind of comprehensive measurement is required to support other key applications within their operation such as in-line quality monitoring, crude blending and oil loss accounting. Typical installation schematics of the combined Roxar Watercut Meter and Micro Motion Coriolis Meter solution are shown in the drawing below (refer to [Figure 6](#)).

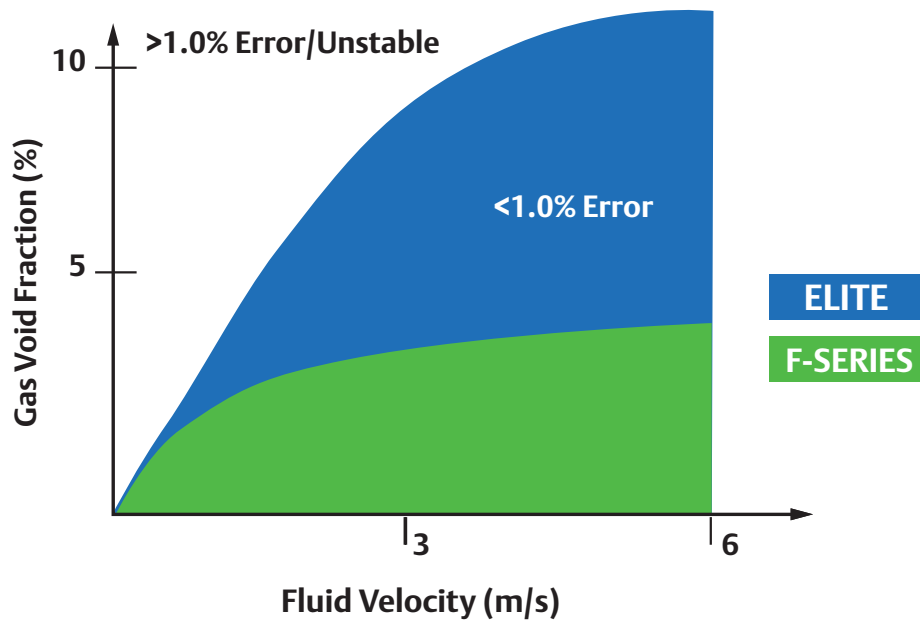


**Figure 6.** Roxar Watercut Meter and Micro Motion Coriolis Metering System installation schematics.

The Micro Motion Coriolis Meter offers considerable return-on-investment with excellent accuracy and reliability, yet very low maintenance costs, even in applications where entrained air (and sometimes other gas) is common. It is not surprising that measurement of such unpredictable flow streams is challenging for other flow technologies and even for some other Coriolis meters in the market.

Micro Motion Coriolis Meters have a strong proven performance record primarily because of the dual-tube sensors with low tube frequency - If a sensor with a high tube frequency is used, the two-phase mixture does not vibrate directly with the flow tube, resulting in large measurement errors – and unmatched MVD technology which employs the latest Digital Signal Processing (DSP) for the fastest response speed. When entrained gas is present, the Coriolis meter filters and removes the noise imposed by the two-phase flow and reports only the “the real flow measurement of the liquid”, thereby providing continuous and accurate measurement data. Micro Motion Coriolis Meters can deliver less than 1% uncertainty contribution for Gas Void Fraction (GVF) below 5% and results will improve as fluid velocities increase (refer to [Figure 7](#)).

### High Viscosity Fluid



**Figure 7.** Uncertainty error contribution by GVF %

\*Results are shown from lab tests with low viscosity fluids (water with air). Higher viscosity fluids tested may perform better, and field application performance varies based on conditions.

## Solution Unique Advantages

There are a considerable number of unique advantages when implementing Emerson’s solutions that utilize best-in-class technology, such as the example we talk about in this white paper, of the Roxar Watercut Meter and the Mirco Motion Coriolis Meter. The table below summarizes the advantages of both technologies working tandem.

Roxar Watercut Meter	Micro Motion Coriolis Meter
Continuous real time measurement of watercut	Continuous direct measurement of Mass, Density and Temperature *Calculated Volume (gross and corrected) and API gravity
Unmatched sensitivity and long-term stability	Unmatched high accuracy and turndown ratio
Full bore measurements in main pipe or by-pass	Bi-Directional and independent of flow properties and profile (no straight runs needed)
No moving or exposed parts	No moving or wearing parts
Patented AutoZero function for automatic oil density correction	Patented MVD technology for entrained gas (2-phase flow) performance
Automatic compensation for process temperature	Direct measurement to support automatic compensation of Watercut meter
User-friendly, menu-based configuration software	Smart Meter Verification (SMV) for self-diagnostic, validation and verification

With the combination of two best-in class solutions, the capability and performance of this system meets the refinery’s requirements to solve their challenges as described earlier. In addition to measuring and monitoring mass, gross volume, corrected net volume, and API gravity, these meters continuously monitor the in-line watercut percentage, temperature, observed density and standard density for further analysis of the crude feed for the desalting process.

## Conclusion

As this refinery in Tianjin has to deal with frequent changes in the crude composition as well as inconsistent water content in the crude, the key concern and challenge for them is to ensure they don’t lose millions of dollars in crude because of inadequate measurement. They needed to achieve the operational objective of crude quality monitoring – water content, API gravity and density – as well as solve their processing issues in the crude unit. By being able to move away from the manual sampling and auto-sampling method of water verification analysis, the efficiency of the desalter process has increased significantly even under the considerable variability in the crude water content.

With the solutions Emerson provided, the refinery now has full visibility on the quality of incoming crudes, which improves reliability for their processes as well as reliability and integrity of their mechanical equipment. They are now able to achieve better formulation optimization of their various systems dealing with crude pretreatment and chemical treatments, which can deliver significant savings on operational costs (e.g. optimization of demulsifier concentration). The refinery has realized an indirect return on investment in other areas of the plant – not just in increased output yield – through a reduction in energy usage and costs, and a decrease in wear and corrosion of the equipment throughout the process.

“Being the first in Asia-Pacific to have this solution implemented successfully, we have a high confidence and trust in the technology, expertise and experience that Emerson has in helping refineries to solve their problems.”

– The Customer

For additional information, visit:  
[www.Emerson.com/Roxar](http://www.Emerson.com/Roxar)

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00870-0100-2602 Rev BA, March 2022