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White Paper

# Multi-phase measurement in the upstream oil & gas industry

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What's Inside:

# Multi-phase measurement in the upstream oil & gas industry

## 1. Introduction

This white paper describes a new approach to allocation and reservoir optimization to help drive more value in upstream oil & gas production operations. New multi-phase Net Oil and Wet Gas measurement solutions can provide more accurate and reliable allocation measurements in real time while reducing capital and operational expenditures in field automation. The basis for these solutions is innovative measurement and modeling technology that can address a wide range of metering challenges.

## 2. Key Challenges

Currently, most fields have a gas-liquid separator on the output of each well to separate the gas from the oil and water in order to measure the flow rate of each component. However, a gas-liquid separator is a very expensive piece of hardware. Additional investments are also necessary, such as tankage to store the liquids that are separated, and equipment to enable water re-injection at the site. An operator may also have to pay for a second pipeline for the gathering facility or for trucks to take the condensate off-site, which again requires a lot of hardware, space and land.

Furthermore, the information from these measurements is at best, reported daily. However, a specific requirement for effective reservoir management is real-time data. Oil & gas companies have billions of dollars tied up in their reservoirs, yet in practice the information they receive on the composition and status of their reservoirs is often one month old and in the worst scenario up to six months old. Making decisions on outdated information is never going to be the most efficient. Therefore, real-time information on reservoir production could provide a significant competitive advantage. Even a 1% improvement in return on capital employed (ROCE) amounts to many millions of dollars.

## 3. Solution

A unique solution based on Coriolis flowmeter technology is now available. This solution allows the measurement of gas, oil and water directly from the wellhead without first having to separate them. This allows the whole stream – liquid and vapor – to be taken right off the well and the oil, gas and water measured to custody transfer standards. This significantly reduces the capital costs of new wells – and can be applied to existing wells.

This new measurement technology allows production to be measured directly from the wellhead, producing variable oil, water and gas streams (other components might also be present), including a range of flow regimes from wet gas to gassy liquid. It eliminates the capital costs of the separator to measure oil & gas production as well as the tanks, valves, level sensors and flowmeters – all of which can be a maintenance nightmare. It is no longer necessary to separate the flow regime in order to provide accurate measurements of oil, gas and water.

## 4. Key Applications

**Net Oil**

By using multi-phase metering in the Net Oil application, measurements are possible in real time and the need for a separator is removed. The Net Oil solution involves a Coriolis flowmeter with an oil and water probe. There is also an RTU with HMI to integrate the net oil computer (NOC) application. The mult-phase meter is skid mounted and easily installed on site. Once connected, it is up and running very quickly.

**Traditional test separator requiring large capital investment**

**A low-cost Net Oil solution**

**Wet Gas**

Typically, a gas field first produces gas before it starts producing liquids. When a phase transition to liquid production occurs, it may be necessary to install additional liquid handling equipment. The problem with wet gas applications is that the production stream is mostly gas with slugs of liquid water and condensate, making it difficult to measure. Multi-phase Coriolis measurement enables such measurements to be made real time in situ at the well head.

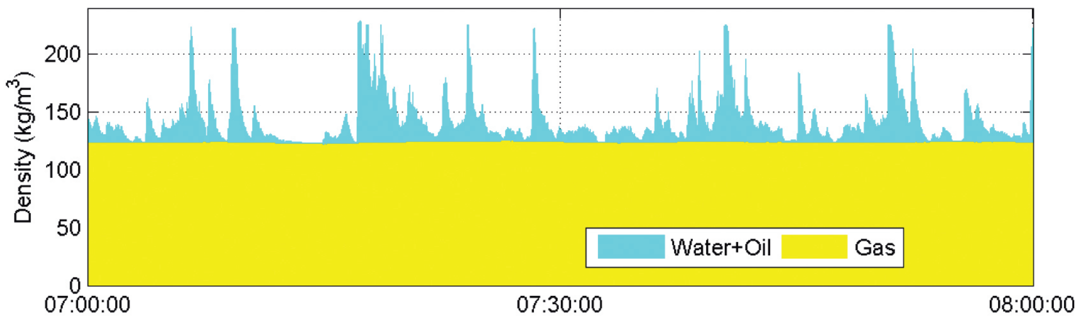
Most reservoir models are based on long-term steady-state situations. Oil wells are typically reported on via well tests once a month, whereas gas wells typically report daily averages. Now with real-time measurements, producers can better understand well production and optimize field operations.

Users of this technology are often surprised at how the water content can change minute by minute. Based upon periodic separator measurements, they had assumed the average gas-to-liquid ratio was steady, whereas now they see that the water and oil content can vary greatly. The real-time reporting of these measurements provides better insight as to what is going on in the reservoir. Oil and Gas companies can use this insight to realize increased profits from their operations.

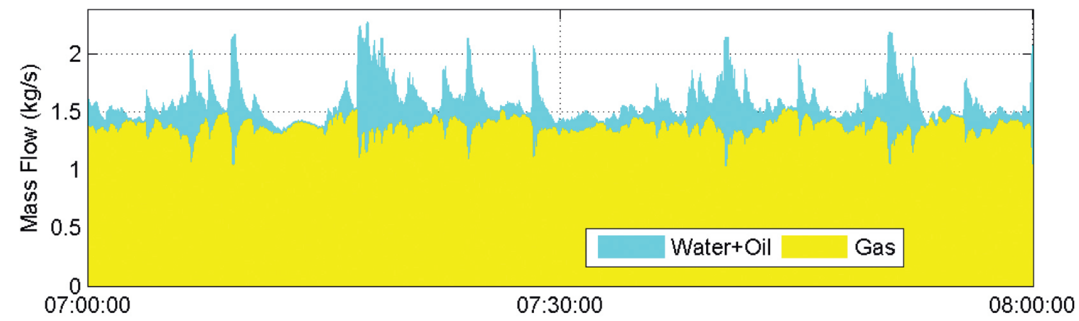
### Multi-phase Coriolis Wet Gas Metering Results

The following is a graphical representation of actual Multi-phase Coriolis measurements of the gas, oil and water components in a three-phase flow stream monitored real-time over a one-hour period at a 1 second update rate.

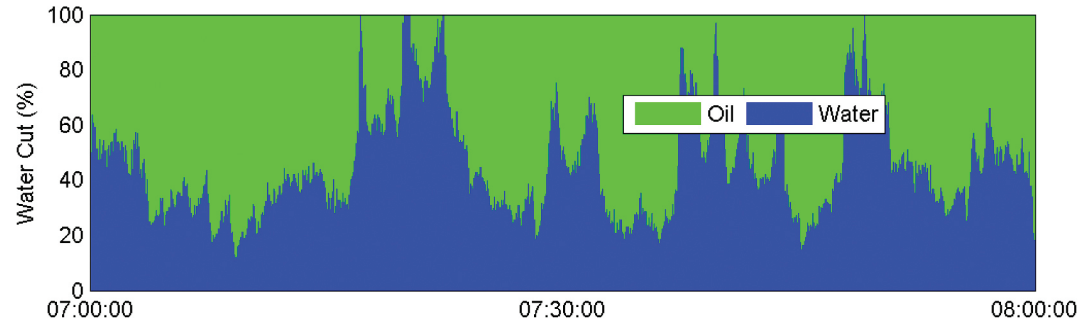
**Graph 1**
Shows three-phase mixture density partitioned into the measured gas component and the residual liquid density of the water & oil component.



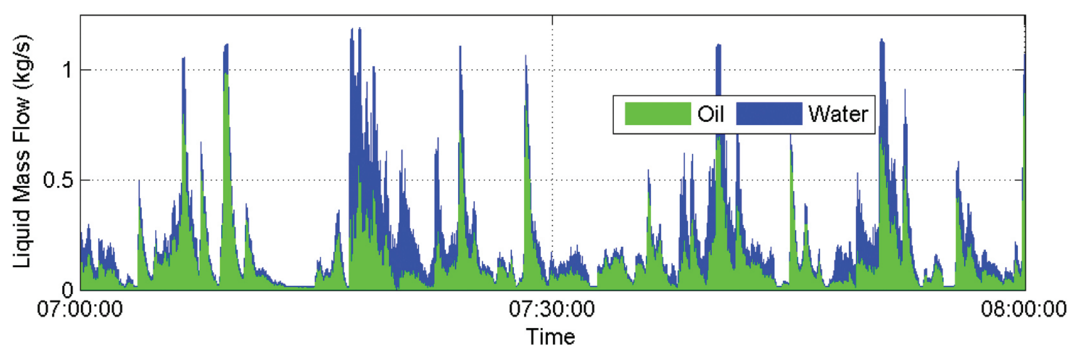

**Graph 2**
Shows three-phase mass flow rate partitioned into the measured gas component and water & oil liquid component.




**Graph 3**
Shows the measured liquid component proportions of % water and % oil.




**Graph 4**
Shows the measured liquid mass flow rate and individual flow rate of the oil and water components. component.



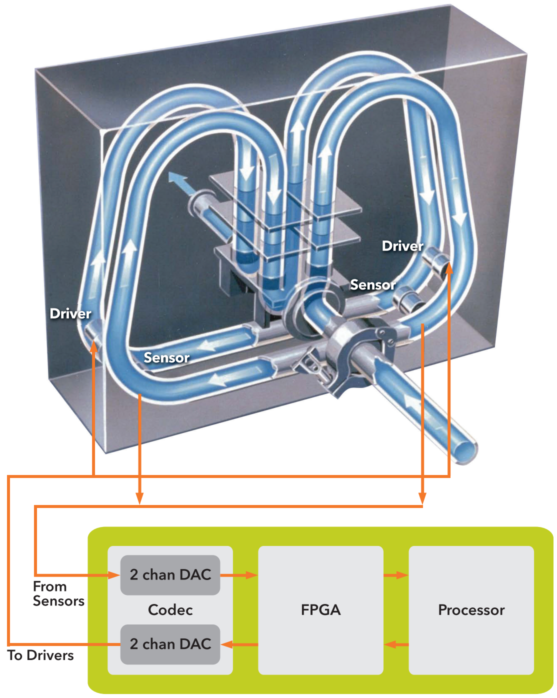
## 5. Coriolis Technology in Detail

Coriolis force arises from a mass moving within a rotating frame of reference. That rotation produces an angular, outward acceleration, together with linear velocity, to define the Coriolis force. With a fluid mass, the Coriolis force is proportional to the mass flow rate of that fluid.

To use Coriolis force for measurement, a Coriolis meter has two main components: an oscillating flowtube equipped with sensors and drivers, and an electronic transmitter that controls the oscillations, analyzes the results, and transmits the information.

Reliable Coriolis measurement depends on consistent, reliable oscillation, which is determined by four factors: the density of the liquid, the balance of the tubes, the dampening caused by the flow stream itself, and the physical isolation of the tubes from the environment.

Compromising even one of these factors will degrade Coriolis meter performance. Yet a mixture of gas and liquid flow compromises every one of them. Thus, applications involving negligible amounts of entrained gas – even as little as 2% volume – have been poor candidates for Coriolis measurement. This has been particularly troubling in applications where reliable, highly accurate flow measurement can offer considerable bottom-line advantage, but where two-phase flow is an integral part of the process or it is necessary to begin with an empty or partially filled flowtube.




**Coriolis Flowmeter Diagram**

Invensys collaborated with researchers at Oxford University in the UK to develop digital technology for accurate measurement of flow, even when the flowtube contains entrained air. The resulting patented product incorporates new signal processing techniques to provide useful measurements of both mass flow and density and the operational aspects of keeping the Coriolis meter running stably in single-phase or two-phase flow conditions.

Invensys has over 20 patents related to multi-phase solutions. One of the patents involves an advanced control and measurement system with high-speed digital signal processing that responds to changing flow conditions many times faster than standard Coriolis flowmeters. Another patent relates to detecting and compensating for two-phase flow conditions and generating a validated mass flow measurement.

## 6. Additional Applications of Coriolis Technology

**Unloading Railcars and Trucks**

With the ability to handle two-phase flow and batching from empty conditions, advanced Coriolis flowmeters have greatly expanded fluid metering applications, including traditionally difficult situations such as custody transfer, proving, tank truck, and tanker loading and unloading.

Accurate measurement at custody transfer points is critical as competitive market conditions drive companies to develop operations that are more efficient. By minimizing wasted materials left on the bottom of transport vessels and improving transfer yields, advanced Coriolis flowmeters provide more accurate material accountability, which is a direct contribution to bottom-line performance. This is a win-win situation for both parties involved in the transaction. Advanced Coriolis technology is increasingly replacing positive displacement meters for custody transfer to attain the benefits of Coriolis accuracy, while reducing total cost of ownership. With no moving parts in the fluid stream, Coriolis meters require little to no maintenance and are easy to install.

In pipeline flow measurement-proving applications, the frequency and duration of calibration can hinder productivity. Advanced digital Coriolis flowmeters offer a solution by providing a much faster response time, and greater accuracy and repeatable proving with small volume provers. A proving run may take as little as 20 seconds. This is particularly beneficial in multi-product pipeline applications where fluids varying from light liquefied petroleum gases to heavy crude oils pass through a common flowmeter. For these applications, flowmeter proving often takes place several times a day, so slashing each proving process to seconds can significantly boost productivity.

Another issue is unloading railcars and tank trucks until they are practically dry. Emptying the tank completely invariably introduces air as the level approaches bottom. Exacerbating this is that in most cases, unloading happens at as high a flow rate as possible to speed up the process. This high flow rate tends to suck air into the flowmeter. Where a conventional Coriolis meter would shut down in this situation, advanced Coriolis meters continue to provide a useful flow measurement, enabling faster, more complete unloading of tank trucks and railcars.

**Truck Unloading: Multi-phase flowmeter accurately measures barrels of net oil regardless of trapped air content without need of an air eliminator**

## 7. Case Study

A highly successful application of two-phase Coriolis technology is in carbon dioxide injection. This is a particularly difficult application as it involves two phases. In many regions of the world, large temperature fluctuations occur over a 24-hour period, from the heat of the day to the cold of the night. As the temperature fluctuates, the carbon dioxide changes phase from liquid to gas and back to liquid. With a two-phase Coriolis meter, carbon dioxide can be measured continuously without issue. Coriolis meter is able to measure $CO_2$ supplied at lower pressures and higher temperatures, enabling the use of above-ground lower pressure rated piping and thus reducing capital costs significantly.

**$CO_2$ is injected for secondary recovery of light oil and reservoir pressure management**

Using carbon dioxide for enhanced oil recovery (EOR) can increase hydrocarbon production by as much as 12%. However, accurate measurement of $CO_2$ injected into the reservoir has been the weakness of the process. A large midstream energy company found the solution by applying advanced Coriolis metering technology as part of a three-stage EOR program. The first stage was primary oil recovery, based on natural gas driving the oil to wellheads. Secondary efforts involved water flood driven production using natural aquifers. As primary and secondary production methods declined in effectiveness, tertiary oil recovery techniques gained attention. A number of EOR options received scrutiny, and $CO_2$ injection into the oil reservoirs was considered to be the most effective method for extracting and moving oil to the well bore. While the yields from this EOR project were significant from the start, engineers felt they could do even better if they could more accurately measure the $CO_2$ flows in each well.

The problem is when $CO_2$ is above the critical point, it exists as a supercritical fluid and is easily measurable with standard devices such as orifice plates. However, below the critical point, it can coexist in two phases, liquid and gas.

The company transfers $CO_2$ in pipelines to multiple injection wells throughout the field, and daily changes in ambient temperature significantly effect the pressurized $CO_2$. On a cool morning, they could have primarily liquid $CO_2$ in the pressurized distribution pipelines. However, in the afternoon, with elevated ambient temperatures, they could have primarily gas.

Possible options considered were orifice plates with multivariable DP transmitters, Vortex meters, and conventional Coriolis flowmeters. None of these options met the company's performance standard, so they explored new avenues of flow measurement technology.

The company tested an advanced digital Coriolis flowmeter to successfully measure two-phase $CO_2$ and based on the results installed the flowmeters at each of the injection wells.

The advanced Coriolis flowmeters reduced the uncertainty of the $CO_2$ measurement by a factor of 3. This provided the immediate benefits of increasing oil output, as well as the long-term advantages of accurate flow measurement data to correlate optimum production efficiency with the volume of $CO_2$ injected, which is critical for developing oil reservoir strategies.

## 8. Benefits

Multi-phase measurement solutions enable real-time measurements, which allow real-time control of the production process. Production optimization applications rely on real time inputs to ensure that contractual obligations are met. In addition, increased production adds incremental contracts from the same assets. Greater return on production assets is critical due to the high capital employed in leasing, exploring, and producing from upstream oil & gas assets.

Multi-phase measurement combined with well field SCADA and optimization solutions provide enormous benefits. Providing real-time measurements allows maximum return from optimization. Production deviations as well as production opportunities are discovered and acted upon to provide maximum value from field operations. Well Field SCADA systems increase completions by dramatically reducing the implementation time for new wells.

## 9. Summary

Multi-phase measurement solutions enable accurate, reliable and real-time allocation measurements using less equipment and reducing capital investments. These solutions are safer and cleaner, thus protecting people as well as the surrounding environment. Real-time measurements enable production and asset optimization.

Invensys has developed an innovative multi-phase measurement solution based on patented Coriolis technology. It is part of a broad range of capabilities that Invensys offers to optimize the profitability of upstream oil & gas operations.