White Paper

IMPROVE ACCURACY AND REDUCE YOUR LEASE OPERATING EXPENSE AND RISK IN UPSTREAM OIL & GAS PRODUCTION

EMERSON
Process Management

Executive Summary

The ability to measure every drop of oil and gas extracted from well sites and improving control of the processes applied to raise, separate, recover and store the resource is more important than ever. Capital and operational expenditure (capex and opex) for upstream operations are on the rise and increasingly stringent regulations, as well as elevated demand to increase revenue, are compelling oil and gas companies to seek new technologies that overcome these issues.

Advanced technologies, such as Coriolis mass flow metering, can help reduce uncertainty in allocation measurement, cut risk in capital investment and daily operations, minimize downtime and reduce lease operating expense. Furthermore, highly accurate measurements at the point of transfer are essential in determining proper royalty payments and establishing defensible records that will satisfy standards and legal review, particularly in lawsuits.

In this whitepaper, we will address both the technical approach to achieving the highest possible accuracy in allocation measurement, during custody transfer, and in process control; as well as the business advantages that can be achieved by incorporating Emerson's Micro Motion flow and density measurement devices into upstream oil and gas production.

Specifically, discussion will include:

- **Accuracy** – Comparison of Coriolis meters with positive displacement (PD) and turbine meters and the impact on allocation measurement, production management and custody transfer
- **Reducing lease operating expense** – How improved operational efficiencies, reduced risk, increased uptime, decreased maintenance, and improved HSE combine to lower total cost of ownership and drive increased profitability
- **Risk** – Improved HSE performance for workers as well as decreased risk to capital investment; the importance of defensible data during litigation

Introduction

There's a renaissance under way in the oil and gas industry in the United States. The Energy Information Administration (EIA) recently stated, "U.S. crude oil production will surge faster than expected to a near historic high by 2016 which sharply raised its annual output forecasts…due to the breakneck speed of shale oil development."[1]

New drilling technologies have enabled previously uneconomic plays to be reopened, reviving extraction of crude. Hydraulic fracturing and horizontal drilling have also created a huge surge in natural gas production as well. Crude output has risen more than 60% over the past five years[2] and the emerging Niobrara Shale play produced 238.4 million cubic feet of natural gas in 2011.[3]

> The EIA's forecasts show that shale will help increase oil output by the world's largest consumer by 800,000 barrels per day (bpd) every year until 2016, when it will total 9.5 million bpd, just below a 1970 record of 9.6 million bpd. That is some 2 million bpd higher than its forecast in last year's Annual Energy Outlook.
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> The EIA raised its forecast on natural gas production to 31.9 trillion cubic feet (tcf) by 2025 from the 28.7 tcf it had forecast last year, and to 37.6 tcf by 2040 against the 33.2 tcf touted earlier.[1]

While unlocking established and newly discovered reserves promises production increases that can help meet the ever-increasing demand for energy around the globe, the costs of upstream operations is also increasing. Technologies to raise, separate, recover and store the resources more effectively can help address this challenge. But taking full advantage of the opportunity that technologies offer requires balancing the expense against the return. A thoughtful report on the economics and fiscal competitiveness of North American tight oil reserves can be found in the May 6, 2013 issue of Oil & Gas Journal. In his report, Barry Rodgers of Rodgers Oil & Gas Consulting compares a number of Canadian and U.S. oil plays. Among other observations, Rodgers states that:

- Fiscal terms can make a significant difference in economic attractiveness
- The lower end of the reported EUR (expected ultimate return) range often shows marginal to sub-economic results for many of the plays (at current O&G prices)

With these considerations in mind, it's clear that maximizing return on investment depends on accurate and repeatable measurement of every drop of produced oil and gas, especially in custody transfer applications. Oil and gas companies rely on accurate meters at the point of transfer to ensure they paid for what's produced and to address industry regulations and tax codes. Tank measurement is still one method used in the field, along with positive displacement (PD) meters and turbines. Coriolis meters, characterized by their high accuracy and dependability, surpass these legacy techniques.

Traceability is part of the regulatory pressure. Industry observers have pointed out that, "As in other sectors, traceability will be a key feature of the rising tide of transparency and accountability, as businesses, customers and consumers become more discerning in their choice of fuel."[4]

"Easy oil" is a thing of the past. New upstream production techniques are being developed, making extraction, measurement, data collection and operations more efficient than ever. But the cost of implementing them is higher – all the more reason why custody transfer accuracy is paramount. Micro Motion Coriolis meters provide the accuracy, dependability, traceability and application flexibility to be the critical component in a range of flow and density measurement solutions.

The constant pressure to improve measurement accuracy is rendering legacy techniques obsolete. In addition to accuracy in fiscal transfer, environment, health and safety concerns are compelling changes to how flow is measured at the wellpad. Consequently, legacy techniques such as tank measurement and positive displacement (PD) or turbine metering are being phased out.

Give-away and slippage in PD meters and turbine measurement systems cause gain/loss errors. This can be a costly problem, especially as meters age and experience wear of bearings and seals or erosion. Figure 1 shows the meter factor of a PD meter in comparison to a Coriolis meter over the course of 14 proving events. One can see that the PD meter is significantly less accurate and wears to the degree that it needs to be replaced relatively early in the product lifecycle. Presence of sand or sediment in crude can greatly decrease expected PD life as the particulates scour the surfaces, allowing fluid to slip through the meter. Additionally, condensates and very light crudes are non-lubricating, causing accelerated wear. Sudden changes in flow rate, viscosity, temperature or phase can result in wear and tear on bearings and seals, destroying meter accuracy again allowing fluid to slip through the meter unaccounted.

Truck loading/unloading applications can be particularly difficult for a PD meter as a variety of crudes and presence of sediment cause accelerated damage and prompt the need to rebuild or replace at frequencies of less than six months.

The meter factor of a PD or turbine can be influenced by fluid conditions. Due to this impact, PD and turbine meters should be calibrated and proved at conditions as close to the normal operating conditions as possible. When crudes are changing often (i.e. blending or truck loading/unloading), it can be tremendously challenging to keep a PD in calibration for every condition and errors may be inherent if the meter is not re-proved with each change of fluid. PD and turbine meters are usually calibrated using water and are therefore inherently less accurate when measuring oil and gas, where process conditions and the fluid being measured can vary greatly over the life of the field. Coriolis meter measurement does not drift or change for changing fluid viscosity, rate or flow, so meter factors remain accurate over a broad range of fluid operating conditions.

In addition to higher accuracy and streamlined compliance, these advantages add up to decreased downtime, one of the most important factors in minimizing lease operating expense and maximizing technology solution value.

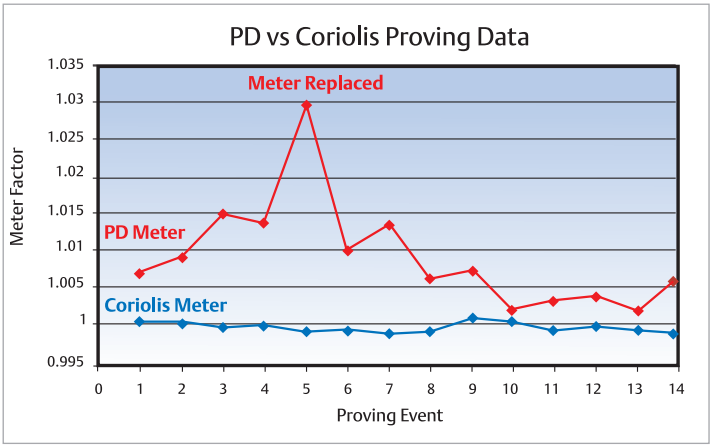

Figure 1 - Coriolis meters demonstrate consistent accuracy throughout their lifetime, far surpassing the meter factor variations often found in PD meters, for example.

Business Challenges

One reason custody transfer is also referred to as "fiscal metering" is because the meter is acting as a cash register. Even a small percentage of error can lead to a significant error in compensation. For example, a very large custody transfer system can meter $6,000,000 worth of natural gas per day, equivalent to $2.2 billion/year. If the measurement is off by 0.25%, the error is $15,000/day, which compounds into $5.5 million/year.[5] Tax implications exacerbate the potential damage.

Lawsuits & Protecting Against Risk

There is a long history of lawsuits alleging inaccurate royalty payments. In 2000, a prominent major American oil company and their affiliates agreed to pay the United States $32.2 million to resolve claims that they violated the False Claims Act by knowingly underpaying royalties owed on natural gas produced from federal and American Indian leases.[6] In 2013, an American independent gas production company, agreed to pay $7.5 million to settle a class action lawsuit alleging the company underpaid gas royalties to leaseholders.[7] In that suit, plaintiffs argued that the company inappropriately deducted operational costs in addition to miscalculating production volumes.

When courts rule in favor of plaintiffs, they can estimate damages for payments as much as three years in arrears. As expected, not all suits are decided against the oil companies. But even in victory, the legal costs associated with the process and damage to the brand can make for an expensive, resource draining headache for the energy company.

Regulatory Pressure and Shifting Energy Policies

A meter's accuracy and the data it produces are critical to addressing state, federal and global custody transfer standards. Custody transfer meters be able to satisfy contractual agreements between the parties involved in custody transfer. Those agreements usually reference AGA, API and ISO standards to ensure fairness. Of course, guidelines such as ISO 3171, the automatic pipeline sampling standard, is of high relevance to this whitepaper, as are national standards set by OIML (International), NIST (U.S.), the BLM and others, depending on the location of the well.

Penalties for not meeting these requirements can seriously undermine the profitability of any play and damage the reputation of the company, and possibly expose the operator to substantial legal action, as just discussed.

Another challenge is that shifting energy policies influence business decisions. According to a report by Deloitte Center for Energy Solutions, "Uncertainty regarding energy policy and potential legislation and regulations has many projects in the United States, as well as Canada, in a state of limbo. These areas of uncertainty, which include potential policy decisions involving LNG exports, cross-border pipeline projects, and evolving environmental regulations, amount to tens of billions of investment dollars at stake."[8]

Shortage in Personnel

The aging population of skilled oil and gas workers adds to business concerns. The oil and gas sector needs to recruit 120,000 new employees worldwide over the next decade to avoid a skills shortage, according to PricewaterhouseCoopers research.[10] In general, there's a global shift in workers moving from blue-collar to white-collar jobs. For example, in Australia: "For every single blue-collar job added to the Australian economy there are four white-collar positions added."[11]

Hiring people with the necessary skills and career ambitions is one aspect, protecting them on the job is another critical part of attracting and retaining skilled workers. Health, safety and environmental (HSE) issues have risen on the oil and gas industry's agenda, reflecting both increased public pressure and more complex operational challenges.[12]

Eliminating maintenance-intensive equipment offers some relief, and incorporating automation into the process eases the burden as well. This feeds into overall maintenance reduction by empowering technicians to take a proactive approach that cuts planned downtime and minimizes reactionary "fire fighting."

New Opportunities, New Risks

Oil and gas companies are exploring for resources in new regions around the globe to meet increased demand. Along with these opportunities come logistics and environmental hurdles. Getting personnel and equipment into remote geographies and coping with temperature extremes presents new risks to capital and human resource investments. One such region is the Arctic, where permafrost tests drilling and extraction equipment to the maximum and very low temperatures make for brutal working conditions. Insuring equipment and people is commensurately more expensive; insight into some aspects of this situation can be found in a recent report by Lloyds: *Drilling in extreme environments: Challenges and implications for the energy insurance industry.*[13]

Balancing the business risks against the revenue potential is a long-standing litmus test for oil and gas companies. But a new problem set is emerging, one that factors in everything from increasingly complex political pressure to environmental concerns and disaster liabilities, and from a retiring workforce to higher expectations from company shareholders. It's a very complex business environment. Fortunately, advances in technology are available that help companies make wise business decisions and further perfect extraction as well as custody transfer. The result is not only greater value for energy companies, but also more precise and defensible royalty payments.

Technical Solutions

While legacy measurement technologies are widely found in oil and gas applications, Coriolis meter use has dramatically increased in both upstream production and custody transfer applications.

Coriolis meters offer unparalleled accuracy, sustained measurement performance and extended durability. They enable wider turndown than other meters, enabling accurate measurement in applications where there is great variance in the flow volume over time. They also accommodate bi-directional flow, enabling process engineers to better cope with more difficult, bi-directional processes.

It's also important to keep in mind the data collection and transfer capabilities. The ability to output raw sensor signals to flow computers or distributed controls systems (DCS) is essential to adhering to custody transfer best practices. The option to communicate in multiple formats is also desirable, enabling the meter to integrate with a variety of automation solutions available.

Micro Motion Coriolis Meter

- Flow
- Density
- Temperature
- Drive Gain

Drive Gain is a measure of the power input required to operate the meter; high drive gain is evidence of multiple phases in the meter tubes (i.e. gas in liquid)

Micro Motion produces Coriolis meters that are accurate to 0.1% mass flow, 0.12% volume flow and 0.0005 g/cc density.

Beyond the meter's role in fiscal metering, one of the most critical technical advantages of Coriolis meters is the ability to troubleshoot meter health and process diagnostics without interrupting the process.

Micro Motion Smart Meter Verification (SMV) technology is an extensive diagnostic test of a sensor and transmitter that assures that they are performing as designed. The tool can be automated and test results can be transmitted wirelessly, eliminating costly and often unnecessary "milk runs" for technicians. Furthermore, investigating the measurement meters is the first step when finding the cause of any process disruptions. With SMV, you know if the issue is in the measurement or the meter.

Additionally, Coriolis diagnostics can identify problems that wouldn't otherwise be found until oil is being loaded out (i.e. water in the bottom of oil tanks). Micro Motion diagnostics can be run that account for mixed oil and water streams (oil in water or water in oil), bubbles in liquid or mist in gas streams. Taken together, these technologies provide insight into upstream operations which legacy technologies simply cannot (see Figure 2).

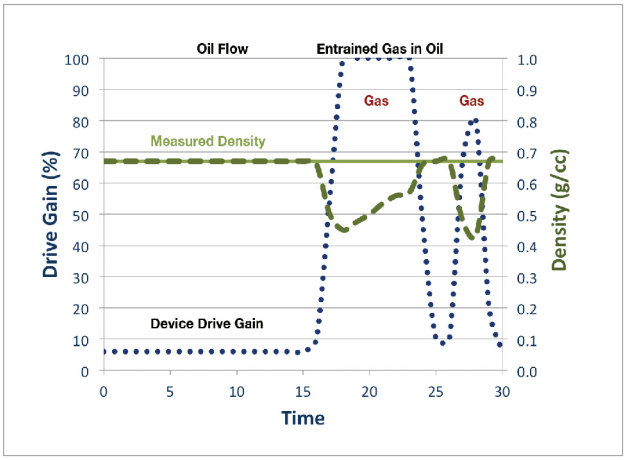

Figure 2

The value of these diagnostic capabilities stretches across the performance, reliability and maintenance of the systems and, in turn, to upstream production profits. As all experienced oil and gas engineers know, when the custody transfer meter is not measuring flow, no money is moving into the cash register.

Business Advantages

Can a perfect measurement solution be achieved? Probably not, even with Coriolis metering and comprehensive data analysis. But, wringing greater efficiency from processes by implementing the most accurate, reliable and durable equipment can help upstream oil production companies approach perfection. Assembling the right instrumentation is a big part of determining the overall value of the application solution.

Part of the challenge for oil companies is balancing the cost for equipment with return on investment. One viable approach to determining value is to consider the maintenance and replacement of one type of meter vs. another. Our experience shows that Coriolis meters, with their characteristically low maintenance and longevity, are often the best value for the application. Mechanical wear in PD and turbine meters invariably leads to higher maintenance costs, more frequent replacement and more hours in planned and unplanned downtime.

In light of an aging and shrinking workforce, the ability to deploy field personnel with greater precision has become a critical factor in controlling operating expenses and minimizing HSE risks.

Elevated accuracy satisfies the need to measure and be paid on every drop of oil. It also eases the burden of meeting regulatory pressures by providing the accuracy dictated by law. Of course, when it comes to fiscal metering and the myriad related considerations – as an example taxes and royalties – accuracy is paramount. The potential damages are also a big part of the equation; business must constantly evaluate liabilities against opportunities, which is what makes prospecting in unknown regions a risky proposition.

Micro Motion meters are built to withstand the harshest conditions, which creates greater return on investment in the meters themselves, cuts downtime, maintenance and field trips, reduces risk to the company in terms of capital investment, HSE and brand, and sets in place technology that gives a competitive edge and a platform for future technology integration and process improvement.

What Coriolis meters reveal that other meters can't.

The technique of Coriolis measurement enables instantaneous recognition of the presence of entrained gases. Decoupled gas bubbles trigger an increase in the device drive gain along with a simultaneous drop in measured density. Taken together, these changes indicate that entrained gas is present.

When using other types of meters, the discrepancy in measurement between allocation meters and fiscal meters can create enough uncertainty that the data is unreliable and indefensible when presented as evidence during litigation.

Conclusion

Advances in upstream oil and gas processes have given new life to old plays, enabled extraction from previously impossible regions and inspired exploration in regions where conditions above and below the ground once made venturing into those territories unthinkable. Meanwhile, the business environment has become more complex, with problems such as an evolving workforce and increasingly stringent regulations – spanning from HSE conditions to transparency and traceability in operations – threatening to counterbalance the opportunity with excessive operational complexity and risks.

Global energy demand steadily increases, compelling energy companies to diversify their portfolio of energy sources and to look to superior technologies, such as Coriolis meters, and solutions from seasoned providers. Emerson Micro Motion is one such provider, delivering unique, innovative technologies that, combined with decades of application experience in the field, have made the company a global leader that can help companies around the globe better utilize their resources and ensure the safety and efficiency of their operations.

About Micro Motion

For over 35 years, Emerson's Micro Motion has been a technology leader delivering the most precise flow, density and concentration measurement devices for fiscal applications, process control and process monitoring. Our passion for solving flow and density measurement challenges is proven through the highly accurate and unbeatable performance of our devices.

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