Generating Greater Accuracy and Robustness from Subsea Multiphase Meters

By Finn Erik Berge, Emerson Process Management

Subsea multiphase meters have faced a growing number of challenges linked to the issues of robustness, accuracy and safety in the last few years.

The remoteness of many of today's subsea fields, for example, with high temperatures, pressures and water depths, is proving a significant challenge to multiphase meters' robustness and their ability to measure flow rates of oil, water and gas in all reservoir conditions. In such circumstances, 100% reliability is key to preventing any Loss Profit Opportunities (LPO) for operators.

Multiphase meters today need to be sufficiently robust to deliver accuracy independent of fluctuating flow conditions and flow regimes and be operational for the extended life time of the wells. Furthermore, with industry analysts, Douglas-Westwood forecasting a global CAPEX of $223 billion between 2013 and 2017 on deepwater developments, the number of remote and challenging fields is only likely to increase.

Accuracy is also an issue. Many oil & gas wells today are being produced over a wider range of process conditions with more liquid and water present as well as high gas volume fractions (GVF). Accuracy in water production, for example, is becoming more important in detecting formation water and producing injected sea water and there is a need to measure the process flow over the entire range of the GVF from 0-100%.

In addition, water salinity and its measurement have also become increasingly important. Accurate salinity measurement can tell the reservoir engineer whether formation water is entering the flow as well as help the process engineer adjust the injection rates of scale and corrosion inhibitors.

Finally, there is safety, flexibility and the ability for such meters to fit seamlessly with existing infrastructure – a crucial criteria for EPCs. Size, weight and instrument compactness are crucial with many subsea manifolds already crowded with instrumentation and little room to spare. For EPCs, the footprint of the meter should be as small as possible – being easy to install and retrieve at minimum costs.

In summary, operators are asking more from their subsea multiphase meters than ever before. Such meters must be robust; operate throughout the lifetime of the field; and deliver accurate results in operating ranges of between 90 and 100% GVF.

The Need to Improve Measurement Accuracy

So are multiphase meters meeting these challenges?

Traditionally multiphase meters have tended to show an increased uncertainty at GVF of around >95%. Between the ranges of 95% and 100% GVF, mixed density measurements have tended to be used as the main input for determining the liquid fraction in wet gas flow results.

Such inputs, however, come with high uncertainties. Liquid fractions are unable to be estimated accurately using density gauges and typically only allow for a resolution between

1-4 kg/m3. Long in-line calibration cycles of the gamma density systems may improve measurement accuracy, but this is often not practical subsea.

In addition, other potential obstacles include a limited mapping of the different flow regimes, the inability to handle varying conditions and questionable accuracy in High Pressure/High Temperature environments.

It is with these issues in mind that Emerson is taking its Roxar topside third generation multiphase meter subsea.

Improved Robustness & Reliability

Improved robustness and reliability was central to the design of the new Roxar subsea meter (see figure 1).

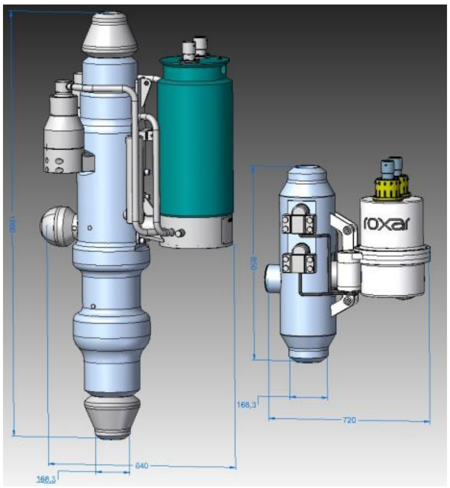


Figure 1

In its design, Emerson opted for a field replaceable insert venturi that allows for extended service life and operating ranges. The meter also includes a Differential Pressure Transmitter (dP) that has been adapted to meet high pressure requirements with enhanced welding and ceramic geometry. Emerson is also looking to adopt ceramics and other materials that can operate at pressures and temperatures of up to 20k PSI and 250 Degree Celsius.

The Electrode Liner Solution, part of the meter, also includes up to six electrodes with the pressure balanced solution consisting of process pressure on both sides of the liner. The meter has two barriers with different barrier principles – the first barrier consists of the liner with metal to metal seals and ceramic to metal seals, and the second barrier consists of a glass-metal penetrator in the meter body.

Furthermore, with low power consumption requirements and fully redundant electronics, the Roxar subsea meter will be able to operate in all challenging environments.

More Combinations & Accurate Fraction Measurements

The new measurement principle for the meter is based on an electrode geometry sensor which allows for measurements in separate sectors, in addition to the full cross-sectional area. This results in more combinations and more accurate fraction measurements and velocities for each segment.

Rather than systems only being able to perform cross-sectional measurements, the subsea meter can perform both rotational near wall measurements and cross-volume measurements, thereby providing a comprehensive mapping of the flow regimes. Challenges such as the need to handle all types of flow regimes varying from horizontal laminar flow to full developed vertical annular flow are also met.

Real-Time Capacitance Measurements

The Roxar meter also incorporates real-time capacitance measurements, pressure and temperature measurements and algorithms that take into account the hydrocarbon composition of the fluid using PVT simulations. This PVT input data provides single phase densities and gas-condensate ratios at operating pressures and temperatures, thereby improving the meter's accuracy.

The subsea multiphase meter's impedance measurement has mainly a capacitive component in oil-continuous flow and a conductive component in water-continuous flow state; hence a capacitive mode and conductance mode. This provides the meter with a measurement principle that is extremely sensitive to changes in the water fraction and is not affected by changes in the salinity of the water.

The impedance measurements in capacitive mode are not suitable when the multiphase flow is in water-continuous state and for this reason the conductance mode is used to determine the water fraction of the mixture. Similar to the capacitance mode in oil-continuous flow, the conductance mode finds the water fraction of the water-continuous mixture.

By combining the known water fraction along with the gas/liquid split found from either patented non-gamma algorithms or the gamma densitometer system, oil fraction, water fraction and gas fraction are known.

A Two-Detector Densitometry system for Improved Accuracy

Linked to this, Emerson has also looked to improve its gamma densitometer system through a new detector with improved reliability, stability and performance in multiphase flow and better density measurement. The system also reduces the detector's size and weight significantly, making it more compact and easier to handle.

Building on improvements made in 2006, which saw the source and detector positioned much closer to the flow for improved measurements, the new system tackles accuracy challenges such as long-term drift as well as coming with improved repeatability.

Furthermore today Emerson is promoting a two gamma detector system which will increase measurement performance and robustness even further.

The single-energy gamma source will emit through two openings, directing two beams from the source to two gamma detectors as in figure 2. The detectors are not aligned next to one another, but at an angle where D1 will detect the photons travelling across the centre of the pipe and D2 will detect the photons close to the pipe wall.

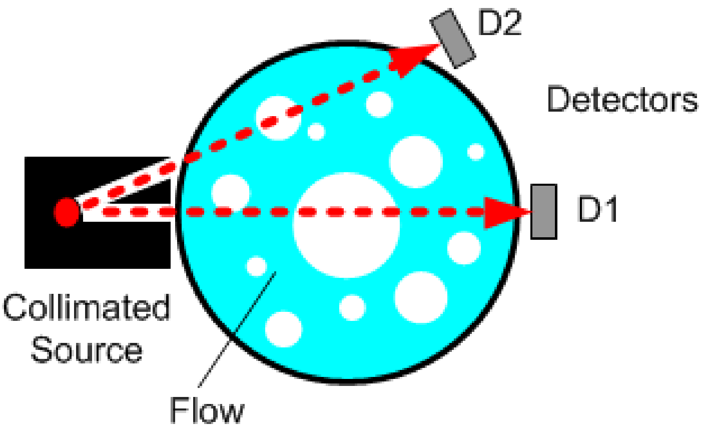


Figure 2

In a typical flow the heaviest medium will get pushed along the wall with the lightest travelling in the centre, in this case the heaviest medium being water and the lightest being gas. By introducing an extra measurement close to the pipe wall, the gamma densitometer will capture this sector and then ultimately improve the gas-liquid ratio.

In introducing a second detector to the gamma densitometer system, the two detectors can also be compared to detect drift. The two detector-sensor system will also improve redundancy, allowing for the switching of components in the unlikely event of component failure.

The introduction of a second and new detector version into the gamma densitometer system as well as a two detector-based system will eliminate traditional negative effects such as drift in gamma detectors and improve the meter's accuracy and uncertainty specifications.

A Salinity Sensor System

The new Roxar Subsea Multiphase meter also comes with a salinity sensor which enables absolute measurements of the salinity of the produced water. The dedicated salinity sensor is based on differential microwave transmissions and is operational in three-phase gas-liquid flows. The sensor measures the effect of the flow on the propagation of the microwave signal in the volume between three probes, with the salinity of the water phase and the local water-liquid ratio then able to be deduced.

Increased Compactness

Finally, as mentioned at the outset, safety and a flexible multiphase meter that can operate alongside existing infrastructure is vital and a key issue for EPCs when making selection decisions.

The Roxar subsea multiphase meter is significantly more compact than previous subsea meters – 20% of the weight and half the height of the previous meter. The reduced size allows operators to install the meter on individual wells and in previously inaccessible locations, as well as replace earlier multiphase meters. The end result is a highly flexible subsea multiphase meter.

Putting the Meter to the Test

Emerson tested the multiphase meter and its applicability for wet gas fields at the Colorado Engineering Experiment Station Inc (CEESI) Multiphase Wet Gas Flow Test Facility in Colorado in June 2011 and then in November 2012.

In the November 2012 tests, the meter was proven to measure results for Hydrocarbon mass flow within +/-5% rel. uncertainty and 0.2% WVF abs in the defined operating range between 95%-100% GVF. In the range between 98%-100% GVF, the WVF (Water Volume Fraction) uncertainty can easily be defined to be less than 0.1%abs WVF. Figures 3 and 4 show the deviations in hydrocarbon flow rate and water volume fractions respectively.

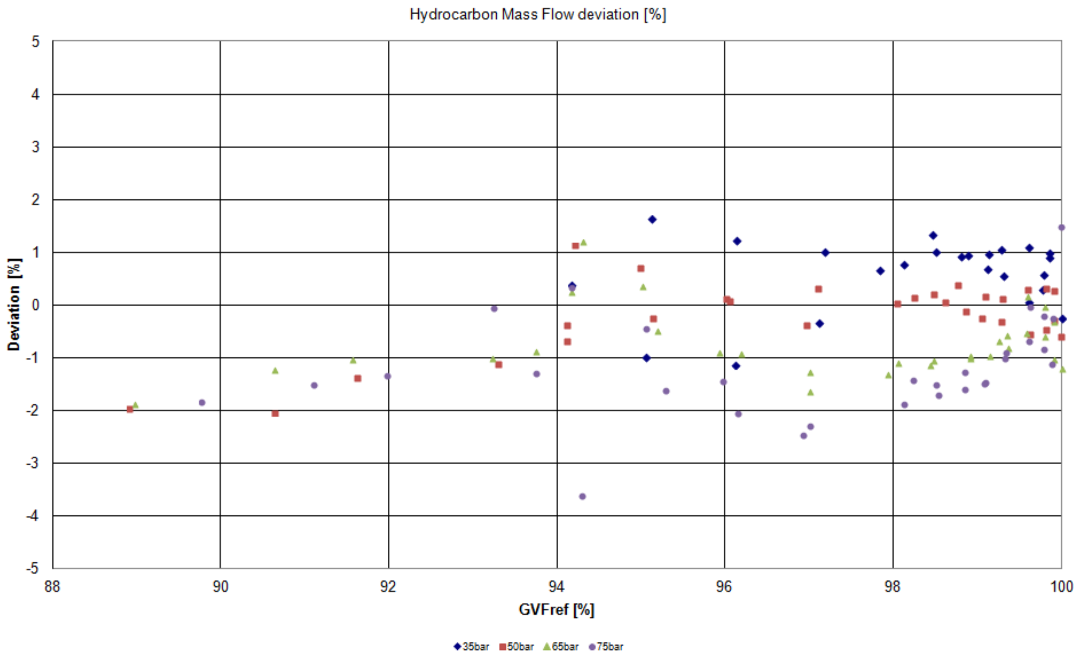
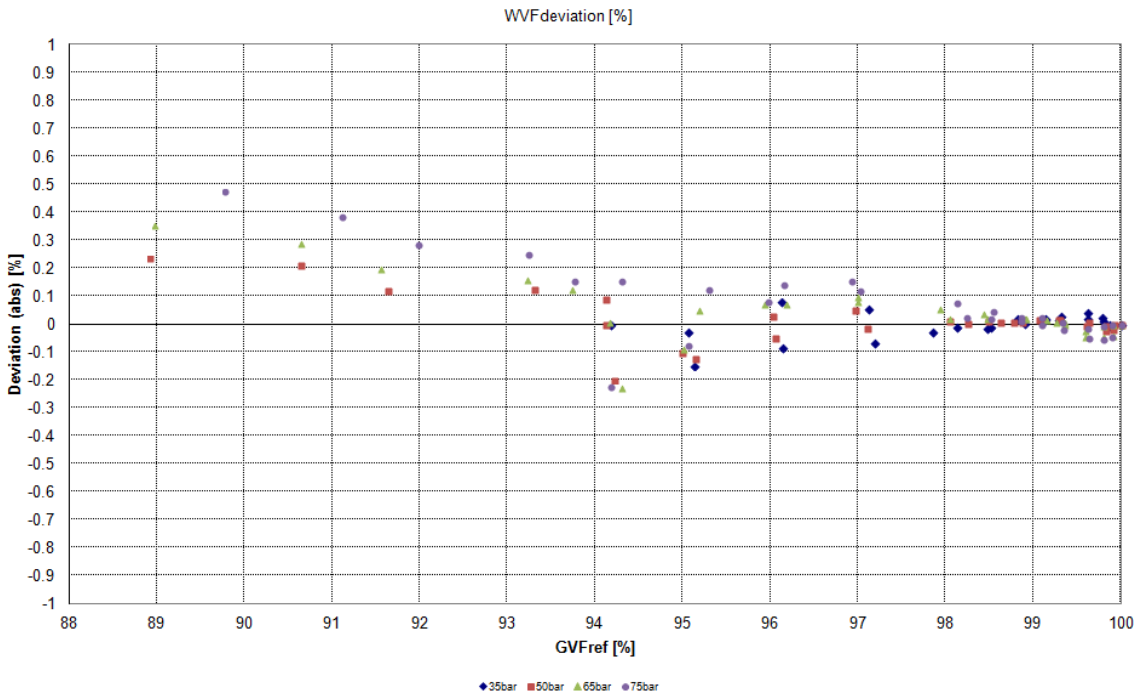


Figure 3

The final test results were found to be well inside the performance specifications of the meter and again confirmed its effectiveness across the lifecycle of the asset and its transition between being a multiphase and wet gas meter. The meter was also able to shift successfully between multiphase- and wet gas mode according to the set criteria.

With the market for multiphase and wet gas meters continuing to grow and the need for accurate flow measurement never more important, it is imperative that today's subsea multiphase meters are able to meet operator challenges. It's encouraging to see that today's technologies are ensuring that this is the case.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Deviation (abs) [%]
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Figure 4