Finn Erik Berge, Emerson Process Management, Norway, shows how deploying more accurate multiphase meters can improve results in well testing, production monitoring and flow assurance.

Subsea multiphase meters today play a crucial role in reservoir management and downhole monitoring with applications for well testing, production monitoring, production allocation and flow assurance.

By providing minute-by-minute information on a well’s capabilities during production (information such as water breakthrough, permeability and flow characteristics) operators are able to use the information to support their downhole monitoring, improve their well control and flow assurance, and ensure a seamless flow of oil and gas from reservoir to refinery.

The last few years, however, have seen a growing number of challenges facing subsea multiphase gas meters. This article will examine how the latest technologies are responding to these challenges and why multiphase metering today remains a key element of an integrated downhole network.

A rapidly changing picture
Operators are facing a rapidly changing picture in regard to their offshore operations. Firstly, there is the growing geological complexity and remoteness of many of today’s fields.
Size, weight and instrument compactness are crucial with many subsea manifolds already crowded with instrumentation and little room to spare.

Offshore exploration is going deeper and into harsher environments, with the high pressure and water depths multphase meters have to operate in providing significant challenges to the accurate measuring of flow rates in the well streams. This focus on deepwater exploration is only likely to grow. Industry analysts, Douglas-Westwood forecast a global Capex of US$ 22 billion between 2013 and 2017, according to their ‘Worldwide Deepwater Market Forecast’.

For multphase meters, this means an increased onus on reliable equipment and communications. Size, weight and instrument compactness are crucial with many subsea manifolds already crowded with instrumentation and little room to spare.

A second challenge is that many oil and gas wells are being produced over a wider range of process conditions with more liquid and water present as well as high gas volume fractions (GVF). This can apply not only to newer deepwater fields, but also to older brownfields.

There is therefore an increasing need to more accurately measure flow rates under such conditions. Accuracy in water production, for example, is becoming more important in detecting formation water and producing injected seawater, and there is also a need to measure the process flow over the entire range of the GVF.

Measuring water salinity has also become increasingly important. Salinity is often a key operational parameter for reservoir management and flow assurance in the field. 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. To date, however, water salinity detection has tended to be viewed as less of a priority by both operators and vendors.

Finally, the last few years have also seen a growth in subsea tie-backs and longer horizontal production pipelines, as operators look to tie in smaller fields to existing infrastructure as well as tie-in remote deeper infrastructure. With longer tiebacks and potential delays to detecting water breakthrough, the need to track threats to pipeline and production integrity and accurately measure production and fiscal allocation is crucial.

In summary, despite their popularity, subsea multphase meters are facing a number of growing demands. They are expected to come with increased robustness and operate throughout the lifetime of the field and they must operate accurately and effectively in the challenging operating ranges of between 90 and 100% GVF. Finally, they must also link seamlessly with other downhole tools to provide a complete production surveillance system.

The rest of this article will examine how recent developments in subsea multphase meters are meeting these challenges.

**Improving the measurement accuracy of subsea multphase meters**

Traditionally, multphase meters tend to show an increased uncertainty at GVF of approximately >95%. Typically between the ranges of 95% and 100% GVF, the use of mixed density measurements is the main input for determining the liquid fraction in wet gas flow results.

Such inputs, however, come with high uncertainties with the fractions of liquid unable to be estimated accurately using density gauges that 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 to the effective deployment of multphase meters subsea include a limited mapping of the different flow regimes and the inability to handle varying conditions.

It is with these issues in mind that Emerson has developed a new measurement system for its subsea multphase meter that makes it more effective in wet gas fields with high GVF.

There are a number of key technologies, which underpin the new meter.

**A field replaceable insert venturi**

Central to the new meter is a field replaceable insert venturi that allows for extended service life and operating ranges, and removes uncertainties in sizing meters based on uncertain production forecasts. The insert venturi is also designed to minimise the effects from swirl and unsymmetrical flow patterns caused by piping geometry upstream of the meter.

Venturi models for measurements of gas flow rates in wet gas flow are well known in the industry and are mostly tested out on two phase gas-liquid systems. By using multphase meters as wet gas meters, additional information about the flow can be retrieved, potentially improving the performance of the gas measurements.

**More combinations and 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 well 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.

Asymmetrical flow and less-than-perfect mixtures of the gas and dispersed phase can also be handled in a manner that was not possible previously, resulting in improved measurement accuracy and an extended operating range.

**Real time capacitance measurements**

The 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 at the operating pressure and temperature.

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 an oil-continuous flow and a conductive component in a 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 measurement in capacitive mode is not suitable when the multiphase flow is in a 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 non-gamma algorithms or the gamma densitometer system oil fraction, water fraction and gas fraction are known, as illustrated in Figure 1.

Furthermore, in order to improve the meter’s performance, a salinity sensor, which enables absolute measurements of the salinity of the produced water has been developed. Two different probes have been developed – both based on microwave technology. There is the wet gas probe, which measures salinity in wet gas and high GVFs, and the multiphase probe, which measures salinity in water continuous multiphase flow.

**Increased compactness**

Finally, the new subsea multiphase meter is also significantly more compact than previous subsea meters: 20% of the weight and half the height of the previous meter. This compactness is crucial with many subsea manifolds already crowded with instrumentation.

The reduced size also opens up enormous potential cost savings in terms of installation and maintenance as well as providing greater flexibility. It 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 flexible subsea multiphase meter with improved accuracy and sensitivity across the field lifecycle with particular accuracy in fields with high GVF.

**Putting the meter to the test**

The new multiphase meter’s applicability for wet gas fields was tested at the Colorado Engineering Experiment Station Inc. (CEESI) Multiphase Wet Gas Flow Test Facility in Colorado in June 2011 and November 2012.

The June 2011 results showed that, once characterised, the multiphase meter was found to be capable of metering the natural gas mass flow rate to within 2% at 95% confidence. The meter was also found to be capable of metering the total hydrocarbon mass flow rate to within 1.5% at 95% confidence.

A differently sized sensor – almost twice the size of the first tested meter – was then tested at CEESI in November 2012. In this case, 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 uncertainty can be defined to be less than 0.1% abs WVF.

Figures 2 and 3 show the deviations in hydrocarbon flow rate and water volume fractions respectively.

The results were found to be 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.

**An integrated downhole network**

Today, the subsea multiphase meter is providing crucial information and input into a broader and integrated downhole network and is able to combine, for example, with systems that can generate multiphase flow measurements from downhole in the well.

Systems such as the Roxar Downhole Flow Sensor System can generate multiphase measurements, including fluid fractions and flow rates, from either single bore or multilateral well configurations. In this way, the system allows operators to control multiple production wells, measure the individual flow zones of oil, gas and water, and establish optimum flow rate control.

**Increasing investment returns from wet gas fields**

What the tests described have demonstrated is the high level of accuracy of new multiphase metering technologies when applied to wet gas mode. The result will be increased production optimisation in the high GVF/wet gas range and a substantial increase in investment returns from operators’ more remote wet gas fields.

With the increased remoteness of offshore fields, the wide range of process conditions and other challenges, such as salinity and subsea tie-backs, technology developments such as this are arriving at exactly the right time.

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