Influence Quantities, Sensitivity Coefficients & Multiphase Meters

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While multiphase meter performance today is measured by outputs and the meter's ability to accurately track the flow rates of oil, gas and water, it is also equally important to focus on the elements surrounding a multiphase meter deployment that are not measured but still have a significant impact on the meter's readings. We call these influence quantities.

These influence quantities are prevalent in many oil & gas fields today and include everything from H2S, CO2 and sand through to inhibitors, such as MEG (Monoethylene Glycol) to prevent hydrates, other additives such as emulsifiers, wax inhibitors and corrosion inhibitors, and a wide variety of different flow regimes. The result is a flow stream consisting of multiple influence quantities.

In order to determine how these influence quantities affect multiphase meter measurements, sensitivity coefficients must also be calculated to provide important data on how the output estimate varies based on changes in the value of the influence quantity. For example, if an x% change in oil density gives a y% change in oil rate, then the change between x% and y% is the sensitivity coefficient, the oil density is the influence quantity, and the oil rate is the measurement from the multiphase meter.

It is through a better understanding of influence quantities and sensitivity coefficients that operators can better quantify uncertainty in their multiphase measurements and better manage and plan their future field development and reservoir management strategies.

This article will examine the influence quantities that need to be considered and how in this case, Emerson's Roxar MPFM 2600 multiphase meter is addressing them. In particular, the article will cover the influence quantities that come out of changing and complex flow regimes, salinity & conductivity, and the injection of thermodynamic inhibitors, such as MEG.

Differing & Complex Flow Regimes

Multiphase meters today must perform in a huge variety of flow regimes, including bubble, slug, mist, churn and annular. Slip flow also occurs regularly when gas rises faster than liquid due to buoyancy effects and the velocity profile of the flow in the pipe.

These different flow regimes can form a series of influence quantities that have a major influence on electrical impedance measurements, uncertainty, and the meter's ultimate accuracy. So can these influence quantities be addressed and compensated for in multiphase meter measurements?

Generally, in order to be able to handle multiple, rapid changing flow regimes, a sufficient number of sensors and calculations must be included within the meter. For example, for annular flows (high gas fractions), compensation must be incorporated into the gamma system in order to achieve accurate measurements.

For rapidly changing slug flows (both water and gas slugs), fast front-end electronics capable of capturing these changes are important. To this end, the Roxar MPFM 2600 includes high resolution sensors capable of capturing very small changes in the electrical properties of the multiphase fluid passing through.

Phase slip also varies greatly due to changes in process conditions and flow regimes, with some multiphase systems requiring complex slip models that can only form an estimation of the slip based on assumptions regarding the flow regime. With the Roxar MPFM 2600, however, the meter's dual velocity system includes a field replaceable insert venturi and cross-correlation capabilities that provide flow regime independent measurements.

Further areas that Emerson is working on to tackle complex flow regimes and reduce their influence include the direct measurement of the degree of annularity, the mapping of non-symmetrical flow, and a cross sectional breakdown of the flow.

Salinity & Conductivity

In water continuous flow, multiphase meters are dependent on an input of water conductivity/salinity values in order to achieve their correct performance specifications.

While variations in water salinity have no influence on the measurements in process conditions at less than ~60 Water Liquid Ratio WLR (i.e. oil continuous flows), at higher water cuts the water conductivity is an important input value to the multiphase meter with significant sensitivity coefficients.

For example, in a scenario of GVF at 80%, WLR at 60% and a water conductivity change at +1% rel, the additional uncertainty would be a Liquid Rate (% rel) at -0.1 % and WLR (% abs) at +0.6 %. At GVF of 95% and WLR of 80%, the additional uncertainty would increase to Liquid Rate (% rel) at - 0.2 % and WLR (% abs) at +1.0 %.

It's with these influence quantities in mind that Emerson has developed a dedicated salinity/conductivity sensor for operation in multiphase flow.

Two different sensors/probes have been developed – both based on microwave technology. There is the wet gas probe which measures salinity in wet gas & high GVF's and the multiphase probe which measures salinity in water continuous multiphase flow.

The salinity sensor for multiphase flow is based on differential microwave transmissions for operating in three-phase gas-liquid flows and 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 WLR then deduced. The result is a better quantification of uncertainty and improved meter measurements.

MEG & Methanol

As mentioned in the introduction, thermodynamic inhibitors, such as Methanol and Ethylene Glycol (MEG), are currently the most effective means of preventing hydrates. Other methods include depressurization, external heating, and various mechanical methods.

Methanol and Ethylene Glycol, however, will be measured as water by the electrical impedance sensor system of the meter. As the densities of these fluids are lower than water, however, the density of the mixed flow can be reduced and, if a considerable amount of MEG is injected, will influence measurements from the electrical impedance and gamma system.

The means of overcoming these challenges are to subtract the MEG injection rate from the reported water rate from the multiphase meter or to provide water density input into the multiphase meter so that measurements can be updated to take into account the combined density of the expected water production and MEG/Methanol injection. This thereby removes the influence quantity effect on the gamma system and improves measurement accuracy.

Other Influence Quantities

What has been described in this article are just a few examples of influence quantities on multiphase meters. There are many more.

For example, erosion might affect a multiphase meter's venturi if significant amounts of sand cause erosion to the venturi throat. In such cases, potential solutions include the right material construction, adjusting the physical inputs to the venturi section to compensate or, in extreme cases, replacing the venturi section only - a feature available on the MPFM 2600.

There is also oil permittivity that can influence the electrical impedance measurement component in oil continuous flow. For example, in a flow where the WLR is very low (i.e. the liquid is more or less oil), a relative change for oil permittivity of 1% will have a $1/5^{th}$ of the effect of the 1% relative change in reference oil density. If a 1% error in oil density gives a 1% error in liquid rate, a 1% error in permittivity would give a 0.2% ($1/5^{th}$) error in liquid rate.

In order to overcome this influence quantity and the accompanying sensitivity coefficient outlined here, it is important to update the oil permittivity as required based on updated compositional analysis and oil densities. The Roxar MPFM 2600's measurement principle achieves this, being extremely sensitive to the water fraction and where measurement is based on permittivity not conductivity.

A Lot to Think About!

Multiphase meters today face a myriad of influence quantities in the production streams. This is only exacerbated by the geological complexity, remoteness and changing process conditions of many fields.

Operators or EPCs should look at these influence quantities, the sensitivity coefficient, and what metering technologies are evolving to address them in order to select their optimum solution and ensure the right multiphase metering solution for the right field.