Roxar™ 2600 Multiphase Flow Meter Performance Monitoring and Meter Verification Using IIoT Supported Solutions
Introduction

Adoption to multiphase flow meter (MPFM) technology has accelerated and this drives the need for better and more direct means to manage a large scale MPFM installed base. Industrial Internet of Things technology enables Roxar 2600 MPFM Performance Monitoring by Emerson, including automated data collection and inline meter verification routines.

Customer Challenges When Operating Multiphase Flow Meters

When multiphase flow meters are used for allocation of revenues, verification of the meter needs to be done regularly and an auditable track record of all changes to settings and calibration needs to be recorded. Verification of meter performance is also important for other multiphase flow meter applications, such as well testing and reservoir and production optimization.

Verification of the multiphase flow meters is typically done by comparing the multiphase flow meter measurement with a test separator. It is often expensive and cumbersome to hook up a test separator inline with a multiphase flow meter and compare the measurement outputs. Mobilizing a separator could costs thousands of dollars for a day and the purpose of multiphase flow meters is to avoid the need for this. At some locations it is even impossible to use a separator due to area constraints or existing separation capacity does not allow for single well testing. Even when a separator is mobilized, the data comparison is not trivial. The separator often operates at significantly different pressure and temperatures than the multiphase flow meter, so in order to compare both, measurements have to be converted to the same pressure and temperature conditions. This sounds easy but in practice it is often a source of error. For example, using slightly different PVT models (Pressure, Volume, Temperature models) can result in relative errors between multiphase flow meters and a separator. Separators are not perfect either. Repeatability of measurements from multiphase flow meters is often better than similar measurements done by a separator. Additional errors may be caused by retention- and stabilization times required for a separator, improperly sized single-phase meters, worn out instruments like orifice plates and turbine meters and/or lack of calibration routines.

It is possible to achieve Roxar 2600 MPFM verification without the need for test separators. However, large amounts of data are required to verify the Roxar 2600 MPFM without test separators. This data often requires trend analysis (data gathered over a period) or the data needs to be gathered during single-phase period. This data is available from the Roxar 2600 MPFM itself and when made available to Emerson experts, Roxar 2600 MPFM meter verification can be done efficiently and with good results.

Another issue is retention of knowledge and skills. Just as separators, multiphase flow meters require metering engineers familiar with input requirements of the instruments and ways to verify the measurements. The right expertise is critical to the operations, but it’s costly to develop experts and tough to retain them. Even when experts are available in the field, their time is often stretched thin with monitoring entire systems, rather than details of one component of the system or tasks prioritized higher than proactive verification.

How Multiphase Flow Meters Can be Verified Without Test Separators

To verify the MPFM, it is important to know how it works and what the critical parts of the MPFM are that should work together. Once this is known and understood it is possible, one by one, to look for indicators, preferably ones that can be monitored directly and online, that tell if the MPFM works as it should or not. Understanding of the measurement technology combined with field experience is important to define effective indicators for multiphase flow meter verification. Multiphase flow meters have 3 main pillars that all work together: sensors, input data and meter algorithms.

Sensors

Example of sensors are: pressure, temperature and differential pressure transmitters, electrical impedance sensors to measure the electrical properties of the flow and density sensors based on a detector counting a pulse rate from a gamma source. Sensors are by default calibrated within a certain range. High speed sensor data is used to identify flow regimes and apply the correct calculation models. Sensors can be contaminated with debris or wax layers causing the base line measurement while the meter is empty (or filled with only gas) to be shifted. Recording periods with a single-phase present in the meter can be used the check if the calibration of the sensor is still valid or if cleaning is required. This data and a combination of it can be used to verify the MPFM. Some examples of these are:
Example 1: Verification of dP Measurements

Emerson’s Roxar 2600 MPFM dP measurements are calibrated between 0-5000 mbar. Measuring outside this range will cause additional uncertainty. This uncertainty will vary depending on the flow-weighted quantity of measurements performed outside of specification. For example: in very sluggish flow liquid slugs may push the limits of the dP transmitter calibrated range, this may cause liquid measurement outside the calibrated range of the dP transmitter.

In addition, this sensor can be blocked by debris causing the output to be inaccurate.

The dP sensor can also be checked using redundant measurements from another sensor. Improper use of the manifold block could lead to the equalizer valve remaining open causing the dP to be too low for the flow passing by the MPFM. The Roxar 2600 MPFM identifies inconsistency of the dP measurement and the secondary velocity measurement calculated from the Roxar 2600 MPFM cross correlation technology.
Example 2: Verification of Impedance Measurements

Layers that are covering the electrodes can be detected. This can be done in different ways depending on the nature of the flow: oil continuous or water continuous and whether the layer is of conductive nature (typical wetted scale, salt deposits) or insulating nature (typically wax). Layers may cause incorrect measurement and cleaning of the meters should be done on time to avoid improper measurement results. Monitoring the layer indicators is important to assure the MPFM measures correctly.

Emerson has developed layer detection based on regression analyses of both density and impedance measurements, trending of single-phase measurements and by analyses of redundant measurement from the 2 and 6 electrode planes. In some areas of the world simply checking the MPFM temperature and pressure measurements against known pressure and temperature problems areas (WAT, Wax appearance temperature) is enough to flag the meter for cleaning maintenance before the measurement can be trusted again.
Input Data

All multiphase flow meters on the market are dependent on input data. PVT conversion factor inputs are required to convert measurements at actual conditions to standard conditions. Most MPFs on the market require input densities of the three phases or HC composition and supporting data to calculate this directly by a built in PVT simulator. Other input data can be water conductivity and phase absorption coefficients for gamma systems.

Input data can be verified using the following methods.

- Gas has the lowest permittivity of all the fluids seen by the meter. If the mixed permittivity measurements during short periods of mainly gas are below the gas permittivity (calculated from pressure and PVT input) then this means that either the capacitance measurement or the input data is incorrect.

- During periods of single-phase gas, for example when the meter is bypassed or during short periods of slugging the measured gas density should be the same as the gas density given by the PVT table input. If a difference exists, the 2600 MPFM can automatically correct itself for this difference with the auto gamma calibration feature, but this does not solve the root cause of the error. If the error is caused by incorrect PVT input data then this also may cause other errors and a PVT update should be performed.

Algorithms

The exact algorithm and models used to calculate the multiphase flow are inherently complex. This is because physical flow models that are developed for single phase or even two-phase flow are extrapolated to be used in 3-phase flow with the help of empirical correction models. These models correct the original single-phase models for presence of gas and for different flow regimes. It is also complex because the models combine measurements from several sensors and input data. Multiphase flow meter vendors test the multiphase models extensively in multiphase flow loops that simulate different conditions. Based on these tests the multiphase vendor establishes an operating range and performance specification.

To verify if the meter is working properly the meter needs to indicate that the multiphase calculation models are still valid and good to be used for the fluid rates flowing through the Roxar 2600 MPFM. This can be done in several ways, but in principle it is based on checking whether the flow characteristics are within range of the tested multiphase models.

Another way to verify the meter is to assume some parameters to be stable or known. Some reservoirs can have stable GOR or water cut, which can be verified with sampling. This information is then used in a secondary model as a fixed input when calculating the flow rates. Tracing the output of the two calculation models assures that the primary model stays on tracks and does not deviate from what is known to be valid. Multi-model verification has been used on Roxar 2600 MPFM since 2017. These analyses can also be done by reprocessing historical data, the Roxar 2600 MPFM transfers raw data from the sensors suitable for future reprocessing to cloud storage and reprocessing by experts as part of the Roxar 2600 MPFM Performance Monitoring Services.
Figure 4 – Caption

Figure 5 – Caption
Example of how multiphase flow models are verified: Unstable flow regimes may cause the meter to operate outside its operating range. For example, the Roxar 2600 MPFM performance specification states an operating range in multiphase mode up to 98% GVF. Flow measured at higher gas fraction without proper input to support Wetgas mode causes additional uncertainty. Continuous online monitoring of the gas volume fraction and the weight % of the hydrocarbons produced in this critical range will indicate if the operating mode is valid. Highly sluggish flow regimes may cause the average GVF to be within operating range but may cause the meter to be outside operating range during periods of time when the slugs pass by. For these cases the meter will require additional PVT data and set up for automatic switching between Wetgas and Multiphase modes. Without meter verification this may pass by undetected and meter results are less accurate.

Besides verification of the MPFM based solely on MPFM data it is also possible to build in an additional layer of meter verification without the need for 3 phase separators per well if bulk separator measurements are available. A one meter per well strategy allows for continuous measurements of all wells on a well pad. The bulk separator measurements from a complete well pad or even from a combination of multiple well pads can be used to compare the sum of the accumulated volumes reported from each multiphase flow meter. Using a one MPFM meter per well strategy for all wells allows calculation of more accurate reconciliation factors, monitoring these factors over time and assigning the service resources to those wells with the highest volume contribution to the total. Emerson’s cloud-based performance monitoring environment allows for uploading bulk separator rates to track the combined performance across all MPFMs on a well pad.

Cloud enabled Empty Pipe Verification is a method used by the Roxar 2600 MPFM Performance Monitoring service. The algorithm identifies periods when the flow is stopped, and the meter is filled with gas under pressure. These periods happen from time to time and are very valuable moments because the measurements during these periods should be within expected levels and the measurements are not impacted by turbulent multiphase flow conditions. For example, when the well is shut in or when the meter is bypassed there is a period where the meter is drained for liquids and only gas is present. During these periods the cloud algorithm automatically records data from the MPFM sensors and plots subsequent periods of empty pipe averages. These trends of the empty pipe measurements indicate layer build up, calibration errors and input data errors. Automated data acquisition combined with standard ways of plotting these allows for easy and effective verification by MPFM experts.

**Emerson’s Roxar 2600 Multiphase Flow Meter Performance Monitoring**

Emerson provides IIoT based performance monitoring services for the Roxar 2600 Multiphase Flow Meter to bring verification data from large MPFM fleet owners together with expert level knowledge.

Three main components are unique in this offering:

1) **Secure First Mile™**: Emerson Connected Services supplement workforces with a variety of scalable, remote monitoring services that leverage Industrial Internet of Things (IIoT) technologies. Utilizing the Secure First Mile to automatically collect data as part of Emerson’s Plantweb™ digital ecosystem. Data collecting is done through secure edge gateways with Microsoft Azure IoT technology for instrument-to-cloud connectivity. The gateways are fully cloud managed and connect to multiple Roxar 2600 MPFM Flow Computers with minimal need for field installation support. Many network architectures and connectivity models are supported, including WIFI, Cellular independent networks and architectures using the existing instrument networks and connectivity through end user managed firewalls.

2) **Verification and Performance Monitoring Methods**: To verify the Roxar 2600 MPFM, verification methods as outlined in this document have been developed together with the operators. The verification methods are based on using millions of data points gathered from installed base Roxar 2600 MPFMs connected to the Internet. Where possible these methods are automated by the cloud-based algorithms. Many MPFM failure modes can have root cause analysis performed with results feeding back into continuous improvement of the verification tools. This is only possible when large installed base data is collected using IIoT technology.
3) **Emerson Experts**: Emerson’s Roxar 2600 Multiphase Flow Meter Performance Monitoring service pairs the installed fleet of MPFM’s with dedicated Emerson experts who utilize advanced analytics to remotely assess and interpret data. This provides actionable insights to improve reliability, safety, performance and meter verification. Data acquisition and representation of data is fully automated and expert time is only used to analyze the data and report on possible issues, together with recommended actions that will optimize meter performance. With Performance Monitoring Services operators can take full advantage of a broad range of expertise, technology and capabilities. Emerson’s consistent tools and proved processes that will enable a proactive maintenance approach that maximizes uptime.

The Performance Monitoring service results in comprehensive installed base overviews, recommended actions like meter cleaning, empty pipe calibration, replacement of parts and flagging meters operating outside its defined operating domain. Based on analysis, operators will receive actionable insight into the health of Roxar 2600 Multiphase Flow Meter. The data collection also centrally stores complete configuration data for each MPFM and tracks changes made to these parameters. This allows for a clear auditing trail required when the meter is used for allocation purposes. This data is securely stored in the cloud and available on request.

### Roxar 2600 Multiphase Flow Meter Performance Monitoring Process

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<td>Diagnostic and time-series data is interpreted to verify meter performance (direct meter verification, base line verification, anomaly detection)</td>
<td>Monthly report reviewed by customer and Emerson team</td>
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<tr>
<td>Software Configuration and Test</td>
<td>Communication of urgent issues seen with meter performance (Phone/MS Teams Site)</td>
<td>Weekly engagement on performance – discussion and action plan for resolving individual meter issues (1 hr/week)</td>
</tr>
<tr>
<td>Online Diagnostics Configuration for Edge Gateway</td>
<td>Peer review for accuracy and consistency</td>
<td>Action plan for specific events (shutdown maintenance, new software release, etc.)</td>
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<tr>
<td></td>
<td>Monthly formal reports generated, containing summary of overall performance in the customer installed base and actionable insight related to anomalies detected</td>
<td>Semi-annual Care Review / Review meters monitored</td>
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Summary

Operators now receive online expert advice to optimize their meter operations and verify the MPFM. Regular ongoing data sharing enables an effective maintenance strategy focusing the attention where and when it is needed.

Emerson multiphase flow meter expert knowledge is maintained on a global scale and can be leveraged and used more effectively when data is shared. This leads to higher quality MPFM measurement and to correct revenue allocations – vital when operators share royalties from the field. The burden of meter verification, full traceability of changes and calibration, often required by governing standards for revenue allocation can be done remotely.

The right expertise is critical to operations, but it is costly to develop experts and tough to retain them. Even when experts are available, their time is often stretched thin. Emerson Connected Services pairs Operators’ teams with Emerson Roxar 2600 Multiphase Flow Meter experts who utilize advanced analytics to remotely assess and interpret data from the meter and provide actionable insights to improve reliability, safety, performance.

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