Calibration or proving of flowmeters can have a serious impact on the operation of a metering system in the field. Sending flowmeters to a calibration laboratory is costly and time-consuming. Including a pipe prover in the metering system offers a good alternative, with the possibility of checking the meter’s accuracy under actual (process) conditions. The Manual of Petroleum Measurement Standards (MPMS) of American Petroleum Institute (API) describes various methods for the calibration of pipe provers. One of these methods is the master meter method, which is not often used in practice, even though it offers some serious advantages compared to the more often used water draw method.

The Azerbaijani company AzMETCO specialises in providing services for the automation of production processes in the oil and gas industry, and is one of the few companies that also offer the master meter method. In this article, Shukur Aghazadeh, General Director at AzMETCO, and Erik Smits, Senior Metrologist Liquid Flow & Volume at VSL, the National Metrology Institute of the Netherlands, provide insight into the various pipe prover calibration methods and the master meter method in particular.

API MPMS describes three methods for calibration of pipe provers: the gravimetric method (API MPMS 4.9.4), the water draw method (API MPMS 4.9.2) and the master meter method (API MPMS
In his work, Smits has seen the pros and cons of these calibration methods. At the most recent meeting of the European Flow Measurement Workshop, he held a presentation about the various calibration methods of pipe provers and the considerations for choosing one or the other.

The most commonly used method for calibration of a pipe prover in a flow metering systems in the field is the water draw method; the gravimetric method is not very often used. Smits explains: “It is only possible to use the gravimetric method for small volumes at low flowrates, and the required conditions can only be met by bringing a mobile laboratory to the site.”

The master meter method is not applied as often as the water draw method but, according to Smits, this is due to the fact that the master meter method is not very well known and not many suppliers offer this option. He notes that “in the terms of contracts for custody transfer, the water draw method as a rule is explicitly mentioned, and I think that in most cases this is only because this method is offered more often, and not necessarily because it is the best option.”

Aghazadeh adds to that, explaining how the calibration procedure using the water draw method is more complex, time-consuming and requires extensive material costs.

**Uncertainty of metering systems**

Calibration is all about staying in control of measurements, thus assuring a high level of confidence in the results. Traceability of measurements is essential to achieve this. For almost all flow measurement systems, traceability starts with the standards of mass that are maintained by National Metrology Institutes, such as VSL (the Netherlands) and NIST (USA). Directly traceable to these standards – only one uncertainty level down from these standards – are the weighing balances and test measures used at these institutes. Both the gravimetric method (which is traceable to mass) and the water draw method (which is traceable to volume) are found on this level, securing low measurement uncertainties. The master meter method is found one level further down.

<table>
<thead>
<tr>
<th>Uncertainty of measurement system</th>
<th>Low (%)</th>
<th>Average (%)</th>
<th>High (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe prover calibration uncertainty (base line)</td>
<td>0.02</td>
<td>0.05</td>
<td>0.07</td>
</tr>
<tr>
<td>Stability of pipe prover calibration volume(s)</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flowmeter calibration/proving</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stability of flowmeter between proving</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design errors</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stability due to changing conditions (in and outside of pipe)</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall measurement uncertainty of metering system</td>
<td>0.149</td>
<td>0.156</td>
<td>0.164</td>
</tr>
</tbody>
</table>

*Measurement uncertainties for the pipe prover (low, average or high)*

Immediately before and after the calibration runs the master meter is calibrated with a master prover or proving tank. Smits believes this might suggest that the gravimetric and water draw method are better – in other words, have a better uncertainty. However, this is not necessarily the case. He reveals that, in fact, many more factors impact the measurement uncertainty of a field unit, and that the calibration method is only one of them. Fundamentally, this holds for all fluids, but particularly when working with a complex liquid such as crude oil, other factors will add considerably to the uncertainty budget.

This is illustrated in Table 1, which shows typical values of uncertainty contributions to the overall measurement uncertainty of the metering system. Clearly, the impact of the calibration uncertainty to the overall measurement uncertainty in the field is limited. The measurement uncertainties are determined by various parameters, such as the design (geometry, flowrate/profile, upstream pipes etc.), fluid properties (viscosity, density, temperature, pressure, homogeneity etc.), instrumentation (temperature and pressure transmitters, flow computer etc.), calculations and the use of standards (fluid property data etc.).

Smits notes: “Before choosing the calibration method, it is important to check the achievable accuracy of the metering system. When the measurement uncertainty for the metering system is large in itself, there is no need for a pipe prover calibration with low measurement uncertainty, as in that case the calibration method is not the determining factor of the overall measurement uncertainty.”

**Field conditions**

Taking this into account, the most suitable calibration condition for the pipe prover volume is the one that comes as close as possible to the actual field conditions. After all, using a model liquid (such as water) or conditions differing from those in the field, lead to an extra translation step, with a corresponding added uncertainty to the performance and stability of the pipe prover in the field. The gravimetric method and the water draw method can only be applied at low flowrates, and the calibration is done only with water. These are two big differences with the actual process conditions. The use of water also has a practical implication, in that the process liquid should be drained from the metering system and the system should be filled with water and after the calibration this should be done in reverse. This not only means a lot of work and cleaning (for obtaining the required purity of water), but also causes serious risk in terms of corrosion of the system.

For example, Smits considers how replacing or repairing a four-way valve of a pipe prover means a huge unaccounted-for investment. This is a serious risk. Moreover, the pipe prover might be out of service for a period of time, during which the meter factors of the flowmeter(s) in the system could shift and cause tangible commercial losses due to incorrect measurement of the liquid passing through the system.

Aghazadeh agrees, stating: “Our customers experience difficulties because of the inability to use the field prover for calibration of flowmeters with process liquid, while rinsing and
cleaning of the field prover for calibration by the water draw method.”

Smits continues, explaining that, in most cases, the master meter method uses the process liquid of the system. This means that the results directly relate to the field situation and, therefore, a much better determination of the performance of the metering system is obtained. Furthermore, the system does not have to be drained, cleaned and filled twice, and there is no risk of corrosion. Additionally, if the calibration system equipment allows for it, field prover calibration is performed at several flowrates, in accordance with API MPMS 4.9.3. Corresponding with this standard, operational conditions are continuously checked, including flowrates, temperature, pressure and density.

**Counting pulses**

While the water draw and gravimetric methods measure the volume or mass between start and stop switches by collecting water in predefined field volume or by weighing measures, the master meter method counts pulses between the switches.

Smits explains that this makes the measurement more dynamic and allows for the use of more than one pair of detectors per calibration run. The detectors are turned on and off by the prover’s sphere passing the switches, which comes much closer to field conditions.

**Which method to choose?**

Considering the benefits of the master meter method brings us back to the question: which of the methods is the best one? When the impact is small, one can select the calibration method that suits the location of the pipe prover best, and select a service company that can perform the calibration in the desired way.

“We use the water draw method in the AzMETCO laboratory only for calibration of our master prover, in order to ensure low uncertainty in its volume. Taking into account the earlier mentioned circumstances, the complexity, the time it takes and the expenses involved, AzMETCO calibrates the field provers in the Azerbaijan-Georgia-Turkey region using the master meter method. We have over 20 years of experience using this method in accordance with API standards. The master prover allows us to calibrate several field provers in a short time and with lower expenses. Therefore, we consider our master meter method, using our mobile master prover and process fluid, the most suitable for calibration of pipe provers,” states Aghazadeh.

Smits concludes: “When the required measurement uncertainty of the metering system is medium to high, there is no need for a pipe prover calibration with low measurement uncertainty. I always advise to choose a calibration method that meets your needs and not the needs of the service provider.”

The topics addressed in this article are amongst the many that will be discussed at the 6th European Flow Measurement Workshop, which will take place in Barcelona from 16 - 19 April 2018.