High Accuracy Metering Applications

Custody Transfer and Fiscal Measurement: Lots of money is at stake

Leak Detection: Pipeline Integrity is critical

Allocation: Companies and their assets are audited

The technology is available to reduce uncertainty
Custody Transfer and Fiscal Measurement

- Custody Transfer – Governed by OIML R117 and API 5.8 Standards – clear installation and performance guidelines?
- Fiscal Measurement – Controlled by government standards that take precedence over OIML or API, but usually incorporate similar performance
- Both situations demand the highest level of performance from the meter during calibration
- Installations are typically proved in-situ

Leak Detection

- Traditionally higher uncertainty is accepted, this trend is changing
- Huge environmental impact can result from poor measurement
- Both wetted and clamp on installations have been implemented
- Usually not proved installations, so installation effects must be considered in overall uncertainty
Industry trend: High accuracy flow meters

Traditional
• Turbine meters
• Positive displacement (PD) meters

State-of-the-art technologies
• Ultrasonic meters
• Coriolis mass meters

The drivers for change to Ultrasonic

Energy costs
• High pressure drop costs money

Installation costs
• Hardware demands for metering skids

Advanced Diagnostics
• Insight into pipeline conditions

Maintenance costs
• Long-term performance
• Higher uptime

Refinement of measurement standards
• OIML R117-1
• API Chapter 5.8
Recognizing flow profile

Problem:
- Flow in a pipe is not always “flat” or uniform
- Due to wall friction a flow profile is present
- Profile depends on flow velocity, viscosity, i.e. Reynolds Number!

Solution:
- Recognizing flow profile for final correction
- Calibration on multi fluids to cover required Reynolds range

• Based on velocity difference between inner and outer cords
• Chord ratio = (2+3)/(1+4)
• Chord ratio is directly proportional to flow profile and Reynolds number
Calibrating High Accuracy Meters

• Water
  • Reference can be gravimetric, master meter, or prover
  • Limited Reynolds Number Range

• Oil
  • Reference is typically prover or master meter
  • Full Reynolds Range Available for most applications

Correction Factors for Applications

Velocity Range
• Based on Flow Rate only
• Very Linear Correction
• Correction used in field proving with flow computer

Reynolds Range
• Either based empirically on Reynolds or on Profile Factor
• Not so linear…
• Accounts for changing conditions
Calibration vs Velocity

Calibration vs Reynolds
24” Meter Test for OIML Approval

24” Sentinel LCT Combined Performance Results

Reference Velocity (ft/sec)
Want to make life easy?

...Use Large Meters!

- Large defined as greater than 24” diameter
- Available calibration facilities are typically limited to water at these sizes
- For refined products – great – Reynolds or profile correction can be used!
- For crudes – trending must be closely monitored to get a sense of true performance

Calibration of 32” LCT meter at USU Water Research Lab
36” Meter Calibration

Leak Detection Applications

Water Calibration?
- Large meters >24” are often used
- Typically repeatability is monitored, looking for trending that would indicate a leak

Multi-Viscosity Calibration?
- Reynolds number for pipeline applications rarely can be matched using water
- Installations are rarely proved – so uncertainty of installation must be considered!

Multi-Viscosity will provide the lowest uncertainty, but what is the uncertainty you can live with?
Proved Installations

- Provers mitigate installation uncertainty
- Correction is made vs. flow rate
- API 5.8 tables are typically used in the field
Proved installations

- Water calibration is transferable if it covers the Reynolds range
- If Reynolds is not used, there will be errors outside of the proved flow rate when conditions change in between proves
- Multi-Viscosity calibrations can reduce errors by covering the Reynolds range...

...However – it’s not always easy...

4" LCT4 Meter Data
Jet Fuel Application
Data on Single Fluid Calibration

- Meter calibrated on Water at VSL to match Jet Fuel application

<table>
<thead>
<tr>
<th>Reference Flow-rate (m³/h)</th>
<th>Indicated Flow-rate (m³/h)</th>
<th>Measurement Error [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>293.41</td>
<td>293.38</td>
<td>-0.01</td>
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<tr>
<td>293.30</td>
<td>293.38</td>
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<td>293.32</td>
<td>293.39</td>
<td>-0.01</td>
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<td>240.20</td>
<td>240.12</td>
<td>-0.03</td>
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<td>240.17</td>
<td>240.11</td>
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<td>240.10</td>
<td>240.01</td>
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<td>135.81</td>
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<tr>
<td>17.412</td>
<td>17.614</td>
<td>+0.91</td>
</tr>
</tbody>
</table>

Multi-Viscosity Calculator

Example

Reynolds Range 4,200 to 200,000
Multi-Viscosity Calibration Results

% Error

Nominal Flow Rate (m/s)
MV Flow Calibration Setup

Calibration performed against Trapil’s large (10m³) ball prover.

Meter Performance

API Repeatability Criteria for verification at 2 flow rates

<table>
<thead>
<tr>
<th>Flow Rate m³/h</th>
<th># of Prover Runs</th>
<th>Meter Repeatability %</th>
<th>API Criteria %</th>
</tr>
</thead>
<tbody>
<tr>
<td>512</td>
<td>7</td>
<td>0.07</td>
<td>0.08</td>
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<tr>
<td>860</td>
<td>16</td>
<td>0.17</td>
<td>0.18</td>
</tr>
</tbody>
</table>

OIML Criteria – 0.12% in 3 runs

- API provides better uncertainty, but verification at 6 flow rates can sometimes take many runs
- Temperature can be problematic, especially on higher viscosity fluids
Does proving at the lab really mimic the field?

Temperature, piping, flow conditioning, changing valve settings?

Example of what happened in our lab

Small Water Test Loop

Water Tank

Master Meter (Turbine)

Chiller

LUSM under Test
Small Water Test Loop

Pump

Small Volume Prover

10 Prover Runs, n Passes - Repeatability vs. Flow Rate - Baseline
Conclusions

• Flow calibration should always be tailored to the application to insure expectations are met
• Be sure to understand how this will take place – the earlier the better
• Make sure to understand what the correction will be giving you
• Things can happen – even at the best facilities!
• Understand the limits of facilities – time, etc.
• Don’t be afraid to enlist the help of metrology experts