LNG Flow Calibration

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Outline

• Flowmetering good alternative for tank level gauging?
• Examples of LNG flowmeters
• Performance demonstration - test and calibration
• Three step approach towards traceable LNG flow
• Primary flow standard prototype design
• Primary flow standard – first test results
• Primary flow standard – ideas for improvement
• Bootstrapping – the upscaling principle
• Industrial scale calibration facility – brief outlook
• Conclusions
Tank gauging vs flowmetering

Tank based measurement: state-of-the-art in LNG custody transfer

- Expanded uncertainty (k=2) 0.42% (GIIGNL custody transfer handbook 3rd edition)
- Ship based measurements
- Tank strapping => tank deformation => errors in tank tables
- Tank level gauging: Floating, microwave radar, electrical capacitance, laser
Tank gauging vs flowmetering

Flow metering: state-of-the-art in other hydrocarbon custody transfer

- LNG flowmeters commercially available and thus far used in special projects, process monitoring and LNG terminal pilot studies
- Expanded calibration uncertainty ($k=2$) 0.4 - 0.5% based on water and LN2 calibrations
- Potential calibration uncertainty ($k=2$) with real LNG reference system ~0.2%
- Flowmeters as alternative for verification of off-shore tank measurements
- For off shore LNG applications (FPSO – Floating Production Storage Offloading)
Flowmetering principles

**Requirement for small pressure drop: Reducing pumping power consumption and flashing**

- Ultrasonic or coriolis meters match the requirements best.

**Ultrasonic flow meter**

- Very small pressure drop
- Minimum diameter required for accurate measurements
- Available in large diameters up to 40”
- Volume measurement – still requiring density measurement
- Sensitive to flow profile (multi-beam USM can partly correct for flow disturbancies)

**Coriolis mass flow meter**

- Pressure drop significant when used at Qmax (so don’t use at Qmax!)
- Very accurate also for small flows and diameters
- Practical upper limit: about 10” (need to use flow meters in parallel)
- Direct mass measurement – no need to measure density
- Not very sensitive to flow profile
Demonstrating performance

Pattern testing

- Tests for maximum errors – flowrate, accuracy, repeatability, stability
- Tests for maximum errors – minimum measured quantity, flow disturbance
- Installation effects
- Material properties

Flow meter calibration

- Instrument error
- Reference standard
- Uncertainty statement
Demonstrating performance

LNG flow meter calibration and testing capabilities

- LNG terminal application (4,000-10,000 m³/h)
- Water flow calibration capabilities
- Small scale LNG application (10-300 m³/h)
- Liquid nitrogen flow calibration capabilities (5-45 m³/h) NIST
Demonstrating performance

LNG flow meter calibration and testing capabilities

• Real LNG calibration at any scale not available anywhere in the world

• Claimed measurement uncertainties are estimated conservatively at 0,4 – 0,5%

• Real LNG testing at large scale:
  – 2005: LNG facility in Kenai Alaska (Mullaly et al., 2007; Brown et al., 2008)
  – Flow meters compared with calibrated storage tanks; measured volumes in agreement to within ±0,5%
  – Flowmeters were not calibrated
  – Repeatability flowmeters down to ±0,15%
Traceable LNG flow metering
Three step approach

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Range</th>
<th>Target uncertainty (k=2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Primary LNG mass flow standard (2008 – 2011)</td>
<td>5 - 25 m³/h</td>
<td>0,05%</td>
</tr>
<tr>
<td>2</td>
<td>1st stage upscaling standard (2011/2012)</td>
<td>25 - 200 m³/h</td>
<td>0,07%</td>
</tr>
<tr>
<td>3a</td>
<td>Design large scale flow standard (2010/2011)</td>
<td>100 – 7,000 m³/h</td>
<td>&lt; 0,15%</td>
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<td>3b</td>
<td>Realisation large scale flow standard (2012/2013)</td>
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Primary LNG mass flow standard
Primary LNG mass flow standard

First test results using LN2

Large deviation at small measurement times due to switching effect
Primary LNG mass flow standard

First test results using LN2

Deviation < ±0,4% at longer measuring times ≥40 s
Primary LNG mass flow standard
Preliminary uncertainty estimate

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Value ( \text{kg} )</th>
<th>Std unc. ( \text{kg} )</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Mass balance reading:</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum of corrections related to <strong>ambient conditions</strong></td>
<td>0</td>
<td>0.088</td>
<td>0.03</td>
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<td>Sum of corrections related to <strong>displaced gas</strong></td>
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<td><strong>Corrected mass balance reading</strong></td>
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Expanded uncertainty (\(k=2\), 95%): 3.268 kg = 1.07%

**Target uncertainty is still 0.05%**
Primary LNG mass flow standard
Ideas for improvements

As is situation around weighing device
Primary LNG mass flow standard

Ideas for improvements

First phase:
1) tubing with higher flexibility
2) neutralizing horizontal forces
Primary LNG mass flow standard

Ideas for improvements

3) Vertical displacement compensator
Primary LNG mass flow standard

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1st stage upscaling standard
Bootstrapping

RM = Reference Meter

1st stage information

2nd stage information

LNG in → RM → RM → RM → RM → RM → RM → RM → RM → RM → RM

LNG out
Full upscaling
Full upscaling
Targeted location:
- Gasunie peak shaving terminal, Rotterdam, Europoort, NL
- 100,000m³ LNG, 19,000m³ LIN Storage
- BOG compression, high pressure gas
LNG flow calibration
Conclusions

- Flowmeters are already available for LNG applications
- Traceability chain (calibration standards) under development
- Primary LNG flow standard operational with LN2 at 1% in 2010
- Primary LNG flow standard operational with LNG at 0.05% in 2011
- 1st stage upscaling (up to 200 m³/h) will be realized in 2012
- Full scale calibration facilities (flow & composition) are being planned (2013)
- International standards (ISO, API, GIIGNL, OIML) are expected to include LNG flow metering as a serious alternative