EMRP
European Metrology Research Programme
Programme of EURAMET
The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

EMPIR
EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

LNGIII project consortium

The EURAMET LNG metrology projects: SI-traceable measurement solutions for LNG

Menne Schakel – on behalf of the LNG III metrology project consortium

LNG METROLOGY



Introduction

- LNG
  - EU's energy security
  - EU's commitment to the Paris agreement

LNGIII project consortium



https://www.consilium.europa.eu/en/infographics/lng-infrastructure-in-the-eu/#:~:text=The%20EU's%20overall%20LNG%20import,40%25%20of%20total%20gas%20demand.

The EURAMET LNG metrology projects

- LNG: *Metrology for Liquefied Natural Gas* 2010 - 2013
  - https://www.euramet.org/research-innovation/search-research-projects/details/project/metrology-for-liquefied-natural-gas/
- LNG II: *Metrological support for LNG custody transfer and transport fuel applications* 2014 - 2017
  - https://www.euramet.org/research-innovation/search-research-projects/details/?tx_eurametctcp_project[project]=1215
- LNG III: *Metrological support for LNG and LBG as transport fuel* 2017 - 2020
  - https://www.euramet.org/research-innovation/search-research-projects/details/project/metrological-support-for-lng-and-lbg-as-transport-fuel/

The EURAMET LNG metrology projects – LNG



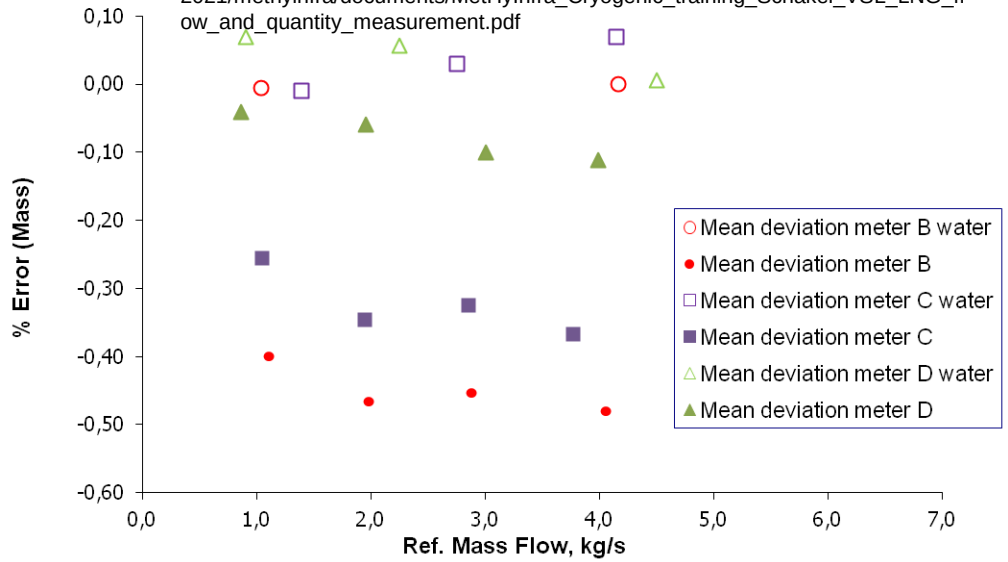
LNG final report

First LNG mass flow primary standard

First LNG flow meter calibration capability using primary standard

Significant difference LNG flow meter error between water and LNG calibration

- Van der Beek et al, Metrologia **51** (2014) 539–551
- https://www.methyinfra.ptb.de/fileadmin/documents/empir-2021/methyinfra/documents/MetHyInfra_Cryogenic_training_Schakel_VSL_LNG_flow_and_quantity_measurement.pdf



The EURAMET LNG metrology projects – LNG



LNG final report

Prototype cryogenic Laser Doppler Velocimetry system



LNG final report

Primary LNG densimeter

First studies into (uncertainty from) composition measurement systems

The EURAMET LNG metrology projects – LNG

International group of liquefied natural gas importers (GIIGNL): *Custody transfer handbook*

Energy = Volume x Density x Gross Calorific Value

$$u_E = (u_v^2 + u_\rho^2 + u_{gcv}^2)^{1/2}$$

Source of uncertainty	*Typical Values (k = 1)*	
Volume	0.10 % - 0.27 %	LNG flow meters
Density	0.23 %	LNG density; LNG composition
GCV	0.02 % - 0.04 %	LNG composition
Energy	**0.25 – 0.37 %**	*k* = 1 !!

The EURAMET LNG metrology projects – LNG II





LNG II final report

Create LNG calibration and test facility: volume, composition, density

Validation of cryogenic Laser Doppler Velocimetry system

Ultrasonic densimeter prototype

Use SI-traceable densitometer to validate and improve commonly employed equations of state for LNG density computation

First steps towards development of SI-traceable LNG reference mixtures

Methane number determination: relevant for LNG as transport fuel

The EURAMET LNG metrology projects – LNG III

Using LNG facility: extensive, representative calibration programme of LNG flow meters in cryogenic conditions

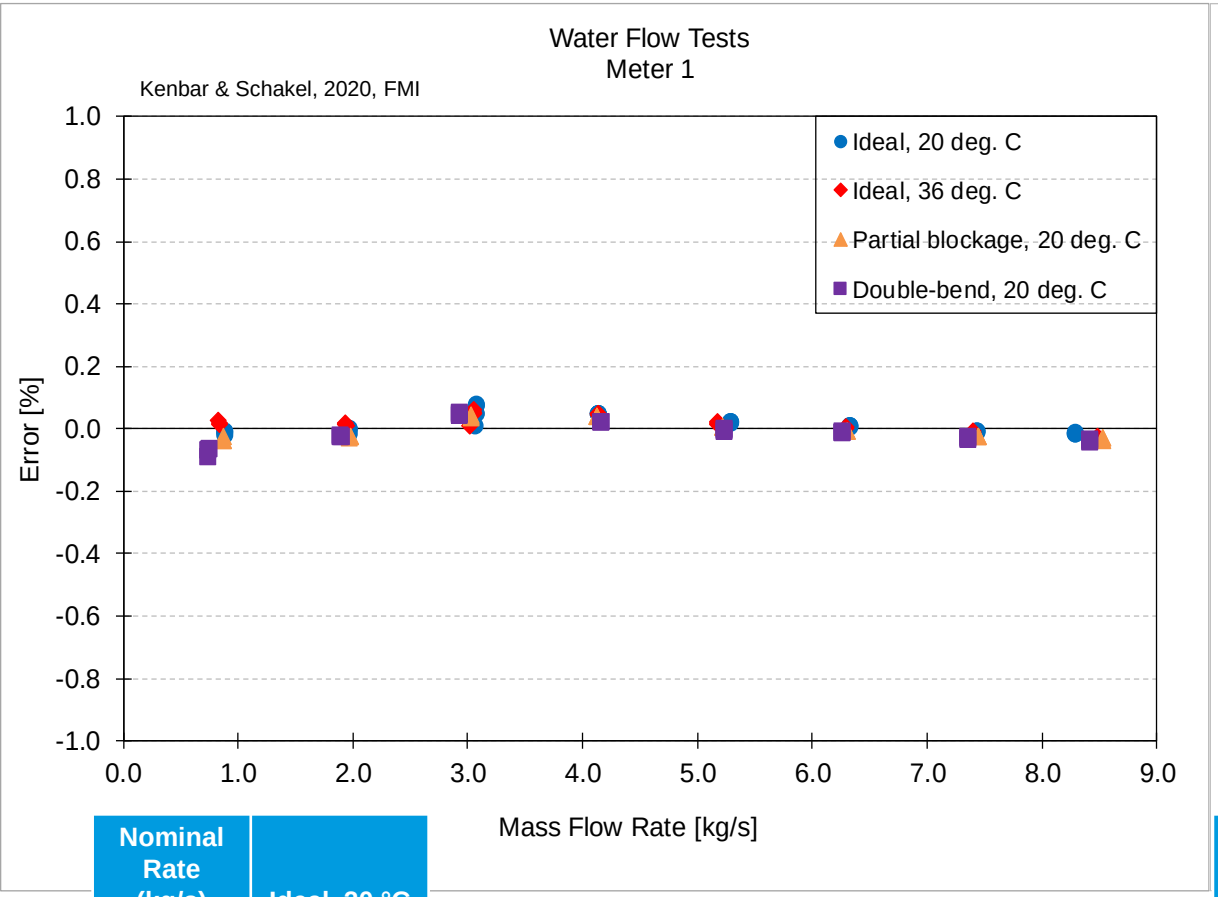
Significant differences of LNG flow meter error between water and LNG calibration were observed, see examples provided here

Systematic underreading of Coriolis Flow Meters: poses financial risk!

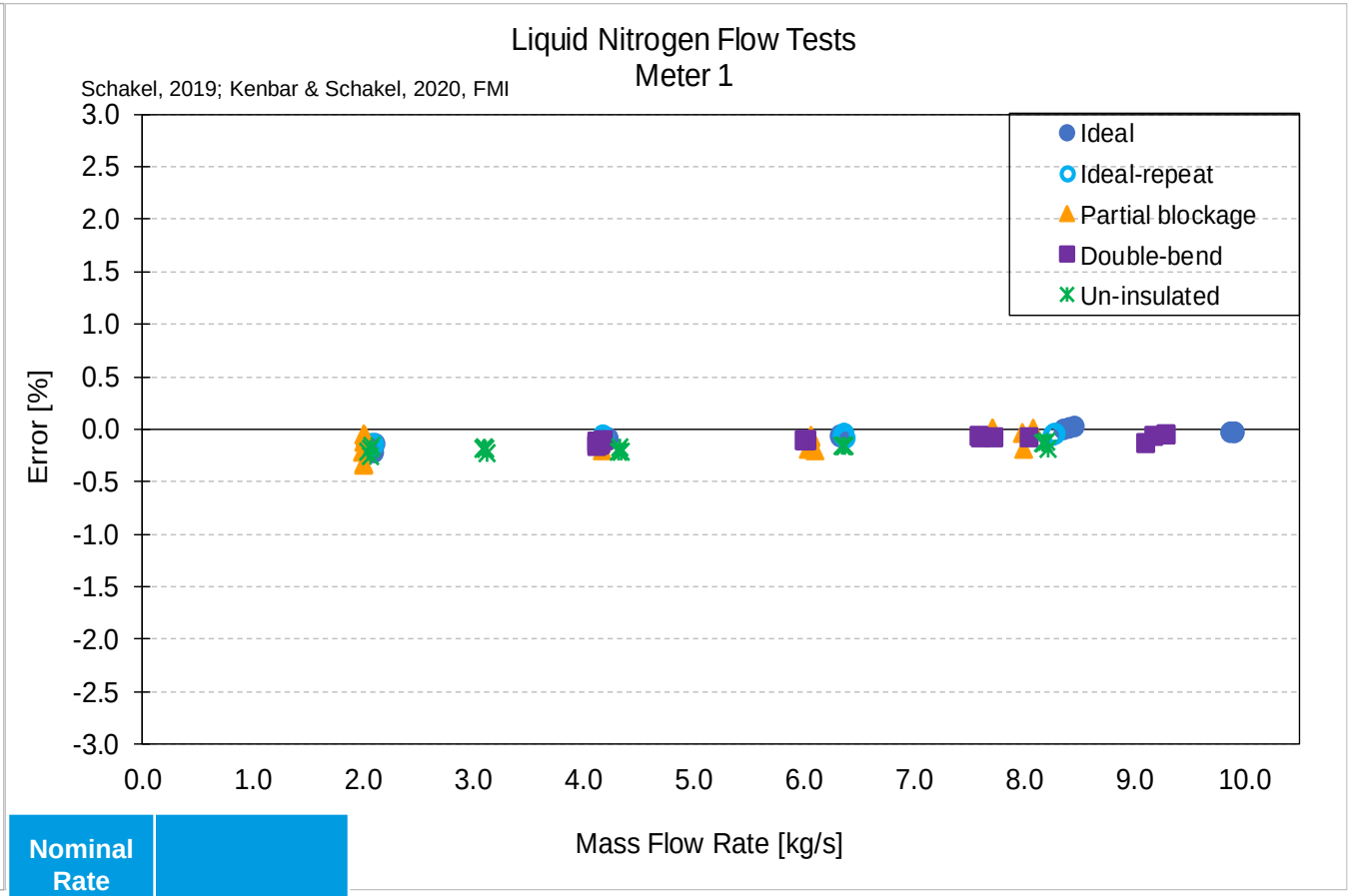
(Additional) meter insulation of Coriolis Flow Meters: has a strong effect!

Smits, 2021, *Global LNG Bunkering Experience* https://www.vsl.nl/en/lng/financial-risks-dynamic-lng-measurement

The EURAMET LNG metrology projects – LNG III



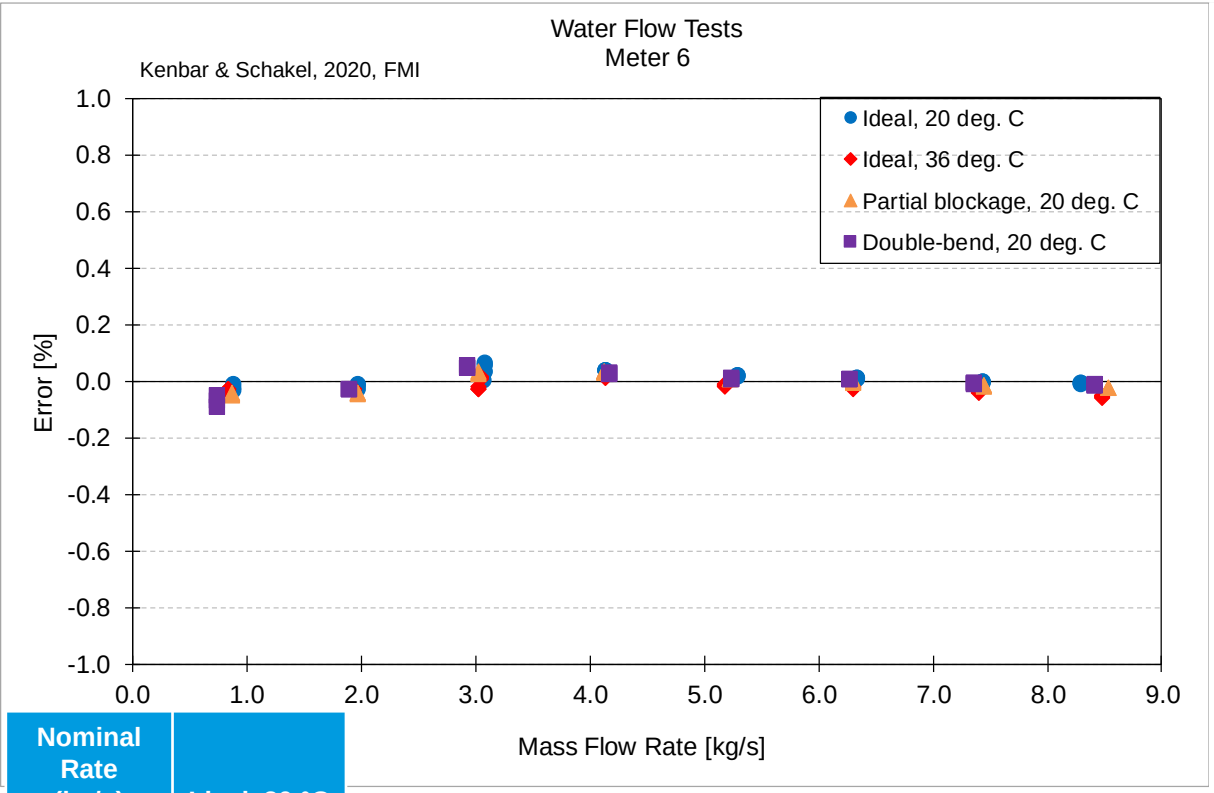
Nominal Rate (kg/s)	Ideal, 20 °C
1	-0.018
2	-0.010
3	0.048
4	0.044
5	0.017
6	0.004
7	-0.013
8.5	-0.018



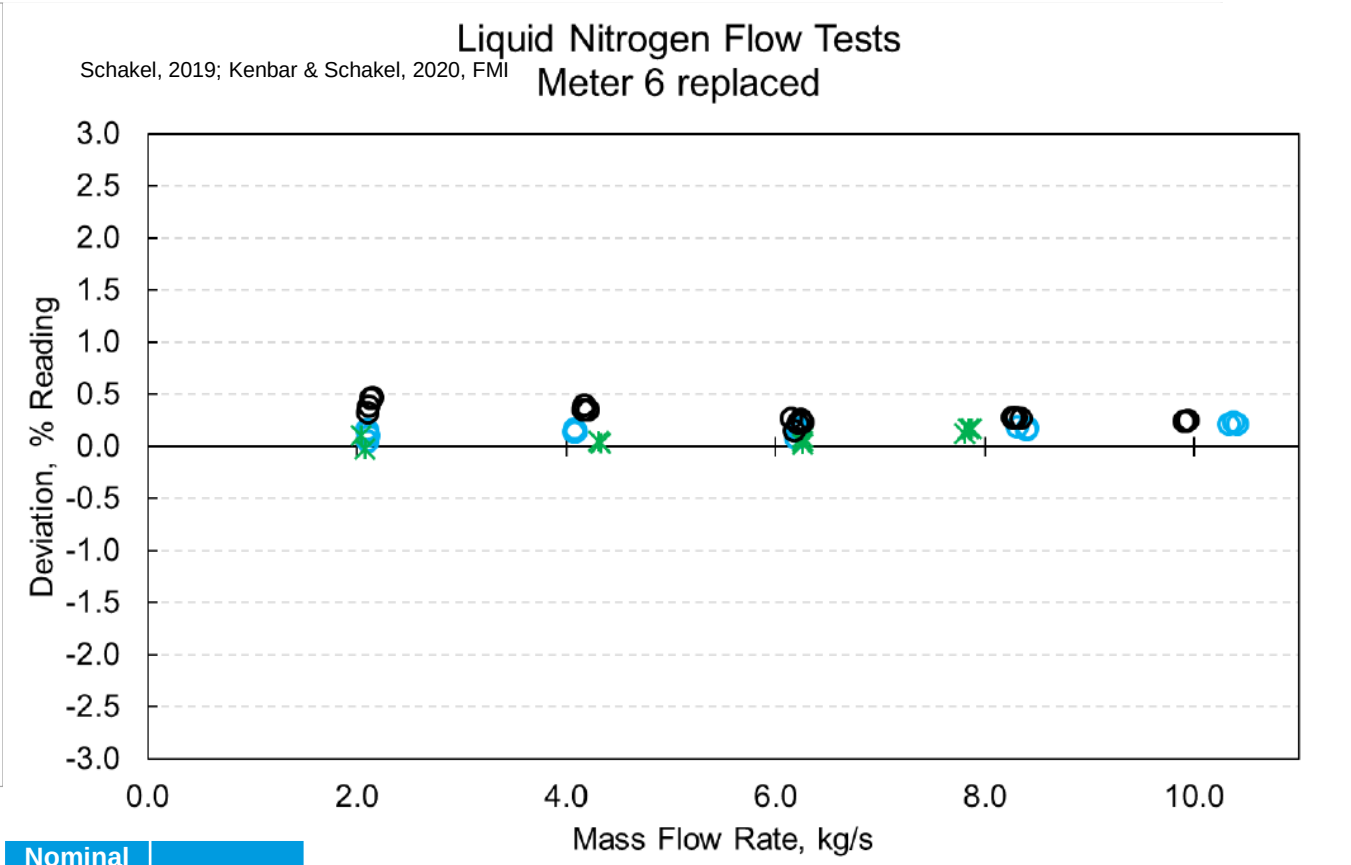
Nominal Rate (kg/s)	Ideal
2	-0.19
4	-0.10
6	-0.07
8	0.00
10	-0.04

Schakel, 2019: https://lngmetrology.info/wp-content/uploads/2020/01/Liquid-nitrogen-calibrations-of-industry-standard-LNG-flow-meters-used-in-LNG-custody-transfer_public_date_added.pdf

Water and LIN calibration results



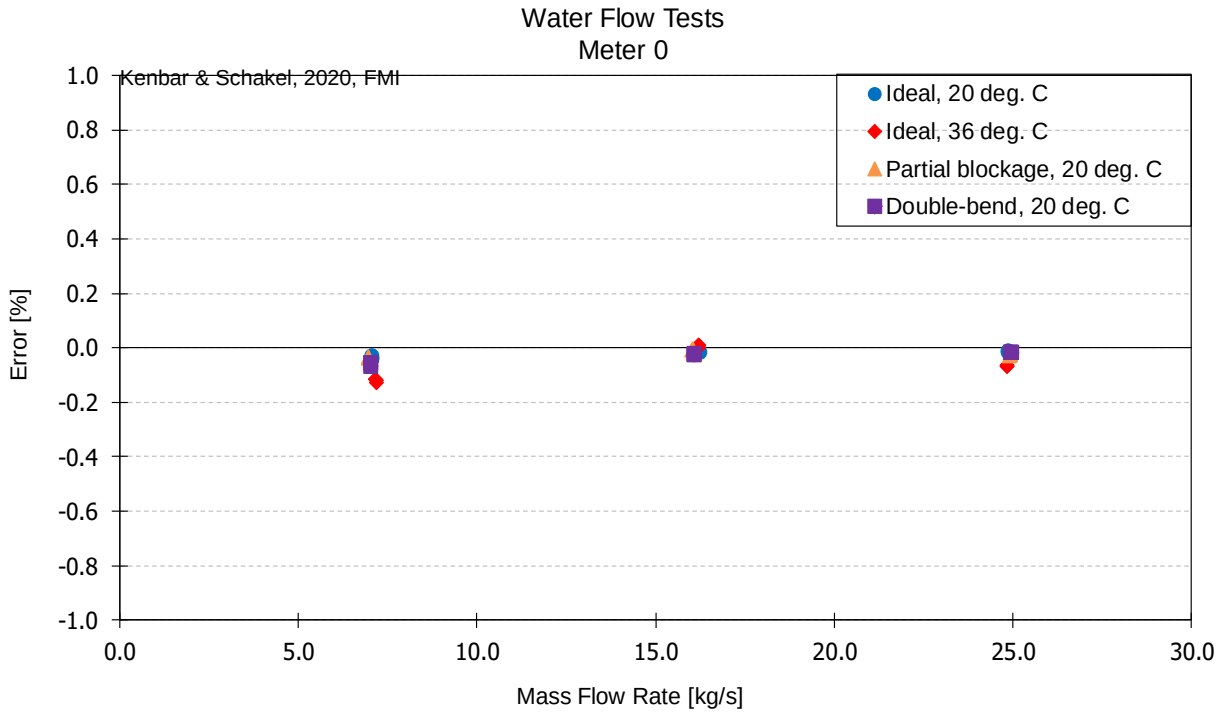
Nominal Rate (kg/s)	Ideal, 20 °C
1	-0.026
2	-0.020
3	0.036
4	0.036
5	0.016
6	0.007
7	-0.006
8.5	-0.010



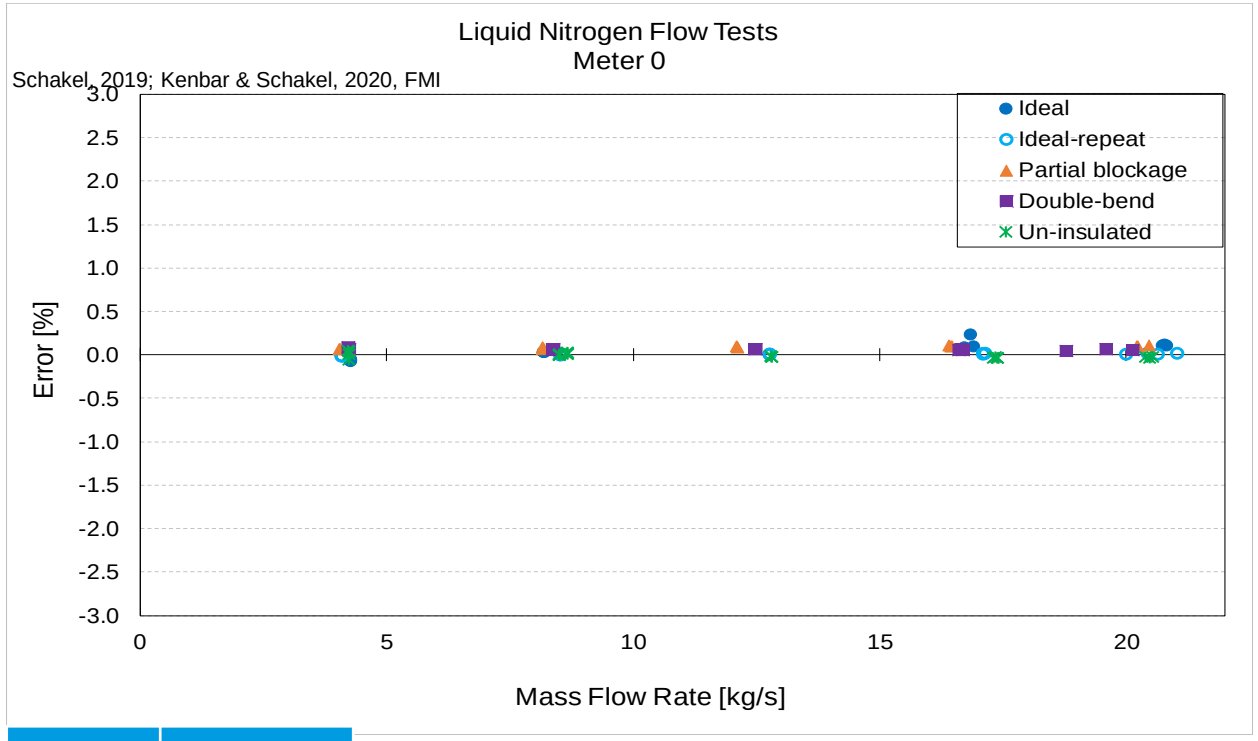
Nominal Rate (kg/s)	Ideal
2	0.26
4	0.44
6	0.52
8	0.60
10	0.59

Schakel, 2019: https://lngmetrology.info/wp-content/uploads/2020/01/Liquid-nitrogen-calibrations-of-industry-standard-LNG-flow-meters-used-in-LNG-custody-transfer_public_date_added.pdf

Water and LIN calibration results



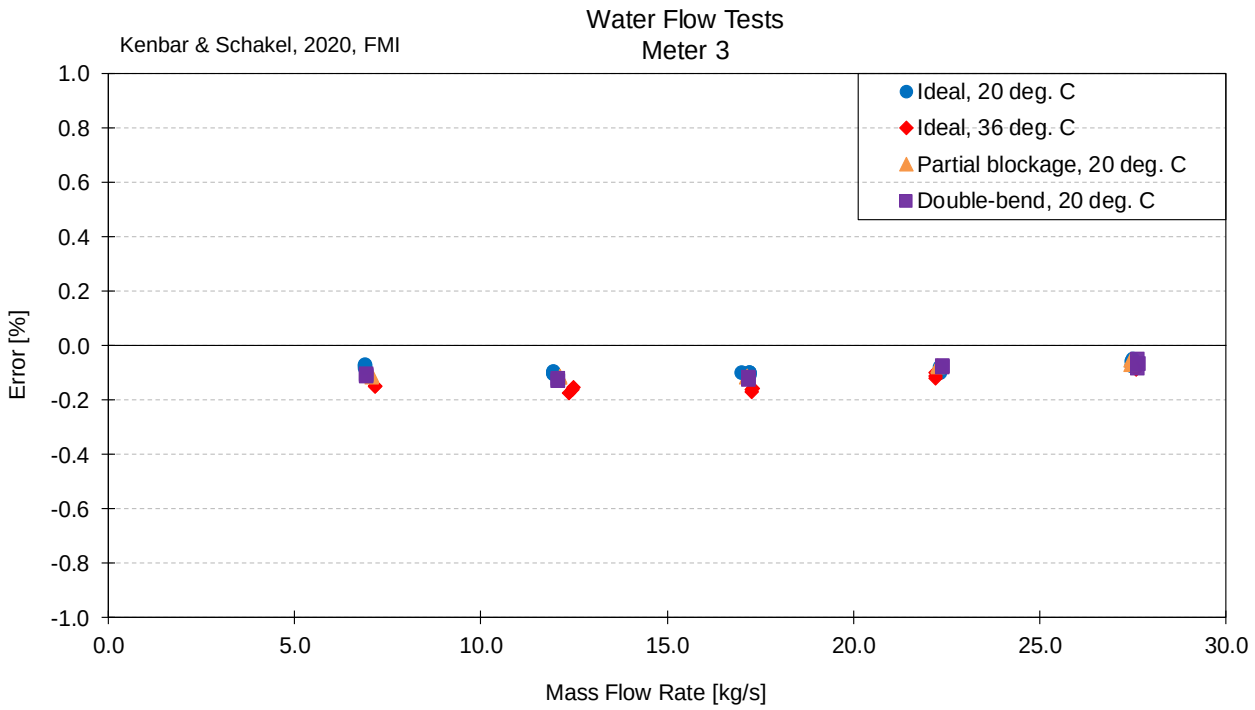
Nominal Rate (kg/s)	Ideal, 20 °C
7	-0.041
16	-0.017
25	-0.018
35	-0.012

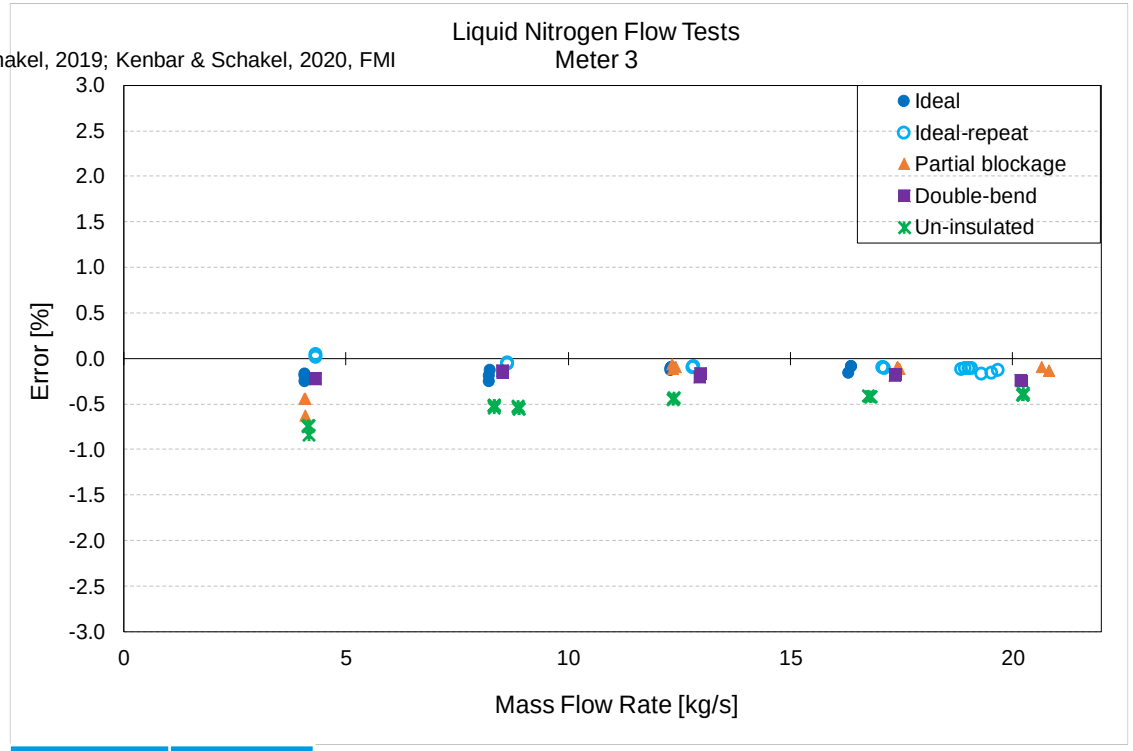


Nominal Rate (kg/s)	Ideal
4	-0.07
8	0.02
12	
16	0.13
20	0.10

Schakel, 2019: https://lngmetrology.info/wp-content/uploads/2020/01/Liquid-nitrogen-calibrations-of-industry-standard-LNG-flow-meters-used-in-LNG-custody-transfer_public_date_added.pdf

Water and LIN calibration results



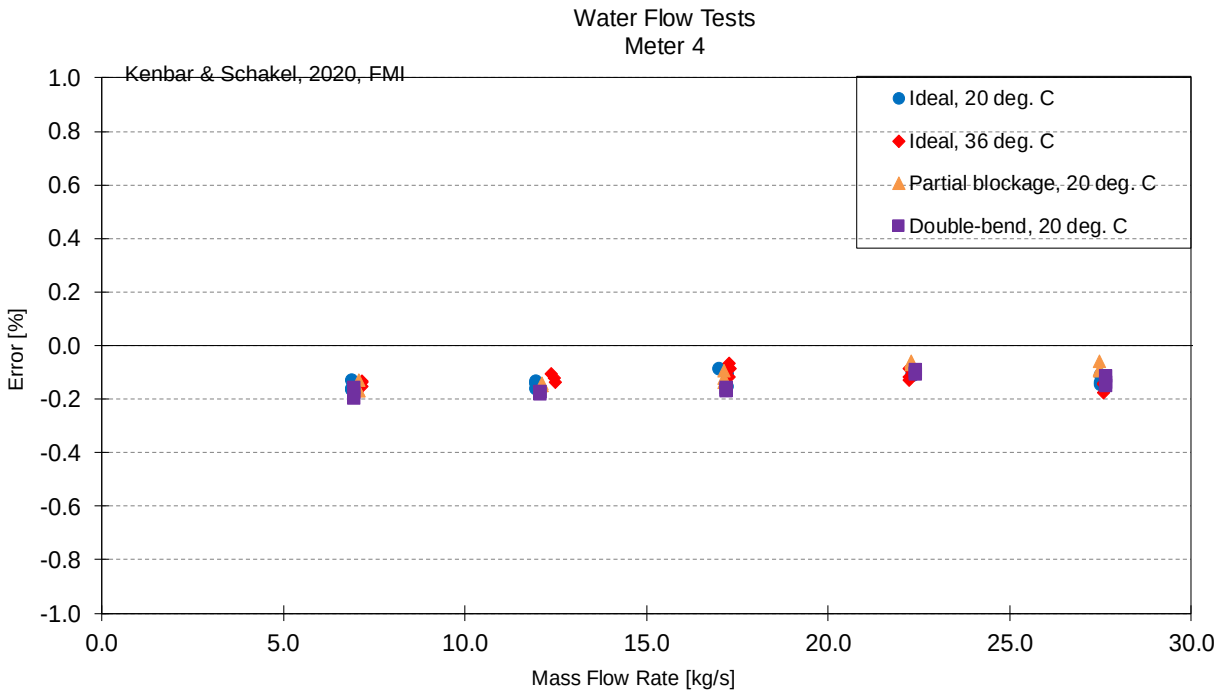


Nominal Rate (kg/s)	Ideal, 20 °C
7	-0.107
12	-0.115
17	-0.123
22	-0.145
28	-0.137

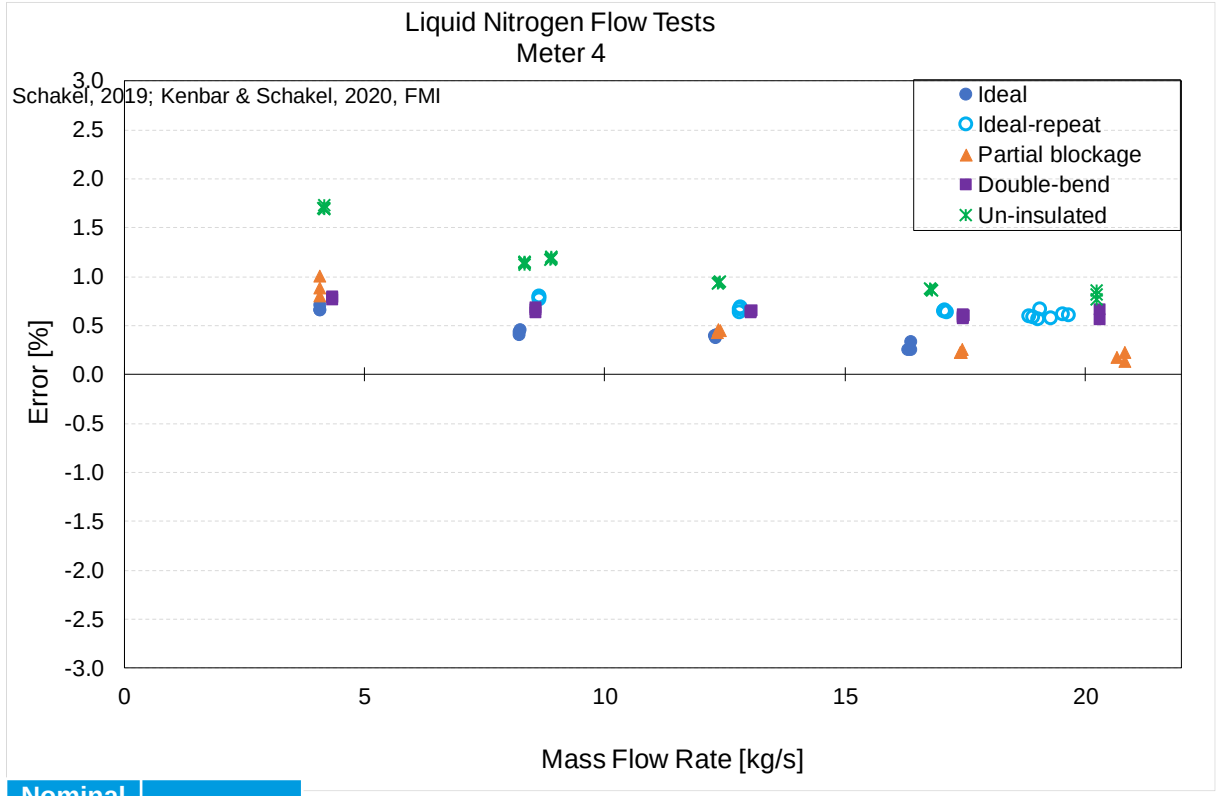
Nominal Rate (kg/s)	Ideal
4	-0.21
8	-0.20
12	-0.12
16	-0.12
20	

Schakel, 2019: https://lngmetrology.info/wp-content/uploads/2020/01/Liquid-nitrogen-calibrations-of-industry-standard-LNG-flow-meters-used-in-LNG-custody-transfer_public_date_added.pdf

Water and LIN calibration results



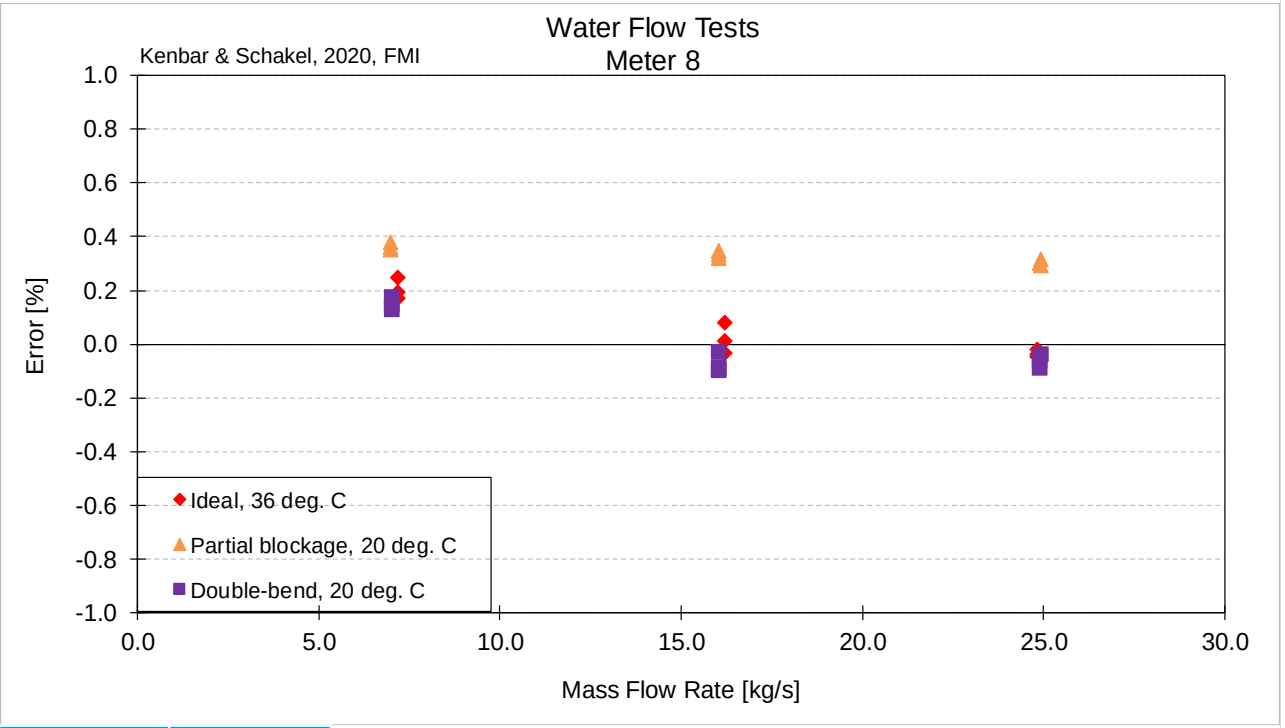
Nominal Rate (kg/s)	Ideal, 20 °C
7	-0.155
12	-0.148
17	-0.118
22	-0.111
28	-0.135



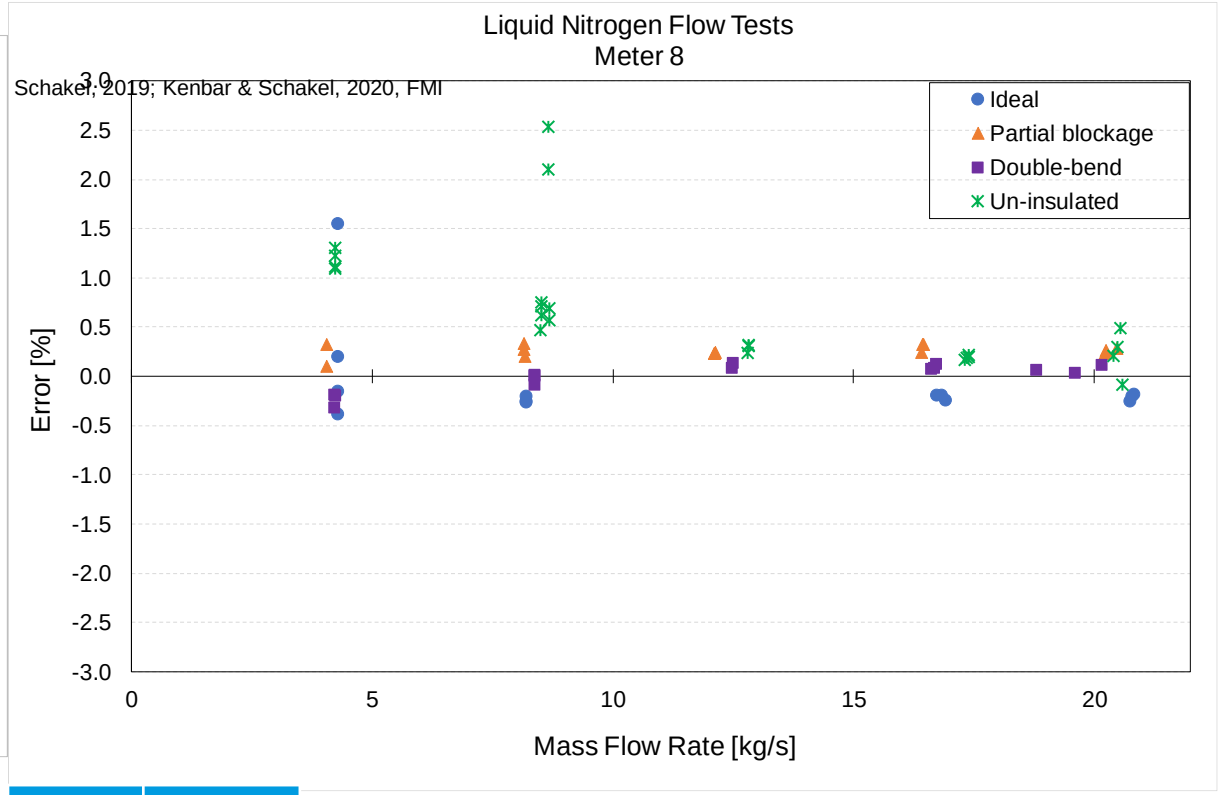
Nominal Rate (kg/s)	Ideal
4	0.67
8	0.43
12	0.38
16	0.27
20	

Schakel, 2019: https://lngmetrology.info/wp-content/uploads/2020/01/Liquid-nitrogen-calibrations-of-industry-standard-LNG-flow-meters-used-in-LNG-custody-transfer_public_date_added.pdf

Water and LIN calibration results



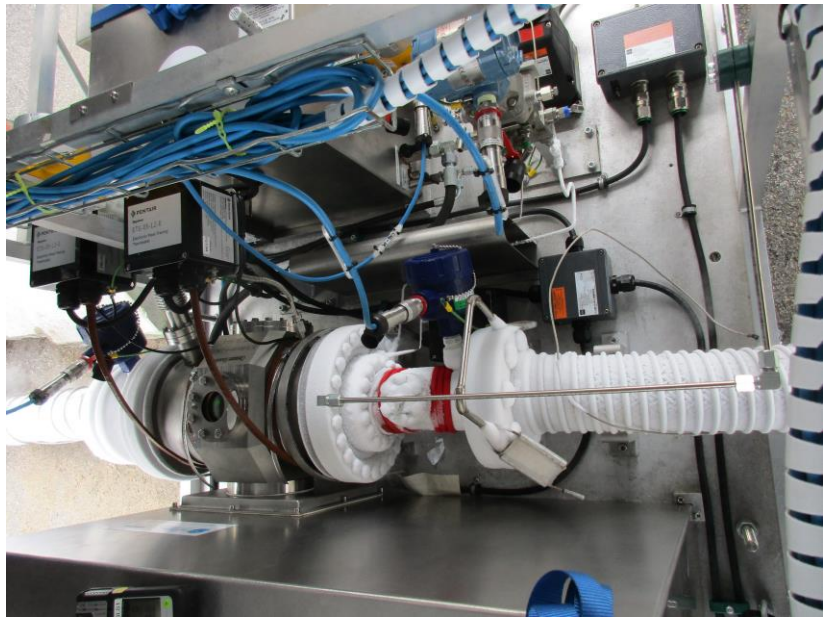
Nominal Rate (kg/s)	Ideal, 36 °C
7	0.204
16	0.021
25	-0.035



Nominal Rate (kg/s)	Ideal
4	0.29
8	-0.25
12	
16	-0.22
20	-0.22

Schakel, 2019: https://lngmetrology.info/wp-content/uploads/2020/01/Liquid-nitrogen-calibrations-of-industry-standard-LNG-flow-meters-used-in-LNG-custody-transfer_public_date_added.pdf

The EURAMET LNG metrology projects – LNG III



https://www.methyinfra.ptb.de/the-project/ *State-of-the-art in traceable cryogenic flow measurement training*

Validated cryogenic Laser Doppler Velocimetry system at LNG terminals

In-situ SI-traceable flow meter calibrations

Journal home > Journal updates > 2022 Ared Cezairliyan Best Paper Award

2022 Ared Cezairliyan Best Paper Award



It is our great pleasure to announce that in recognition of an outstanding contribution to the field of thermophysics research

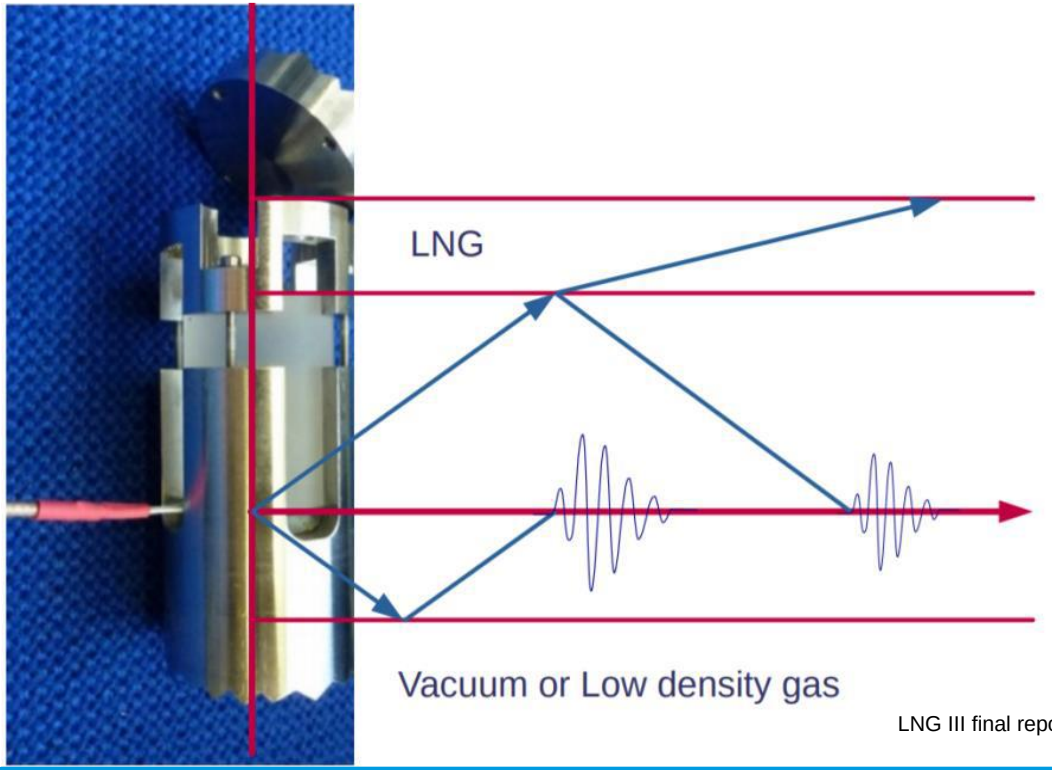
2022 Ared Cezairliyan Best Paper Award

is awarded to the paper titled "***Density Measurements of Two Liquefied Biomethane-Like Mixtures over the Temperature Range from (100 to 180) K at Pressures up to 9.0 MPa***", International Journal of Thermophysics **42**:43 (2021)

authored by

- Giuseppe Cavuoto, INRIM: Istituto Nazionale di Ricerca Metrologica, Italy
- Nils von Preetzmann, Ruhr-Universitat Bochum Fakultat fur Maschinenbau, Germany
- Philipp Eckmann, Technische Universitat Chemnitz, Germany
- Jianrong Li, VSL- Dutch Metrology Institute, Netherland
- Adriaan M. H. van der Veen, VSL- Dutch Metrology Institute, Netherland
- Reiner Kleinrahm, Ruhr-Universitat Bochum Fakultat fur Maschinenbau, Germany
- Markus Richter, Technische Universitat Chemnitz, Germany

metrology projects – LNG III



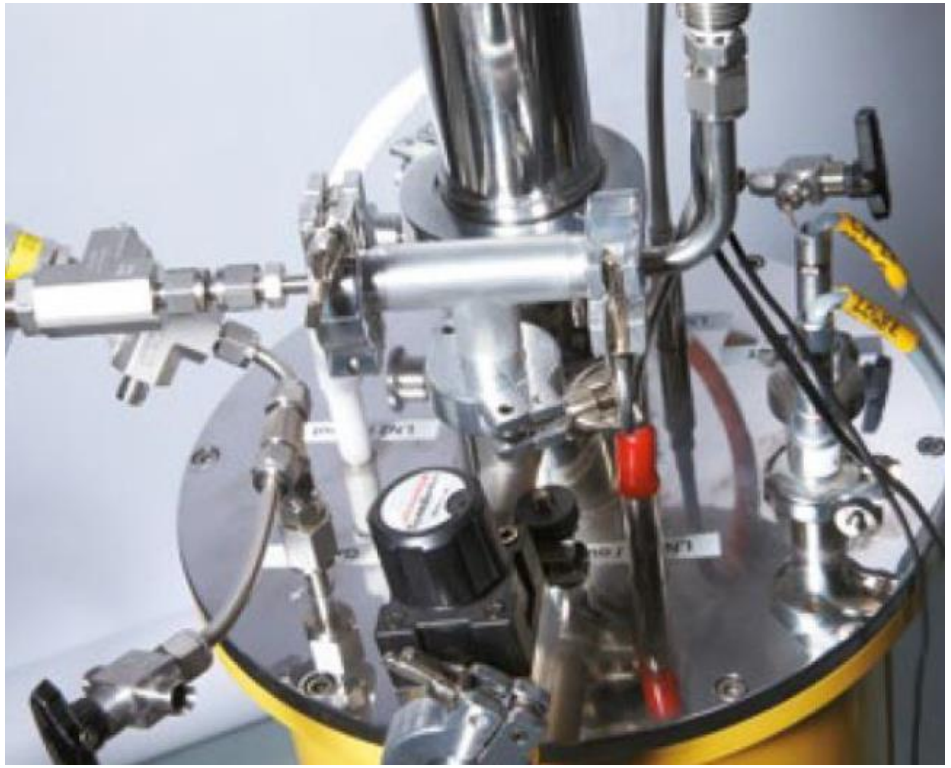
LNG III final report

Ultrasonic densimeter prototype validation

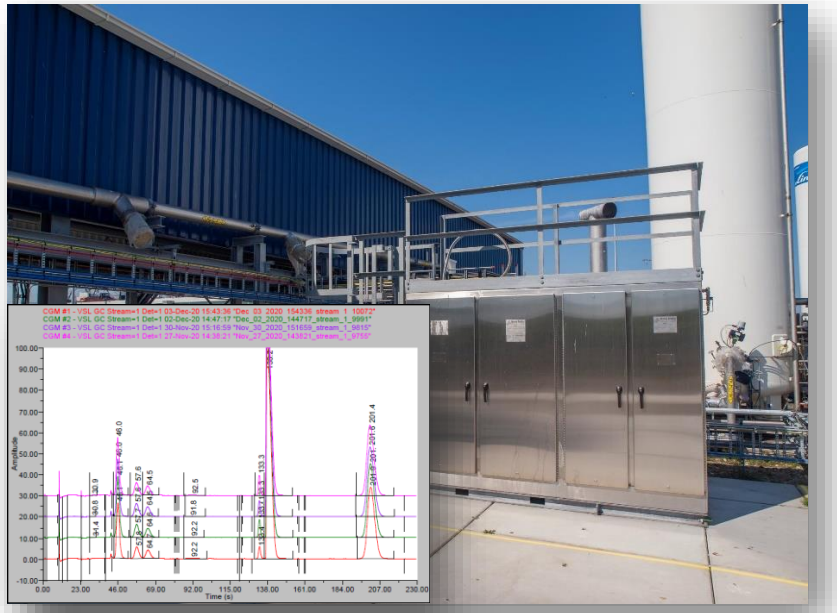
SI-traceable LNG density measurements

LNG equation of state

The EURAMET LNG metrology projects – LNG III



https://www.euramet.org/casestudies/casestudiesdetails/news/ensuring-confidence-in-liquid-natural-gas-composition



Smits, 2021, *Global LNG Bunkering Experience* https://www.vsl.nl/en/lng/financial-risks-dynamic-lng-measurement

Validated standards for LNG composition measurement

Calibration of LNG composition

The EURAMET LNG metrology projects – LNG III

Three Sensors developed for composition and methane number of gasified LNG:

1. Electro Chemical Capacitive sensor array (ECC or CSA)
2. Tunable Filter Infrared (TFIR)
3. Fourier Transform Infrared (FTIR)

APPLICATION PARAMETERS

Parameter	ECC/CSA	TFIR	Alternative method
Standard deviation	1.2	1.0	1.5
Measured parameters	Composition, MN	Composition, MN	MN
Additional parameters	WI, CV, density	WI, CV, density	-
Response time	10-30 minutes	< 10 seconds	1-5 minutes
Position	In-line in fuel line	Off-line in engine bypass	Off-line in lab or bypass
Applicable without T, P control	Yes	No	No
Size	~20 cm^3	~1000 cm^3	Lab-equipment
Costs	1-2 k€	2-5 k€	40 k€

LNG III final report

Validated Cost effective (gasified) LNG composition measurement sensors: important for LNG as transport fuel

Cost effective (gasified) LNG composition measurement sensors

Summary

- During the 2010 – 2020 decade continuous effort in development of LNG metrology has led to SI-traceable measurement solutions for:
  - LNG volume ✓
  - LNG density ✓
  - LNG composition ✓

- This has placed Europe in the leading position of LNG metrology

- But: calibrations show unanticipated measurement errors. Further work is needed to improve LNG measurement accuracy during custody transfer and corresponding financial risk to LNG importers/exporters
- The statement holds for small-, mid-, and large-scale LNG custody transfer

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National Metrology Institute