Improvements to the primary LNG mass flow standard

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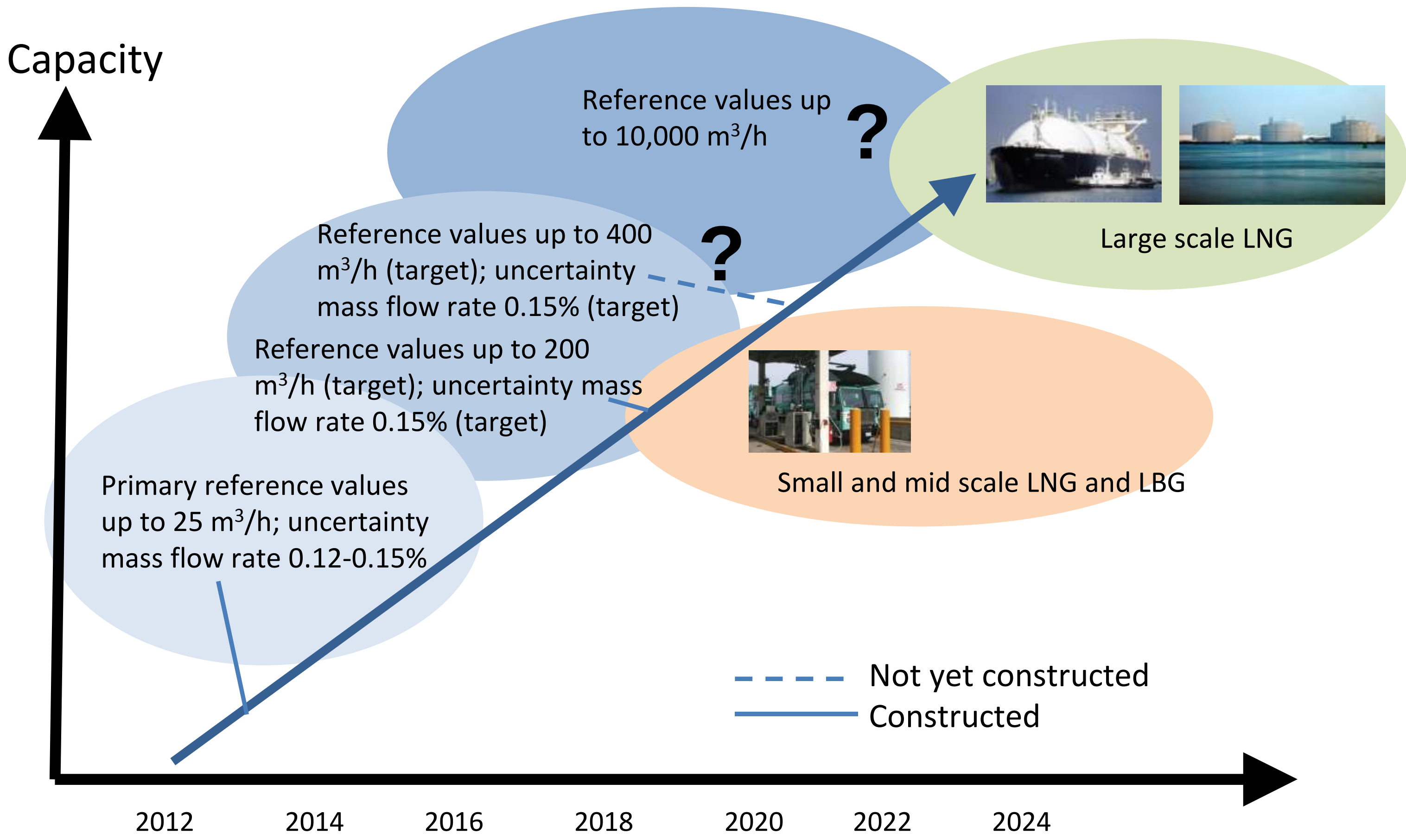
Introduction

- Cryogenic research and calibration facility
- LNG mass flow standard
- Improvements to the primary mass flow standard:
  - Level Compensation System control
  - Dry break coupling
- Summary

Cryogenic research and calibration facility



Cryogenic research and calibration facility

Dutch
Metrology
Institute

Cryogenic field lab

- Effects of flow meter insulation, flow disturbances, multi-phase flow, variable subcooled conditions
- Improved accuracy and robustness of cryogenic temperature measurements
- Prototype cryogenic measuring device calibrations – flow, density, speed-of-sound, composition, temperature, etc…..
- Cryogenic training for operators and metering experts
- Cryogenic equipment field testing

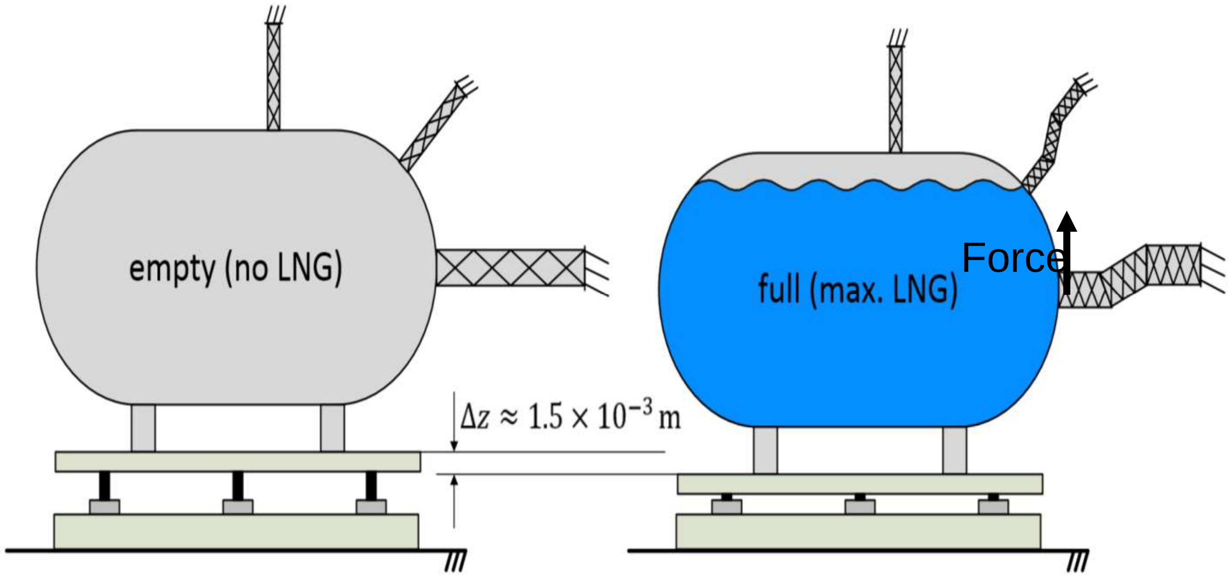
LNG mass flow standard

Primary standard established within the European Metrology Research Program (EMRP) co-funded by the Dutch Ministry of Economic Affairs

Gravimetric standard
Estimated CMC: 0.12% – 0.15%

van der Beek et al., 2014, *Metrologia*

LNG mass flow standard



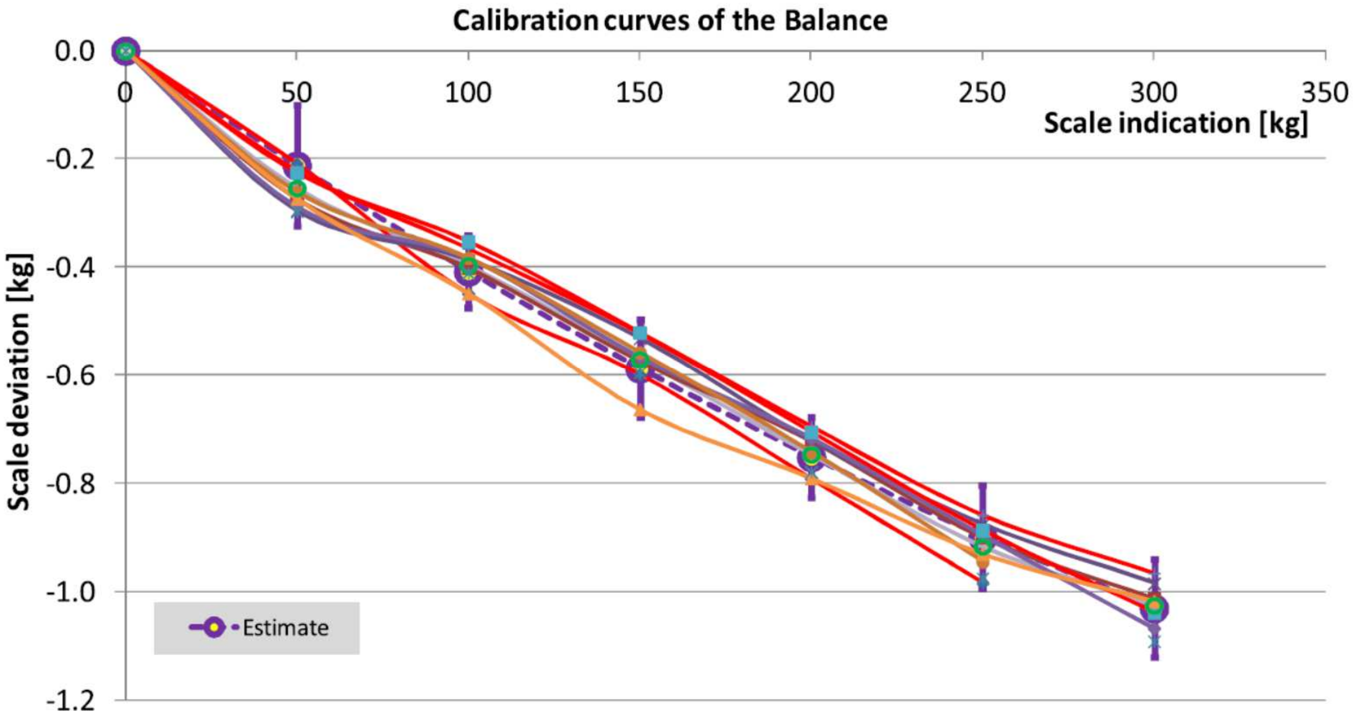
When the tank is loaded during the filling process of the weighing tank, a resulting force is created due to the lowering of the tank and the stiffness of the filling pipe

A smaller mass reading than the actual mass is expected

This “parasitic force” must be corrected for

This correction is accompanied by an uncertainty

Improvements to the primary mass flow standard



Van der Beek et al., 2014, *Metrologia*

This correction due to the parasitic forces is accompanied by an uncertainty

Improvements to the primary mass flow standard

Quantity	Legend	Value/kg	Sensitivity		Budget type	u par	Unc/%
m_1	Avg reading balance t_0	118.25	$\delta m_{\text{ref}}/\delta m_1$	0.505 73% kg^{-1}	Type A	0.016 kg	0.008
m_2	Avg reading balance t_1	314.16	$\delta m_{\text{ref}}/\delta m_2$	0.505 73% kg^{-1}	Type A	0.002 kg	0.001
C_{m1}	Correction of balance indication	0.48	$\delta m_{\text{ref}}/\delta C_{m_1}$	0.505 73% kg^{-1}	Hysterisis due to parasitic forces	0.084 kg	**0.043**
C_{m2}	Correction of balance indication	1.07	$\delta m_{\text{ref}}/\delta C_{m_2}$	0.505 73% kg^{-1}	Hysterisis due to parasitic forces	0.068 kg	**0.034**
$m^{\text{a}}_{\text{vapor}}$	Totalized vapour mass	1.82	$\delta m_{\text{ref}}/\delta m_{\text{vapour}}$	0.505 73% kg^{-1}	Uncertainity of model and EoS	0.034 kg	0.017
Clp	Compensation for linepack error	0.038	$\delta m_{\text{ref}}/\delta \text{Clp}$	0.505 73% kg^{-1}	Uncertainity of model and EoS	0.023 kg	0.012
Cinc	Compensation for inclination error	0.127	$\delta m_{\text{ref}}/\delta \text{Cinc}$	0.505 73% kg^{-1}	Calibration with air	0.087 kg	**0.044**
t	Run time	99.04	$\delta m_{\text{ref}}/\delta t$	1.0097% s^{-1}	Calibration and type A	0.082 s	**0.082**
m_{MuT}	Totalized mass during t seconds by MuT	198.10			Type A, 2s avg ($n = 5$)		**0.051**
		m_{ref} **Deviation MuT** **Flow rate**	**197.73 kg** **−0.20%** **2.00 kg s^{-1}**		**Uncertainity at $n = 5$ repeats**	**(2s)**	**0.12%**

van der Beek et al., 2014, *Metrologia*

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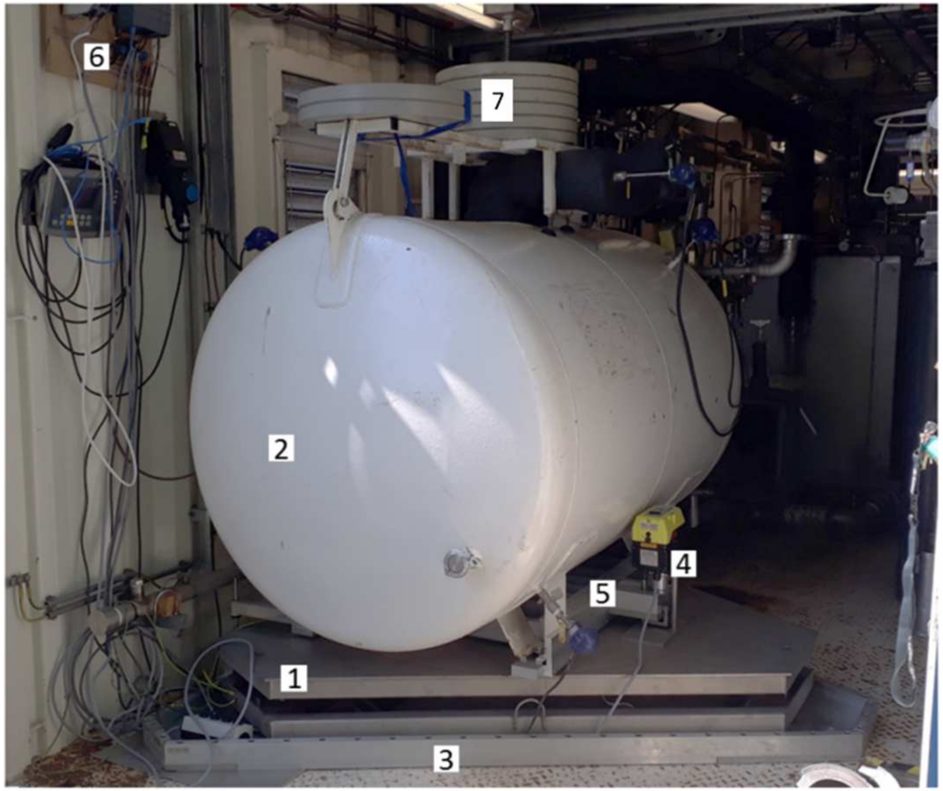
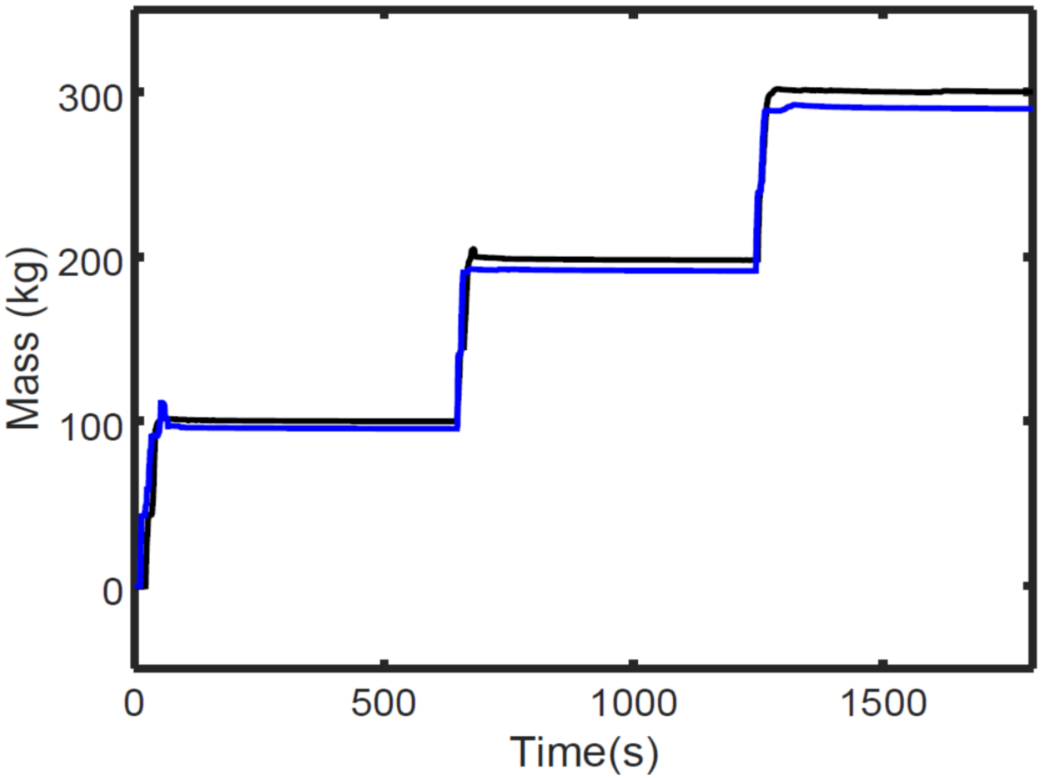
Improvements to the primary mass flow standard



1. Balance
2. Weighing vessel
3. Floor board
4. Actuators
5. Tank frame
6. Level Compensation System (LCS) control
7. Calibration weights

Improvements to the primary mass flow standard



Mass readings as a function of time with LCS on (black) and LCS off (blue)

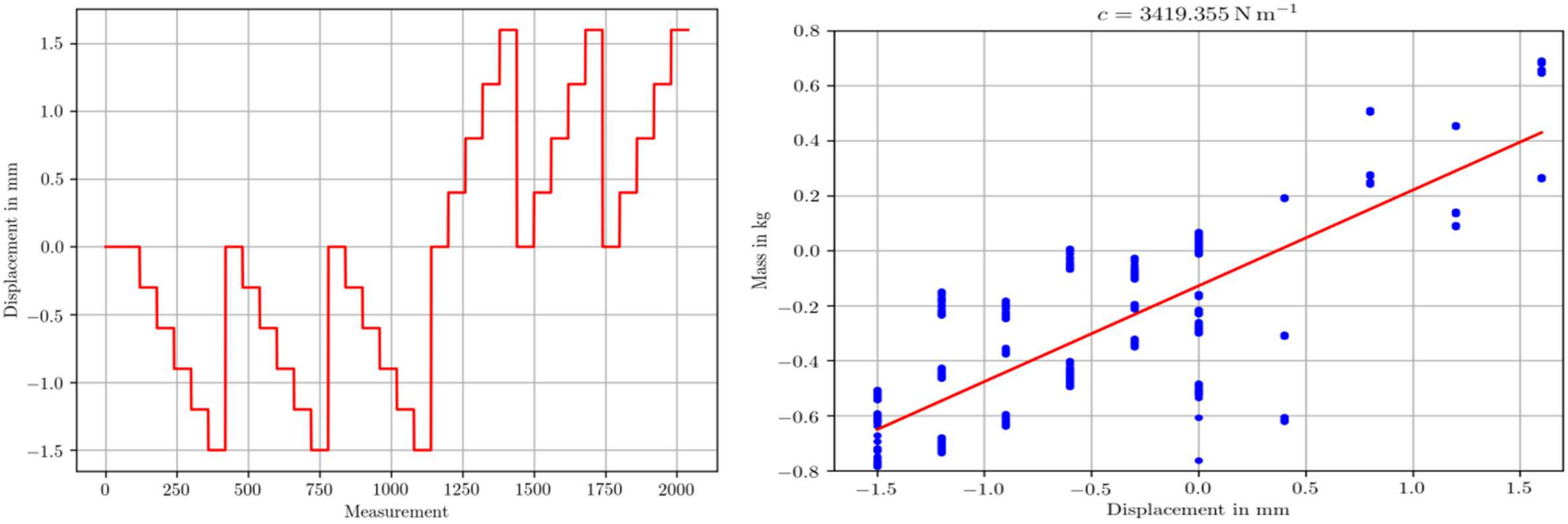
Mass readings with LCS on are higher than with the LCS off (closer to the corresponding calibration masses)

The experiment indicates that the LCS is reducing the parasitic forces

Independent measurements with level gauges confirmed that the vessel was kept in place during the weighing process

Further validation experiments required

Improvements to the primary mass flow standard



- Enforce displacements with the LCS
- Compute the corresponding stiffness from the mass deviation: 3 x 10^3 N/m ± 3 x 10^3 N/m (k = 2)
- Independent measurement: 7.84 x 10^3 N/m ± 2.14 x 10^3 N/m (k = 2)
- Further validation experiments required

Improvements to the primary mass flow standard

1. Filling pipe
2. Dry-break coupling
3. Swivel pipe

Disconnect filling pipe
Connect
Fill vessel
Detach

Swivel pipe is flexible

Summary

- A primary LNG mass flow standard was improved by two systems:
  - Level Compensation System control
  - Dry break coupling
- Initial estimated CMC at 0.12 % – 0.15% in mass flow rate, future activities will establish the CMC due to new system(s) installed
- The LCS initial results indicate that the parasitic forces are reduced indeed, and therefore the corresponding uncertainty is expected to be reduced as well
- The cryogenic research and calibration facility enables research in a variety of topics and acts as a cryogenic field lab

Acknowledgement & references

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- van der Beek, M., Lucas, P., Kerkhof, O., Mirzaei, M., Blom, G., *"Results of the evaluation and preliminary validation of a primary LNG mass flow standard"*, *Metrologia*, 51(5), 539, 2014.