METROLOGY for HYDROGEN VEHICLES

Design of gravimetric primary standards for field testing of hydrogen refuelling stations

Marc de Huu, Martin Tschannen, Hugo Bissig (METAS)
on behalf on the MetroHyVe project partners

FLOMEKO 2019, Lisbon
26-28 June 2019

EMPIR EURAMET

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EMPIR Metrology for Hydrogen Vehicles

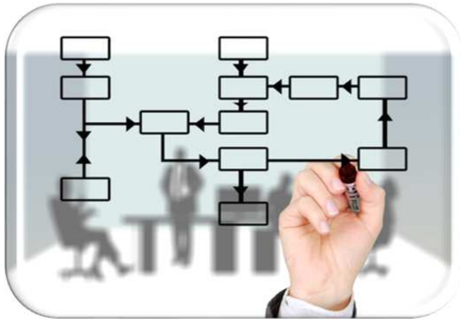
WP1: Flow metering

WP2: Quality assurance

WP3: Quality control

WP4: Sampling

WP5: Creating impact



WP6: Management

20 project partners:

June 2017 – May 2020

Project co-ordinator:

Arul Murugan

Other talks from MetroHyVe

Who	When	Where	Title
Oliver Büker	Wed 11:30 to 13:00	Session S2.9, room 5	Pressure dependence of Coriolis mass flow meters used at hydrogen refuelling stations
Rémy Maury	Thu 11:30 to 13:00	Session S10.5, room 2	Hydrogen refuelling station calibration with a traceable gravimetric standard
Marc MacDonald	Fri 11:30 to 13:10	Session S19.9, room 2	Air and Nitrogen testing of Coriolis flow meters designed for hydrogen refuelling stations

Introduction

Aim of this project:

- Development of a metrological infrastructure for hydrogen vehicles because hydrogen fueling is critical to the success of a hydrogen economy

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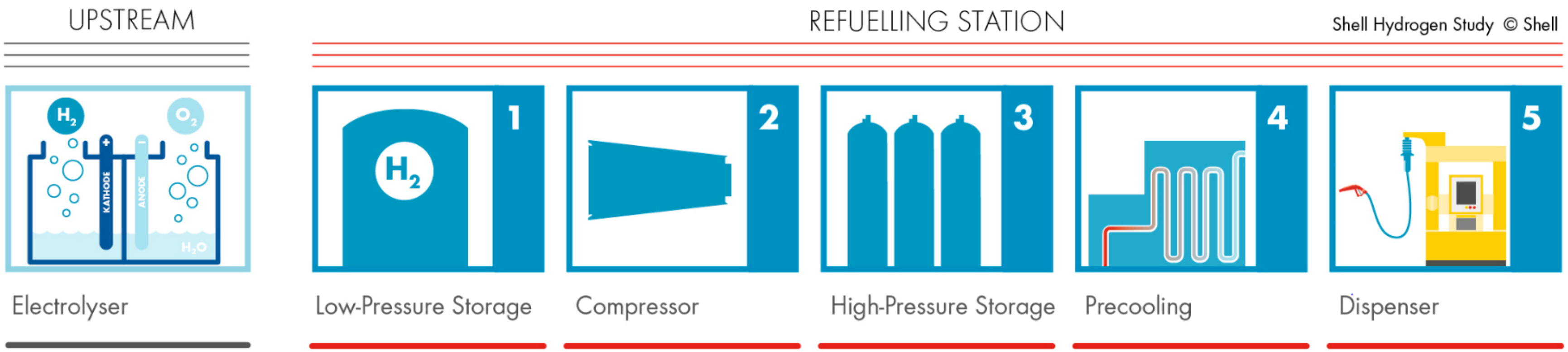
Introduction



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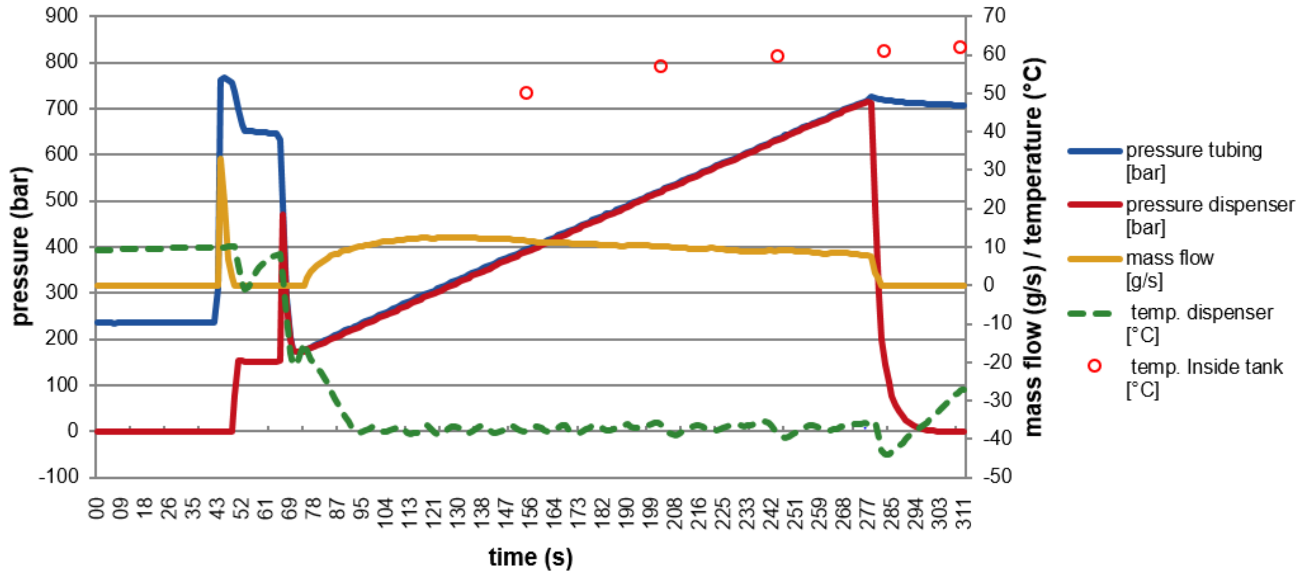
(R) Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles



Introduction

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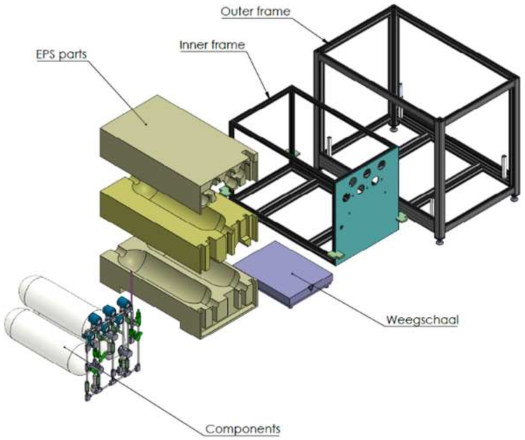
OIML R139-1
International Recommendation
Compressed gaseous fuel measuring systems for vehicles
Part 1: Metrological and technical requirements

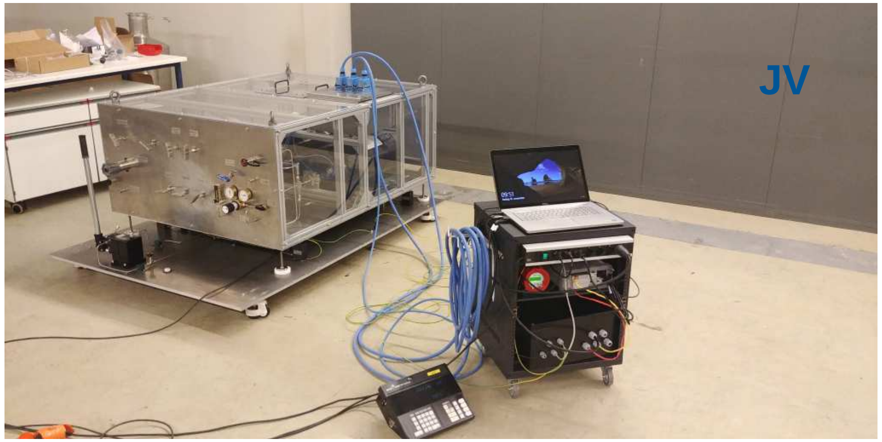
Table 1 - MPE values

Accuracy class		MPE for the meter [in % *of the measured quantity value*]	MPE for the complete measuring system [in % of the measured quantity value] at type evaluation, initial or subsequent verification	MPE for the complete measuring system [in % of the measured quantity value] in-service inspection under rated operating conditions
For general application	1.5	1	1.5	2
For hydrogen only	2	1.5	2	3
	4	2	4	5

Develop mobile gravimetric standard for field testing with 1/5 of MPE (0.3%)

VSL





JV

Design of METAS field test standard

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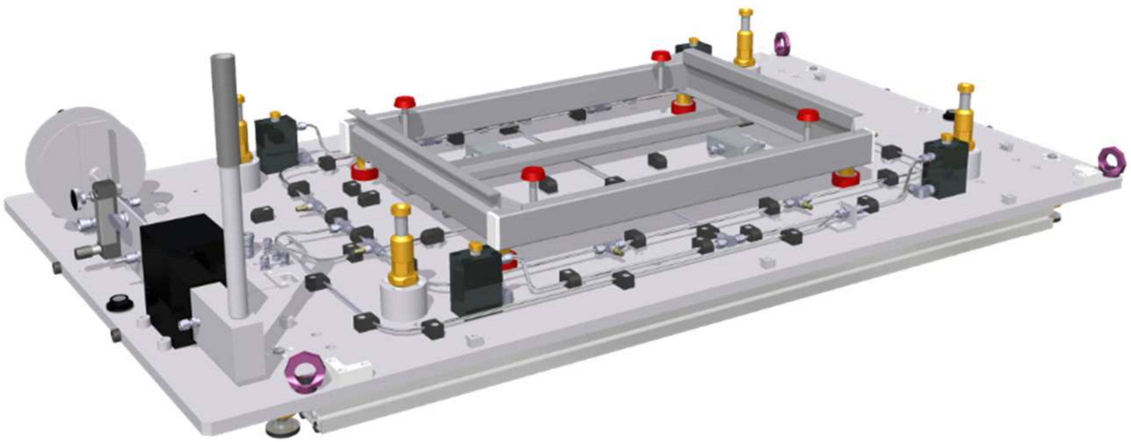
METAS Hydrogen Field Test Standard (HFTS)



Design of METAS field test standard

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Design of METAS field test standard

36 L type 4 cylinders
1.44 kg H_2 @ 70 MPa

Pt 100 probe, 27 cm inserted in tank

100 MPa pressure transducer

Venting line

300 kg scale
0.1 g resolution

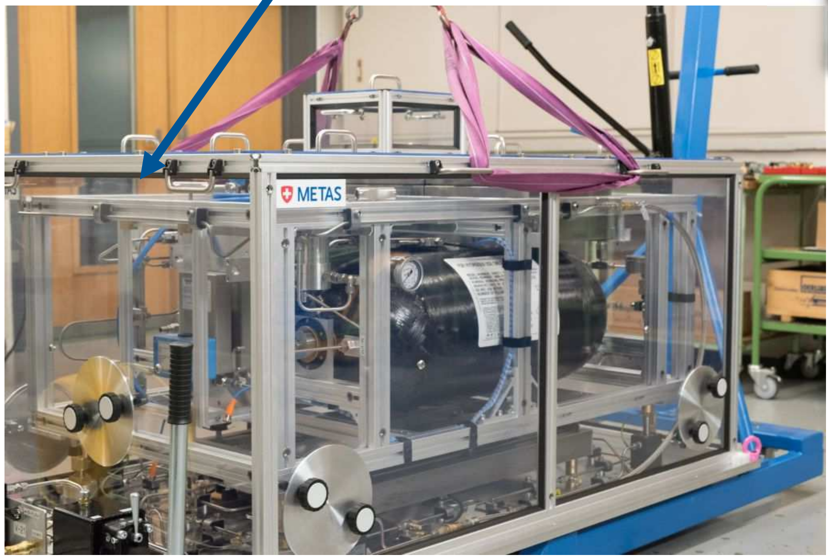
Medium pressure ¼" tubing, NPT and FK series fittings and valves in 316-stainless steel

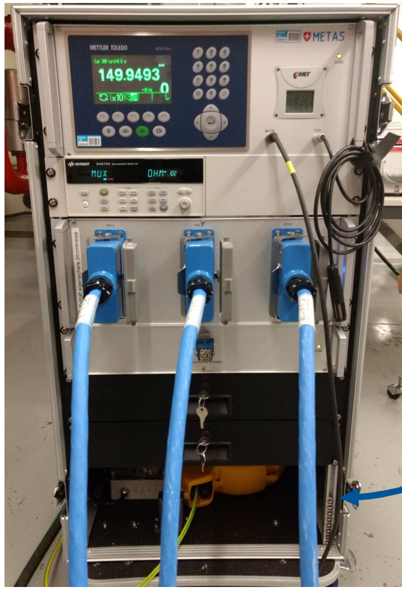
Design of METAS field test standard

ESD plastic frame to protect the scale from the environment, acts like a greenhouse

Environment with explosive atmosphere → **certification**

ESD Plastic frame can be moved for better air circulation





Design of METAS field test standard

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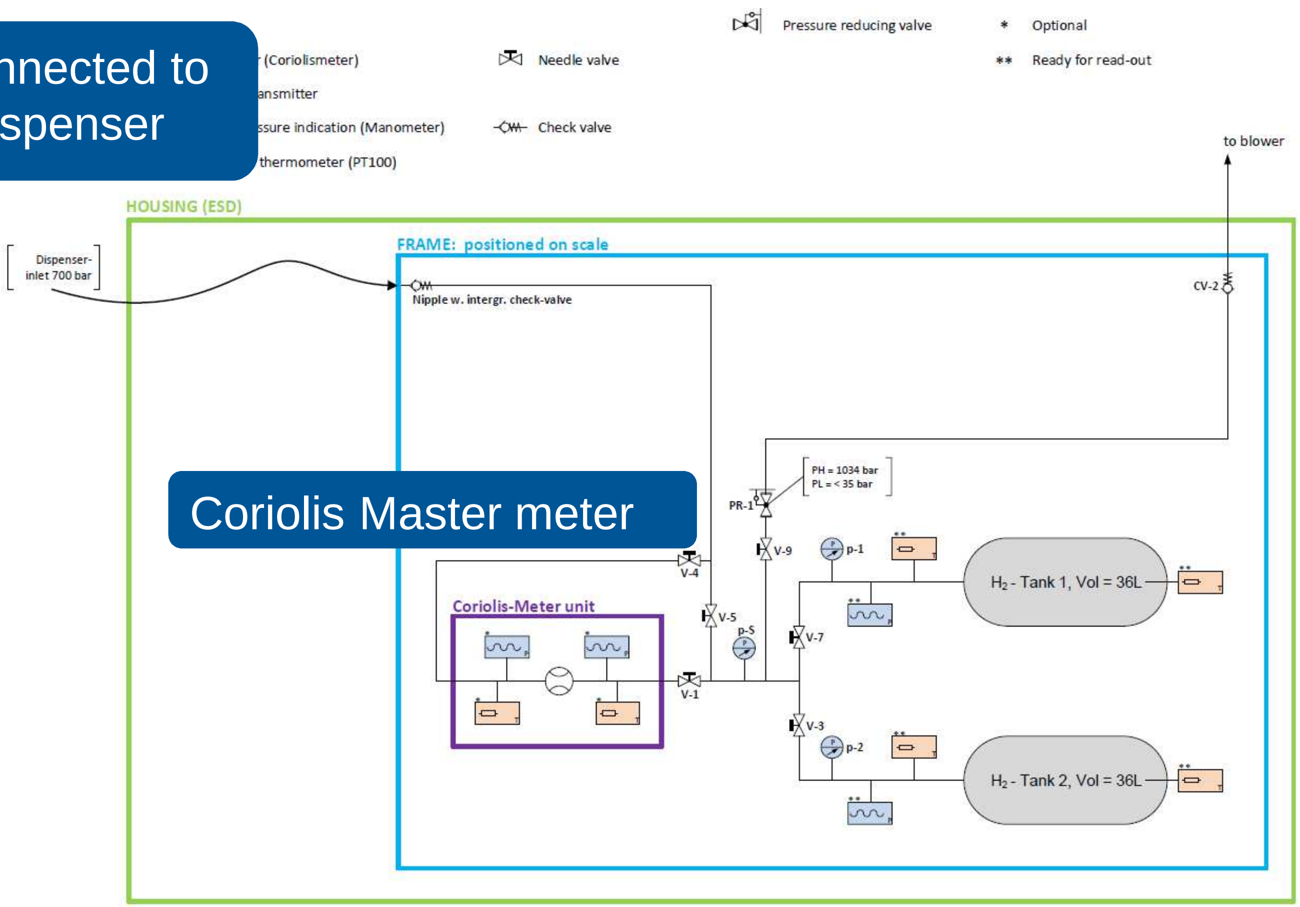
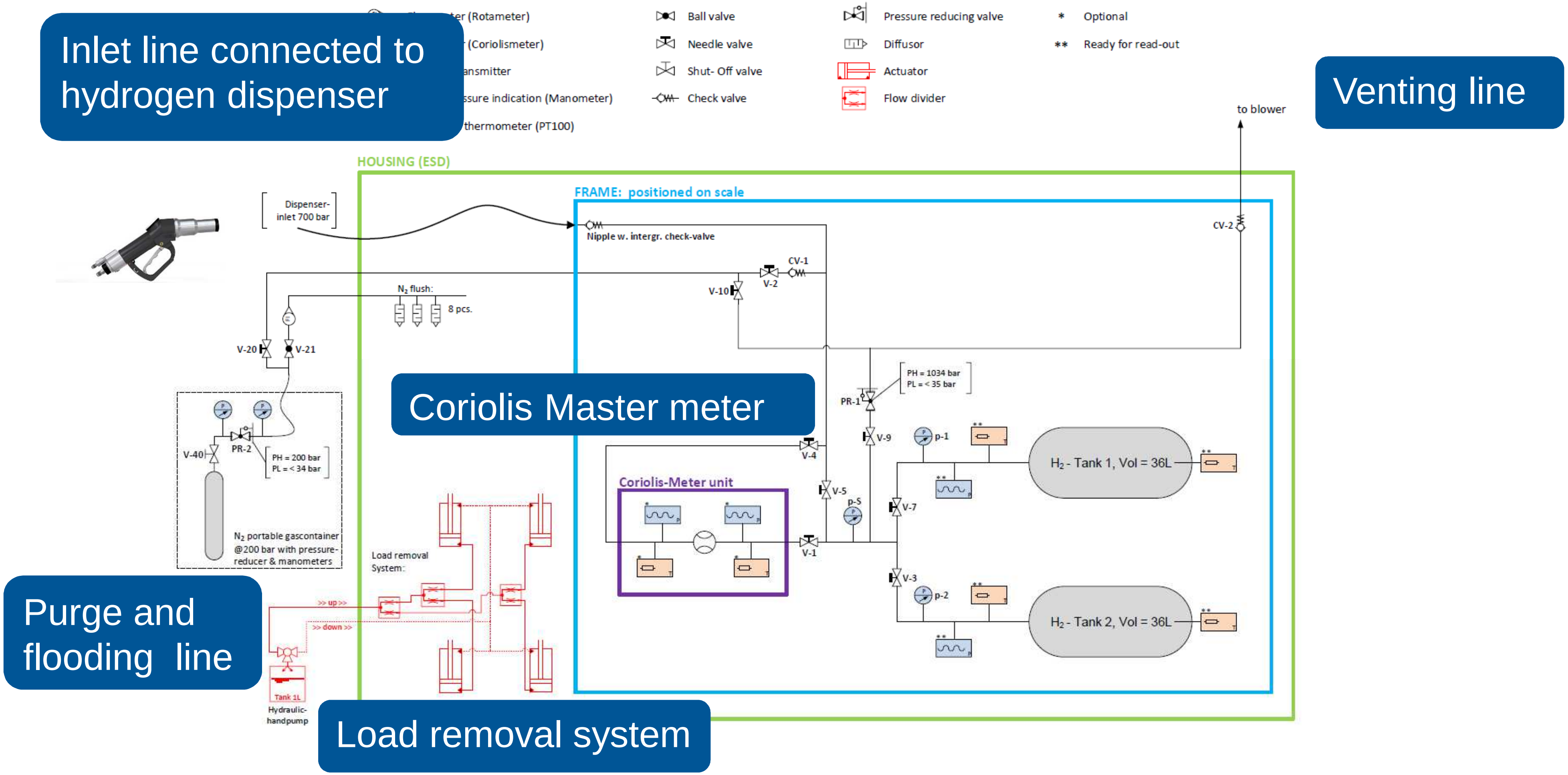
Inlet line connected to hydrogen dispenser



Venting line

Coriolis Master meter

Design of METAS field test standard



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Measurement method

Mass after and before fill

$$m_{H2} = m_2 - m_1$$

Thermal expansion … negligible

pressure expansion 0.92 L @ 70 MPa

$$V_{tank} = V_0 \cdot (1 + 3 \cdot \alpha \cdot \Delta T) \cdot (1 + \lambda \cdot \Delta P)$$

Scale readings

$$m_{H2} = (W_2 - W_1) \cdot \left(1 - \frac{\rho_0}{\rho_N}\right)$$
$$+V_0 \cdot [\rho_{air2} \cdot (1 + \lambda \Delta P_2) - \rho_{air1} \cdot (1 + \lambda \Delta P_1)] + V_{frame} \cdot (\rho_{air2} - \rho_{air1}),$$

Buoyancy correction

Weigh empty tank

- **before**: disconnect all cables and hoses from the frame and lower the HFTS on the scale
- **after**: Lift the HFTS and connect all cables and hoses

Fill the tanks

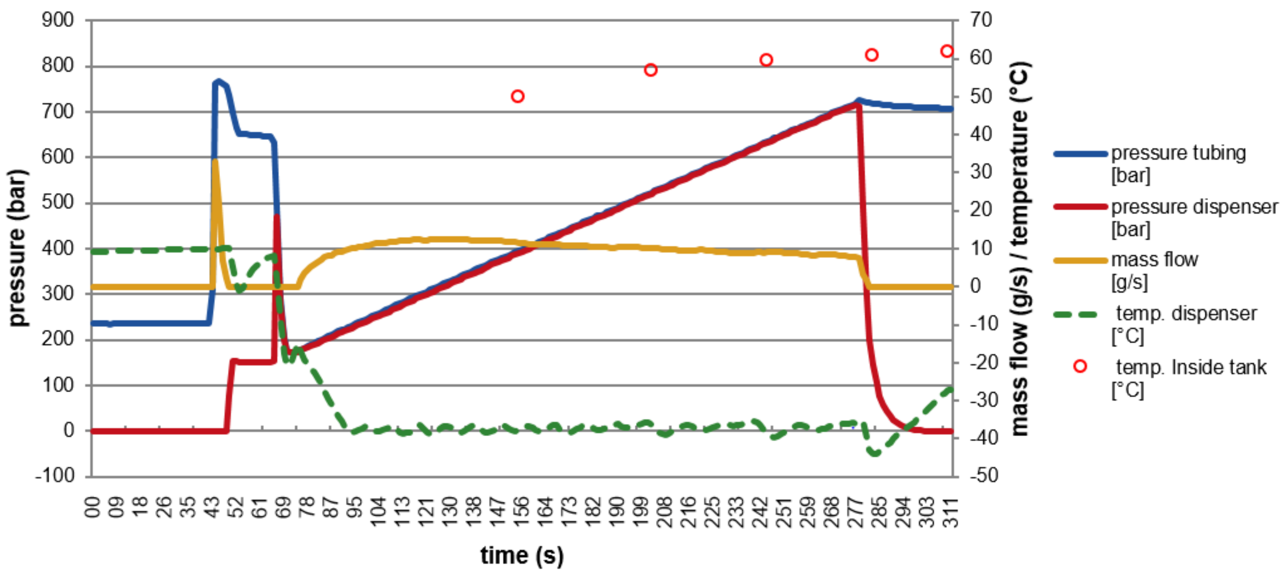
- **before**: connect gas source
- **during**: monitor and record data
- **after**: disconnect gas source

Weigh full tank

- **before**: disconnect all cables and hoses from the frame and lower the HFTS on the scale
- **during**: wait until scale reading stabilises and record value
- **after**: Lift the HFTS from the scale, connect all sensors and connect the vent stack to blow down the gas

Laboratory tests with N_2 @ -40°C

- Reproduce field tests as closely as possible and elaborate a testing procedure
- 5.5 MPa N_2 source, cooled down to -40°C to reproduce temperature conditions of hydrogen delivered by a HRS



Laboratory tests with N_2 @ -40°C

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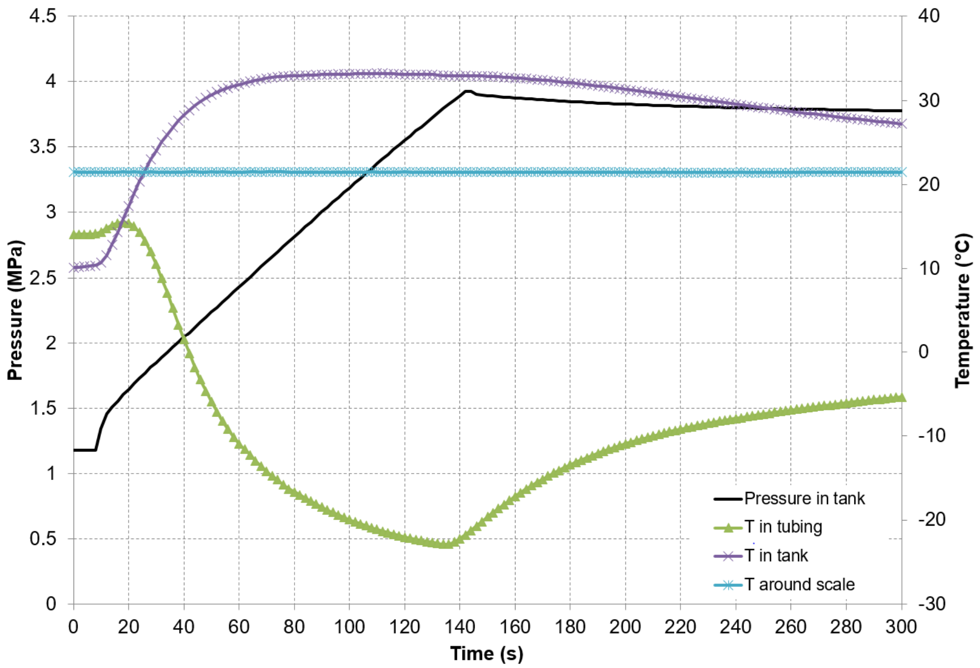
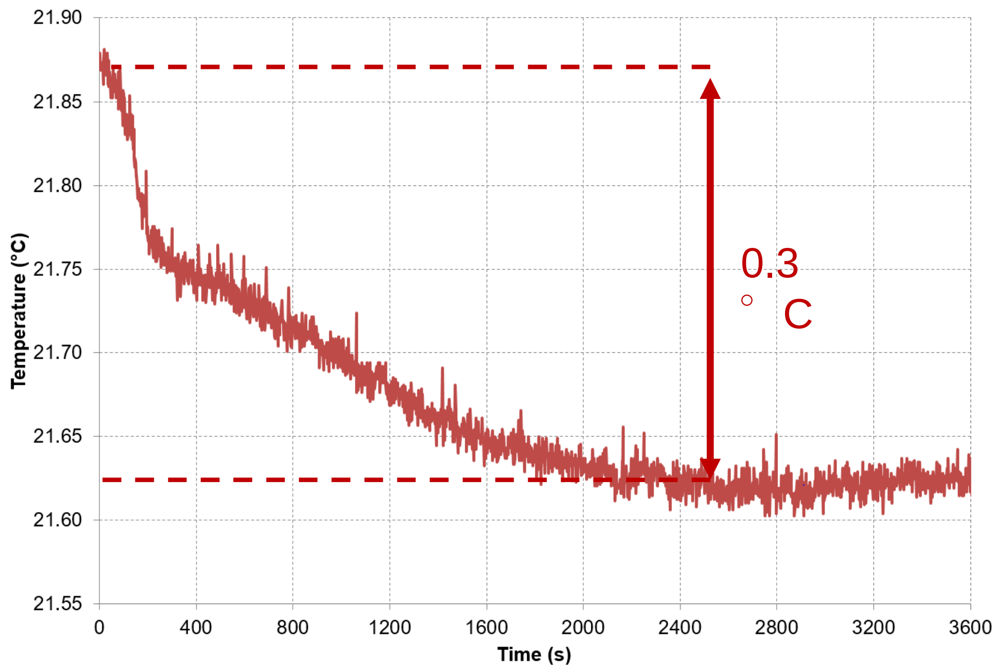
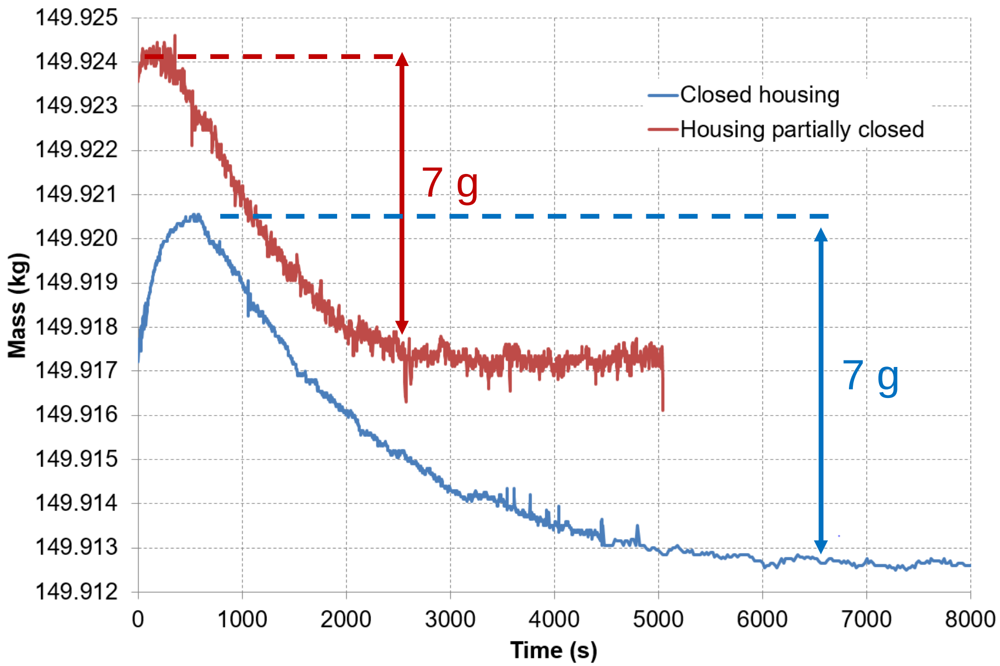




- Temperature increase in tank due to compression heating
- Tubing temperature below freezing point of water during fill
- Temperature around scale is constant

- Temperature profile around scale after fill with a closed housing
- Heat transfer from tank to air

Laboratory tests with N_2 @ -40°C



- Cold gas freezes humidity on pipes
- Ice is not part of mass of dispensed gas
- Scale reading profile after fill shows melting and evaporation of ice
- Better air circulation accelerates loss of mass

Uncertainty budget

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Uncertainty component	Nominal value	$u(x_i)$ %	Contribution %
Initial mass	150.0000 kg	$4.7 \cdot 10^{-4}$	40.5
Final mass	151.0000 kg	$4.7 \cdot 10^{-4}$	40.5
Tank volume	0.120 m^3	4.17	0.16
Frame volume	0.070 m^3	7.14	< 0.1
Initial air density	1.1500 kg/m^3	0.15	8.9
Final air density	1.1500 kg/m^3	0.15	9.0
Initial tank pressure	0.10 MPa	20	< 0.1
Final tank pressure	35.00 MPa	0.057	< 0.1
Pressure coefficient	$2.2 \cdot 10^{-10}$ Pa^{-1}	10	0.93

- Expanded uncertainty for the gravimetric method: 0.22 %
- Contribution from icing and condensation can be minimised if we wait long enough: 1 g spread (k=1)
- Expanded uncertainty for measurements in the field: 2.5 g for 1 kg (0.25%)
- Required uncertainty of 0.30% is achieved
- Measurements in the field under real conditions to validate some assumptions

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Summary

- Presented design of METAS HFTS
- Presented experimental results with HFTS under laboratory conditions with N_2 gas at -40° C to mimic real fill conditions
- Varying temperature and scale reading profiles
- Condensation on pipes leads to change of mass over time → not negligible
- Presented uncertainty budget: U = 0.25%
- Guide for future designs of similar field testing instruments based on gravimetric principel

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THANK YOU