Introduction to hydrogen flow metering

Marc de Huu

Workshop on Hydrogen Quality and Flow Metering for Hydrogen Fuel Cell vehicles
11 September 2019

Overview

What are the challenges related to hydrogen flow metering?

- Certification process of metering systems for HRS in Europe
  - How to approve HRS according to OIML R139?
  - No testing facilities in Europe for hydrogen at NWP of 700 bar
  - No alternative testing method for type approval
  - No testing method for on site verification of HRS

- Existing OIML R139-2014 not adapted for hydrogen dispensers

OIML

INTERNATIONAL RECOMMENDATION

OIML R 139-1

Edition 2014 (E)

Compressed gaseous fuel measuring systems for vehicles.

METROLOGY for HYDROGEN VEHICLES

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Overview of tasks MetroHyVe WP1

Organised in 5 tasks

1. Collect information on HRS design and establish basis on how HRS operate
2. Investigate alternative methods for type approval testing of flow meter using substitute substances to hydrogen
3. Investigate the influence of pressure on the accuracy of Coriolis meters using water
4. Develop 4 independent mobile gravimetric standards to deliver traceability to HRS up to 700 bar
5. Develop uncertainty budgets for type approval testing, periodic verifications and gravimetric standards

Expected outcomes

1. Methodologies for testing and calibrating hydrogen flow meters
2. Traceability chain for hydrogen flow metering
3. Field testing of HRS
4. Good practice guide for type approval procedure

Overview external activities

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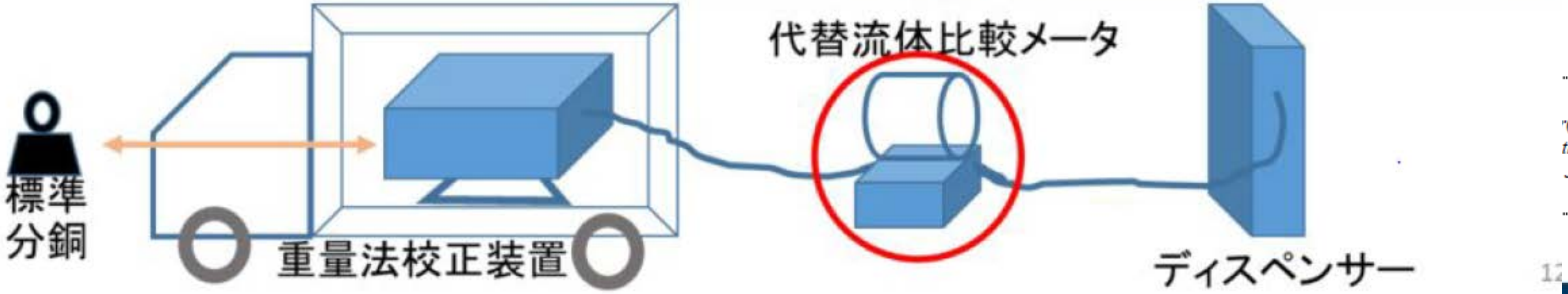
2. FCH-JU
   Define a

3. NEDO i ... er
   meter m

4. NREL ir



FINAL DELIVERABLE

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(s) and do not necessarily reflect the
the accuracy of the data included in
JU's behalf may be held responsible

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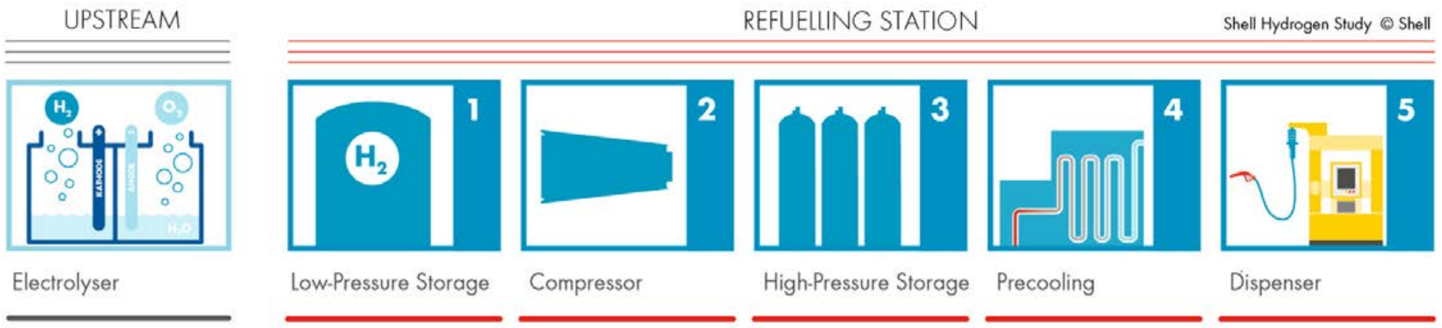
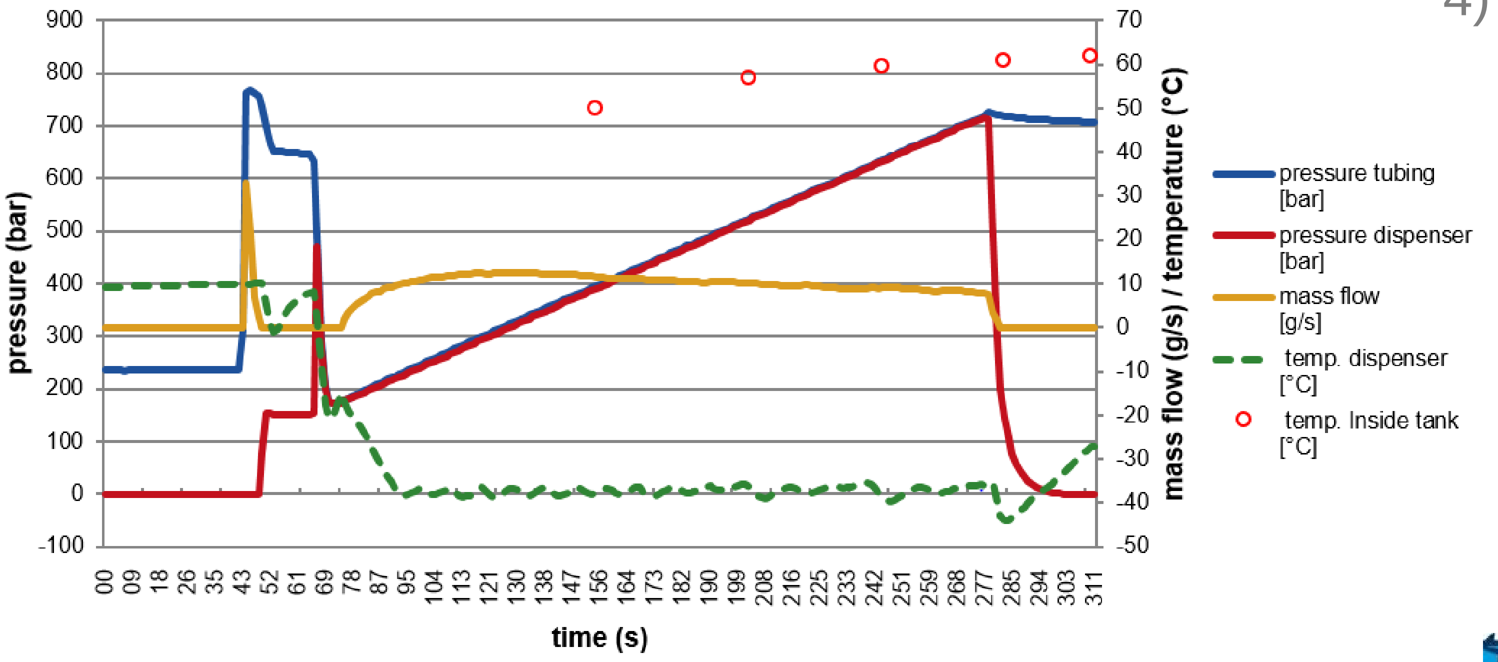
Flow metering

Operation of HRS





1) Connect and lock the nozzle
2) *Optional*: IR communication link between car and dispenser: Tank- Volume & Temperatur & Pressure
3) Pressure pulse (determine tank volume & leak test)
4) Fillling according to protocole «SAE J2601»
«Society of Automotive Engineers»

SAE INTERNATIONAL J2601®

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

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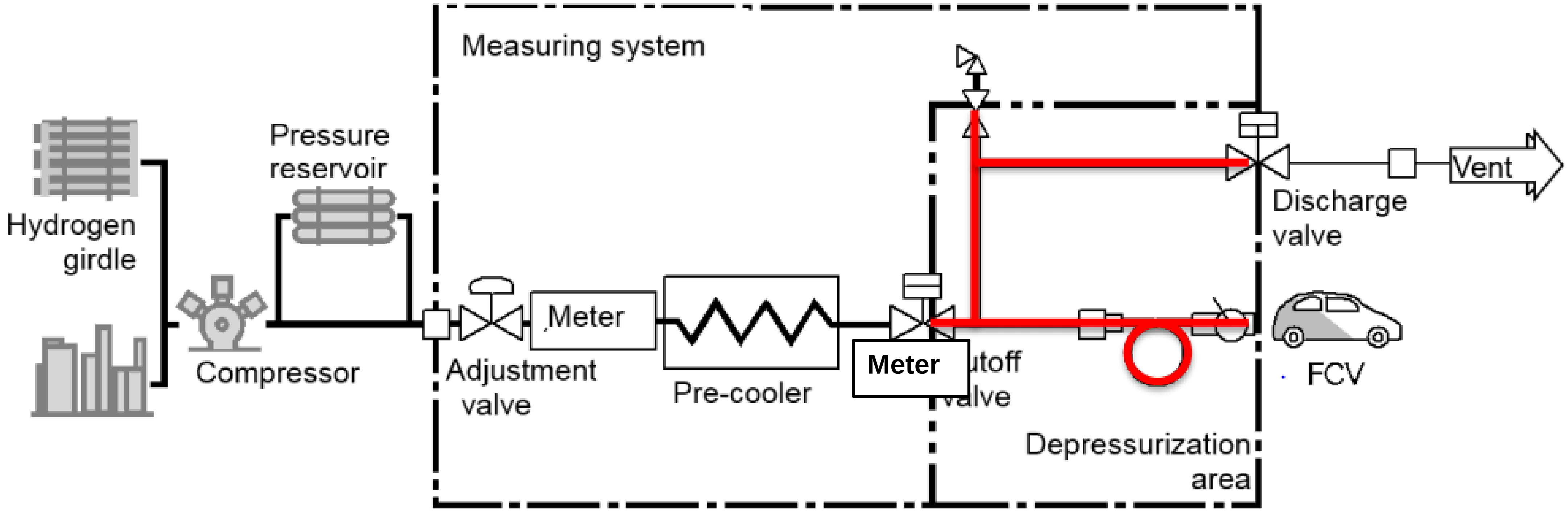
Flow metering



Uncertainty sources:

- Flow meter: behaviour as a function of pressure and temperature
- Dead volume between flow meter and transfer point: pressure changes in the line after the flow meter between fills affect the measured value by the flow meter
- Depressurization losses after fill

Flow metering

How to approve a HRS according to OIML R139?

- Flow meter: test with substitute substances (non-flammable gases) [illegible]adily available to testing labs instead of 700 bar hydrogen and perform temper[illegible]ell
- Initial verification and on site verification: on site with [illegible] → development of gravimetric systems

Build metrological infrastructure

NMI	Master meter	[illegible]	[illegible]ntity at 700 bar	Status
CESAME	Not i[illegible]	[illegible]4 L	4.2 kg	Rental from Air Liquide
JV	[illegible]s	3 x 36 L	4.2 kg	Ready, certification ongoing
METAS	Yes, Rheonik	2 x 36 L	2.8 kg	Ready, field tested
VSL	Not included	3 x 52 L	6 kg	Design ready, hope to be up and running in Q4 2019

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Design of gravimetric systems

- Display of dispenser in mass (kg), delivered mass
- Experience with gravimetric systems used for CNG (Compressed Natural Gas)
- Requirement of 1/5 of MPE (0.3% to 0.4%)

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	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

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Design of METAS field test standard

36 L type 4 cylinders
1.44 kg H_2 @ 70 MPa

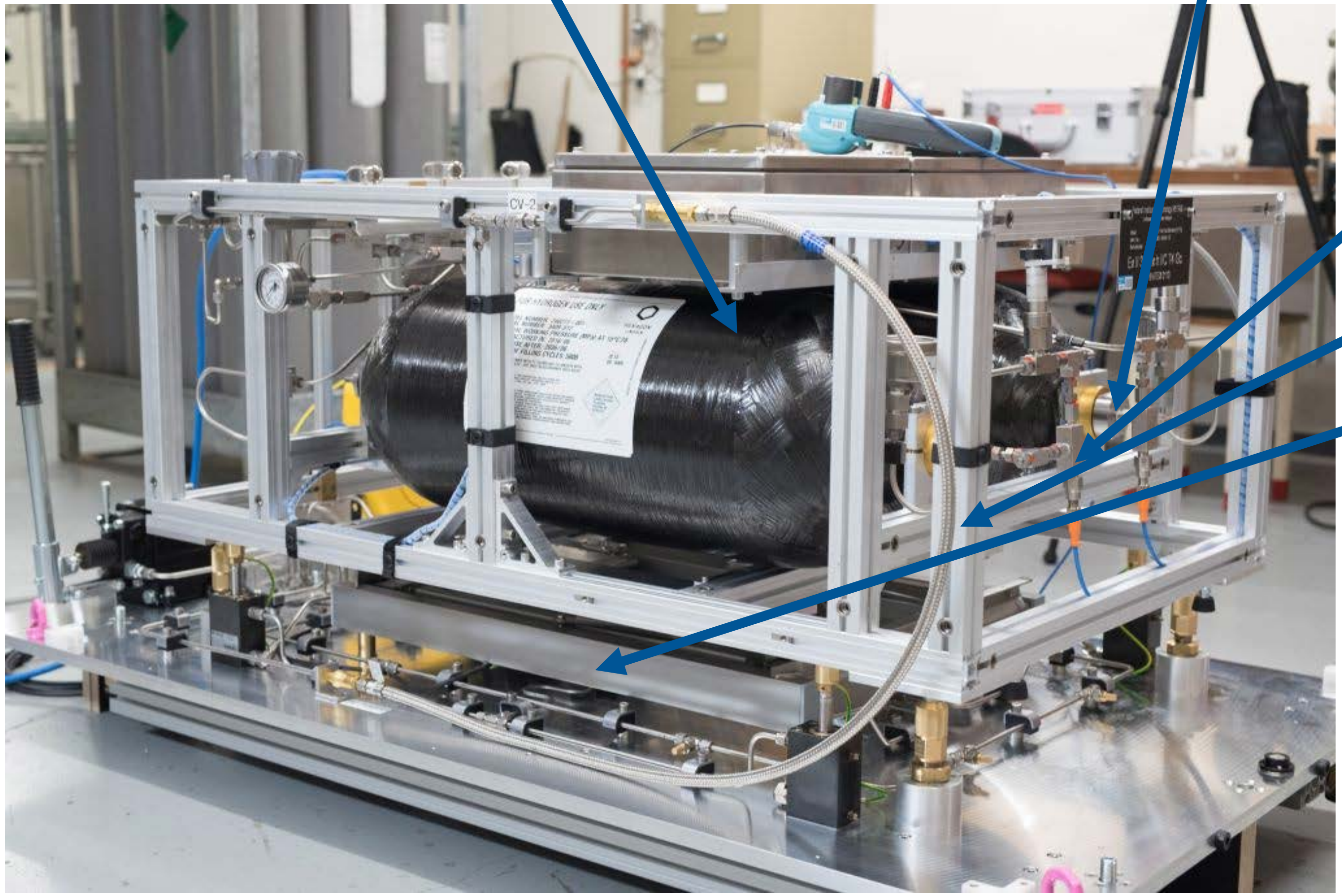
Pt 100 probe, 27 cm inserted in tank

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

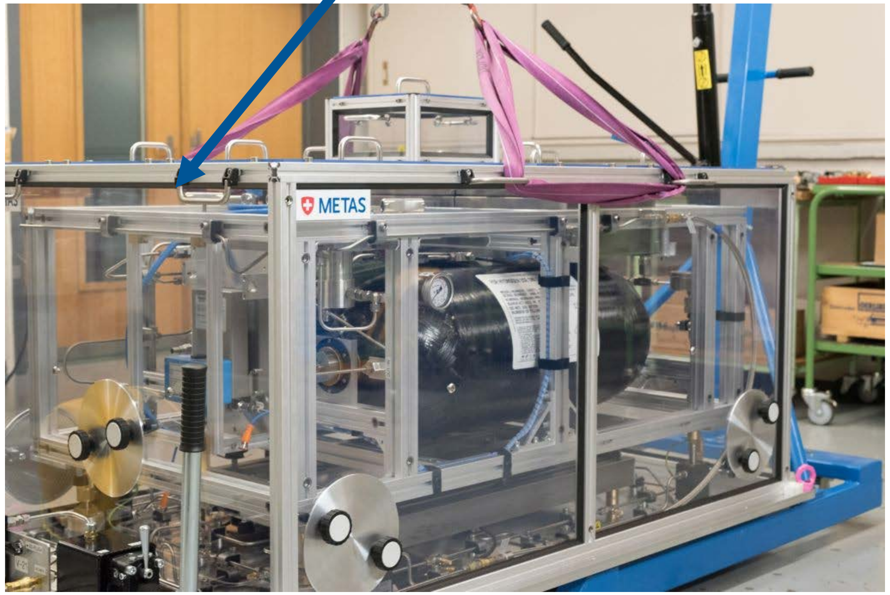


Design of METAS field test standard

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



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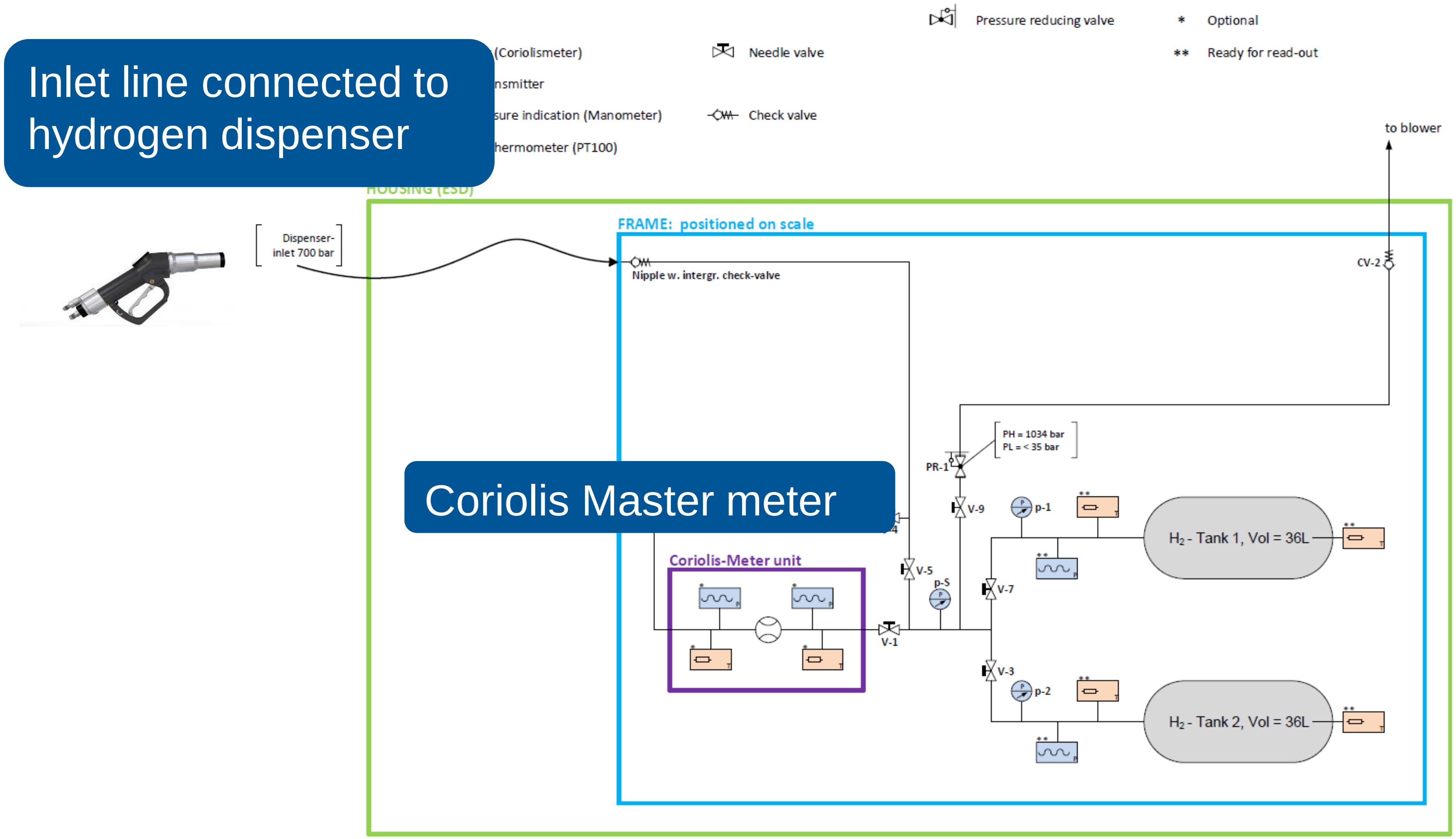
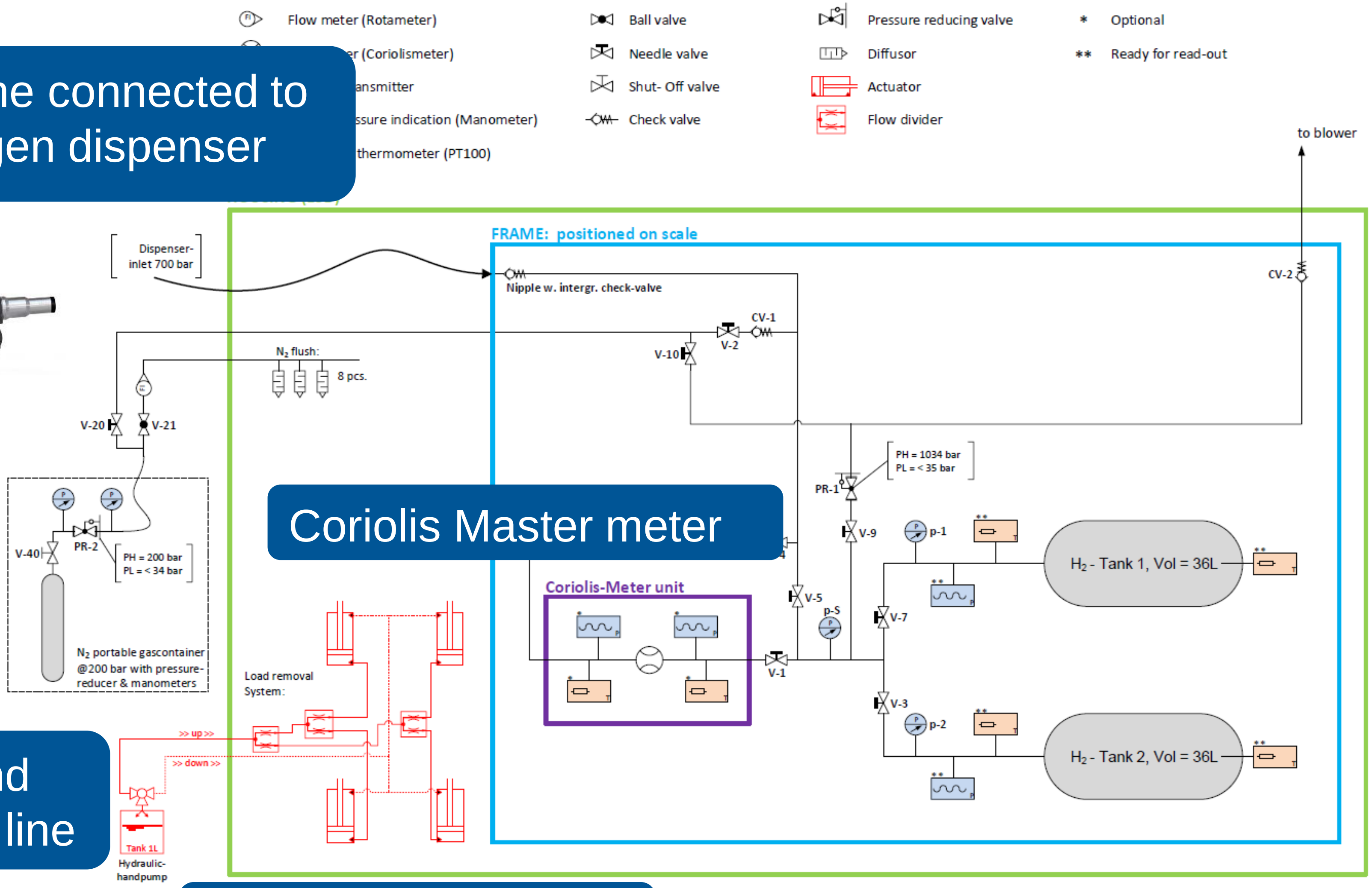
Design of METAS field test standard



Design of METAS field test standard

Inlet line connected to hydrogen dispenser

Venting line



Coriolis Master meter

Purge and flooding line

Load removal system

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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

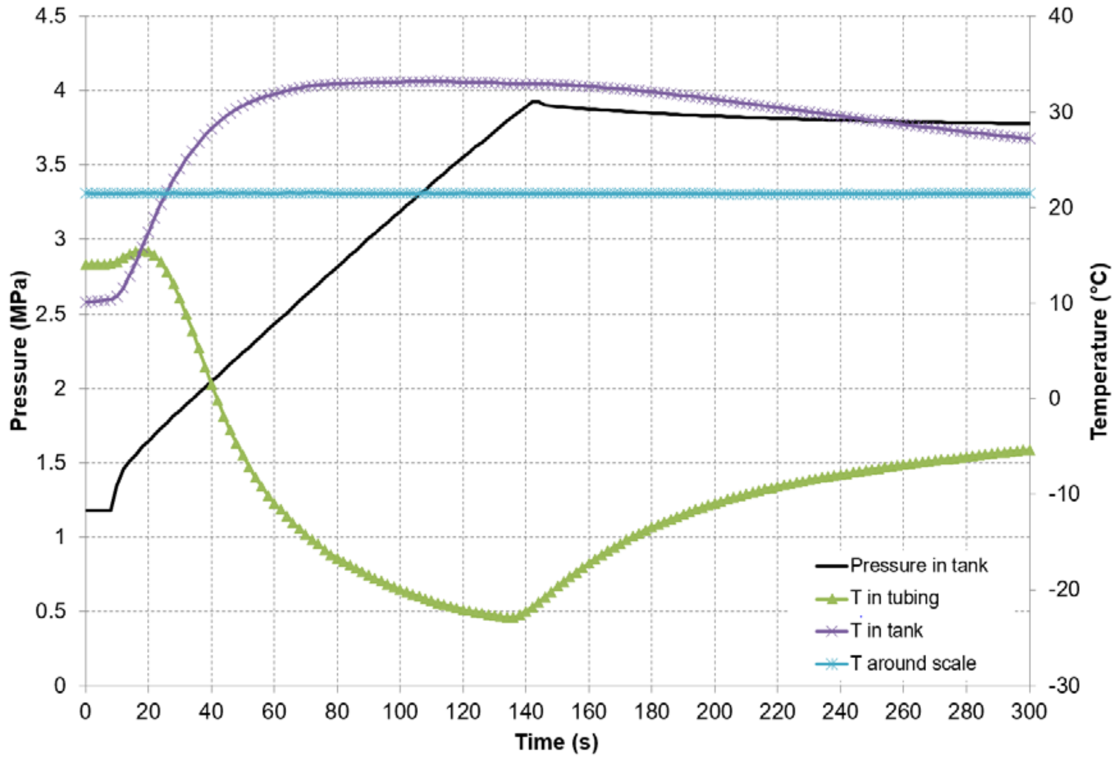
Fill the tanks

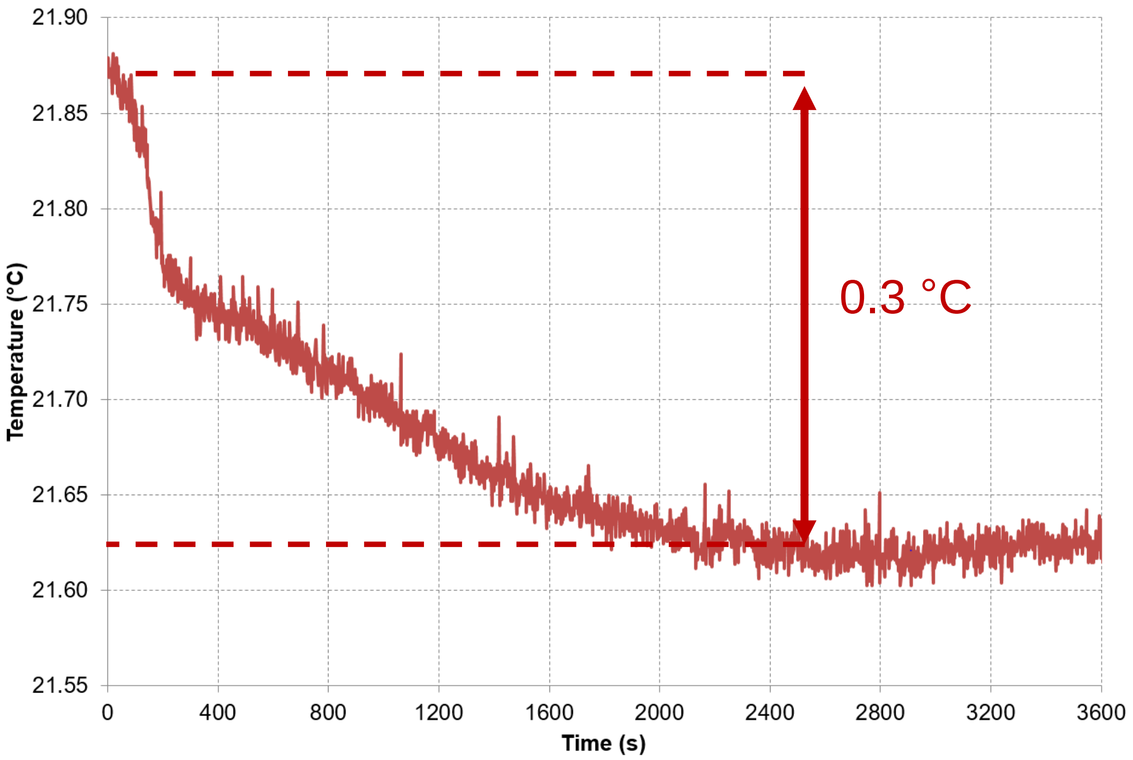
- **before**: connect gas source
- **during**: monitor and record data
- **after**: disconnect gas source

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





- 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

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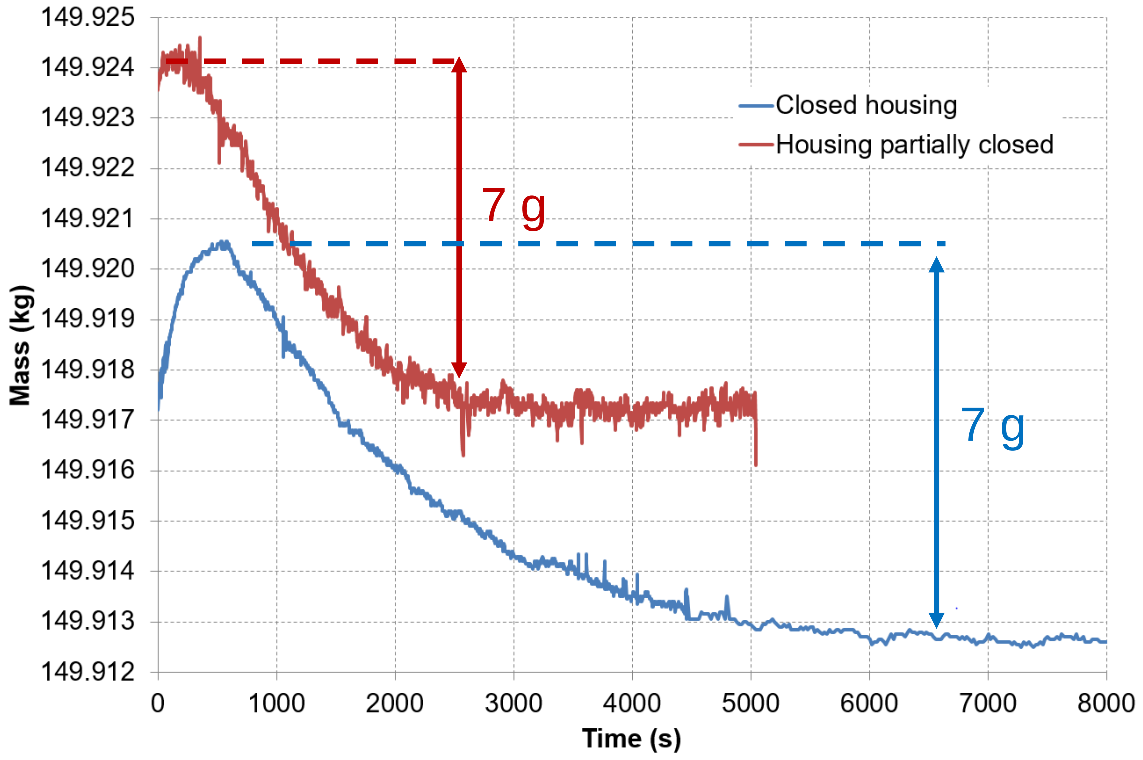
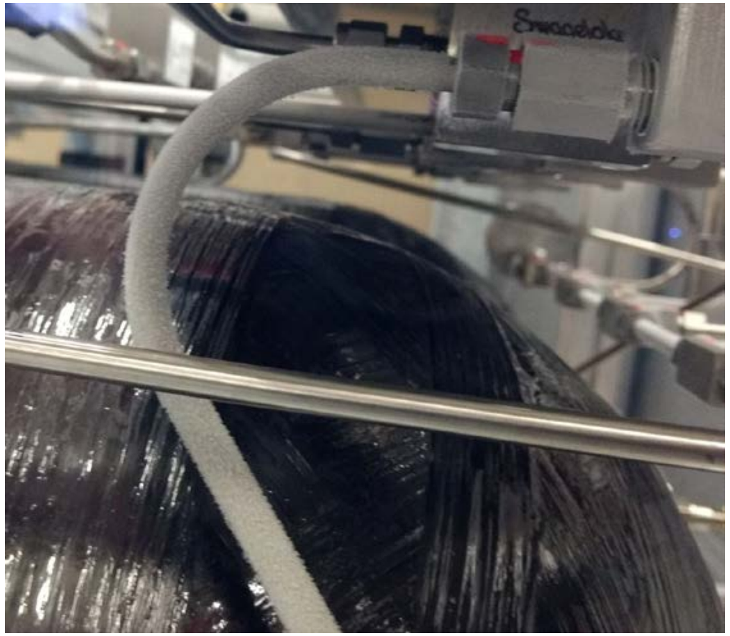


- Cold gas freezes humidity on pipes
- Ice is not part of mass of dispensed gas
- Scale reading profile after fill shows melting and evaporation of ice
- Better air circulation accelerates loss of mass



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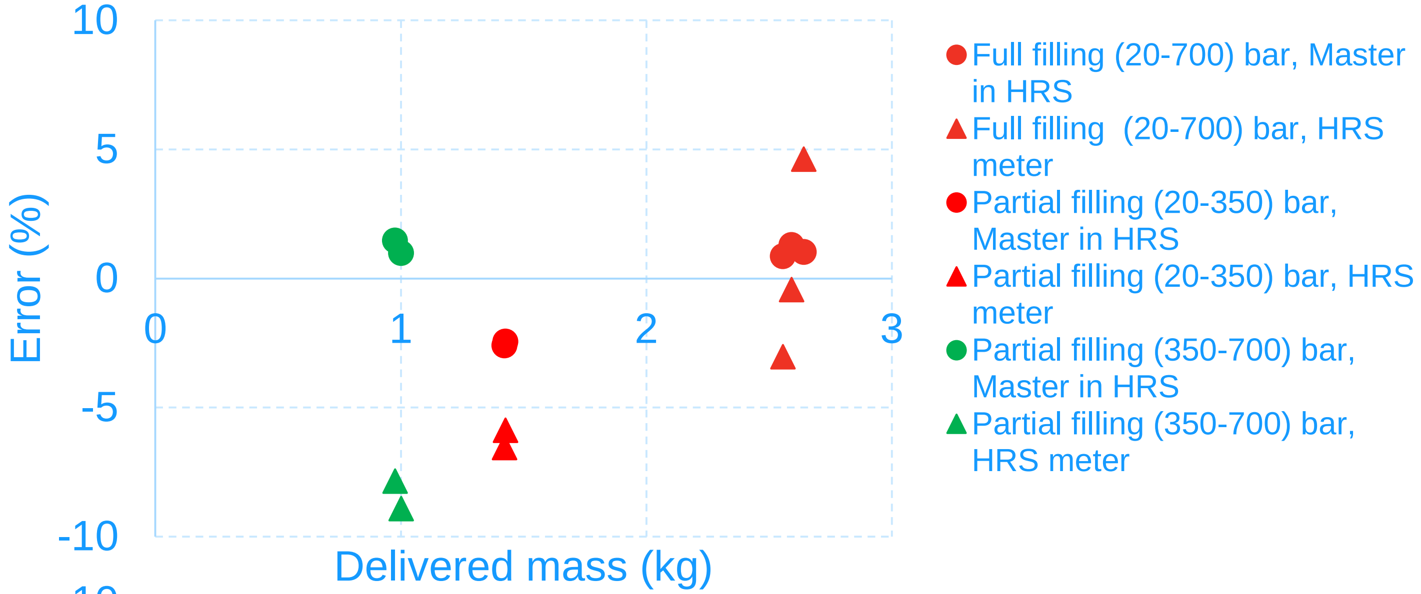
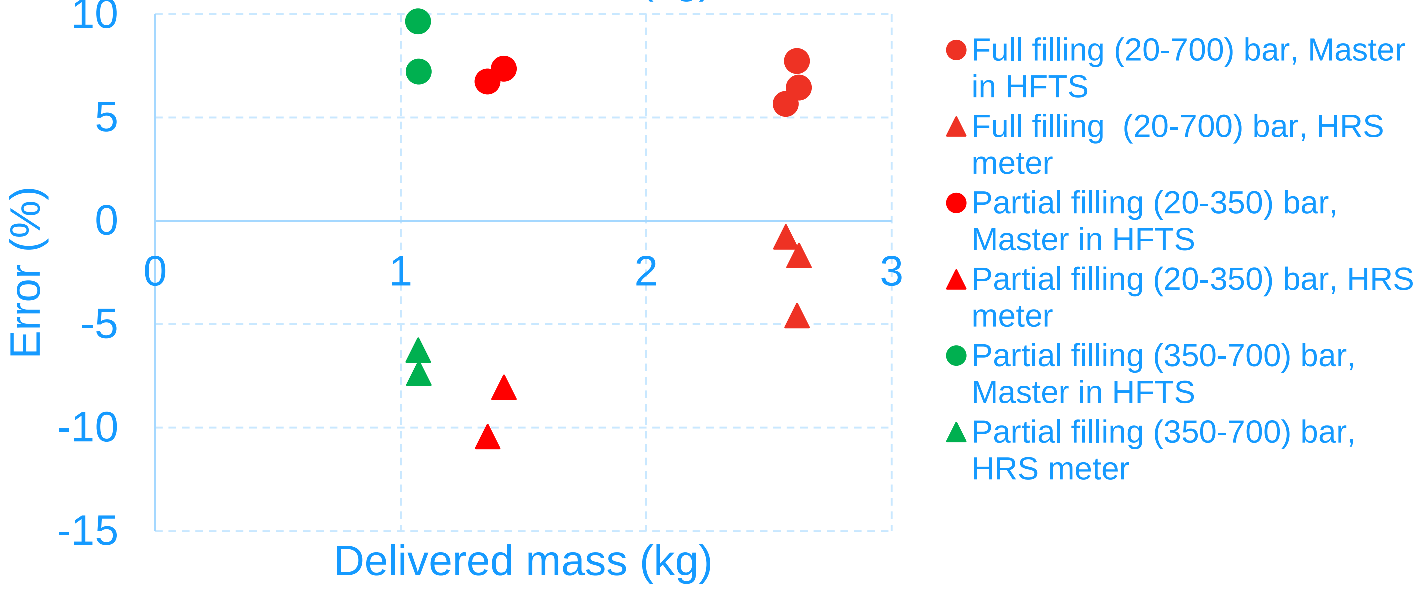
Uncertainty budget

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

Field results

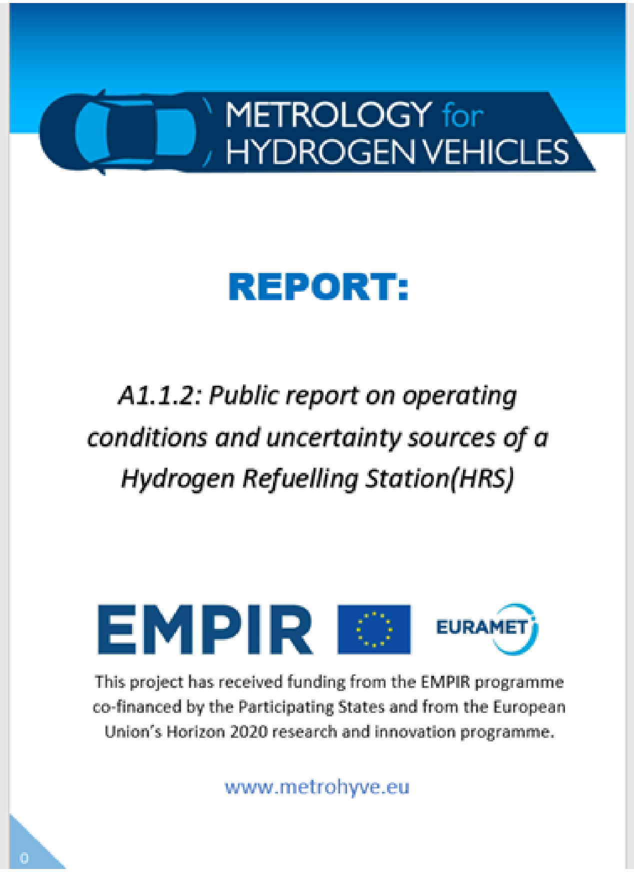




Available resources

www.metrohyve.eu

- Report
- Presentations
- Publications (more to come)



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REPORT:

A1.1.2: Public report on operating conditions and uncertainty sources of a Hydrogen Refuelling Station(HRS)

EMPIR EURAMET

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www.metrohyve.eu

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

M. de Huu, M. Tschannen, H. Bissig

Federal Institute of Metrology METAS, Lindenweg 50, 3003 Bern-Wabern, Switzerland
E-mail (corresponding author): marc.dehuu@metas.ch

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