Schweizerische Eidgenossenschaft
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Federal Institute of Metrology METAS

Introduction to hydrogen flow metering

Marc de Huu

Agenda

1. Introduction / Overview
2. Basic operating principle of a HRS station
3. Design of testing standards
4. Field testing
5. Outlook

The work presented here has been realized within several European projects

MetroHyVe 1 & 2 – EURAMET EMPIR call

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

FCH-JU : FCH / OP / 196 : “Development of a Metering Protocol for Hydrogen Refuelling Stations”

Overview

What are the challenges related to hydrogen flow metering?

Situation in Europe a few years ago…

METAS

Overview

What are the challenges related to hydrogen flow metering?

Situation in Europe a few years ago…

1. 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

2. 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.

Overview

Situation now

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

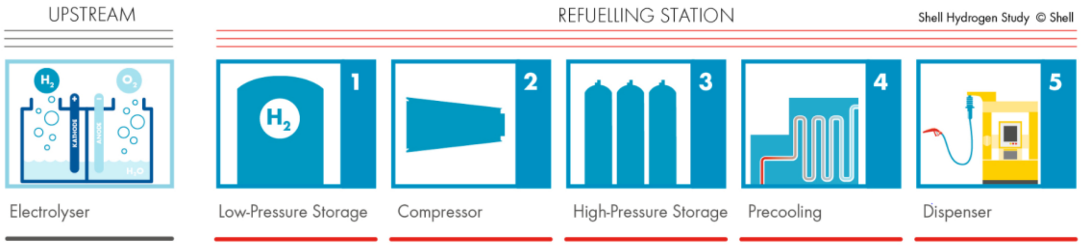
1. Publication of OIML R139 2018

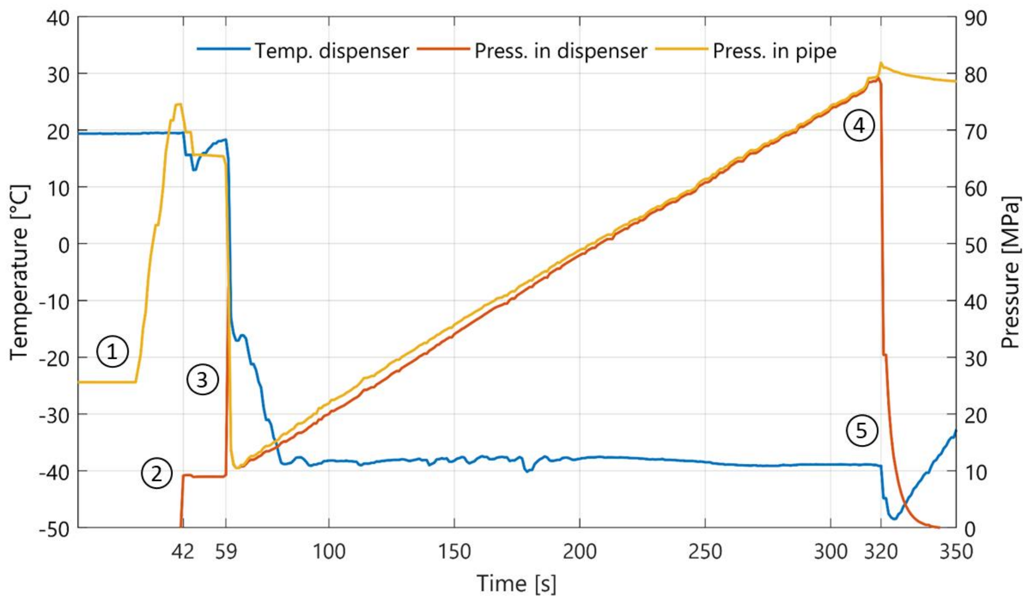
2. FCH-JU study “Development of a metering protocol for hydrogen refuelling stations”

   Define an accelerated test protocol to quickly certify HRS without certified meters

3. MetroHyVe 1: Field calibration with gravimetric system, alternative testing, good practice guides

Operation of HRS



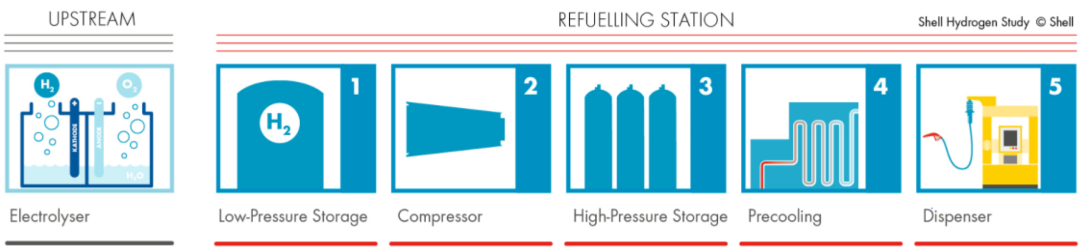


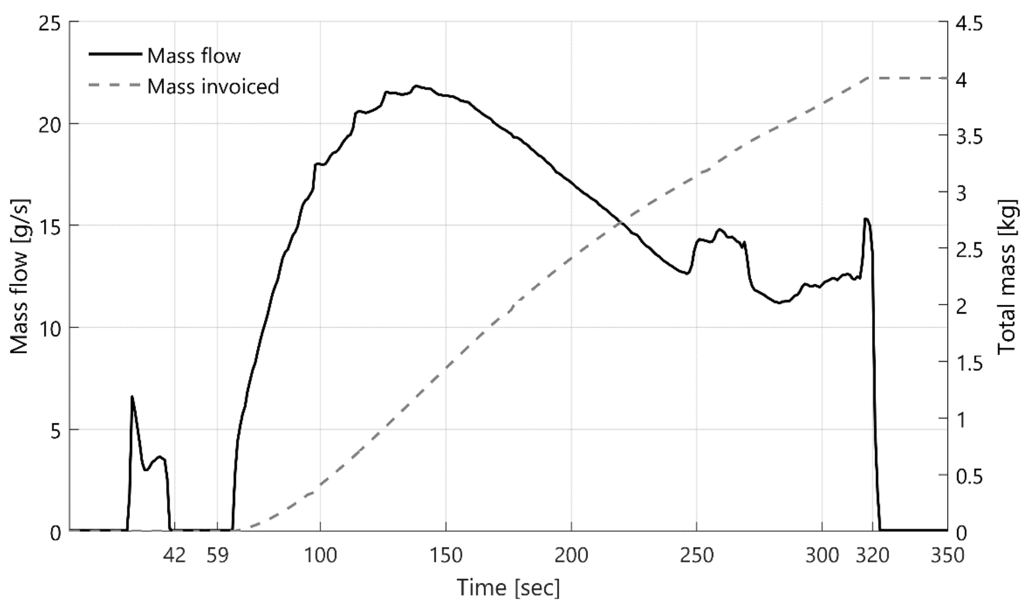
1) Connect and lock the nozzle
2) *Optional*: IR communication link between car and dispenser:
   Tank- <u>Volume</u> & <u>Temperatur</u> & <u>Pressure</u>
3) Pressure pulse (determine tank volume & leak test)
4) Fillling according to protocole «SAE J2601»
   «Society of Automotive Engineers»
5) *Precooling for 700 bar*
6) *No precooling for 350 bar*

J2601®

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

Operation of HRS





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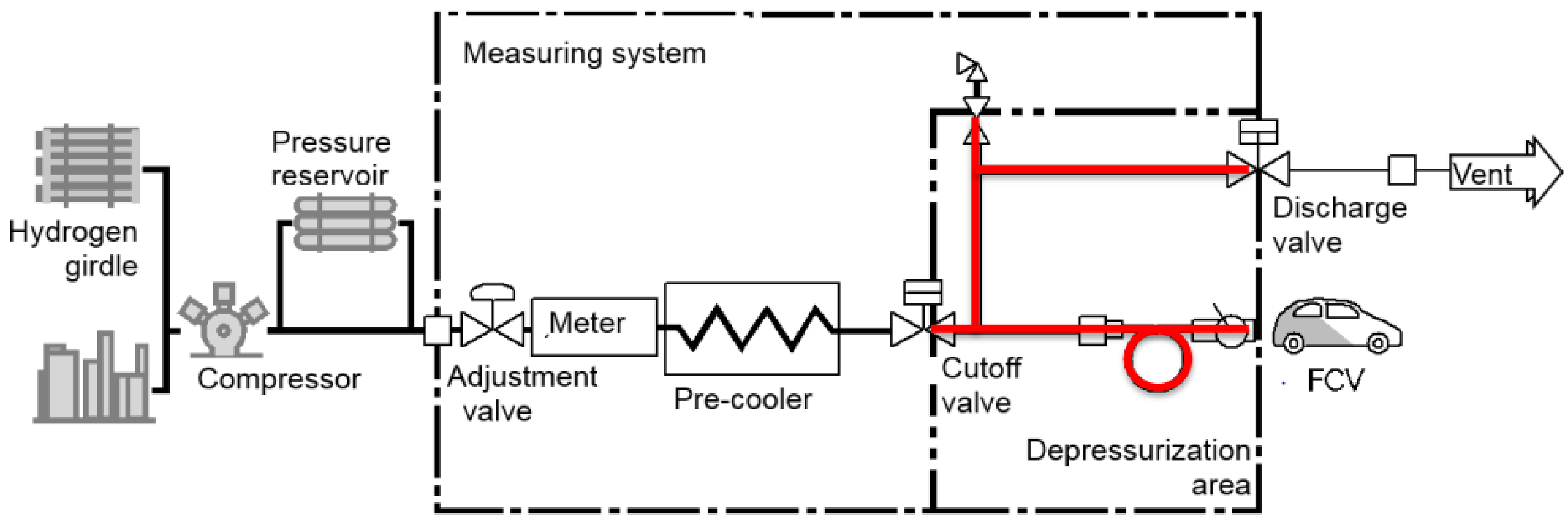


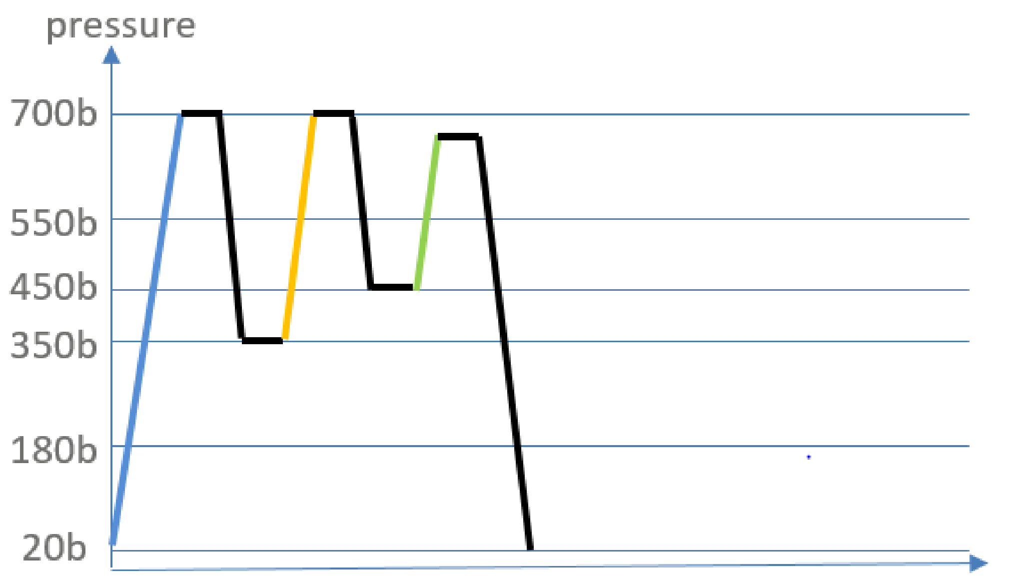
More recent HRS have the meter and the pre-cooler mounted directly in the dispenser

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 (in older designs)
- Depressurization losses after fill

Testing of HRS

- On site accuracy tests based on OIML R139-2018
  - Full fill: fill an empty tank up to the automatic stop of the HRS (700 bar or 350 bar)
  - Partial fill: fill from half full up to automatic stop of the HRS
  - Minimum Measurable Quantity (MMQ), manual or automatic stop
- 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% for 1 kg of H_2)



Tests required by OIML R139

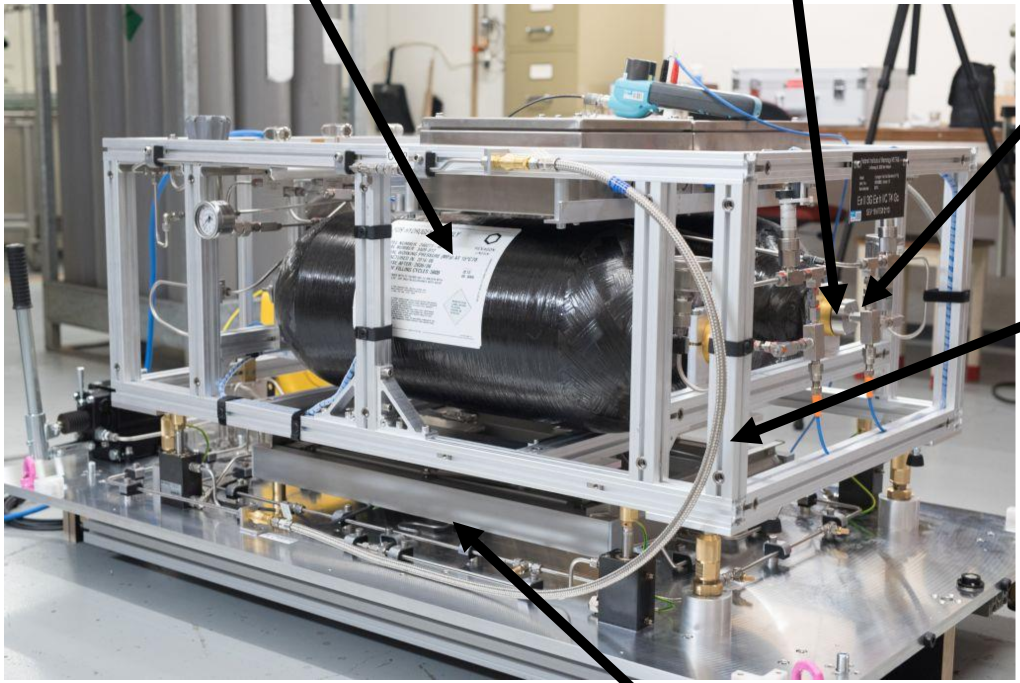
Design of METAS field test standard

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



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

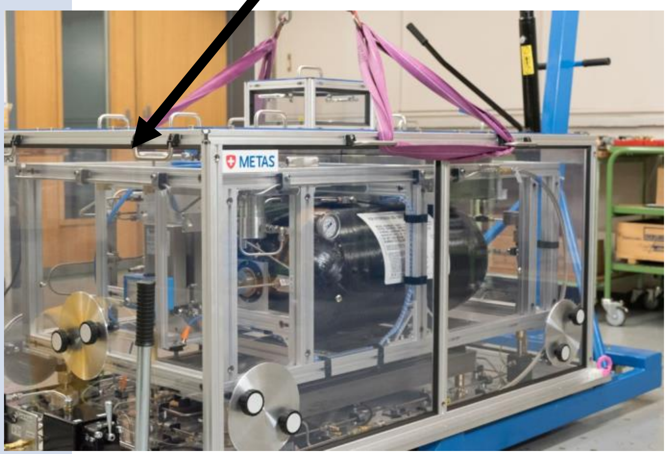
300 kg scale
0.1 g resolution

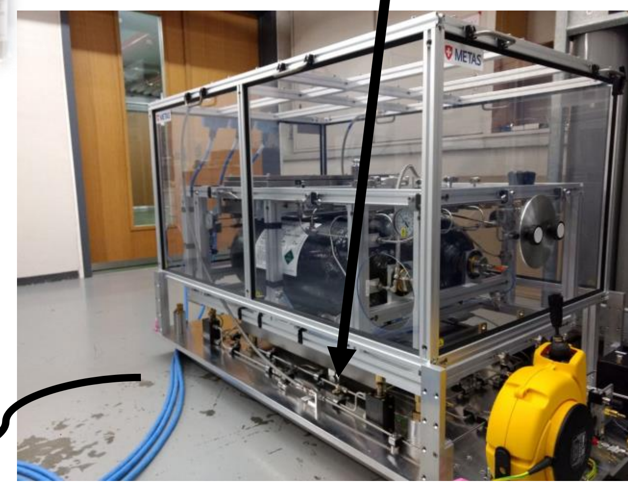
Design of METAS field test standard

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





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

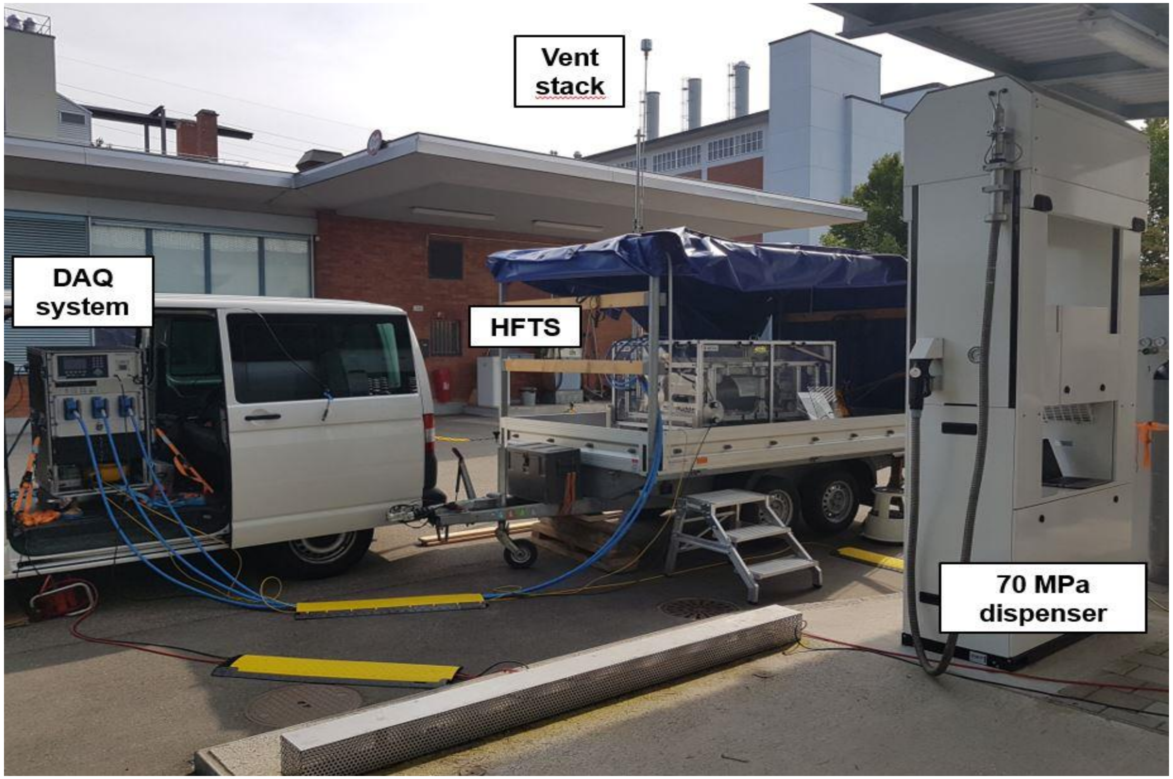
- **before**: connect gas source
- **during**: monitor and record data
- **after**: disconnect gas source

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

Field testing

- Installation: 2 h
- Scale calibration: 30 min
- Testing at 700 bar: 3 days
    - 3 x full fills
    - 2 half fills
    - 3 MMQ
- Stabilization time: 20 min



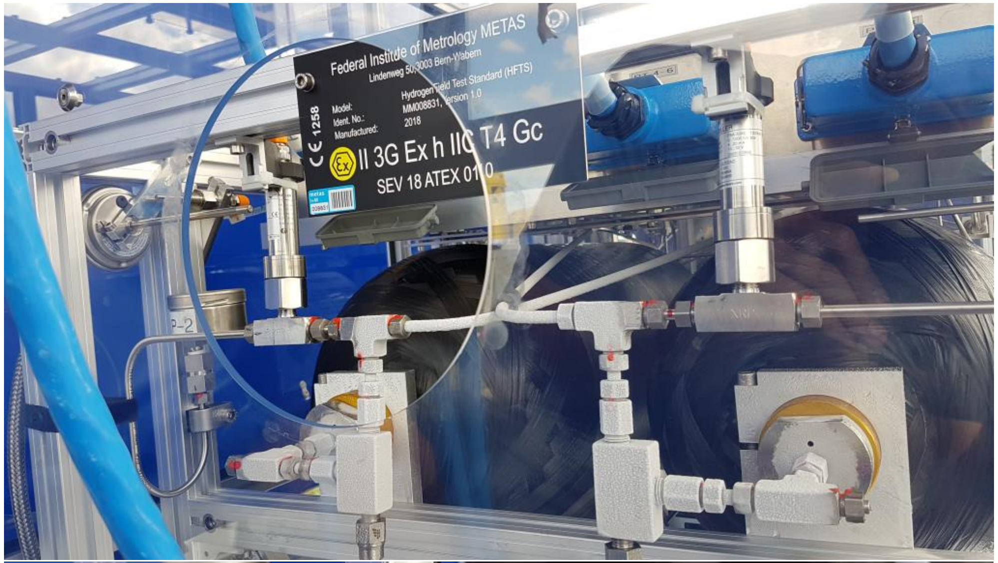
- Venting from 700 bar to 20 bar: 1.5 h
- Flushing with Nitrogen before transport: 1.5 h
- Packing for transport: 1.5 h

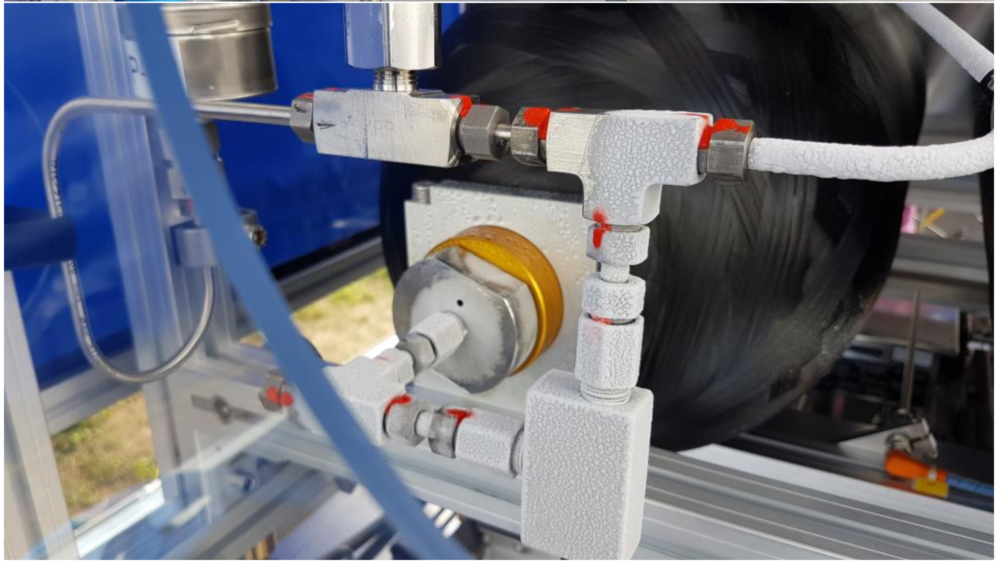
Field testing

Field testing

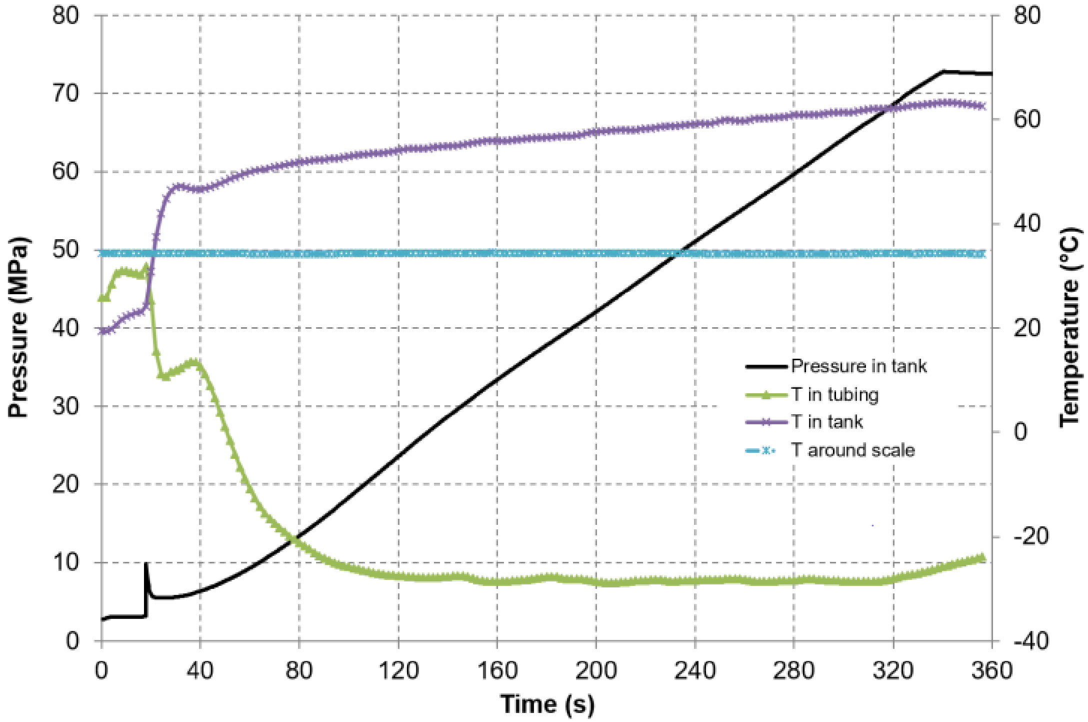
Field testing

Ice formation on the piping



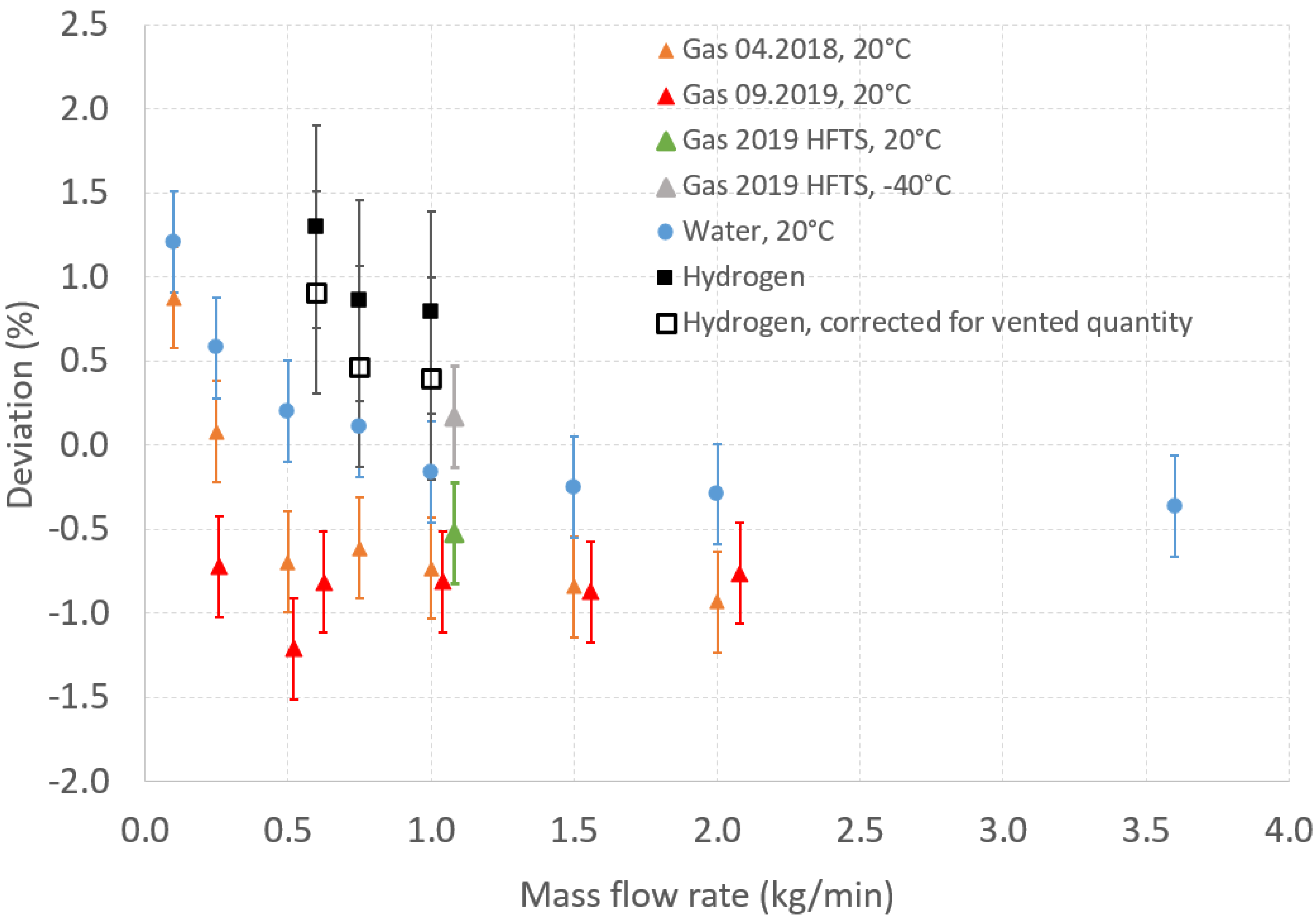


Field testing



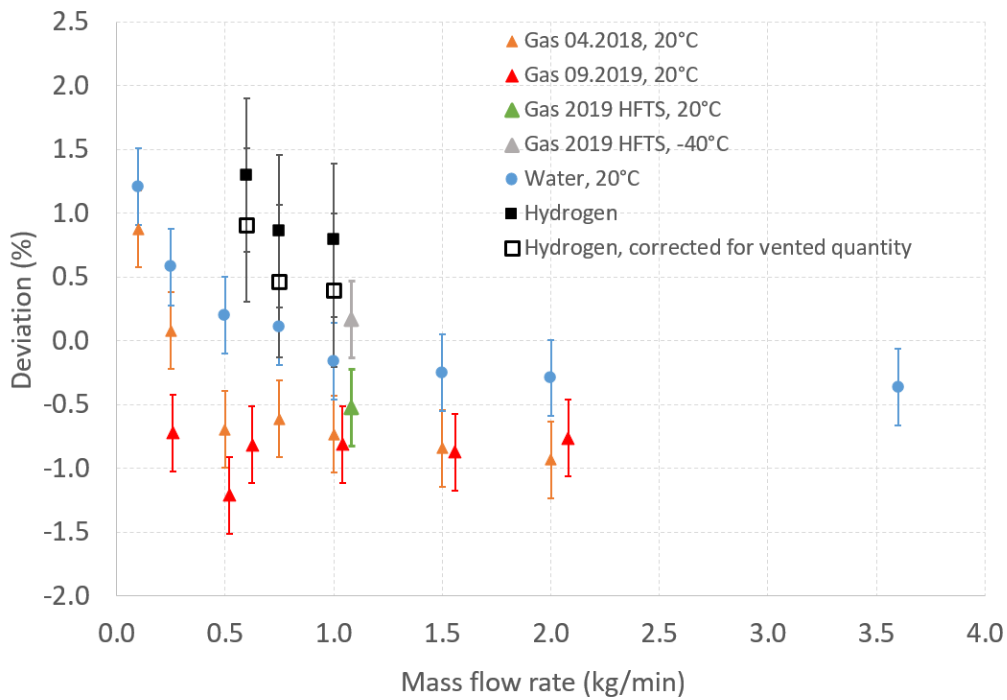
- Steady pressure increase in the tanks
- Sharp increase in tank temperature followed by steady increase
- Sharp decrease in piping temperature due to hydrogen at -40 °C

Field testing vs substitute substances



Field testing vs substitute substances

- All tests with N_2 are consistent
- Shift of 1 % to 1.7 % between H_2 and N_2
- Shift of 0.3 % to 0.6 % between H_2 and water at 20 °C
- Only limited set of data is available
- No total confidence of describing the characteristics of a CMF with hydrogen using substitute substances
- More data on the equivalence are needed



Still to come and outlook

- Task 1.1: Key comparison with existing gravimetric standards (**CESAME**, BEV, JV, METAS, NEL, Empa)
  - Establish trust
- Task 1.2: New primary standards for heavy-duty vehicle refueling (**METAS**, NEL, Empa, BEV, CESAME)
  - Expand measurement capabilities to higher flow rates
- Task 1.3 Development and validation of a method using secondary standards (master meters) for vehicle refueling capable of covering light-duty to heavy-duty vehicles (**CESAME**, BEV, JV, METAS, NEL, Empa)
  - Establish less time-consuming method for field verification
- Task 1.4: Develop a model for assessing the uncertainty at HRS (**NEL**, BEV, CESAME, JV, METAS)
  - Distribute knowledge on uncertainty sources
- Task 1.5: Recommendation on the periodic verification of HRS (**BEV**, CESAME, JV, METAS, Empa)
  - Harmonize verification periods

Still to come and outlook

1. To develop a metrological framework for calibrating critical nozzles with hydrogen up to 800 bar
   - Use a Coriolis meter as master meter, calibrate it against a gravimetric standard
   - Calibrate critical nozzles over a pressure range up to 800 bar with hydrogen

2. To develop test rigs for calibrating flow meters with hydrogen up to 30 bar and 4 kg/h

Still to come and outlook

Met4H_2

1. To develop measurement standards to enable calibration and validation of flow metering equipment under actual conditions (pressure, temperature), used to accurately quantify flow rates of hydrogen (including blended hydrogen) through the hydrogen supply chain, and to ensure compliance with respect to e.g. OIML R139, OIML R140, and the Measurement Instruments Directive

2. CMCs for flow metering mixed with natural gas

Thank you very much for your attention