Workshop on the harmonisation of verification periods for HRS in Europe

Challenges in field testing

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Agenda

- Field testing in a nutshell
- Test equipment challenges
- Measurement challenges
- Conclusion

Field testing in a nutshell

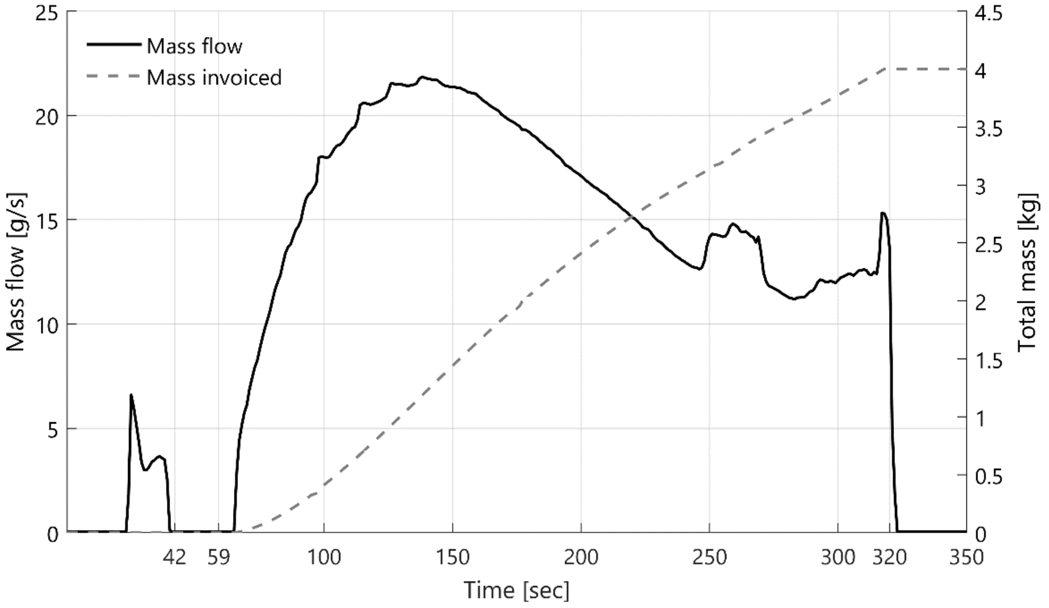
METROLOGY for HYDROGEN VEHICLES 2

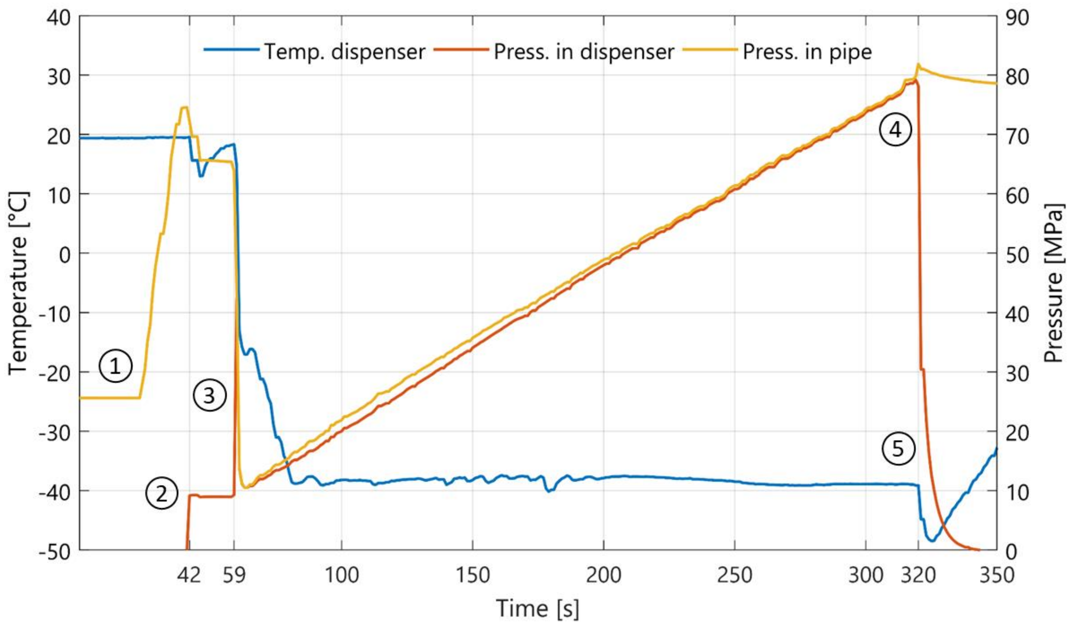
OIML R 139-2

Edition 2018 (E)

Compressed gaseous fuel measuring systems for vehicles.

Part 2: Metrological controls and performance tests





J2601®

SAE INTERNATIONAL

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

Field testing in a nutshell

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

Table 2 - E_{min}

Accuracy class	E_{min} [g; kg]		
	for the meter	for the complete measuring system	
		at type evaluation, initial or subsequent verification	at in-service inspection
1.5	0.02 MMQ	0.03 MMQ	0.04 MMQ
2	0.03 MMQ	0.04 MMQ	0.06 MMQ
4	0.04 MMQ	0.08 MMQ	0.1 MMQ

Table 6 - Initial settings for tests on systems without sequential control

Test #	Initial state
Test 4	Initial test receiver pressure of 0 kPa or higher if so required for safety reasons Initial station storage pressure at P_{st}
Test 5	Initial test receiver pressure of 0.5 P_v Initial station storage pressure at P_{st}

Test #	
Test 7 (minimum measured quantity)	The conditions for test 3 or 6 are adapted in order to test the minimum measured quantity. For this purpose, the pressure does not have to be P_v in the test receiver at the end, but may be any pressure (as close as practical to P_v) such that the quantity of transferred gas shall be at least the minimum measured quantity.

- Not possible to calibrate the meter separately with hydrogen in the relevant pressure and flow rate range
- 8 measurements in total
- Testing performed at HRS with a traceable standard

Test equipment challenges

Requirement	Solution
Testing of complete measuring system with hydrogen	On-site field testing • Mobile test rig • Can be placed next to the HRS • Can be connected to the HRS
Safety (explosive atmosphere)	Certification of test rig (Ex)
Safety (additional or national regulations)	?
Nominal working pressure of 70 MPa or 35 MPa	Standard with required pressure rating
Temperature range (-40 °C hydrogen, heating due to flow force, ambient temperature conditions, …)	Standard with required temperature rating, protected from weather conditions

Test equipment challenges

- Uncertainty requirements on the traceable standard
  - Less than 1/5 of applicable MPE for type-approval

Quantity	MPE		Uncertainty of test rig	
1 kg (MMQ)	4 %	40 g	8 g	0.8 %
4 kg	2 %	80 g	16 g	0.4 %

  - Less than 1/3 of applicable MPE for verification

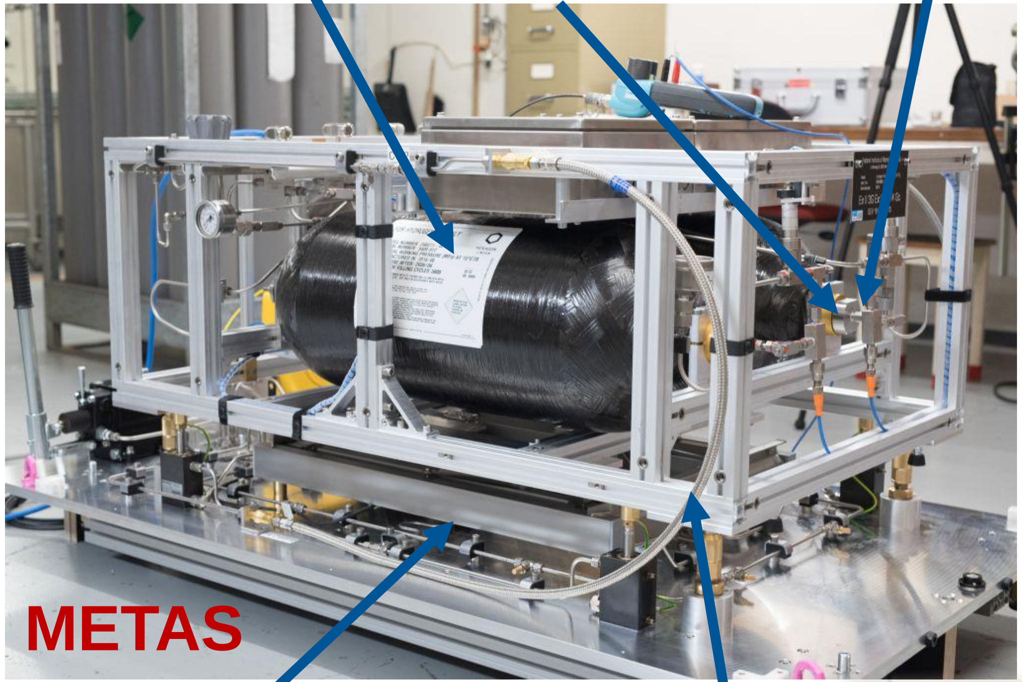
Quantity	MPE		Uncertainty of test rig	
1 kg (MMQ)	4 %	40 g	13.3 g	1.33 %
4 kg	2 %	80 g	26.7 g	0.67 %

Test equipment challenges

100 MPa pressure transducer

36 L type 4 cylinders
1.44 kg H_2 @ 70 MPa

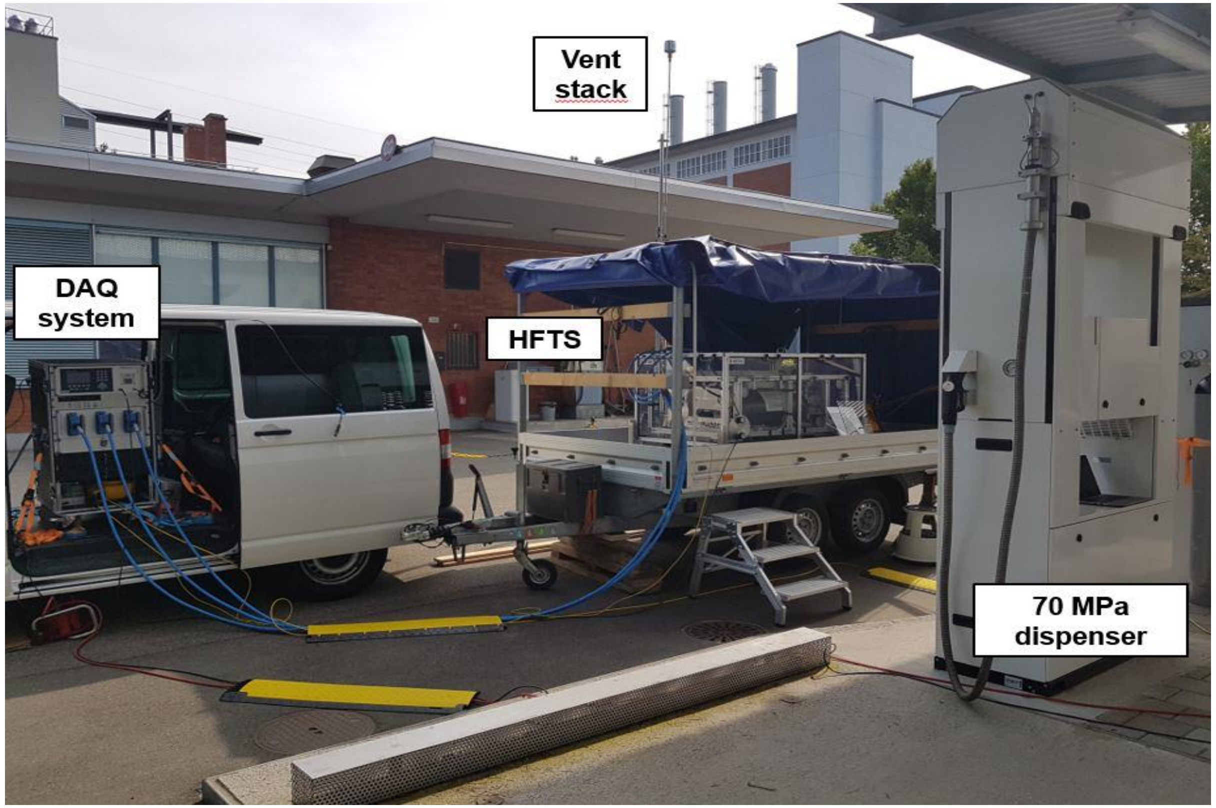
Pt 100 probe, 27 cm inserted in tank

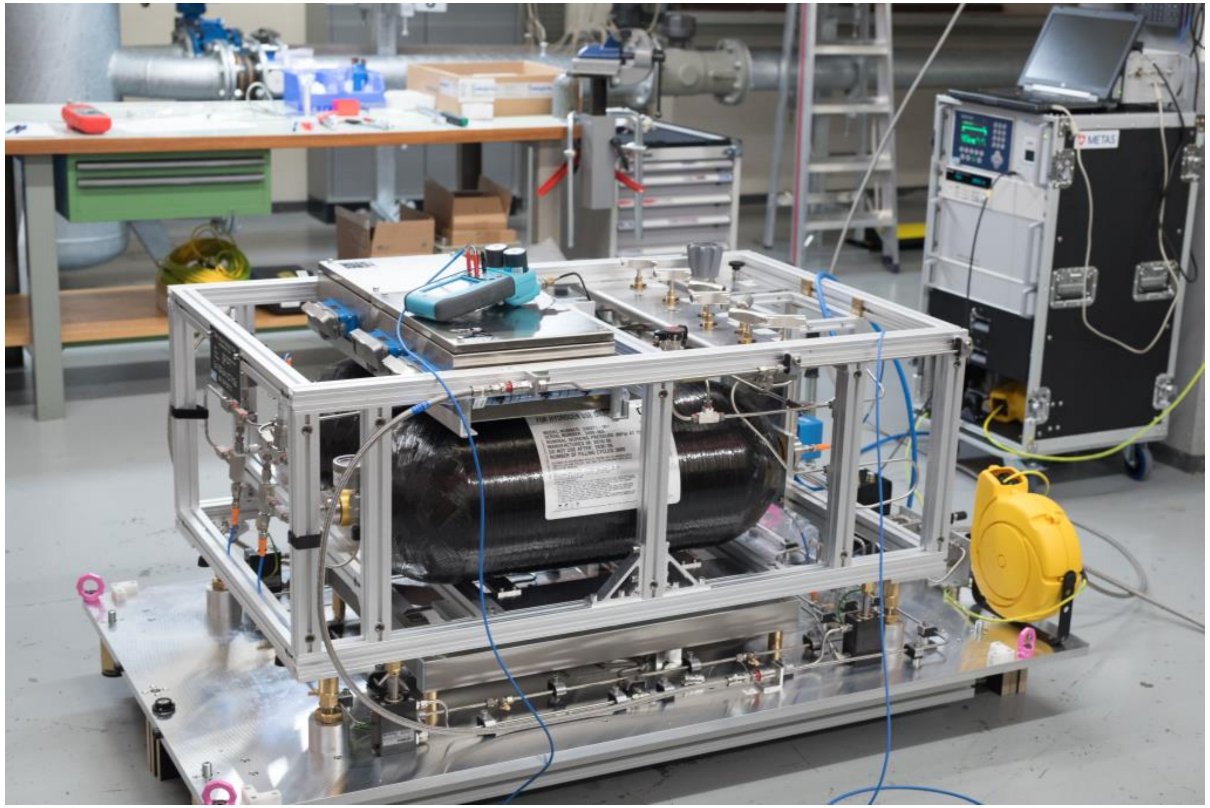


300 kg scale
0.1 g resolution

Venting line

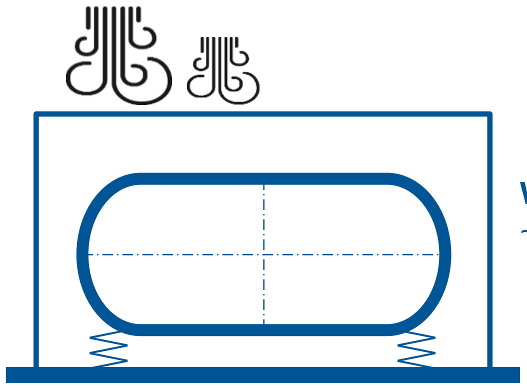
Test equipment challenges



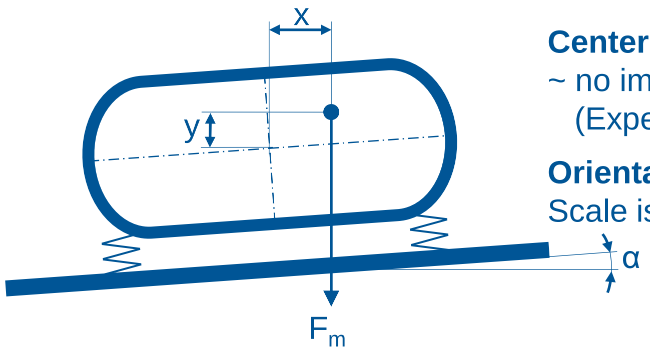


U(k=2) = (3 to 5)g

Challenges due to testing method

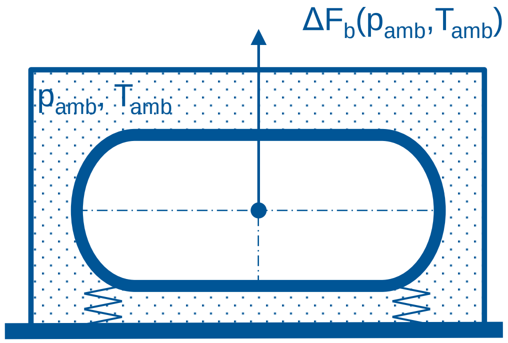


Wind:
~ almost no impact



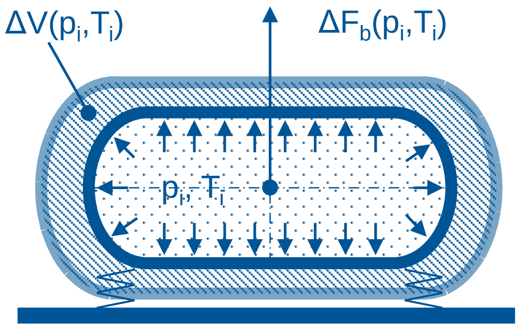
Center of mass:
~ no impact
(Experiment)

Orientation:
Scale is levelled.



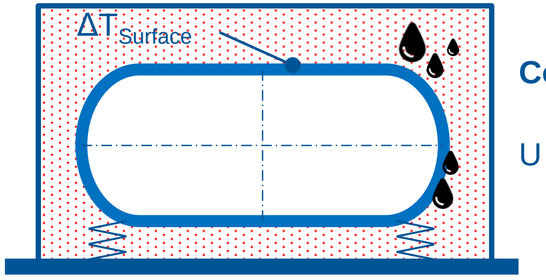
Buoyancy change:
ΔT_{amb} of 1 K ≈ 0.8 g
with U = 2.5 K ≈ 2 g

Buoyancy change:
Δp_{amb} of 1 mbar ≈ 0.2 g
with U = 0.5 mbar ≈ 0.1 g



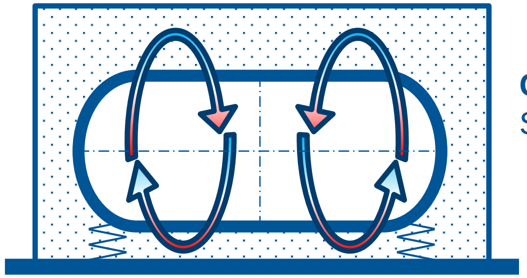
Buoyancy change :
Thermal expansion:
$\alpha = -0.1 * 10^{-6}$ /K

Buoyancy change :
Material expansion:
Δp_i of 700bar ≈ 2 g
with U = 20% ≈ 0.4 g



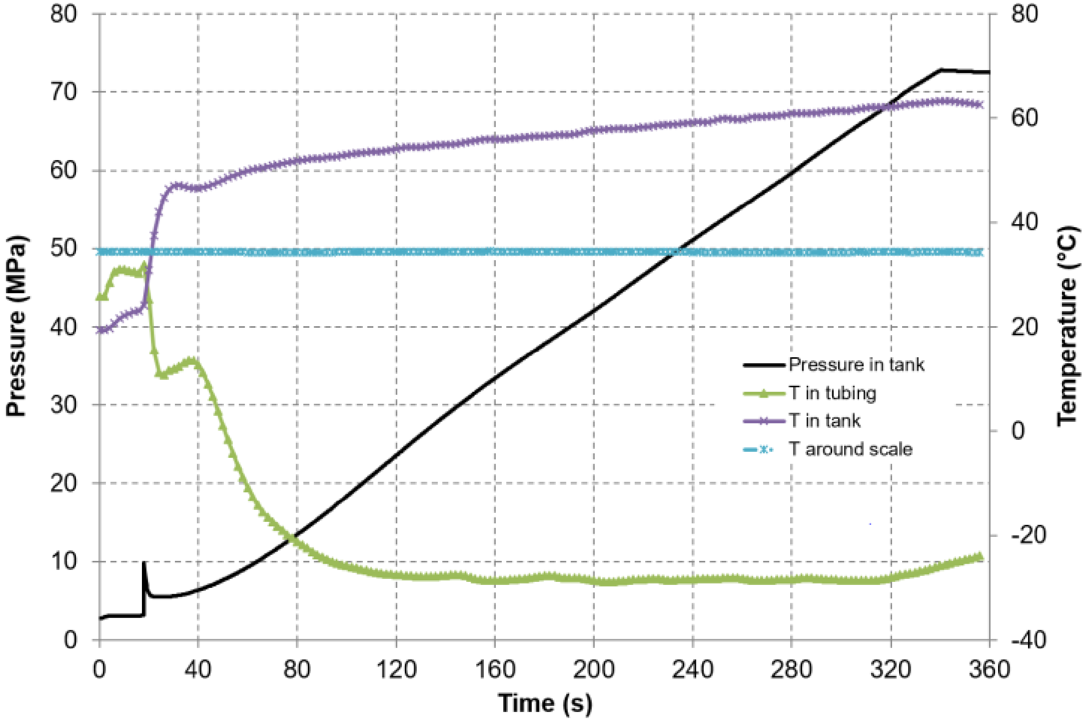
Condensation, ice:

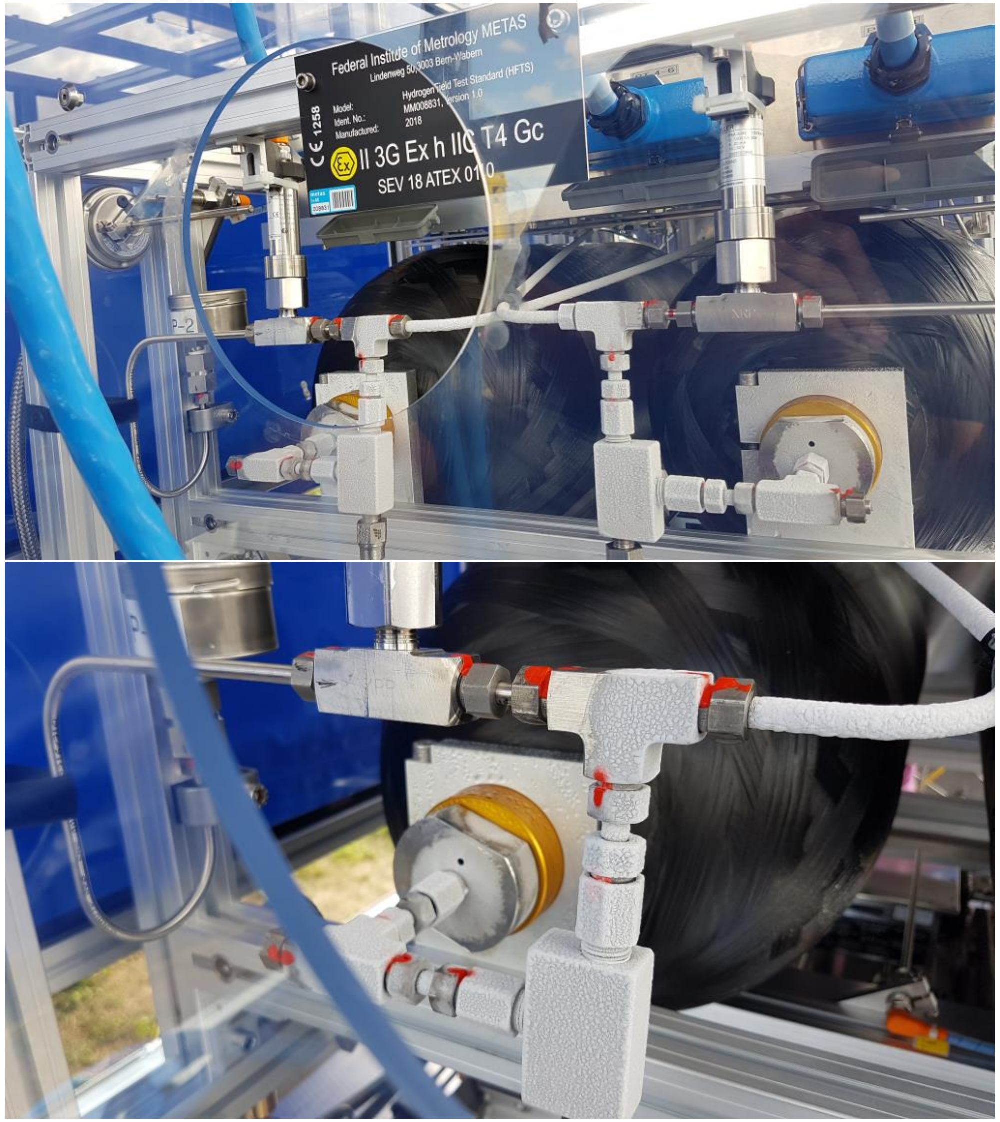
U = **1** g



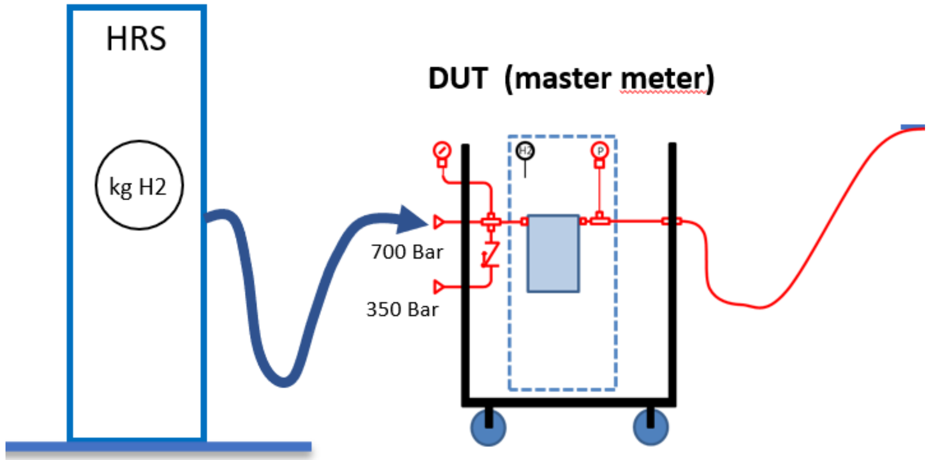
Convection currents:
Stability of temperature

Challenges due to testing method

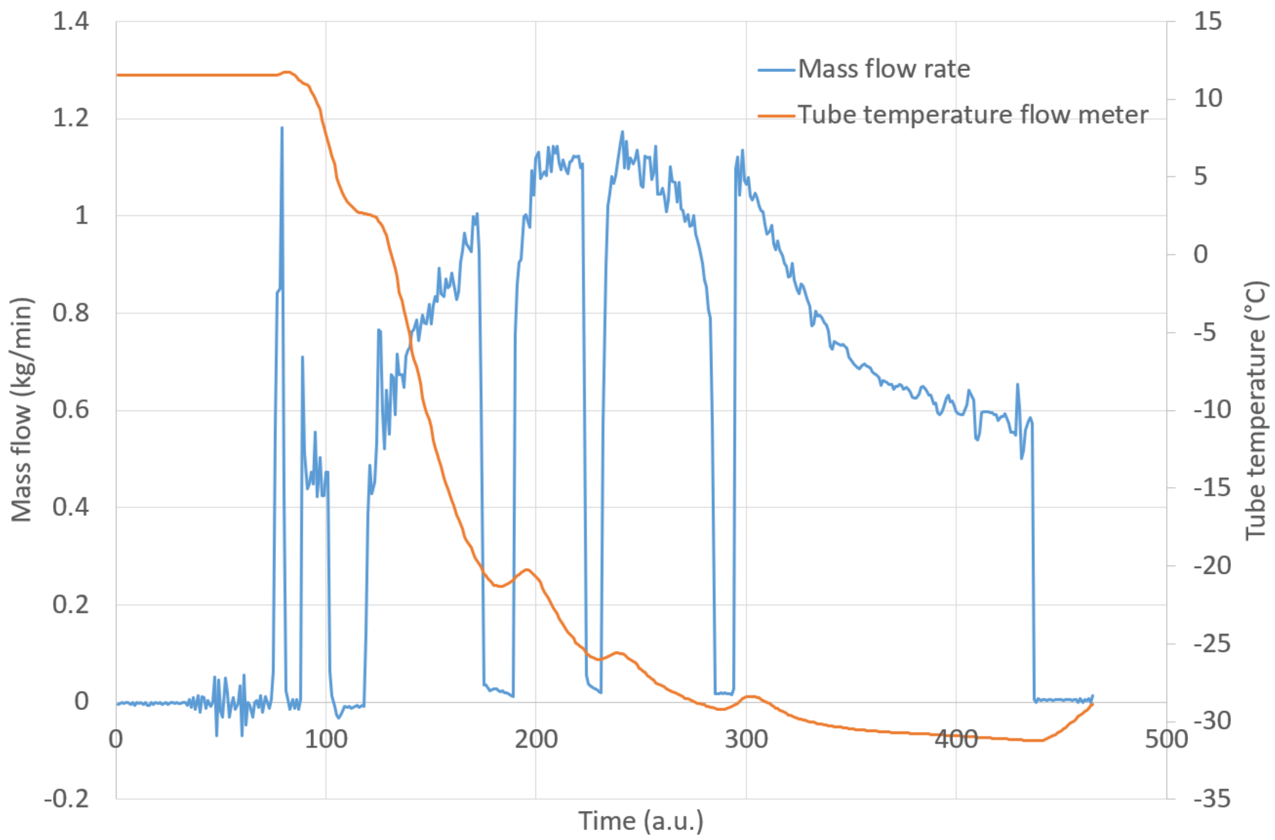




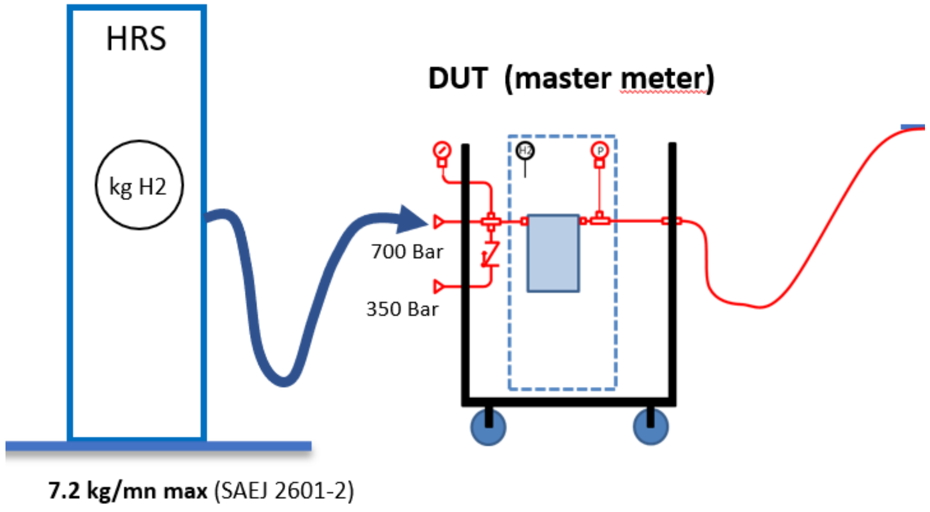
Challenges due to testing method

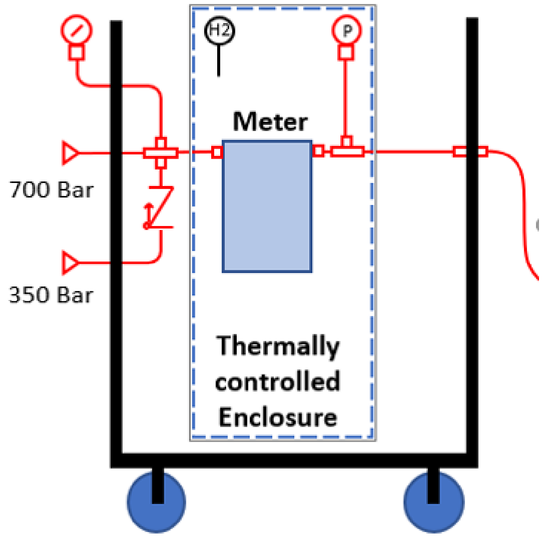


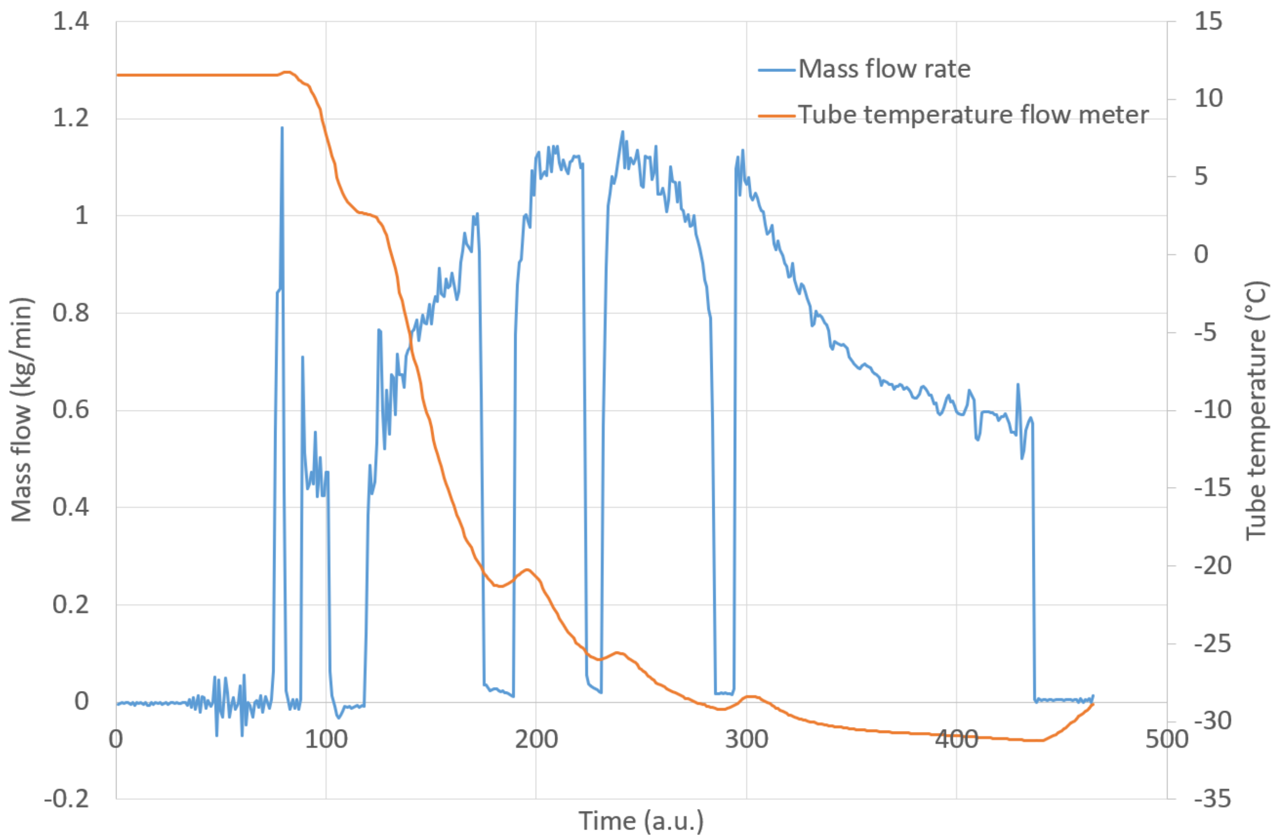
7.2 kg/mn max (SAEJ 2601-2)



Challenges due to testing method







Limited data in Europe about stability of master meter method

Challenges due to testing method

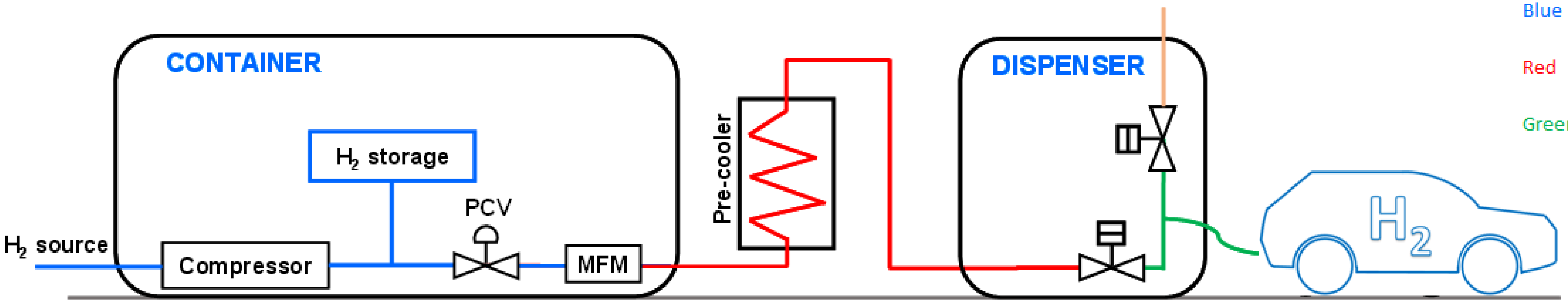
INPUTS

Station configuration	update				
Flow meter location	In main station, after PCV				
Pre-cooler	YES				
Vented volume correction applied	YES				
Dead volume correction applied	NO				
Volume			**Uncertainty**		
Between meter and pre-cooler	0.30	litres		10	%
Pre-cooler	3.00	litres		10	%
After pre-cooler	3.00	litres		10	%
Vented	0.20	litres		10	%

OUTPUTS

Parameter	**Value**	**Uncertainty (k = 2)**	
	kg	%	kg
Total metered mass	1.936	**0.75**	**0.014**
Dead volume mass	0.098	**6.77**	**0.007**
Vented volume mass	0.006	**10.00**	**0.001**
Total delivered mass	1.831	**0.87**	**0.016**

Dead volume mass error / kg	0.098		
Vented volume mass error / kg	0.001		
Expected error range / kg	0.083	to	0.115
as % of total delivered mass	4.54	to	6.27



Blue Un-metered hydrogen

Red Dead volume - metered but not delivered to vehicle

Green Vented volume - metered but not delivered to vehicle

Conclusion

- Field testing has its challenges
- Test equipment must fulfil safety and metrological requirements
- Testing method requires good understanding and characterisation of the test equipment
- Gravimetric system has an upper limit on size
- Testing method requires good understanding of the design of the HRS and of error sources
- Further characterisation work and improvements on the master meter method are needed

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THANK YOU