Department for Science, Innovation & Technology

TÜV SÜD

TÜV SÜD Master Meter system for testing of Hydrogen Refuelling Stations accuracy

The Measurement Focus Group Meeting,
10th of June 2026

Add value.
Inspire trust.

Contents

Shift towards zero-emission vehicles

- UK and the European Union are committed to net zero by 2050
- Transport remains the highest carbon emitting sector in the UK and EU
  - 29% of GHG emissions in the EU (2022) and UK (2023)
- UK's Zero Emission Vehicle (ZEV) mandate with 100% ZEV by 2035

Annual target for ZEV sales shares from 2024 to 2035

Year	2024	2025	2026	2027	2028	2029	2030
Target	22%	28%	33%	38%	52%	66%	80%

- EU Fit for 55 package
  - Reduce GHG emissions from vehicles by at least 55% by 2030
- Two options for ZEVs: battery electric vehicles and hydrogen-powered vehicles
- Advantages when using hydrogen-powered vehicles
  - Shorter refuelling times (under 5 minutes for cars)
  - Longer range (ideal for heavy duty vehicles)
  - Higher energy density (lightweight powertrain)

2023 Net UK GHG Emissions by TES Sector

Source: https://assets.publishing.service.gov.uk/media/6604460f91a320001a82b0fd/uk-greenhouse-gas-emissions-provisional-figures-statistical-release-2023.pdf

Source: S Mathison- FirstElement Fuel Inc. , "How to Deploy H2 Trucks", in 2024 Mission - Hydrogen Online conference, 2024

Regulatory requirements for refuelling stations

- Accurate refuelling at the station affects customer confidence and the UK government (fuel duty & VAT)
- **OIML R 117:** For liquid fuels (petrol, diesel, etc.) - error at the dispensing nozzle must be -0.5% to 1.0% at minimum measured quantity (MMQ) of 5 L
- **OIML R 139:** For gaseous fuels - 2018 version sets out accuracy requirements for hydrogen refuelling station (HRS) dispensers
- Two accuracy classes for hydrogen gas

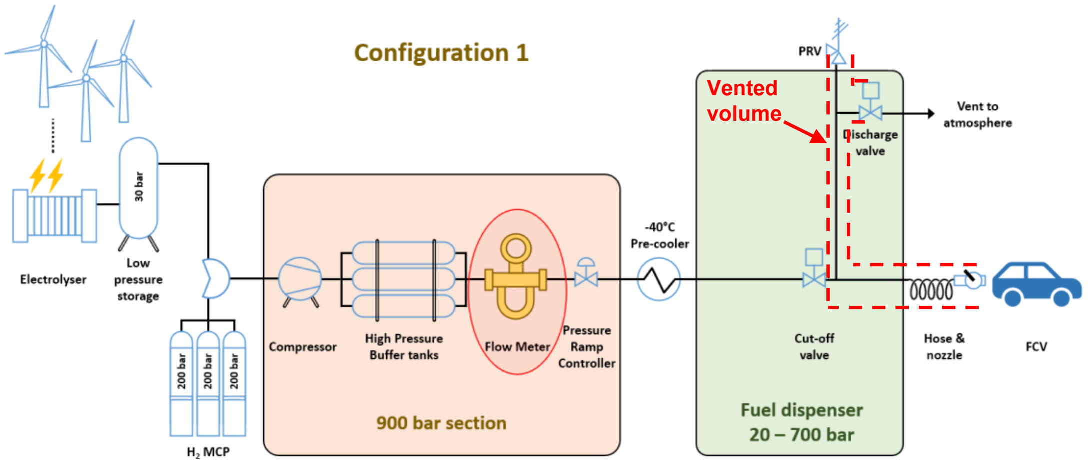
Accuracy class		MPE for the meter [in % of the measured quantity value]	MPE for the complete measuring system [in % of the measured quantity value]	
			at type evaluation, initial or subsequent verification	in-service inspection under rated operating conditions
For general application	1.5	1	1.5	2
For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

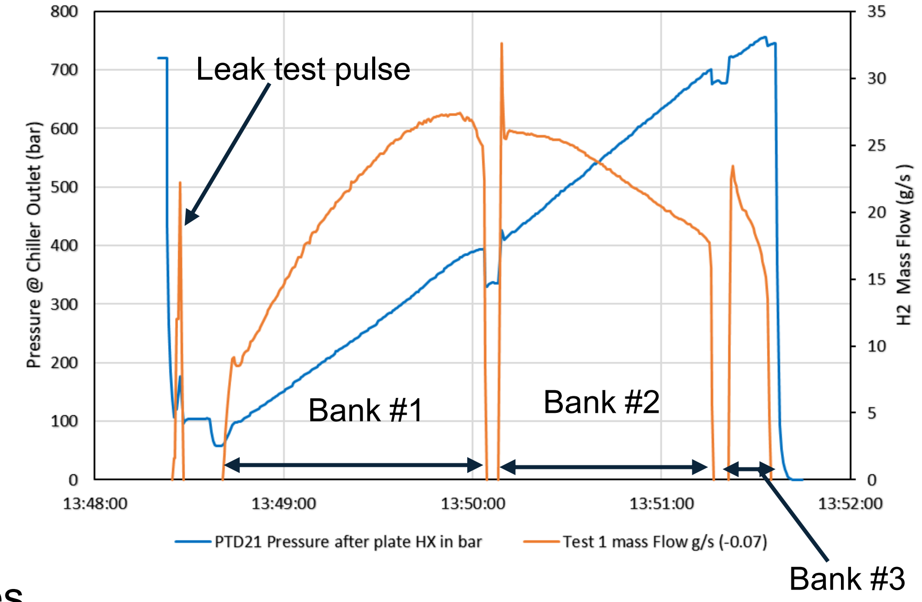
- Minimum Measured Quantity (MMQ) for hydrogen = 1 kg
- Maximum Permissible Error (MPE) is doubled at MMQ:
- Challenging due to the HRS operating conditions specified in SAE J2601

Requirement to verify performance of the HRS flow meter and the dispenser as a complete measuring system

OIML R 139 provides no specification for the testing equipment, but NMIs favour a gravimetric approach

Measurement challenges when fuelling hydrogen vehicles



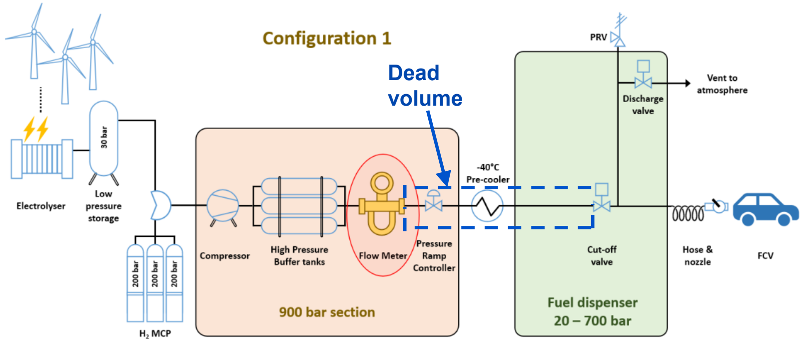


- Hydrogen refuelling process
  - Leak test pulse - also checks initial vehicle pressure and tank capacity
  - Bank switching at some HRS dispensers as the vehicle pressure increases
  - Venting of hydrogen in the hose after refuelling is completed before the nozzle can be disconnected
- Measurement challenges
  - Hydrogen supplied can vary up to 875 bar in pressure
  - Dead volume (up to 200 g)
  - Fast refuelling flow rates requires precooling of hydrogen to -40 °C
  - Vented gas (ca. 10 g)
- Appendix B of OIML R139 - A method to correct for the vented gas

$$Depressurisation\ quantity\ (kg) = M \sum \left(\frac{PV}{RfT} \right)$$

Where:
M: H_2 molecular mass
T: Temperature
P: Pressure
R: Gas constant
V: Volume of depressurisation area
f: Compressibility factor

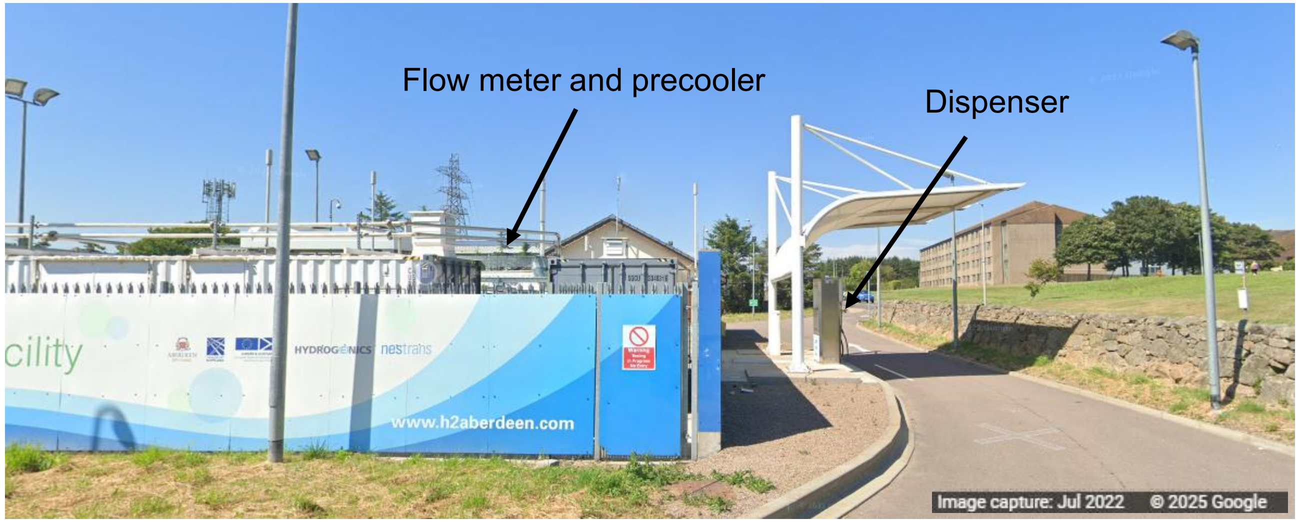
HRS configurations and effect on flow measurement



Meter at 900 bar section before pre-cooler

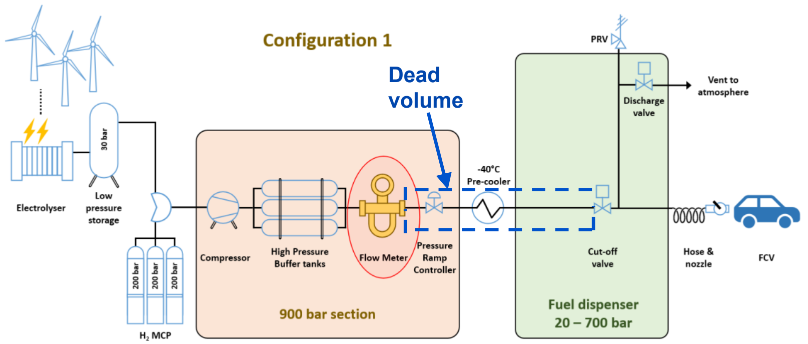
- **Pro:** relatively constant near ambient temperature
- **Con:** significant 'dead volume' containing gas measured by flow meter but not delivered to the FCEV

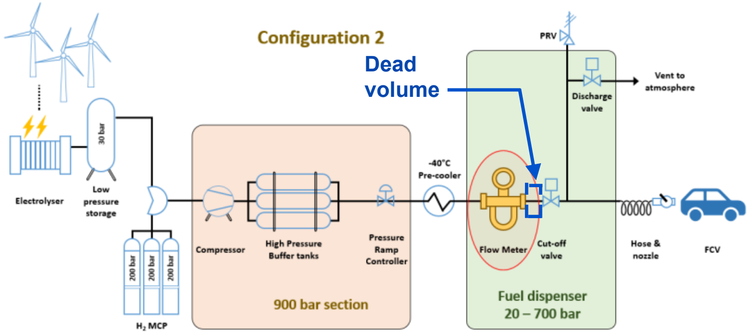
Aberdeen Cove Bay HRS

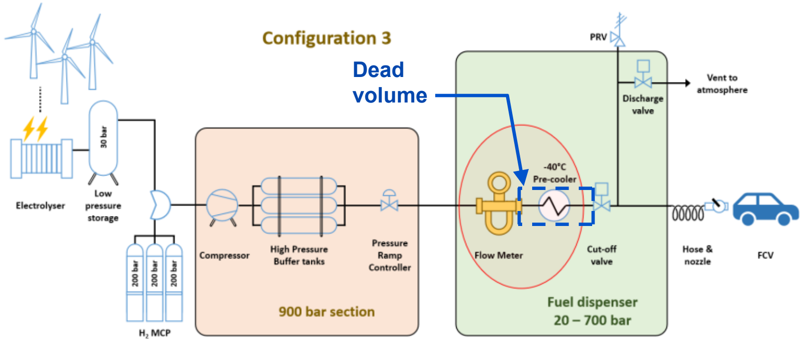


Source: https://www.google.com/maps/place/Aberdeen+Hydrogen+Centre

HRS configurations and effect on flow measurement







Meter at 900 bar section before pre-cooler

- **Pro:** relatively constant near ambient temperature
- **Con:** significant 'dead volume' containing gas measured by flow meter but not delivered to the FCEV

Meter at dispenser after pre-cooler

- **Pro:** 'dead volume' minimised
- **Con:** large change hydrogen gas temperature from initial ambient to -40 °C

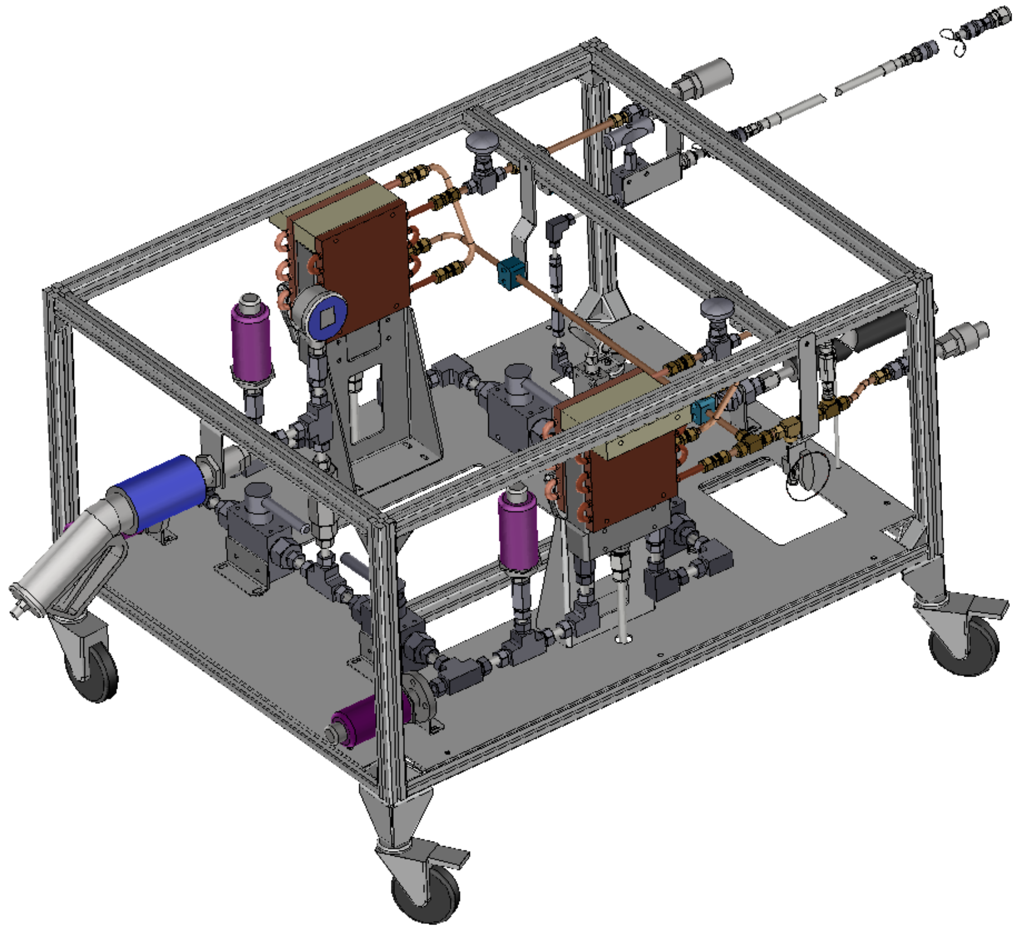
Meter at dispenser but before pre-cooler

- **Pro:** relatively constant near ambient temperature whilst reducing the 'dead volume'
- **Con:** could be expensive for large stations with multiple dispensers

Requirement to verify performance of the HRS flow meter and the dispenser as a complete measuring system

TÜV SÜD Master Meter Standard

- Project is partially funded by DSIT and EURAMET MetroHyVe 3 project
- Requirement: Evaluate accuracy of hydrogen dispensed from light duty HRSs with respect to OIML R139
- Target uncertainty is ≈ **1.2%**
- Partially based on experience from LD HFTS design
- Master Meter system with a hydrogen capacity flow rates up to **18kg/min**
- Capability to verify dispensers filling hydrogen to **700 bar**
- Safety Studies include HAZOP and Hazardous Area Classification study
- Needs to conform to UK regulations
  - Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR)
    - ATEX/ UK EX – Zone 2
    - Pressure Systems Safety Regulations



TÜV SÜD Master Meter Standard

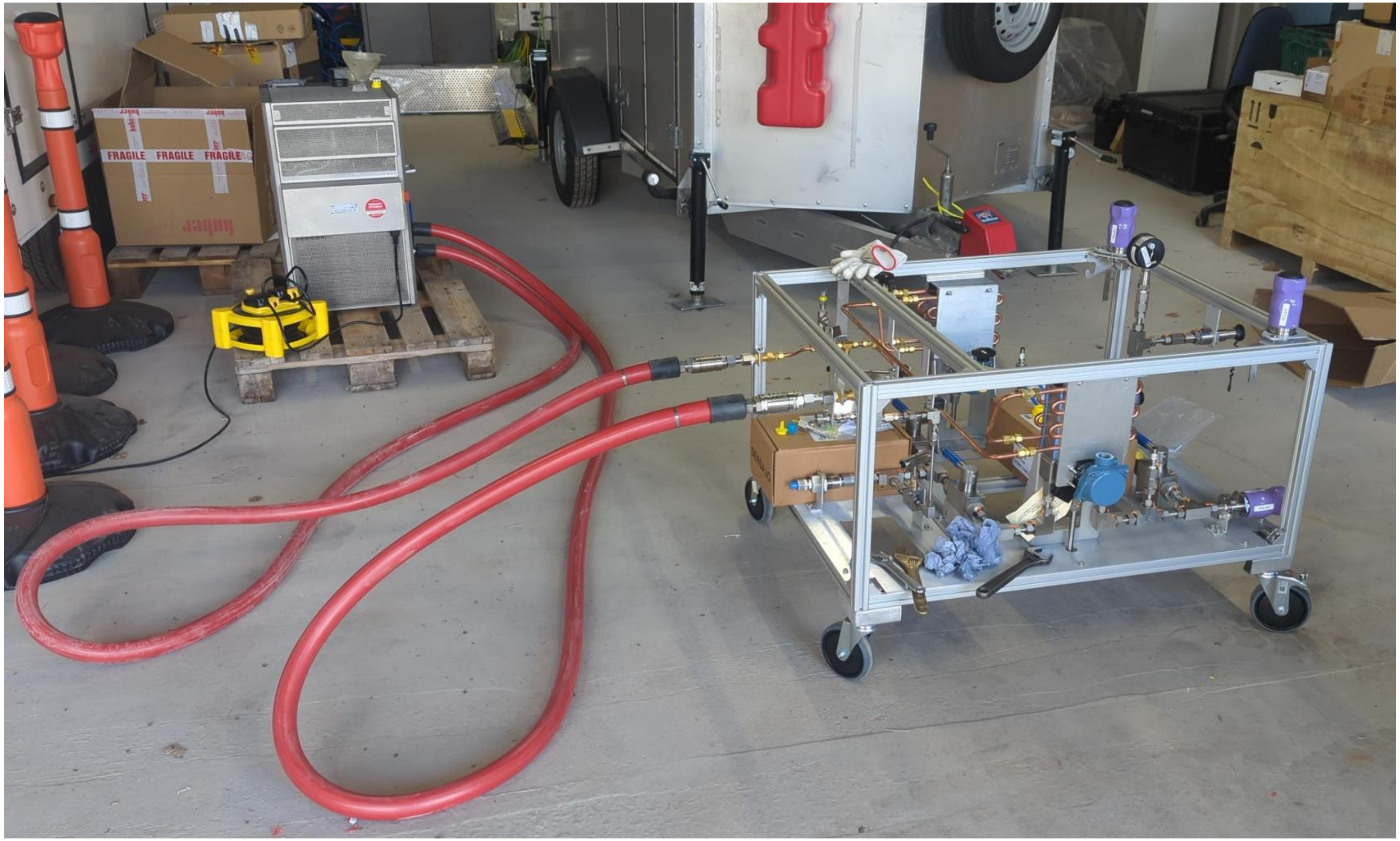
TÜV SÜD Master Meter Standard

Key components of the system:

- Two parallel installed Coriolis mass flow meters, each capable of hydrogen flow rate up to 18kg/min at 700bar (future refuelling standard for trucks, trains)
- Cold plates aligned with the flow meters to allow for temperature compensation during test
- Two wireless temperature sensors
- Two wireless pressure sensors
- H70 receptacle used as inlet (different fitting is possible)
- H70 nozzle used as outlet (different fitting is possible)
- Huber Unistat 705 used as the supply of cooling liquid to cold plates
- Earth Monitoring System – to prevent operation in case some static charges are detected on the frame or system is not properly grounded
- Venting stack

TÜV SÜD Master Meter Standard

- The MMS connected to Huber cooling bath
- Partially deployed for cooling system performance tests



TÜV SÜD MMS: Design difference to gravimetric system and the challenges the system faces

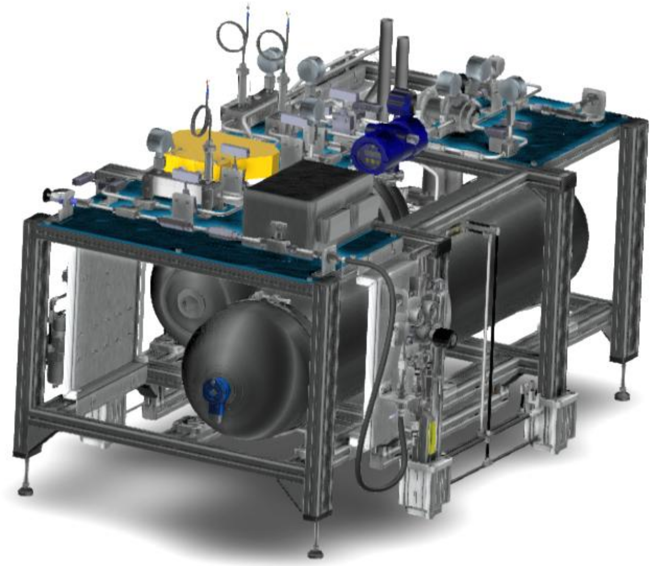
- The gravimetric system has best level of uncertainty due to its direct traceability to mass standard.

However:

- The system requires time to deploy, approximately 2 hours
- The system is very sensitive to external conditions like:
  - Low temperature, below 10ºC operations is very limited due to balance performance being affected, condensation and/or freezing affecting the balance indications
  - Wind may affect the balance reading stability
- The balance stability is always an issue due to system being mobile. Levelling the trailer and then the balance takes a lot of time on the site what is not preferred by the HRS operators
- The tanks installed on the weighted frame require venting what takes quite a lot of time due to tank manufacturer limits set at 10bar/min

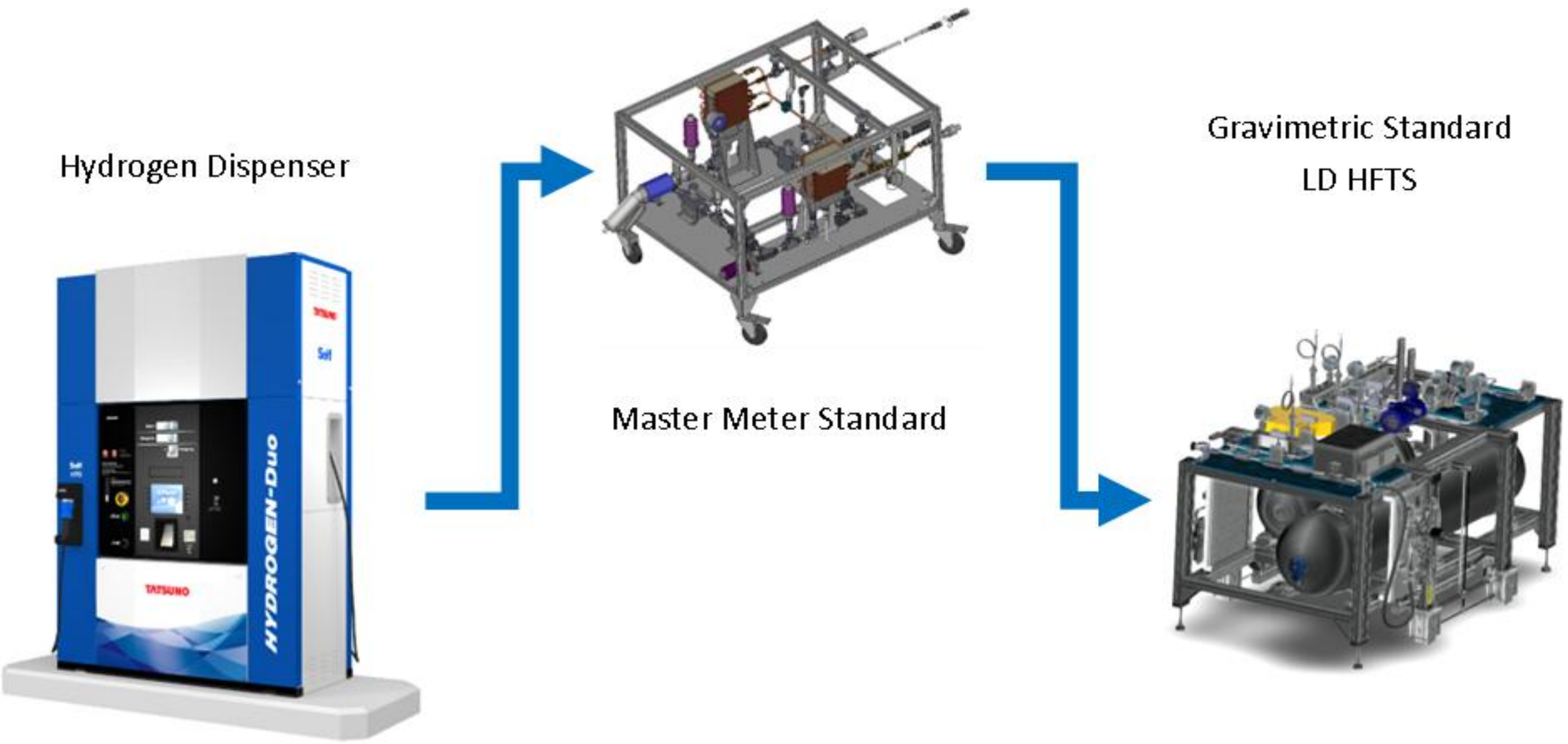
TÜV SÜD LD HFTS – Gravimetric standard

- TÜV SÜD LD HFTS is gravimetric standard used to calibrate hydrogen refuelling stations using direct weighting of the hydrogen dispensed.
- It has 51L + 103L storage tanks
- At 700 bar the approximate mass of hydrogen is 6 kg
- System was tested at operating HRS and took part in intercomparison during EURAMET MetroHyVe 2 project.



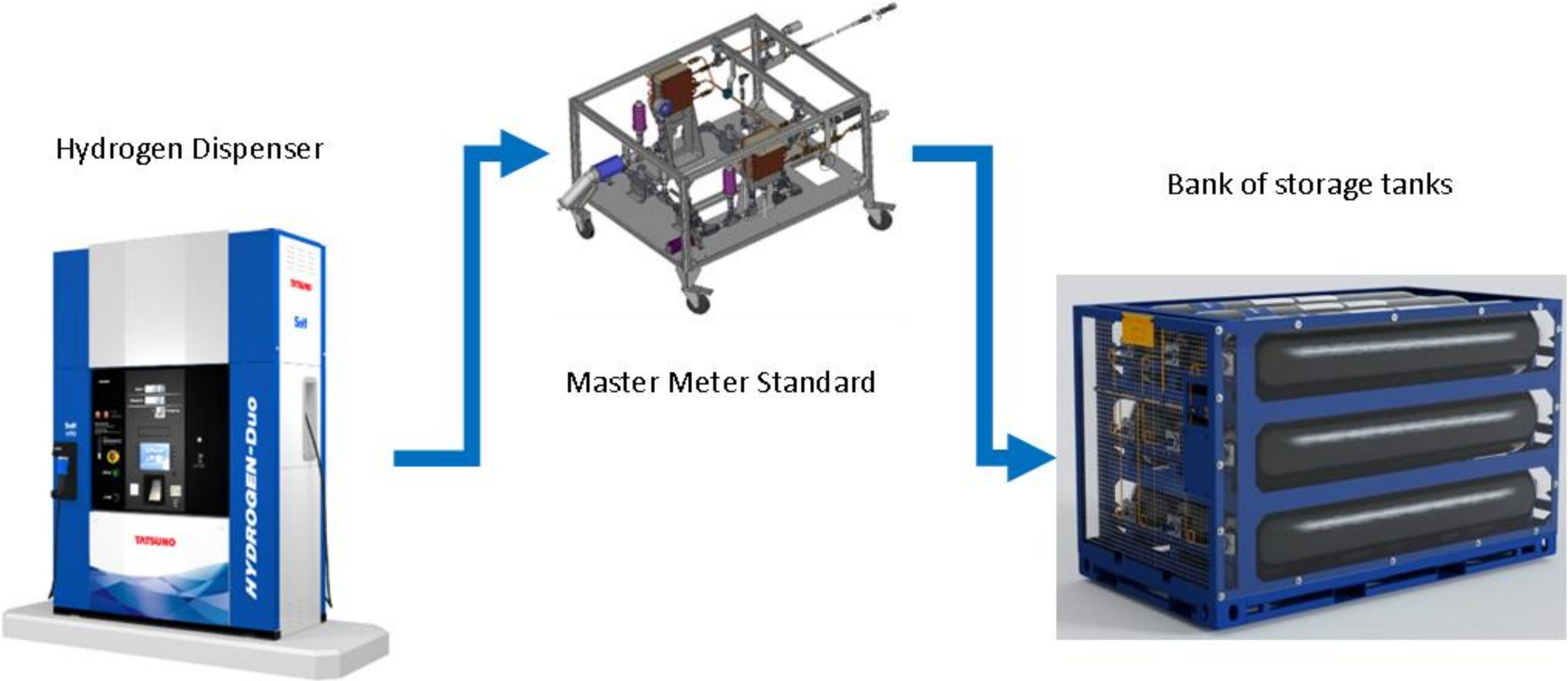
Master Meter Calibrated against gravimetric standard (LD HFTS)

- Master meter initially needs to be calibrated against gravimetric standard at HRS. The diagram shows the setup
- Hydrogen from the dispenser flows through master meter where flow meters indicate the mass passed through.
- After passing the master meter hydrogen is injected in the gravimetric system (LD HFTS) where the gas is being compressed.
- This connection allows the dispenser to work in same conditions as during normal car refuelling. The fill profile is exactly as during refuelling the hydrogen car.



Master Meter operating without gravimetric standard

- The normal mode of operation for the master meter requires storage tanks.
- Presence of storage tanks allows the dispenser to operate in its normal vehicle refuelling mode.
- Bundle of hydrogen tanks will allow taking multiple test points without necessity of immediate venting as when operating with gravimetric standard.



TÜV SÜD MMS: Design difference to gravimetric system and the challenges the system faces

- Master Meter is portable system which weighs approximately 50 kg and can be easily transported in van
- It doesn’t carry any compressed gas inside during transport and therefore doesn’t fall under Carriage of Dangerous Goods Regulations
- The system can work in any conditions allowed by the components manufacturer (currently +5^{o}C is lowest)
- The system is not affected by wind or rain
- During development phase it was decided to minimise the number of wired connections and thus the only wired elements are the two flow meters installed in the skid
- The Huber cooling bath is outside the ATEX zone and can be kept in the van during operations (hose connection is 7.5m long)
- The pressure and temperature sensors operate via Bluetooth and can be read safely from the distance
- The system requires storage tanks, currently LD HFTS is being used as the MM is undergoing trials and its uncertainty is being verified against the gravimetric standard
- Future development aims at separate tanks bundle that will allow multiple test points taken without venting
- System can be coupled with infrared interface from LD HFTS

MMS Uncertainty key points

- The core components of the system are **two flow meters installed in parallel**. Estimated uncertainty is at **0.6%** based on the initial tests done in NEL gas lines.
- The additional components of uncertainty is **vented and dead volume** of the supply tubing. The estimate uncertainty of these should be below **0.1%**
- The EURAMET project MetroHyVe 3 set the uncertainty limit to be below 1.2% for MMQ, but at TÜV SÜD we aim to reduce it significantly
- The current traceability chain has two possible routes:

1. Against LD HFTS, what will allow checking the uncertainty up to 3.6kg/min for each flow meter separately (low flow of the LD HFTS is the limit)
2. Against stationary standards in NEL: kerosene (gravimetric) or gas (nitrogen as fluid and reference sonic nozzles as reference)

Each of the routes has its advantages and disadvantages. The stationary standards can provide stable steady flow but real conditions at HRS can be replicated only via calibration against gravimetric system like LD HFTS.

Possible alternatives of the Master Meter use

- The MMS will be traceable to the mobile primary standards (LD HFTS) and stationary standards (nitrogen, water or kerosene)
- The above allows to use the MMS as portable transfer standard where high pressure and flow rates up to 18kg/min are required
- The system is not designed for gas only - it can be used with wide range of liquids
- The flow rates range depends on the fluid as the flow meters need to work below Velocity of Sound (VoS) to keep the desired level of error and uncertainty
- Flow meters are within a temperature-controlled enclosure designed to keep the flow meters close -40ºC to minimise flow measurement uncertainty due to rapid temperature change during fuelling of hydrogen. Different temperature range is allowed if necessary.

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TÜV SÜD

Thank you

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