Metrology for the hydrogen supply chain

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MET4H2

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Overview

The urgent need to mitigate climate change and to limit greenhouse gas emissions is driving actions to reduce the use of fossil fuels. Meeting current and future energy needs necessitates however the increased use of alternative energy sources such as hydrogen from renewable sources. To achieve this goal, the metrological infrastructure for hydrogen needs to address all parts of the supply chains. This project will provide novel and improved standards for the safe application of hydrogen flow measurement, hydrogen quality assessment and custody transfer. Together with outcomes from previous projects, an infrastructure will be established that provides measurement data that are fit for demonstrating compliance with regulations and contracts. This infrastructure will facilitate ramping up the use of hydrogen and society to adapt to using hydrogen instead.

HEALTH, SAFETY AND ENVIRONMENTAL ASPECTS OF THE HYDROGEN SUPPLY CHAIN

OBJECTIVE

- Leak rate measurement
- Leak and permeation assessment
- Protocol and test rig for hydrogen quality sensors
- Odorization standards

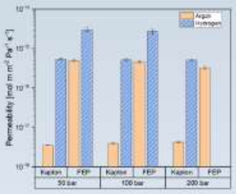
METHOD

- leak test, calibration of measuring volume, safety issues
- measuring procedure also for pressure increase method
- test at high pressure (inert gases, H_2) with reference materials
- tests with humidified test materials

The high-pressure cell with insert for foil measurements (left) and insert for O-Ring measurements (right)

RESULTS

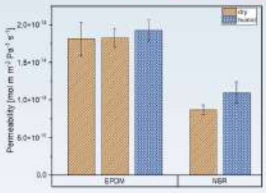
Test measurements with pressure increase method - foils



Selectivity:

- Significant permeablity difference in Ar vs. H_2
- PI (Polyimide) = Kapton® → $P_{Ar}/P_{H2} = 130$
- FEP (Fluorethylenpropylen) → $P_{Ar}/P_{H2} = 6$
- Application: PI membranes for gas separation

Measurements on humidity preconditioned O-ring



O-rings were humidified until saturation at 100 % rH before measurement

⇨ problem: humidity varies with time

Flow measurement

- Collection of hydrogen flow metering results
- Intercomparison with blends of 20% hydrogen and 80% natural gas
- Domestic meter accuracy for hydrogen with nitrogen (2%)
- Traceability chain for large scale hydrogen transportation

The reference systems for gas meter calibration: pVT-t system, CESAME, France (left); drum-type gas meter VSL, Netherlands (right)

Hydrogen Quality Control

- A good practice guide and new sampling system
- Equivalence between water vapor gas standards and portable standards
- The metrological infrastructure for key reactive gases for electrolysers and the supply chain
- Metrological guidelines for the onsite calibration and analysis of key contaminants of the supply chain (i.e. H2O)

New sampling systems for hydrogen supply chain:

The high-pressure sampling system developed by DTU (LEFT) and the low -pressure sampling system developed by NPL (RIGHT)

Portable humidity generators to provide traceability for trace water measurement:

TPHG developed by INRIM (LEFT) and the right the generator developed by VSL (RIGHT)

Summary of probability of occurrence of the contaminants in hydrogen supply chain

Contaminants	Threshold in ISO 14687:2019 (µmol/mol)	Probability of occurrence of contaminants in SMR	Probability of occurrence of contaminants in pipeline: Repurposed network	Probability of occurrence of contaminants in pipeline: Dedicated hydrogen pipeline	Probability of occurrence of contaminants in transport hydrogen as ammonia
Inert gas N2	300	Possible (3)	Frequent (4)	Very rare (1)	Possible (3)
Inert gas Ar	300	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)
Oxygen	5	Rare (2)	Rare (2)	Very rare (1)	Very rare (1)
Carbon dioxide	2	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)
Carbon monoxide	0.2	Rare (2)	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)
Methane	100	Very rare (1)	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)
Water	5	Possible (3)	(0)	Rare (2)	Rare (2)
Total Sulphur compounds	0.004	Very unlikely (0)	Frequent (4)	Very unlikely (0)	Very unlikely (0)
Ammonia	0.1	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)	Possible (3)
Total Hydrocarbons (excluding CH4)	2	Rare (2)	Frequent (4)	Very unlikely (0)	Very rare (1)
Formaldehyde	0.2	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)
Formic acid	0.2	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)
Halogenated compounds	0.05	Very unlikely (0)	Very rare (1)	Very rare (1)	Very unlikely (0)
Helium	300	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)	Very unlikely (0)

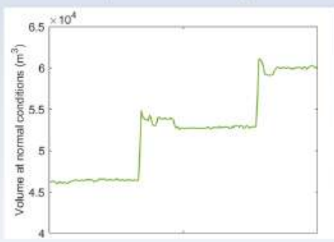
MEASUREMENT UNCERTAINTY IN FISCAL METERING

OBJECTIVE – to establish best practice in the evaluation of measurement uncertainty of quantities related to fiscal measurement along the hydrogen supply chain.

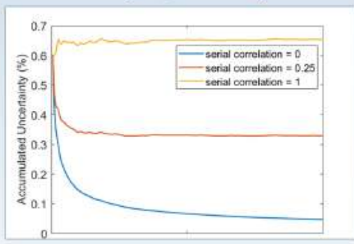
METHOD – A framework for uncertainty analysis of total quantity, energy, and purity exposure according to well-established methods (e.g. OIML R140, EN 1776, ISO 15112) have been implemented. This framework is extended to evaluate time series data set achieved from user cases. Methods for including the influence of serial correlations and correlations among measurements relying on the same input quantities are assessed and will be included in the framework. The serial correlation factors are determined using statistical time-domain techniques, including (partial) autocorrelation and autoregressive moving average

RESULTS – The assessment under more or less steady-state conditions shows that serial and instrumental correlations affect the measurement uncertainty significantly. It is found that serial correlations may increase the uncertainty by more than 30% on example cases. The discretization error of the totalization is found to be inversely proportional to the square of the number of measurement results.

Example of volume measuring data



Uncertainty analysis of total energy



References

ISO 14687:2019 - Hydrogen fuel quality — Product specification

BS EN 1776:2015 Gas infrastructure. Gas measuring systems. Functional requirements (en-standard.eu)

ISO 15112:2018 - Natural gas — Energy determination

OIML R140 , OIML 137

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