WHEN TRUST MATTERS

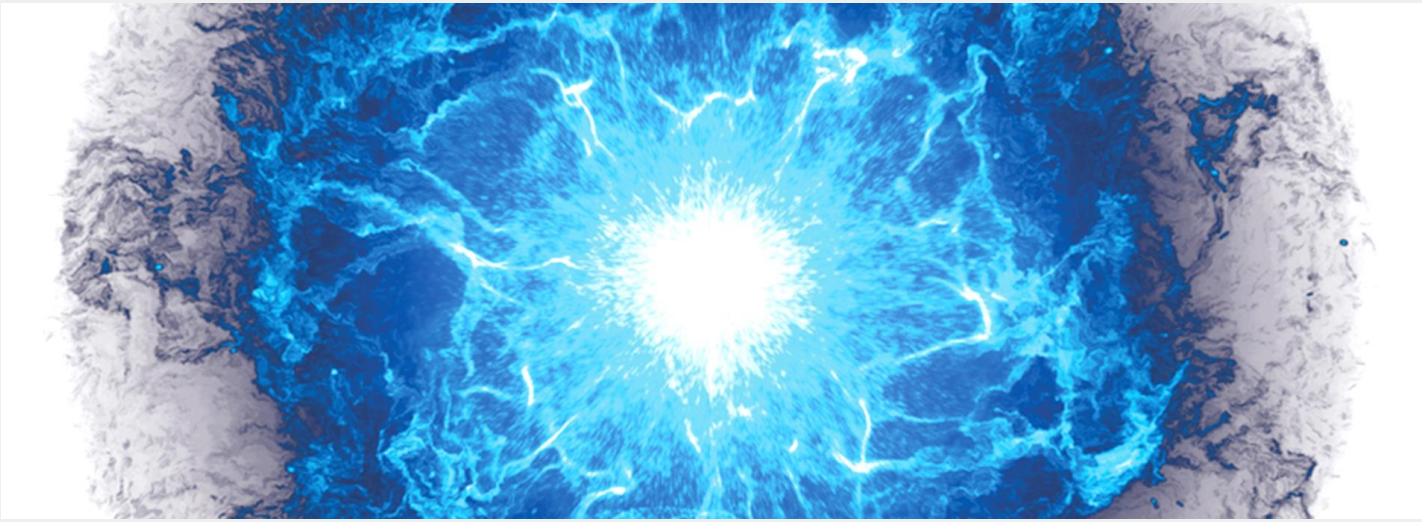
Hydrogen flow capacity and Hydrogen flow metrology

presentation on 9th of April at Enagas H2 technical day

Henk Riezebos – DNV Energy Systems – Groningen, Netherlands

2024

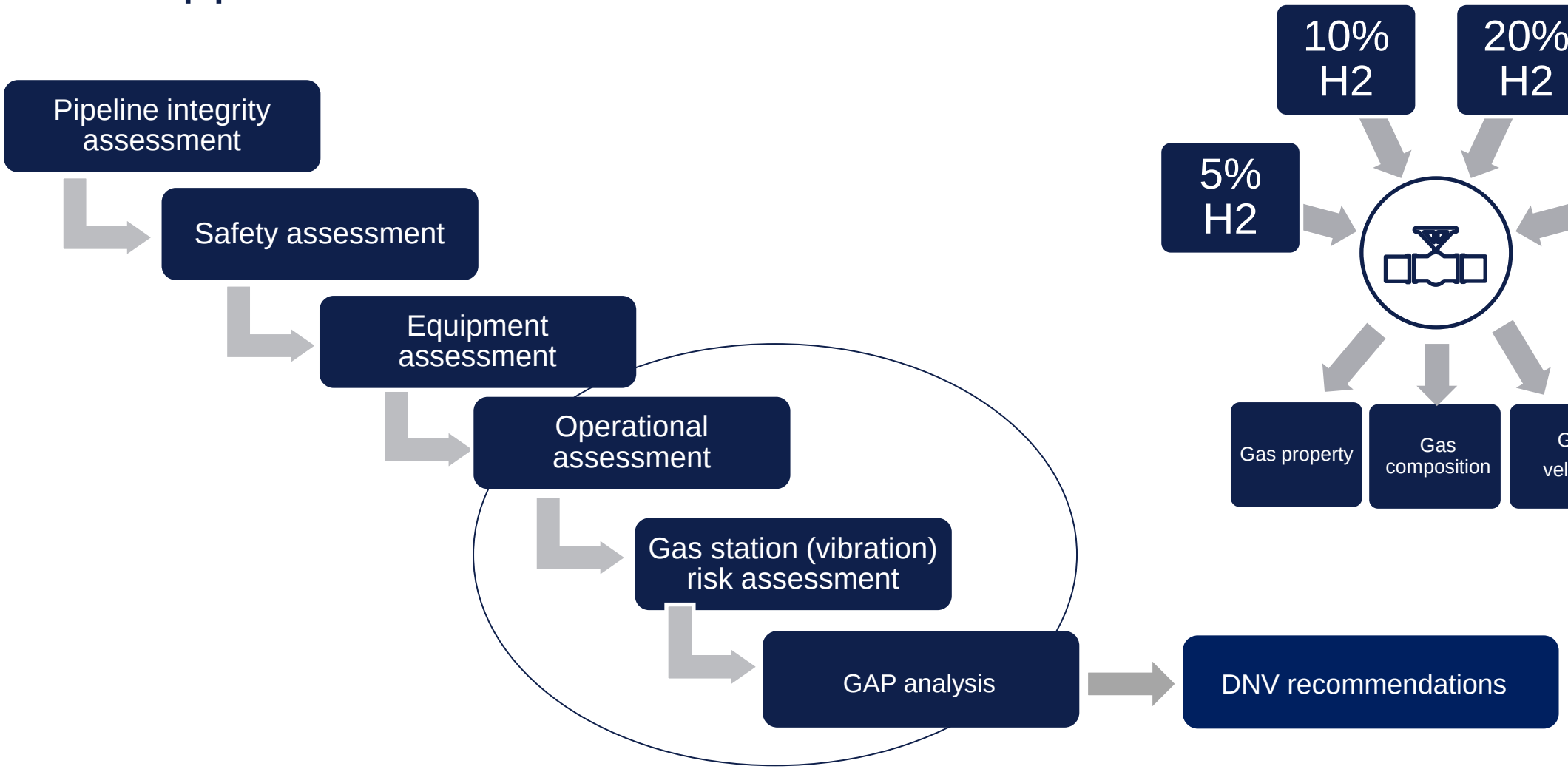
Content



- Summary of GERG report on Energy Capacity in NG/hydrogen flow related effect on network capacity and integrity – 2022-6 GERG-Energy-Capacity-final-publishable-summary.pdf
- Flow metering in hydrogen and hydrogen blends (JIP H2BLEND and JIP-H2MET)

https://www.dnv.com/article/metrology-for-hydrogen-flow-h2met-243842/

Hydrogen network readiness
DNV approach



Hydrogen network readiness –repurposing of natural gas pipelines - Operational assessment

The transport capacity of a transmission system will change if the gas composition has been changed.

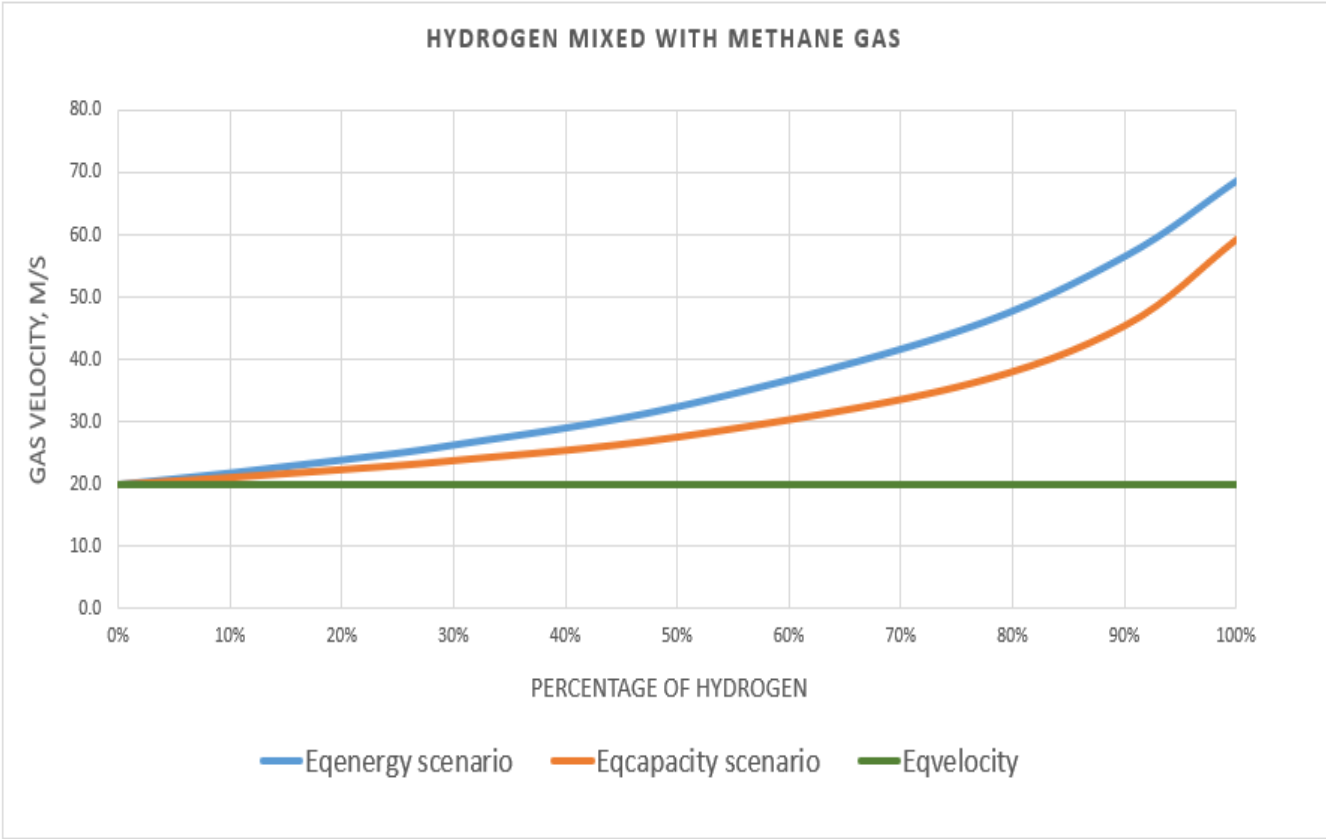
Adding hydrogen will affect the amount of energy per cubic meter of gas. Depending on the hydrogen percentage, the velocity would need to be increased make use of the pipeline's capacity and/or to transport an equal amount of energy.

There are 3 operational flow scenarios:

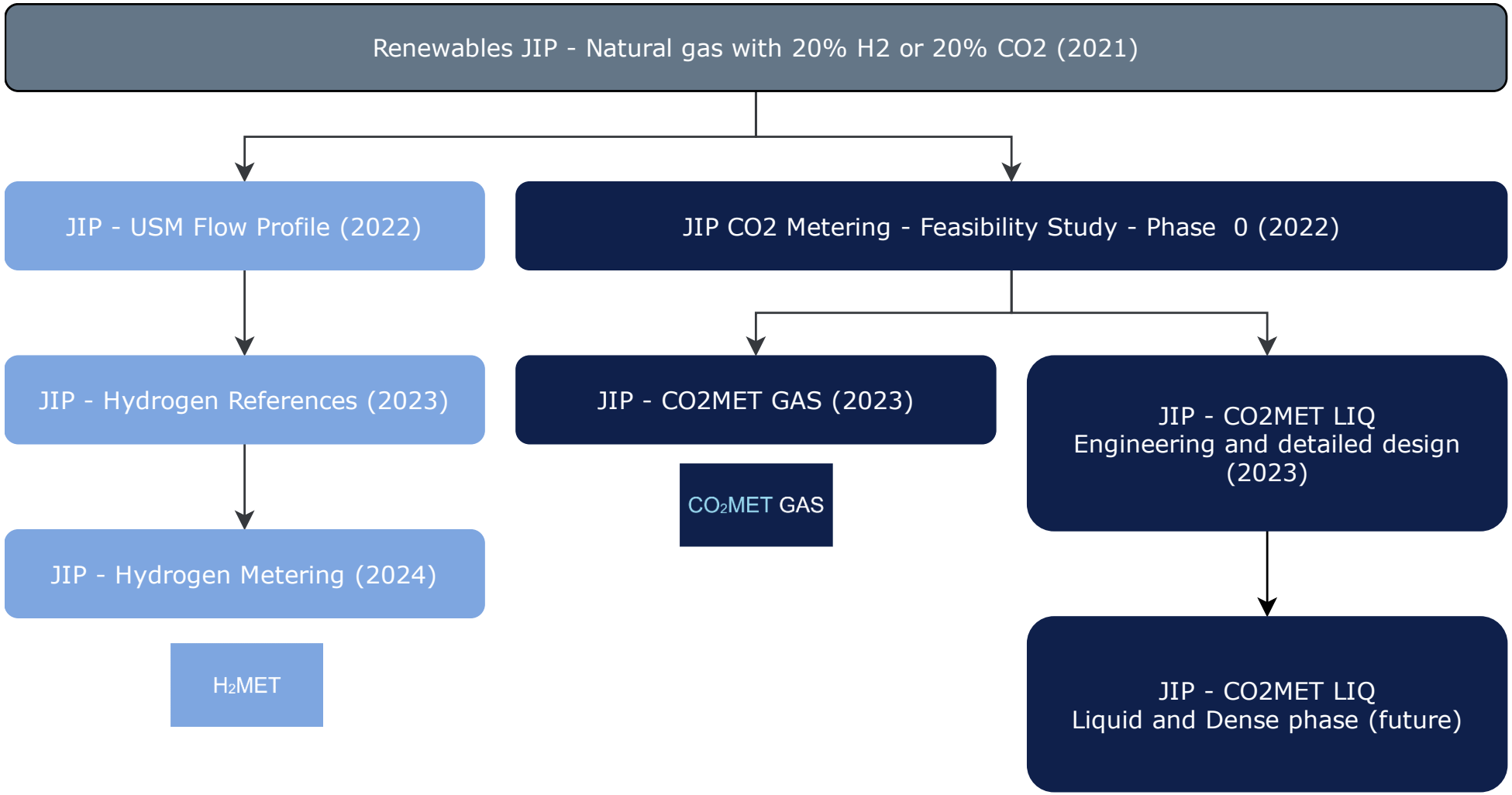
1. **Equal maximum velocity** in all scenarios with hydrogen (most conservative option)

2. **Equal Pipeline capacity** as determined by **pipeline pressure loss**

3 **Equal energy flow** in future scenarios:



Overview DNV led JIPs Flow metering with H2/CO2



JIP H2BLEND 2021 Renewable Gases Influence on Performance of Natural Gas Flow Meters

Challenge

More frequent occurrence of high-CO_2 biogas **and hydrogen** in natural gas grids demands the verification of gas flow meters under various gas compositions. Scaling rules between different gas compositions exist and depend on the metering technology used. However, these rules have not been tested systematically. **19 JIP parties (10 European TSO, 9 manufacturers of Flow equipment)**

Solution

The aim of this JIP is to investigate the performance of different metering technologies (USM and TM) to the introduction of non-conventional gases and validate the outcome to high-pressure, large-scale calibration with different gas compositions. Tests at (Multi-Phase Flow Laboratory Groningen) MPFLG with different gases and natural gas up to 30% H2 and/or 20% CO2

Benefits

Meter vendors received a calibration certificate stating the measurement uncertainties of their technology under the conditions tested. The end-users received an elaborate report with the response of the different metering technologies to the use of non-conventional gases.

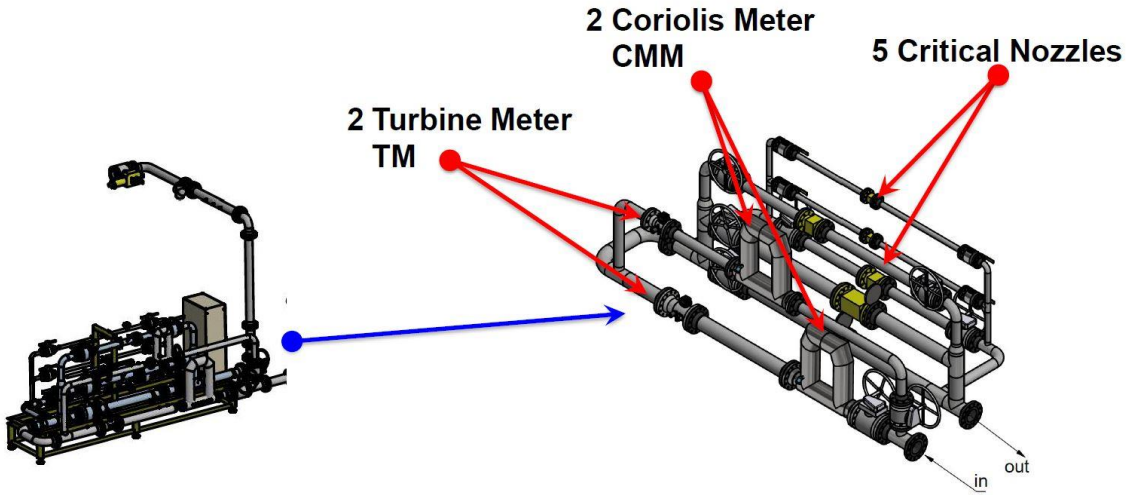
(Technology Qualification of flow meters in renewable gas environment)

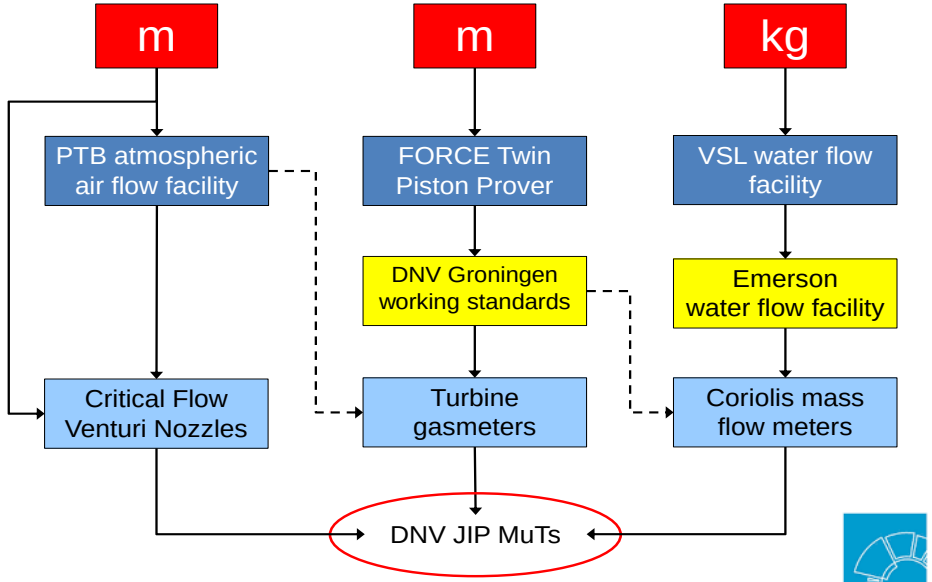
Value

- Understanding of metrological impact
  This JIP has provided understanding how flow meters behave up to 30% hydrogen and 20% CO2
- Demonstrated evidence on a unique facility
  With very high accuracy (0.05%) drift flow average quantities could be studied for all gases
- Documented step – roadmap to energy transition
  Without this knowledge, the risk of loss of revenue of an end-user can be minimised

JIP H2 Blend reference – PTB assessment and approval

DNV-JIP – Reference Unit

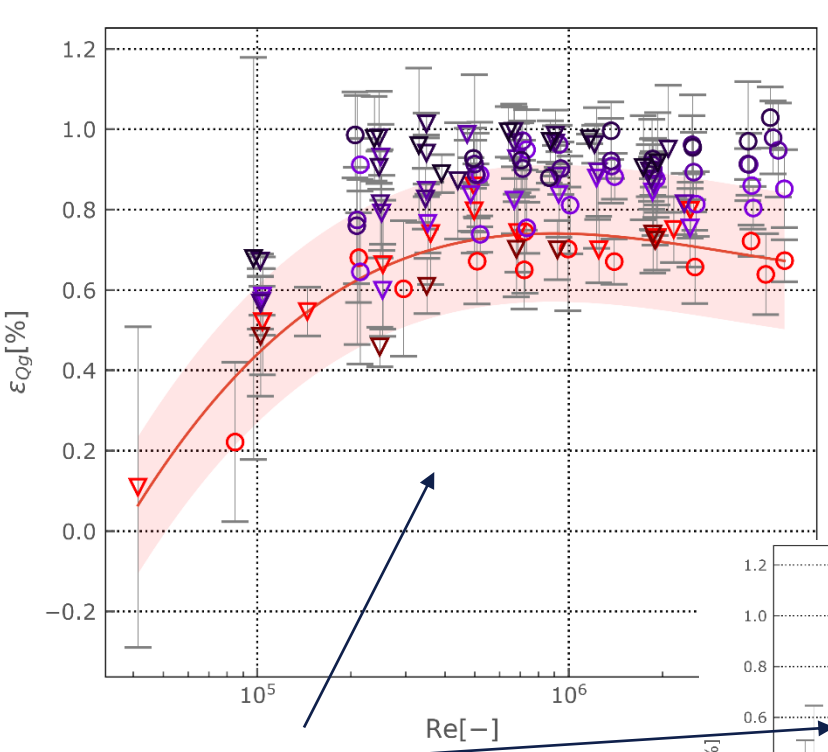


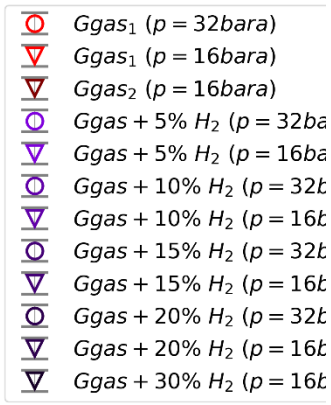


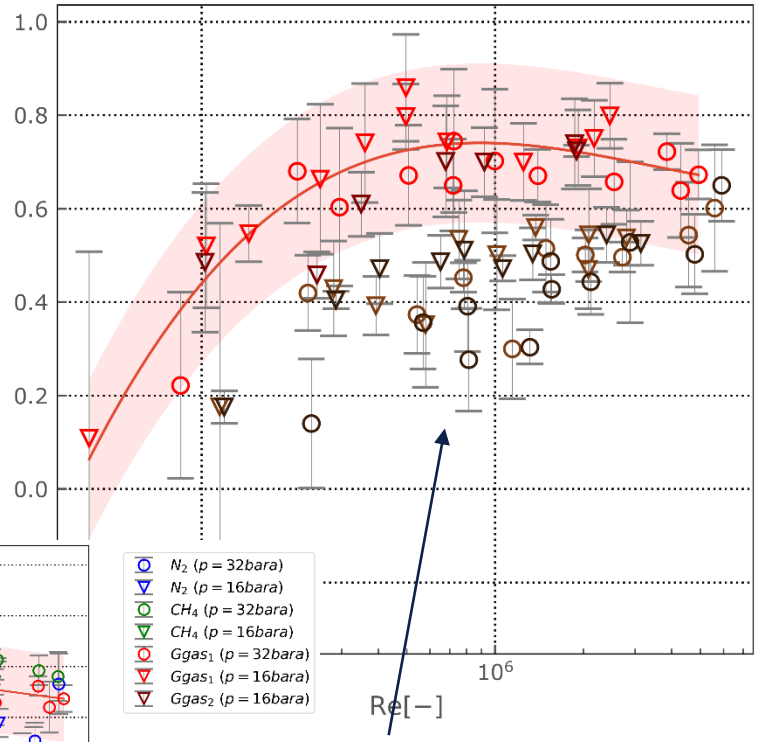
Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

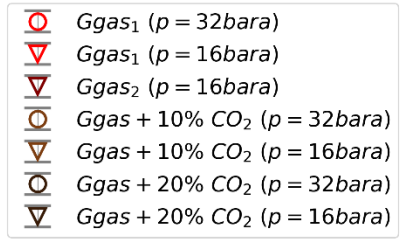
- Repeatability (minute-to-minute reproducibility) references < 0.015%
- Reproducibility (day-to-day– same setup, gas, p,T, flow) reference system < 0.10 %
- Transferability (day-to-day - other gas same setup, p,T, flow) reference system < 0.14% / (with optimised gas composition 0.11%)
- Gas composition -> molar mass uncertainty <0.1%
- Details of uncertainty analysis see NSFW 2021 paper presented by Jos van der Grinten (PTB)

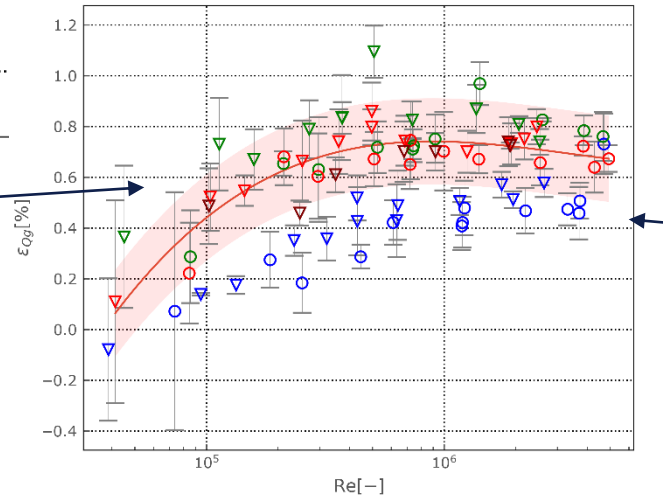
JIP H2 Blend results showcase
consistent molar mass dependent drift of US meter











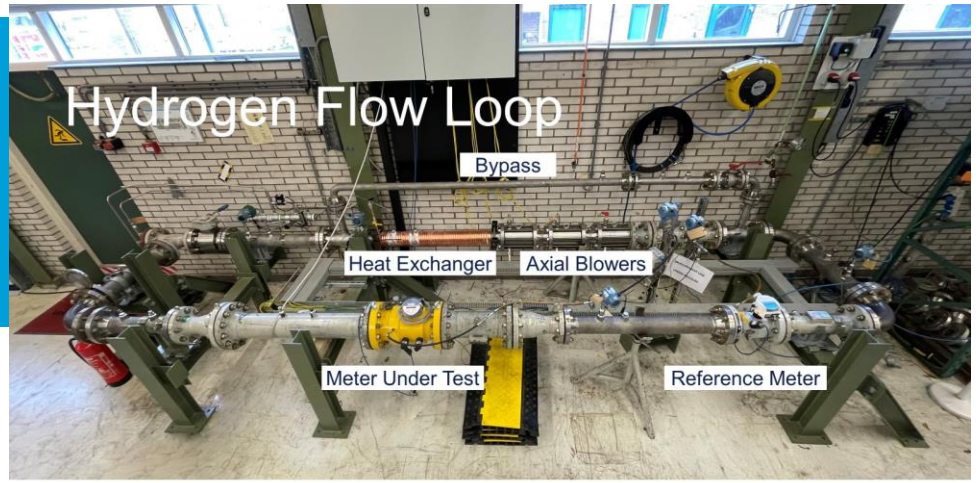
Consistent drift behaviour upward at lower molar mass M (Hydrogen) and CH4

Consistent drift behaviour downward at higher molar mass M (CO2-mix) and N2

JIP-H2REF evaluate and test flow technologies for 100% Hydrogen References (2023)

Challenge

The energy transition is rapidly advancing due to various short-term factors. Extensive research and development are required for manufacturers to produce suitable hydrogen trading products. While the hydrogen trading market is expected to flourish in 5-10 years, preparations for well-defined metrology support should begin now. **6 JIP parties DNV, PTB, and 4 TSOs**



Solution

The aim of this JIP is to investigate the theoretical impact of hydrogen of different metering technologies including turbine, ultrasonic, rotor, dp flow (venturi and orifice), and Coriolis flow meters. Develop a reference flow meter in collaboration with PTB using the PTB-Turbine model. Build a test environment to enable hydrogen flow meter testing research and development.

Benefits

This JIP has initiated the groundwork for creating hydrogen metrology reference equipment. Initial research can commence to address industry inquiries. Manufacturers of flow meters can commence the design and development of equipment tailored for hydrogen applications, utilizing the DNV Hydrogen Flow Laboratory Groningen (HyFLG).

Value

- Understanding of metrological impact
  This JIP provided understanding how flow meters behave in hydrogen environment.
- Demonstrated evidence on a unique hydrogen flow facility
  Testing environment with mass uncertainty of 0,3-0,5%
- Hydrogen testing capabilities
  A unique test facility enabling research and development of hydrogen flow meters

JIP H2-ref technology results 2022 / 2023 for 100% hydrogen

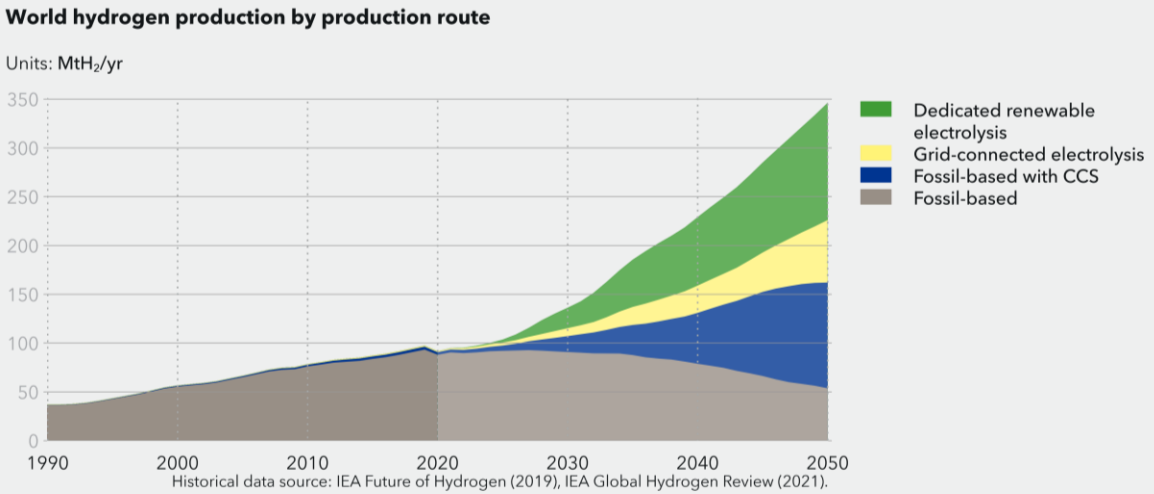
- Reference system results (high level)
  - **Nozzles** deliver the highest accuracy/ lowest uncertainty (<0.15%)
  - Good reliable, reproducible results for **rotary and orifice** based reference systems (packages)
  - **Turbine** flow reference is fine especially at higher flows
  - **Coriolis** reference used for NG+hydrogen blends also performs reasonably well on 100% Hydrogen
- Results have been used to define accurate reference system for both loops.
- Reference system and loops at DNV Technology Center Groningen are (almost) ready for 100% Hydrogen

  - **DNV HYFLG** 0.3% - 0.5% (is available since 2022 , limited pressure drop, flow up to 500 m^3/hr)
  - **DNV AGFLG** 0.15% - 0.25% for 100% Hydrogen (readiness as part of **JIP H2MET** in 2024/early 2025

JIP H2MET 2024 – 2025 Metrology for 100% H2 scope

In this Joint Industry Project, which is scheduled for the period 2024 – 2025, DNV intends to is to join forces in 100% hydrogen metrology to achieve the following objectives:

- **For (future) Hydrogen Operators**: Make large steps in understanding the performance (drift, uncertainties) of different flow technologies in near 100% Hydrogen and create industry standards. Application is for measuring production and large-scale trading of Hydrogen
- **For (flow) Technology provider**s: Facilitate the development of flow solutions by creating a high-level testing environment for different technologies in 100% Hydrogen. Understanding performance and improve quality of 100% Hydrogen flow measurement systems
- For **invited metrology companies (PTB** and **VSL**) to facilitate and review the reference systems, determine uncertainties and use JIP information to setup up the (inter) national metrology infrastructure



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Current challenges for hydrogen flow and facilities

- The specific physical properties of Hydrogen, its low density, its high compressibility and low heating value per m3 high velocities, high permeability, high SOS can be challenging for meters and facilities, that have been developed for natural gas
- **No primary references/ system of traceability.** European metrology work Empir ongoing (Decarb, Met4H2, H2flowtrace)
- **Limited hydrogen labs /testing possibilities for 100% Hydrogen**: Current only DNV (5-35 bar 1000 m3/h) and RMA (up to 55 bar and 5000 m3/h) offer testing opportunities.
- **No international standards exist for hydrogen** for any flow technology

Need/Request for:

- **Market trust – funding** of labs even if no calibration market is still there
- **JIP** (Collaboration of Industry and TSO's) to make it happen

Let’s join forces to overcome tomorrow’s industry challenges today

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JIP H2MET scope

- Step 1: Design and construction of Hydrogen reference system

  Basis will be the JIP-H2REF results and the JIP-Reference system developed for JIP 2021 on Hydrogen/CO2 blends (nozzles, Coriolis, turbine). Target uncertainty <~0.2 % in volume and mass flow.

- Step 2: Upgrade the pump and all-gas loop of the AGFLG facility of DNV in Groningen.

  to make it FFP for 100% Hydrogen operation (flow range 20-1000 m3/hr; pressure range 5-35 bar)

- Step 3: Commissioning of the AGFLG facility and H2MET-reference system on 100% Hydrogen;

  Tests with selected MUT, example; travel standards of PTB/VSL; output: PTB/VSL report with statement of uncertainty

- Step 4a: Prepare Test Plan to determine the test conditions for the performance test

  (proposed as start: **composition**: 80%,95%,98%,99.5% Hydrogen; **pressures** 8,16,32 bar, **temperature** fixed ~20 C; connecting **diameter**s 4”-8” **flow** to max 1000 actual m3/hr, or max 2600 kg/hr(for pure 100% H2);

- Step 4b: Execute and analyse performance test of different manufacturer technologies and solutions
  - Tests with all participating JIP manufacturer technologies and solutions; preferably as much as possible simultaneously thus creating a vast database of test results
  - Deliverables for all USERS, Substantiation of the facility CMC for hydrogen; Details of the test setup; Overall performance report with all results and grouped by technology
  - Outputs: for all MANUFACTURERS, a performance report (basis for (type) approval on (near) 100% Hydrogen service of their own meters under test