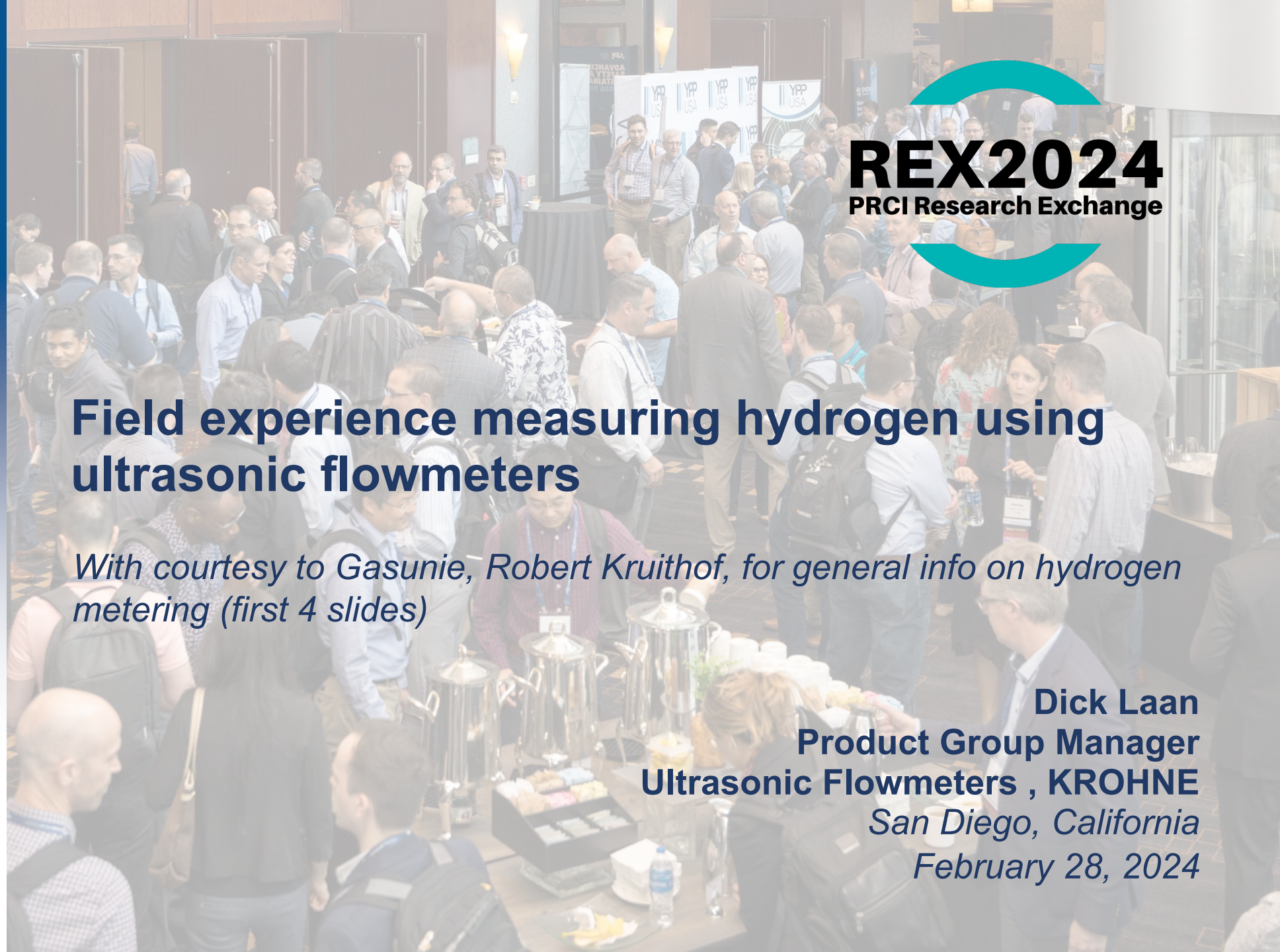

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# Field experience measuring hydrogen using ultrasonic flowmeters

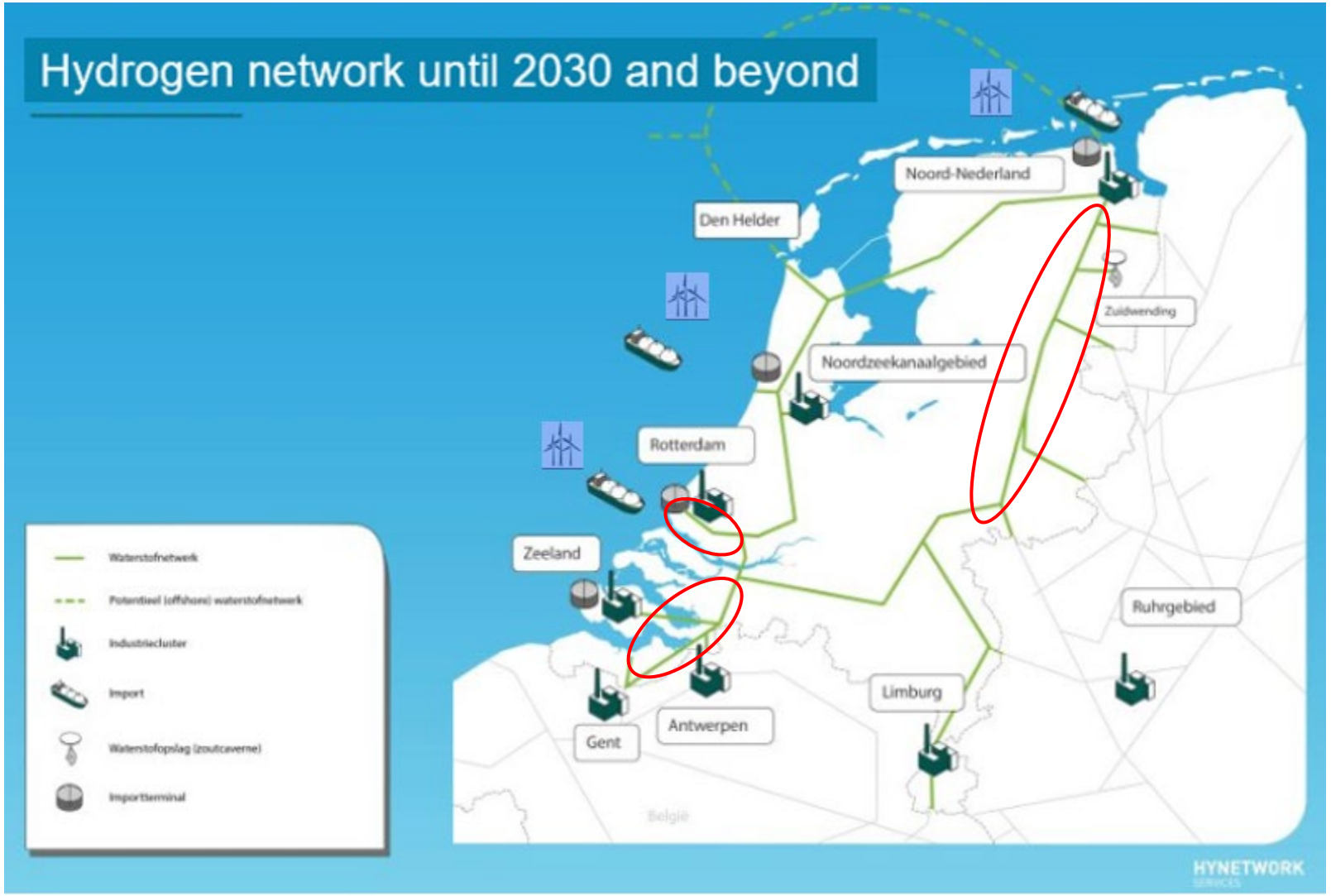
*With courtesy to Gasunie, Robert Kruithof, for general info on hydrogen metering (first 4 slides)*

**Dick Laan**
**Product Group Manager**
**Ultrasonic Flowmeters , KROHNE**

*San Diego, California*
*February 28, 2024*

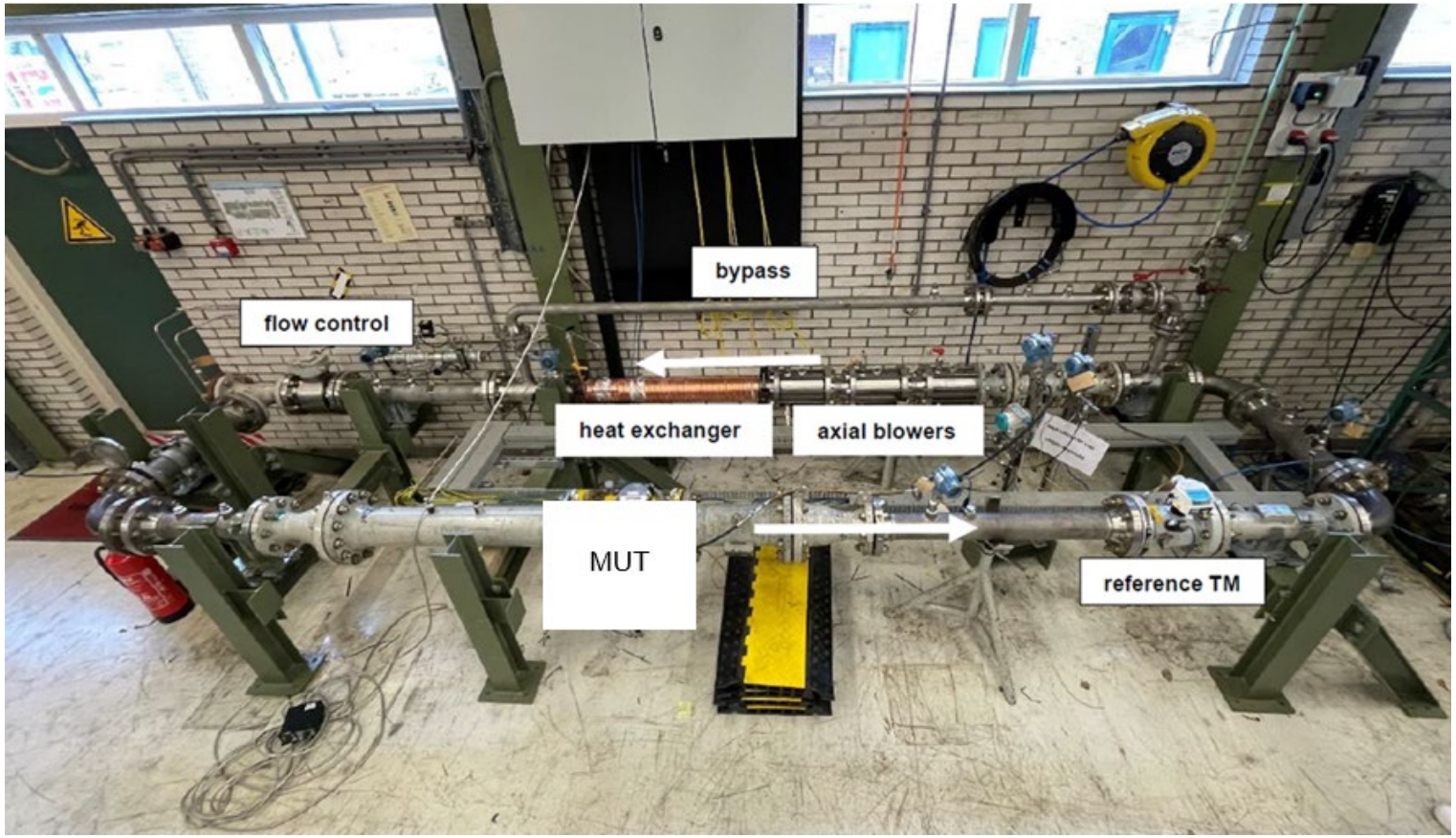
PRCI LEADING PIPELINE RESEARCH
Pipeline Research Council International

# Development of Hydrogen network Netherlands




- **2025 - 2027**
  - First three H2 pipelines
  - Import / production
  - Storage
  - Industrial clusters
- **2028 - 2029**
  - First three parts connected
  - Extension to other industrial clusters
- **Operating conditions:**
  - 30 – 50 bar (finally 65 bar)
  - Max. gas velocity 40 – 60 m/s
- **Need for hydrogen flow measurements for custody transfer**

# Test Set-up DNV Hydrogen Flow Facility




The first tests with hydrogen of the usual flow meters for custody transfer of natural gas

| HyFLG flow loop specifications | |
|---|---|
| Pressure | 5-40 bar(a) |
| Temperature | Ambient conditions (15°C -25 °C) |
| Flow rate | 5-500 $m^3/h$ |
| Gas composition | 0-100% for $H_2$, $N_2$, $CH_4$ (and blends) |
| Test section diameter | 1-6 inch |
| Reference uncertainty | 0.3% high Re, 0.5% low Re (see section 4) |
| Technologies | USM, Turbine, Rotor, dP, Coriolis* |

*limitation in max. differential pressure of 60 mbar

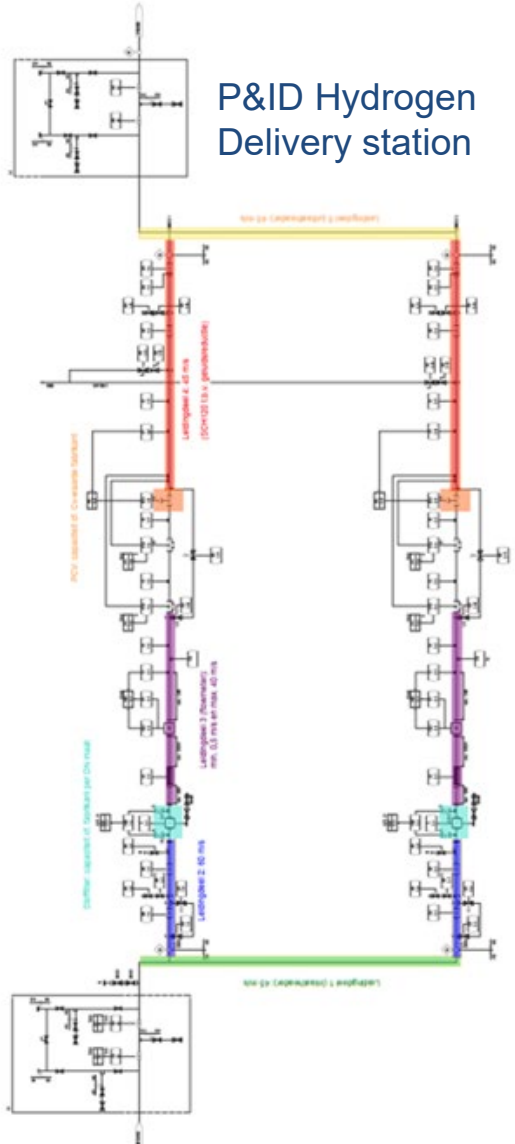
# H2 Flow GAP analysis– preliminary conclusions

**Restriction: status Q2 2023 and based on limited number of tests and diameters**

- **Properties H2 compared to NG (CV / 3 ; Density / 8 ; Speed of Sound * 3) have an impact on meters and design of the measuring installation -> best to measuring at high pressure and 40 m/s**

- **Current status of flow meters, suitable for H2?**
  - Turbine meters: limited capacity due to maximum gas velocity 20m/s, not maintenance free
  - Ultrasonic: new meter types needed or to be modified or reconfigured, but the ability for higher gas velocities and diagnostic monitoring (also for e.g. H2 purity)
  - Coriolis: only small diameters due to minimum density and limited flow range at the low end 10-15%Qmax

- **Limited available test facilities**
  - DNV (Netherlands) 40 bar 400 m3/hr 2022;  50 bar 1000 m3/hr 2024
  - RMA (Germany) 8-50 bar 6500 m3/hr Q4 2023



P&ID Hydrogen Delivery station

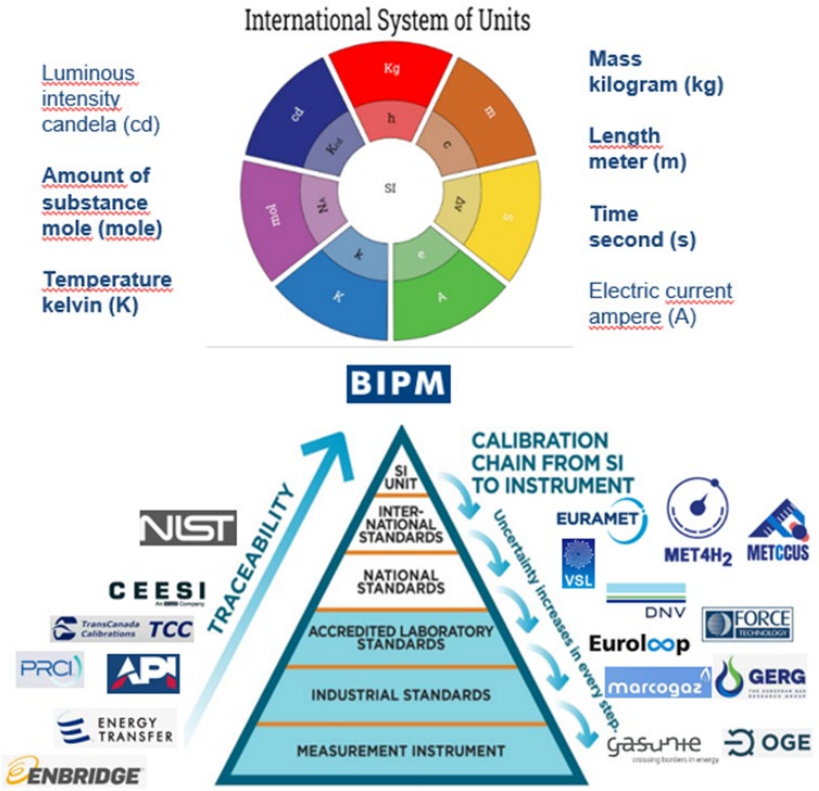
# H2 Flow GAP analysis– preliminary conclusions

**Restriction: status Q2 2023 and based on limited number of tests and diameters**

- **Other open questions/ideas/developments:**
  - Impact of high velocity on intrusive components like thermowells, samplers, upstream lengths and flow conditioners?
  - Transferability of calibration with other gases to hydrogen?

- **No primary H2 flow standards for Midstream conditions and dimensions**
- **No calibration facilities with ISO17025 accreditation**
- **Critical timeline for Gasunie (First applications in 2025)**
  - Provisional mutual agreements on meter type selection and calibration procedure without accreditation

- **Next steps:**
  - Innovation by OEM's
  - JEFI-02-03 Hydrogen Measurement
  - Joint Industry Project DNV H2MET



# AGENDA

**Field experience measuring hydrogen using ultrasonic flowmeters**

1. **Ultrasonic flowmeter for hydrogen**
2. Lab test on mixtures of natural gas and hydrogen
3. Field test of 10” flowmeter on hydrogen
4. Lab test of 4” flowmeter on hydrogen
5. Summary and conclusions

# Ultrasonic flow measurement principle

## *Altosonic V12 – ultrasonic custody transfer gas flowmeter*


- Transit time measurement
- Time difference between upstream and downstream signal
- Flow velocity and speed of sound
- Multiple paths combined for high accuracy
- Diametric path for maximum Renolds independence

# Measurement Challenges for $H_2$

***ultrasonic technology***

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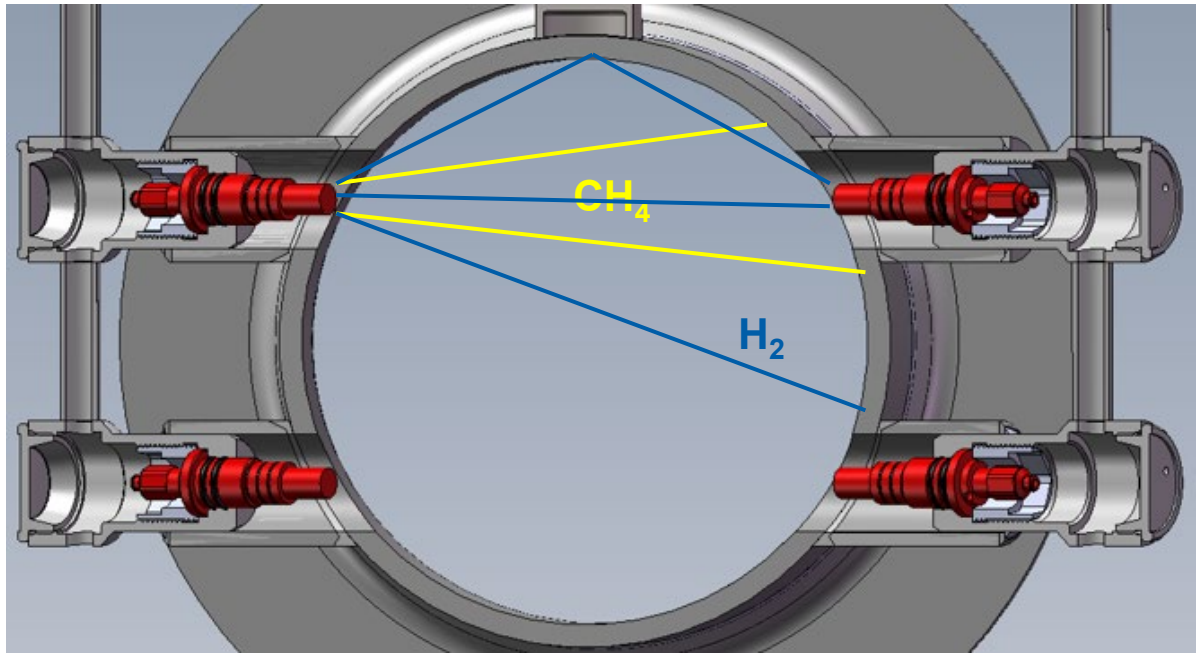
- **Low density (8 times lower than natural gas)**
  - *Impacts SNR*
- **Speed of sound (3 times higher than natural gas)**
  - *Short transit time*
  - *Larger opening angle*
- **(un)-Availability of calibration facilities**



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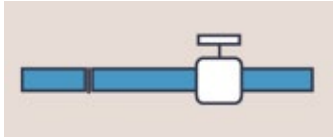
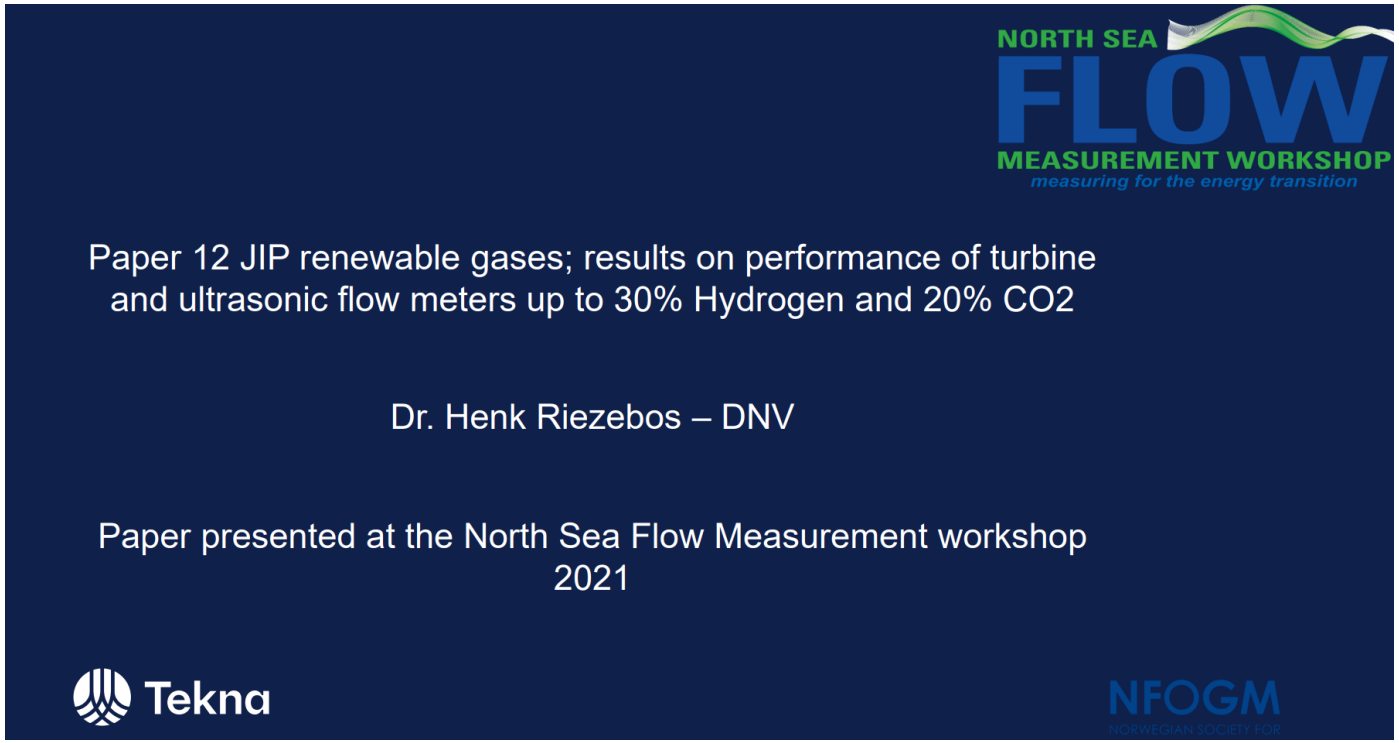
# Mixture of natural gas and $H_2$

- **Mixing $H_2$ with natural gas**
  - Low volume of $H_2$ / no dedicated $H_2$ network
  - Reuse existing infrastructure
  - Decarbonizing NG use



- **DNV joint industry project for renewable gases**
  - 10 TSO's (pipeline operators)
  - 9 manufacturers

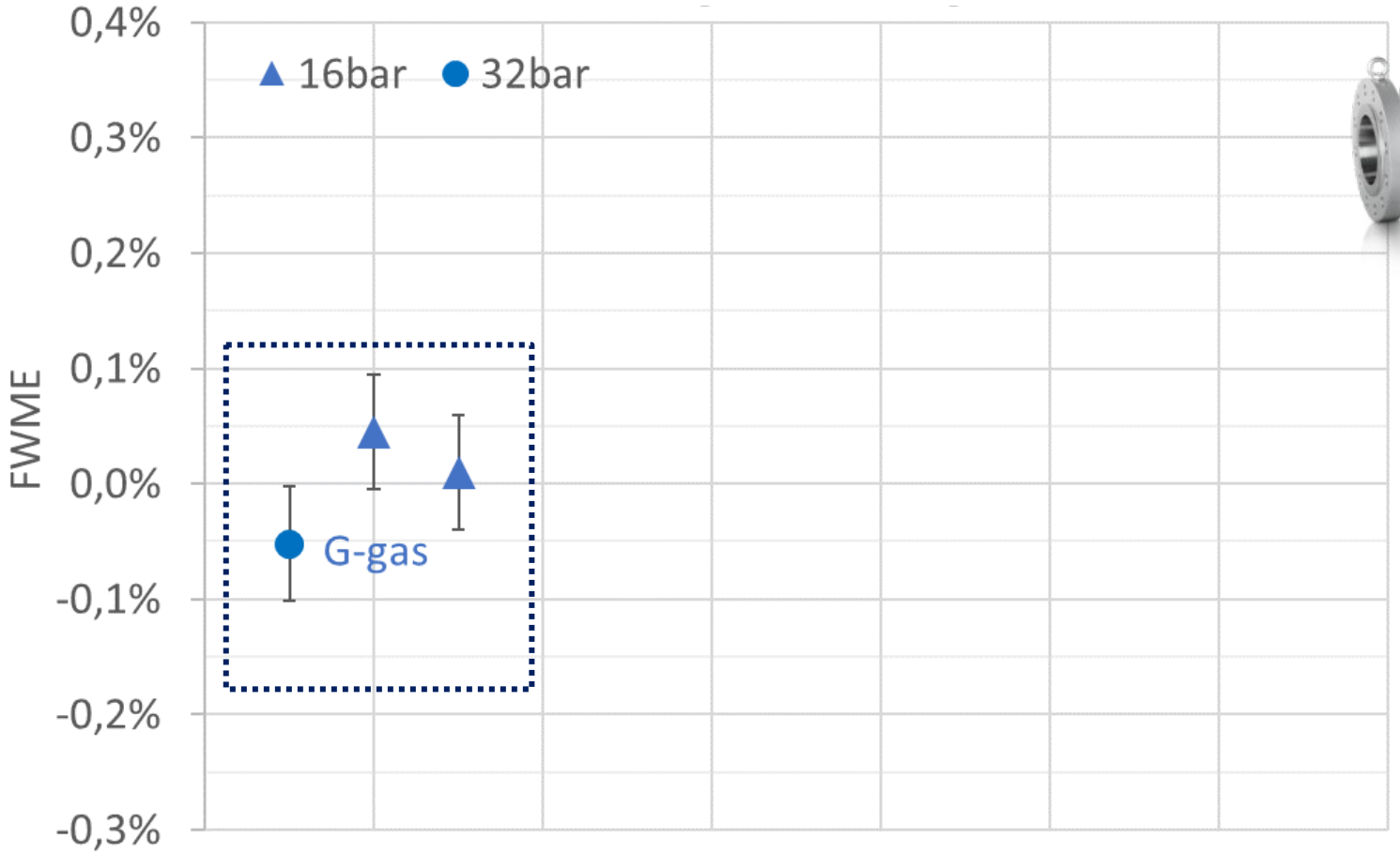
- **Results presented at the North Sea Flowmeasurement workshop, 2021**
  - 4 turbines
  - 5 CT ultrasonic flowmeters
  - 4 process ultrasonic flowmeters



# Mixture of natural gas and $H_2$

## *Results for ALTOSONIC V12 – DNV JIP renewable gases*

*FWME = Flow Weighted Mean Average Error*





**8” Flowmeter calibrated and certified for natural gas**

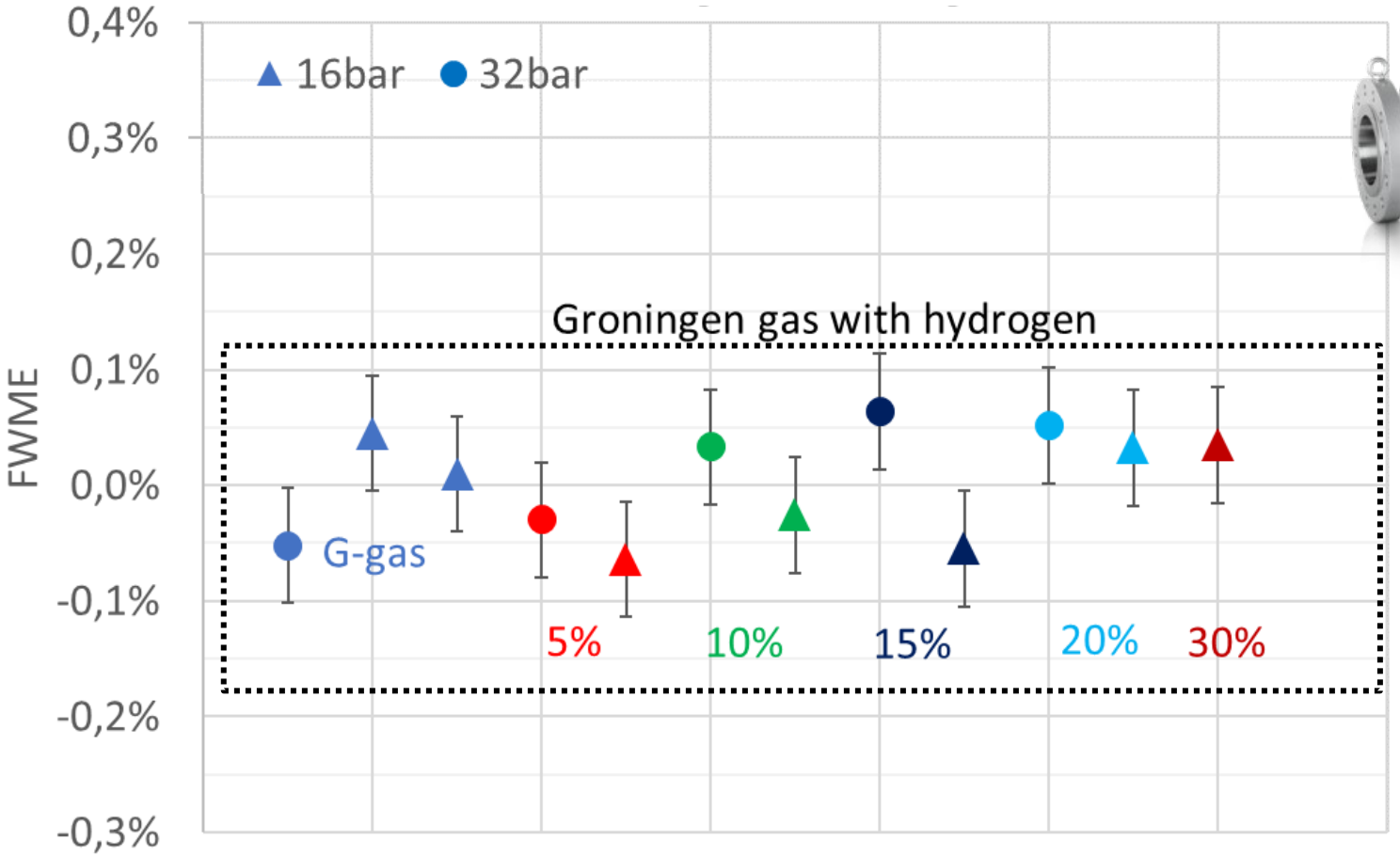
**Flowmeter output compared to reference system of flow lab**

- ***10 flowrates***
- ***3 repetitions***
- ***FWME calculated***

# Mixture of natural gas and $H_2$

## *Results for ALTOSONIC V12 – DNV JIP renewable gases*

*FWME = Flow Weighted Mean Average Error*





- 8” Flowmeter calibrated and certified for natural gas
- Flowmeter output compared to reference system of flow lab
- Tested in laboratory with blends of hydrogen and natural gas
- Performance of the flowmeter is not impacted by mixing hydrogen

# AGENDA

**Field experience measuring hydrogen using ultrasonic flowmeters**

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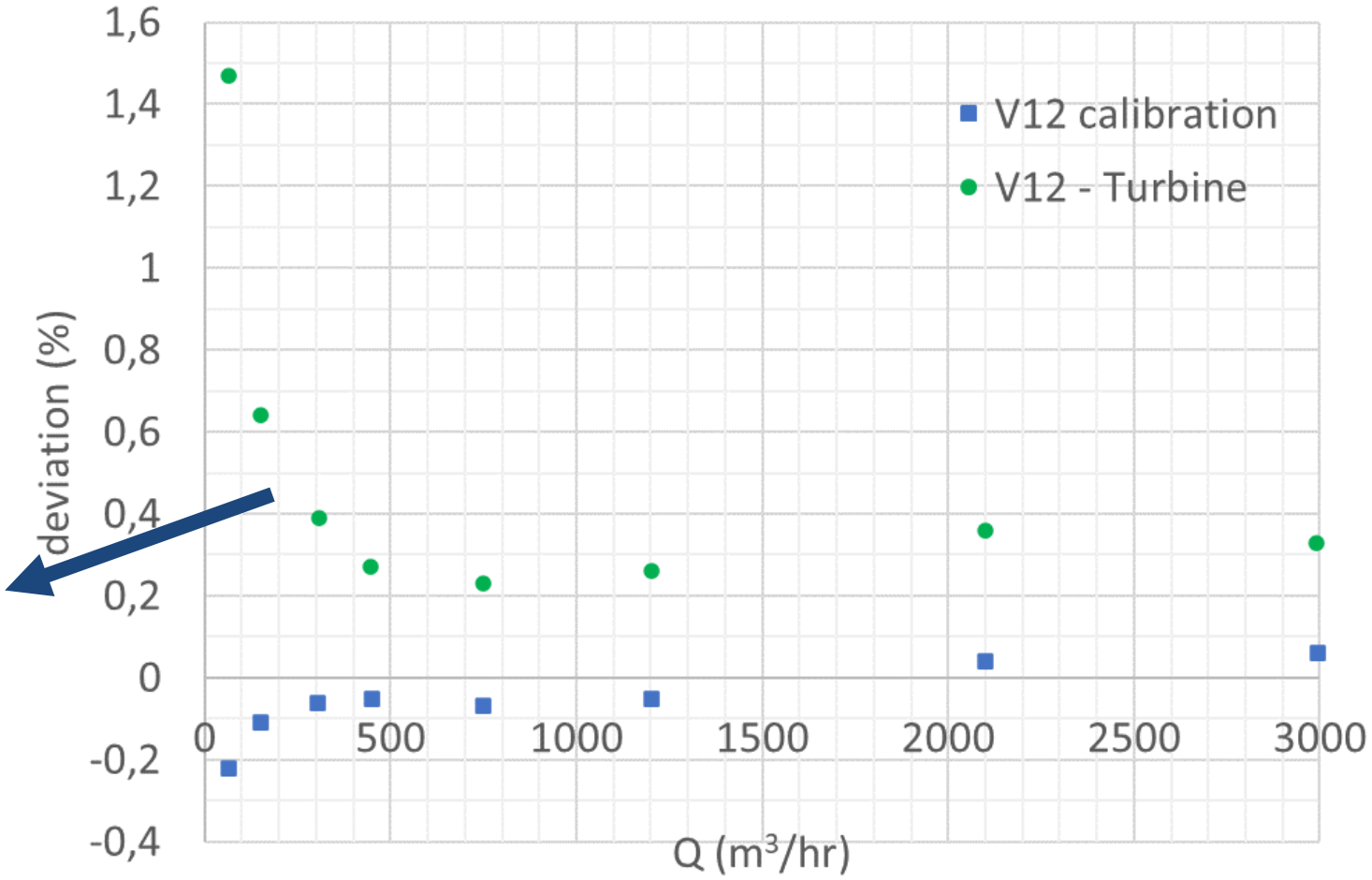
# Field test 10” UFM on hydrogen

- 2021 fieldtest initiated by OGE (Open Grid Europe, TSO) and EVONIK
- Chemical park Marl in Germany
- Hydrogen pipeline network (19 bar)
- 10” ALTOSONIC V12 (ultrasonic) is compared against turbine meter *(already installed at field)*
- Initial results presented at GFMW 2022 (Global Flow Measurement Workshop).
- Today updated results are presented

# Field test 10” UFM on hydrogen

***step 1: calibration of UFM on natural gas at Pigsar lab***

***step 2: comparison (UFM vs Turbine) on natural gas at Pigsar lab***




***Turbine:***
***Qmin=200m3/hr***

**Baseline curve determined for deviation of Turbine vs. V12 on natural gas**

**ALTOSONIC V12 in spec on natural gas**

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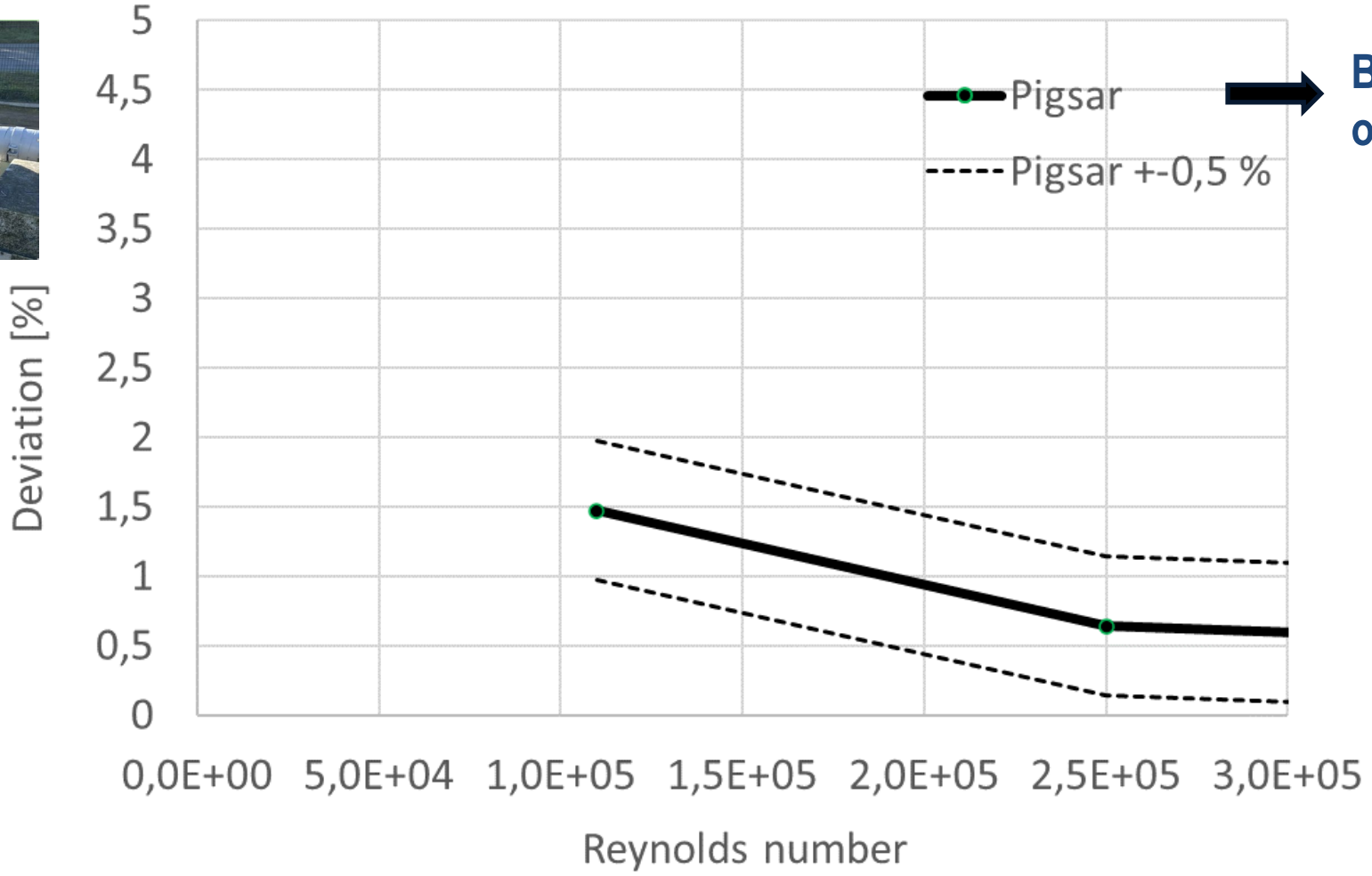
# Field test 10” UFM on hydrogen

***step 3: comparison (UFM vs Turbine) on hydrogen in the field***

# Field test 10” UFM on hydrogen

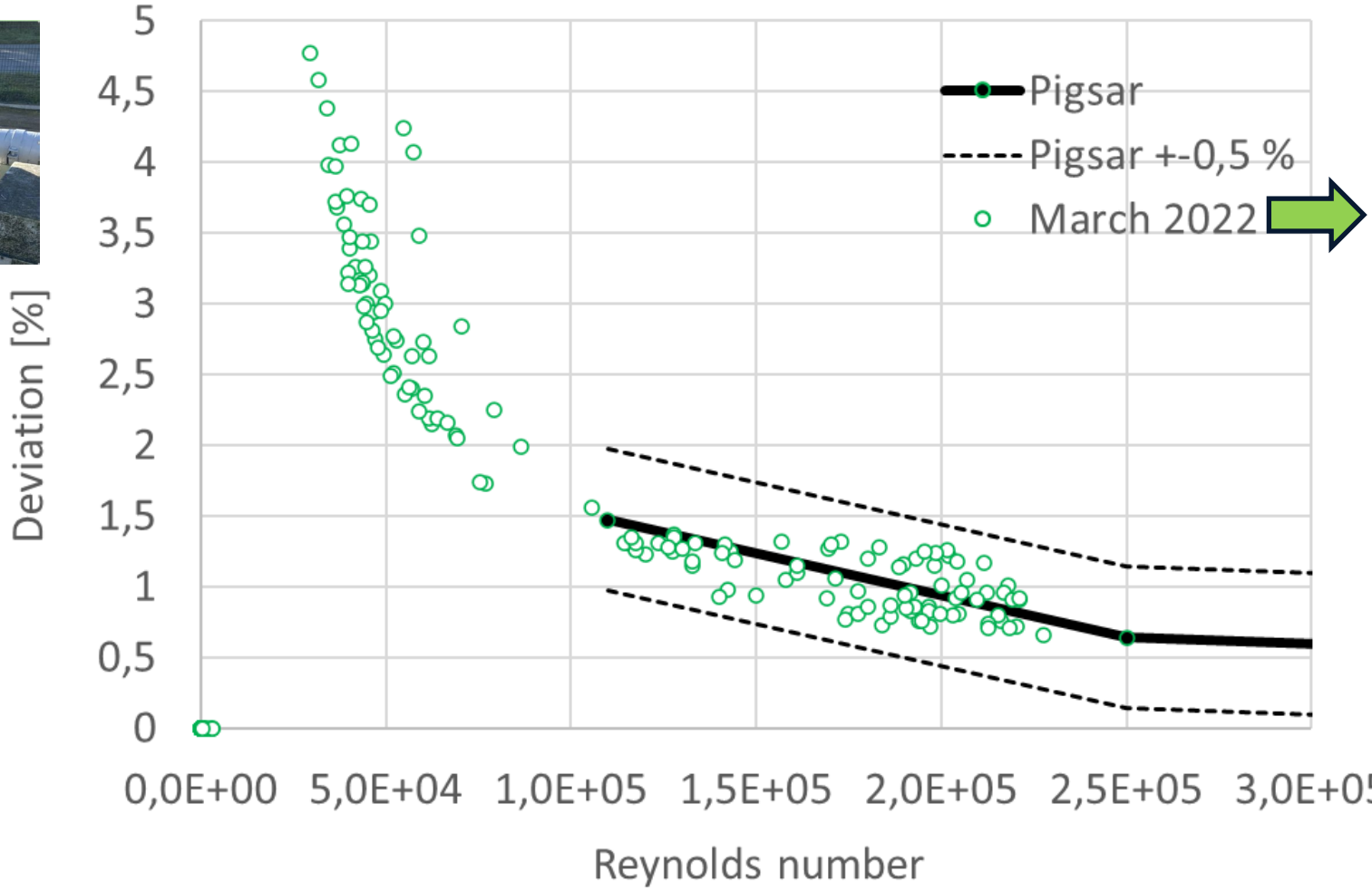
***step 3: comparison (UFM vs Turbine) on hydrogen in the field***




**Baseline curve obtained on natural gas**

# Field test 10” UFM on hydrogen

***step 3: comparison (UFM vs Turbine) on hydrogen in the field***




**Field data on $H_2$ as presented last year.**

- ***Hourly averages are compared***
- ***Optimised settings ($H_2$) of the signal processing chain have been applied (topic of presentation last year)***

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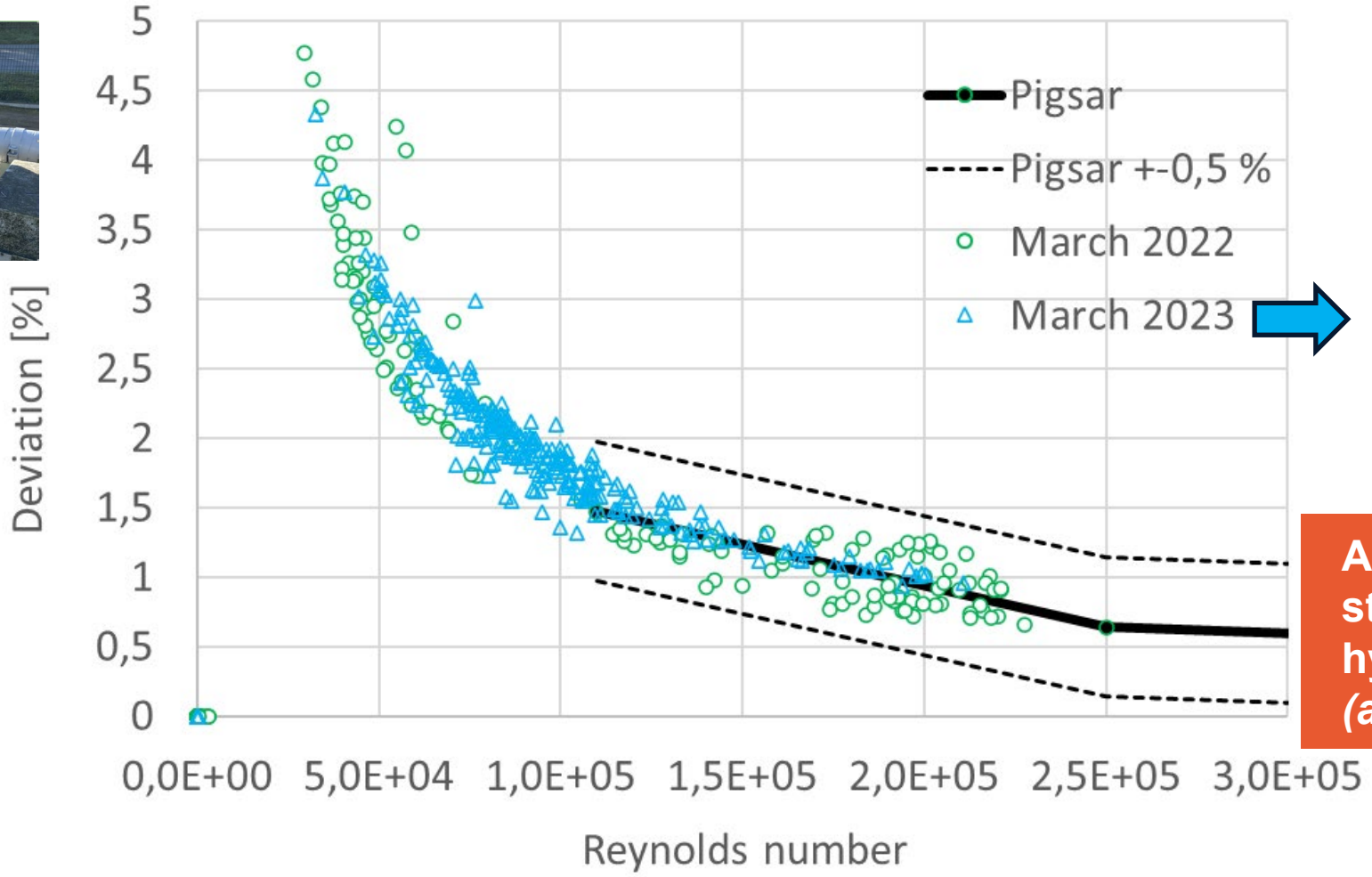
# Field test 10” UFM on hydrogen

***step 3: comparison (UFM vs Turbine) on hydrogen in the field***




**New field data.**
***-one year later***
***-unchanged settings of flowmeter***

**ALTOSONIC V12 showing stable performance on hydrogen in the field.**
***(already for 18 months)***

# AGENDA

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# Lab test of 4” UFM on hydrogen

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- **First tests executed in August 2022 in cooperation with Gasunie and Air Liquide**
- **Second tests executed in September 2023, after implementing improvements**
- **Hydrogen flowloop at DNV (Groningen, the Netherlands)**
- **Turbine meter is applied as reference**
  - Calibrated on air at DNV and natural gas at PTB
  - PTB turbine meter model is applied for corrections
  - Flow rate 20-400m3/hr
  - Reynolds number: 10,000 to 400,000
- **Estimated uncertainty 0.3-0.5% for Re>10,000**

# 1st Lab test of 4” UFM on hydrogen

**4” ALTOSONIC V12 is tested at DNV**

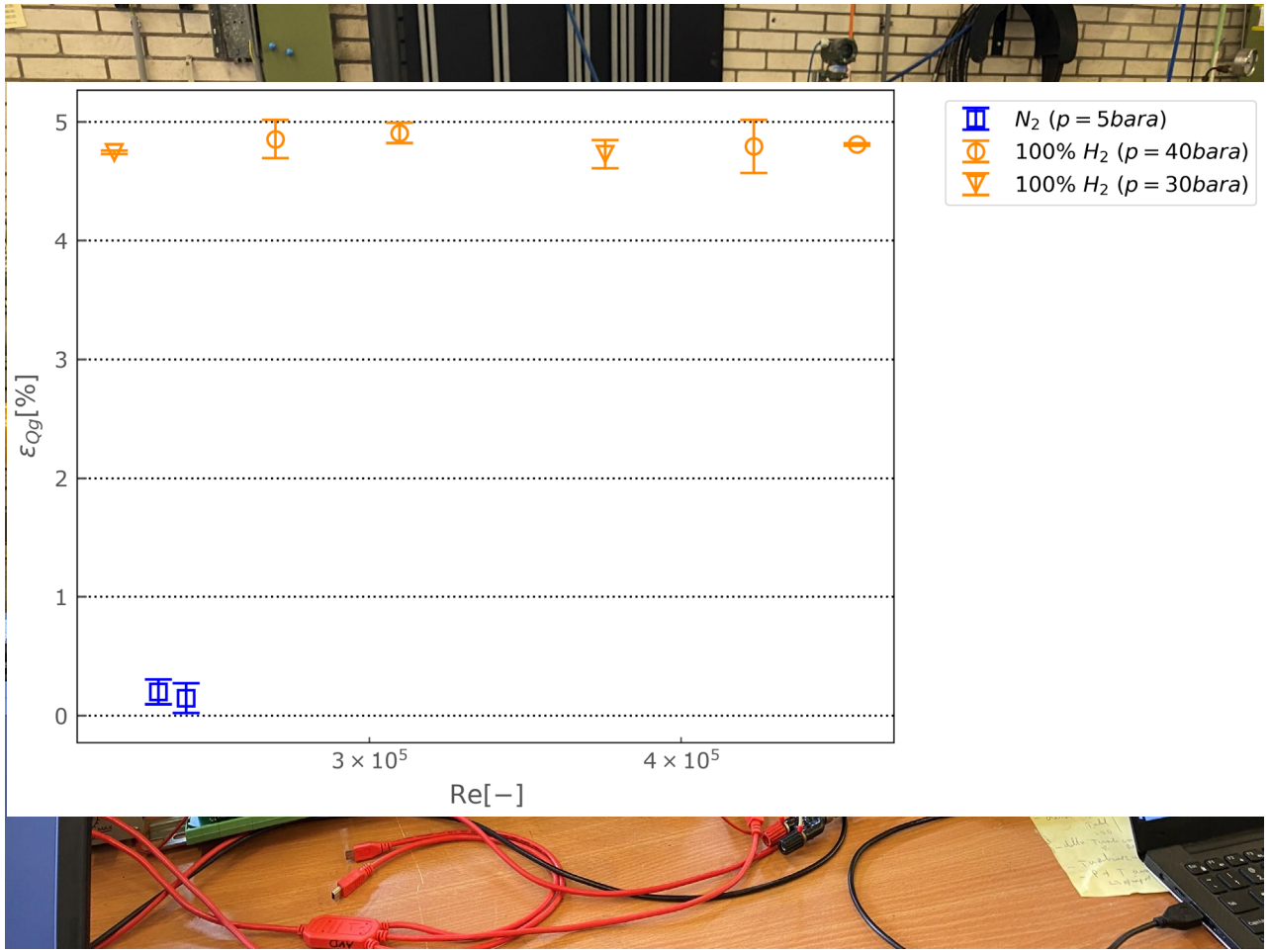
Tests have been performed in August 2022

**Lessons learned from fieldtest (10”) have been applied**

**Reynolds correction curve for natural gas has been applied**

**Result:**

- **Good linearity**
- **Good repeatability**
- **Deviation with nitrogen test**
- **Correct mass flow calculation by Summit flow computer**



# 2nd Lab test of 4” UFM on hydrogen

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**4” ALTOSONIC V12 is tested at DNV**

- Tests have been performed in September 2023

**Lessons learned from previous test have been applied**

- Optimised signal processing chain settings as determined for $H_2$ have been applied

**Reynolds correction curve for natural gas has been applied**

**Meter factor is determined on $H_2$**

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# Lab test of 4” UFM on hydrogen

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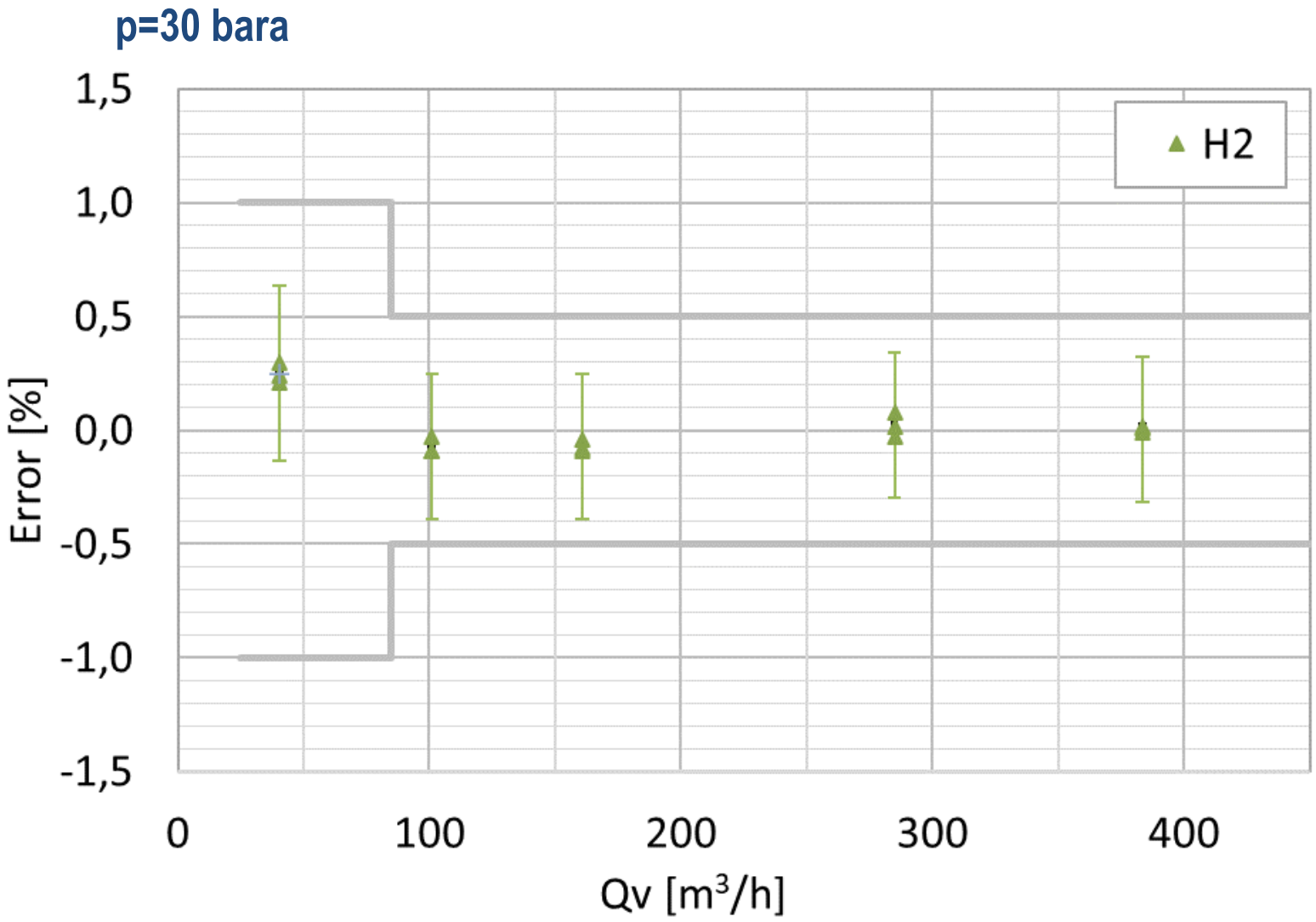
3 repetitions per flowrate (good repeatability)

Error bars denote total uncertainty (dominated by test circuit)

Linearity similar to natural gas application

Individual measurement paths meet expected and desired quality



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5. **Summary and conclusions**

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# Summary and Conclusion

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1. ALTOSONIC V12 ultrasonic gas flowmeter keeps its performance when mixing hydrogen to natural gas (tested up to 30%)

2. 10” ALTOSONIC V12 shows stable and good results in field test on pure hydrogen (run time > 18 months)

3. 4” ALTOSONIC V12 tested at $H_2$ loop of DNV and shows performance similar to typically achieved on natural gas

4. Despite challenges (e.g. density, speed of sound) our ultrasonic technology is suited for measurement of hydrogen and mixtures of natural gas and hydrogen

5. R&D efforts will continue, to push the limits even further!

thank you

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**Dick Laan**

*Product Group Manager Ultrasonic flowmeters*

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