METROLOGY for HYDROGEN VEHICLES

Air and Nitrogen Testing of Coriolis Flow Meters Designed for Hydrogen Refuelling Stations

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EMPIR EURAMET

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Project Team

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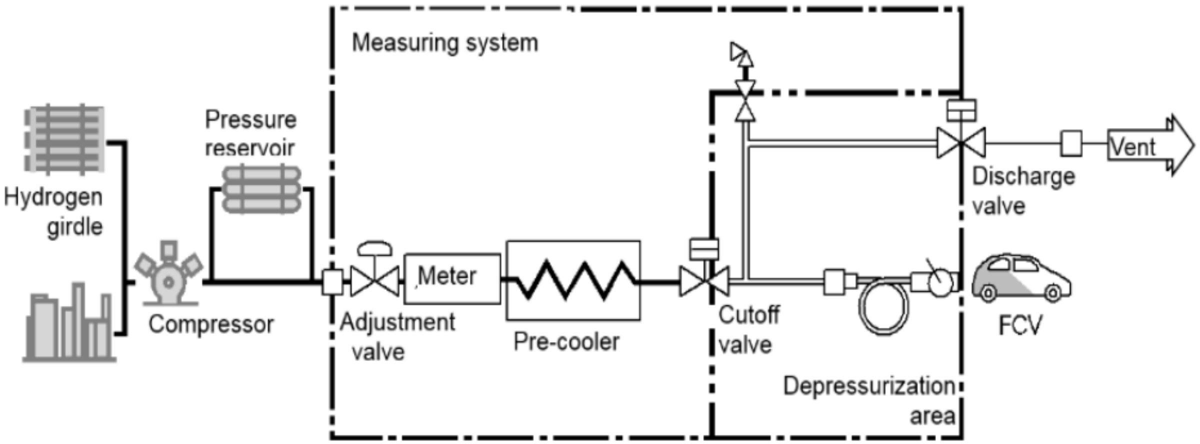
WP1 Flow Metering

Aim is to realise a traceability chain for hydrogen in the range typical for refuelling applications in accordance with SAE J2601.

- Pressures up to 875 bar (filling to 350 bar and 700 bar)
- Pre-cooling to -40°C (up to 85°C in receiving vehicle)
- Transient flow as vehicle fills
- Vented quantities?
- Dead volumes?
- Location of flow meter?



No independent flow facilities operate with hydrogen at these conditions!

Other MetroHyVe Papers

Session	Paper	Title	Presenter
Oral Session S2.9	1046	Investigations on Pressure Dependence of Coriolis Mass Flow Meters Used at Hydrogen Refuelling Stations	Oliver Buker
Oral Session S5.5	1015	Design of Gravimetric Primary Standards for Field Testing of Hydrogen Refuelling Stations	Marc de Huu
Oral Session S10.5	1064	Hydrogen Refuelling Station Calibration with a Traceable Gravimetric Standard	Rémy Maury

WP1 Flow Metering

Tasks

1. Identifying and assessing uncertainty sources for hydrogen metering

2. Investigate alternative methods for type approval testing using substitute substances to hydrogen

3. Investigate the influence of pressure on the mass flow measurement accuracy of CMFs using water

4. Develop 4 independent mobile gravimetric standards to deliver traceability to HRS at NWP of 350 and 700 bar

5. Develop uncertainty budgets for type approval testing, periodic verifications and gravimetric standards

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WP1 Flow Metering

2. Investigate alternative methods for type approval testing using substitute substances to hydrogen

AIM

To investigate whether non-flammable gases can be used to characterise and calibrate mass flow meters used for metering hydrogen

RATIONALE

To provide a safe methodology for flow laboratories to utilise, for type approval processes for instance, instead of using 875 bar hydrogen

At 30° C and 350 bar(a)
$\rho_{H_2} \sim 23\ kgm^{-3}$

At -40° C and 700 bar(a)
$\rho_{H_2} \sim 46\ kgm^{-3}$

At 20° C and 20 bar(a)
$\rho_{N_2} \sim 23\ kgm^{-3}$

At 20° C and 40 bar(a)
$\rho_{N_2} \sim 46\ kgm^{-3}$

This work

Testing with nitrogen and air, ambient temperature

Three members of the MetroHyVe Consortium

- NEL – 20 and 40 bar
- CESAME – 20 and 40 bar
- METAS – 20 and 40 bar (up to 86 bar at higher flow rates)

MetroHyVe Stakeholder

- KRISS – 10, 20, 30 and 40 bar

Effect of Temperature

- METAS nitrogen tests at -40 and 20°C

Effect of Pressure

- RISE water tests at 100 and 700 bar (separate paper)

This work

Four flow meters tested

- All Coriolis type, used in hydrogen refuelling stations
- Previously calibrated by manufacturers with water (Q_{min} = 0.2 to 0.5 kg/min)

Laboratory	Meters Tested
NEL	Meter A, B and C
METAS	Meter A, B
CESAME	Meter A, B
KRISS	Meter D

Flow Laboratories

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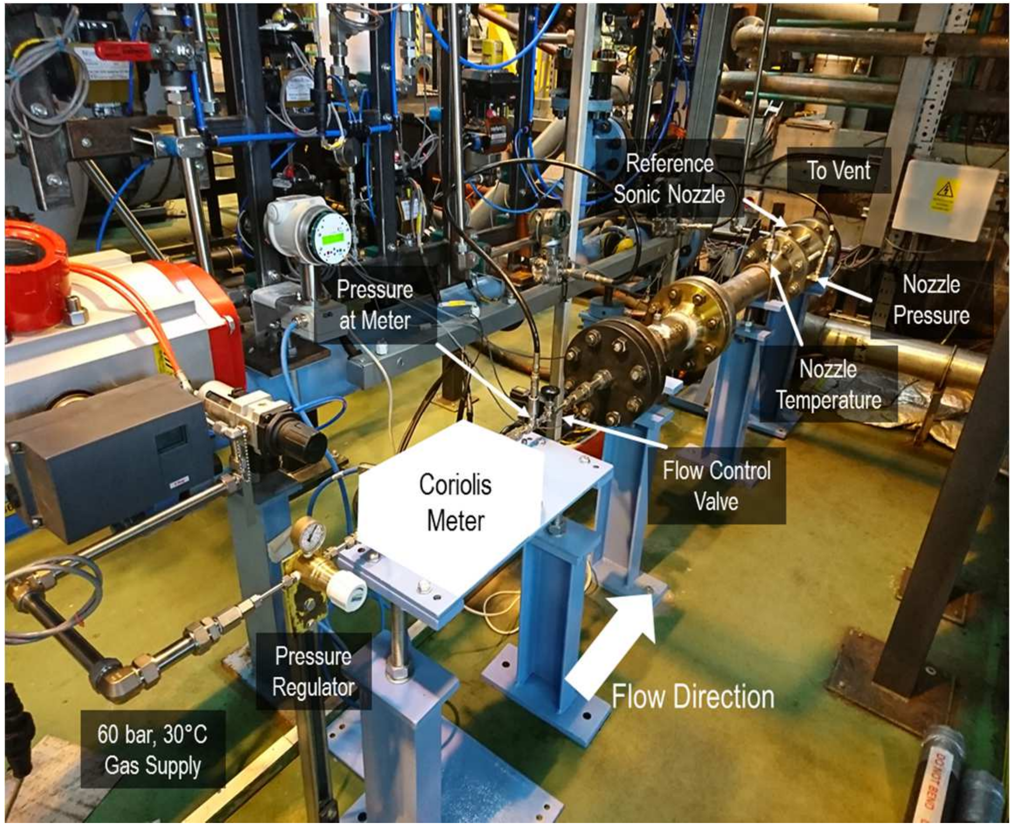
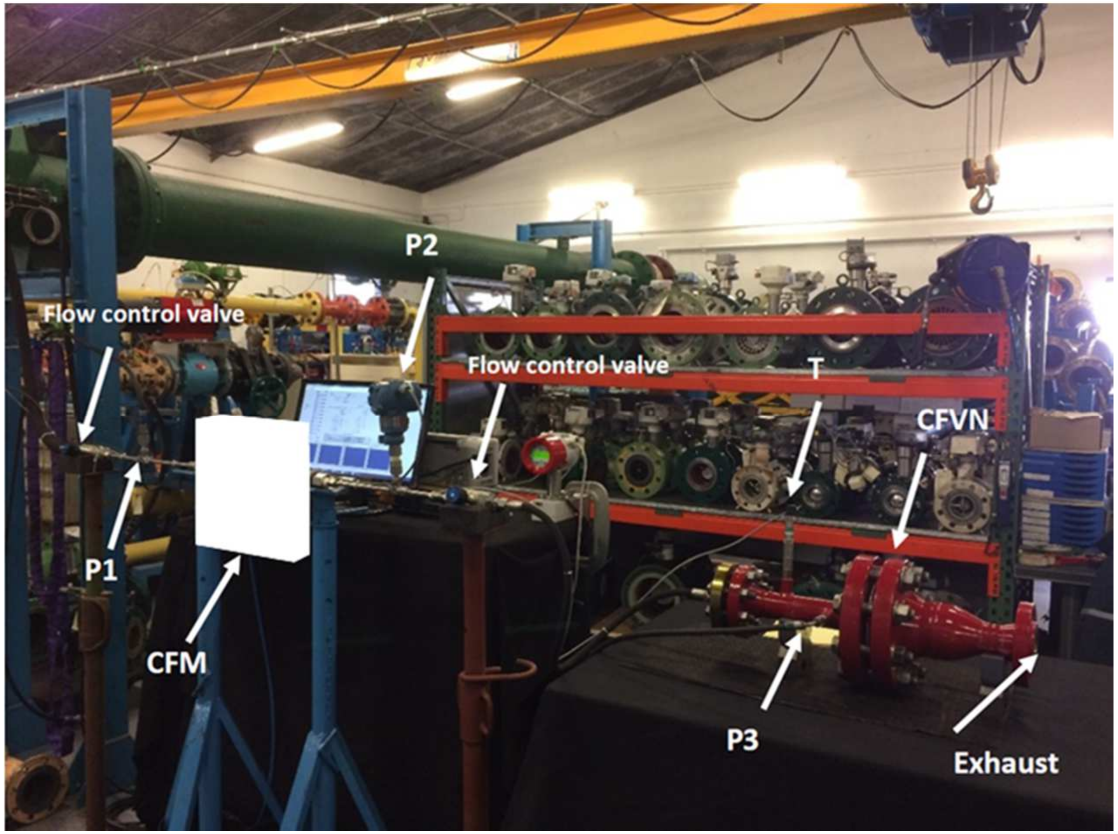
NEL

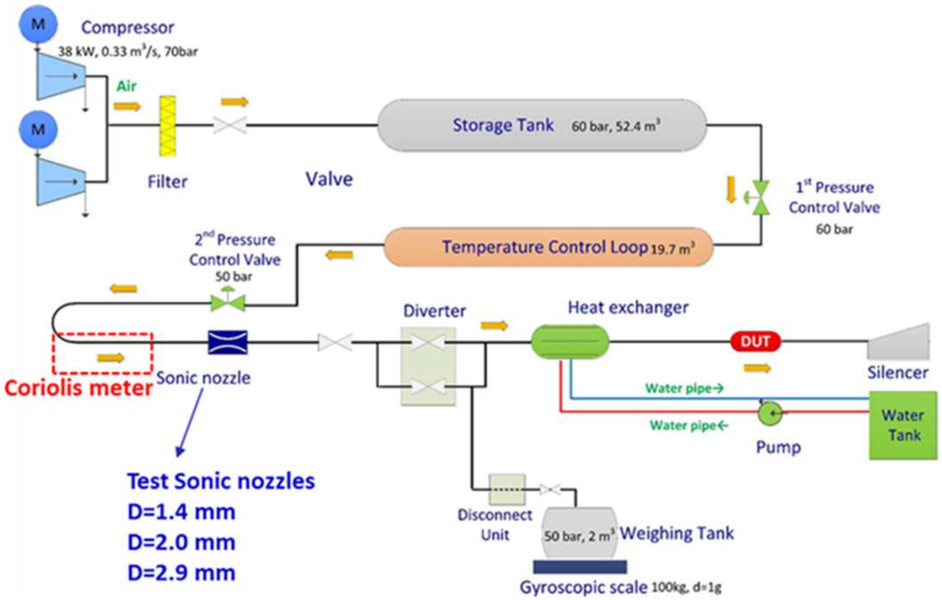


CESAME

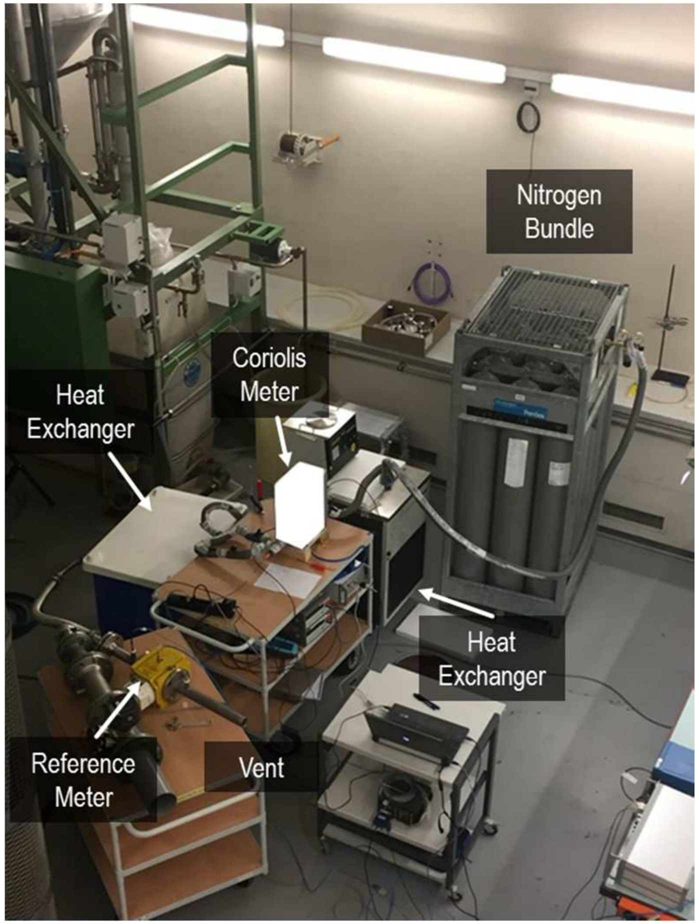


Flow Laboratories

KRISS



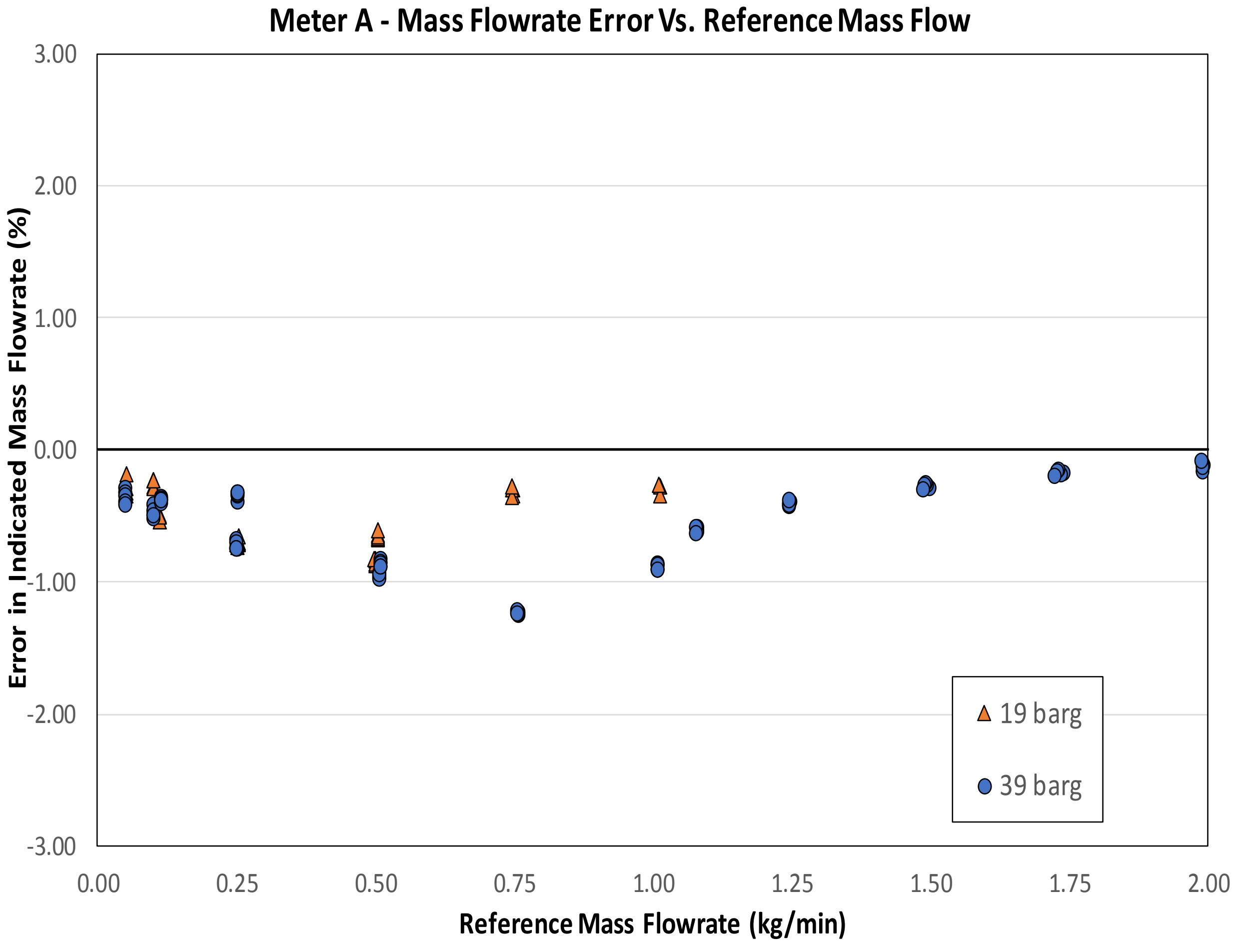
METAS



Test Results

NEL Meter A

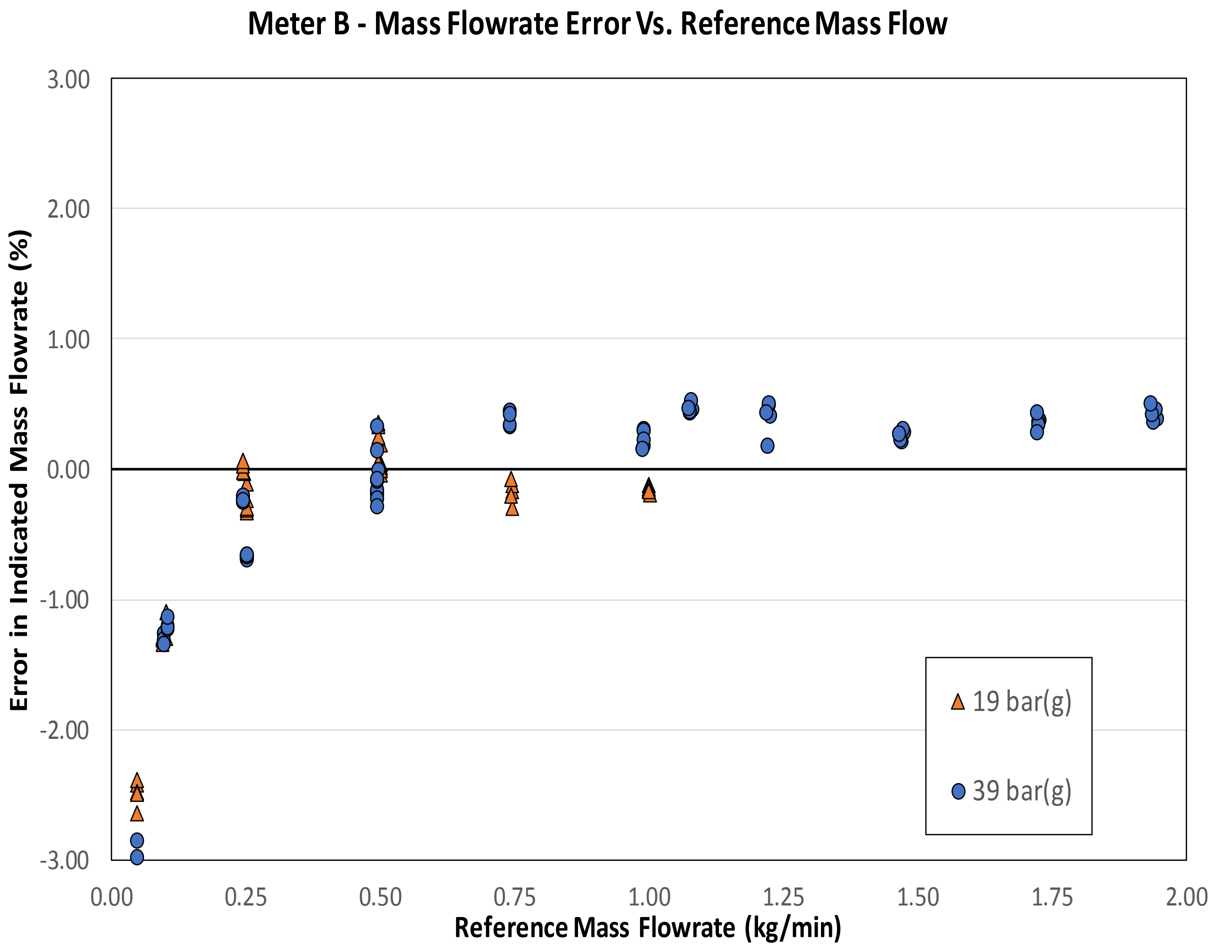
- Offset Approx. -0.5%
- Errors Range -1.26 to -0.09%
- Most Results within ±1%
- Average repeatability ±0.024%



Test Results

NEL Meter B

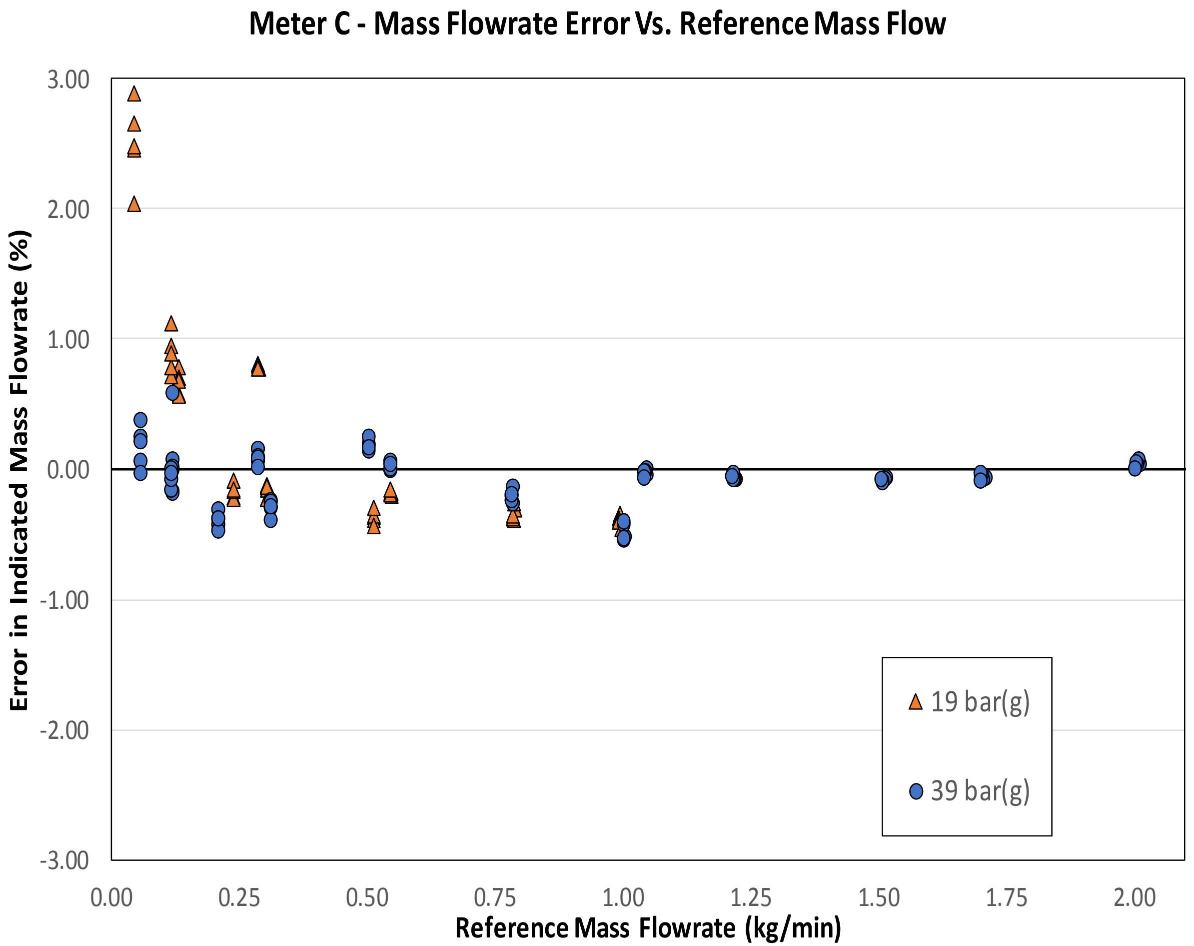
- No offset
- Errors Range -3.05 to 0.52%
- Above 0.25 kg/min, most results within ±0.5%
- Average repeatability ±0.06%



Test Results

NEL Meter C

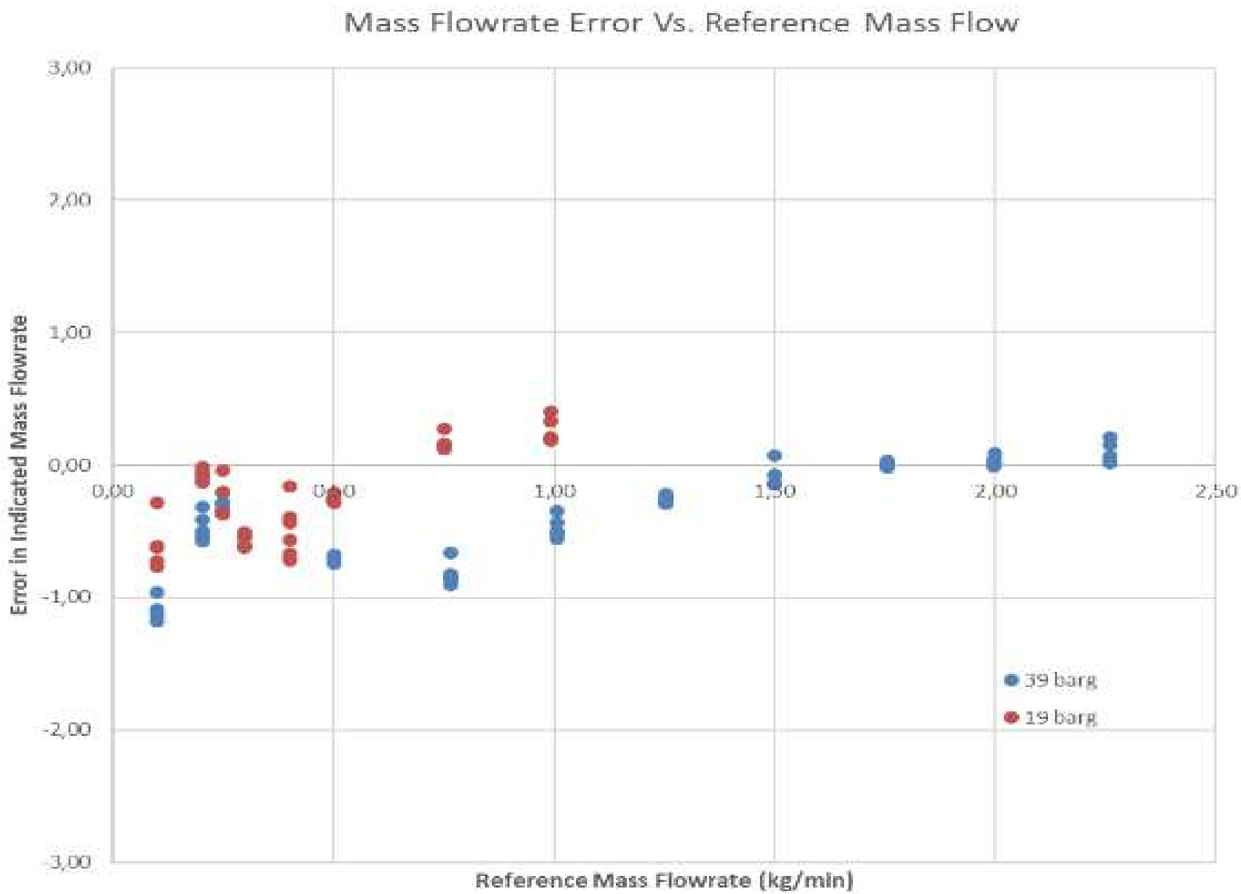
- No offset
- Errors Range -0.54 to 2.89%
- Above 0.25 kg/min, most results within ±0.5%
- Average repeatability ±0.065%



Test Results

CESAME Meter A

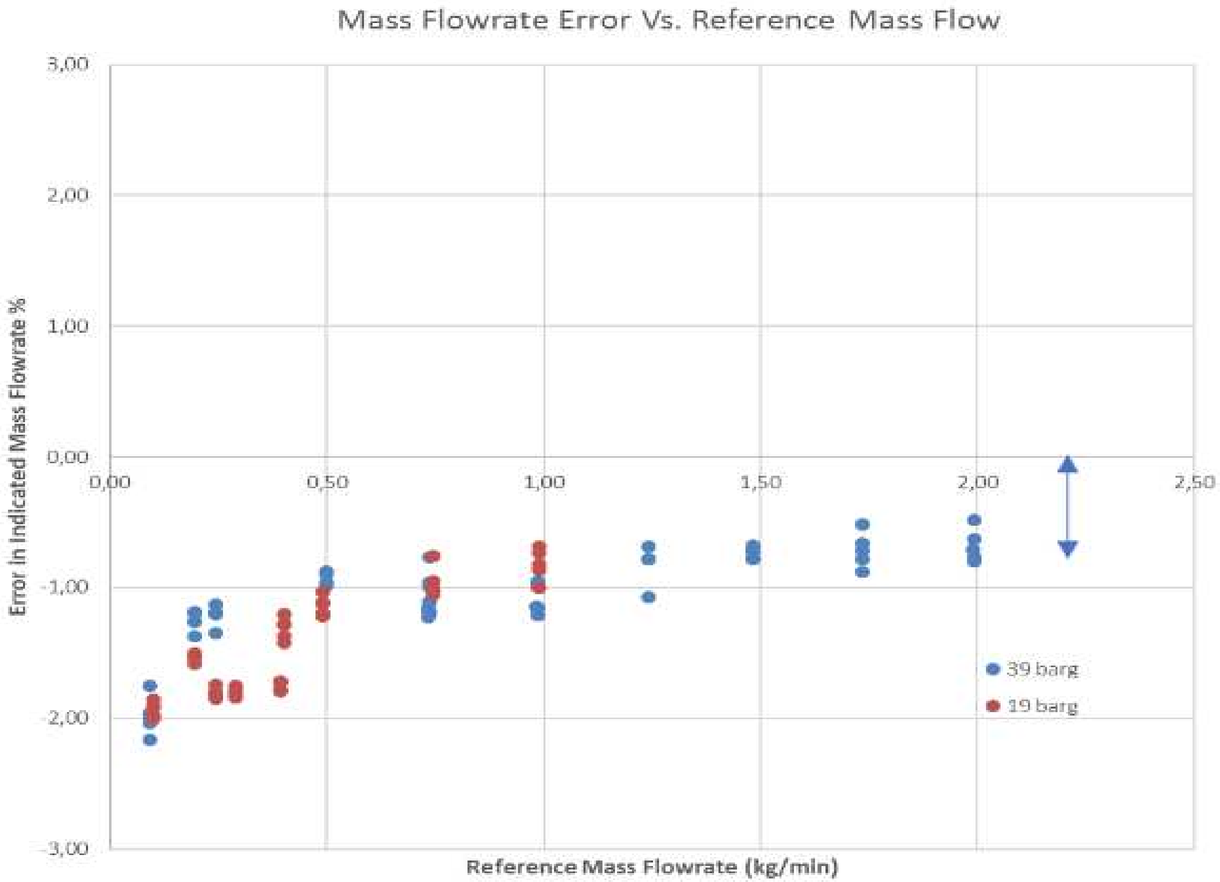
- Offset Approx. -0.25%
- Errors Range -1.18 to 0.41%
- Most Results within ±1%
- Average repeatability ±0.04%



Test Results

CESAME Meter B

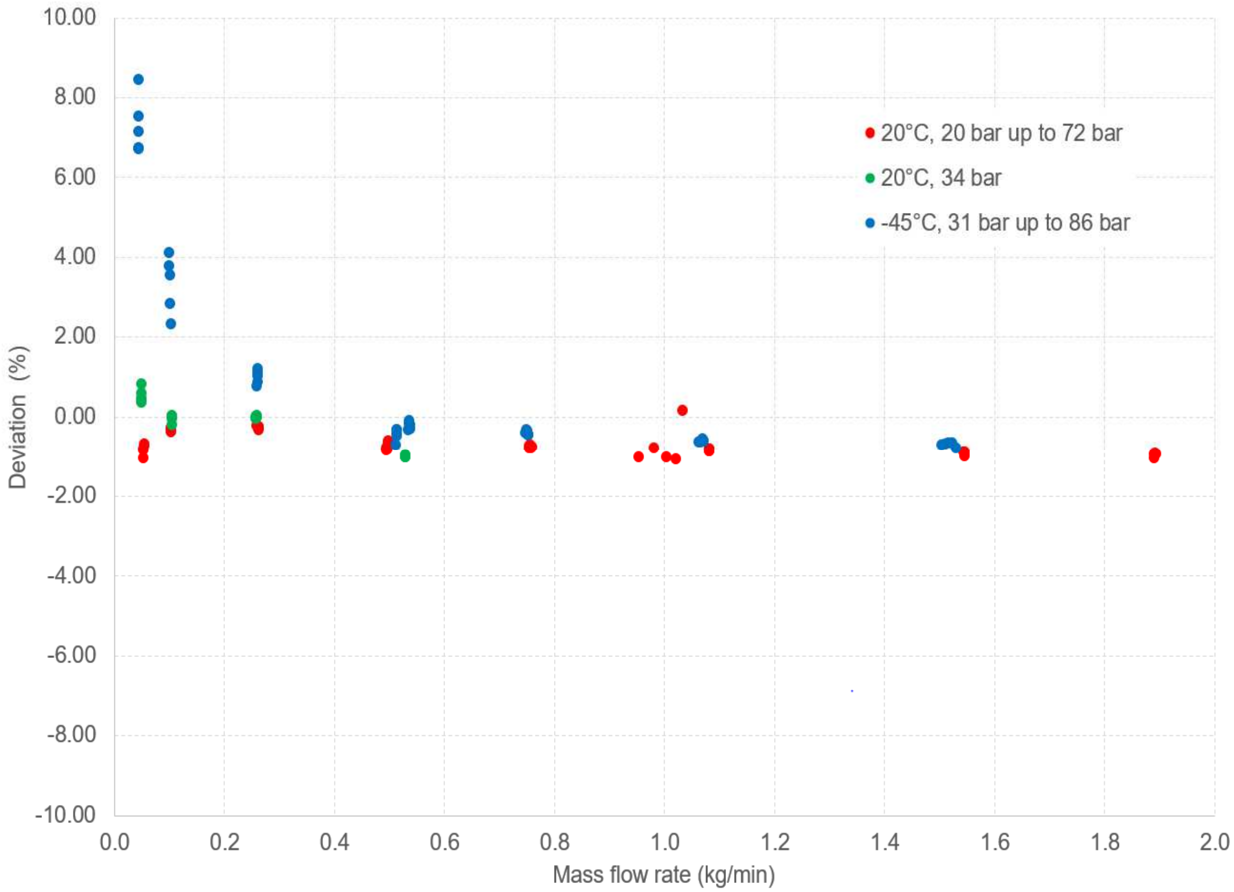
- Offset Approx. -0.7%
- Errors Range -2.16 to -0.49%
- Average error -1.05%
- Average repeatability ±0.06%



Test Results

METAS Meter A

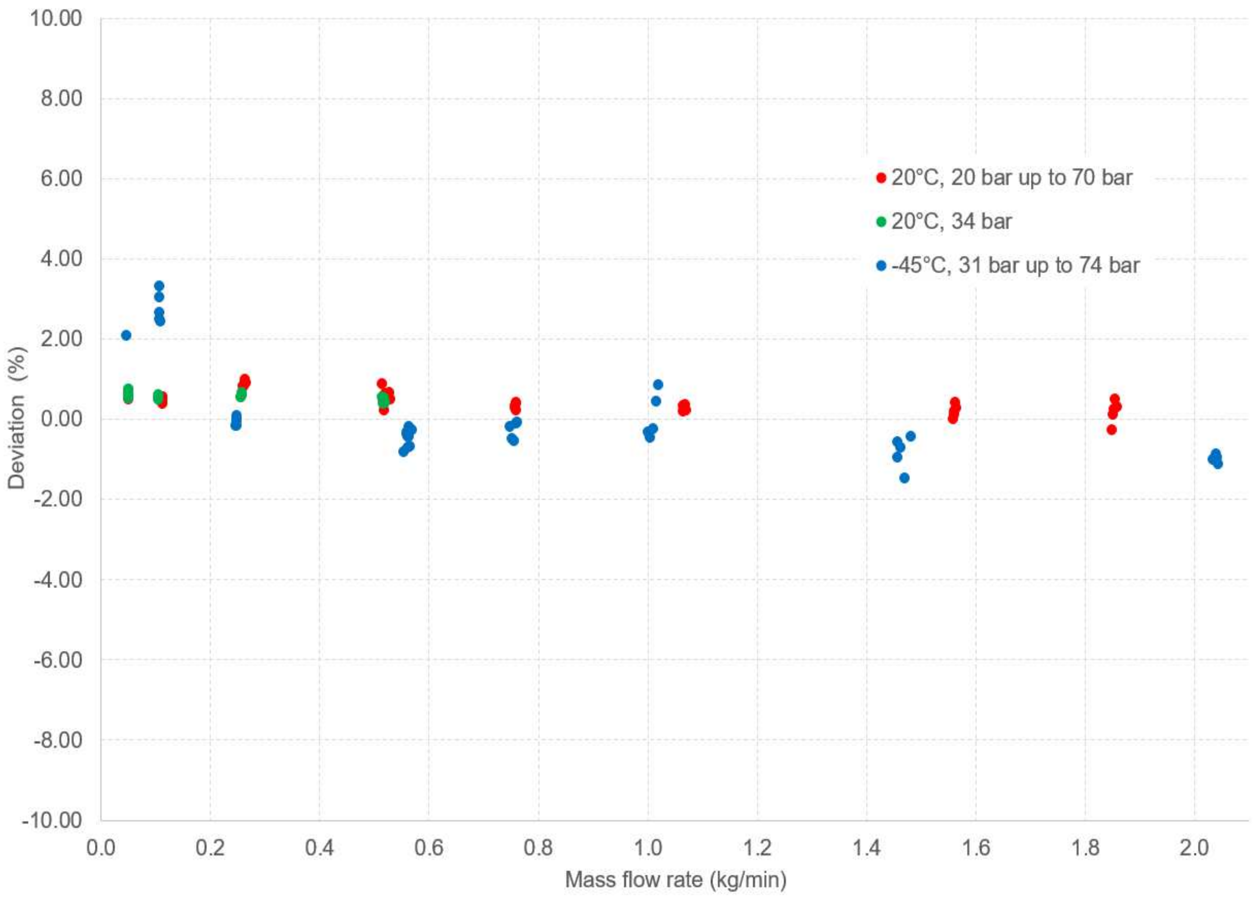
- Errors Range -1.08 to 8.44%
- Most 20°C results within ±1%
- Influence of temperature only at low flow rates
- Largest errors at -40°C, <0.4 kg/min
- Above 0.4 kg/min, average error -0.8%



Test Results

METAS Meter B

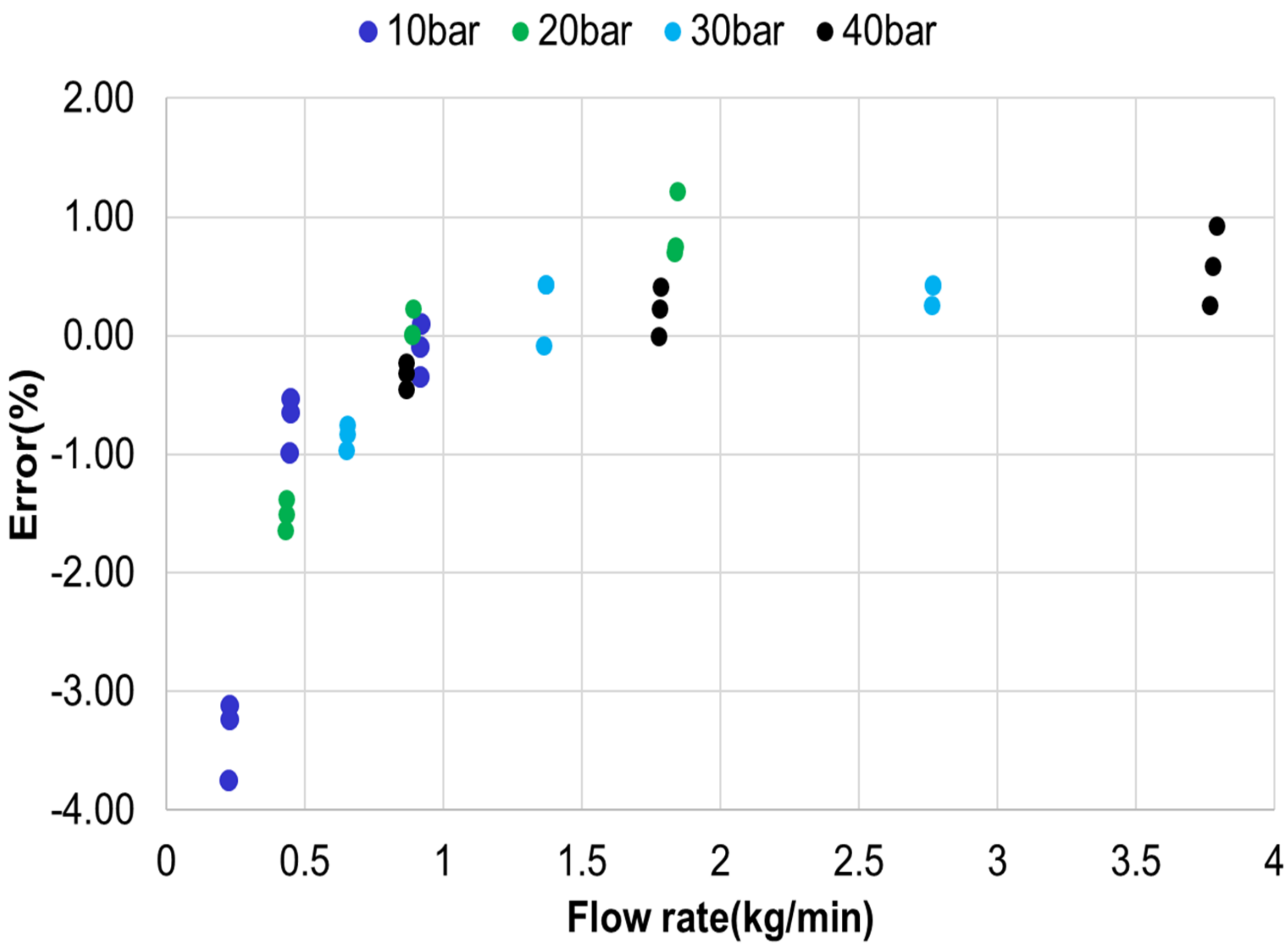
- Errors Range -1.48 to 3.33%
- All 20°C results within ±1%
- Influence of temperature
  - Positive errors at low flowrates, <0.2 kg/min
  - Negative errors >0.2 kg/min



Test Results

KRISS Meter D

- Errors Range -3.4 to 1.22%
- Above 0.5 kg/min, most results within ±1%
- No pressure effect observed



Conclusions

- Largest errors occurred at low flow rates
- At medium to high flow rates, errors for most meters were within ±1%
- Shows potential for calibration using alternative fluids, each meter previously calibrated by manufacturers using water

- Influence of temperature observed, greater errors and wider spread occurred at -40°C compared to 20°C.
  - Meter A: larger errors (up to 8.44%) at -40°C, but only at low flow rates. No temperature dependence for flow rates ≥ 0.4 kg/min
  - Meter B: Slight temperature dependence for all flow rates, errors up to 3.33%. Positive errors at low flow rates and vice versa.

- No pressure effect observed at 10 to 86 bar
- Pressure effect is separately investigated using water (RISE paper)

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THANK YOU