METROLOGY for HYDROGEN VEHICLES

HYDRAITE

Laboratory Calibrations Using Gas

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11th September 2019

EMPIR EURAMET FCH

Overview

- Overview of MetroHyVe Flow Metering Tasks
- Flow Measurement Challenges in Hydrogen Refuelling Stations
- Method for Flow Calibration using Substitute Fluids
- Flow Laboratories
- Calibration Results
- Conclusions

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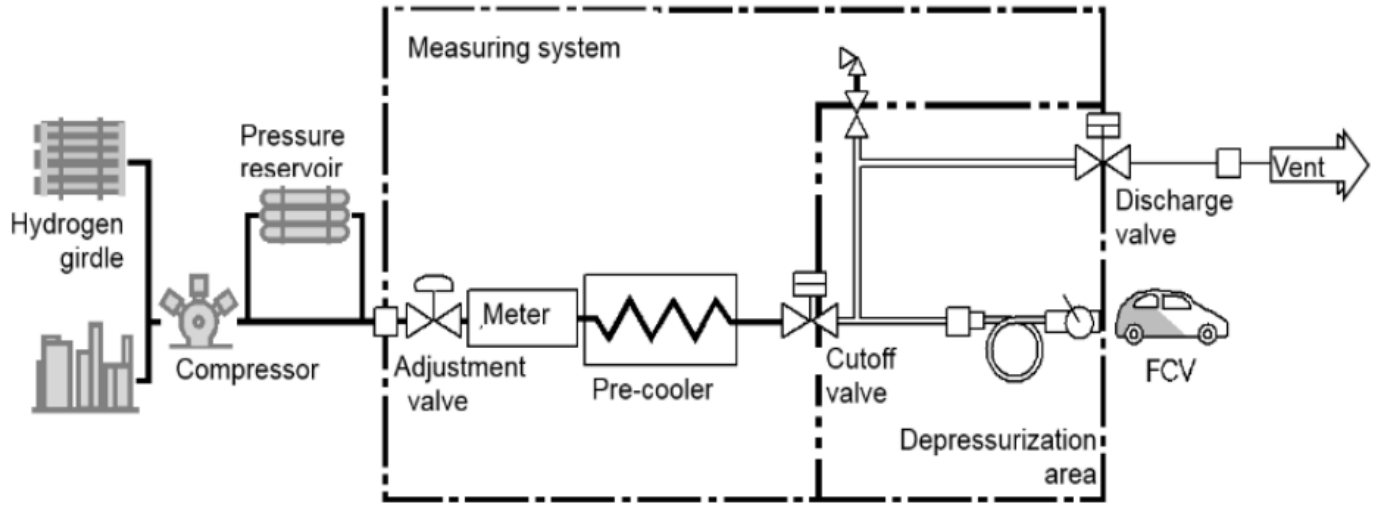
WP1 Flow Metering

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!

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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

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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)
ρ_{H_2} ~ 23 kgm^{-3}

At -40°C and 700 bar(a)
ρ_{H_2} ~ 46 kgm^{-3}

At 20°C and 20 bar(a)
ρ_{N_2} ~ 23 kgm^{-3}

At 20°C and 40 bar(a)
ρ_{N_2} ~ 46 kgm^{-3}

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Calibration with Substitute Fluids to Hydrogen

Nitrogen and air, ambient temperature
- NEL – 20 and 40 bar
- CESAME – 20 and 40 bar
- METAS – 20 and 40 bar (up to 86 bar at higher flow rates)

Effect of Temperature (Stable)
- METAS nitrogen tests at -40 and 20°C
- NEL nitrogen tests at 0 and 40°C

Effect of Temperature (Transient)
- METAS nitrogen tests at -40 and 0°C

Effect of Pressure (next presentation)
- RISE water tests at 100 and 700 bar

Field Testing at HRS (presentation after next)
- Comparison against gravimetric primary standard using hydrogen

Calibration with Substitute Fluids to Hydrogen

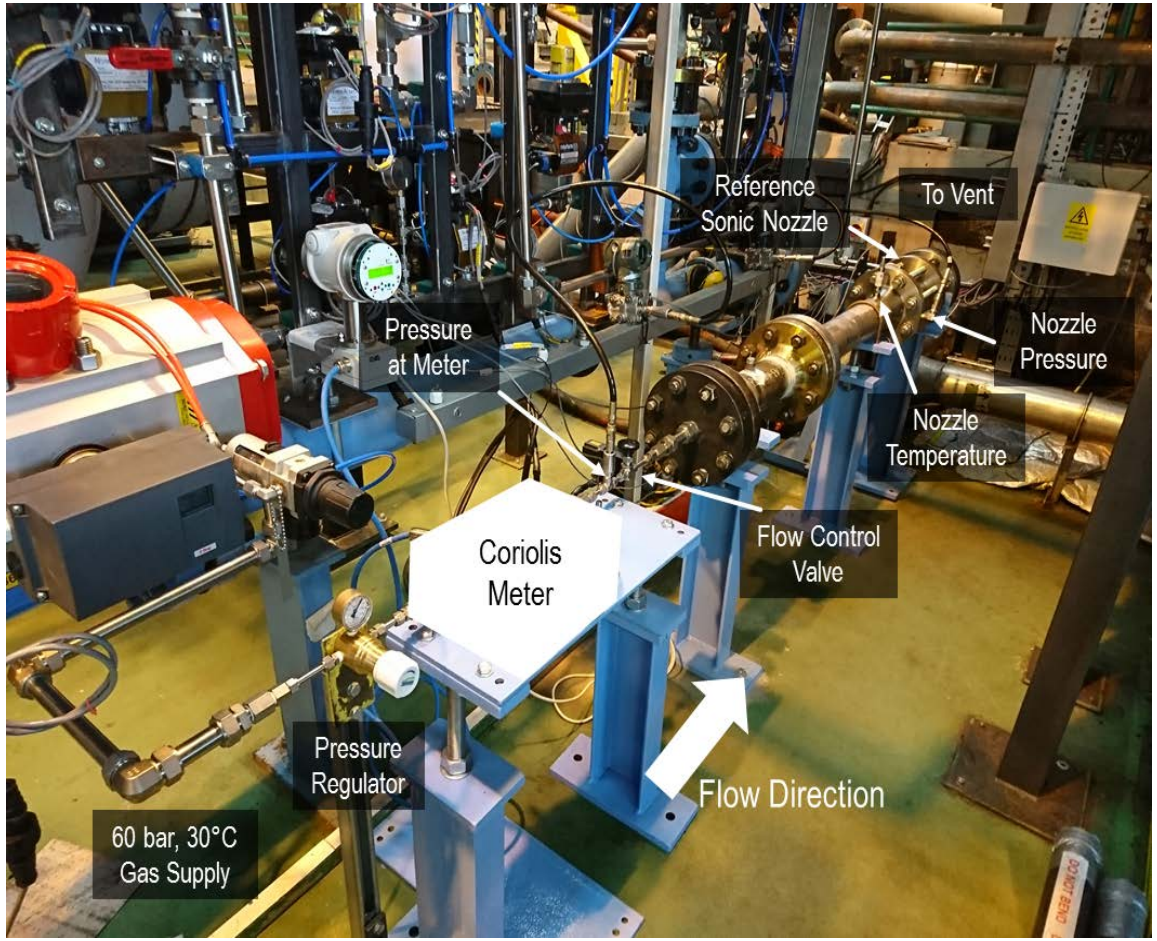
Four flow meters tested

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

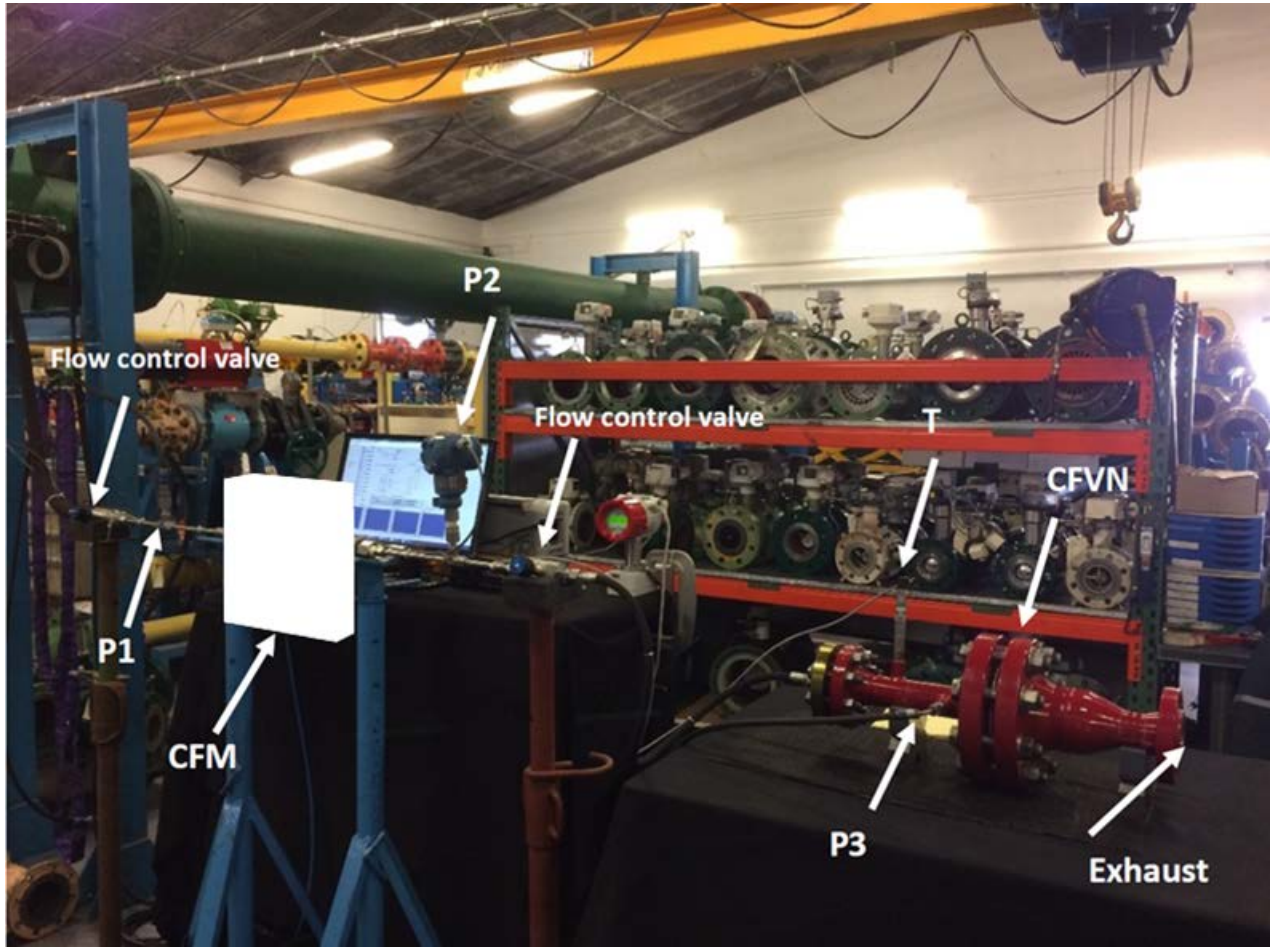
Laboratory	Meters Tested
NEL	Meter A, B and C
CESAME	Meter A, B
METAS	Meter A, B and D

Flow Laboratories

NEL



CESAME



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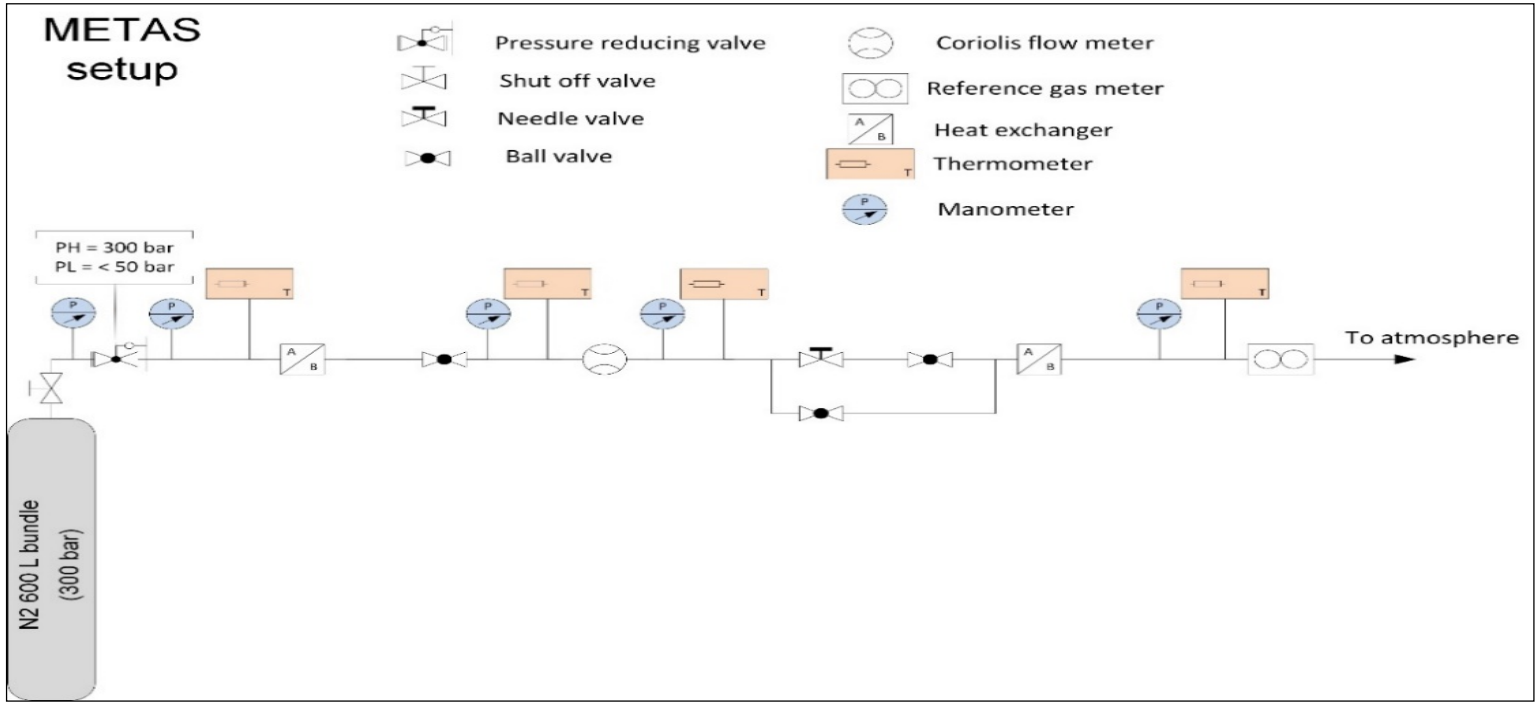
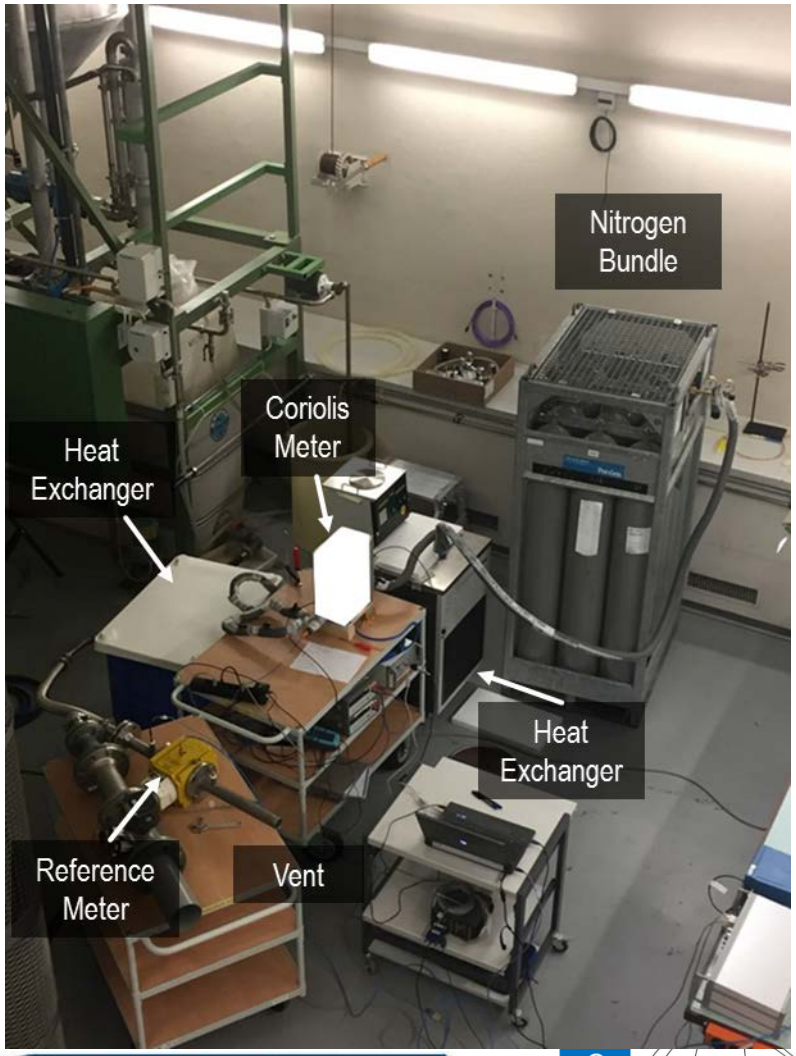
Flow Laboratories

METAS





METAS Temperature Tests

- Stable: Initial temperatures of meter and upstream nitrogen are similar, temperature stability confirmed before logging test points
- Transient: Initial temperatures of meter and upstream nitrogen are different, logging test points immediately after opening valve upstream of the meter

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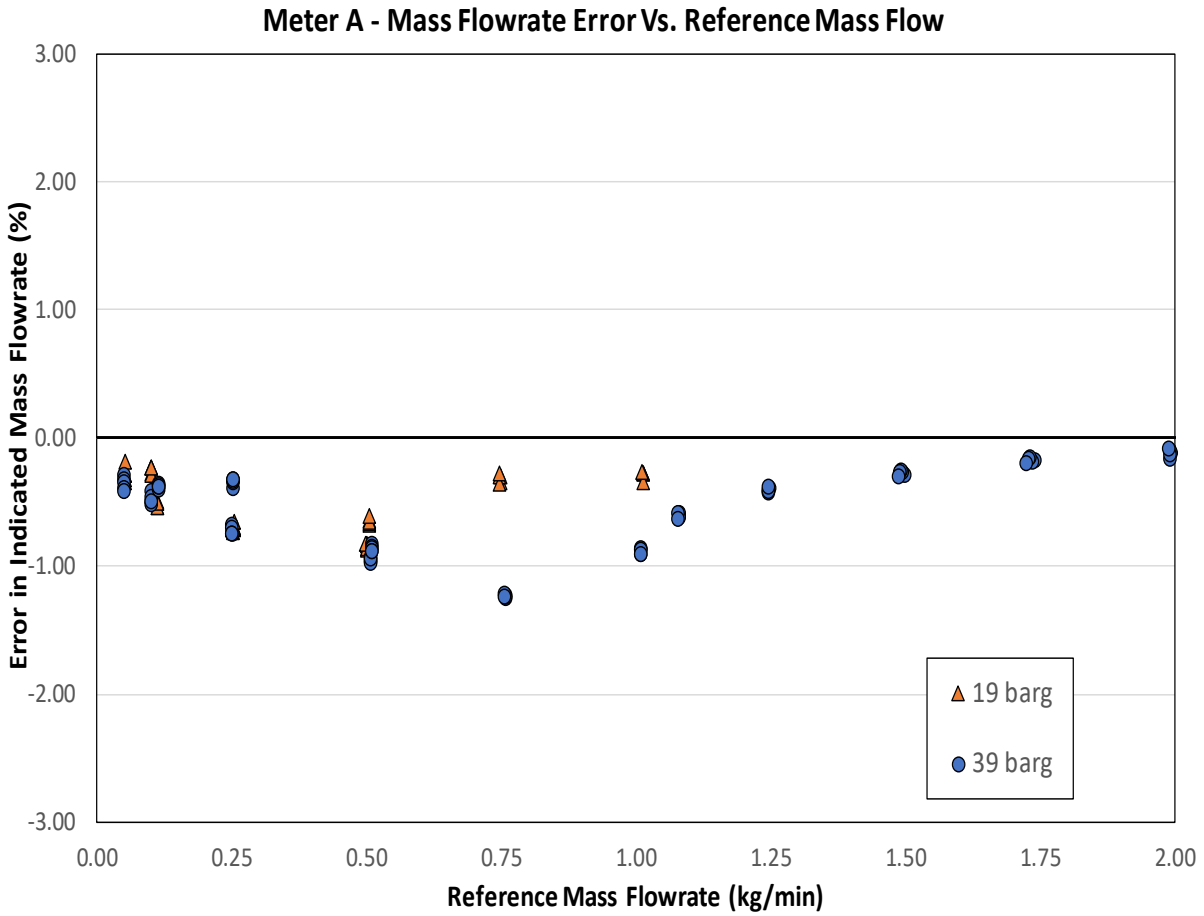
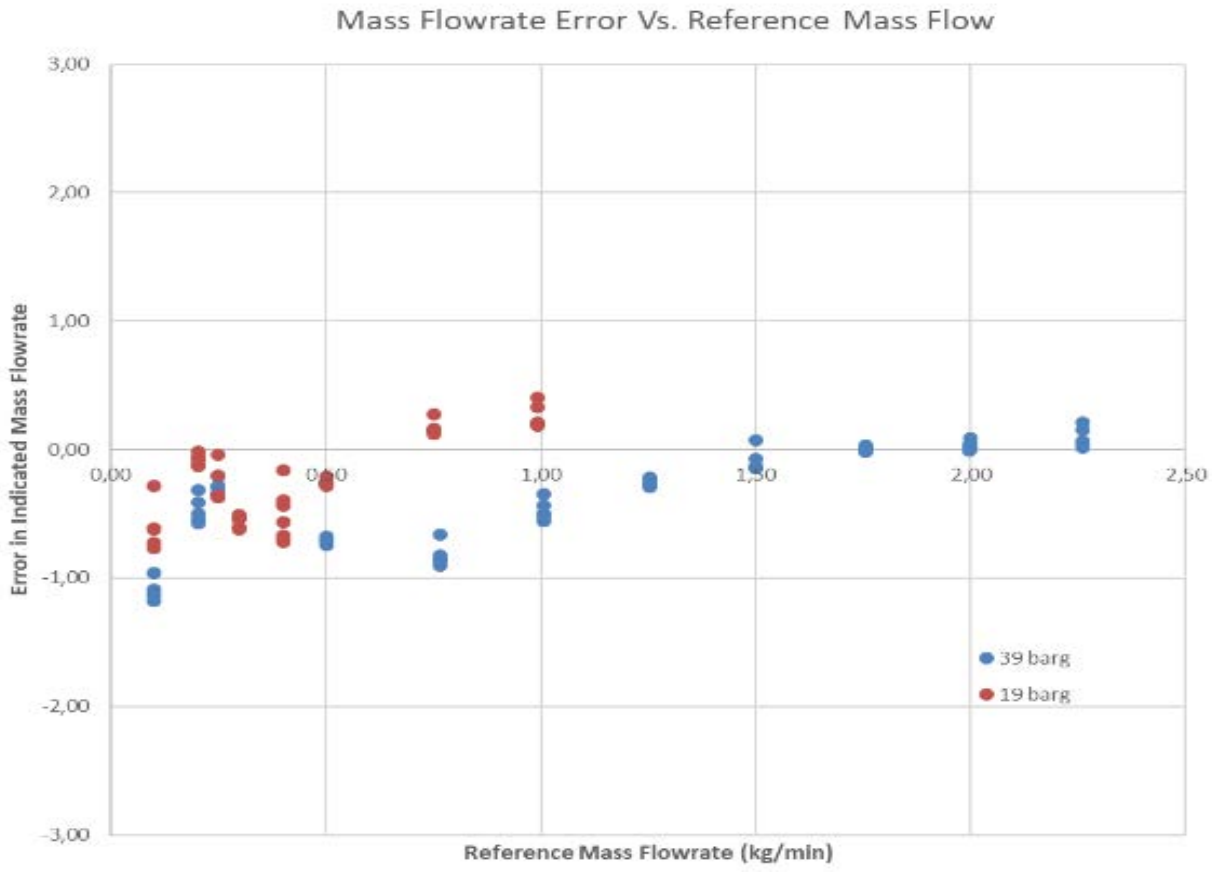
Calibration Results – Meter A

NEL



CESAME



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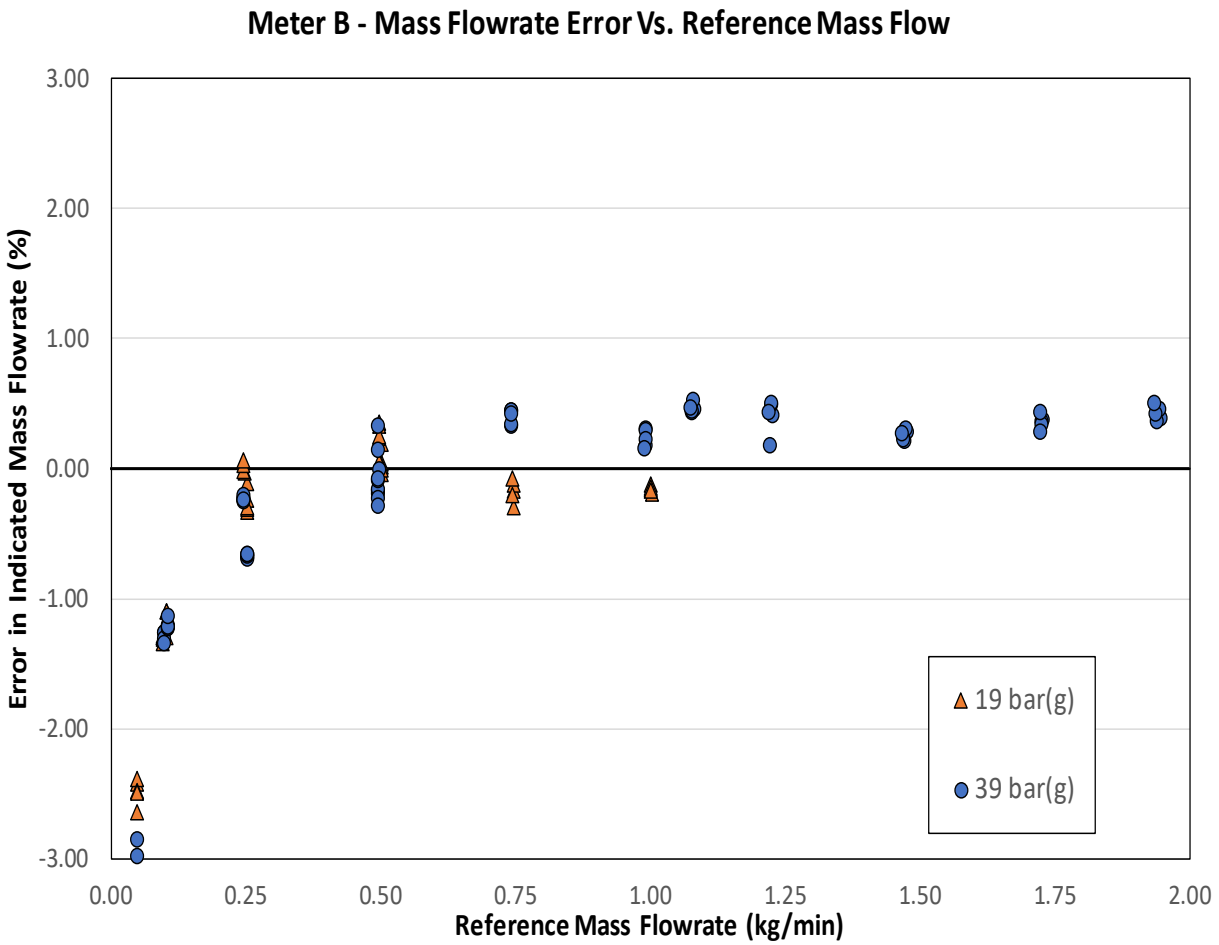
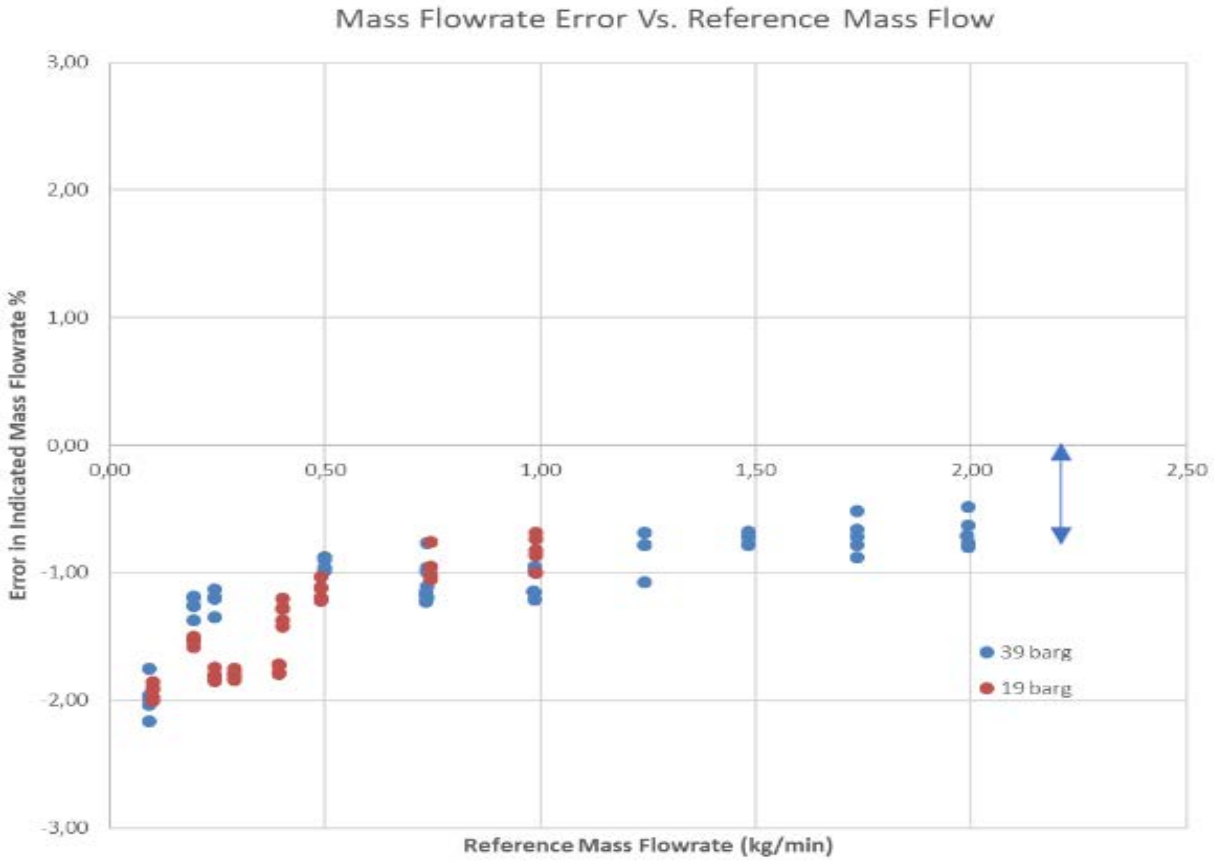
Calibration Results – Meter B

NEL



CESAME



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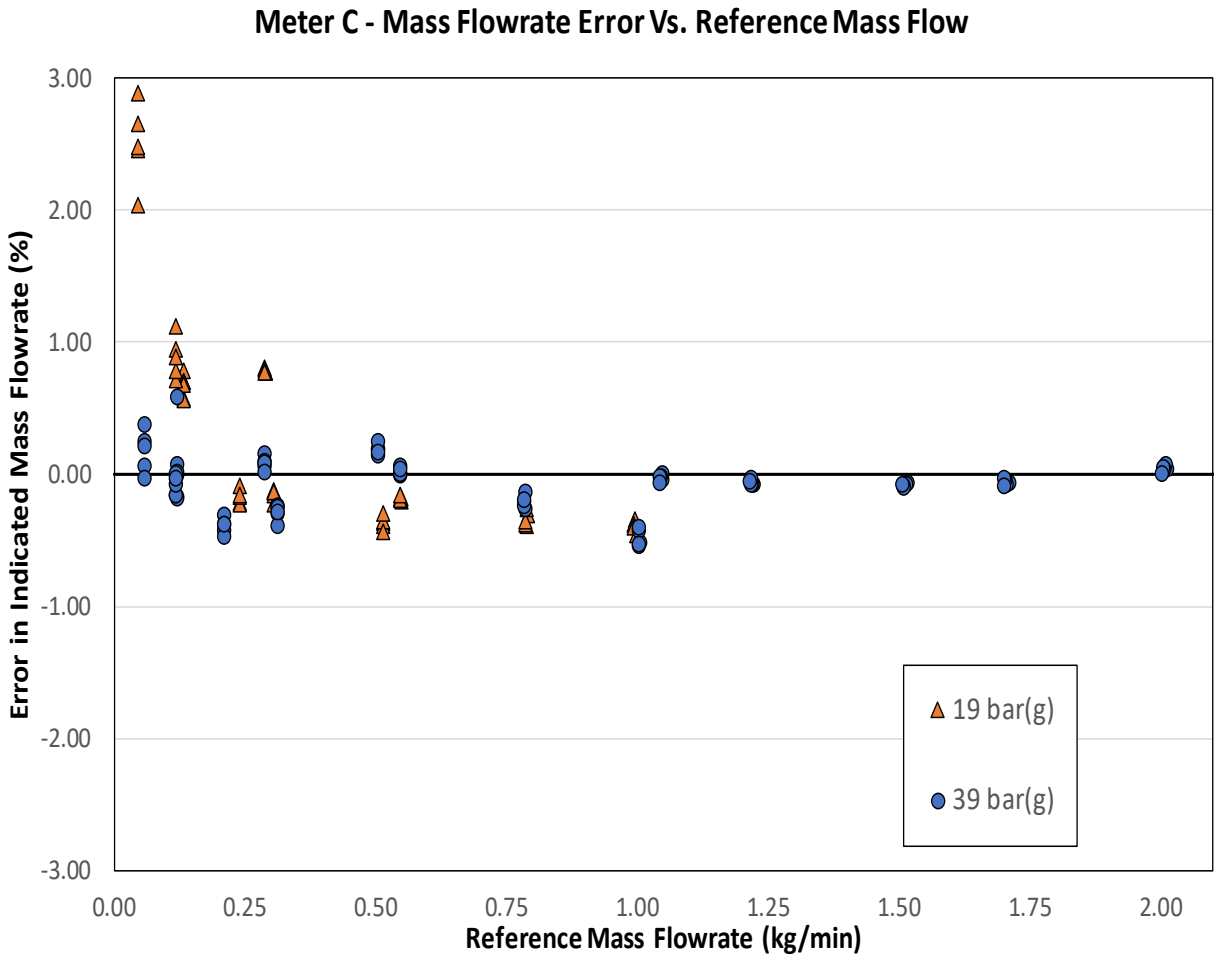
Calibration Results – Meter C

NEL



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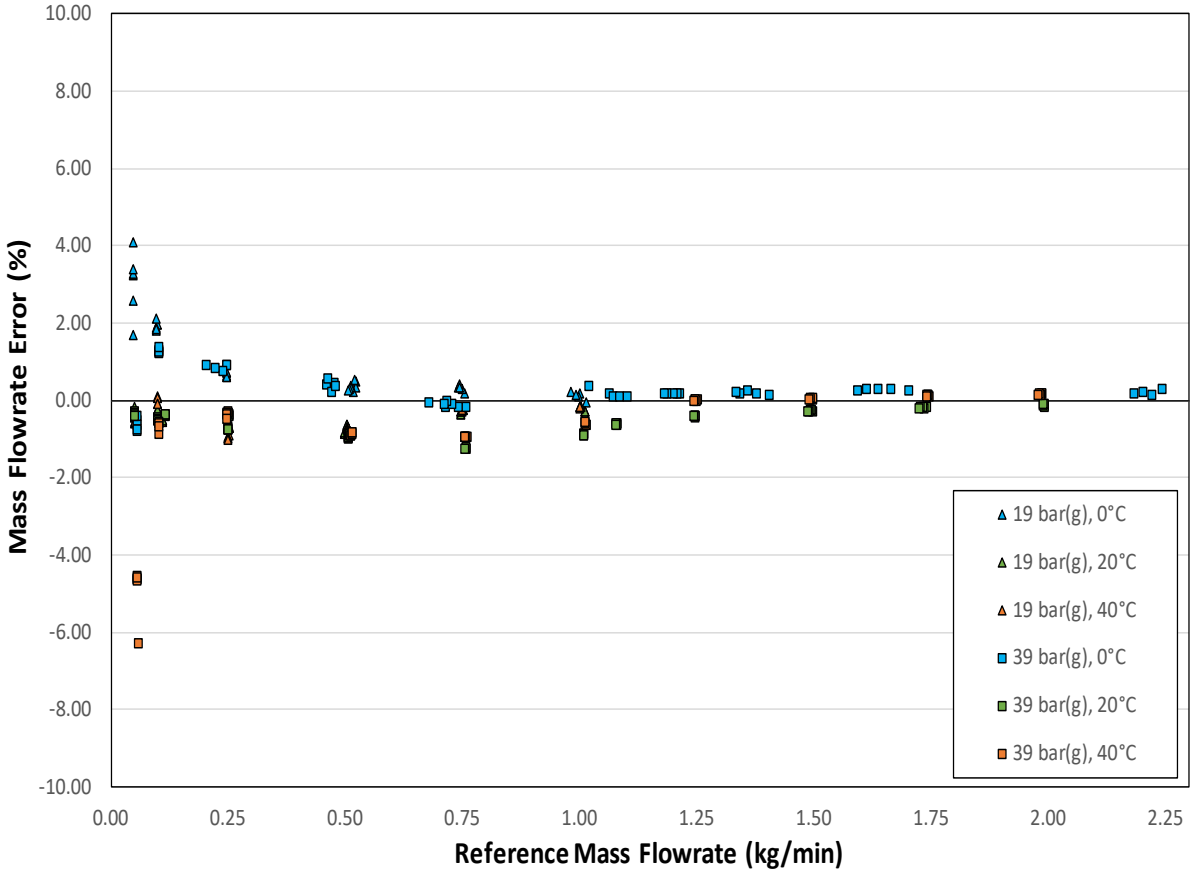
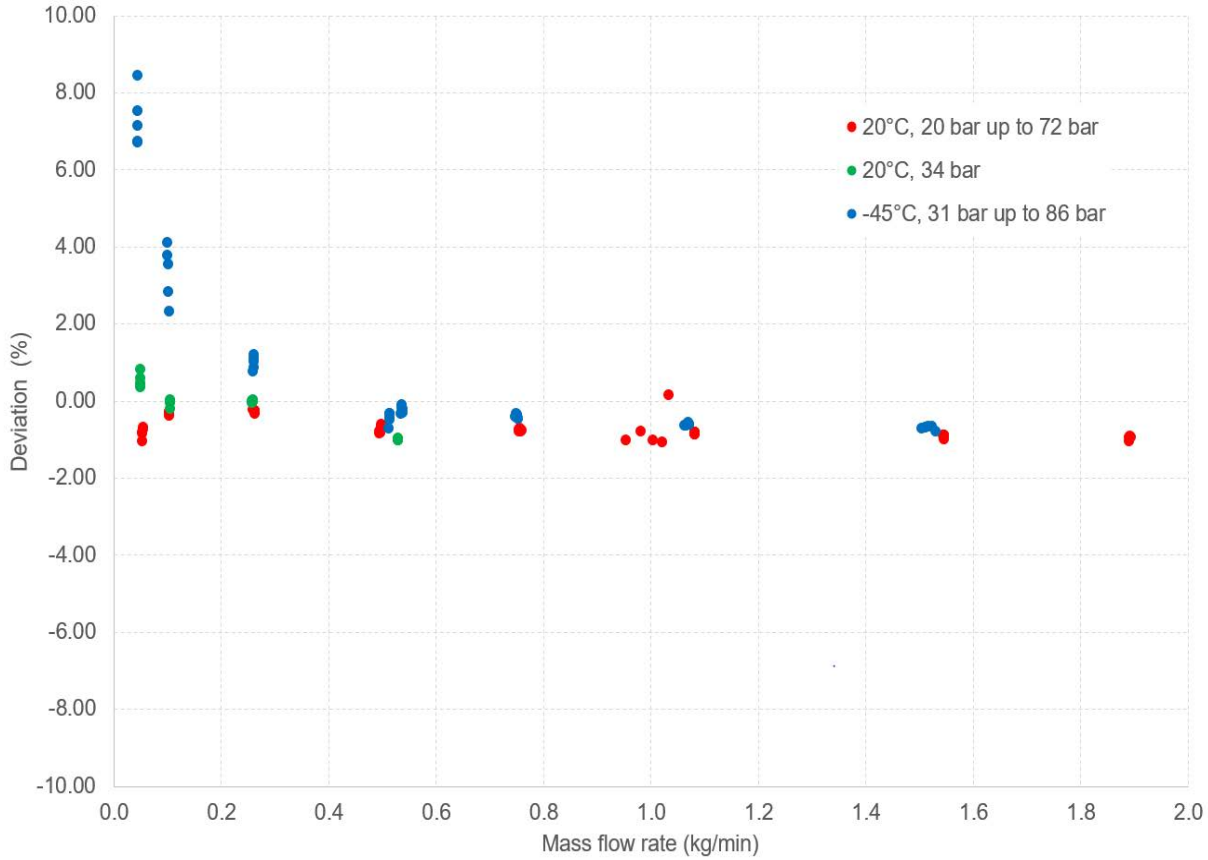
Temperature Tests – Meter A

NEL



METAS



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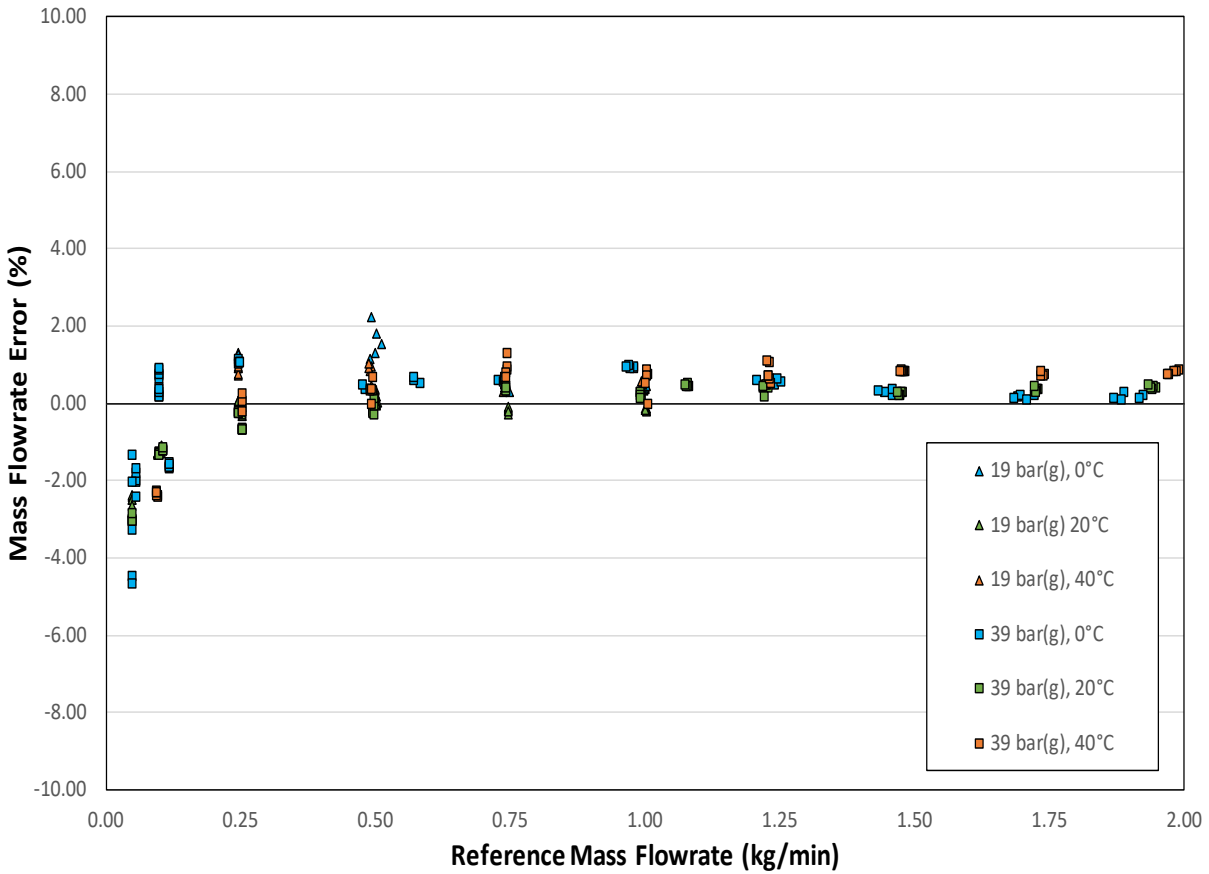
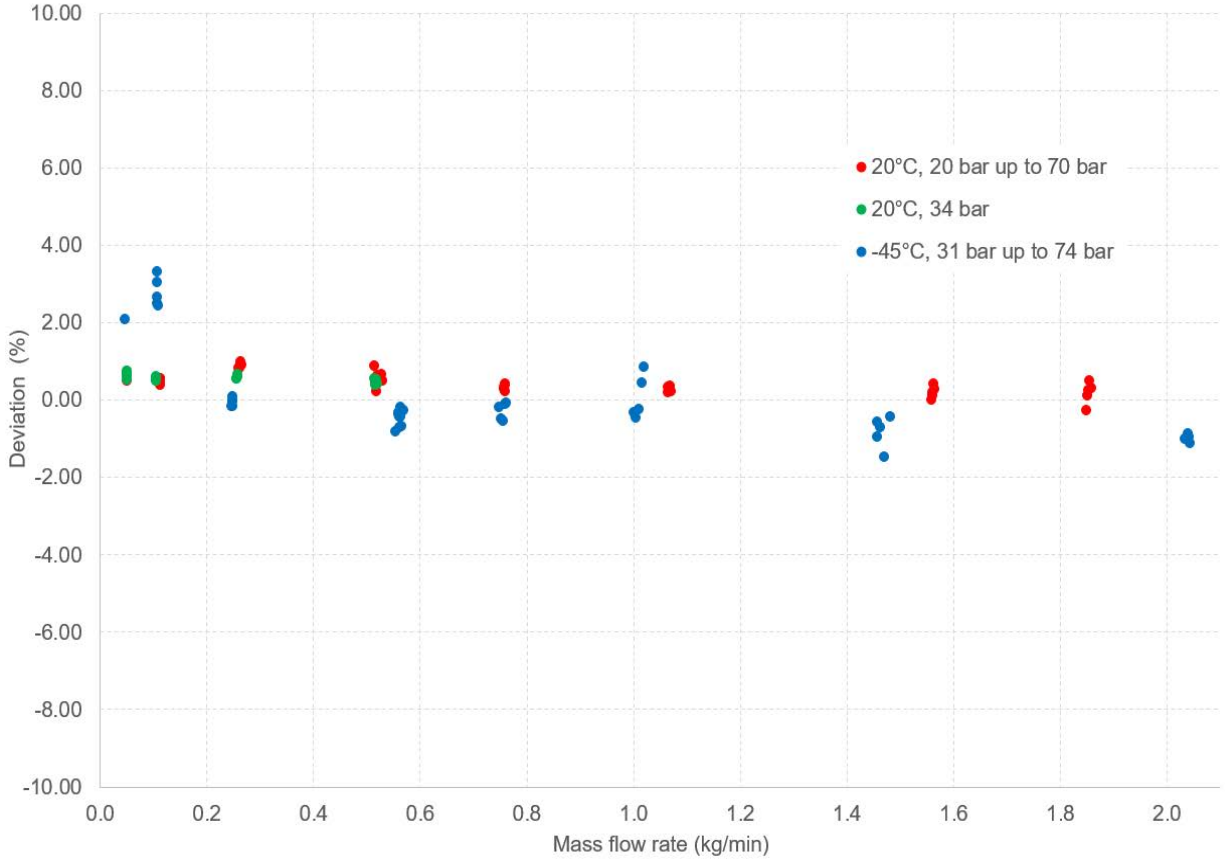
Temperature Tests – Meter B

NEL



METAS



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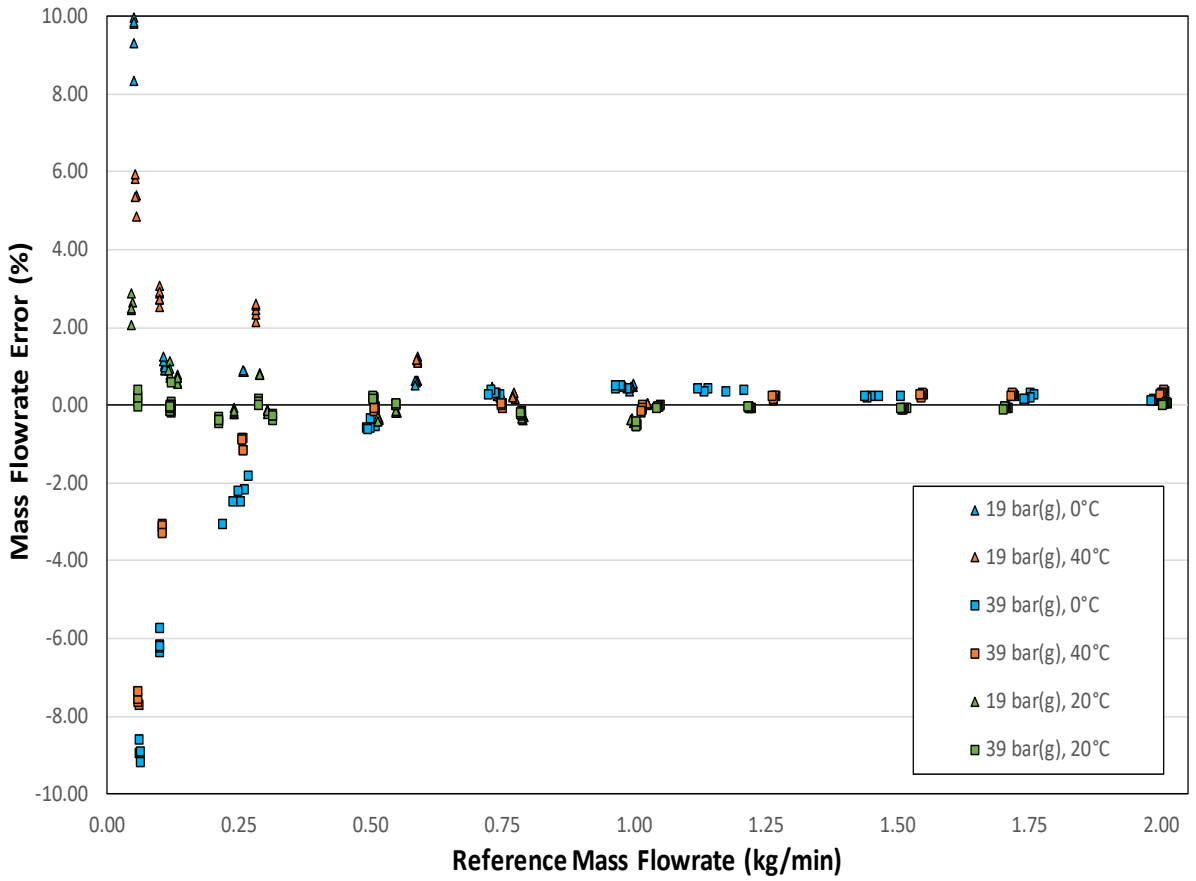
Temperature Tests – Meter C

NEL



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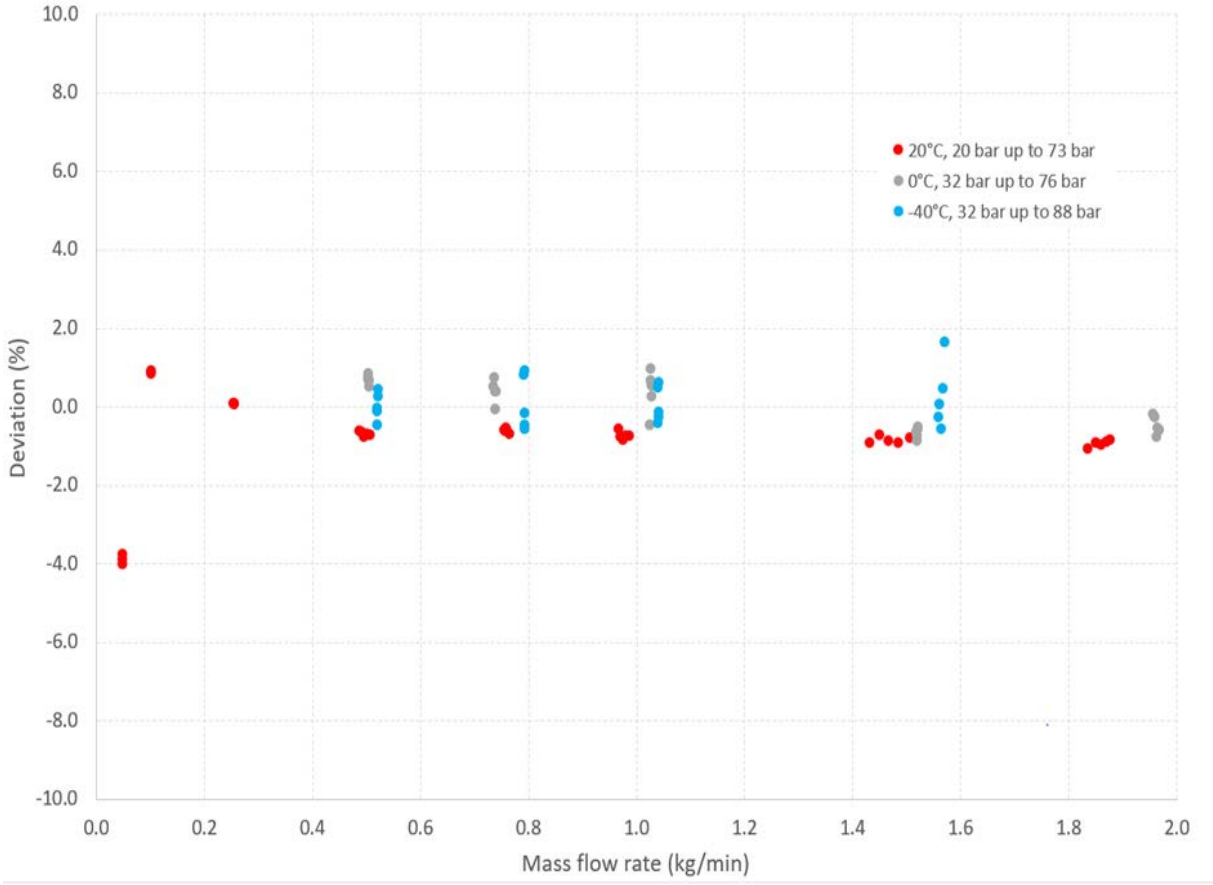
Temperature Tests – Meter D

METAS



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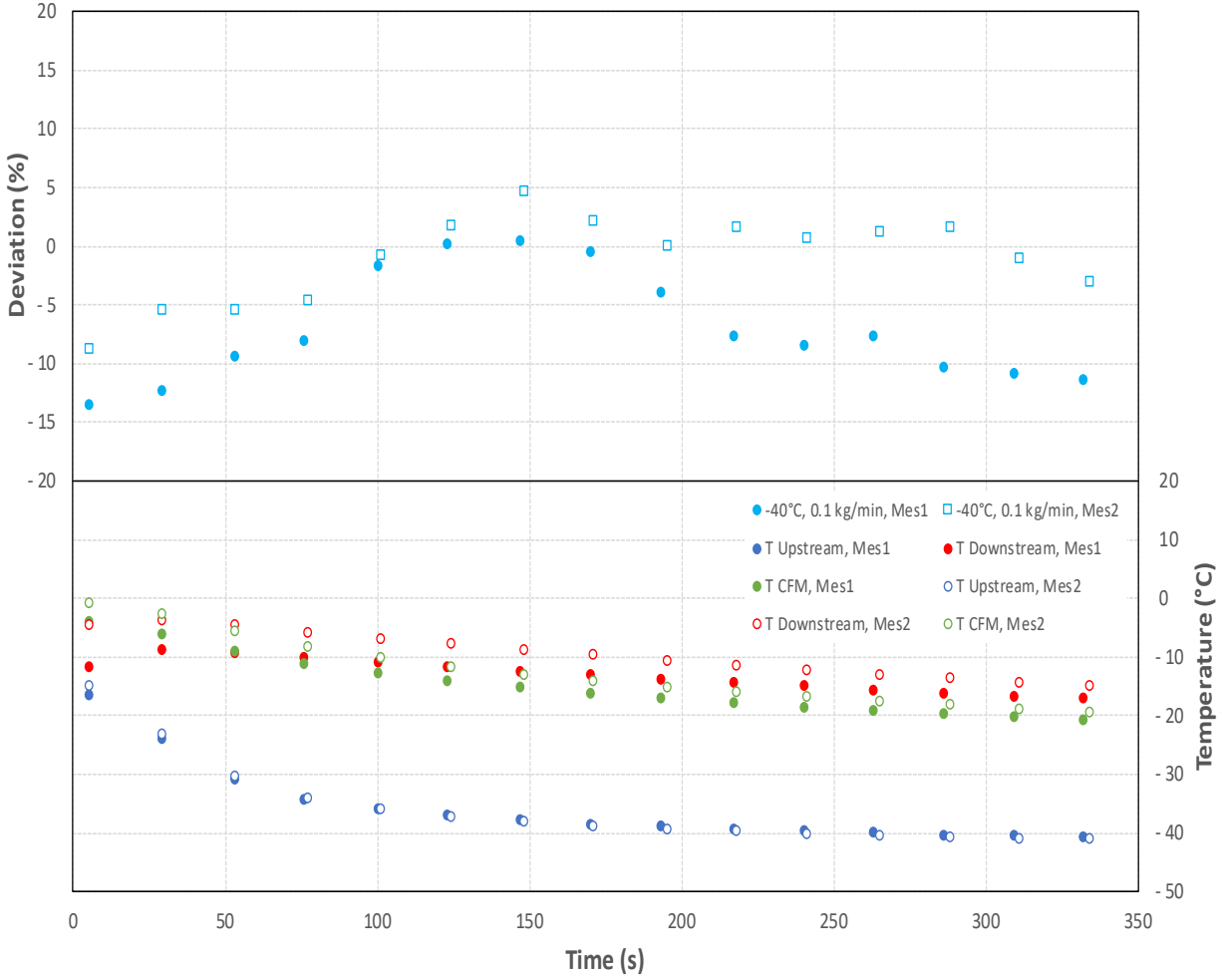
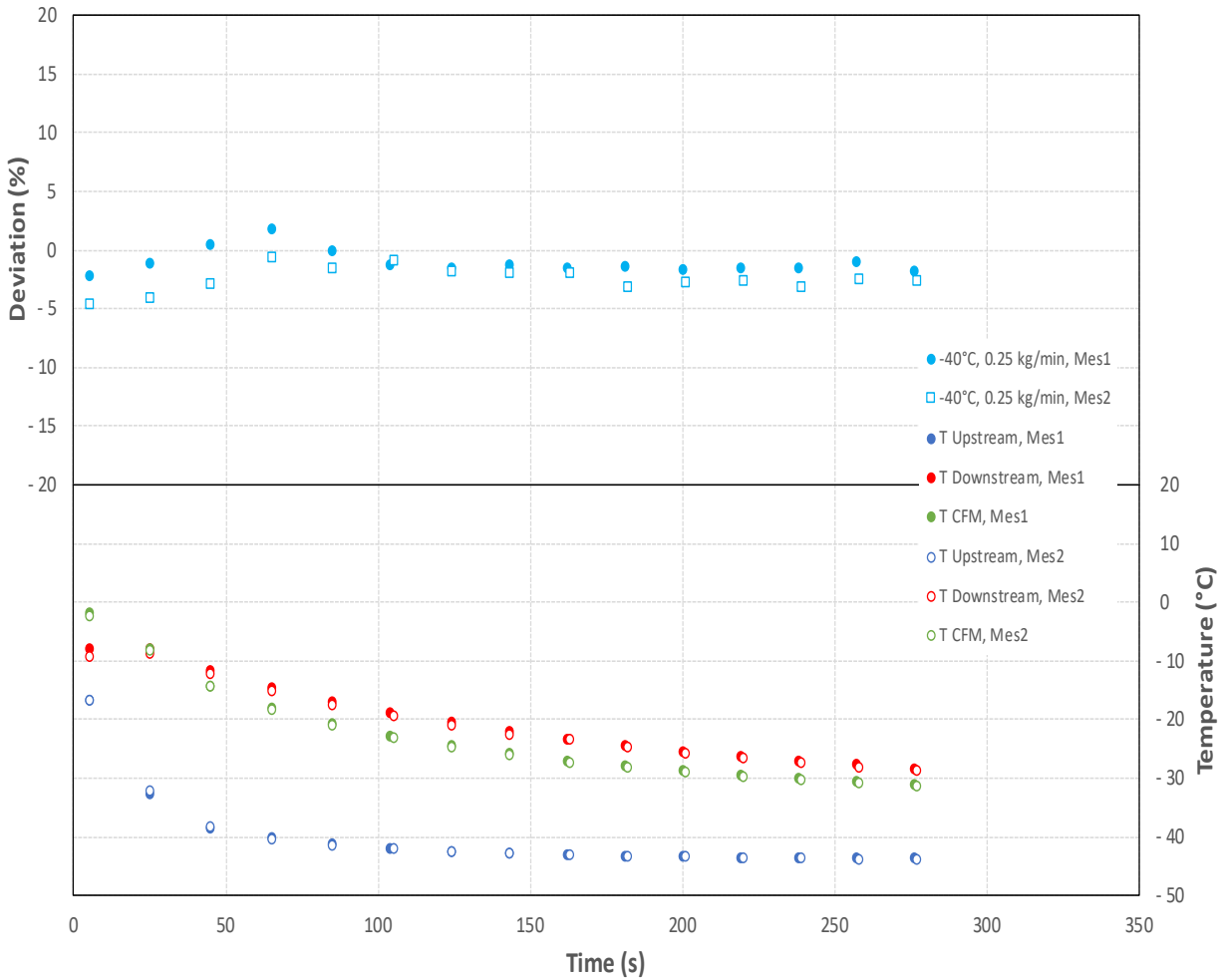
Unsteady Temperature Tests (METAS Meter D)

-40°C, 0.1 kg/min



-40°C, 0.25 kg/min



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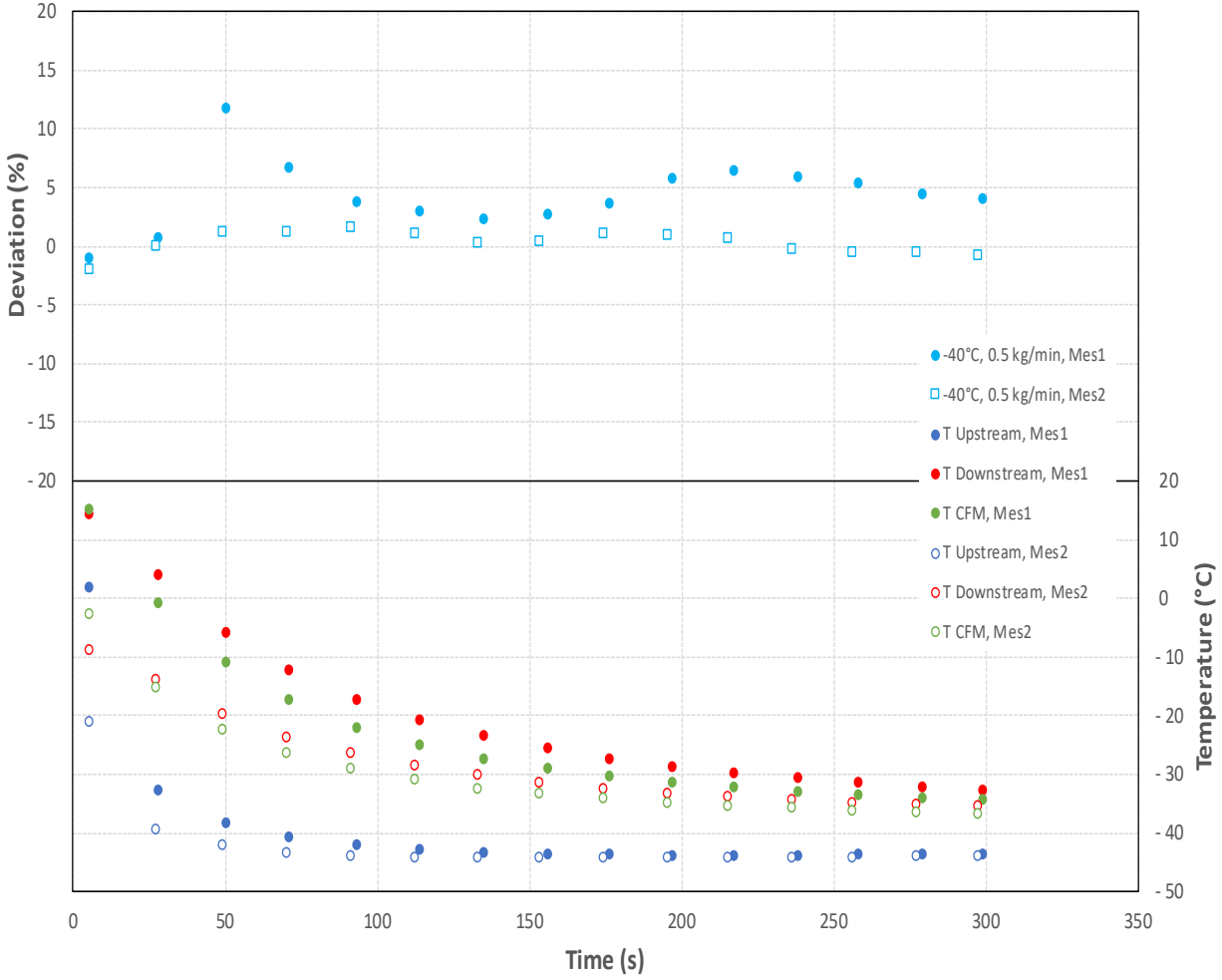
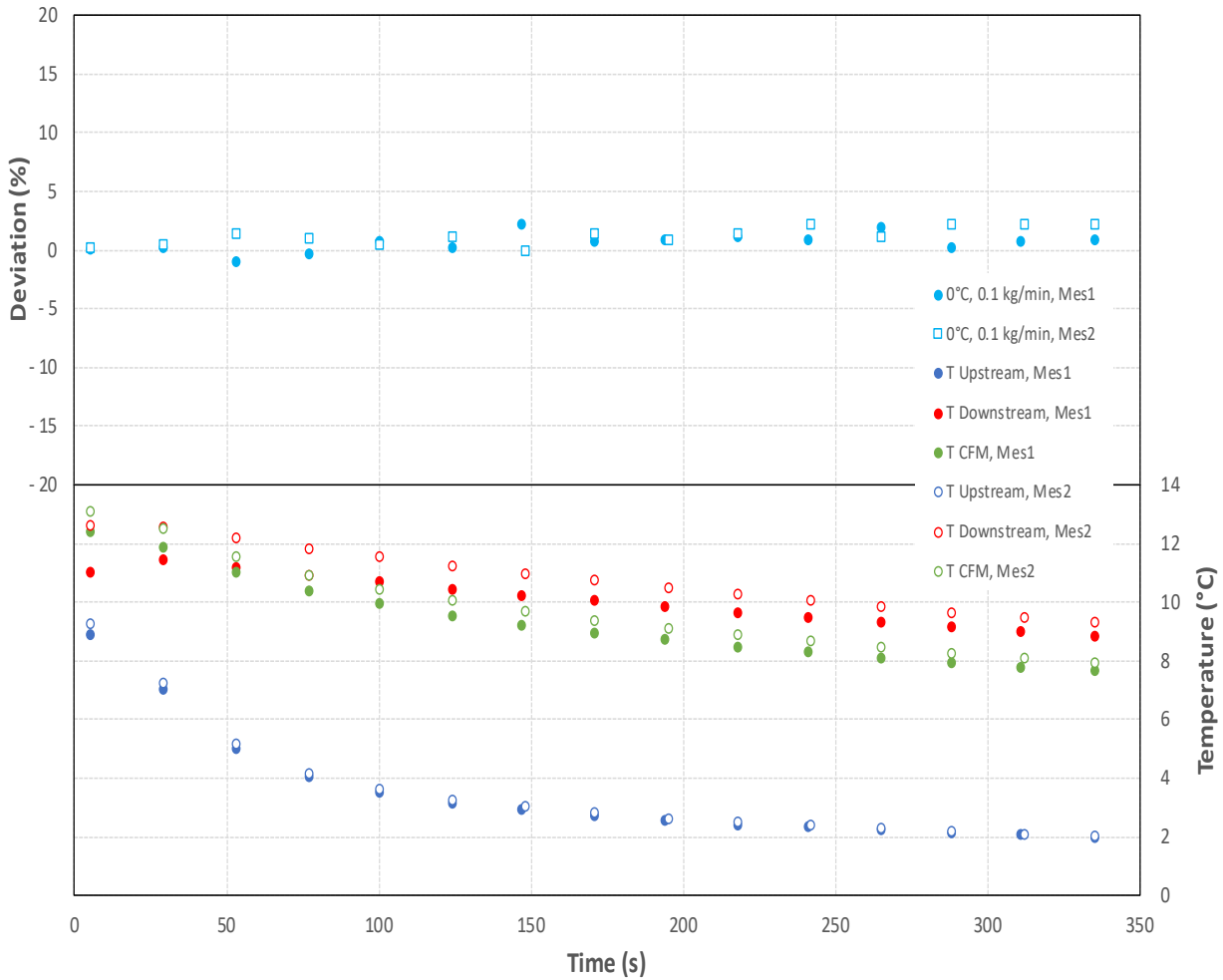
Unsteady Temperature Tests (METAS Meter D)

-40°C, 0.5 kg/min



0°C, 0.1 kg/min



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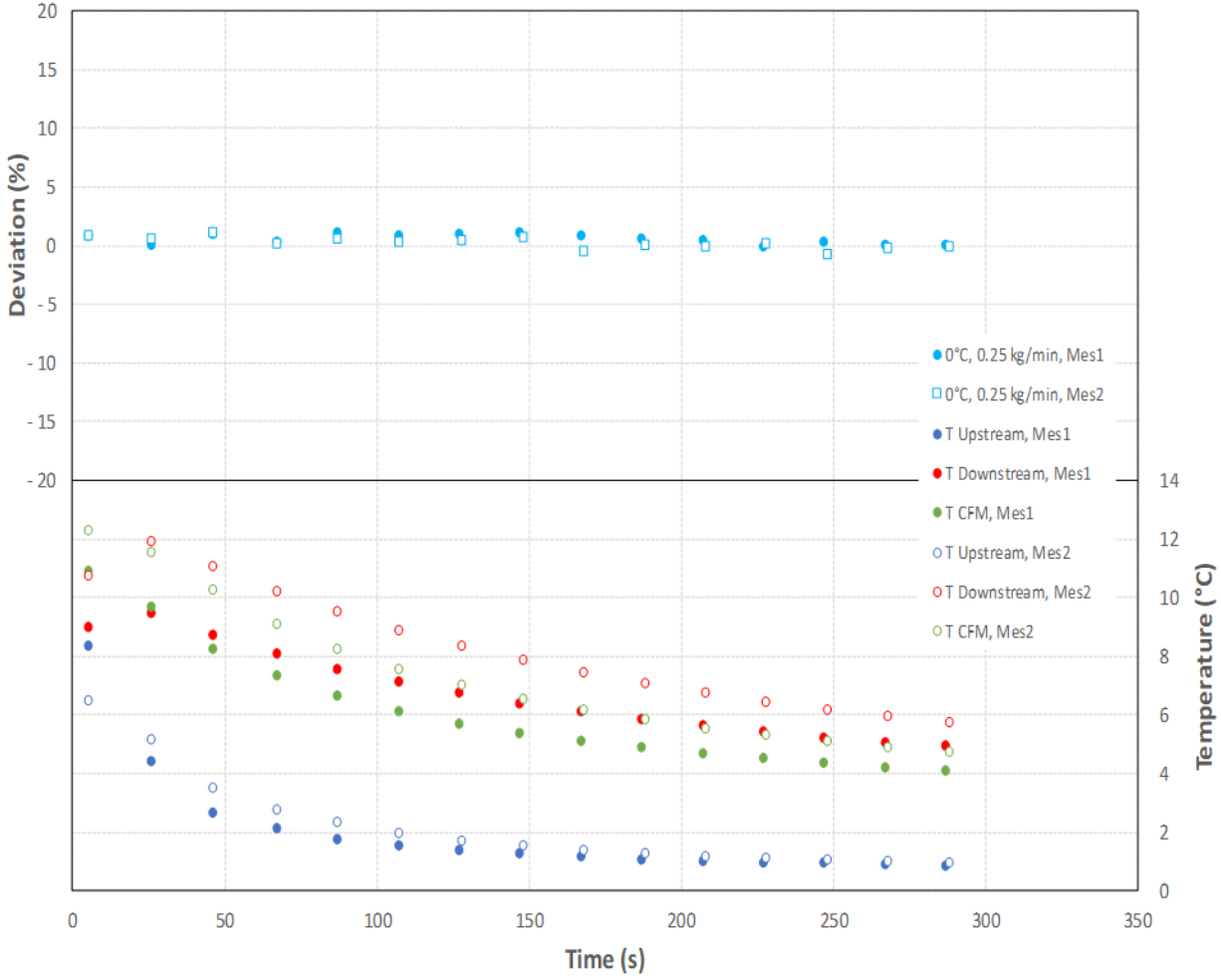
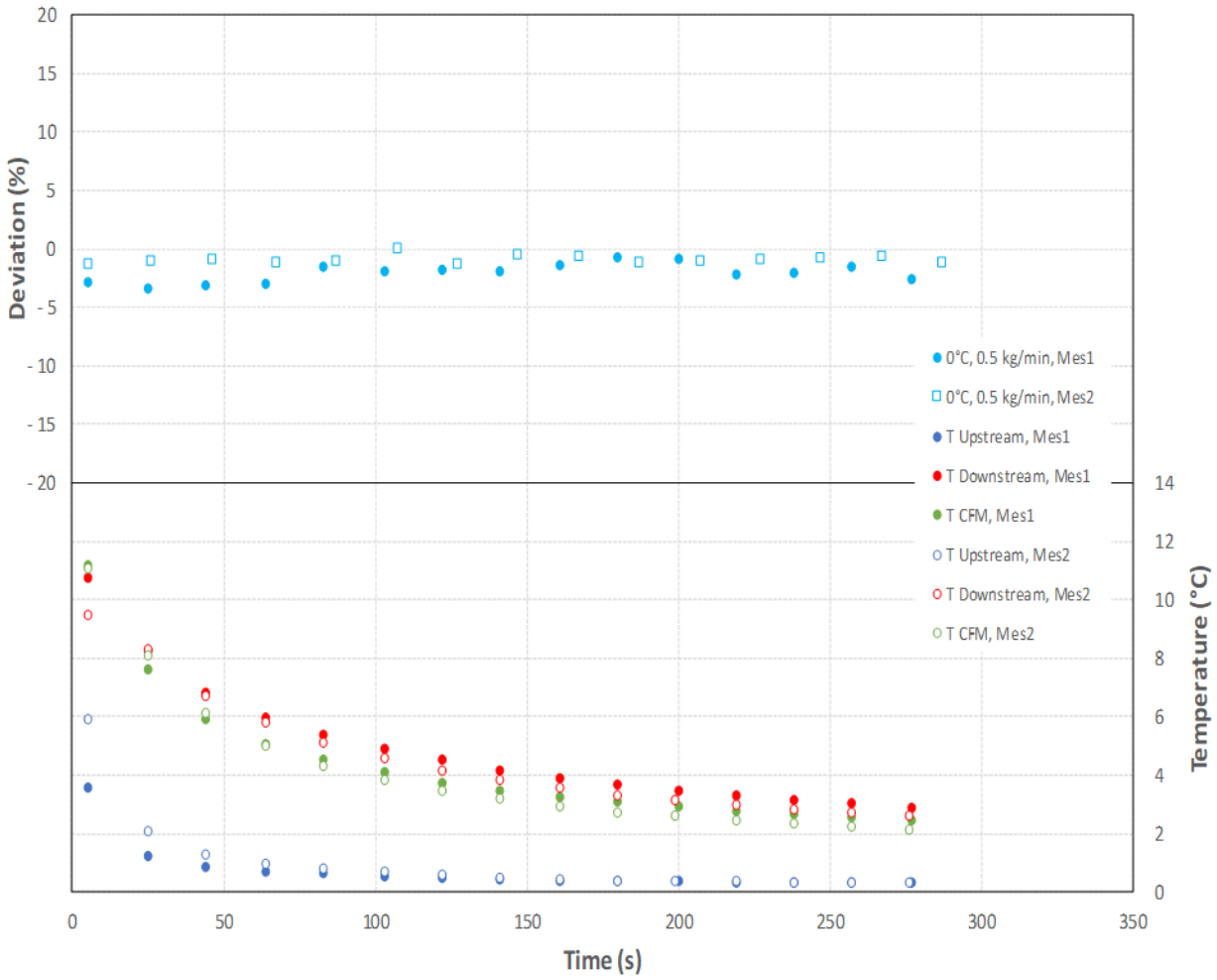
Unsteady Temperature Tests (METAS Meter D)

0°C, 0.25 kg/min



0°C, 0.5 kg/min



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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

- No pressure effect observed at 20 to 86 bar
- Pressure effect is also investigated using water (next presentation)

- Influence of temperature observed
  - At stable conditions, greater errors and wider spread of errors occurred at -40°C compared to 20°C. Errors up to 10% at the lowest flow rates, but within ±2% at moderate to high flow rates.
  - When incoming gas was much colder than the meter, performance of the meter shifted significantly as temperatures stabilised. Errors ranged -15 to 15% and depended more on the difference between the T Upstream and T CFM than gas flow rate.

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[Acknowledgements…]

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