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Validation of a new method for flow measurement in cryogenic systems

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The Cal²-Flow measurement principle

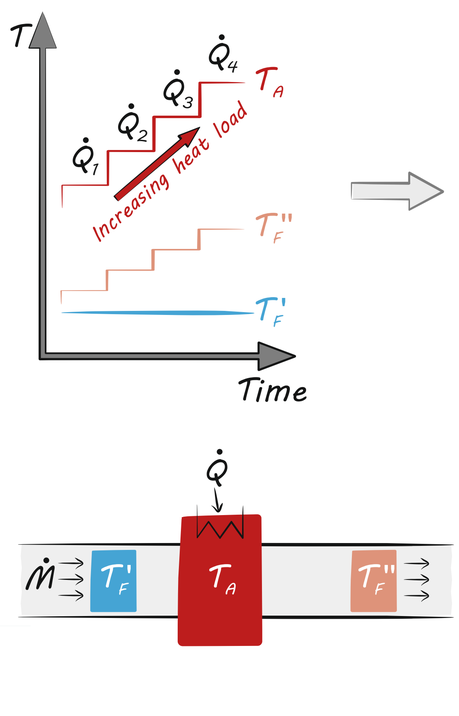
Principle

- Caloric measuring principle
- Combined evaluation of energy balance and energy transport
- In situ calibration during operation
- Complete compensation of systematic measuring uncertainties

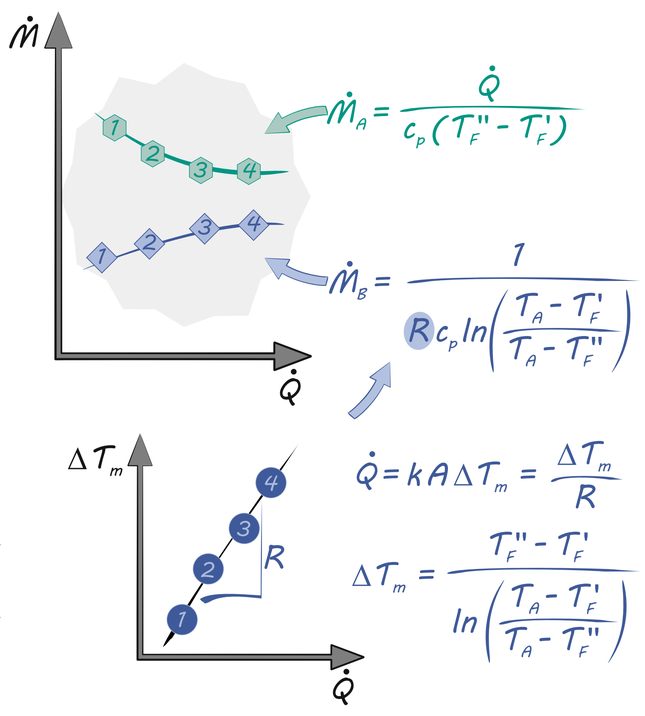
Advantages

- No additional pressure drop
- Negligible heat input
- Fluid temperature increase of just a few mK
- Uncertainties < 1% w.r.t. the actual flow rate

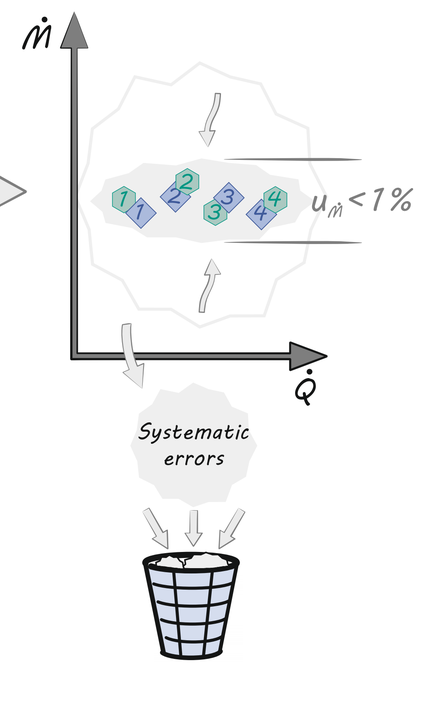
Measurement



Data evaluation

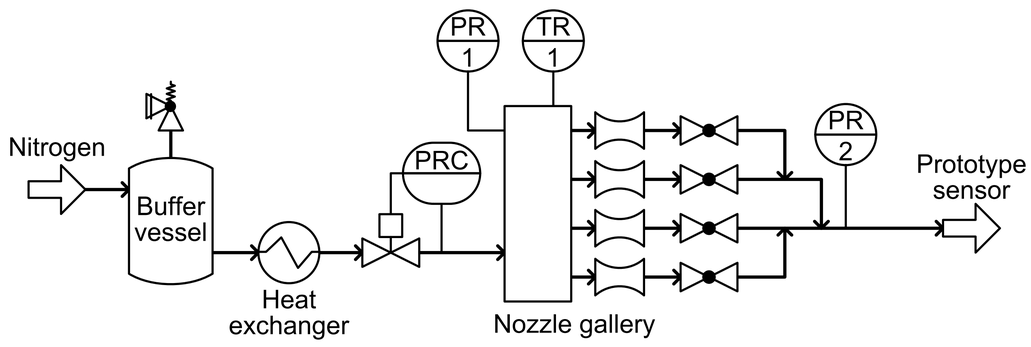


Minimization



Experimental validation at room temperature

Reference method

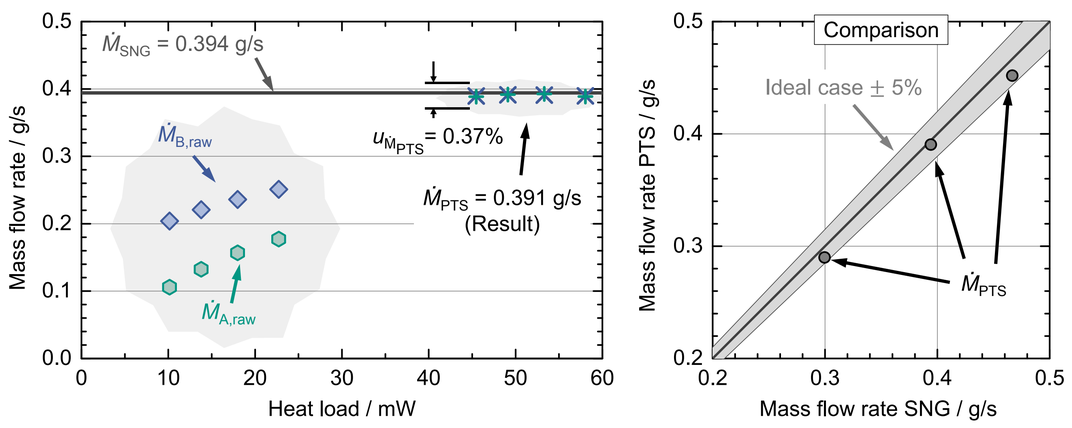


- Sonic nozzle gallery (SNG) with 4 calibrated nozzles
- Flow range: 0.04 g/s ≤ $\dot{M}_{SNG}$ ≤ 0.5 g/s
- Uncertainty of the reference method: $u_{\dot{M}_{SNG}} \leq \pm 0.33\%$

Prototype sensor (PTS)

- Designed for room temperature experiments
- Tube diameter: 4 mm, total length: 250 mm
- Temperature measurement with 3 PT100 sensors (class A) mounted on copper blocks
- Integrated heating element

First experimental results



Reference $\dot{M}_{SNG}$ / g/s	Prototype $\dot{M}_{PTS}$ / g/s	Offset g/s
0.300 ± 0.17%	0.290 ± 0.95%	- 0.010
0.394 ± 0.15%	0.391 ± 0.37%	- 0.003
0.467 ± 0.10%	0.452 ± 0.36%	- 0.015

- Successful validation of the Cal²-Flow measurement principle
- Small heat loads: $\dot{Q}$ = 10 …40 mW
- Fluid temperature increase: T_F'' - T_F' = 30 …180 mK
- Design improvement to eliminate remaining offset
  - Mean fluid temperatures
  - Heater performance
- Ongoing development of cryogenic sensor and electronics

Literature

Grohmann, S. (2014): A new method for flow measurement in cryogenic systems. *Cryogenics*, vol. 60, March–April 2014, pp. 9-18.

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