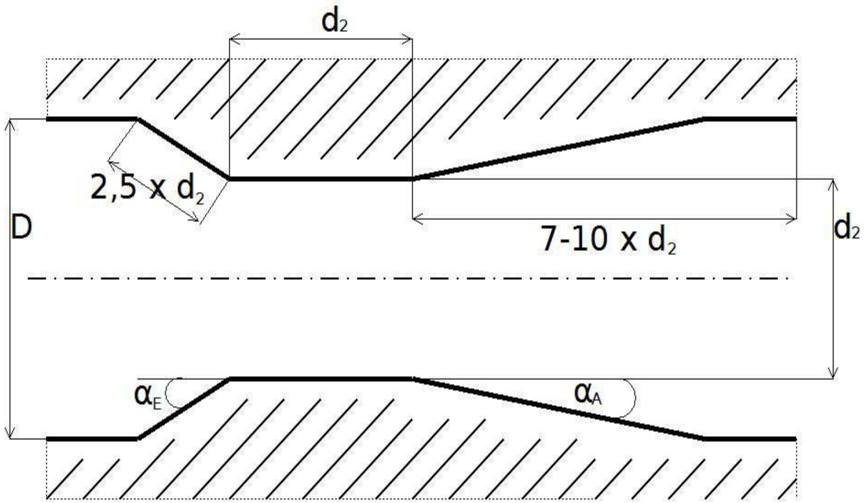
Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Cavitating Herschel Venturi nozzle test rig

Heiko Warnecke, Dep. 1.53 Liquid Flow

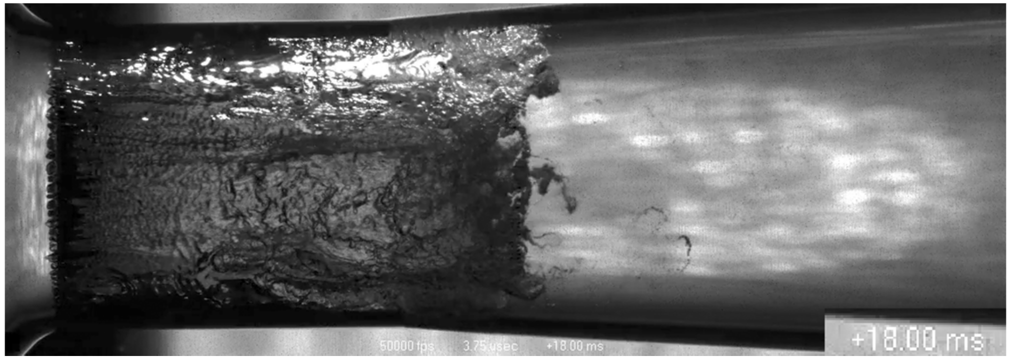
introduction



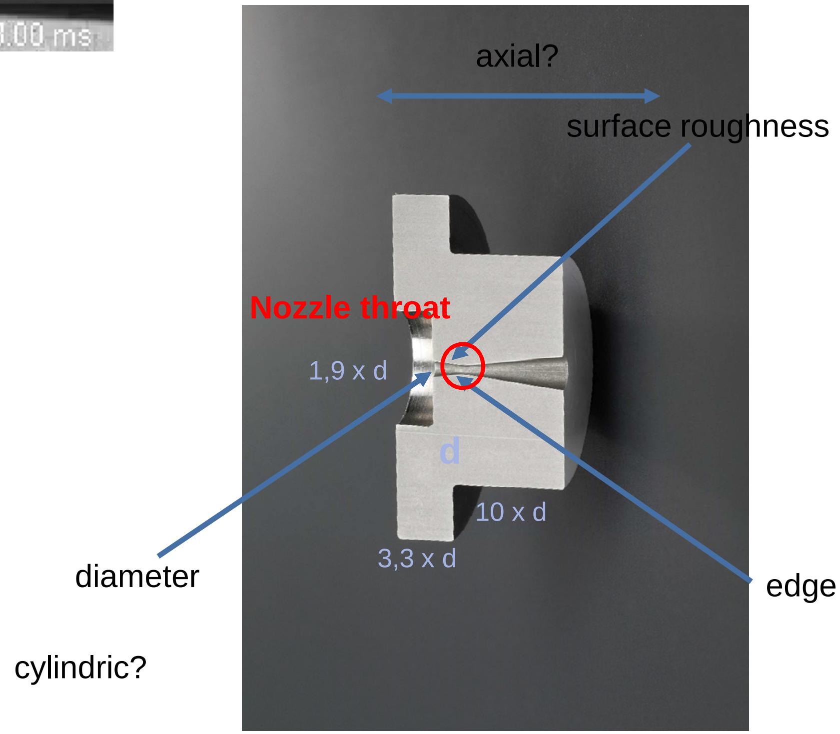
- Reproducibility
- Flow rate stability
- Fast reaction time
- Small
- Cheap
- …

- Flow rate control device
- Proportioning of liquids
- Flow meter

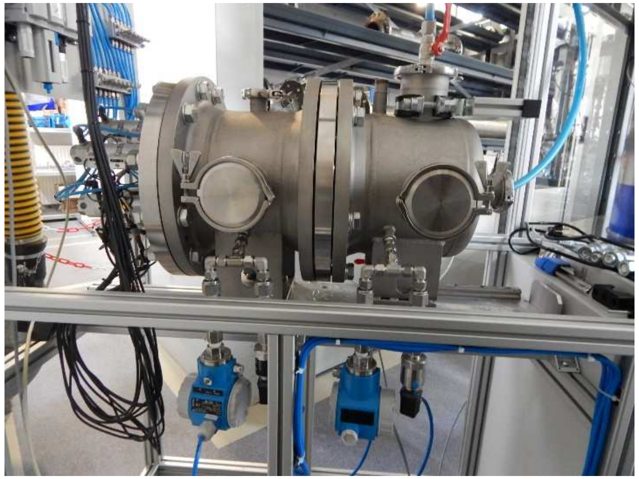
introduction



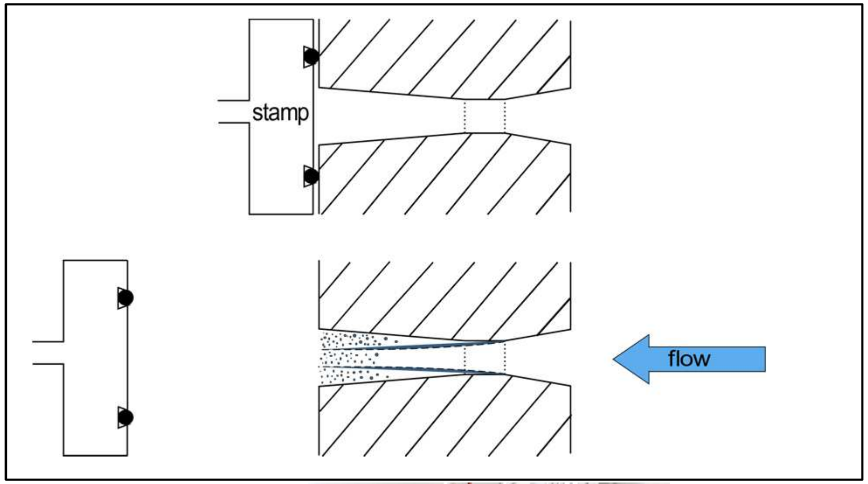
- Influence of numerous factors on the cavitation
  - Flow cross-section
  - Liquid
  - Reynolds-number
  - Upstream and downstream pressure

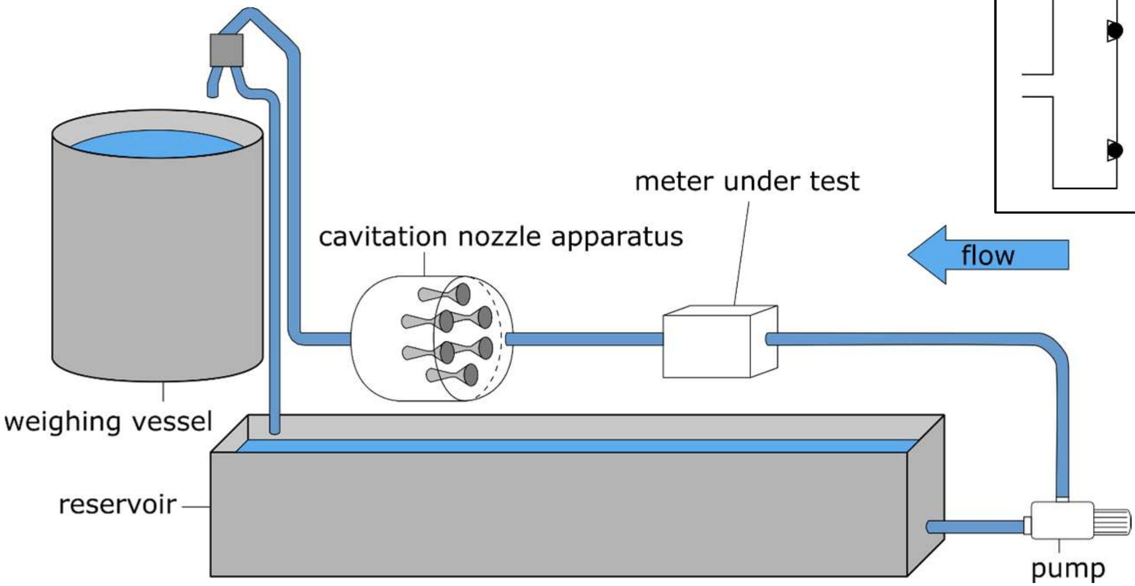


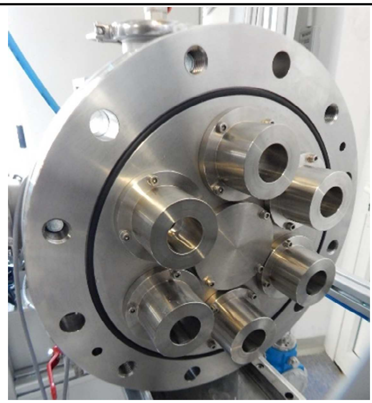
set-up



- 6 nozzles with a nominal diameter of 0.74 mm, 1.4 mm and 2.6 mm are characterised
- flow rates between 37 l/h and 588 l/h





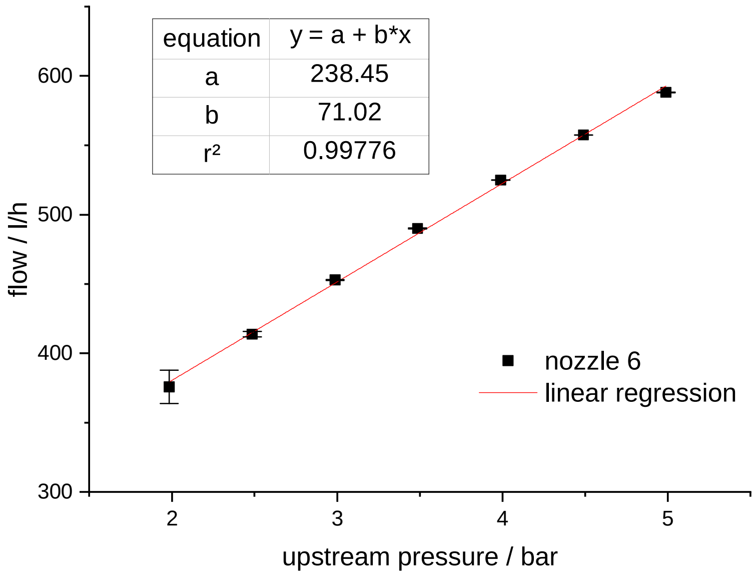


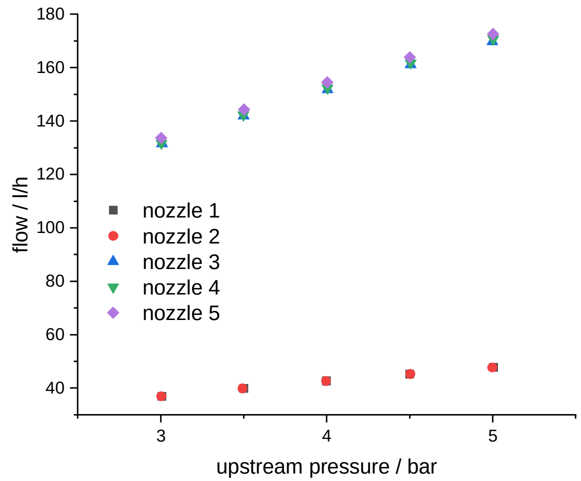
characterisation

characterisation

- Assumption of a linear correlation between flow rate and upstream pressure

Nozzle nr. i	Diameter D mm ± 1 µm	Flow Q (4 bar) l/h ± 0.1 %	Slope b l/h/bar
1	0.740	42.69	5.4 ± 0.2
2	0.738	42.65	5.4 ± 0.2
3	1.396	151.80	19.2 ± 0.4
4	1.397	152.40	19.5 ± 0.5
5	1.393	154.50	19.5 ± 0.5
6	2.601	527.80	71.0 ± 1.4





characterisation

- Different nozzles with same nominal diameter
- Significant difference of the flow rates

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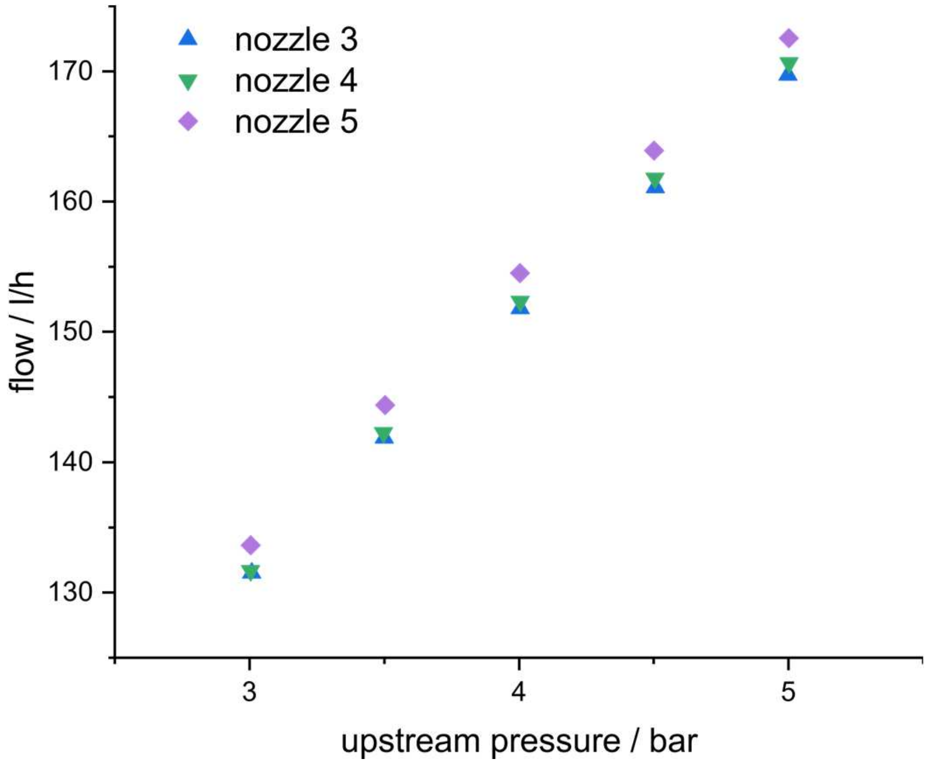
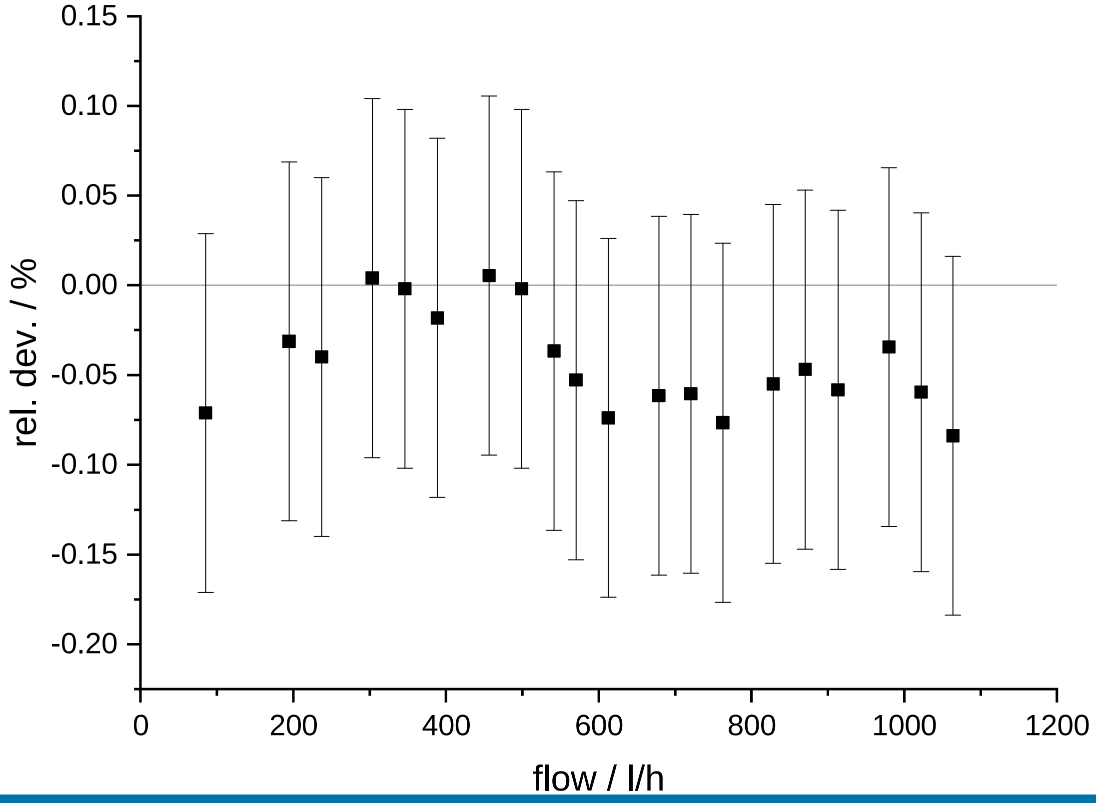


additivity

$$Q_{sum} = \sum_i (Q_i + (p_j - p_i) * b_i)$$

$$rel.dev. = \frac{Q_{exp} - Q_{sum}}{Q_{sum}}$$

Q_i: single nozzle flow rate
b_i: calculated slope of each nozzle
p_i: upstream pressure of single nozzle flow
p_j: upstream pressure of multiple nozzle flow



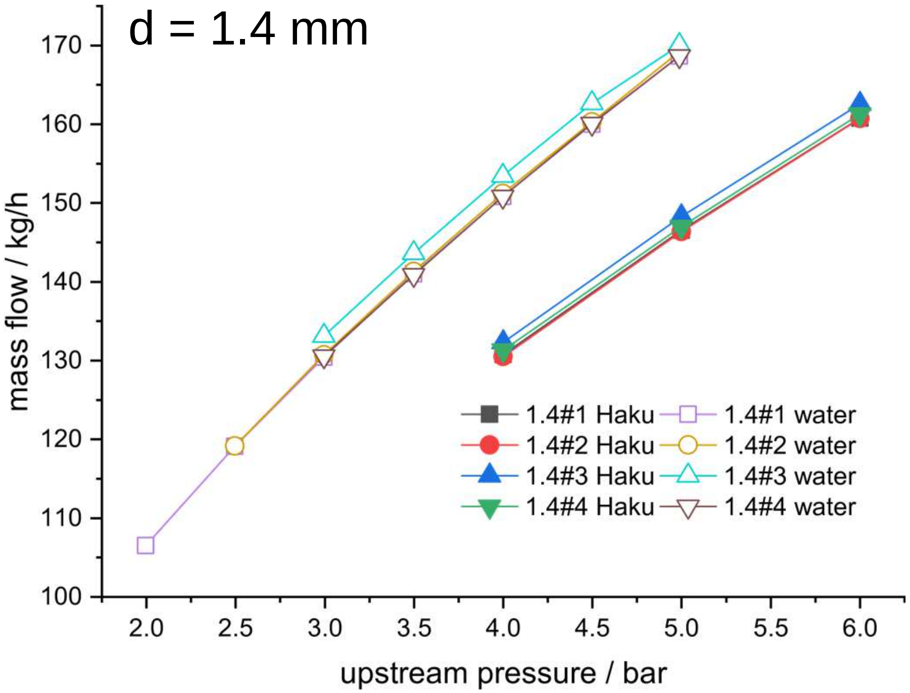
different liquids

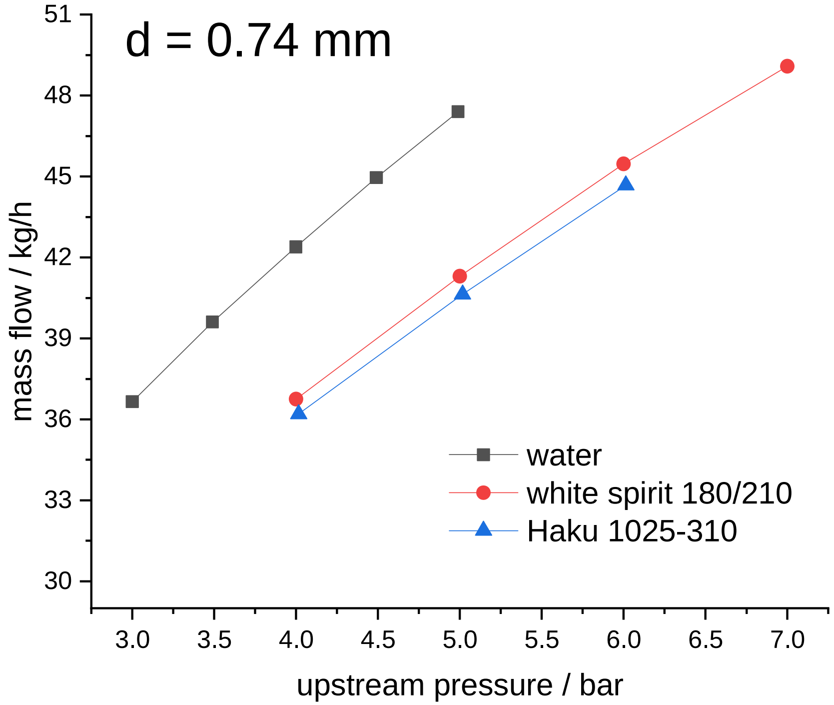
different liquids

Medium	Principal constituents	Density g/cm^3	Vapour pressure mbar	Viscosity mm^2/s
White spirit	Hydrocarbon, C10 – C13, n-Alkane, iso-Alkane, cyclic compound	0.785	0.5	1.2
Haku 1025-310	Hydrocarbon, C11 – C14, iso-Alkane, cyclic compound	0.761	0.6	1.3
Water	Tap water	0.998	23.4	1.0

physical properties density, vapour pressure and kinematic viscosity at 20°C

different liquids





Medium	Standard deviation
White spirit	0.097 %
Haku	0.018 %
Water	0.023 %

⇒Similar flow rates of white spirit and cleaner solvent

⇒The flow rate of water is higher at the same upstream pressure

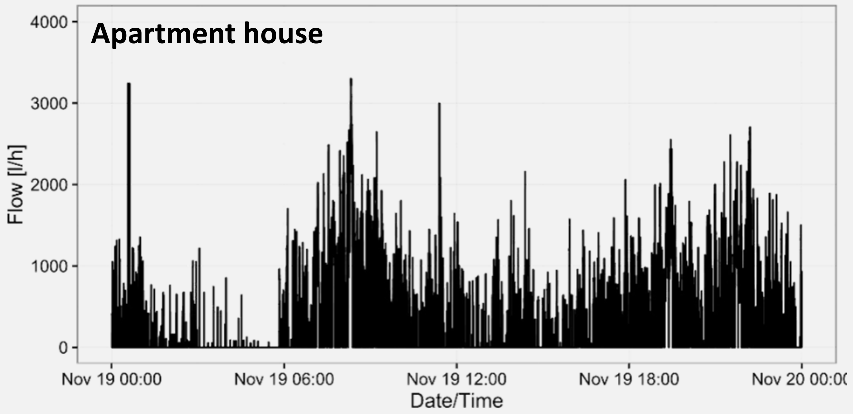
⇒Comparable standard deviation for different liquids

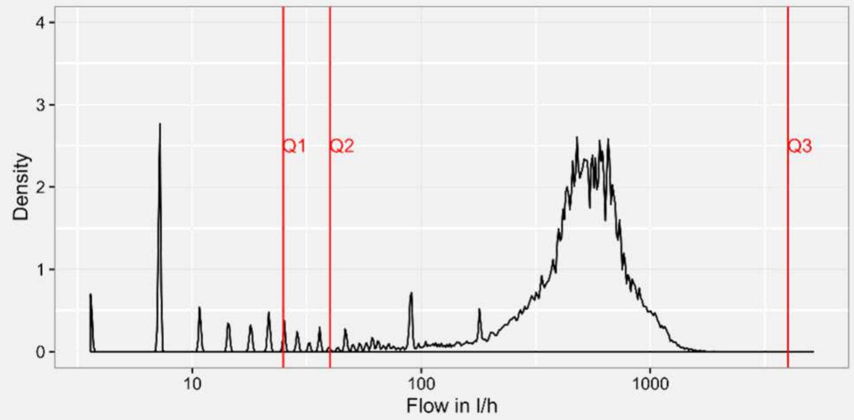
load profiles

load profile

New characterisation for water meters close to real world conditions

Example





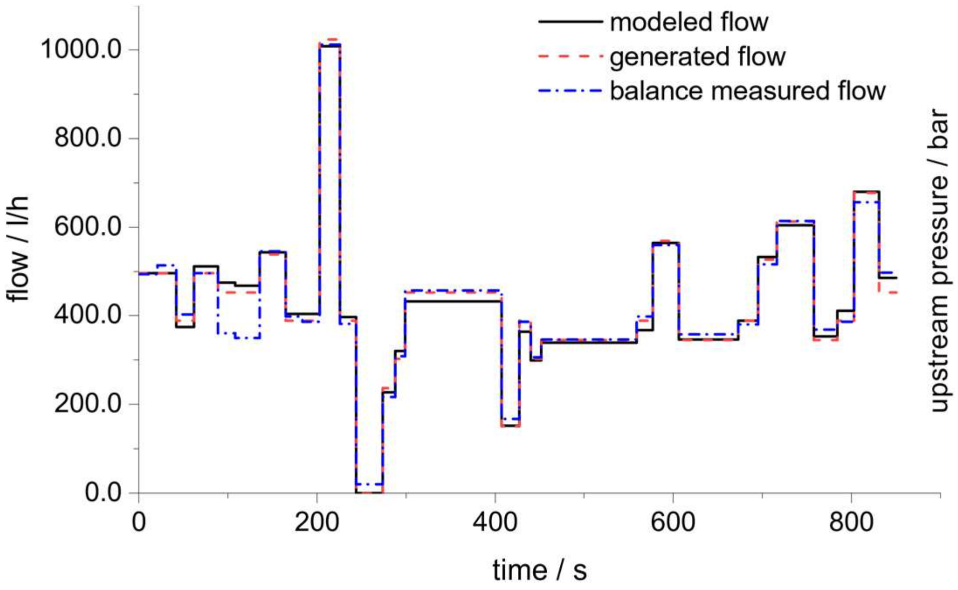
[Schumann et al. 2017]

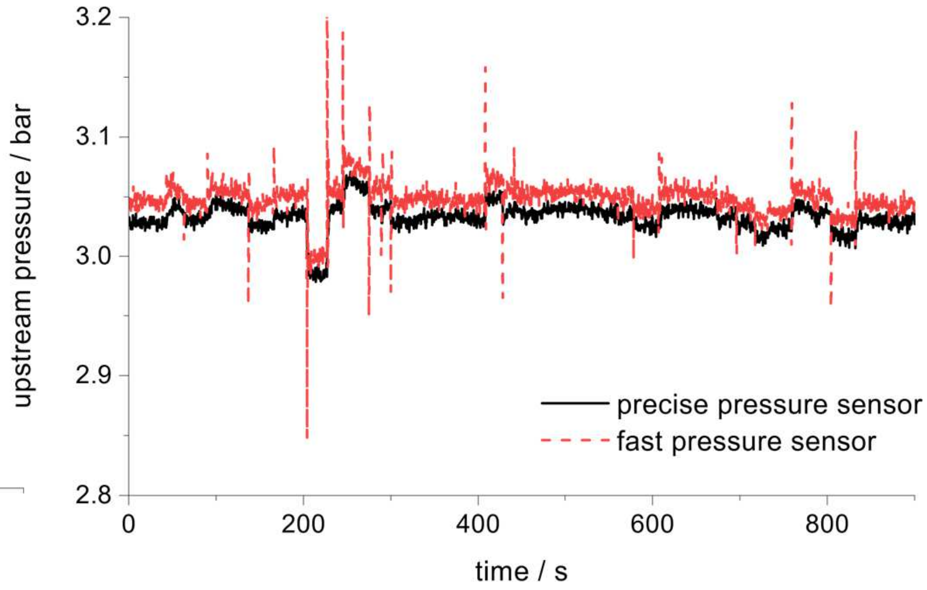
Load profiles of a typical german household are generated

$\Rightarrow$How can a load profile be realised in a test rig?

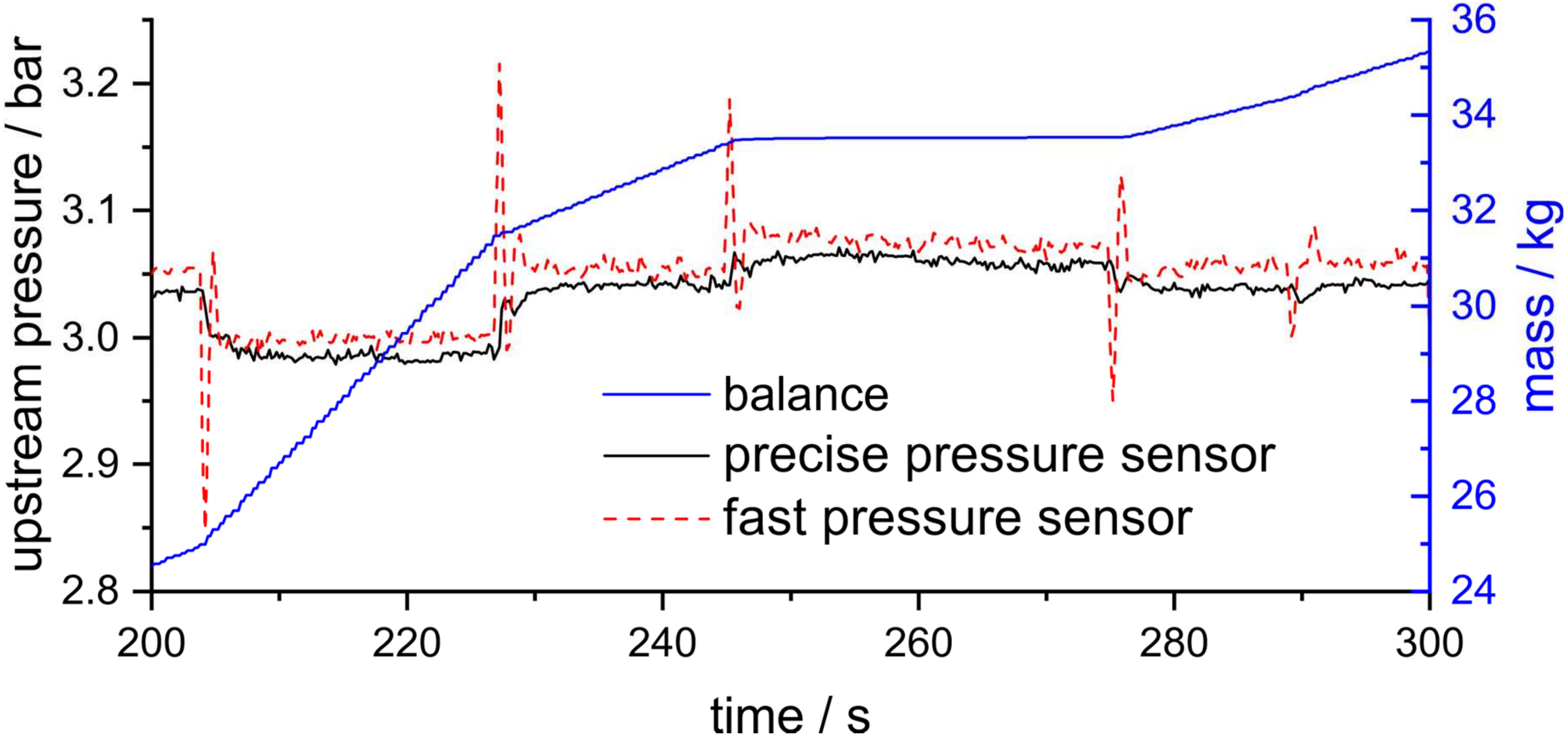
load profile

- Flow rates at constant upstream pressure
- pressure ratio smaller than 0.6





load profile section



⇒pressure excursions of 7% for about 1 s

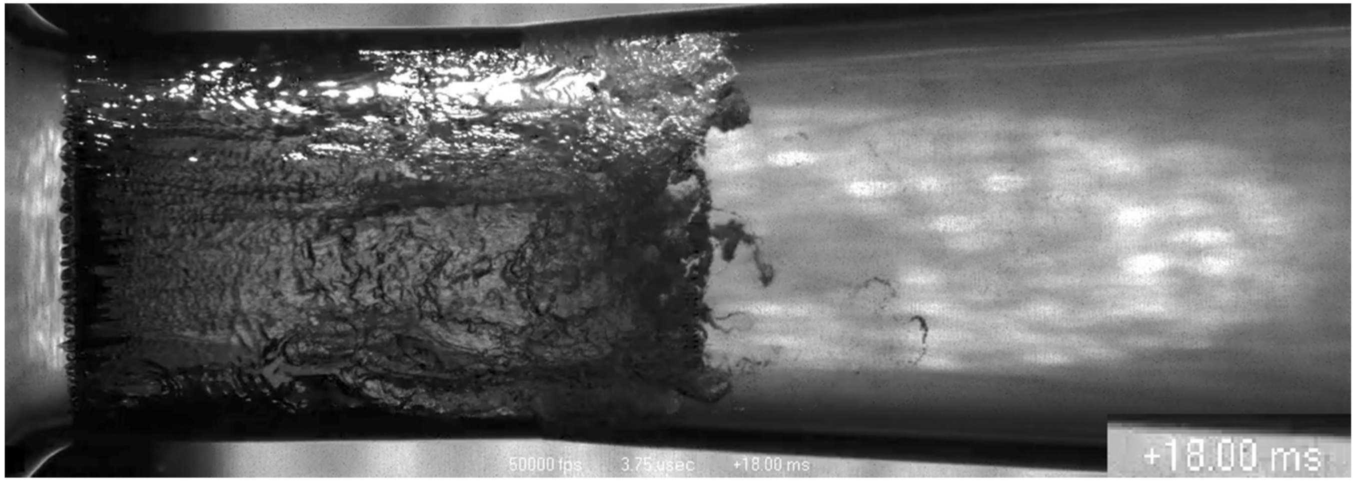
⇒No effect seen on the balance signal

conclusion

- Flow rates of the individual nozzles sum up to the expected flow rates
- A constant mass flow can be generated with different liquids, including liquid mixtures
- With the nozzles a load profiles can be generated with fast flow rate changes

outlook

- Characterisation and verification of liquid properties (vapour pressure, viscosity, etc)
- Characterisation of nozzle properties (surface roughness, edges, etc)
- Variation of measurement conditions (pressure, temperature, etc)



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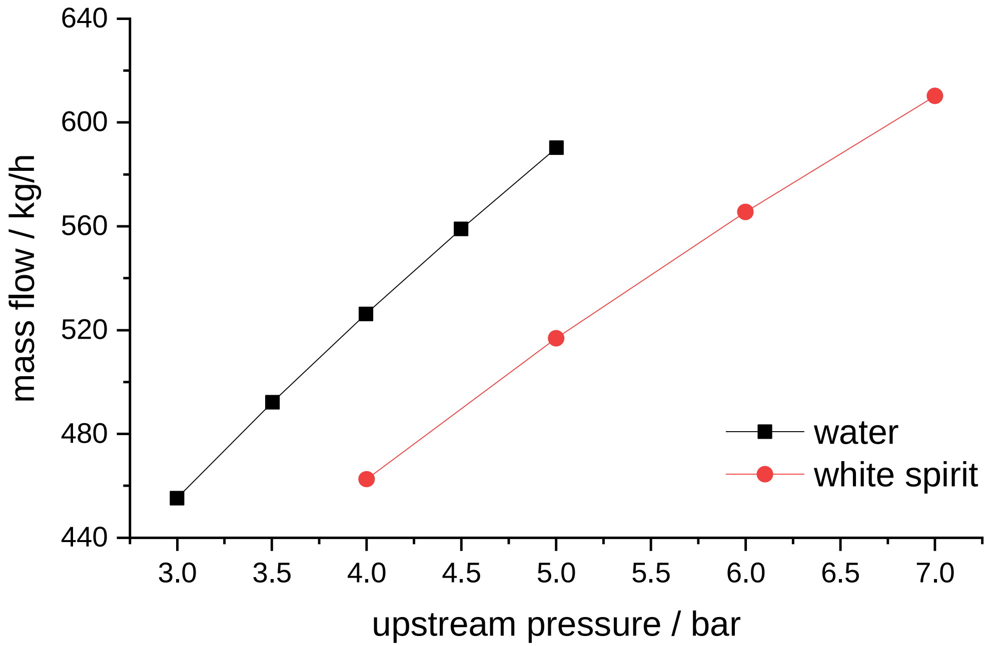
Stand: 06/2019

Different liquids

- Nominal diameter 1.4 mm (left) for water and cleaner solvent and 2.6 mm (right) for water and white spirit



⇒Different flow rates of water and the two other liquids at the same pressure