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Fast Techniques for Measuring Small Flows in Mass Production

8th Workshop Low Flows in Medical Technology

Author: Niklaus Schneeberger

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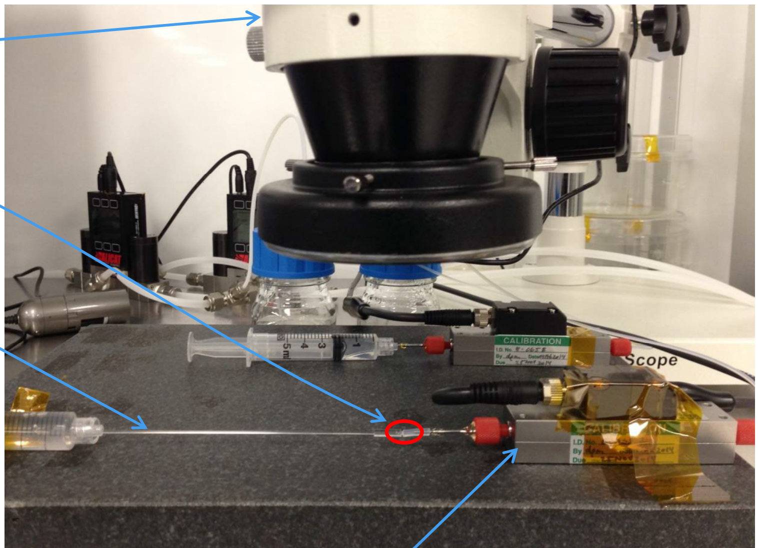
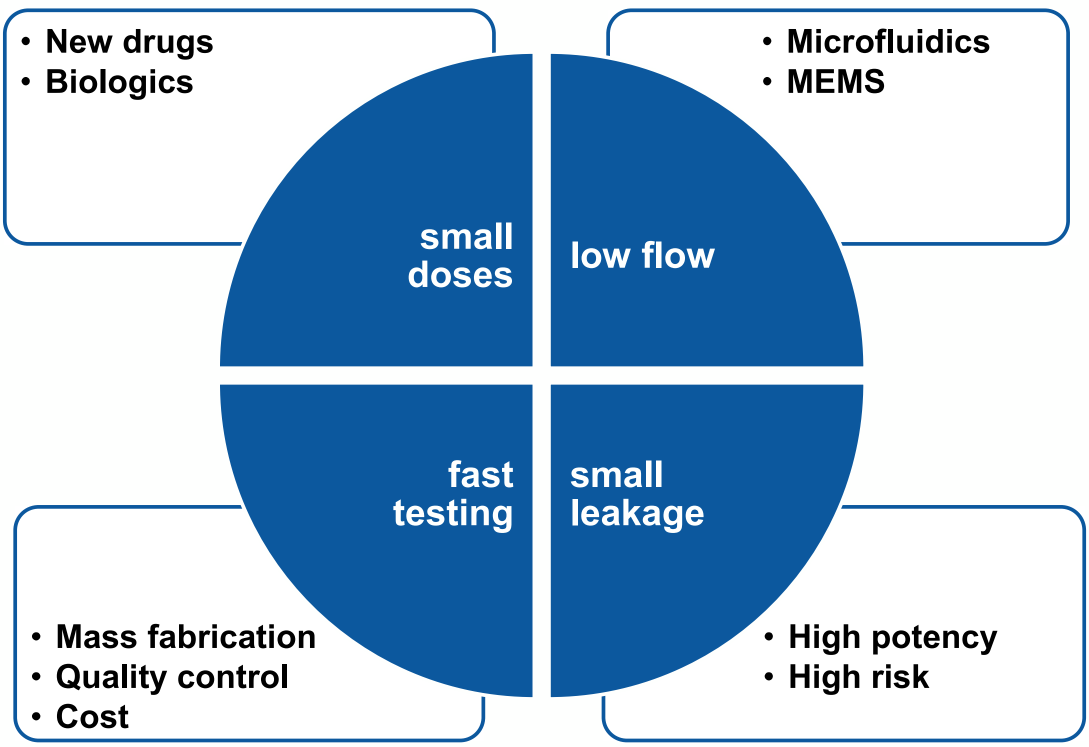
Hebling Technik Bern AG, Stationsstrasse 12, CH-3097 Liebefeld-Bern

Measuring Low Flows



Content

Motivation



Requirements

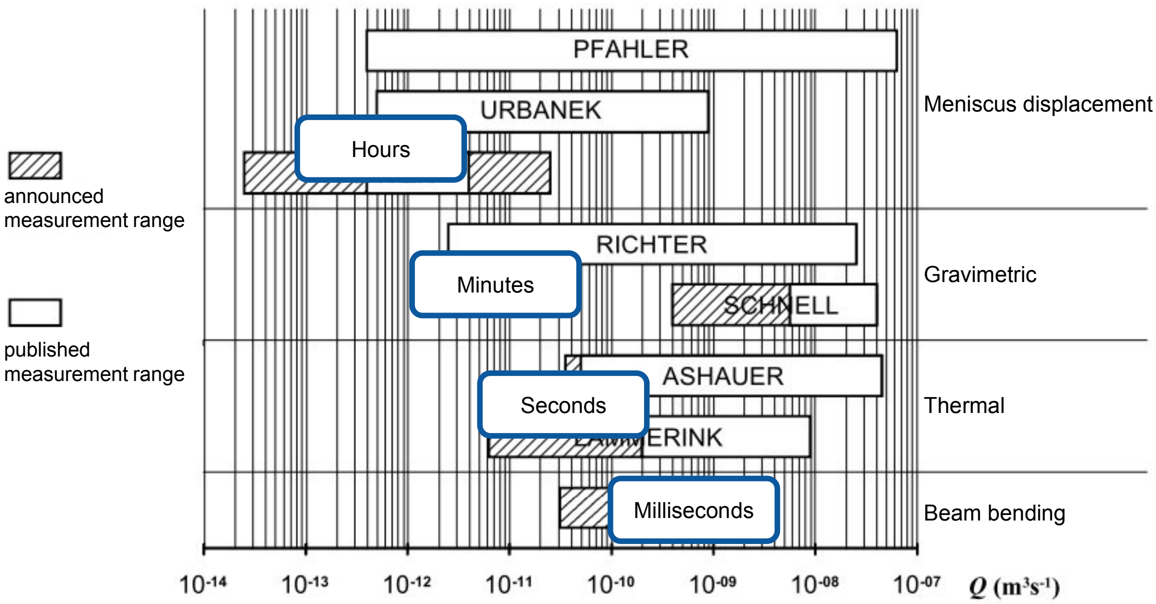
Measuring

- Flow rate range
  - flows
    - 100 mL / min ~ 10^{-6} m^3/s
    - 100 µL / d ~ 10^{-12} m^3/s
  - leakage flow
    - 1 mL / min ~ 10^{-8} m^3/s
    - 100 nL / h ~ 10^{-14} m^3/s
    - 10 µL / mt ~ 10^{-15} m^3/s
- Maximum tolerated pressure
  - 1 kPa – 100 kPa
- Repeatability
  - 5 % - 20 %

Fabrication

- Cadence
  - 10’000 / a ➢ 5 min testing time
  - 1’000’000 / a ➢ 5 s testing time
- Sterility
  - liquids introduce contaminations (bio-burden)
  - water is not compatible with some sterilization methods
  - drying is cumbersome, slow, or destructive
  - dry testing preferred

Flow Measurement Principles



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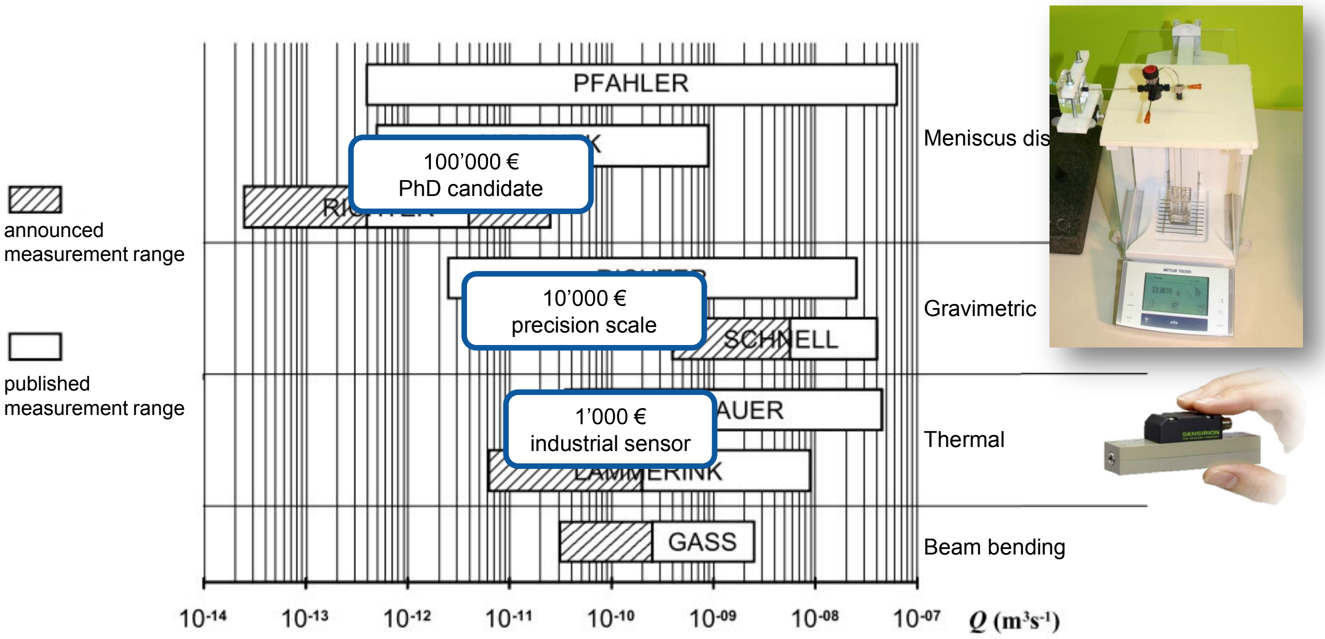
Etude experimentale et numérique de microécoulement liquides dans les microsystèmes fluidiques, PhD thesis, INSA, Marc Anduze, 2000

Flow Measurement Principles



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Case Study 1

Quality control for micromachined flow restrictor

- Flow rate range target: 100 µL/d ~ 10^{-12} m^3/s
- Dry measurements to avoid contamination
- For laminar flow conditions
  - for liquids

$$Q_l = \frac{\Delta p}{K_{geo} \cdot \mu_l}$$

  - for gas

$$Q_g = \frac{1}{p_0} \cdot \frac{{p_{in}}^2 - {p_{out}}^2}{K_{geo} \cdot 2 \cdot \mu_g} \approx \frac{\Delta p}{K_{geo} \cdot \mu_g}$$

- gain in flow rate
  - from water to air

$$\frac{Q_g}{Q_l} = \frac{\mu_g}{\mu_l} \approx 50$$

  - resulting gas flow rate ~3 µL/min

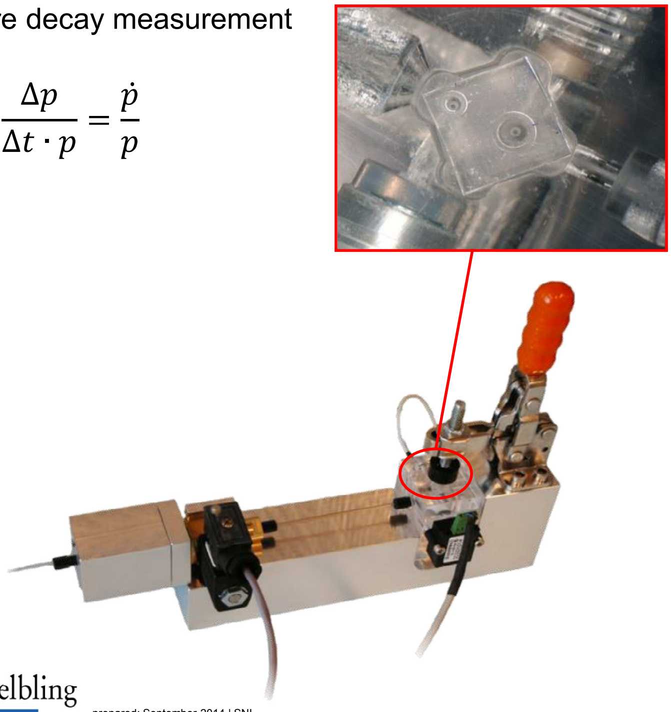
Case Study 1

Pressure decay

- Measuring with compressible gas enables pressure decay measurement

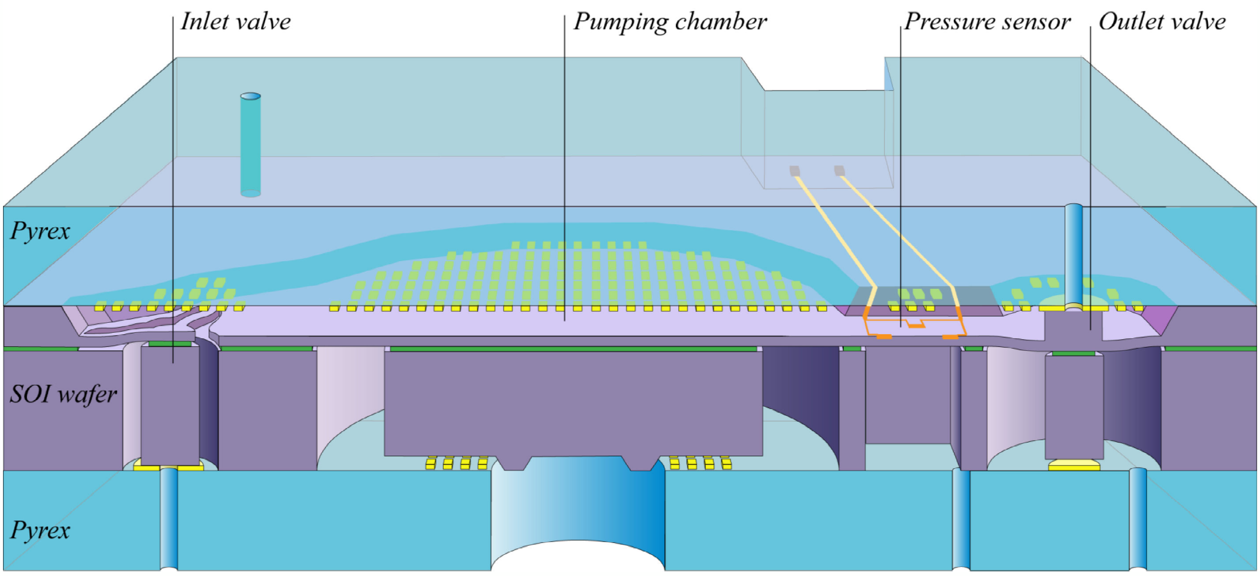
$$\frac{Q_v}{V} = \frac{\Delta V}{\Delta t \cdot V} = \frac{\Delta p}{\Delta t \cdot p} = \frac{\dot{p}}{p}$$

- Pressure measurements are relatively easy
- Small volumes allow to «amplify» the signal
  - e.g. with $V = 100\ \mu L$
  - $\frac{\dot{p}}{p} = 0.05\ \%/s$



Case Study 2

Quality control for drug delivery micropump

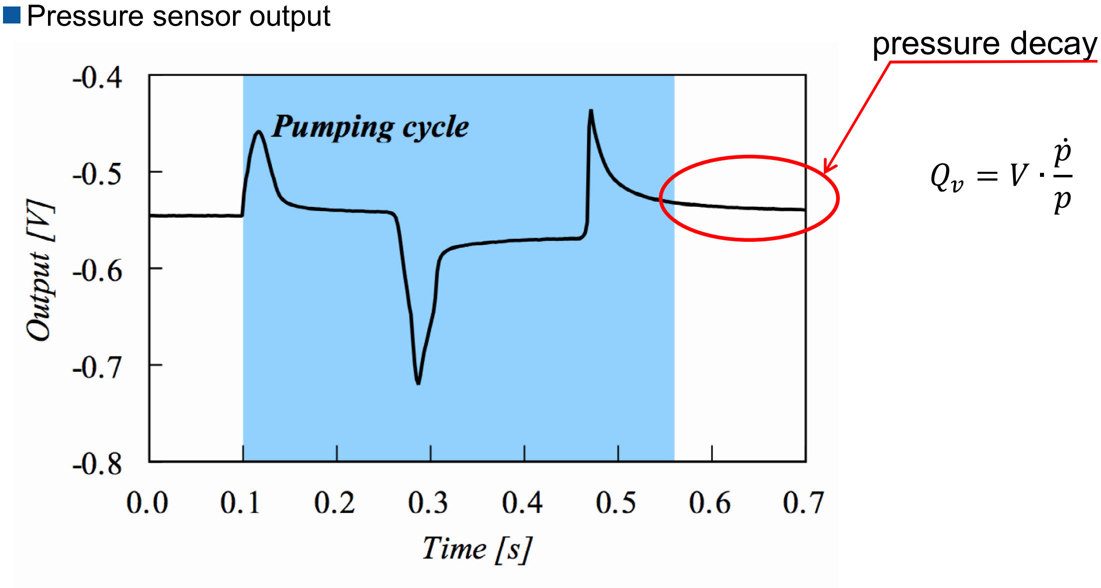


Source: Drug Delivery Micropump with Built-In Monitoring,
N. Schneeberger, R. Allendes, F. Bianchi, E. Chappel, C. Conan, S. Gamper, M. Schlund, Eurosensors XXIII, 2009,

Case Study 2

Quality control for drug delivery micropump

- Pressure sensor output



$$Q_v = V \cdot \frac{\dot{p}}{p}$$

Source: Drug Delivery Micropump with Built-In Monitoring,
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Summary

- Modern drugs require small doses
- Microfluidics & MEMS enable low flow devices
- Medical quality control requires testing
- Sterility demands dry testing
- Mass fabrication requires fast cadence

- Pressure decay testing is dry and can be fast
- Small dead volumes allow measuring small flows at high speed

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Thank you for your attention!

Your contact

Niklaus Schneeberger
Head of Microsystems

Helbling Technik Bern AG
Stationsstrasee 12
CH-3097 Liebefeld-Bern
Telefon +41 31 979 16 04
Fax +41 31 979 16 11
Niklaus.Schneeberger@helbling.ch
www.helbling.ch

Helbling Unternehmensgruppe

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