Aspects and requirements of traceability in fluid flow measurement

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CONTENTS:

International vocabulary of metrology (VIM)

SIMPOSIO METROLOGÍA

2.42
metrological traceability chain
traceability chain
sequence of **measurement standards** and **calibrations** that is used to relate a **measurement result** to a reference

NOTE 1 A metrological traceability chain is defined through a **calibration hierarchy.**

NOTE 2 A metrological traceability chain is used to establish **metrological traceability** of a measurement result.

NOTE 3 A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the **quantity value** and **measurement uncertainty** attributed to one of the measurement standards.

2.43
metrological traceability to a measurement unit
metrological traceability to a unit
metrological traceability where the reference is the definition of a **measurement unit** through its practical realization

NOTE The expression "traceability to the **SI**" means 'metrological traceability to a measurement unit of the **International System of Units**'.

BIPM CMC data base entries: *PTB water flow facility*

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BIPM
Bureau International des Poids et Mesures

Home | Key and supplementary comparisons | Calibration and Measurement Capabilities - CMCs

Home > CMCs Search > M search form > Country list > CMC information

CMCs - Result of the search — KCDB

Metrology area
- AUV
- EM
- L
- M
- PR
- QM
- RI
- T
- TF

Traceability to the SI through the BIPM
- BIPM calibration and measurement services

Related links
- KCDB Statistics
- KCDB FAQs
- CIPM MRA
- JCRB
- Find my NMI
- Metrologia

Contact us
- BIPM.KCDB@bipm.org

Calibration and Measurement Capabilities
Mass and related quantities

In the CMCs uncertainty statements, the notation Q[a, b] stands for the root-sum-square of the terms between brackets: **Q[a, b] = [a² + b²]^1/2**

Result of the search

Your selection : Mass and related quantities, Fluid flow, Fluid flow, Volume of liquid

Germany, PTB (Physikalisch-Technische Bundesanstalt)
Complete CMCs in Mass and related quantities for Germany (PDF file)

Liquid flowing quantity, volume. Any flow measurement instrument or flow device, **50 l**
Relative expanded uncertainty (k = 2, level of confidence 95%) in %: **0.4**
Pulsed, electrical, digital and optical outputs, various methods
Liquid: water
Temperature: 80 °C to 180 °C
Pipe size: DN 40 - 150, PN 25
Approved on 03 January 2007
Internal NMI service identifier: DE9

Liquid flowing quantity, volume. Any flow measurement instrument or flow device, **5 l to 250 l**
Relative expanded uncertainty (k = 2, level of confidence 95%) in %: **0.5**
Pulsed, electrical, digital and optical outputs, various methods
Liquid: glycol-water solutions
Temperature: -15 °C to 80 °C
Pipe size: DN 10 - 32
Approved on 03 January 2007
Internal NMI service identifier: DE13

Liquid flowing quantity, volume. Any flow measurement instrument or flow device, **50 l to 2800 l**
Relative expanded uncertainty (k = 2, level of confidence 95%) in %: **0.2**
Pulsed, electrical, digital and optical outputs, various methods
Liquid: water
Temperature: 20 °C to 80 °C
Pipe size: DN 50 - 200
Approved on 03 January 2007
Internal NMI service identifier: DE1

Volume. Flowmeters, **30 l to 30000 l**
Relative expanded uncertainty (k = 2, level of confidence 95%) in %: **0.02**
e.g. mechanical, electromagnetic, ultrasonic meters
Liquid: water
Temperature: ambient
Maximum pressure: 6 bar
Pipe size: DN 20 - 400
Approved on 03 January 2007
Internal NMI service identifier: DE23

Measurand (unit):
Total volume flow

Expanded measurement uncertainty: 0.02 %

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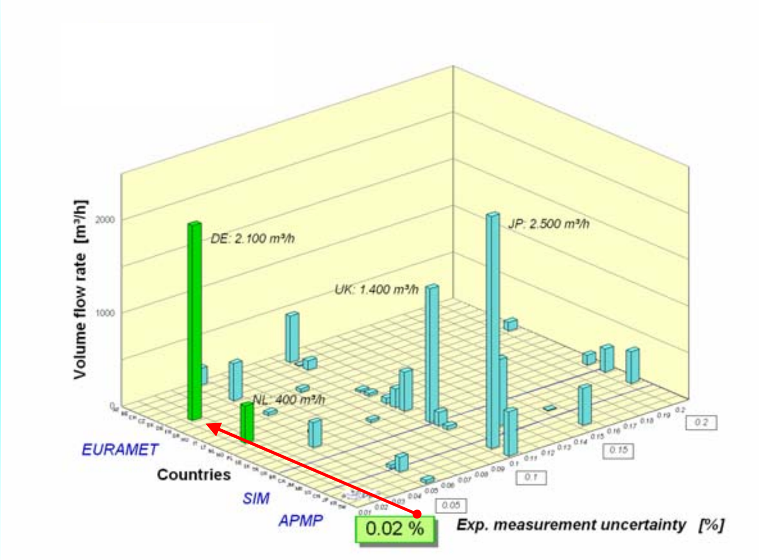
Calibration & measurement capabilities of NMIs



Water flow CMCs

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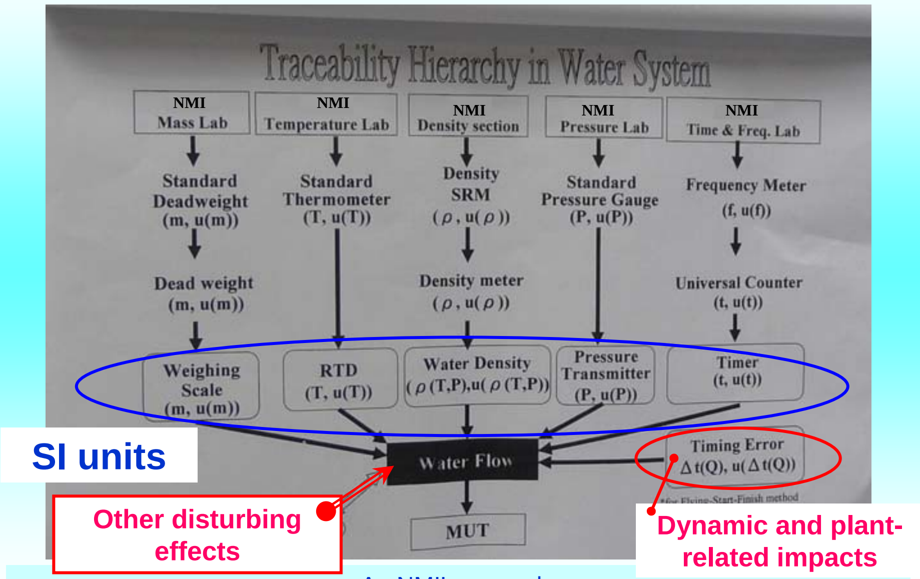
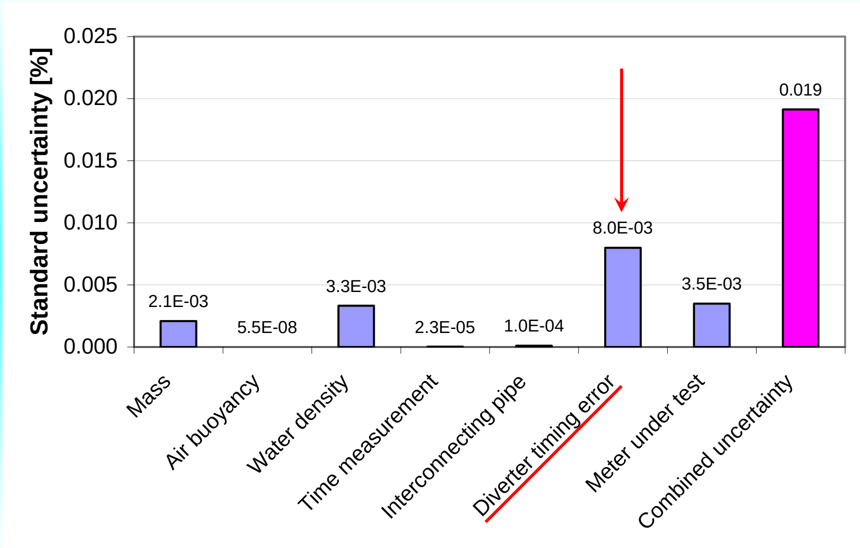
"General" practice to provide traceability in fluid flow



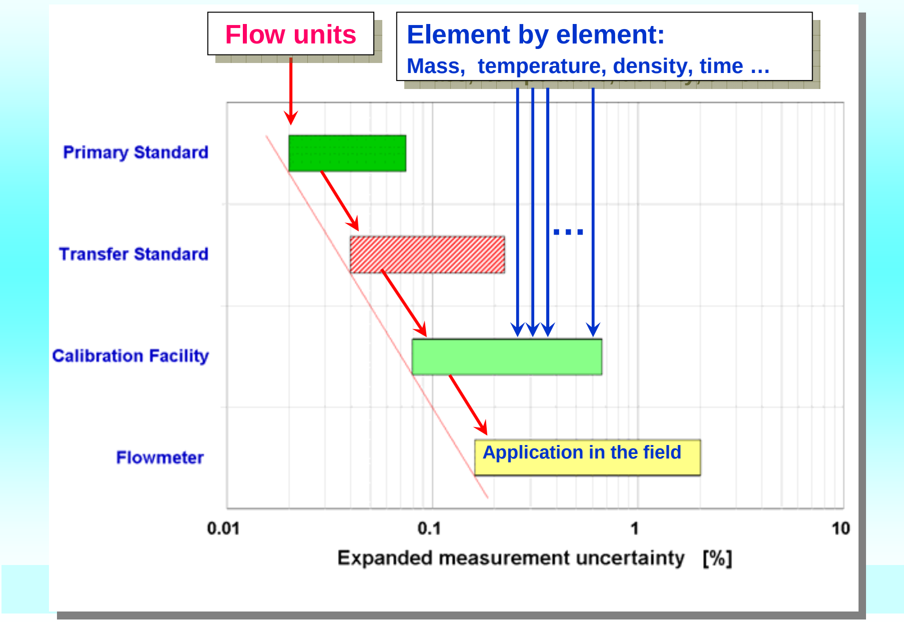
An NMI's example

Expanded measurement uncertainty



Uncertainty contributions of relevant component parts

Traceability in fluid flow



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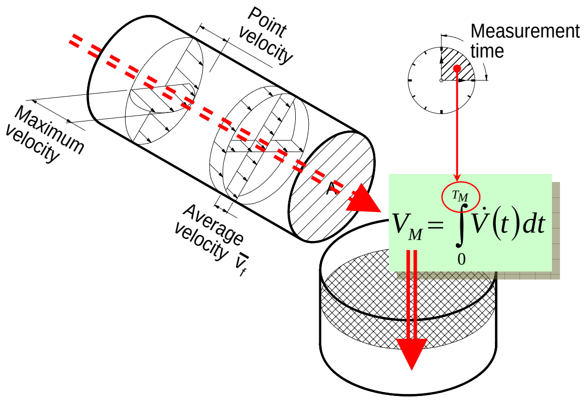
Principle of flow metering

Volumetric flow rate



$$V_M = \int_0^{T_M} \dot{V}(t)\,dt$$

Quantity measurement (Volume)

Measurands:

- Volume flow
- Mass flow
- Total volume & mass

Demands:

- Flow velocity profile
- Quantity measurement (weighing)
- Time measurement
- Density determination
- Const. process quantities:
  - *Flow rate*
  - *Pressure*
  - *Temperature*

The measurands of *Fluid flow*

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Measurands in fluid flow measurement

- **Fluid flow standard facility** (realization of the units):

- Volume flow rate:	$\dot{V}$	- Total volume flow:	$V_M = \int_0^{T_M} \dot{V}(t)\,dt$
- Mass flow rate:	$\dot{m}$	- Total mass flow:	$m_M = \int_0^{T_M} \dot{m}(t)\,dt$

- **High accuracy calibration facility:**

- Meter K-factor:

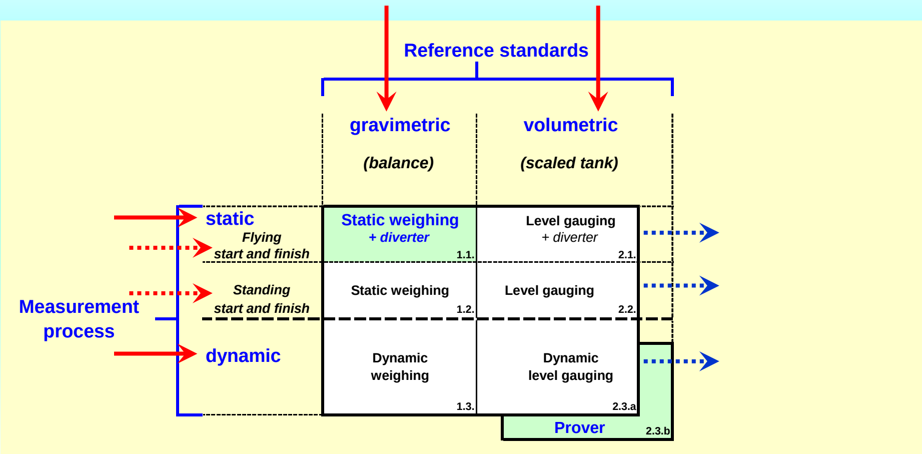
$$K_{Meter} = \frac{f_{Meter}}{\dot{V}_{REF}} = \frac{N_{Pulses} / T_{MEAS}}{V_{REF} / T_{MEAS}}$$

- Measurement deviation:

$$\frac{\Delta V}{V_{REF}} = \frac{V_{MUT}(T_{MEAS}) - V_{REF}}{V_{REF}}$$

Model equations of the measurement process

Basic operation principles of flow standard facilities and dedicated measurands



Flowmeter calibration facilities: *Measurands*

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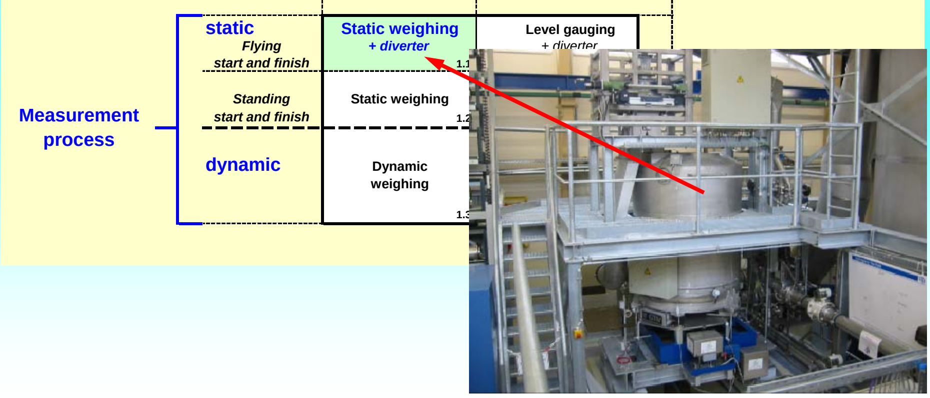
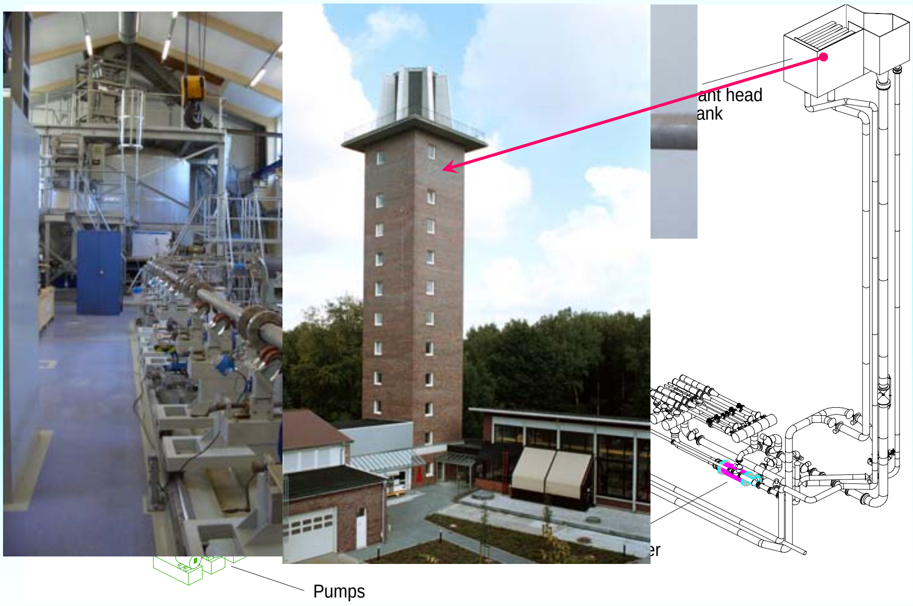
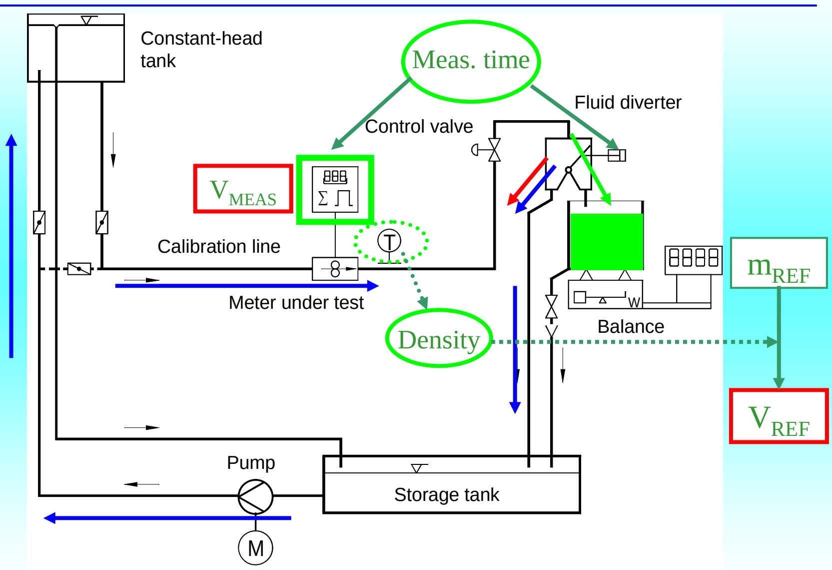
- Mass flow rate: $\dot{m} = \frac{m_{REF}}{T_{MEAS}}$
- Volume flow rate: $\dot{V} = \frac{V_{REF}}{T_{MEAS}} = \frac{m_{REF}}{\rho_{Water} \cdot T_{MEAS}}$



PTB's "Hydrodynamic Test Field"



Gravimetric-reference flow facility : *operation principle*



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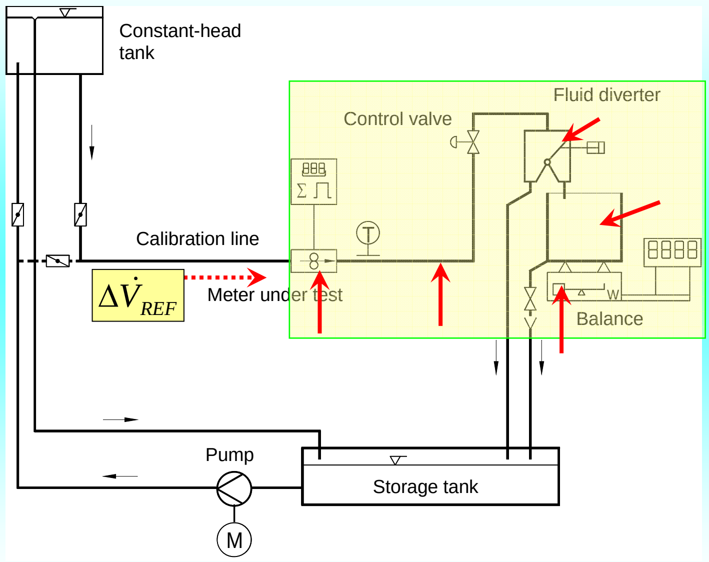
Operation principle



Measurement uncertainty: ***Factors of influence***

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Traceability of a gravimetric liquid flow facility

Basic SI units

Dynamic effects, generally, are not taken into account

Element-by-element flow traceability

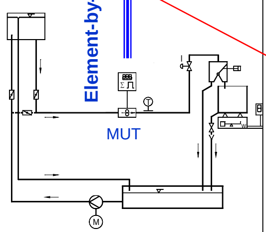
$$\Delta V_{Meas} = V_{FUT} + \Delta V_{IP} - m_{REF} / \rho_{Water}$$

Fluid density
- Density measurement
- Temp. measurement (FUT)

Gravimetr. reference (balance)
- Mass of water
- Balance parameters/calibration
- Density of air (buoyancy)
- Density of water
- Diverter operation

Volume variation in interconnecting pipe
- Temp. change during measurement
- Compressibility of water
- Pressure change during measurement

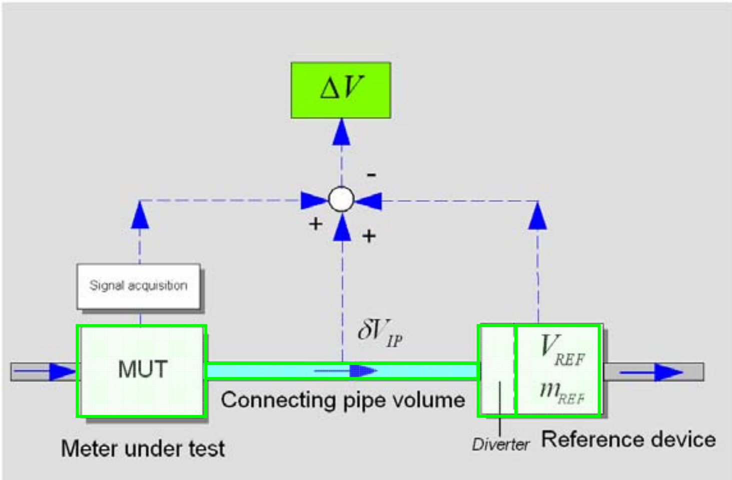
FUT's reading
- Water density
- Time measurement of divertion
- Temp. change during a calibration run
- Compressibility of water
- Change in flow rate
- Pressure change during a calibration run
- Meter readability, velocity profile, and others



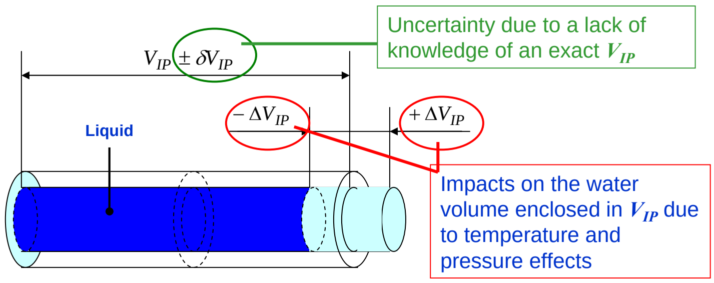
Standard flow facility #1

PTB — Liquid flowmeter calibration: *principles* — SIMPOSIO METROLOGÍA

Principle: Flow calibration facility



PTB — "Rough" model: inter-connecting pipework — SIMPOSIO METROLOGÍA



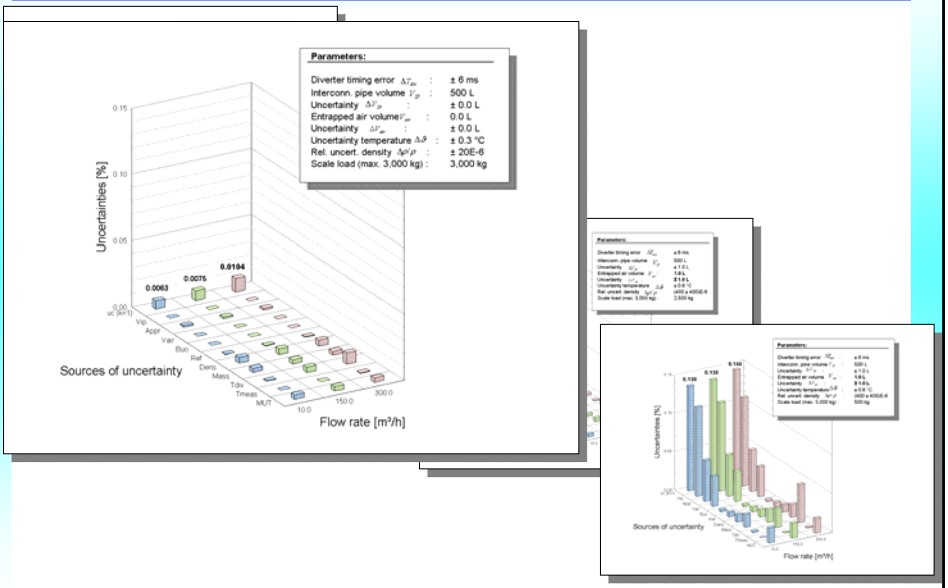
Impacts on: *1) - inter-connecting pipe volume* *2) - entrapped air volume*

$$\Delta V_{IP} = \left[\frac{\pi}{4}\cdot\left[d_i + \frac{(p_{finish}-p_0)\cdot d_i^{2}}{2\cdot w\cdot E}\right]^2\cdot l\cdot\left[1+3\cdot\alpha\cdot(\vartheta_{finish}-\vartheta_0)\right] - V_{air,0}\cdot\frac{p_0}{p_{finish}}\cdot\frac{\vartheta_{finish}+273.15}{\vartheta_0+273.15}\right] - \dots$$

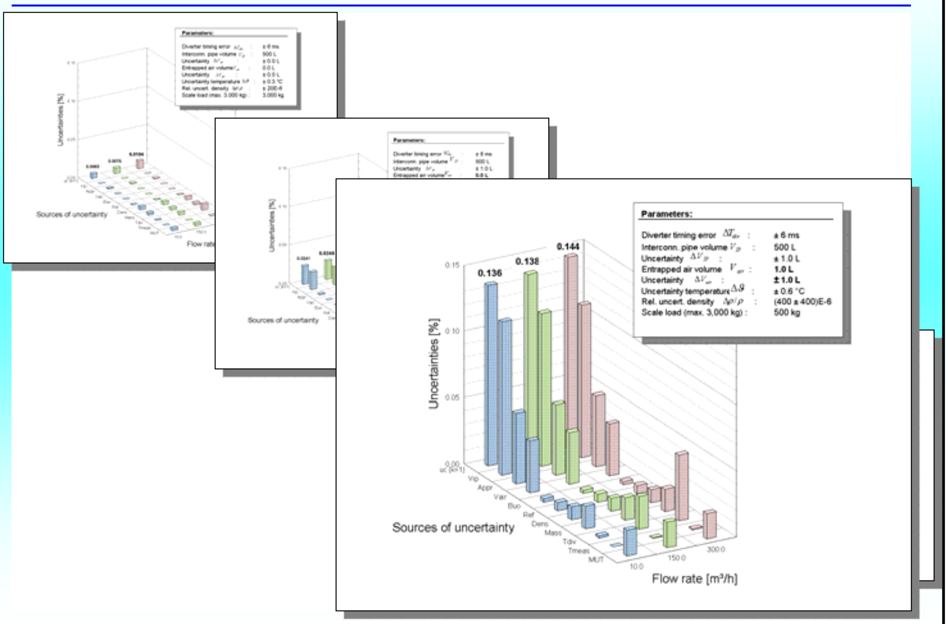
$$\dots - \left[\frac{\pi}{4}\cdot\left[d_i + \frac{(p_{start}-p_0)\cdot d_i^{2}}{2\cdot w\cdot E}\right]^2\cdot l\cdot\left[1+3\cdot\alpha\cdot(\vartheta_{start}-\vartheta_0)\right] - V_{air,0}\cdot\frac{p_0}{p_{start}}\cdot\frac{\vartheta_{start}+273.15}{\vartheta_0+273.15}\right]$$

3) - enclosed liquid volume

PTB **Impacts on measurement uncertainty** SIMPOSIO METROLOGÍA



PTB **Impacts on measurement uncertainty** SIMPOSIO METROLOGÍA



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NMIs & Accredited calibration laboratories

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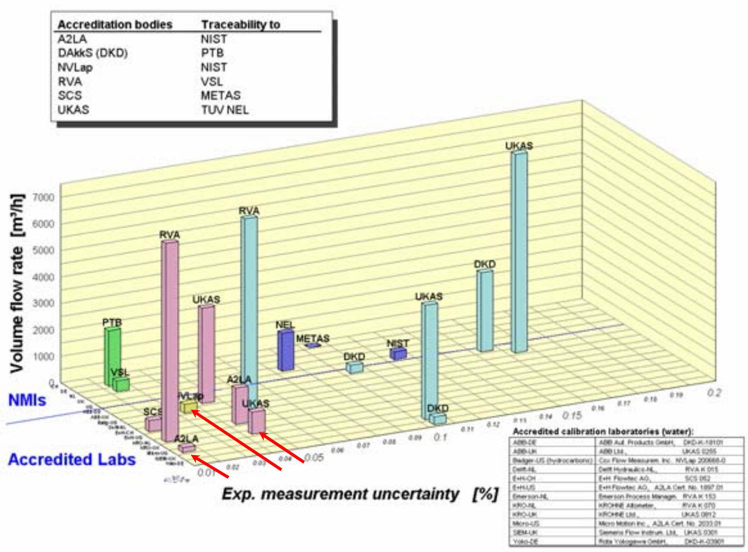

Water flow CMCs

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Conclusions

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- **Element-by-element traceability**
  - is **not sufficient** in order to proof the reliability of uncertainty estimations in flow applications (MU < 0.08% … 0.1%).
- **Comparison measurements must be the basis of traceability in fluid flow measurement**
  - applying an uncertainty model that refers to the “real” measurand
  - which is the meter K-factor *(not the CMC entry)*.
- **Measurement uncertainty is to be referred to defined and stable conditions** (reference conditions: 20°C)
  - In practical applications, the process conditions, generally, differ from the reference conditions *(i.e. ideal conditions)*.

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Conclusions (cont.)

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→ • **Measurement uncertainty models that refer to flow facilities without provisions for stable reference temperature operations**
  – **will not deliver** realistic uncertainties **below 0.1 %** (in liquid flow) !

→ • **"Real" traceability**
  – **must** comprise **all** measurement-related impacts which are known as the state-of-the-art knowledge (MU < 0.05 % … 0.08 %).

→ • **"Real" traceability**
  – **must** include comparison measurements referenced to the national flow standard, i.e. **traceability via flow measurements**

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Thank you

for your attention.

Gracias por su

atención.

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