# The importance of traceability in dimensional metrology in microfluidic systems

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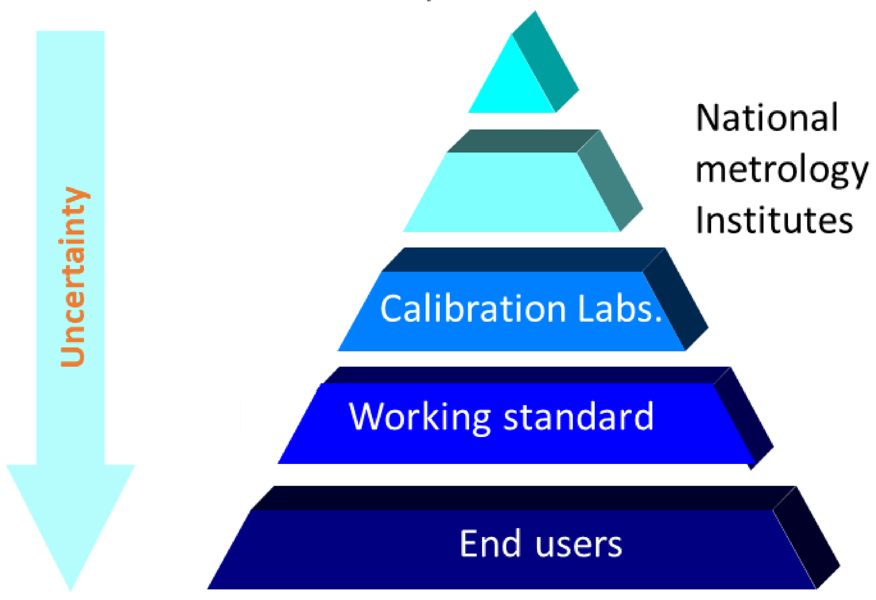
## EURAMET – 20NRM02 MFMET

This project aims to contribute to the development of globally accepted standards for microfluidics and disseminate them to end users in industry (health and pharmaceutical sectors) and academia.

DEVELOPMENT OF CONSENSUS-BASED MEASUREMENT PROTOCOLS & GUIDELINES • BY THE DISSEMINATION OF METROLOGY STANDARDS TOWARDS NORMATIVE COMMITTEES (ISO TC48/WG3), INDUSTRY AND END USERS

**Objective of the work:** assessment of the suitability of components of 3 different microfluidic chips in order to assure dimensional traceability to primary standards.

**Metrological compatibility** is a property of a set of measurement results for a specified measurand, such that the absolute value of the difference of any pair of measured quantity values from two different measurement results is smaller than some chosen multiple of the standard measurement uncertainty of that difference.



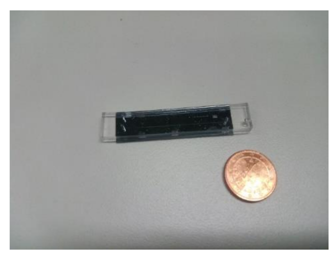

Traceability is a guarantee for quality of calibration results

**Measurement Traceability** is a property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty. (VIM)

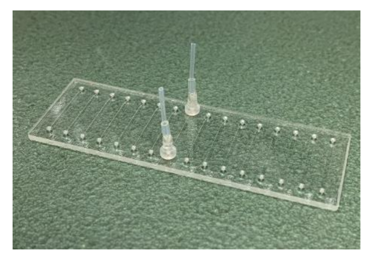
## TESTED CHIPS

Three different chips made of Polydimethylsiloxane (PDMS) and of Cyclic Olefin Copolymer (TOPAS) were used. The dimensional characteristic of the connection were determined by a profile projector and a interferometer. The flow rate was determined using the gravimetric method and the front track method.

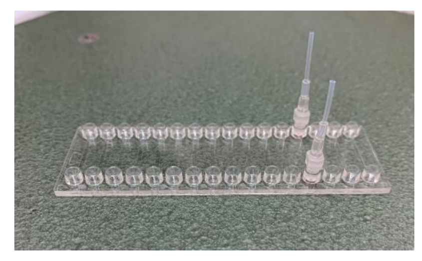
PDMS

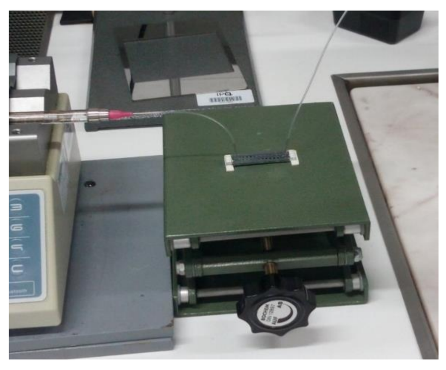


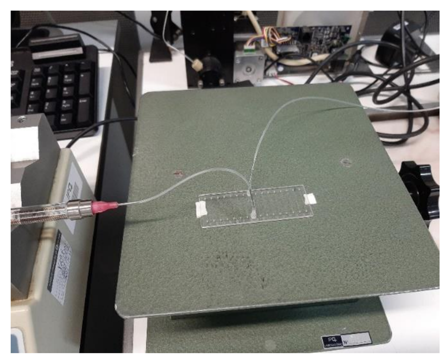
CHIP A TOPAS

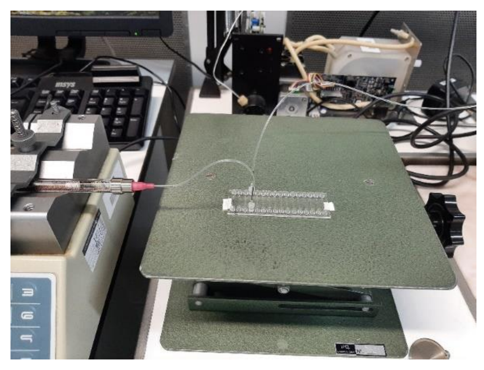


CHIP C TOPAS



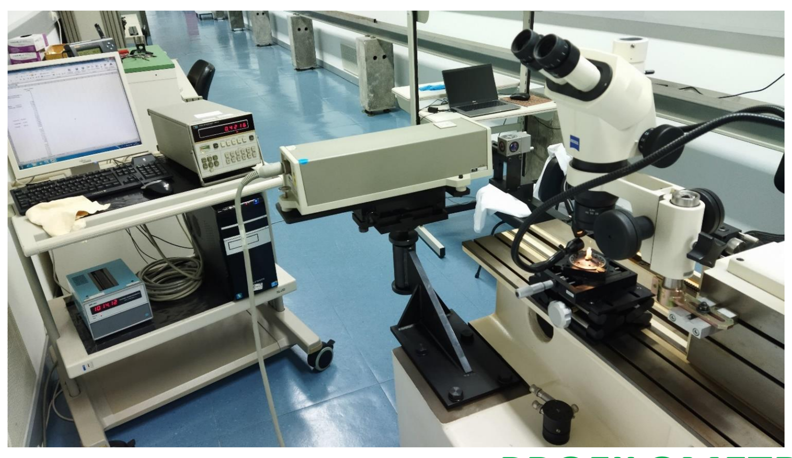


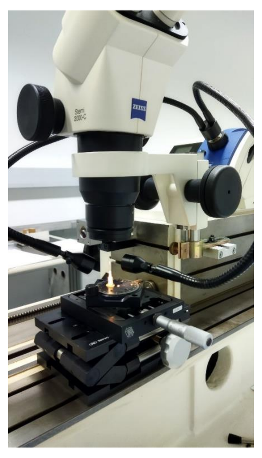




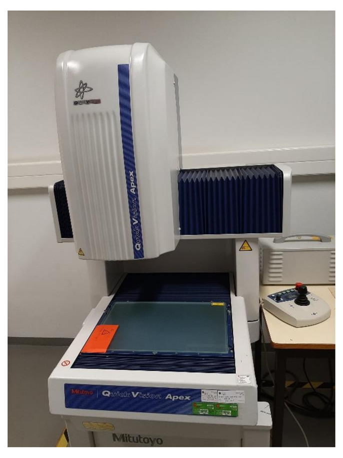
## DIMENSIONAL CALIBRATION METHODS

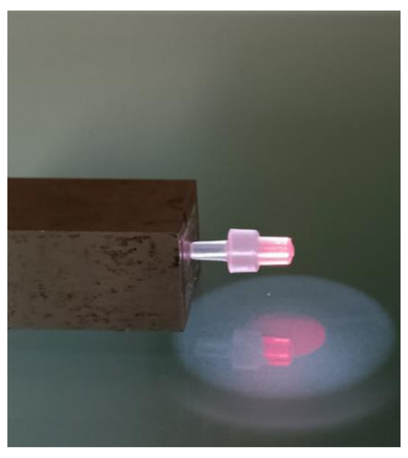
### INTERFEROMETRY

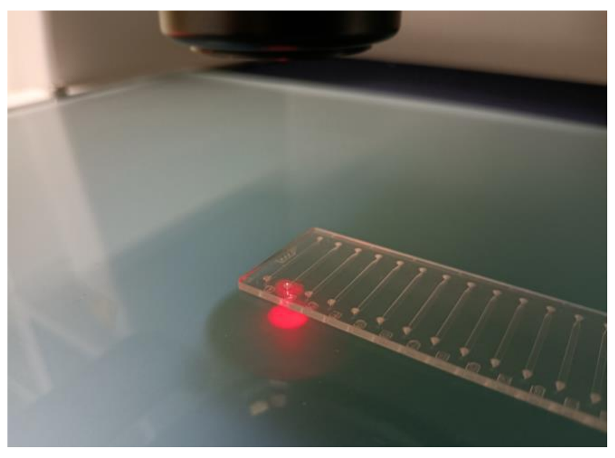




### PROFILOMETRY



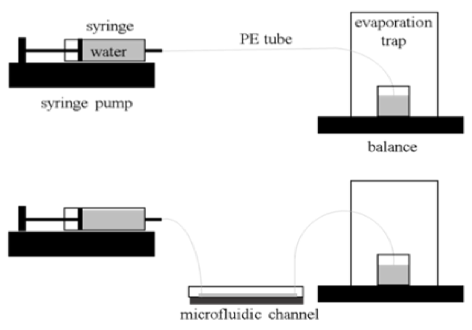




## FLOW CALIBRATION METHODS

### Gravimetric method

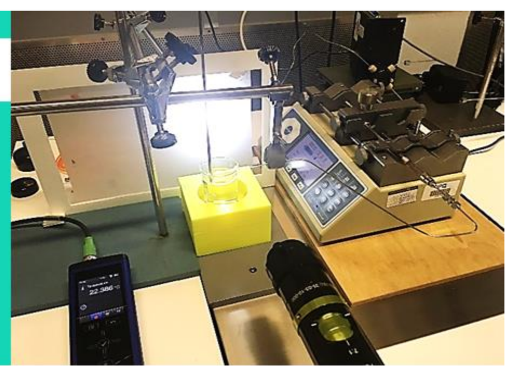
The gravimetric method relies on weighing the mass of the working fluid delivered by the instrument under test for a set time




$$Q_{20} = \frac{1}{t_f - t_i}\left[\left((I_f - I_i) - (\delta m_{buoy})\right) \times \frac{1}{\rho_W - \rho_A} \times \left(1 - \frac{\rho_A}{\rho_B}\right) \times [1 - \gamma(T_W - 20)]\right] + \delta_{evap}$$

### Front track method

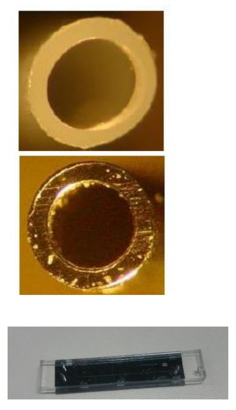
The experimental setup consists of using a high-resolution camera and an image processing software (Python) to track the distance traveled by the meniscus of a liquid in a capillary tube and calculate the flow rate.



$$Q_{20} = \frac{x_2 - x_1}{\Delta t} \times \pi \times r^2 \times [1 - \gamma\,(T_W - 20)]$$

## DIMENSIONAL MEASUREMENT RESULTS

### Interferometry

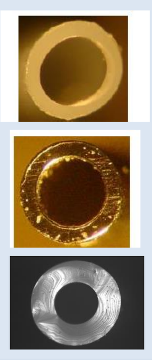


| | Measurand | Value [mm] | *U* [mm] |
|---|---|---|---|
| Plastic tube | Inner diameter | 1.26 | 0.040 |
| Tube tip | Inner diameter | 0.912 | 0.010 |
| Chip hole | Inner diameter | 0.710 | 0.003 |

Chip PDMS

### CHIP A

Interferometry



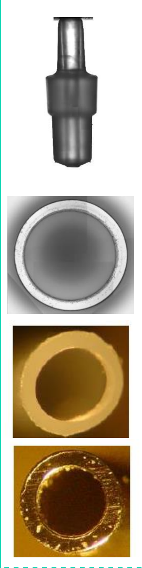
| | Measurand | Value [mm] | *U* [mm] |
|---|---|---|---|
| Plastic tip | Inner diameter | 1.260 | 0.040 |
| Tube tip | Inner diameter | 0.912 | 0.010 |
| Rubber tube | Inner diameter | 0.806 | 0.005 |

Profilometry

| | Measurand | Value [mm] | *U* [mm] |
|---|---|---|---|
| Chip hole | Inner diameter | 1.384 | 0.038 |
| Connector | External diameter of top | 1.77 | 0.44 |
| Rubber tube | Inner diameter | 0.820 | 0.039 |

### CHIP C

Interferometry



| | Measurand | Value [mm] | Standard Deviation [mm] |
|---|---|---|---|
| Connector | Small inner diameter | 0.93 | 0.11 |
| Connector | External large diameter | 2.577 | 0.012 |
| Chip hole | Inner diameter | 2.883 | 0.007 |

| | Measurand | Value [mm] | *U* [mm] |
|---|---|---|---|
| Plastic tip | Inner diameter | 1.26 | 0.040 |
| Tube tip | Inner diameter | 0.912 | 0.010 |

Profilometry

| | Measurand | Measurand estimation [mm] | *U* [mm] |
|---|---|---|---|
| Connector | External large diameter | 2.78 | 0.18 |
| Chip hole | Inner diameter | 2.843 | 0.019 |

## FLOW MEASUREMENT RESULTS

| | | Front track method | | | Gravimetric method | | | |
|---|---|---|---|---|---|---|---|---|
| Chip | Nominal flow [mL/h] | Measured flow [mL/h] | Error [%] | *U* [%] | Measured flow [mL/h] | Error [%] | *U* [%] | En |
| PDMS | 0.001 | -0.0014 | -171 | 14.0 | 0.00092 | -8 | 23 | -6.04 |
| | 1 | 1.0411 | -3.9 | 5.3 | 0.9945 | 0.55 | 2.4 | 0.77 |
| A | 0.01 | 0.0095 | 5.3 | 3.7 | 0.0099 | 1.0 | 5.0 | -0.69 |
| | 0.1 | 0.0967 | 3.4 | 2.8 | 0.0983 | 1.7 | 3.8 | -0.36 |
| | 1 | 0.9819 | 1.8 | 6.2 | 0.9907 | 0.93 | 0.19 | -0.15 |
| C | 0.01 | -0.0033 | -403 | 43 | 0.0069 | 31 | 5 | 9.94 |
| | 0.1 | 0.0996 | 0.5 | 1.9 | 0.097 | 2.6 | 3.4 | 0.55 |
| | 1 | 1.0259 | -2.5 | 4.0 | 1.017 | -1.7 | 3.0 | 0.17 |

## SUMMARY

- **Length measurements**: the measured values (estimation of the length measurands) and the uncertainties obtained with the two methods used, interferometry and profile projection, are compatible. When using interferometry, the definition of the measurement plane of the accessories of translucent material presented technical difficulties mostly due to the available equipment. As such, for these measurements, only the standard deviation of the measurements was indicated.
- **Shape deviations** intrinsic to the accessories (roundness, cylindricity) of plastic material are identified as the main factors for the high standard deviations found (of the order of 0.01 mm, when the interferometer has a resolution of 0.01 µm). The shape deviations and the plasticity of the constituent material of the tubes and connectors prevented measurements with superior accuracy, even when using the interferometer as measuring equipment to guarantee the metrological traceability of these accessories. With the profile projector it was possible to calculate the uncertainties obtained and image all accessories, even the translucent.
- The **flow rate** was calibrated for three chips and small deviations from nominal values were observed. The high percentage of error for the smallest flow rates in Chip C is possibly due to leakage occurring because of the incompatibility of dimensions between the feeding tube and the microfluidic channel connection.

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