Progress Report to CCM from 2021 to 2022

Report prepared for the meeting of the Consultative Committee for Mass and Related Quantities (CCM)

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1 Research and development report METAS

1.1 Flow

MeDDII
Within the framework of the European Metrology Programme for Innovation and Research (EMPIR) the laboratory participated in the Metrology for Drug Delivery II (MeDDII) project coordinated by IPQ which started in June 2019 and ended in November 2022. The project aimed at improving dosing accuracy, enable traceable measurements of existing drug delivery devices and investigate fast changing flow rates, physical properties of mixtures of liquids and occlusion phenomena in multi-infusion systems.
The outcomes for METAS were the following:

- Extension of the flow range of its primary standard from currently 100 nL/min down to 5 nL/min and validated it down to 20 nL/min with CMCs.
- METAS developed a working pipe-viscometer to measure in-line viscosity of liquids and participated successfully in a pilot comparison
- The METAS facilities have also been upgraded to enable traceable in-line measurement of the dynamic viscosity of liquids.

Large water meter test rig
The large water meter test rig has had a complete overhaul of its data-acquisition system. The test rig runs now in a completely automated way and allows much greater flexibility for measurements. Special care was dedicated to reducing the amplitude of waves in the water head tank as water levels are measured by probes placed at varying levels in the head tank. Reduction of the waves amplitude lead to a better repeatability of the measurements.

Hydrogen flow metering
METAS participates in several EMPIR projects related to hydrogen flow metering.

- MetroHyVe II (started in August 2020): METAS is developing a new field test standard dedicated to calibrating and testing hydrogen refuelling stations for heavy-duty vehicles.
- MetHyInfra (started in June 2021): METAS is actively involved in the part on calibrating critical flow Venturi nozzles with hydrogen up to 800 bar. METAS is also developing a new PVTt test rig for hydrogen covering the flow rate range (0.1 to 2000) L/min and pressure range (1 to 50) bar.
- Met4H2 (started in June 2022): METAS is involved in the Work Package dedicated to flow metering and will make use of the PVTt system developed in MetHyInfra to characterise flow meters with hydrogen and mixtures of hydrogen and natural gas.

1.2 Mass, force and pressure

1.2.1 Mass

We have completely revised the quality assurance documents of six automatic mass comparators in our laboratory. In addition, the measuring site of the M_One mass comparator was peer-reviewed by BEV (Austria) in November 2021. Only two non-conformities were found in relation to the documents, which were subsequently corrected.

We had a second set of working standards from 1 g to 20 kg laser-marked by *Häfner Gewichte GmbH* to ensure clear identification. All the weights were re-calibrated after the laser marking. For the re-calibration we used the traditional group weighing method on our automatic comparators located in air-tight chambers and conducted the measurements in two different air densities. This allowed us to determine the mass and volume of each weight simultaneously. We also determined the volume of each weight by our standard hydrostatic weighing method according to OIML R-111. The results of the two methods were in excellent agreement.

We are participating in the CCM.D-K1.2023 comparison in which we determined the density of a 1 kg silicon sphere by hydrostatic weighing. Draft A is expected in November 2023.

In recent months, we have introduced a new *Laboratory Information Management System* (LIMS) in our mass laboratory to drive the digital transformation, which is a key element of METAS' strategy for the coming years with regard to digitalisation in metrology.

To keep the process of calibration under control, we have started to carry out regular control measurements on all our mass comparators, robots and balances. This way, we can monitor our instruments and reference weights.

1.2.2 Force

In 2021 the complete stack of the 110kN force machine was disassembled and every disk was recalibrated. A transfer standard was measured before the disassembly and after for assuring continuity. In 2021 the laboratory was audited and became accredited laboratory for OIML R134.
The final measurements required for the connection of the participants to the comparison CCM.F-K23 have been performed.

1.2.3 Pressure

The pressure laboratory worked in improving the definition of the effective area of the primary piston-cylinders. The four piston-cylinders with a primary definition have been compared together following a scheme of circular comparison. The results demonstrate the excellent definition of the effective area but also revealed the influence of non-homogenous temperature in the pressure balance.

1.2.4 Kibble Balance

After having implemented a number of modifications to improve the adjustment and the monitoring of all the parameter of the experiment, two measurement campaigns where conduced in 2021. The obtained results and a full description of the setup were then published [ref]. Based on these results METAS has participated to the CCM key comparison of kilogram realizations CCM.M-K8.2021 [ref].
During 2022 METAS has pursued its efforts to improve its Kibble Balance experiment. The main tasks are the following:

- Improvement of the regulation to reduce the type A uncertainty in the dynamic phase,
- Improvement of the interferometer to get a better stability in vacuum,
- Integration of a commercial interferometer to have an online monitoring of the attitude of the coil in both phases,

- Implementation of a force profile along the gap. This will help to determine the order of the polynomial fit and give the possibility to run the experiment at different position in the gap,
- Characterization of a new set of KB reference masses.

2 Relevant comparisons

- CCM.M-K8.2021 Final report
- CCM.D-K1.2023 in progress
- CCM.F-K23 Draft B published
- EURAMET project F 1515 Final report (air speed)
- Pilot study intercomparison of ultra-low liquid flow rates in range below 100 nL/min Final report

3 Relevant publications

- A Eichenberger *et al* 2022 First realisation of the kilogram with the METAS Kibble balance *Metrologia* 59 0255008
- M Stock *et al* 2023 CCM.M-K8.2021 *Metrologia* 60 07003
- K. Marti und Ch. Wüthrich. „Simultan Masse und Volumen bei Gewichten bestimmen“. METinfo 28, Nr. 1 (2021): 8–11.
- C. Wuethrich, G. Boschung and F. Grasso Toro, Improving the characterization of pressure gauge setup by condition monitoring, Measurement: Sensors, Vol. 18, December 2021, 100190 https://doi.org/10.1016/j.measen.2021.100190
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