Progress Report to CCM from 2019 to 2021

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

H. Baumann

1 Research and development report METAS

1.1 Flow

MeDDII and complex fluids
Within the framework of the European Metrology Programme for Innovation and Research (EMPIR) the laboratory participates in the Metrology for Drug Delivery II (MeDDII) project coordinated by IPQ which started in June 2019. The project aims at improving dosing accuracy, enable traceable measurements of existing drug delivery devices and will investigate fast changing flow rates, physical properties of mixtures of liquids and occlusion phenomena in multi-infusion systems.
METAS extended 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. A comparison is in preparation and METAS characterized the transfer standards. The METAS facilities have also been upgraded to enable traceable in-line measurement of the dynamic viscosity of liquids.
In parallel to the MeDD II project, the laboratory is working on a METAS internal project on changing flow rates and the development of a pipe-viscometer to characterize non-Newtonian liquids.

Gas piston provers in pressure-regulated mode
METAS runs a couple of piston provers as gas flow primary standards. Their measurement principle relies on pressing a known volume of gas through a flow meter. To increase measurements capabilities, their functioning mode has been extended to allow sucking in gas at ambient conditions and moving the pistons in a pressure-regulated mode. The former improvement permits the calibration of flow meters that work in suction mode while the latter opens up the way to calibrating all types of flow meter that require either a high upstream pressure (molblocs or critical nozzles for instance) or downstream pressure below ambient conditions (typically critical nozzles). Additionally, the flow rate range was extended from 100 mL/min down to 2 mL/min (air at 20 °C and 1013 hPa).

High pressure hydrogen flow metering
METAS participated in the EMPIR project Metrology for Hydrogen Vehicles (MetroHyVe) and lead the work package on flow metering. This very successful project lead to the development of the METAS hydrogen field test standard (HFTS) for calibrating and testing hydrogen refueling stations (HRS) on site up to 700 bar. The standard is based on the gravimetric principle and weighs the amount of delivered hydrogen by collecting it in high pressure vessels mounted on a scale. The HFTS has an Ex-certification for working in explosive environments. METAS participates in the follow-up project MetroHyVe II, which started in August 2020, and will develop a new field test standard dedicated to heavy-duty vehicles as well as a method to verify HRS using master meters.

1.2 Mass, force and pressure

1.2.1 Mass

In the past three years, we have been improving the quality assurance in the mass laboratory. We purchased six new primary mass standards made of stainless steel that will serve as an additional level in the mass hierarchy and act as a link between our working standards and our national kilogram prototypes. In addition, we had our working standards from 1 g to 20 kg marked with laser by *Häfner Gewichte GmbH* for an unambiguous identification. We also introduced new methods for simultaneously determining the mass and volume of multiples and submultiples of a set of weights by using group weighings in different air densities. In this way, both the mass and the volume of all weights involved are traceable to the mass and volume of the reference weight. The mass of the reference weight is traceable to the SI definition of the mass and the volume of the reference weight is traceable to a silicon sphere through hydrostatic weighing. To guarantee the most accurate mass and volume measurements with lowest uncertainties, we have revised our volume comparators and introduced periodical control measurements on all comparators.

1.2.2 Force

The measurements for the CCM.F-K23 comparsison (200 N & 500 N) have been performed almost completely in 2020. The innovative circulation of the transfer standards supplied by the participants made possible to achieve the measurements in time of the pandemic. The preparation of this comparison was an opportunity for the laboratory to assess the traceability of two of the force standards and to correct for the unavoidable wear of such systems.

1.2.3 Pressure

The pressure laboratory has been working on the coherence of the pressure scale defined over 13 decades. We are building confidence between the definition of the pressure in the range 1 Pa to 100 Pa with static expansion and digital piston system FRS4. We also concentrated our effort in the range 5000 Pa to 9500 Pa covered with the FRS4 and the 20 cm^2 pressure balance.

1.2.4 Kibble Balance

During the last years, METAS has pursued its efforts in the improvement of its Kibble Balance experiment. The main modifications that have been implemented are the following:

- To reduce the oscillation of the suspension, essentially in the static mode, close-circuit magnetic dampers were developed.
- The noise reduction in the dynamic mode was achieved by a complete redesign of the interferometer.
- A green laser, operated by the laboratory Length, provides now the laser reference beam.
- The integration of three interferometers allows to determine the attitude of the coil in both phases of the experiment.

Based on these improvements, all parameters for the alignment of the experiment seem to be under control. During the last month of 2020 an extensive campaign under vacuum with the JVC reference has been undertaken. The results showed a type A uncertainty of some ppb.

During the coming months the experiment will be properly adjusted and run for a first realisation of the mass unit

2 Relevant comparisons

- EURAMET-P1225 Final report
- EURAMET.M-FF-K4b Final report

- CCM.F-K23 Measurements finished
- EURAMET.M.P-K1.c: Approved for equivalence

3 Relevant publications

- H. Bissig. M. Tschannen, M. de Huu, *Improving process quality by means of accurate and traceable calibration of flow devices with process-oriented liquids*, Chimia 72 (2018) 124.129
- A. Murugan, M. de Huu, T. Bacquart, J. van Wijk, K. Arrhenius, I. te Ronde, D. Hemfrey, *Measurement challenges for hydrogen vehicles*, International Journal of Hydrogen Energy Vol. 44 Issue 35 (2019) 19326-19333
- M. de Huu, O. Büker, R. Christensen, M. MacDonald, R. Maury, M. Schrade, H.T. Petter, P. Stadelmann,*The European research project on metrology for hydrogen vehicles – MetroHyVe*, J. Phys.: Conf. Ser. 1065 092017
- H. Bissig. M. Tschannen, M. de Huu, *Water collection techniques at very low flow rates including strong capillary effects*, Flow Meas. Instrum. 73 (2020) 101744
- R. Maury, C. Auclercq, C. Devilliers, M. de Huu, O. Büker, M. MacDonald, *Hydrogen refuelling station calibration with a traceable gravimetric standard*, Flow Meas. Instrum. 74 (2020) 101743
- M. de Huu, M. Tschannen, H. Bissig, P. Stadelmann, O. Büker, M. MacDonald, R. Maury, P.T. Neuvonen, H.T. Petter, K. Rasmussen, *Design of gravimetric primary standards for field-testing of hydrogen refuelling stations*, Flow Meas. Instrum. 73 (2020) 101747
- O. Büker, K. Stolt, M. de Huu, M. MacDonald, R. Maury, *Investigations on pressure dependence of Coriolis mass flow meters at hydrogen refuelling stations*, Flow Meas. Instrum. 76 (2020) 101815
- H. Bissig. M. Tschannen, M. de Huu, *Traceability of pulsed flow rates consisting of constant delivered volumes at given time intervals*, Flow Meas. Instrum. 73 (2020) 101729
- Wuethrich, Ch, und K. Marti. „Simultaneous Determination of Mass and Volume of a Set of Weights in Group Weighing“. ACTA IMEKO 9, Nr. 5 (31. Dezember 2020): 17–22. https://doi.org/10.21014/acta_imeko.v9i5.931.
- C. Wuethrich, S. Souiyam, „Monte Carlo determination of the uncertainty of effective area and deformation coefficient for a piston cylinder unit“, ACTA IMEKO 9, Nr. 5 (31. Dezember 2020): 338–342. http://dx.doi.org/10.21014/acta_imeko.v9i5.996
- Su, Yi, Kilian Marti, und Christian Wuethrich. „Volume Determination of Weights in the Range from 1 g to 5 Kg: A Comparison of Hydrostatic Weighing and Double-Weighing in Air Using Monte-Carlo Simulation“. ACTA IMEKO 9, Nr. 1 (30. März 2020): 61–68. https://doi.org/10.21014/acta_imeko.v9i1.715.
- Marti, K., C. Wuethrich, M. Aeschbacher, S. Russi, U. Brand, und Z. Li. „Micro-Force Measurements: A New Instrument at METAS“. Measurement Science and Technology 31, Nr. 7 (April 2020): 075007. https://doi.org/10.1088/1361-6501/ab79c7.
- Marti, K., M. Aeschbacher, S. Russi, und C. Wuethrich. „Microforce Measurements – a New Instrument at METAS“. Journal of Physics: Conference Series 1065, Nr. 4 (2018): 042024. https://doi.org/10.1088/1742-6596/1065/4/042024.
- Marti, Kilian. „Dissemination of the kilogram at METAS: Extended Method of Lagrange Multipliers for Air Buoyancy Correction“. In IMEKO 23rd TC3, TC5 and TC22 International Conference. Helsinki, Finland, 2017.