

EURAMET TC-M, Density and Viscosity Area Roadmap

Background

Density and viscosity metrology is mainly important in the following three areas:

- Process controlling: Accurate equations of state, i. e. density, viscosity, sound velocity and other quantities as function of temperature and pressure, help to design and improve the process controlling in industry.
- Traceability of density measurements is economically important for all goods that are sold according to mass but measured in volume and vice versa. This concerns in particular the gas and oil industry.
- Metrologically important are improved density and volume measurements of solids for density and mass measurements. The density is one of the key quantities for the realization of the new kg definition by the Avogadro method. The research for the Avogadro constant determination is yielding density standards with improved stability and accuracy. Improvements in density realization will also help to build liquid column manometers with unprecedented accuracy for the primary realization of the pressure unit.

Improvements can be expected from scientific investigations concerning

- hydrostatic weighing methods for gases, liquids and solids,
- surface effects on solids in gases and liquids,
- surface modifications of solid samples by ion-beams, atomic layer deposition etc.,
- surface (layer) characterisation, e. g. by XRR, XRF, XPS and spectral ellipsometry.

Technological improvements are expected concerning:

- hydrostatic weighing by magnetic suspension,
- temperature controlling,
- flotation methods for density comparison of solids (silicon),

Basic Science (for metrology)

A new definition of the mass unit kilogram is expected for the next few years [1,2]. For the realisation of the new kg by the Avogadro method, the density of the silicon crystal is one of the main quantities [3]. The perfection and homogeneity of the crystal has to be checked by ultra-high level density comparison measurements using the flotation method. In order to reach the necessary accuracy, investigations of surface effects between flotation liquid and silicon have to be performed and the temperature controlling has to be improved to μK stability and spatial homogeneity.

For the dissemination of the new kg, mass comparisons between silicon spheres and platinum-iridium or stainless steel mass standards have to be performed in air. Here, the air buoyancy is the largest uncertainty contribution. Special air buoyancy artefacts allow to determine gravimetrically the air density and to perform high accuracy mass comparisons between silicon spheres and stainless steel mass standards (or platinum iridium mass standards). The volumes of these artefacts have to be calibrated by hydrostatic weighing with very high accuracy. For this, surface effects have to be investigated and taken into account.

As a spin-off of the Avogadro experiment, primary density standards with uncertainty below 0.05 ppm will become available. This is mainly due to new surface preparation methods and improved surface characterization methods. In order to disseminate the density unit on this level of accuracy, new and improved methods are necessary.

Improvements in density realization will also help to build liquid column manometers with unprecedented accuracy for the primary realization of the pressure unit, in particular in the low pressure range.

Scientific investigations of density and viscosity of liquids confined in small dimensions will allow ensuring the traceability of measurements in the field of nanotechnology [4].

Grand Challenges: Energy, Environment, Health

New challenges on the field of energy arise from biogases and bio liquids having compositions that are differing widely from natural gas [5]. In particular the concentrations of carbon dioxide, nitrogen,

oxygen, hydrogen, water vapor and sulfur hydrogen are extraordinary. Therefore, the state equations of these new gases and oils have to be measured traceable to the SI in order to calculate the density at reference conditions used for custody transfer. This concerns also the calculation of mixtures of biogas and natural gas in the European gas transportation net. For these measurements the hydrostatic weighing by magnetic suspension has to be improved and adopted to the new compositions. Additionally, investigations of surface effects due to the new gases and oils are necessary.

The development of oil manometers with integrated density determination will allow to discard mercury manometers also in the low pressure range and, thus, to avoid the risks by mercury for environment and health [6].

Most of the investigations on the energy field are also important for industrial applications, see below.

Innovation (for industrial applications)

The state equations for the new bio gases and oils are also necessary for process design and control. Here a wider range of pressure and temperature has to be taken into account. Extended ranges in pressure and temperature for process control and optimization of industrial processes are necessary also for the usual natural gas.

Pressures ranging up to 100 bar (or in special cases even up to 400 bar) and temperatures ranging from -50 °C to +500 °C are asked for by the industry concerning mineral oil, air planes, fuels, heat exchangers, thermal transport media for power plants, solar industry and cooling. The use of liquefied natural gas (LNG) needs state equations for temperatures as low as -160 °C [7].

Oscillation-type density meters?

References

(Standards, white papers, regulations, EU documents)

- [1] http://www.bipm.org/en/si/new_si/
- [2] Resolution 1 of the 24th meeting of the CGPM (2011), <http://www.bipm.org/en/CGPM/db/24/1/>
- [3] B. Andreas *et al.*, Counting the atoms in a ^{28}Si crystal for a new kilogram definition, *Metrologia* **48** (2011) S1 – S13
- [4] Communication from the Commission. “Towards a European strategy for nanotechnology”: COM (2004) 388 final, http://ec.europa.eu/nanotechnology/pdf/nano_com_en.pdf.
- [5] Directive 2008/0013 (COD) of the European Parliament and of the Council amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community
- [6] UN's Mercury Conference in Stockholm - preparation for a global agreement on Mercury, Stockholm, 7 to 11 June 2010, <http://www.norden.org/en/nordic-council-of-ministers/councils-of-ministers/nordic-council-of-ministers-for-the-environment-mr-m/events/uns-mercury-conference-in-stockholm-preparation-for-a-global-agreement-on-mercury>
- [7] Directive 2003/55/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in natural gas