Title: Establishing traceability for liquid density measurements

Abstract

Pre-packaged liquid products are often sold in terms of volume but their quantity is verified by weighing, and this requires that the density of the liquid is determined. Whilst several NMIs possess the necessary equipment and facilities to perform liquid density measurements at both primary-level, with a hydrostatic weighing apparatus, and secondary-level, with oscillation-type density meters, other NMIs have indicated limitations regarding the hydrostatic weighing method, with unsatisfactory results and uncertainties up to 22 times higher than the pilot laboratory. Poor results from this method can jeopardise the accuracy and precision of the density traceability chain down to the second-level measurements, which are the ones most required by customers, such as accredited bodies, industries and laboratories. There is a requirement for the development of national metrological capacity in liquids density metrology in some emerging NMIs.

Keywords

Liquid density, hydrostatic weighing apparatus, oscillation-type density meter, density standards

Background to the Metrological Challenges

When the quantity of a liquid product in a package is expressed in terms of volume but verified by weighing, it is also necessary to determine the density of the product. However, the methods for measuring density of these liquid products are frequently not well understood, leading to significant systematic errors. The OIML (International Organization of Legal Metrology) Guide 14 (2011) and the OIML Bulletin number 96 (1984), recommend oscillation-type density meters as suitable measuring instruments to determine the density of several types of liquids, e.g. liquids without dissolved carbon dioxide or other gases; viscous liquids such as lubricating oils, paints and varnishes; solvents; cleaning, cosmetic and washing products. The quantities of prepacked products are regulated by European Directives (Council Directive 76/211/EEC; Council Directive 80/232/EEC and Directive 2007/45/EC of the European Parliament and of the Council), and this mandatory control of the volume of the liquid in prepacked products has intensified the request of these industries to NMIs to provide calibration services.

The hydrostatic weighing method for liquid density determination is considered to be the highest level of density determination allowing traceability of this derived quantity to the base units, kilogram and metre, through means of a solid density standard, i.e. a sphere of traceable mass and volume. Using this method it is possible to determinate the density of liquids with a low uncertainty. These calibrated liquids are then be used as density reference materials for the calibration of oscillation-type density meters, which can be considered a second-level density measurement method. Recently, this type of density meter has shown great versatility and has been used in various branches of industry. This widespread use in industry with different types of liquid samples makes adequate calibration of these instruments crucial.

Several NMIs possess the necessary equipment and facilities to perform liquid density measurements at both primary-level, with a hydrostatic weighing apparatus, and secondary-level, with oscillation-type density meters, for measurements at atmospheric pressure and up to 600 bar. However, in the latest EURAMET intercomparison (EURAMET.M.D-K2 (1019)) some NMIs indicated limitations regarding the hydrostatic weighing method, with unsatisfactory results and uncertainties up to 22 times higher than the pilot laboratory. Poor results from this method can jeopardise the accuracy and precision of the density traceability chain down to the second-level measurements, which are the ones most required by customers, such as accredited bodies, industries and laboratories.

There is therefore a requirement for the development of metrological capacity in liquids density metrology in emerging NMIs, with sufficiently low measurement uncertainties, using state-of-the-art density measuring systems, and addressing the quantities influencing density, such as temperature, pressure and viscosity. This may require the review and upgrade of existing capabilities and needs, validation of existing systems or the development of new systems, with the support of the more experienced NMIs.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the development of metrological capacity in liquid density measurements.

The specific objectives are

1. To develop traceable measurement capabilities in liquid density measurement by the hydrostatic weighing method, in the density range from 600 kg/m^3 to 1700 kg/m^3, at atmospheric pressure and temperatures from 5 °C to 60 °C, with an uncertainty from 0.002 kg/m^3 to 0.005 kg/m^3.
2. To develop traceable measurement capabilities in liquid density measurements performed with oscillation-type density meters, in the density range from 600 kg/m^3 to 1700 kg/m^3, for liquids with dynamic viscosity up to 2000 mPa·s, at atmospheric pressure and temperatures from 5 °C to 60 °C, with an uncertainty from 0.010 kg/m^3 to 0.050 kg/m^3.
3. To develop traceable measurement capabilities in liquid density measurement with high-pressure oscillation-type density meters, in the density range from 600 kg/m^3 to 1700 kg/m^3, for liquids with dynamic viscosity up to 2000 mPa·s, at 20 °C, from atmospheric pressure up to 600 bar, with an uncertainty from 0.10 kg/m^3 to 0.50 kg/m^3.
4. To establish the degree of equivalence of the density measurements performed with the first and second-level measuring systems developed in the project via comparisons.
5. For each participant, to develop an individual strategy for the long-term operation of the capacity developed, including regulatory support, research collaborations, quality schemes and accreditation. They should also develop a strategy for offering calibration services from the established facilities to their own country and neighbouring countries. The individual strategies should be discussed within the consortium and with other EURAMET NMIs/DIs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Joint Research Proposals submitted against this SRT should identify

- the particular metrology needs of stakeholders in the region,
- the research capabilities that should be developed (as clear technical objectives),
- the impact this will have on the industrial competiveness and societal needs of the region,
- how the research capability will be sustained and further developed after the project ends.

The development of the research potential should be to a level that would enable participation in other TPs.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET has defined an upper limit of 500 k€ for the EU Contribution to any project in this TP, and a minimum of 100 k€.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 10 % of the total EU Contribution to the project.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the "end user" community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Provide a lasting improvement in the European metrological capability and infrastructure beyond the lifetime of the project,

- Facilitate improved industrial capability or improved quality of life for European citizens in terms of personal health or protection of the environment,
- Transfer knowledge to the packaged liquids sector and the metrology community.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)".

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.