Report Final

Bilateral comparison of one 100 mL pycnometer

EURAMET identifier: 1587

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1 Introduction

The CIPM Mutual Recognition Arrangement (CIPM MRA) is the framework through which National Metrology Institutes demonstrate the international equivalence of measurement standards. In this context, BIPM publishes on the KCDB website a list of Calibration and Measurement Capabilities of the institutes which have signed the CIPM MRA. Calibration services can, however, only be included if a quality management system according to ISO/IEC17025 for competent laboratories is established. However, quality assurance and confidence in the capabilities of laboratories can be ensured by the successful participation in a comparison in which the degree of equivalence with other national metrology institutes or designate institutes is determined.
This comparison has been performed to support the existing liquid volume CMC claims of VSL in the KCDB after moving the volume laboratory from Dordrecht to Rotterdam Maasvlakte.
The comparison was coordinated and piloted by Timo Jacobs from VSL.
Per Wennergren from RISE was asked to determine the volume of one 100 mL glass pycnometer at a reference temperature of 20 °C using the gravimetric method to confirm the CMC of VSL for this volume. VSL is responsible for the evaluation of the comparison results.

2 Participants

	NMI	Country	Responsible	Contact
1.	**VSL**	The Netherlands	Timo Jacobs	**Email:** tjacobs@vsl.nl **Address:** VSL Walrusweg 5 3199 ME Maasvlakte (Rt) The Netherlands **Phone:** +31 6 1180 3647
2.	**RISE**	Sweden	Per Wennergren	**Email:** per.wennergren@ri.se **Address:** Research Institutes of Sweden Brinellgatan 4 501 15 Boras Sweden **Phone:** +46 105 16 54 67

3 Transfer standards

3.1 Technical details

One transfer standard (volumetric instrument) was chosen for this comparison:
1) One 100 mL glass pycnometer with serial number 14. The pycnometer is produced by Isolab (see figure 1).
The glass pycnometer used for this comparison is made of borosilicate glass with a cubical thermal expansion coefficient of 9.9×10^{-6} /ºC [2]. This coefficient is linked to the material and is equal for both participants.

3.2 Photo

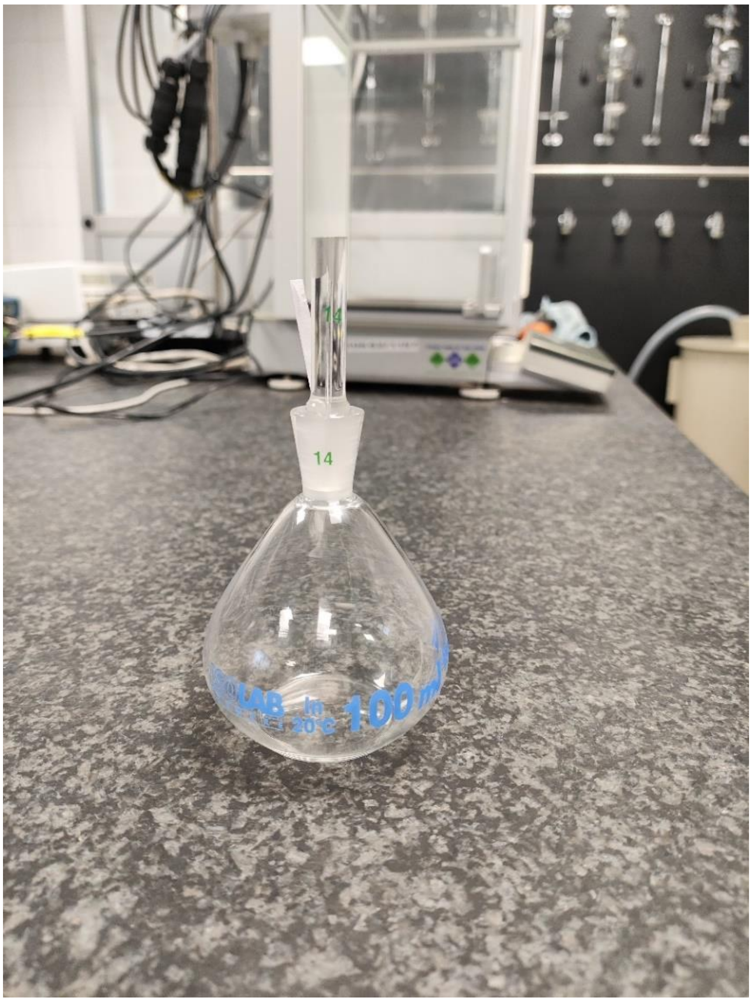


Figure 1 – The 100 mL glass pycnometer

4 The measurement procedure

4.1 Getting the volumetric instrument ready for volume measurements

The volumetric instrument must be handled with care, i.e., only by qualified metrology personnel. Avoid any mechanical shock. The instrument must be stored at a place where it is protected from dust, aerosols, and vapours.
Each participating laboratory shall make use of its own instruments and procedures to measure the volume. The gravimetric method for determination of the volume must be used.
For temperature uniformity, it is highly advisable to bring the volumetric instrument and the water to be used for these measurements into the laboratory at least 24 hours before any measurement is performed, at a temperature near 20 ºC.

4.2 Ambient conditions of the measurements

The ambient conditions of the laboratory room during the measurements should be the following:

- humidity higher than 50 %;
- ambient temperature between 17 ºC up to 23 ºC;

4.3 Measuring points

The glass pycnometer will be calibrated at its nominal volume of 100 mL.
10 consecutive measurements should be performed.

4.4 Volume determination formula

Calibration of the volumetric instrument will consist of the determination of the amount of water that the volumetric instrument contains at the reference temperature of 20 ºC, using the gravimetric method. The following equation described in EURAMET Calibration Guide No. 19 [1] can be used

$$\boldsymbol{V_0 = (I_L - I_E) \times \frac{1}{\rho_W - \rho_A} \times \left(1 - \frac{\rho_A}{\rho_B}\right) \times [1 - \gamma(t - t_0)]} \qquad (1)$$

With:

V_0 volume of the volumetric instrument, at the 20 ºC, in mL
I_L weighing result of the volumetric instrument full of liquid, in g
I_E weighing result of the empty volumetric instrument, in g
ρ_W water density, in g/L, at the calibration temperature t, in ºC
ρ_A air density, in g/L
ρ_B density of masses used during measurement (substitution) or during calibration of the balance in g/L
γ cubic thermal expansion coefficient of the material of the volumetric instrument, in °C^{-1}
t water temperature used in the calibration, in °C
t_0 reference temperature, in °C

4.5 Calibration procedure

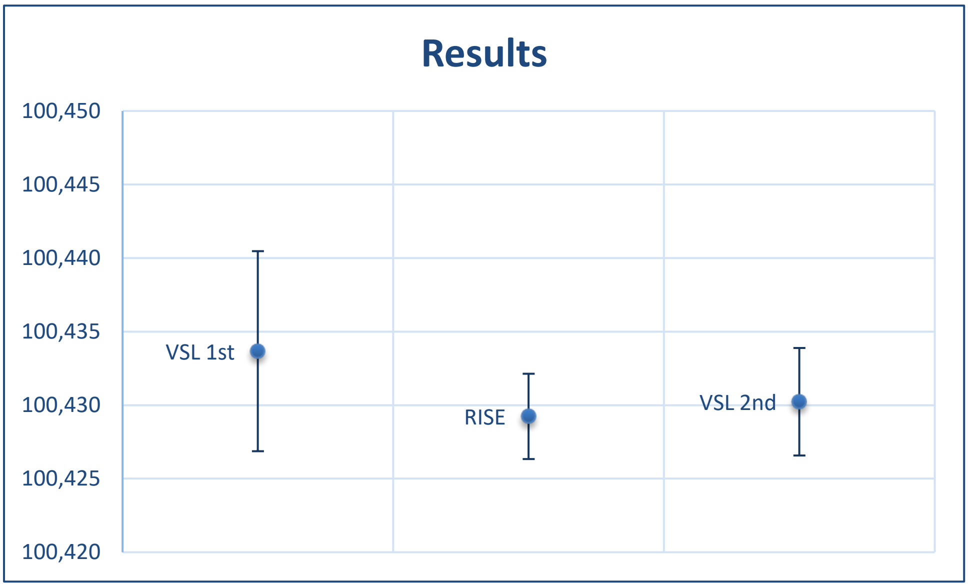
The laboratories should use their own calibration procedures for the gravimetric method.

5 Summarised results

5.1 Calibration results

The volumes (mL) at the reference temperature of 20 °C are:
VSL 1st: 100.434 mL
RISE: 100.429 mL
VSL 2nd 100.430 mL

The expanded measurement uncertainties (k=2) for these volumes are:
VSL 1st: 0.0068 mL
RISE: 0.0029 mL
VSL 2nd: 0.0037 mL



5.1 Drift evaluation

After the calibrations, VSL calibrated the volume of the pycnometer at the reference temperature of 20 °C.
Volume: 100.430 mL and with an expanded measurement uncertainty of 0.0037 mL
Drift is 0.004 mL per 1 year.
Drift was not included in the uncertainty used for the evaluation of the comparison data as the uncertainty from drift is insignificant.

5.2 Summary Equipment and other info

RISE:

Device	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler-Toledo	XPR205	0-220 g	10 µg
Thermometer for water measurement	Unisystem	U241	-73 - +135 °C	0,001 °C
Thermometer for air measurement	Vaisala	Indigo 520	-40 - +60 °C	0,01 °C
Barometer	Vaisala	Indigo 520	500 - 1100 hPa	0,01 hPa
Hygrometer	Vaisala	Indigo 520	0 - 100 %RH	0,01 %RH

CMC according BIPM

Quantity	Instrument or Artifact	Method of Measurement	Measurand	Uncertainty	Approval date	NMI Service Identifier	KCDB CMC ID
Volume of liquid	Glassware	Any type of instruments	[10.0 , 20000.0] mL	[0.01 , 0.003] % (Relative)	2019-09-11	SE1 + SE2 + SE3	EURAMET-M-SE-000008HA-2

VSL:

Device	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler-Toledo	AG245	0-210 g	0.1 mg
Thermometer for water measurement	Beamex	MC5-IS	-10 - +60 °C	0,01 °C
Thermometer for air measurement	Novasina	Quantadat	+14 - +30 °C	0,1 °C
Barometer	Drück	DPI 142	700 - 1150 hPa	0,001 hPa
Hygrometer	Novasina	Quantadat	15 - 95 %RH	0,1 %RH

CMC according BIPM

Quantity	Instrument or Artifact	Method of Measurement	Measurand	Uncertainty	Approval date	NMI Service Identifier	KCDB CMC ID
Liquid static volume	Laboratory volumetric instruments	Gravimetric method	[0.01 , 25.0] L	0.01 % (Relative)	2012-12-19	VSL/NE21	EURAMET-M-NL-000009GP-1

6 Evaluation of comparison measurement

The results are considered equivalent if:

$$\frac{|V_{RISE} - V_{VSL}|}{\sqrt{u_{RISE}{}^2 + u_{VSL}{}^2}} \leq 2 \qquad (2)$$

Where:
V_{RISE} = volume reported by RISE in mL
V_{VSL} = volume reported by VSL in mL
u_{RISE} = standard uncertainty reported by RISE in mL
u_{VSL} = standard uncertainty reported by VSL in mL

$\frac{|100.429 - 100.434|}{\sqrt{0.0015^2 + 0.0034^2}} \leq 2$ is true. The calculated value is 1.35.

7 Conclusion

The purpose of the bilateral comparison was to support the Calibration and Measurement Capabilities (CMC) of the National Metrology Institute of the Netherlands (VSL) for liquid volume after moving the volume laboratory to the new location.
The results have proven that moving the volume lab from the location Dordrecht to the new location in Rotterdam, had no effect on the measurement capabilities of VSL.

8 References

1. Euramet "Guidelines on the Determination of Uncertainty in Gravimetric Volume Calibration" Calibration Guide No.19 2018 v3.0;
2. Euramet "Guidelines on the Calibration of Standard Capacity Measures Using the Volumetric Method" Calibration Guide No. 21 2021 v2.1;
3. JCGM 100:2008; Evaluation of measurement data – Guide to the expression of uncertainty in measurement;
4. M.G. Cox, The evaluation of key comparison data, Metrologia, 2002, Vol. 39, 589-595.