



BILATERAL COMPARISON BETWEEN EIM (Greece) & DMDM (Serbia) IN THE FRAMEWORK OF EuropAid PROGRAM

Gravimetric Calibration of a 100 ml Volumetric Flask

Technical Report

Coordinator of the comparison

Zoe Metaxiotou (EIM)

September 2010

Abstract

*In the framework of the **EuropAid** program a bilateral comparison was organized between the Hellenic Institute of Metrology (EIM) and the Directorate of Measures and Precious Metals (DMDM) of the Republic of Serbia with the Laboratory of Fluid Flow & Volume of EIM acting as the pilot laboratory. The comparison aim was to evaluate the degree of agreement in the results and the stated uncertainties of the two laboratories in the calibration of a 100 ml volumetric flask using the gravimetric method. In this document the equipment used, the technical details and method of calibration applied by the participating laboratories, the results of their measurements and the degree of equivalence between the two laboratories are presented in detail.*

HELLENIC INSTITUTE OF METROLOGY (E.I.M.)
MECHANICAL MEASUREMENTS DEPARTMENT
Laboratory of Fluid Flow & Volume

Dr. Zoe Metaxiotou, Laboratory Head

Postal Address:

Industrial Area of Thessaloniki, SINDOS
Block 45
57 022, Thessaloniki
GREECE

Phone: + 30 2310-56 99 62, + 30 2310-56 99 99

Fax: + 30 2310-56 99 96

e-mail: zoe@eim.gr

Table of Contents

| | |
|---|----|
| Abstract | 2 |
| 1. Equipment | 4 |
| 2. Experimental Procedure & method of Calibration | 4 |
| 3. Calculations | 4 |
| 4. Time Schedule and Transportation | 5 |
| 5. Results | 6 |
| 6. Uncertainty evaluation | 7 |
| 7. Determination of the Reference Value | 8 |
| 8. Degree of Equivalence | 9 |
| 9. Conclusions | 10 |
| 10. Literature | 10 |
| APPENDIX I | 11 |
| APPENDIX II | 13 |

1. Equipment

The transfer standard (TS)

The transfer standard in this bilateral comparison is a 100 ml (class A) volumetric one mark flask (*Manufacturer: John Poulten Ltd, S/N: 84056, Asset Number: Δ4 / 0084*) and is provided by EIM. The flask is made of borosilicate glass with the following thermal characteristics:

- Cubical thermal expansion coefficient = $9,6E-06 \text{ } ^\circ\text{C}^{-1}$

2. Experimental Procedure and Method of Calibration

The purpose of this comparison was to determine the “contained” volume of the flask at 20 °C by the gravimetric method. Each laboratory was asked to use its own experimental procedure of calibration. However, in order to be able to compare the results on a common basis some basic experimental aspects should be kept common:

- Each laboratory should perform a series of ten (10) consecutive measurements. The measurements should preferably be performed within the same day.
- Fresh distilled or de-ionized water which satisfies the requirements of ISO 3696 standard should be used for the calibration.
- Adequate quantities of such water should be acclimatized in the laboratory where the measurements are going to be performed at least 24 hours before calibration.
- The prevailing ambient conditions and the temperature of the water should be recorded with auxiliary equipment which has valid calibration certificates at the time of the comparison.
- The TS to be used was clean and did not require any chemical cleaning before use. However, between consecutive runs the TS could be flashed with pure acetone and dried with dry clean compressed air. This is the procedure used at EIM.
- The operator was advised to use cotton gloves during the whole calibration procedure.
- Finally, it was strongly recommended to use optical means to determine the correct position of the meniscus.

The detailed experimental procedures and equipment used by the participating laboratories during their measurements are given in Appendix I and II for DMDM and EIM, respectively.

3. Calculations

The volume contained by the flask up to the mark at 20 °C should be calculated on the basis of the equation (1) according to ISO 4787.

$$V_{20} = (I_L - I_E) \cdot \left(\frac{1}{\rho_w - \rho_A} \right) \cdot \left(1 - \frac{\rho_A}{\rho_B} \right) \cdot (1 - \gamma(t_w - 20)) \quad (1).$$

It was recommended to use unified symbols for the different measures involved in the calculation of the contained volume according to the following list:

- V_{20} is the contained volume of the TS at 20 °C
- I_L is the balance indication for the filled standard, [g]
- I_E is the balance indication for the empty standard, [g]
- ρ_A is the air density, [g/cm^3]

- $\rho_B = 8.0 \text{ g/cm}^3$ is the density of the reference weights used
- ρ_w is the density of water at the temperature of measurement t_w , [g/cm^3]
- γ is the cubical thermal expansion coefficient of the material of the TS ($9,6 \times 10^{-6} \text{ }^\circ\text{C}^{-1}$)
- t_w is the water temperature during each measurement [$^\circ\text{C}$]

4. Time Schedule and Transportation of the TS

The bilateral comparison was completed in three stages. The calibration of the TS was first performed by the pilot laboratory (EIM). It was then sent to DMDM and after the completion of the measurements the TS was sent back to the pilot laboratory (EIM) for the final series of measurements. The first series of measurements at EIM were performed by the end of April 2010. The TS was sent back to EIM for the final series of measurements in June 2010. The final series of measurements were performed by the pilot laboratory in September 2010.

The transportation costs of this comparison are described in the relevant economic offer of EIM. The participants, the persons responsible, their contact details and the final time schedule followed are given in Table 1.

Table 1. List of participants in the Bilateral Comparison

| Country | NMI | Period | Responsible | Contact Details |
|-----------------------|------|--------------------------------|----------------|--|
| Greece | EIM | April 2010 / September 2010 | Zoe Metaxiotou | Laboratory of Fluid flow & Volume Block 45, Industrial Area of Thessaloniki, 57 022 SINDOS E-mail: zoe@eim.gr |
| Republic of Serbia | DMDM | June 2010 | Ljiljana Micic | Laboratory of Volume Directorate of Measures and Precious Metals Mike Alasa 14, 11000 Belgrade Serbia E-mail: ljmicic@dmdm.rs |

5. Results

The results obtained by the participating laboratories in the form of the average value of their 10 measurements and the corresponding expanded uncertainties are given in Table 2 and are also shown in Figure 1.

Table 2. Bilateral comparison results

| Laboratory | Volume (ml) | U_{exp} (ml) |
|------------|-------------|----------------|
| EIM-1 | 99,972 | 0,021 |
| DMDM | 99,998 | 0,019 |
| EIM-2 | 99,981 | 0,022 |

The detailed results of both laboratories are summarised in Table 3.

Table 3. Complete set of results as obtained by EIM-1 & 2 and DMDM

| BILATERAL COMPARISON BETWEEN EIM (Greece) AND DMDM (Republic of Serbia) | | | | | | |
|--|---|-----------|---------|----------------------------------|----------------------------------|----------------------------------|
| Gravimetric Calibration of a 100 ml Volumetric Flask (S/N: 84056) | | | | | | |
| Pilot laboratory | Laboratory of Flow & Volume, Hellenic Institute of Metrology (EIM) | | | | | |
| Person responsible | Dr. Zoe Metaxiotou, Laboratory Head | | | | | |
| Responsible for measurements | Dr. Zoe Metaxiotou, Laboratory Head | | | Date of calibration: | 30.04.2010 / | |
| Participating Laboratory | Laboratory of Volume, Directorate of Mesures and Precious Metals (DMDM) | | | Date of calibration: | 20.09.2010 | |
| Responsible for measurements | Ljiljana Mičić, Adviser - Metrologiest for volume | | | Date of calibration: | 21.06.2010. | |
| Measured Volume and Uncertainties | | | | DMDM | EIM-1 | EIM-2 |
| | No | | | GRAVIMETRIC | GRAVIMETRIC | GRAVIMETRIC |
| | Test | | | METHOD | METHOD | METHOD |
| | | | | Contained Volume at 20 °C | Contained Volume at 20 °C | Contained Volume at 20 °C |
| | | | | V₂₀ [ml] | V₂₀ [ml] | V₂₀ [ml] |
| | 1 | | | 99,986 | 99,959 | 99,971 |
| | 2 | | | 99,992 | 99,960 | 99,985 |
| | 3 | | | 99,989 | 99,979 | 99,984 |
| | 4 | | | 99,995 | 99,975 | 99,997 |
| | 5 | | | 100,000 | 99,966 | 99,995 |
| | 6 | | | 99,999 | 99,976 | 99,966 |
| | 7 | | | 99,996 | 99,971 | 99,971 |
| 8 | | | 100,003 | 99,972 | 99,993 | |
| 9 | | | 100,003 | 99,981 | 99,973 | |
| 10 | | | 100,012 | 99,980 | 99,977 | |
| Average Contained Volume | | mL | | 99,998 | 99,972 | 99,981 |
| Type A Uncertainty | u(A) | mL | | 0,0025 | 0,003 | 0,004 |
| Type B Uncertainty | u(B) | mL | | 0,0092 | 0,0102 | 0,0102 |
| Combined Uncertainty | u | mL | | 0,0095 | 0,011 | 0,011 |
| Degrees of Freedom | n | | | 196 | 9 | 9 |
| Coverage factor at 95% c.l. | k | | | 2,00 | 2,00 | 2,00 |
| Expanded Uncertainty | U | mL | | 0,019 | 0,021 | 0,022 |

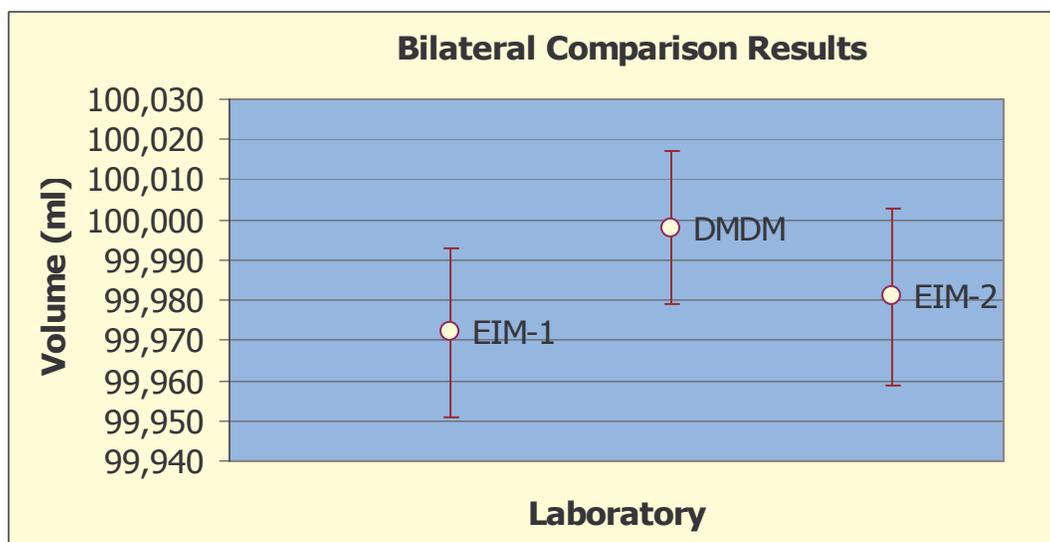


Figure 1. Volume results in graphical form

6. Uncertainty evaluation

The details of the uncertainty evaluation in the determination of the volume of the 100 ml flask by DMDM are given in Table 4.

Table 4. Uncertainty budget of DMDM

| UNCERTAINTY BUDGET DMDM | | | | | | | |
|--|-------------------|---------------|--------------------|-------------------|---------------------|---------------|--------------------|
| Calibration of 100 ml volumetric flask | | | | | | | |
| Variable | Units | Best estimate | Source of infor | Stand.uncertainty | Sensitivity coeffic | Contribution | Degrees of freedom |
| | | \bar{x}_i | | $u(x_i)$ | c_i | $u_i(V_{20})$ | |
| repeatability | | | | | | | |
| | cm ³ | 2,48E-03 | | 2,48E-03 | 1,00E+00 | 0,0025 | 9 |
| balance | | | | | | | |
| resolution | g | 1,00E-04 | sertificate | 2,89E-05 | 1,004 | 2,90E-05 | ∞ |
| weights | | | | | | | |
| calibration | g | 3,57E-04 | OIML R 111 | 2,06E-04 | 1,0036 | 2,07E-04 | ∞ |
| density | g/cm ³ | 7,95 | OIML R 111 | 7,00E-02 | 1,84E-03 | 1,29E-04 | ∞ |
| air density | | | | | | | |
| air density | g/cm ³ | 0,001164 | EURAMET/cg-19/v.01 | 2,89E-07 | 87,7954 | 2,53E-05 | 9 |
| water density | | | | | | | |
| variation of density | g/cm ³ | 0,00015 | estimation | 4,27E-05 | -1,00E+02 | -4,28E-03 | 9 |
| Tanaka formula | g/cm ³ | 0,99740 | reference* | 4,50E-07 | -1,00E+02 | -4,52E-05 | ∞ |
| water temper | | | | | | | |
| calibration | ?C | 23,59 | sertificate | 0,003 | -9,60E-04 | -2,88E-06 | ∞ |
| artifact | | | | | | | |
| expans coef | ?C ⁻¹ | 9,60E-06 | protocol | 2,77E-07 | -3,59E+02 | -9,96E-05 | ∞ |
| meaniskus | | | | | | | |
| reading meanis | cm ³ | 0,0081 | | 0,0081 | 1 | 8,12E-03 | ∞ |
| | | | | sum of squares | 0,000091 | | |
| | | | | Stand.uncertainty | 0,0095 | | |
| | | | | effective df | 196,9 | | |
| | | | | t(95) | 2,00 | | |
| | | | | expanded uncert | 0,019 | | |
| Volume at 20°C | cm ³ | 99,998 | | | | | |

Source of uncertainty

1. Measurement repeatability is obtained as experimental standard deviation of measurement results divided by square root of number of measurement results.
2. The standard uncertainty of the balance is obtained from the resolution of the balance using a rectangular distribution.
3. According to OIML R111 - 1: 2004, Weights of classes E1, E2, F1, F2, M1, M2, M3 standard uncertainty for weights is estimated from maximum permissible error of weights class E2 and assumed density.
4. The standard uncertainty of the air density is obtained from the value provided by Spieweck's
5. The standard uncertainty of the water density is obtained from the value provided by Tanaka and also from the difference between maximum and minimum value of water density.
6. The standard uncertainty of the water temperature is obtained from the value of the thermometer calibration using a coverage factor of 2.
7. The cubical thermal expansion coefficient of the flask is given in protocol, we assumed the expanded uncertainty of 5% and rectangular distribution.
8. The standard uncertainty of meniscus reading is obtained from geometric approach, based on ISO 4787 and taking into account the error in meniscus position and the neck diameter.

The corresponding calculations for EIM are presented in Table 5.

Table 5. Uncertainty budget of EIM

Uncertainty evaluation for gravimetric determination of a 100 ml volumetric flask (Contained Volume)

Mathematical model:

$$V_{20} = (I_f - I_e) \times \left(1 - \frac{\rho_a}{\rho_s}\right) \times \left(\frac{1}{\rho_w - \rho_a}\right) \times [1 - \beta(T - 20)] = \left(\frac{O_{2f} m_f}{O_{1f}} - \frac{O_{2e} m_e}{O_{1e}}\right) \times \left(1 - \frac{\rho_a}{\rho_s}\right) \times \left(\frac{1}{\rho_w - \rho_a}\right) \times [1 - \beta(T - 20)] = 99,9593$$

| definition | symbol | factors of uncertainty in connection with the mathematical model | | | |
|--|-----------------------------------|--|--------------------------------------|----------------------------|---|
| nominal mass of control weights equal to filled standard | m_f (kg) | 0,148258142 kg | $u(m_f)$ (kg) | 2,45E-07 kg | |
| nominal mass of control weights equal to empty standard | m_e (kg) | 0,048590114 kg | $u(m_e)$ (kg) | 1,69E-07 kg | |
| density of control weights | ρ_{ss} (kg/m ³) | 7950 kg/m ³ | $u(\rho_{ss})$ (kg/m ³) | 70 kg/m ³ | |
| density of air | ρ_{air} (kg/m ³) | 1,201330745 kg/m ³ | $u(\rho_{air})$ (kg/m ³) | 0,000435 kg/m ³ | |
| density of water at actual temperature | ρ_{H2O} (kg/m ³) | 998,1313573 kg/m ³ | $u(\rho_{H2O})$ (kg/m ³) | 0,02 kg/m ³ | |
| temperature of water in the standard | T_{H2O} (°C) | 20,36 °C | $u(T_{H2O})$ (°C) | 0,015 °C | |
| coefficient of cubical thermal expansion of the material of the standard | β (1/°C) | 9,60E-06 1/°C | $u(\beta)$ (1/°C) | 4,80E-07 1/°C | |
| balance indication for filled standard | O_{2f} | 0,14825812 | $u(O_{2f})$ | 5,00E-08 kg | zoe: Για την ανάλυση της τιμής της αβεβαιότητας βλ. διπλά |
| balance indication for control weights of nominal mass m_f | O_{1f} | 0,15 | $u(O_{1f})$ | 5,00E-08 kg | |
| reference temperature of standard | | 20 °C | | 0 °C | |
| balance indication for empty standard | O_{2e} | 0,04859022 | $u(O_{2e})$ | 5,00E-08 kg | |
| balance indication for control weights of nominal mass m_e | O_{1e} | 0,0486 | $u(O_{1e})$ | 5,00E-08 kg | |
| additional uncertainty factors | | | | | |
| air bubbles in the water | | | $u(\Delta_{bb})$ | 0 ml | |
| error in reading the water meniscus | | | $u(\Delta_{mr})$ | 0,010 ml | |
| variation in the amount of liquid residue | | | $u(\Delta_r)$ | ml | |
| loss by the evaporation | | | $u(\Delta_e)$ | ml | |

Uncertainty in balance indication

$$u_{ind} = \sqrt{u_{res}^2 + u_{ecc}^2} = 0.051 \text{ mg}$$

$u_{res} = 0.01 \text{ mg}$

$u_{ecc} = 0.2 \text{ mg}$

The uncertainty due to eccentric loading is estimated to be much smaller than the above figure in practice and a maximum value should be 0,05 mg.

Calculation of sensitivity coefficients

| Pm_f | Pm_e | $P\rho_{ss}$ | $P\rho_{air}$ | $P\rho_{H2O}$ | PT_{H2O} | $P\beta$ | PO_{2f} | PO_{1f} | PO_{2e} | PO_{1e} | $P\Delta_{er}$ |
|-------------------------|-------------------------|-------------------------------------|---------------------------------------|---------------------------------------|---------------------------------|-----------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|---|
| 0,001002924 | -0,001002925 | 1,90028E-12 | 1,00297E-07 | 1,00267E-07 | -9,60E-10 | -3,61101E-05 | 0,001002924 | -0,001002923 | -0,001002923 | 0,001002924 | 1 |
| $Pm_f^2 \cdot u(m_f)^2$ | $Pm_e^2 \cdot u(m_e)^2$ | $P\rho_{ss}^2 \cdot u(\rho_{ss})^2$ | $P\rho_{air}^2 \cdot u(\rho_{air})^2$ | $P\rho_{H2O}^2 \cdot u(\rho_{H2O})^2$ | $PT_{H2O}^2 \cdot u(T_{H2O})^2$ | $P\beta^2 \cdot u(\beta)^2$ | $P^2O_{2f} \cdot u(O_{2f})^2$ | $P^2O_{1f} \cdot u(O_{1f})^2$ | $P^2O_{2e} \cdot u(O_{2e})^2$ | $P^2O_{1e} \cdot u(O_{1e})^2$ | $P^2\Delta_{er} \cdot u(\Delta_{er})^2$ |
| 6,04E-20 | 2,85586E-20 | 1,76942E-20 | 1,90352E-21 | 4,0214E-18 | 2,07193E-22 | 3,00428E-22 | 2,51464E-21 | 2,51464E-21 | 2,51E-21 | 2,51E-21 | 1,00E-04 |
| 6,04E-08 | 2,85586E-08 | 1,77E-08 | 1,90352E-09 | 4,02E-06 | 2,07193E-10 | 3,00E-10 | 2,51464E-09 | 2,51E-09 | 2,51E-09 | 2,51E-09 | 1,00E-04 |
| u_i [ml] | 0,000245716 | 0,000168993 | 0,00013302 | 4,36294E-05 | 0,002005343 | 1,43942E-05 | 1,73329E-05 | 5,01462E-05 | 5,01462E-05 | 5,01462E-05 | 0,01 |

Standard uncertainty (u) 1,02E-02 Type B
Expanded uncertainty (U) 0,020409851

| | | | | |
|--------------------|---|-----------|---------------|----------|
| Measurement result | = | 99,972 ml | ± | 0,021 ml |
| | | | Rel. Tot. U = | 0,021 % |

7. Determination of the bilateral comparison reference value

The reference value was determined as the average value of the two results of EIM while its uncertainty was set equal to the highest uncertainty value obtained by EIM. Thus the bilateral comparison reference value and its uncertainty are equal to:

$$\bar{X}_{EIM} = 99,977 \text{ ml} \pm 0,022 \text{ ml}$$

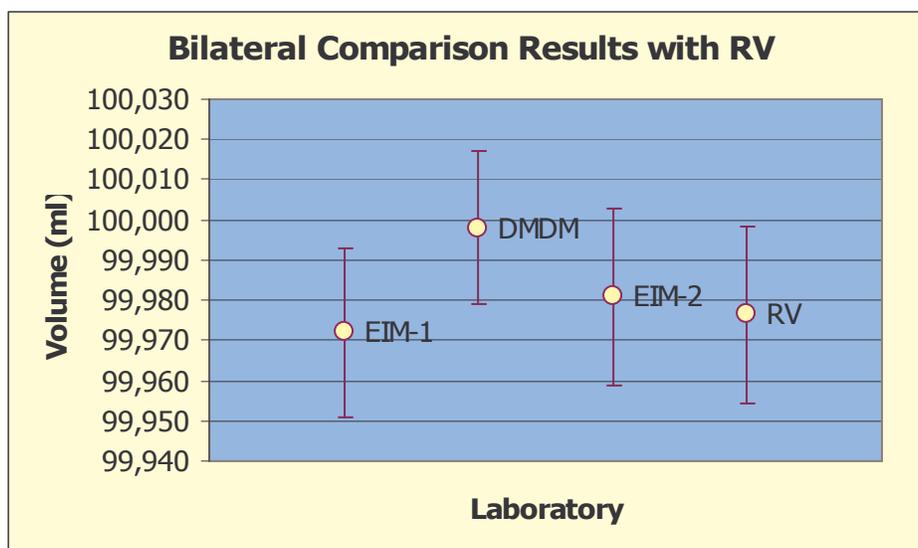


Figure 2. Volume results with reference value

8. Degree of equivalence

The degree of equivalence between the two laboratories was calculated according to the equation (2) and is given in Table 6.

(2)

$$E_n = \frac{(X_{DMDM} - \bar{X}_{EIM})}{\sqrt{U_{DMDM}^2 + U_{EIM}^2}} \leq 1$$

where:

- X_{DMDM} = Volume result, DMDM [ml]
= Reference value as determined by the two volume determinations of EIM, [ml]
- \bar{X}_{EIM}
- U_{DMDM} = Expanded uncertainty in volume, DMDM [ml]
 U_{EIM} = Expanded uncertainty in reference value of EIM, [ml]

Table 6. Degree of Equivalence between EIM and DMDM

| Calculation of the Degree of Equivalence between EIM and DMDM in the Gravimetric determination of the volume of a 100 ml flask | | | | | |
|--|-------------|--------|-------------|--------|-------------|
| Nominal volume [ml] | DMDM | | EIM | | E_n |
| | Volume [ml] | U [ml] | Volume [ml] | U [ml] | |
| 100 | 99,998 | 0,019 | 99,977 | 0,022 | 0,72 |

According to Table 6 the two laboratories are considered to be equivalent with respect to the gravimetric calibration of a 100 ml volume flask.

9. Conclusions

A bilateral comparison of a 100 ml volume flask was organized between EIM (Greece) and DMDM (Republic of Serbia) with EIM acting as pilot laboratory. The comparison reference value was determined by the laboratory of Volume of EIM as the average of the two volume determinations obtained in the beginning and the end of the comparison.

Minor differences in the calibration procedure were found which, however, did not noticeably affect the degree of agreement between the two laboratories. During calibration DMDM filled the artefact just once and produced the series of 10 repeated measurements by slightly emptying the flask, filling again and readjusting the meniscus. EIM on the other hand completely emptied and dried the flask between consecutive measurements.

No significant differences were either found in the uncertainty budgets of the two laboratories. The relative magnitudes of the Type A and Type B uncertainties reported were approximately the same.

Finally, satisfactory agreement between the two laboratories was also found based on the calculated degree of equivalence.

10. Literature

- [1] ISO 4787 (1984), Laboratory Glassware – Volumetric Glassware – Methods for Use and Testing of Capacity.
- [2] ASTM E542: Standard Practice for Calibration of laboratory Volumetric Apparatus (2000).
- [3] BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, Guide to the expression of uncertainty in measurement (GUM), Geneva, 1995.
- [4] M.G.Cox, "The evaluation of key comparison data", Metrologia, 2002, Vol. 39, 589-595.

APPENDIX I

Experimental Procedure & Equipment DMDM

MEASUREMENT PROCEDURE

Gravimetric calibration of 100 ml volumetric flask - Bilateral comparison EIM - DMDM

We used single substitution gravimetric method.

- Weigh the empty flask clean and dry
- Weigh a set of weights of known value close to the mass of empty flask
- Put the flask on plane surface and fill it with water
- Adjust the meniscus. Cover the flask
- Ensure that there are no water droplets adhere to the exterior of the flask or the inner walls above the meniscus and that there are no bubbles in water
- Weigh the flask with water and record the value of the mass
- Weigh a set of weights of known value close to the mass of full flask
- Measure the water temperature
- Read the ambient air parameters
- In the following tests remove a small amount of water, adjust the meniscus and this cycle is repeated ten times

Used volume calculation formula:

$$V_{20} = (I_L - I_E) \frac{1}{\rho_W - \rho_A} \left(1 - \frac{\rho_A}{\rho_B} \right) [1 - \gamma(t - 20)] = \left(\frac{O_{2f} m_f}{O_{1f}} - \frac{O_{2e} m_e}{O_{1e}} \right) \frac{1}{\rho_W - \rho_A} \left(1 - \frac{\rho_A}{\rho_B} \right) [1 - \gamma(t - 20)]$$

| TECHNICAL SPECIFICATIONS AND TRACEABILITY | | | | | | | |
|--|---|---|-------------------|------------|----------------------|------------------|---|
| TECHNI SPECIF | | | | | | | |
| Gravimetric calibration of 100 ml volumetric flask - Bilateral comparison EIM - DMDM | | | | | | | |
| Instrument | Manufacturer | Type | Upper range value | Resolution | Standard uncertainty | Calibration date | Traceability |
| Balance | Sartorius AG | | 250 g | 0,0001 g | | | |
| Weights | HAIGIS | | N.A. | E1 | | 2004 | DKD |
| Water temperature | Fluke Corporation Hart Scientific Division | Thermometer model 1521 with 100 Ohm PRT model 5618B-6 | | 0,001 °C | 0,006 °C | 14.06.2010. | DMDM |
| Ambient temperature | TESTO, Germany | testo 177-H1 data logger | | 0,1 °C | 0,06 °C | 10.06.2010. | DMDM |
| Pressure | Ficher, Germany | 104 | | 100 Pa | 60 Pa | 17.11.2008. | DMDM |
| Relative Humidity | TESTO, Germany | testo 177-H1 | | 0,10% | 1% | 02.06.2008. | Faculty of physics, University of Belgrade |
| | | | | | | | |

| | Production Method | De-aerated (Yes or no) | Density formula (or table) |
|---------------|----------------------|------------------------|--|
| Water density | Tanaka | Yes | $\rho = a_5 \{ 1 - [(t+a_1)^2 (t+a_2)] / a_3 (t+a_4) \}$ |
| Type of water | Ultra pure distilled | | |

APPENDIX II

Experimental Procedure & Equipment EIM

Calibration Equipment and Environmental Conditions

The following equipment was used for the gravimetric calibration of the 100 ml flask:

- A Mettler-Toledo XP 205 analytical balance
 - Capacity 220 g
 - Resolution 0.01 mg
- A set of standard weights in (1,2,2,5) series with nominal values 1 mg...5 kg F1 OIML class
 - Calibration certificate: MAS-08-003C / EIM 2008

The temperature of the water was measured with a Pt-100 thermometer accompanied by an Agilent 34401A digital multi meter (Calibration certificate: TEM-10-002B / EIM 09.03.2010).

The ambient temperature and relative humidity in the laboratory were measured with a Rotronic A.G. digital thermo hydrometer. Atmospheric pressure was measured with a Lufft precision aneroid barometer with 0,5 mbar resolution.

All equipment used as well as adequate quantities of fresh and clean water was acclimatized in the laboratory one day before the actual measurements. The temperature, pressure and relative humidity within the laboratory were stabilized within $\pm 0,7$ °C, ± 2 mbar and ± 2 % respectively, during the volumetric determinations.

The density of the water used during this exercise was measured as a function of temperature in the range of the actual water temperatures with an Anton Paar DMA 5000 density meter. Based on these results a linear function was established for this limited temperature range and it was used as such for the calculation of the density of water.

Calibration method

A single substitution weighing scheme was applied for the determination of the mass of the water using appropriate reference weights. The ISO 4787 standard formula was used for the volume calculation modified accordingly to be suited for the single substitution weighing scheme applied. Ten runs were executed in each measurement series while the flask was emptied and dried between consecutive runs. All 10 runs were performed during the same day. Distilled water was used for the calibration of the volumetric flask. The water was not de-aerated.