Final report

EURAMET key comparison EURAMET.M.M-K2.6 (1345)
of mass standards of 100 mg, 2 g, 20 g, 500 g (sub-multiple of the kilogram)

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1 Introduction

This report describes a European regional bilateral key comparison of stainless steel standards of 100 mg, 2 g, 20 g, and 500 g as a submultiple of the kilogram carried out under the auspices of EURAMET and designated project 1345. This comparison is also a KCDB Regional Key Comparison, registered as EURAMET.M.M-K2.6.

The objectives of the comparison were to check the measurement capabilities in the field of mass of BEV and provide a basis for the review of new calibration measurement capabilities (CMC).

Results are linked to the key comparison reference values of CCM.M-K2 ([2]).

BEV (Austria) was the pilot laboratory and the provider of the transfer standards. NPL provided the link to the CCM KC and MKEH collected the measurement data and helped ensuring impartiality.

Table 1: List of Participating Laboratories

Laboratory		Country
Bundesamt für Eich- und Vermessungswesen	BEV	Austria
National Physical Laboratory	NPL	United Kingdom

The time schedule

Table 1: Time schedule of the comparison

Time - start	Time - end	Action
June 2014	July 2014	Measurements in BEV
August 2014	September 2014	Measurements in NPL
October 2014	November 2014	Draft A
December 2014	December 2014	Draft B
January 2015	January 2015	Final Draft

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List of contact persons

Table 2: List of contact persons

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Description of the transfer standards

The transfer standards consisted of four weights with nominal values 100 mg, 2 g, 20 g, and 500 g. The 100 mg is a plate the others are OIML cylindrical design.

The density and the magnetic susceptibility of the transfer standards were determined by the pilot laboratory. The densities of the mass standards above 1 g were determined by hydrostatic weighing, the density of the 100 mg weight was assumed based on a value provided by the weight manufacturer.

Table 3: Data of transfer standards (density and volume)

nominal value	**density ρ kgm^{-3}**	**uncertainty U_ρ kgm^{-3}**	**volume V cm^3**	**uncertainty U_v cm^3**	**gravity heights [mm]**
500 g	8010,18	0,2	62,421 0	0,001 6	28,70
20 g	8011,39	0,5	2,496 44	0,0001 6	9,84
2 g	8002,60	6	0,249 92	0,0001 9	4,82
100 mg	8015 (Manufacturer)	60	-	-	-

Table 4: Data of magnetic properties

nominal value	**magnetic susceptibility χ**	**uncertainty u_χ**
All weights	≤0,004	0,001

3 Summary of results reported by the participants

Stability of the transfer standards

The transfer standards were measured twice at BEV. The first (Mass I.) was the official measurement nominally dated on the 11.07.2014. The second (Mass II.) was done after the weights had returned to BEV, dated on the 23.11.2014.

The drift of the travelling standard was modelled by a linear equation based on the stability measurements by BEV and the elapsed time between these measurements.

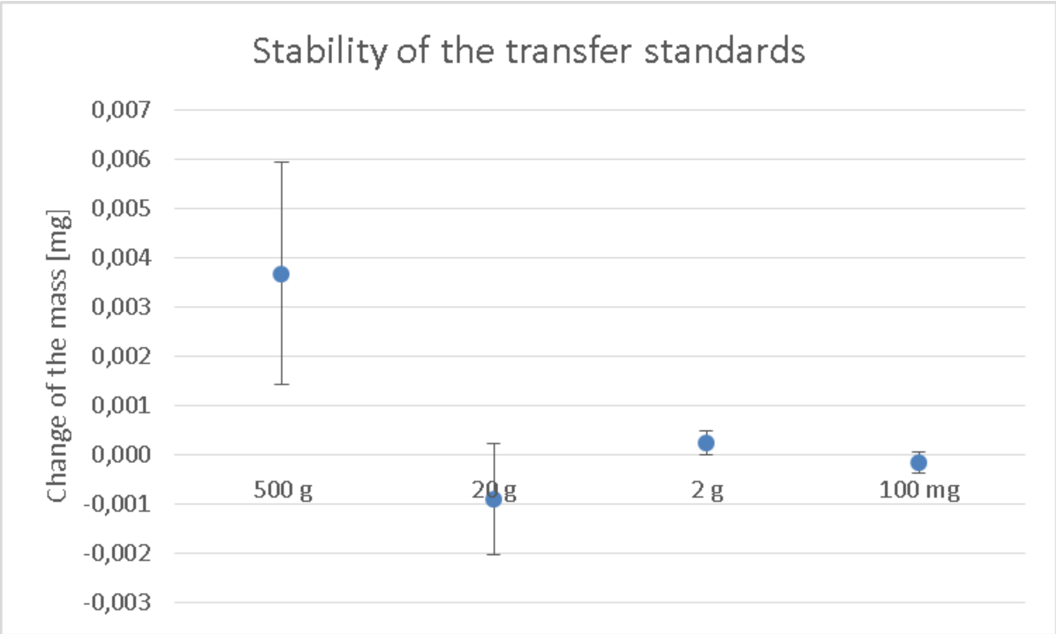
Table 5: Data of the stability of the transfer standards

Nominal value	Mass I. Nominal + [mg]	Mass II. Nominal + [mg]	Drift [mg]	U_{Drift} (k=2) [mg]
500 g	3,684 0	3,687 7	0,003 7	0,002 3
20 g	-0,052 2	-0,053 1	-0,000 9	0,001 1
2 g	-0,011 6	-0,011 3	0,000 26	0,000 24
100 mg	-0,144 5	-0,144 6	-0,000 15	0,000 21

The uncertainty of the drift (U_{Drift}) was calculated by taking into account the strong correlation between the measurements carried out at BEV.

The analysis shows that there was a moderate drift in case of the 500 g standards. All the other standards might be considered as having no drift at all. For the sake of the best results, the corrections for the drift were applied for each travelling standards.

Figure 1: Stability of the transfer standards



Measured values of mass and uncertainties

The results have been expressed as the reported mass value and the associated expanded uncertainty. For the pilot (BEV) the values of the first measurements (BEV I) were used in the evaluation. The results are shown in Table 6 alongside their corresponding expanded uncertainty (k=2).

Table 6: Reported true mass values and the associated expanded uncertainties

Laboratories	Measured true mass	expanded uncertainty U(k=2)
BEV I	500 g +3,684 0 mg	0,014 0 mg
NPL	500 g +3,686 4 mg	0,013 8 mg
BEV II	500 g +3,687 7 mg	0,014 4 mg
BEV I	20 g -0,052 21 mg	0,002 0 mg
NPL	20 g -0,051 4 mg	0,002 0 mg
BEV II	20 g -0,053 1 mg	0,002 0 mg
BEV I	2 g -0,011 6 mg	0,000 4 mg
NPL	2 g -0,011 1 mg	0,000 8 mg
BEV II	2 g -0,011 3 mg	0,000 4 mg
BEV I	100 mg -0,144 47 mg	0,000 3 mg
NPL	100 mg -0,144 80 mg	0,000 4 mg
BEV II	100 mg -0,144 62 mg	0,000 3 mg

BEV I and NPL were carried out using a subdivision method, while BEV II measurements were carried out only using direct comparison with multiple standards.

Calculation of reference values and the associated uncertainties

The reference values of this comparison are the measured values of the link laboratory (NPL) corrected with the results of the degree of equivalence given in the report of CCM.M-K2. These values were also corrected for the drifts of the travelling standards to the time of the measurements carried out by BEV.

The reference value in this comparison was:

$$m_{ref}=m_{NPL}-(D_i)_{NPL,CCM.M\text{-}K2}+m_{Drift}$$

$$\boldsymbol{m_{Drift}=(\Delta m\ /\ \Delta t_T)\ x\cdot\Delta t}\ \ [mg],$$

where:

Δm is the change of mass between BEV II and BEV I measurements
- Δt_T is the total elapsed time in days between BEV II and BEV I measurements
- Δt is the time in days between the measurement of NPL and BEV.

The uncertainty of the reference value has been calculated with the following assumptions:

- The correlation coefficients associated with a measured values provided by the linking laboratory in this comparison and the CCM.M-K2 were 0,3 for the 500 g standard and 0,1 for the other ones. These values were estimated, based on the relative long time between the CCM.M-K2 comparison and this comparison.
- The correlations associated with measured values provided by the participant and the linking laboratory are negligible.

- Uncertainty of the instability (drift) of the travelling standards are negligible. $u(m_{inst})$

$$u^2\,(m_{ref}) = u^2(m_{NPL}) + u^2[(D_i)_{NPL,CCM.M\text{-}K2}] - 2\cdot cov\,[m_{NPL}, (D_i)_{NPL,CCM.M\text{-}K2}] + u^2(m_{inst})$$

Table 7 a. Data for the calculation of the reference values

	Equivalence of NPL in CCM.M-K2		NPL results in this comparison		Correlation
Nominal value	D_i [mg]	$U(D_i)$ [mg]	Mass [mg]	U (k=2) [mg]	
500 g	-0,001	0,017	3,686 4	0,013 8	0,3
20 g	0,000 8	0,005 3	-0,051 4	0,002 0	0,1
2 g	0,000 1	0,001 5	-0,011 1	0,000 8	0,1
100 mg	0,000 1	0,001	-0,144 8	0,000 4	0,1

Table 7 b. Reference values without and with correction for the drift.

	Reference value without drift correction	Drift corrected reference values for the time of the BEV I measurement	
Nominal value	Mass [mg]	Mass [mg]	U (k=2) [mg]
500 g	3,687 4	3,685 9	0,021 8
20 g	-0,052 2	-0,051 9	0,005 7
2 g	-0,011 2	-0,011 3	0,001 7
100 mg	-0,144 9	-0,144 8	0,001 08

4 Degree of equivalence, mass difference and uncertainty between the measured values of BEV and the reference values

In order to compare the values of BEV it was necessary to link them to the reference values of the comparison CCM.M-K2 through the link laboratory (NPL).
The mass differences between BEV and the key comparison reference values (KCRVs) of the CCM.M-K2 value were calculated from:

$$D_{iBEV} = m_{BEV} - m_{ref}$$

The uncertainties have been calculated in accordance with the GUM [1]. The uncertainties of the differences between the measurements of BEV and the reference values contain two components:

- the uncertainty of the reference value $u(m_{ref})$
- the uncertainty of the measurement of BEV $u(m_{BEV})$

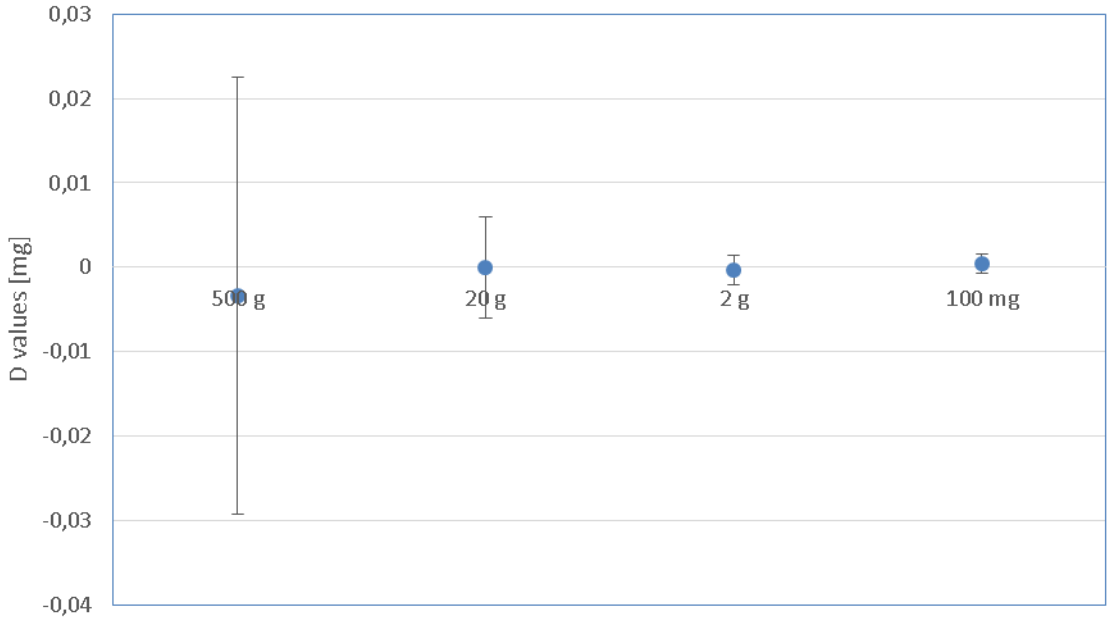
$$u^2\,(D_{iBEV}) = u^2\,(m_{ref}) + u^2(m_{BEV})$$

The degree of equivalence is defined [3] by two quantities: first the difference between the value obtained by the laboratory and the reference value and second the uncertainty of this difference at a level of 95 % confidence. The mass difference between BEV measurements m_{BEV} and the KCRVs of CCM.M-K2 along with the associated uncertainty can be found in Table 8 and seen in Figure 2.

Table 8. Degree of equivalence of the BEV measurements.

Nominal value	D_{iBEV} [mg]	U (D_{iBEV}), (k=2) [mg]
500 g	-0,003 40	0,025 8
20 g	-0,000 01	0,006 0
2 g	-0,000 40	0,001 75
100 mg	0,000 43	0,001 12

Figure 2: Degrees of equivalence of the BEV measurements



6. Discussion

The objectives of the present comparison were to check the measurement capabilities in the field of mass of BEV to demonstrate the metrological equivalence between the laboratories in Europe, and to check and support the calibration measurement capabilities (CMC).

The results of this comparison are linked to the Key Comparison CCM M.M-K2.

For acceptable measurement results in a comparison with a known reference value, the condition $|m_{BEV}-m_{ref}| < U(m_{BEV}-m_{ref})$ should be fulfilled. This condition is fulfilled for all weights in this comparison (see Table 8: the absolute values of D_{iBEV} are smaller than the associated expanded uncertainties $U(D_{iBEV})$.

8 References

[1] Guide to the Expression of Uncertainty in Measurement, BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 1993

[2] Final Report on CIPM key comparison of multiples and submultiples of the kilogram (CCM.M-K2), Metrologia 40 (2003)

[3] Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes, BIPM, Paris, 14 October 1999