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EURAMET.M.M-S11.1

Comparison of mass standard, 20 kg

SUPPLEMENTARY COMPARISON

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Final Report
EURAMET.M.M-S11.1
BILATERAL COMPARISON OF MASS STANDARDS: 20 kg

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Abstract
In order to validate SMU's calibration measurement capabilities (CMCs), this supplementary comparison of mass standard has been carried out under the auspices of the EURAMET. EURAMET identifier is 1715. This is a comparison of the 20 kg stainless steel mass standard. BEV, Austria was the pilot laboratory. Measurements were performed between 9 June 2025 – 11 September 2025.
The results of the two laboratories were not in agreement.

1. Introduction

This is a comparison of the 20 kg stainless steel mass standard. The objectives of the comparison were to validate the SMU's calibration measurement capabilities (CMCs). The comparison was undertaken within the EURAMET. The comparison was piloted by BEV, Austria. It was initiated after the SMU in the previous comparison (EURAMET.M.M-S11) was not in agreement with the comparison reference value.

2. Participants

Two National Metrology Institutes took part in this supplementary comparison.
The participating laboratories are listed in Table 1.

Table 1. Participating laboratories

National Institute of Metrology	Acronym	Country
Bundesamt für Eich- und Vermessungswesen (Federal Office of Metrology and Surveying)	BEV	Austria
Slovenský Metrologický Ustav	SMU	Slovakia

3. MASS COMPARATOR USED BY PARTICIPANTS

The weighing instruments used by participating laboratories are listed in Table 2.

Table 2. Weighing Instruments used by participant laboratories.

NMI	Manufacturer	Type	Range	Resolution	Standard deviation of balance
BEV	BEV, Sartorius	Robot comparator based on CC20000 mass comparator	20 kg	1 mg	0.03 mg, 10 cycles ABA
SMU	Mettler Toledo	Mass comparator KA-30/P	23 kg	2 mg	2 mg for 10 cycles ABBA

Note: Certain commercial equipment, instruments, or materials are identified in this paper to foster understanding. Such identification does not imply recommendation or endorsement by any of the participating organisations nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

4. TRAVELLING STANDARD

The travelling standard for this comparison was a 20 kg weight (stainless steel). The travelling standard and transportation box are presented in Picture 1.



Picture 1. The mass standard and the box

The properties of the mass standard have been determined by BEV and are listed in Table 3.

Table 3. Data on the travelling standard

Identification	MM003595
Nominal Value	20 kg
Density at 20 °C	8013.1 kg/m^3
Standard uncertainty	1.5 kg/m^3
Coefficient of cubic expansion 10^{-6} °C^{-1}	48
Magnetic susceptibility	< 0.004
The centre of gravity height	97.3 mm. u=0.3 mm
Height	225.1
Serial number	1942950

BEV used this standard in the monitoring of the travelling standard of the previous comparison, so its mass and stability was known and considered as very good.

5. CIRCULATION OF THE TRAVELLING STANDARD

For this comparison, the weight was circulated among participants according to the dates listed in Table 4.

BEV measured the mass of the standards at the beginning and at the end of the circulation in order to evaluate the stability of the transfer standard.

Table 4. Circulation of the transfer standard

NMI	**Arrival date**	**Departure date**
BEV1	–	31.07.2025
SMU	31.07.2025	09.09.2025
BEV2	09.09.2025	–

6. Summary of the participants' results

Each participating laboratory was requested to provide the following information to the pilot laboratory:

- The conventional mass value of the travelling standard and the associated uncertainty.
- The mass value of the travelling standard and without uncertainty.
- Details of the balance used in the comparison.
- Details on the mass standards used, including their traceability.
- Laboratory conditions during the measurements.
- Uncertainty calculation of the conventional mass value.

The uncertainty claimed by each participant had to be supported by the relevant uncertainty budget, which followed the template provided in the technical protocol. The project has not collected uncertainty for the true mass result because, in most of the laboratories, it is not significantly different.

The results of laboratories are listed in Table 5 as

$$y_i = m_i - m_0$$

where
y_i: is the mass of the travelling standard as reported by Participant *i*
m_0: is the nominal mass of the travelling standard, 20 kg.

Table 5. Results as reported by participants

NMI	**Starting date of the measurements**	y_i	$u_{\mathrm{lab}}(y_i)$
		Conventional mass	**Uncertainty (*k*=1)**
			mg
BEV[1]	09.07.2025	20 kg + 0.32 mg	0.55
SMU	31.07.2025	20 kg -6.6 mg	1.8
BEV[2]	11.09.2025	20 kg + 0.40 mg	0.50

7. Calculation of reference value and evaluation of the results

8.1 Stability

The stability of the transfer standard was monitored by BEV. The transfer standard was measured several times. The results of the stability measurements are given in Table 6 as the measured deviation

of the conventional mass from nominal mass, during the stability measurements. *U* is the associated expanded uncertainty.

Table 6. Results of the stability measurements in BEV

Date	**Conv. Mass**	**U(*k*=2) mg**
13.11.2023	20 kg + 0.32 mg	1.10
09.07.2025	20 kg + 0.40 mg	1.02
11.09.2025	20 kg + 0.29 mg	1.01
14.10.2025	20 kg + 0.19 mg	1.04

The laboratory's measurement results were correlated, and a correlation coefficient of 0.95 was estimated from the uncertainty analysis. Considering the correlation between the BEV results a small drift of the transfer standard was noticed.
To finalise the drift and instability estimation. only the results of BEV were included.
The calculated drift was found to be 0.00080 mg/day with a standard uncertainty of 0.000 0196 mg/day. We have not included it in the calculations. because it is insignificant. (This change was about 0.016 mg during the 80 days of the comparison with the estimated standard uncertainty of 0.001 5 mg).
We assumed that the magnetic properties of the standard are not contributing significantly to the instability of the reference values or the uncertainties estimated by the participating laboratories. An overall instability of the travelling standard can be estimated as 0.25 mg as an expanded uncertainty.

8.2 Analysis of the Results

The evaluation of the comparison was made by a simple equation, because of the obvious discrepancy. See in Figure 1 where the measured values are shown.

For the calculation, the negligible drift and therefore the second BEV result were ignored.

The uncertainty the deviation of the laboratories is calculated according to this equation:

$$u_i = 2\sqrt{u^2(y_i) - 2 \cdot cov(R, y_i) + u^2_{\text{drift}} + u^2_{\text{inst}}}$$

where

- $2 \cdot cov(R, y_i)$ is coming from the uncertainty of the consensus value and at the 20 kg weights is -0.04 mg.
- u^2_{drift} is the uncertainty from the drift. negligible
- u^2_{inst} is the overall instability of the travelling standard (0.25 mg)

Table 7. Results for conventional mass

NMI	**Results**	
	y_i **mg**	u_i **mg**
BEV	+0.32	0.40
SMU	-6.6	1.8

From these y_i *and* u_i values the weighted average has been calculated:

$$\bar{y} = \frac{\sum(W_i \cdot y_i)}{\sum W_i} \text{ with } W_i = \frac{1}{u_i^2}$$

The reference value uncertainty combining these effects is:

$$u_{\text{ref}} = \frac{1}{\sqrt{\sum W_i}}$$

$\bar{y}$ = -0.01 mg with the expanded uncertainty (u_{ref}) of 0.77 mg (reduced by the influence of the consensus value). The not reduced expanded uncertainty is 1.1 mg.

$$U_{Di} = 2\sqrt{u_i^2 - u_{\text{ref}}^2}$$

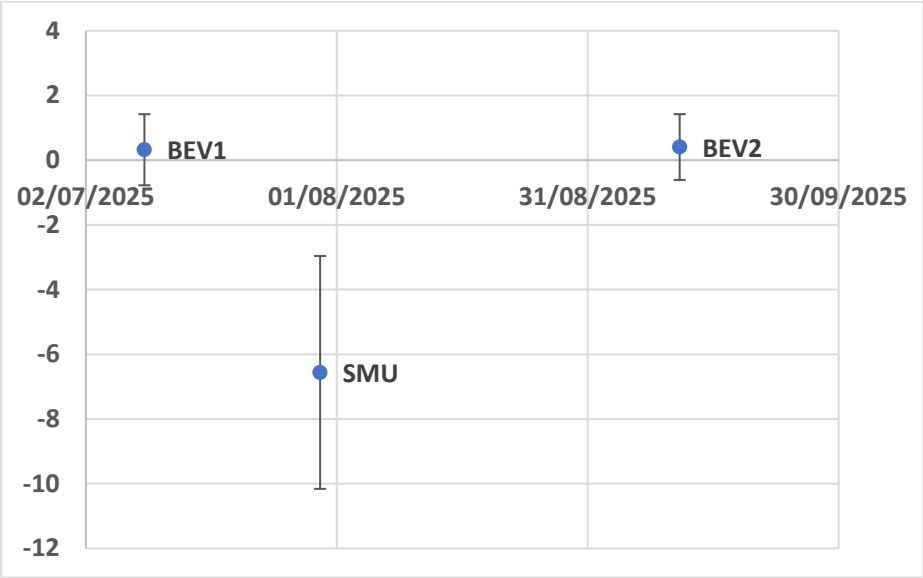
The normalised error calculated as deviation of the mass value measured by the laboratories from the reference value divided its expanded uncertainty.

$$E_n = d_i / U_{Di} = (y_i - \bar{y})/U_{Di}$$

Table 8. Results for conventional mass

NMI	Deviations		Norm. deviation
	d_i mg	U_{di} mg	E_n
BEV	+0.32	0.175	1.9
SMU	-6.6	3.44	-1.9

Figure 1. Measurement results. Data in mg. Error bars represent the expanded (*k*=2) uncertainties of the laboratories.



The measurement results for (true) mass are not included because they do not give more information about the performance of the laboratories.

8. Conclusions

The comparison EURAMET.M.M-S11.1 was piloted by BEV with the only participant SMU calibrated the conventional mass of the 20 kg transfer standard.

The pilot asked the laboratories to review their results because they appeared to be discrepant.
BEV has not modified its result.

SMU updated their result on the 20th of March 2026 per email. stating the measured conventional mass as 20 kg - 10.6 mg with the same uncertainty of 1.8 mg (k=1).

The updated result has not solved the discrepancies.

9. References

[1] Measurement comparisons in the CIMP MRA. CIPM_RGA-G-11
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