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Comparison reports

EURAMET.M.M-S12

Comparison of mass standards

SUPPLEMENTARY COMPARISON

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EURAMET.M.M-S12: Supplementary Bilateral comparison of mass standards

2 kg, 1 kg, 100 g, 100 mg

Final Report

EURAMET project No. 1721

Pilot

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Participants

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Abstract

To support CMC claims in the field of mass standards of INM (Moldova) the supplementary comparison was organised with CMI (Czechia) as piloting laboratory. The results show good consistency with one exception. The comparison is registered as supplementary comparison EURAMET.M.M-S12 (EURAMET project No. 1721) in KCDB.

July 2026

1 Objectives

The scope of this supplementary comparison is the calibration of stainless-steel mass standards of multiples and sub-multiples of the kilogram by the participating institutes. The objective of the comparison is to provide a basis for the submission and review of updated or new CMCs.

2 Participants

The pilot laboratory for the comparison was Czech Metrology Institute (Czechia). The list of participants with their contact details is given in the Table 1.

Table 1: Participants of the comparison

Institute (Acronym)	Czech Metrology Institute (CMI) **(Pilot)**
Contact person in TC (Name and email)	Jaroslav Zuda Jaroslav.zuda@cmi.gov.cz
Technical contact person for comparison (Name and email)	Jaroslav Zuda Jaroslav.zuda@cmi.gov.cz
Institute (Acronym)	INM-Moldova (INM-MO)
Contact person in TC (Name and email)	Corina Tonu, corina.tonu@inm.gov.md
Technical contact person for comparison (Name and email)	Ana Rusu, ana.rusu@inm.gov.md

3 Transfer standards

The travelling standards comprise a set of stainless-steel mass standards of nominal values 2 kg, 1 kg, 100 g and 100 mg. Each participating NMI is asked to determine the mass of the travelling standards against their own stainless-steel standards.

The properties of the standards have been determined by CMI before the start of the comparison and are summarised in Table 2.

The mass stability of the standards was monitored by CMI prior to the start of the comparison. No cleaning of the travelling standards should be carried out. The stability of the transfer standards during the comparison was evaluated from the initial and final measurements in the pilot laboratory.

Table 2: Summary of properties of transfer standards

Nominal value in g	Identification	Volume at 20 °C in cm³	Uncertainty (*k=2*) in cm³	Coefficient of cubic expansion in K^{-1}	CofG height in mm	Volume magnetic susceptibility	Magnetic polarization in µT
2 000	*	251.119	0.010	48×10^{-6}	45.8	0.003	0.22
1 000	*	125.428	0.004	48×10^{-6}	36.5	0.003	0.30
100	*	12.5634	0.0010	48×10^{-6}	17.1	0.003	0.31
0.1	Lifted end	0.01257	0.00003	48×10^{-6}	1	-	-

Figure 1: Transfer standards

4 Circulation schedule

The transfer standard circulated between participants according to the list in **Chyba! Nenalezen zdroj odkazů.**.

It was the responsibility of the participating laboratories to organize the transport to the next participant. The standards were accompanied by an ATA Carnet, which was provided by CMI. The transfer standards were transported between the participating laboratories by courier companies.

When the standards arrived at the participating laboratory, the transportation container and its contents were checked for damage. A visual inspection of the surfaces of the standards was made and the results noted on the measurement report. No significant accidents occurred during the circulation.

Table 3: Circulation schedule of the comparison

NMI	Country	Date	Remarks
CMI	Czech Republic	July 2025	also used for stability evaluation
INM-MO	Moldova	August 2025	
CMI	Czech Republic	October 2025	also used for stability evaluation

5 Calculation of reference value and normalised error

The participating laboratories determined the true and conventional mass value of the transfer standards according to their standard calibration procedure. Each participating laboratory reported its measured true and conventional mass of the transfer standard together with the expanded uncertainty.

The stability of the transfer standards was monitored by CMI. The transfer standards were measured at the beginning and at the end of the comparison. The results of the stability measurements are given in the Table 4 in the form of the deviation from the nominal value.

Table 4: Stability of the transfer standard, all values are given in mg

	M_0 = 2 kg		**M_0 = 1 kg**		**M_0 = 100 g**		**M_0 = 100 mg**	
Date	m_{CMI}	u_{CMI}	m_{CMI}	u_{CMI}	m_{CMI}	u_{CMI}	m_{CMI}	u_{CMI}
07/2025	1.79	0.20	0.63	0.08	0.094	0.016	0.0002	0.0012
10/2025	1.89	0.20	0.58	0.08	0.090	0.016	0.0004	0.0012
Reference value	**1.84**	**0.40**	**0.61**	**0.16**	**0.092**	**0.032**	**0.0003**	**0.0024**

The reference value for the transfer standards was calculated by weighted least squares analysis of the measurement results of the pilot laboratory. Since the uncertainties of the pilot laboratory are equal in both measurements, the reference value is equal to the average value of those two measurements. As the comparison is bilateral with approximately equal time between the individual measurements, the results are not corrected for the drift of the mass value. The drift is considered in the evaluation of the normalised error by the difference between pilot laboratory results.

The normalized error E_n was calculated by difference between the participant's measured value m_{lab} and the reference value m_{ref} considering uncertainties of both results by

$$E_n = \frac{m_{lab} - m_{ref}}{\sqrt{U_{lab}^2 + U_{ref}^2 + U_d^2}},$$

Where

- m_{lab} is the measurement result of the laboratory,
- m_{ref} is the average value of the pilot laboratory,
- U_{lab} is the expanded uncertainty of the result of the participating laboratory,
- U_{ref} is the expanded uncertainty of the result of the pilot laboratory and is given by

$$U_{ref} = 2 * \sqrt{\frac{\sum u_{ref_i}^2}{n}} = \sqrt{2\left(u_{CMI_1}^2 + u_{CMI_2}^2\right)},$$

- U_d is the expanded uncertainty related to the drift of the transfer standard and is evaluated by $U_d = \frac{|x_{ref_1} - x_{ref_2}|}{\sqrt{3}} = \frac{|m_{CMI_1} - m_{CMI_2}|}{\sqrt{3}}$.

The value $|E_n| < 1$ is considered as satisfactory.

6 Summary of the results

Each participating laboratory was requested to report the following information:

- The true and conventional mass value of the transfer standard and associated expanded measurement uncertainty,
- Uncertainty budget,
- Details on the used reference mass standards including their traceability,
- Details of the balance used in the comparison (listed in the Table 5),
- Laboratory environmental conditions during the measurements.

The uncertainties were supported by the relevant uncertainty budgets, which followed the templates provided in the technical protocol.

Table 6 summarises all results used for evaluation of E_n. The graphs in Figure 2 show overall agreement of the results.

Table 5: List of equipment

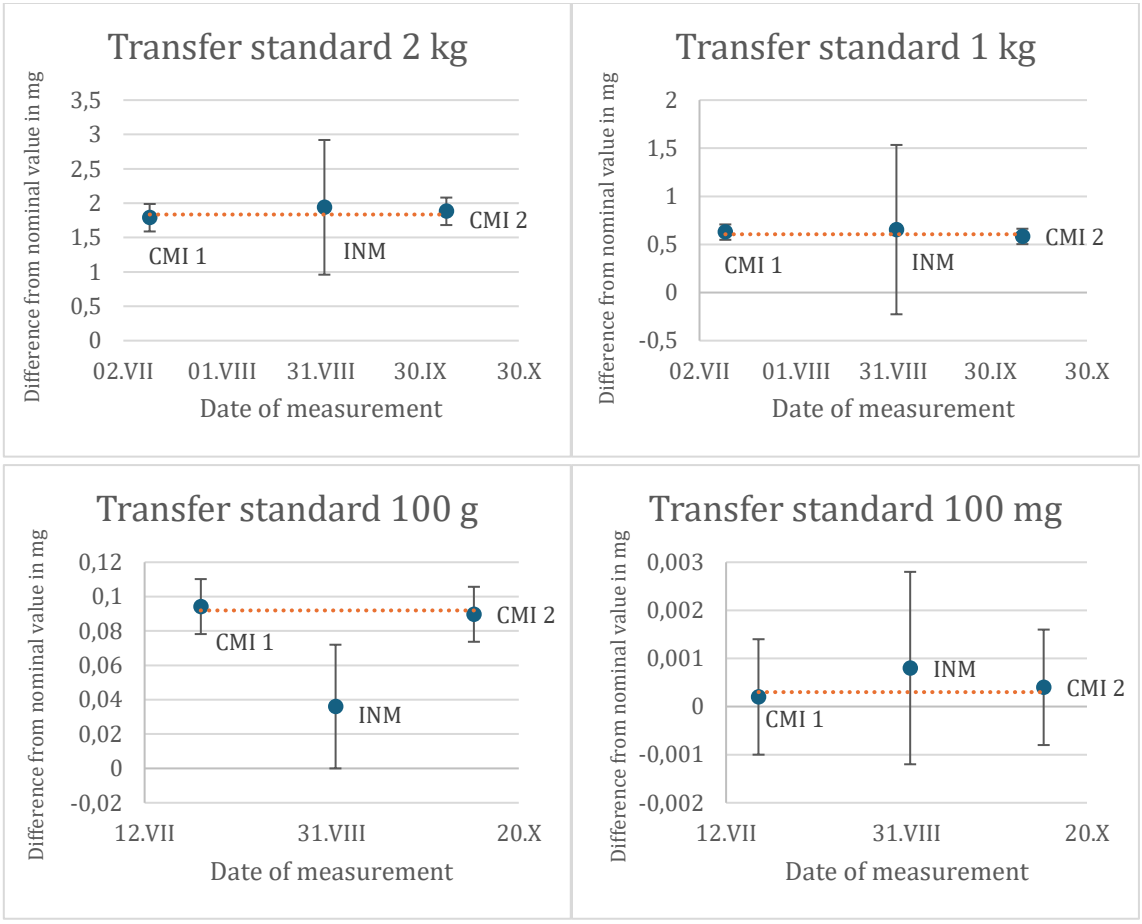
Laboratory	Balance	Capacity	Resolution
CMI	Radwag UMA5	6.1 g	0.0001 mg
	Sartorius MCM106	111 g	0.001 mg
	Mettler Toledo AT1006	1011 g	0.001 mg
	Mettler Toledo AT10005	10011 g	0.01 mg
INM	Sartorius CCE6	6.1 g	0.0001 mg
	Radwag XA 200.4Y.A.KB	210 g	0.01 mg
	Sartorius CCE 40K3	41 kg	1 mg

Table 6: Summary of results; reported values are given as difference from nominal value, uncertainty as reported by the laboratory multiplied by $k = 2$.

	2 kg	U_{2kg}	E_n	**1 kg**	U_{1kg}	E_n
CMI 1	1.79 mg	0.20 mg		0.63 mg	0.08 mg	
INM	1.94 mg	1.04 mg	0.10	0.65 mg	0.88 mg	0.05
CMI 2	1.89 mg	0.20 mg		0.58 mg	0.08 mg	

	100 g	U_{100g}	E_n	**100 mg**	U_{100mg}	E_n
CMI 1	0.094 mg	0.016 mg		0.0002 mg	0.0012 mg	
INM	0.036 mg	0.036 mg	-1.16	0.0008 mg	0.0020 mg	0.19
CMI 2	0.090 mg	0.016 mg		0.0004 mg	0.0012 mg	

Figure 2: Evaluation of transfer standards; reference value indicated by dotted line. Error bars correspond to expanded uncertainties.



6.1 Re-evaluation of results for 100 g weight

After initial evaluation of the results the laboratory of INM was asked to check for any incorrect results or issues in uncertainty evaluation. The laboratory identified issue with one of the comparators used for measurement. The issue could not be resolved in the reasonable time, so the decision was to include additional uncertainty contribution. The increased uncertainty was used for re-evaluation of the respective weight. The new result for the weight of nominal mass 100 g is in Table 7.

Table 7: Comparison with updated uncertainty value for the transfer standard of 100 g.

	100 g	U_{100g}	E_n
CMI 1	0.094 mg	0.016 mg	
INM (new)	0.036 mg	0.090 mg	-0.10
CMI 2	0.090 mg	0.016 mg	

7 Conclusion

The supplementary bilateral comparison EURAMET.M.M-S12 was piloted by CMI. The task of the participating laboratory was to evaluate mass of the transfer standards provided by the pilot laboratory.

The comparison was conducted between July 2025 and October 2025.

The results show good agreement between the laboratories with exception of the weight with nominal mass of 100 g whose $|E_n| > 1$. INM-MD identified issue with the respective mass comparator and reported updated uncertainty value $U_{INM_{100g}} = 0.090$ mg. With this new uncertainty, $|E_n| < 1$.

INM-MD explained the previously undetected instability occurred in the months around the comparison. After analysis of other results, the laboratory identified the issue and updated uncertainty budget for instability of the balance used. Laboratory is resolving the issue with the comparator. Once the issue is resolved, the comparison of the 100g weight can be repeated.

EURAMET Guide on Comparisons (1) suggests that the participants should give a written statement indicating if their results are consistent with the CMC claims or not. Following are the participants' statements regarding the CMCs.

Laboratory	**Written statement indicating if the result is consistent with the CMC claims or not. If not, corrective actions should be described.**
CMI	The results are consistent with CMC claims
INM-MD	Laboratory does not have CMC claims.

8 References

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