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EURAMET 1279: Comparison of 500 kg and 1000 kg weights

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Abstract

Mass comparison of conventional masses of 500 kg and 1000 kg weights between three laboratories (Metrosert, MIKES, and SP) was carried out in 2012. MIKES was the pilot laboratory. For both, 500 kg and 1000 kg, the results show an agreement between the laboratories.

Contents

1 Introduction

EURAMET 1279: Comparison of 500 kg and 1000 kg weights. The intension of this comparison is to qualify that the 2000 kg mass comparator of MIKES situated in the new premises at Kajaani, Finland, gives comparable results with SP and Metrosert.

2 Organisation

2.1 Participating laboratories

Three laboratories participated.

Laboratory		Country
Metrosert	Metrosert	Estonia
Centre for Metrology and Accreditation	MIKES	Finland
Sveriges Tekniska Forskningsinstitut	SP	Sweden

2.2 Comparison scheme

The traveling standards of 500 kg and 1000 kg were circulated among the participants. The travelling scheme was the following: MIKES – SP - Metrosert - MIKES. At MIKES the mass of each travelling standard was determined two times. These measurements were used to monitor the stability of the weight. The average of the measurements was used in the comparison.

2.3 Characteristics of the mass standards

The travelling standard of 500 kg (MIKES) is manufactured from stainless steel (AISI 304). The form of the weight is a cylinder, high 336 mm, diameter 490 mm, fixed lifting eye. The density of travelling standard is 7900 kg/m^3 with expanded uncertainty U = ± 11 kg/m^3 (k=2).

The travelling standard of 1000 kg (Inspecta) is manufactured from steel and it is painted. The form of the weight is a rectangular plate, total length 1780 mm with lifting pivots (body length 1585 mm), width 500 mm, total high 355 mm (body high 150 mm). For the density of travelling standard, the value 8000 kg/m^{3}was used with expanded uncertainty $U = \pm 70$ kg/m^3 (k=2).

2.4 Travelling methods

Both weights were packed into a wooden case and transported to the laboratories by car transportation. No damage to the case or to the standard was observed.

3 Results and comparison

3.1. Stability of the traveling mass standard

The MIKES laboratory monitored the stability of the travelling standards by measuring their masses against 50 kg standards. These comparisons were made at the beginning and at the end of the circulation. The results of the stability comparison are given in Table 2. The standard uncertainty of the mass drift Δd contains only the contributions which are relevant for the determination of mass change. They are the mass difference between the travelling standard and the monitoring standard, stability of the monitoring standard, air buoyancy difference and the linearity of the mass comparator. The uncertainty of d_{av} is the uncertainty of the average of the two d values and in this case it is the same as the uncertainty of one value. The drift Δd is less than the uncertainty with which it can be determined. Therefore, no correction was made for the drift in the travelling standard. The uncertainty due to the drift is included in the uncertainty budget.

Table 2. The mass stability value of the conventional mass of the travelling standard d, its uncertainty and its change $\Delta d = max(d)-min(d)$ during the comparison. The average mass stability value d_{av} and its estimated uncertainty are also given.

		500 kg		1000 kg	
Date	Quantity	Value (d - 500 kg)	Standard uncertainty (k=1)	Value (d - 1000 kg)	Standard uncertainty (k=1)
29.5.2012	d	0.23 g	0.38 g	56.10 g	0.75 g
6.11.2012	d	0.25 g	0.38 g	55.40 g	0.75 g
Average	d_{av}	0.24 g	0.38 g	55.75 g	0.75 g
Drift	Δd	0.02 g	0.30 g	-0.70 g	0.75 g

3.2 Results reported by the participants

Table 3 and 4 shows the results for conventional mass of the 500 kg and 1000 kg weights, respectively, and the uncertainties as given by the participants. All participants have used the coverage factor k=2. The results are also given in Figure 1.

Table 3. Reported results of the participants: 500 kg mass

Laboratory	*Date*	m_A-m_0	$u(m_A)$	$U(m_A)$
MIKES	29.5.2012	0.24 g	0.38 g	0.75 g
Metrosert	16.10.2012	1.20 g	1.05 g	2.10 g
SP	20.8.2012	0.90 g	0.45 g	0.90 g

Table 4. Reported results of the participants: 1000 kg mass

Laboratory	*Date*	m_A-m_0	$u(m_A)$	$U(m_A)$
MIKES	29.5.2012	55.75 g	0.75 g	1.50 g
Metrosert	16.10.2012	23.00 g	20.00 g	40.00 g
SP	20.8.2012	67.90 g	6.50 g	13.00 g

In Table 3 and Table 4, m_A is the conventional mass of the travelling standard, m_0 is the nominal mass value, $u(m_A)$ is standard uncertainty and $U(m_A)$ is expanded uncertainty.

3.4 Reference value

The weighted mean of all participants was taken as the reference value. The reference value and its uncertainty were calculated using formulas in Ref. [1]. The reference value and its standard uncertainty are given in Table 5.

Table 5. Reference values m_{ref} for 500 kg and 1000 kg weights with standard uncertainties $u(m_{ref})$.

	500 kg		1000 kg	
Reference value	m_{ref} - m_0	$u(m_{ref})$	m_{ref} - m_0	$u(m_{ref})$
Weighed mean	0.56 g	0.28 g	55.86 g	0.74 g

3.5 Degree of equivalence of the participants

The degree of equivalence $deq_A = m_A - m_{ref}$ of laboratory A is equal to the difference between the participant's value and the reference value.

The uncertainty of the degree of equivalence $u(deg_A)$ has the following uncertainty components; the uncertainty given by the laboratory $u(m_A)$, the uncertainty of drift of

the travelling standard $\Delta d/\sqrt{12}$ (rectangular distribution), the uncertainty of the determination of the drift $u(d_{av})$ and the uncertainty of the reference value $u(m_{ref})$.

$$u(deq_A) = \sqrt{u^2(m_A) + \frac{(\Delta d)^2}{12} + u^2(d_{av}) - u^2(m_{ref})} \qquad (1)$$

The correlation between the laboratory value and the reference value is included in Eq. 1 (see Ref [1], Eq. 5). Table 6 gives the degree of equivalence deq_A of each laboratory with assigned uncertainty $U(deg_A)$ (95 % coverage). The results are also shown in Fig. 2.

Table 6. Degree of equivalence.

	500 kg		1000 kg	
	deg_A g	U(deg_A) g	deg_A g	U(deg_A) g
MIKES	-0.32	0.78	-0.11	1.56
Metrosert	0.64	2.11	-32.86	40.00
SP	0.34	0.93	12.04	13.01

3.6 Mass differences and uncertainties between participants

Table 7 and 8 gives the mass differences and uncertainties between participants for 500 kg and 1000 kg, respectively. The mass difference is independent of the reference value. The following formulas were used:

$$\Delta m_{A,B} = m_A - m_B \qquad (2)$$

$$U(\Delta m_{,A,B}) = 2 \times \sqrt{u_A^2 + u_B^2 + u^2(d_{av}) + \frac{(\Delta d)^2}{12}} \qquad (3)$$

Table 7. Differences $\Delta m_{A,B}$ for 500 kg between laboratory A (left column) and laboratory B (top row) and the corresponding expanded uncertainties (95 % coverage) $U_{A,B}$.

	MIKES		Metrosert		SP	
	$\Delta m_{A,B}$ g	$U_{A,B}$ g	$\Delta m_{A,B}$ g	$U_{A,B}$ g	$\Delta m_{A,B}$ g	$U_{A,B}$ g
MIKES			-0.96	2.35	-0.66	1.39
Metrosert	0.96	2.35			0.30	2.40
SP	0.66	1.39	-0.30	2.40		

Table 8. Differences $\Delta m_{A,B}$ for 1000 kg between laboratory A (left column) and laboratory B (top row) and the corresponding expanded uncertainties (95 % coverage) $U_{A,B}$.

	MIKES		Metrosert		SP	
	$\Delta m_{A,B}$ g	$U_{A,B}$ G	$\Delta m_{A,B}$ g	$U_{A,B}$ g	$\Delta m_{A,B}$ g	$U_{A,B}$ g
MIKES			32.75	40.06	-12.15	13.18
Metrosert	-32.75	40.06			-44.90	42.09
SP	12.15	13.18	44.90	42.09		

4 Mass Comparators used by the participants

Table 9 gives some information on the mass comparators.

Table 9. Mass comparators

Laboratory	Manufacturer	Type
MIKES	Raute	
Metrosert	Mettler Sartorius	KC500-1 CCT2000K
SP	Mettler Schenck	KC500-1 Uniprint

5 Mass standards used by the participants

Some details of the mass standards used in this comparison are given in Table 10.

Table 10. Mass standards

Laboratory	Description	Standards calibrated by
MIKES	F1 20 x 50 kg	MIKES
Metrosert	F1 9 x 50 kg Working standard 50 kg 2 x 500 kg	Metrosert
SP	F1 500 kg K 500 kg	SP

6 Environmental conditions

Table 10 gives the minimum and maximum values for environmental parameters in the laboratories during the comparison.

Table 10. Environmental conditions during the comparison

Quantity / LAB	*MIKES*		*Metrosert*		*SP*	
	500 kg	*1000 kg*	*500 kg*	*1000 kg*	*500 kg*	*1000 kg*
Temperature °C	*20 ± 0.2*	*20 ± 0.2*	*19 ± 1*	*17.7 … 19.4*	*20 ± 2*	*22.2 ± 0.2*
Pressure (hPa)	*973± 1*	*988 ± 1*	*989 ± 1… 1011 ± 1*		*994 ± 1*	*994 ± 1*
Humidity (%RH)	*21 ± 3*	*21 ± 3*	*55 ± 10*	*44 ± 1… 48 ± 1*	*70 ± 5*	*71 ± 5*
Air density (kg/m3)					*1.17*	*1.16*

8 Conclusions

The result of this 500 kg and 1000 kg comparison shows an agreement between the participating laboratories. However, the result of 1000 kg comparison is not as good as with the 500 kg comparison. One reason for the differences in the mass of the 1000 kg weight can be too high value for density.

9 References

[1] M.G.Cox, “The evaluation of key comparison data”, Metrologia 39, 589, 2002

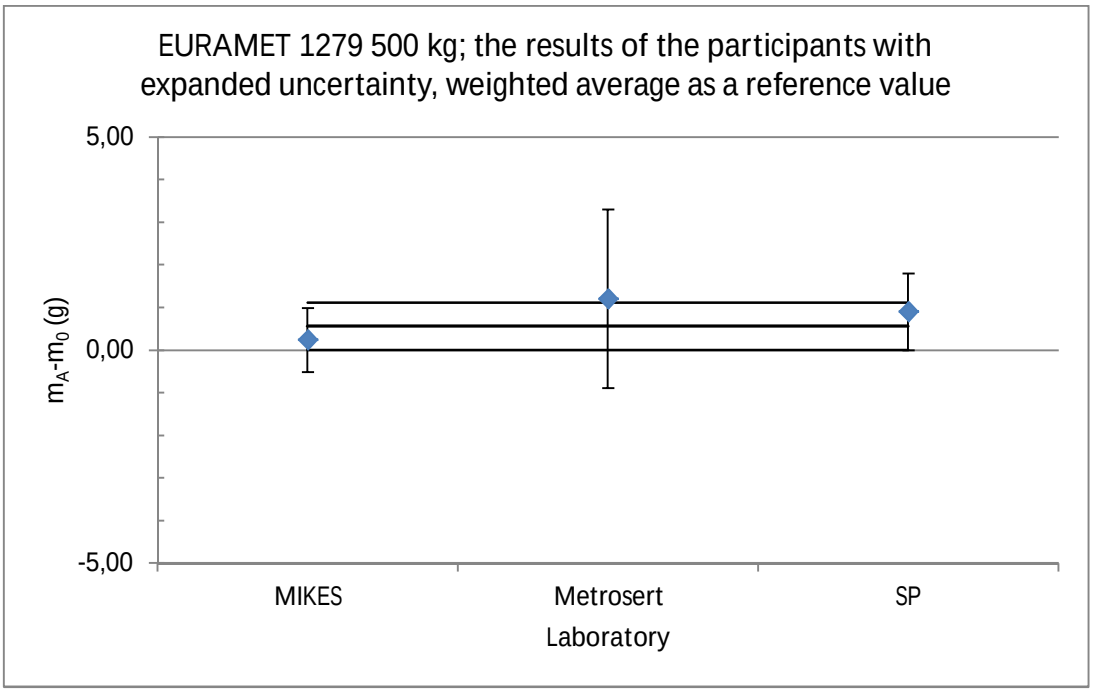

Fig. 1. Original results from the participants for the 500 kg weight with expanded uncertainties. The thick solid line is the reference value and the thin solid line is the expanded uncertainty of the reference value.

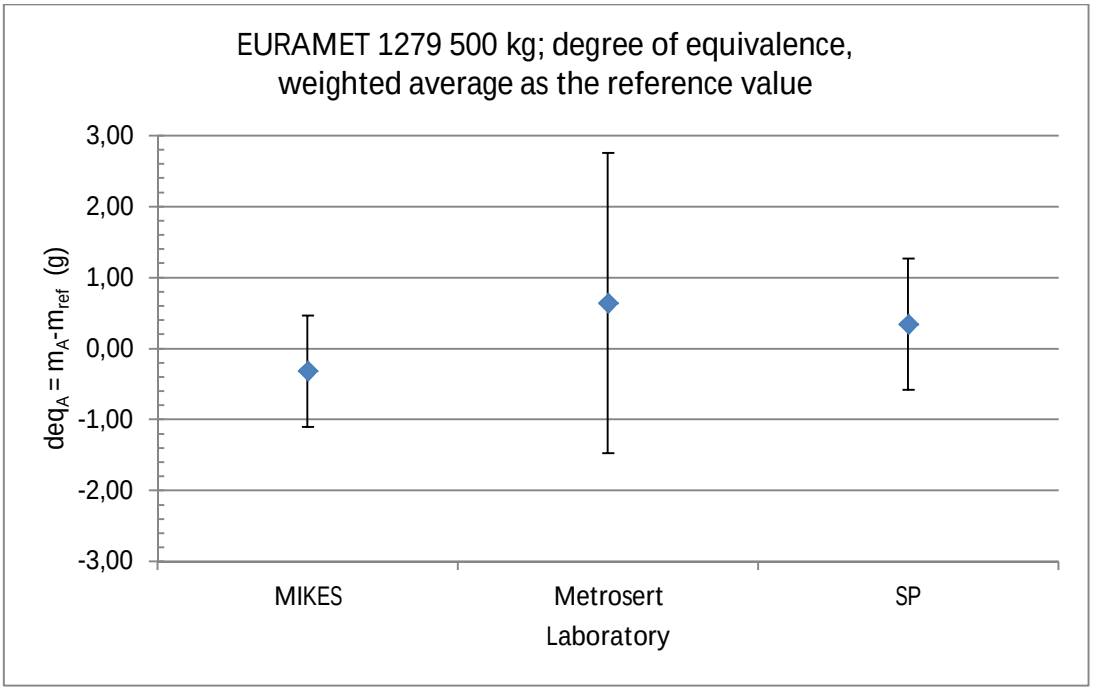

Fig. 2. Degree of equivalence deq_A for the 500 kg weight and the expanded uncertainty $U(deq_A)$

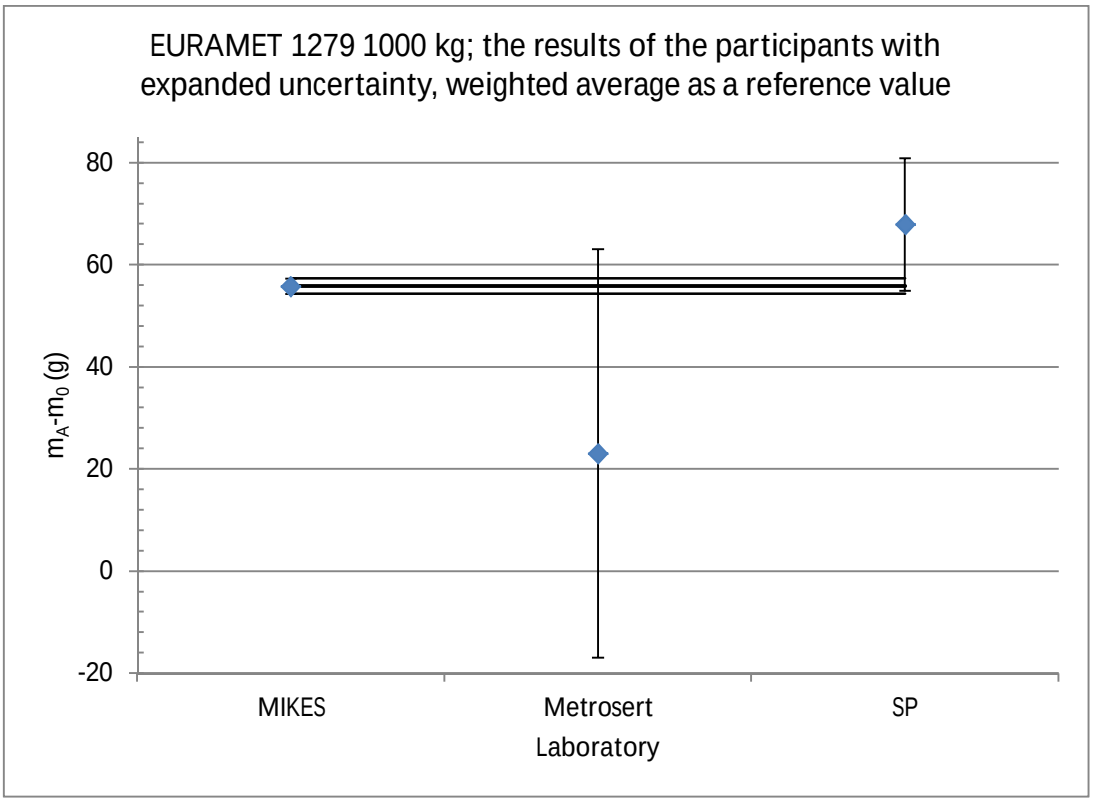

Fig. 3. Original results from the participants for the 1000 kg weight with expanded uncertainties. The thick solid line is the reference value and the thin solid line is the expanded uncertainty of the reference value.

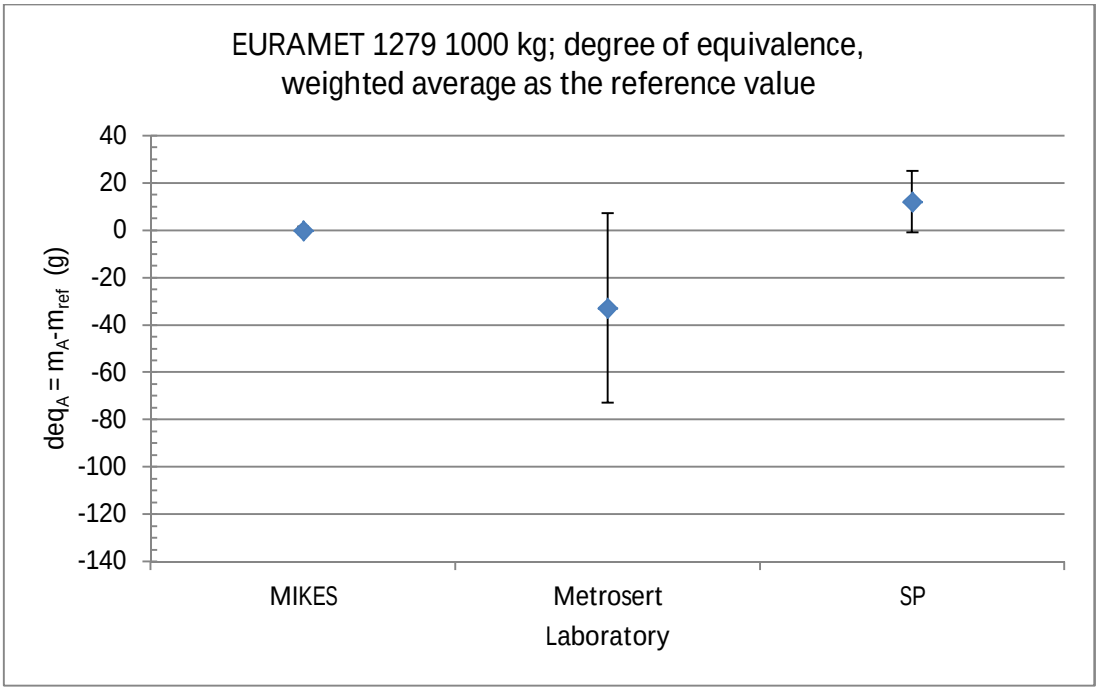

Fig. 4. Degree of equivalence deq_A for the 1000 kg weight and the expanded uncertainty $U(deq_A)$

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