FINAL REPORT ON EUROMET SUPPLEMENTARY COMPARISON OF 500 KG STANDARD (EUROMET.M.M-S1)

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ABSTRACT

This report describes the results of the international comparison EUROMET.M.M-S1 (also known as Eurmet Project No. 461) between 15 participants. The comparison started in June 2001 and finished in July 2003.

Czech Metrology Institute was the pilot laboratory of the project. The transfer standard with nominal mass of 500 kg was provided by Raute Precision (Finland).

Agreement between all participants is good except one laboratory. The result of the laboratory was stated as an outlier and was not used for calulating of the reference value.

1. INTRODUCTION

This report describes a European regional supplementary comparison of 500 kg standard in stainless steel. The comparison is designated as Euramet Project No. 461 and recognised as Euromet.M.M-S1 comprising fifteen participants including the pilot laboratory.

CMI (CZ) was the pilot laboratory. The transfer standard was provided with the cooperation of Raute Precision (FI) that was the owner of the standard weight.

The participating laboratories are listed in the Table 1.

Laboratory		Country
Bundesamt fur Eich- und Vermessungswesen	BEV	Austria
Federal public service economy	SMD	Belgium
Czech Metrological Institute	CMI	Czech Republic
Force Technology	FORCE	Denmark
Raute Precision	Raute Precision	Finland
Hellenic Institute of Metrology	EIM	Greece
National Metrology Laboratory	NML	Ireland
Istituto Nazionale di Ricerca Metrologica	INRIM	Italy
Justervesenet	JV	Norway
Metrology Institute of the Republic of Slovenia	MIRS	Slovenia
Centro Español de Metrologia	CEM	Spain
SP Measurement Technology	SP	Sweden
Federal Office of Metrology	METAS	Switzerland
Tübitak Ulusal Metroloji Enstitüsü	UME	Turkey
National Physical Laboratory	NPL	United Kingdom

Table 1: List of participating laboratories

The Participants were divided in two groups to make two loops of the measurement as is shown in Table 2.

1	CMI – Pilot	June 2001	9	RP	June 2002
2	MIRS	June 2001	10	SP	August 2002
3	BEV	August 2001	11	JV	September 2002
4	EIM	August 2001	12	FORCE	October 2002
5	UME	October 2001	13	NML	February 2003
6	INRIM	December 2001	14	NPL	March 2003
7	CEM	January 2002	15	SMD	May 2003
8	METAS	March 2002	P	CMI - Pilot	July 2003
P	CMI - Pilot	May 2002			

Table 2: Measurement Order

2. DESCRIPTION OF THE TRANSFER STANDARD

One piece of 500 kg weight made of stainless steel was used as a transfer standard in this comparison. The weight was provided by Raute Precision (FI) together with accompanying information including the value of density (determined by dimensional measurement) and data regarding the magnetic properties. This weight was circulated amongst the participants.

Fifteen participants (including the pilot laboratory) determined the conventional mass value of the standard. The stability of the standard was not tested before the comparison. For checking the stability during the comparison, the three measurement of the pilot laboratory were used (see also point 3.2). Transportation was carried out by different shipping companies individually chosen on the responsibility by each participant. For transportation a special wooden box was provided by the pilot laboratory.

3. SUMMARY OF RESULTS REPORTED BY THE PARTICIPANTS

3.1. CONVENTIONAL MASS VALUES AND UNCERTAINTIES

For each participant the results have been determined as the difference between the reported mass value (m) and the nominal mass value (m_0). These results are shown in the Table 3 together with their corresponding uncertainty (k=1).

Lab ID	Result	
	m_i [g]	u_{mi} [g]
CMI	0,21	0,80
MIRS	1,40	2,5
BEV	1,50	0,12
EIM	-0,64	1,2
UME	0,60	0,4
INRIM	-0,83	1,2
CEM	0,05	0,08
METAS	0,36	0,38
RP	0,19	0,38
SP	0,10	0,75
JV	0,03	0,86
FORCE	-0,60	2,80
NML	-3,50	10
NPL	0,24	0,060
SMD	-1,00	0,72

Table 3: Results of the participating laboratories

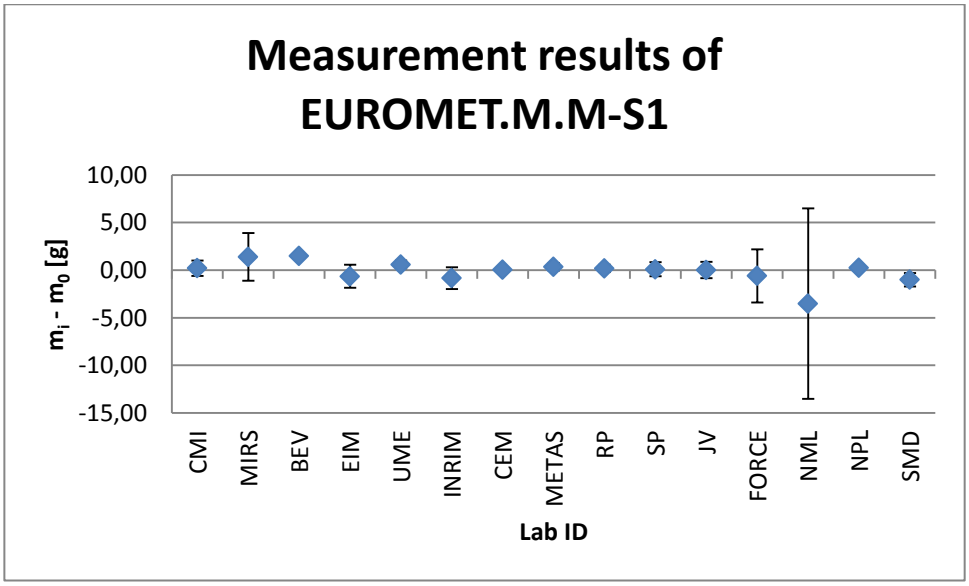

Figure 1: Results of the participating laboratories

3.2. STABILITY OF THE TRANSFER STANDARDS

The transfer standard was returned three times (including the initial measurement) to the pilot laboratory, CMI, at intervals between two loops of the measurement. The three measurements of the pilot laboratory were used as a check of the stability. However the stability of the standard was assumed to be not significant. The uncertainty of the drift of the transfer standard taken from the

biggest difference among the three measurements performed by the pilot laboratory (using rectangular distribution) was 0,04 g. Such an uncertainty does not significantly affect the corresponding calculations and can be neglected.

Date of measurement	Result	
	m_i [g]	u_{mi} [g]
June 2001	0,19	0,80
May 2002	0,17	0,80
July 2003	0,28	0,80

Table 4: Drift measurements of pilot laboratory

3.3. PILOT LABORATORY'S MASS VALUE

Estimate of the pilot laboratory's mass value is the mean of three measurements made during the measurement of the all participants (see Table 4).

4. CALCULATION OF REFERENCE VALUE AND UNCERTAINTY

For the purposes of this comparison, the reference value has been taken to be a weighted mean of the reported measured mass differences of each participant (including the pilot laboratory). The squared standard uncertainties reported by the participants were used as weights. The standard deviation of the weighted mean was calculated using the uncertainties of the participating laboratories according to the following equations.

$$m_{ref} = \frac{\sum_{i=1}^{15} \frac{m_i}{u_{m_i}^2}}{\sum_{i=1}^{15} \frac{1}{u_{m_i}^2}}$$

$$u_{m_{ref}}^2 = \frac{1}{\sum_{i=1}^{15} \frac{1}{u_{m_i}^2}}$$

The mass difference of the reference value and each participant is calculated from

$$\Delta m_i = m_i - m_{ref}$$

The uncertainties have been calculated in accordance with the international guide. The uncertainty of the difference between the reference value and a participant's measurement is generally made up of the following components:

- The uncertainty of the participant's measurement, u_{mi}
- The uncertainty due to the drift or instability of the transfer standard, u_d (negligible)
- The uncertainty of the reference value, u_{mref}

If the measurement m_i is included in the reference value than the uncertainty is calculated from

$$u_{\Delta m_i} = \sqrt{u_{m_i}^2 - u_{m_{ref}}^2}$$

In the other case, with excluded result, the uncertainty is

$$u_{\Delta m_i} = \sqrt{u_{m_i}^2 + u_{m_{ref}}^2}$$

The expanded uncertainties $U_{\Delta m_i} = 2u_{\Delta m_i}$ are used in the following tables and graphs.

Additionally the normalized deviations for detection of the possible outliers were calculated for each participant following the equation

$$d_i = \frac{\Delta m_i}{u_{\Delta m_i}}$$

The results are shown in Figure 2 and Table 5. In the case that the value $d_i > 2$ the result is stated as outlier and is excluded from the calculation of the reference value. One result has $d_i = 10$ and therefore is excluded.

The reference value before the check for the outliers was

$$m_{ref} = 0{,}347\ g, u_{m_{ref}} = 0{,}044\ g$$

The reference value without the outlier is

$$m_{ref} = 0{,}174\ g$$

with corresponding uncertainty

$$u_{m_{ref}} = 0{,}046\ g$$

The differences between the reference value and each participant, together with their associated standard uncertainties, are given in Figure 3 and Table 5.

Lab ID	Difference from the reference value		Normalized deviation	Included?
	m_i - m_{ref} [g]	$U_{mi-mref}$ [g]	d_i	y/n
CMI	0,036	1,600	0,05	y
MIRS	1,226	5,000	0,49	y
BEV	1,326	0,260	10,31	n
EIM	-0,814	2,400	-0,67	y
UME	0,426	0,800	1,07	y
INRIM	-1,002	2,300	-0,87	y
CEM	-0,120	0,130	-1,84	y
METAS	0,181	0,760	0,48	y
RP	0,016	0,760	0,04	y
SP	-0,074	1,500	-0,10	y
JV	-0,144	1,720	-0,17	y
FORCE	-0,774	5,600	-0,28	y
NML	-3,674	20,000	-0,37	y
NPL	0,066	0,078	1,75	y
SMD	-1,174	1,500	-1,64	y

Table 5: Differences from the reference value without outliers

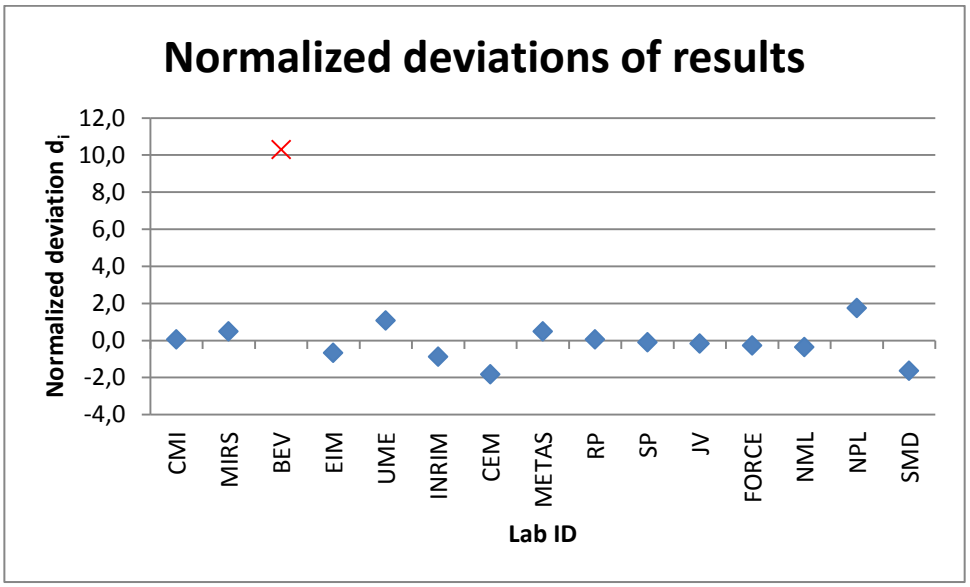

Figure 2: Normalized deviations

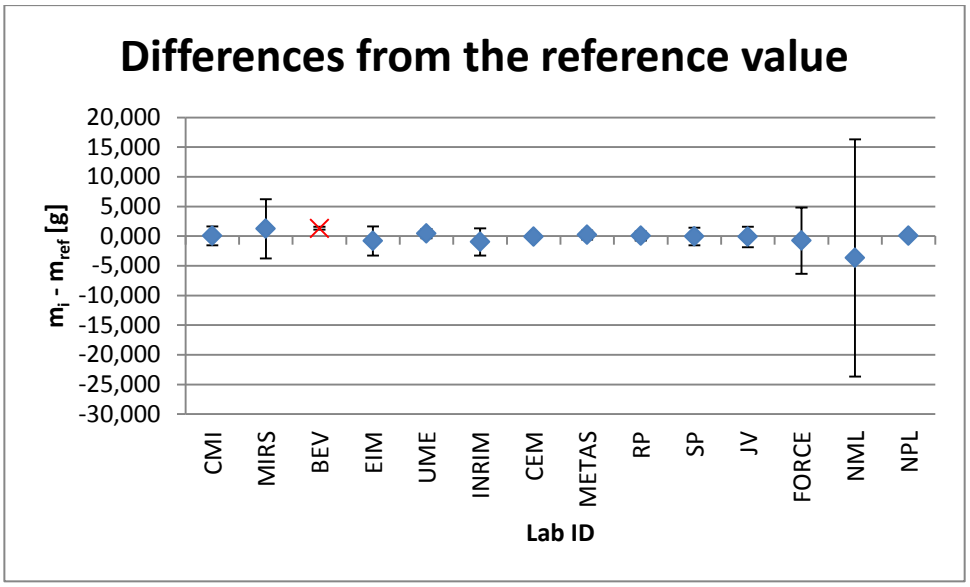

Figure 3: Differences of the measurements and reference value with the corresponding expanded uncertainties

5. CONCLUSION

For all participants except one, the difference from the reference value is less than the expanded uncertainty associated with this difference.

REFERENCE

International Organization for Standardization. (1993). *Guide to the Expression of Uncertainty in Measurement.* Geneva, Switzerland.