

**APMP.M.M-K6 (SUB) multiples mass key comparison**



**ASIA – PACIFIC METROLOGY PROGRAMME**

**Final Report of**

**APMP Comparison of Mass standards**

APMP.M.M-K6 (SUB) multiples mass key comparison

Coordinated by: Vietnam Metrology Institute  
The Mass Laboratory - Vietnam Metrology Institute  
8 Hoang Quoc Viet – Cau Giay – Ha noi (Viet Nam)

Assisted by: National Measurement Institute, Australia  
National Measurement Institute, Australia  
Bradfield Road, Lindfield, NSW 2070, Australia

## **Final Report: APMP.M.M-K6 Comparison of Mass standards multiples and submultiples of the kilogram 1 kg, 500 g, 20 g, 2 g and 100 mg (Class OIML E<sub>2</sub>)**

### **Abstract**

This report summarizes the results of a comparison of Mass Standards conducted between fourteen participating members of the Asia-Pacific Metrology Program. Two weights sets with five nominal mass values: 1 kg, 500 g, 20 g, 2 g, and 100 mg (OIML Class E<sub>2</sub>) were used as travelling artifacts. These nominal values were chosen as they followed the nominal values of CCM.M-K1 and CCM.M-K2 except the 10 kg. The program was sponsored by Physikalisch-Technische Bundesanstalt (PTB) and Vietnam Metrology Institute, VMI was the coordinating laboratory with National Measurement Institute (NMIA) being a technical assisting laboratory as well as a link laboratory to the CCM comparisons. The comparison was carried out from May 2005 to November 2006.

### **Introduction**

The Asia Pacific Metrology Program (APMP) is a grouping of national and territorial measurement laboratories from the Asia-Pacific region helping to develop international recognition for regional measurement competence and, hence, underpin confidence in traded products and services. Some of the successful methods used by APMP to reach its objective are comparisons using artifacts. Measurement comparisons bring the laboratories a confidence in the measurement standards and lead to the international acceptance of the measurement standards. This inter-laboratory comparison was based on a suggestion from the APMP.DEC committee on 12 April 2004. It was part of the activity of a regional PTB project. The comparison was approved by the APMP Technical Committee of Mass (TCM) and by the Chair of the working group on mass standards of the CCM. The chairman of APMP TCM invited APMP.DEC member countries to participate. The results of the participating laboratories have been calculated to give the degrees of equivalence with the key comparison reference values (KCRVs) of comparisons CCM.M-K1 and -K2 to which this comparison is linked.

## CONTENTS

### Section

Abstract	2
1. General	4
2. Description of the program	5
3. Description of artifacts	5
4. Calibration time schedule	5
5. Description of measurement method	6
6. Results	7
7. Analysis and Linking to CCM.M-K1 and CCM.M-K2	8
8. Conclusion	11
Table 1: Mass change of the transfer standards and reference standards as measured by NMIA during the comparison.	7
Table 2: Mass measurement data for the transfer standards during the comparison as measured by VMI/NMIA.	7
Table 3: Results of link laboratories from CCM.M-K1, CCM.M-K2, APMP.M.M-K1 for the deviation from the KCRV	9
Table 4: Measurement Results for APMP.M.M-K6	12
Table 5: Difference from KCRV	13
Table 6-11: Difference in mass value between pairs of laboratories 1 kg, 500 g, 20 g, 2 g, 100 mg	14-16
Figure 1: Results of 1 kg true mass standard for all participants relative to KCRV	17
Figure 2: Results of 1 kg conventional mass standard for all participants relative to KCRV	18
Figure 3: Results of 500 g mass standard for all participants relative to KCRV	19
Figure 4: Results of 20 g mass standard for all participants relative to KCRV	20
Figure 5: Results of 2 g mass standard for all participants relative to KCRV	21
Figure 6: Results of 100 mg mass standard for all participants relative to KCRV	22

## **1. General**

The comparison in the field of mass standards was conducted between participating APMP member laboratories. The aim of the program was to provide participating laboratories with an opportunity to compare national standards with other economies in the region and to share experience with each other.

## **2. Description of the program**

Two weights sets with five nominal mass values: 1 kg, 500 g, 20 g, 2 g, and 100 mg were chosen as travelling artifacts. During the APMP.DEC meeting, National Institute of Metrology (Thailand), NIMT agreed to lend two 1 kg artefacts for this intercomparison. The other eight artifacts were bought by NMIA with the funding from PTB. They were enclosed in their weights boxes, and then placed in two plastic containers. The mass stability of all the artifacts was monitored for a period of six months at NMIA from May 2004. The standards were sent to VMI in late 2004. VMI made the mass measurement of all the artifacts in May, 2005, and then circulated the artifacts between participating laboratories in two loops (A and B). After every three laboratories had finished their measurements, the artifacts were returned to VMI for re-measurement before being sent out to the next group of participating laboratories in the same loop. Time taken for all fourteen participating laboratories to complete the measurement was approximately 20 months.

The participating laboratories are as follows:

1. Vietnam Metrology Institute (VMI)
2. South Africa National Metrology Laboratory (CSIR-NML, CSIR for short)
3. Syria National Standards and Calibration Laboratory (NSCL)
4. National Measurement Institute, Australia (NMIA)
5. Industrial Technology Development Institute (ITDI)
6. National Institute of Metrology Thailand (NIMT)
7. Mongolia Agency for Standardization and Metrology (MASM)
8. Egypt National Institute for Standards (NIS)
9. Measurement Units, Standards and Services Department (MUSSD)
10. Nepal Bureau of Standards and Metrology (NBSM)
11. National Physical Laboratory of India (NPLI)
12. National Physical & Standards Laboratory of Pakistan (NPSL)
13. Indonesian Institute of Sciences (KIM-LIPI)
14. Industrial Laboratory Center of Cambodia (ILCC) formerly Cambodia Department of Metrology (DoM-MIME)

### 3. Description of artifacts

Two sets of masses each one for loops A and B were circulated among the participants for calibration. Each set consisted of five non-magnetic stainless steel mass standards and have the form and characteristics that are recommended by OIML for weights of accuracy class E<sub>2</sub>.

Each set of artifacts were placed in the weight boxes, and then placed in a plastic container. The serial numbers of the two sets are M47384A & M47384B. The weight of each set in its carrying case is approximately 3.8 kg. The purchase/manufacturing cost of both artifacts was approximately 5,000 USD but the artifacts were described as having no commercial value (not for sale).

Specifications for the artifacts are as follows:

	S/n: M47384A			S/n: M47384B		
Nominal mass	Identification	Density kg/m <sup>3</sup>	Uncertainty kg/m <sup>3</sup> (k=1)	Identification	Density kg/m <sup>3</sup>	Uncertainty kg/m <sup>3</sup> (k=1)
<b>1kg</b>	<b>2 dots</b>	<b>8006.27</b>	<b>0.07</b>	<b>4 dots</b>	<b>8006.09</b>	<b>0.07</b>
		<b>Density Limit kg/m<sup>3</sup></b>			<b>Density Limit kg/m<sup>3</sup></b>	
<b>500 g</b>		<b>7810 - 8210</b>		<b>1 dot</b>	<b>7810 – 8210</b>	
<b>20 g</b>				<b>1 dot</b>		
<b>2 g</b>				<b>1 dot</b>		
<b>100 mg</b>	<b>Δ</b>			<b>Δ</b>		

### 4. Calibration time schedule

The fourteen participating laboratories were divided into 2 loops as described below.

There was a problem in the transportation of the artifacts as the A.T.A. Carnet was not recognized by some of the custom authorities of the participating countries. This caused a difficulty in custom clearance of the artifacts and delayed the starting date of the laboratory's measurement. The artifacts could not be circulated on schedule and the date of completion of the program was delayed.

#### Loop A

Participants		Arrivals	Report	Note
NMIA	Australia	July 2004		Weight sets were acquired and monitored for stability
VMI	Vietnam 1	12/ 05/ 2005	31/ 05/ 2005	
CSIR	South Africa	02/ 06/ 2005	01/ 11/ 2005	
NSCL	Syria	25/ 07 / 2005	05/ 09/ 2005	
NMIA	Australia	12/ 09/ 2005	08/ 10/ 2005	
VMI	Vietnam 2	08/ 11/ 2005		
NIMT	Thailand	05/ 12/ 2005	16/ 01/ 2006	NIMT exchange date with ITDI
ITDI	Philippines	17/ 01/ 2006	26/ 02/ 2006	
MASM	Mongolia	01/ 03/ 2006	27/ 04/ 2006	
VMI	Vietnam 3	25/ 04/ 2006		
NIS	Egypt	July 2006	08/02/2007	
VMI	Vietnam 4	16/ 11/ 2006	21/11/ 2006	
NMIA	Australia	March 2007		Recheck after comparison

## Loop B

Participants		Arrivals	Report	Note
NMIA	Australia	July 2004		Weight sets were acquired and monitored for stability
VMI	Vietnam 1	02/ 05/ 2005		
MUSSD	Sri Lanka	03/ 06/ 2005	11/ 07/ 2005	
NBSM	Nepal	02/ 08 / 2005	11/ 08/ 2005	
NPLI	India	10/ 2005	08/ 10/ 2005	
VMI	Vietnam 2	12/ 12/ 2005		
NPSL	Pakistan	28/ 01/ 2006	20/ 02/ 2006	Prominent scratch of 1 kg reported
KIM-LIPI	Indonesia	05/ 03/ 2006	21/ 07/ 2006	Scratch of 1kg, and deep scratch of 500g reported
ILCC (DOM-MIME)	Cambodia	28/ 06/ 2006	10/ 08/ 2006	Scratch of 1kg, and deep scratch of 500g reported
VMI	Vietnam 3	25/ 10/ 2006		
NMIA	Australia	March 2007		Recheck after comparison

## 5. Description of measurement method

After the first calibration of the artifacts at VMI in May 2005, both sets of artifacts were circulated between participants in two loops (designated A and B). Participating laboratories were asked to measure the artifacts as follows.

### 5.1 The determination of mass and conventional mass value

For the determination of true mass and conventional mass values, participating laboratories should carry out the substitution method ((ABBA) or (ABA) see OIML-R111) by using a weighing instrument with their own weighing cycle design. The indication of the weighing instrument should be used only for the difference between the indication of reference weight and the indication of test weight. The air buoyancy correction should be considered. An approximate formula of CIPM should be used for air density determination which requires the temperature, humidity, and air pressure for calculation. The conventional mass can be calculated from the mass value.

### 5.2. The uncertainty of measurement

The uncertainty of measurement should be expressed in accordance with the International Organization for Standardization, "Guide to the Expression of Uncertainty in Measurement", 1993 (GUM) published by ISO or OIML International Recommendation R111.

If any laboratory did not follow the published procedures, the description of the procedure used was required to be attached to the measurement results given to the program coordinator (VMI).

## 6. Results

A full calibration report with all relevant data and uncertainty estimates based on comparison protocol was requested to be sent to the program coordinator (VMI) while the artifacts were sent to the next participating laboratory. Fourteen APMP members or associate members participated in the comparison program using two sets of mass standards. All fourteen laboratories have performed measurements and submitted the results to the program coordinator.

The measurement results of the APMP comparison program of 1 kg, 500 g, 20 g, 2 g, 100 mg mass standards are summarized in Table 4. Each laboratory reported the measured mass value (true mass and conventional mass) that it assigned to the 1 kg artifacts and the conventional masses of the other sub-multiple artifacts, together with their standard uncertainties. The results given in Table 4 are the deviations from nominal (with the deviation defined as measured mass value minus nominal mass value).

### Stability of artifacts

The stability of the travelling artifacts was assessed in two ways. Firstly, NMIA measured the mass values of the artifacts before and after each circulation loop. The mass changes for all the artifacts in loop A and the three smaller artifacts in loop B were found to be small or in the order of their uncertainties. No evidence of instability was found for these 8 artifacts. However, the 1 kg and 500 g artifacts used in measurement loop B have a decrease of 78  $\mu\text{g}$  and 4.6 mg respectively.

Table 1. Mass change of the transfer standards and reference standards as measured by NMIA during the comparison. Mass values were measured against the NMIA working standards before and after the comparison.

$m_o$	Mass change $\delta m$ from August 2004 to April 2007 $\delta m$ in micro grams			
	Transfer standard		Reference standard	
	A	B	1	2
1 kg	-5	-78	+10	-3.2
500 g	-17	-4594	-5	-15
20 g	-5.2	5.3	1	2
2 g	-1.8	0.9	-0.8	-0.6
100 mg	0.3	0.9	0.4	0

Secondly, VMI measured the mass values of the artifacts before, during and after the course of each loop as shown in the schedule. Two of the artifacts in loop B – 1 kg and 500 g were found to be damaged during the later stage of the comparison. NPSL, KIM-LIPI and DoM-MIME reported the damage when they received the artifacts. Therefore the measurement results of these two artifacts in loop B were considered not valid after December 2005 affecting NPSL, KIM-LIPI and DOM-MINE.

Table 2. Mass measurement data for the transfer standards during the comparison as measured by VMI/NMIA. Mass values were measured against the VMI reference standards before, during and after the comparison. Value in brackets indicates weight has been damaged.

Date	1 kg (true)			1 kg (conv.)			500 g		20 g		2 g		100 mg	
	Deviation from nominal mass (mg)			Deviation from nominal mass (mg)			Deviation from nominal mass (mg)		Deviation from nominal mass (mg)		Deviation from nominal mass (mg)		Deviation from nominal mass (mg)	
	A (VMI)	A (NMIA)	B (VMI)	A (VMI)	A (NMIA)	B (VMI)	A (VMI)	B (VMI)	A (VMI)	B (VMI)	A (VMI)	B (VMI)	A (VMI)	B (VMI)
Jul-04		0.110			0.227									
May-05	0.069		-0.107	0.187		0.007	0.213	0.148	0.003	0.001	0.0125	-0.0040	-0.0060	0.0025
Oct-05		0.096			0.213									
Dec-05	0.071		-0.140	0.188		-0.025	0.201	0.139	0.006	0.004	0.0115	-0.0050	-0.0080	0.0028
May-06	0.063			0.180			0.209		-0.001		0.0110		-0.0050	
Nov-06	-0.038		(-0.297)	0.080		(-0.183)	0.198	(-4.450)	-0.006	0.011	0.0096	-0.0040	-0.0060	0.0034
Mar-07		0.105			0.222									
<b>s.d.</b>	0.053	<b>0.007</b>		0.053	<b>0.007</b>		<b>0.007</b>		<b>0.005</b>	<b>0.005</b>	<b>0.0012</b>	<b>0.0006</b>	<b>0.0013</b>	<b>0.0005</b>
<b>u<sub>d</sub></b>	0.007		0.010	0.007		0.010	0.007	0.003	0.005	0.005	0.0012	0.0006	0.0013	0.0005

As seen from Table 2, the standard deviations of the measurement results of VMI during the course of comparison except for the 1 kg A and B and the 500g B give a reasonable indication of the stability of these artifacts, they are therefore taken to be the drift uncertainty  $u_d$  for the mass instability of these seven travelling standards. For the 1 kg A, the last measurement made by VMI in Nov 06 after the renovation of their mass laboratory did not seem to repeat very well and did not match the mass value measured by NMIA in April 2007. Therefore, the  $u_d$  of 1 kg A is calculated using the standard deviation of 3 sets of measurements measured by NMIA in 2004, 2005 and 2007. For the 1 kg and the 500g B, the decrease in masses seems to have taken place after Dec 2005. There were two measurements made by VMI before the artifacts were damaged, so the uncertainties of stability for 1 kg B and 500g B artifacts during the period May to Dec 05 were calculated using

$$u_d = \sqrt{\frac{(m_{VMI2} - m_{VMI1})^2}{12}} \quad (1)$$

where  $m_{VMI1}$  is the mass measurement by VMI in May 05 and  $m_{VMI2}$  is the mass measurement by VMI in Dec 05

## 7. Analysis and Linking to CCM.M-K1 and CCM.M-K2

The comparison results were analyzed and linked to the key comparison reference values (KCRVs) obtained in the CCM key comparisons CCM.M-K1 and CCM.M-K2 using Generalized Least-Squares (sometimes known as Gauss-Markov) estimation. This analysis directly combines the APMP comparison results with the CCM results of the link laboratories to estimate the degree of equivalence for each laboratory relative to the CCM KCRVs and the degree of equivalence between pairs of laboratories, as required by the MRA. No reference value is calculated - or required - for the APMP comparison.

The analysis follows the method used in APMP.M.M-K1 [1] [2]. The analysis is represented by

$$y = X \beta + e \quad (3)$$

where  $y$  is a vector of the measurement results,  $X$  is a design matrix,  $\beta$  is a vector of unknowns and  $e$  is a vector of random errors or disturbances. Each measurement is represented in a row of a design matrix  $X$ , while the measurement result is in the corresponding row of vector  $y$ .



For the 1 kg in loop A, there are three link laboratories (NMIA, NIMT, CSIR) used to determine the difference from the KCRV while in loop B, NPLI acts as the link laboratory. Although NSCL did take part in APMP.M.M-K1, their deviation from KCRV was comparatively large ( $71 \pm 177$ )  $\mu\text{g}$ . It was decided this value was not used as a link to this comparison. For the 500 g, 20 g, 2 g and 100 mg in loop A, NMIA acts as the link laboratory to the KCRV. The average of the first two sets of measurements in May 05 and Dec 05 in loop A was chosen as the comparison result of VMI and its deviation from KCRV was determined from this loop. It then acts as the link laboratory for loop B for the 500g, 20 g, 2 g and 100 mg weights. These first two sets of results from VMI were chosen because the loop A link laboratory NMIA made measurements within this period. The instability factor of the artifacts due to transportation which may affect the reliability of linking could be minimized.

From the *Final Report on CIPM key comparison of 1 kg standards in stainless steel (CCM.M-K1)*, the *Final Report on CIPM key comparison of multiples and submultiples of the kilogram (CCM.M-K2)* and the *Final Report of APMP Comparison on 1 kg mass standard (APMP.M.M-K1)*, the following values are obtained:

Table 3. Results of link laboratories from CCM.M-K1, CCM.M-K2, APMP.M.M-K1 for the deviation from the KCRV

$m_o$	NMIA -KCRV	NIMT-KCRV	CSIR-KCRV	NPLI-KCRV
1 kg	(5 $\pm$ 29) $\mu\text{g}$	(-4 $\pm$ 33) $\mu\text{g}$	(4 $\pm$ 44) $\mu\text{g}$	(4 $\pm$ 33) $\mu\text{g}$
500 g	(-9 $\pm$ 41) $\mu\text{g}$			
20 g	(-3.7 $\pm$ 7.9) $\mu\text{g}$			
2 g	(-1.1 $\pm$ 2.0) $\mu\text{g}$			
100 mg	(0.1 $\pm$ 1.0) $\mu\text{g}$			

where the number following the symbol  $\pm$  is the expanded uncertainty determined with a coverage factor  $k = 2$ . To explain, the result of the 1 kg, say, is interpreted as the mass value assigned by NMIA to the mass of the travelling standard is 5  $\mu\text{g}$  greater than the KCRV. These differences from the KCRVs were determined in the course of the key comparisons CCM.M-K1 and CCM.M-K2. The KCRVs for CCM.M-K1 and CCM.M-K2 are defined as the median values assigned by the participating laboratories to the average mass of the travelling standards.

For APMP.M.M-K6, eleven results are included for the measurements for each artifact in loop A and nine results are included in loop B. The measurement results are given in Table 4.

The equation describing each APMP comparison measurement for artifact (x) can be written

$$m_x(\text{Lab}_i)_p - m_o = \Delta_i - (m_o - m_x) + e_{i,p} \quad (4)$$

where  $m_x(\text{Lab}_i)_p$  is the  $p^{\text{th}}$  value assigned to artifact (x) by laboratory i,  $m_o$  is the nominal mass of the artifact,  $m_x$  is the mass of artifact (1 kg, 500 g, 20 g, 2 g or 100 mg),  $\Delta_i$  is the bias of laboratory i, and  $e_{i,p}$  is a random error associated with the measurement. Similarly, the equation for the results of the link laboratories is

$$m_{cx}(\text{Lab}_i) - K_x = \Delta_i - (K_x - m_{cx}) + e_i \quad (5)$$

where  $m_{cx}$  is the median mass values of the CCM.M-K1, CCM.M-K2 or APMP.M.M-K1 travelling standards,  $K_x$  is the key comparison reference value, and  $m_{cx}(\text{Lab}_i) - K_x$  is the measured deviation between the link laboratory i and the KCRV at  $m_o$ (see (Table 3) above).

The known values are  $m_x(\text{Lab}_i)_p - m_o$  and  $m_c(\text{Lab}_i) - K$ . For 1 kg in loop A, the unknowns are  $\Delta_1$  to  $\Delta_8$ ,  $m_o - m_x$ , and  $K - m_c$ . Solving the 11 equations defined by (4), 3 equations defined by (5) and requires a constraint. For this we choose  $K - m_c = 0$  so that the values obtained for  $\Delta_1$  to  $\Delta_8$  from the solution are the expected deviations of each laboratory's result from the KCRV. The constraint is in the 15th row of X. Design matrix X has 10 columns. Similarly, for 500 g, 20 g, 2 g and 100 mg in loop A, the unknowns are  $\Delta_1$  to  $\Delta_8$ ,  $m_o - m_x$ , and  $K - m_c$ . Solving the 11 equations defined by (4), 1 equation defined by (5), and  $K - m_c = 0$ . The constraint is in the 13th row of X. Design matrix X has 10 columns. Using the same method for loop B, solving the 9 equations defined by (4), 1 equation defined by (5), and  $K - m_c = 0$ . The constraint is in the 11th row of X. Design matrix X has 9 columns.

Results vector  $\beta$  (the estimated value of  $\beta$ ) is given by

$$\beta = C X^T \Phi^{-1} y \quad (6)$$

with uncertainty (variance-covariance) matrix C

$$C = (X^T \Phi^{-1} X)^{-1} \quad (7)$$

Hence,  $\beta_1$  (the first element of  $\beta$ ), is an estimate of the unknown  $\Delta_1$ .

Matrix  $\Phi$  is an input uncertainty (variance-covariance) matrix. The diagonal terms of  $\Phi$  are the variances (standard uncertainty squared) associated with each measurement plus the  $(u_d)^2$  variance associated with the instability of the artifact. Off-diagonal terms in  $\Phi$  allow known correlations to be included (see below). Matrix C is the calculated variance-covariance matrix from which the uncertainties in the results of the analysis are obtained.

With the constraint  $K - m_c = 0$ , the elements of  $\beta$  and the corresponding diagonal terms of C directly give the expected deviation of each laboratory's result from the KCRV and the variance associated with this deviation. For pairs of laboratories i and j,  $\beta_i - \beta_j$  is the difference of their deviations from the KCRV that in their degree of equivalence, and  $C_{ii} + C_{jj} - 2C_{ij}$  is the variance associated with this.

Correlations arise for the link laboratories (a common reference standard is used by each link laboratory for the CCM and APMP comparisons). In addition, all the measurement results are correlated with each other to a small extent through the uncertainty in the air density formula [3]. Off-diagonal terms are included in  $\Phi$  to account for all these correlations.

The results of this analysis are summarized in Figures 1 to 6, which show the difference of the mass value assigned by each laboratory from the KCRV, together with the expanded uncertainty in this mass value (calculated using  $k = 2$ ). The zero value corresponds to the KCRVs of comparisons CCM.M-K1 and CCM.M-K2.

These figures show that the majority of the results of the participating laboratories are consistent with each other and with the KCRV considering the uncertainties that apply.

More detailed results of the analysis are given in Tables 5 to 11. Table 5 gives the deviation from the KCRV for each laboratory, together with the associated uncertainty. Note that the differences and uncertainties in Table 5 for the link laboratories differ by no more than 1  $\mu\text{g}$  from the CCM.M-K1, CCM.M-K2 and APMP.M.M-K1 values (see Table 3). Tables 6 to 11 give the differences in assigned mass values and their uncertainties between pairs of laboratories for different nominal weights.

## 8. Conclusion

- 8.1 The majority of the results of the participating laboratories are consistent with each other and with the KCRVs of CCM.M-K1, CCM.M-K2 and APMP.M.M-K1. These participating laboratories have demonstrated their measurement capabilities of OIML Class E<sub>2</sub> weights.
- 8.2 The result of the 20 g artifact reported from one laboratory differs significantly from the KCRV and from the results of other laboratories. Three laboratories reported uncertainties associated with the measurement results of several artifacts higher than OIML recommended values for Class E<sub>2</sub> weights.
- 8.3 One laboratory recorded damage to the 1 kg artifact after inspection on arrival. However, the pilot laboratory was not notified at the time.
- 8.4 Two laboratories recorded damage to the 1 kg and 500 g artifacts after inspection on arrival. However, the pilot laboratory was not notified at the time.
- 8.5 Both 1 kg and 500g B artifacts were found to be damaged upon return to the pilot laboratory at the end of loop B. Two drilled holes were also found on the wooden box housing the 1 kg weight.
- 8.6 One laboratory exchanged the time slot with another participating laboratory.
- 8.7 The program coordinator sent out notification to seven laboratories for rechecking and reconfirming their results while preparing the draft A report.
- 8.8 Six participating laboratories replied and confirmed their results. Two participating laboratories made corrections to their original mass values of one artifact. One withdrew the result of one artifact after finding a problem with the reference standard.
- 8.9 After an accident happened to the original reference standards used for the first measurement of the 1 kg and 500 g masses in loops A and B, the program coordinator (VMI) changed their reference standards for the subsequent measurements.
- 8.10 Typing errors found in VMI's uncertainty values for the 20g A and B in the draft A report have been rectified in this report.
- 8.11 NBSM requested a change of their results for mass values of 1 kg, 500 g, 20 g and 2 g after errors were found by NPLI in calculating their buoyancy corrections. The buoyancy corrections should have been subtracted rather than added to the mass values. An email was sent to VMI on 8 May 2007 before the draft A was sent to all the participants. The request was accepted and their results were corrected in this report.
- 8.12 Due to the damage of the 1 kg and 500 g artifacts in loop B during the comparison, the measurement result of KIM-LIPI for these two nominal masses is invalid. KIM-LIPI requested another comparison of 1 kg to support their Country Measurement Capability (CMC) on the BIPM database.
- 8.13 NIMT investigated the possible discrepancy of the measurement result for the 100mg. They borrowed the two 100 mg transfer standards for re-measurement in October 2007 after the comparison finished. The result obtained for both standards resembled those obtained at NMIA but were different from their results during the comparison in Dec 2006. The discrepancy remained unexplainable.

## References

- [1] CM Sutton (Metrologia 41, 272-277, 2004)
- [2] Lars Nielson (Danish Institute of Fundamental Metrology Report DFM-99-R39)
- [3] Picard and Fang (Metrologia 39, 31-40, 2002)

Table 4: Measurement Results for APMP.M.M-K6

Participating Laboratory	True mass 1 kg		Conv mass 1 kg		Conv mass 500 g		Conv mass 20 g		Conv mass 2 g		Conv mass 100 mg	
	Dev. from Nominal mass (mg)	uncer. k=1 ±(mg)	Dev. from Nominal mass (mg)	uncer. k=1 ±(mg)	Dev. from Nominal mass (mg)	uncer. k=1 ±(mg)	Dev. rom Nominal mass (mg)	uncer. k=1 ±(mg)	Dev. from Nominal mass (mg)	uncer. k=1 ±(mg)	Dev. from Nominal mass (mg)	uncer. k=1 ±(mg)
<b>Loop A (M47384 A)</b>												
VMI 1	0.069	0.0414	0.187	0.0414	0.213	0.0207	0.003	0.0022	0.0125	0.001	-0.006	0.001
CSIR	0.1	0.25	0.2	0.25	0.17	0.125	0.006	0.0135	0.014	0.0065	-0.005	0.0025
NSCL	0.09	0.11	0.2	0.11	0.2	0.11	0.009	0.007	0.0122	0.003	-0.0056	0.0011
NMIA	0.096	0.015	0.213	0.015	0.228	0.024	0.0026	0.0032	0.0128	0.0011	-0.0046	0.00047
VMI 2	0.0705	0.0749	0.188	0.0749	0.201	0.0374	0.0057	0.0029	0.0115	0.001	-0.008	0.001
ITDI	0.088	0.051	0.205	0.051	0.265	0.043	0.013	0.011	0.006	0.01	0	0.009
NIMT	0.087	0.08	0.21	0.08	0.237	0.038	-0.002	0.004	0.0112	0.0021	0.0021	0.0008
MASM	0.026	0.05	0.143	0.05	0.2049	0.03	0.00081	0.006	0.0116	0.001	-0.003751	0.0004
VMI 3	0.0625	0.0749	0.18	0.0749	0.209	0.0374	-0.00074	0.0030	0.011	0.001	-0.005	0.001
NIS	-0.031	0.039	0.086	0.039			-0.018	0.009	-0.008	0.007	-0.0054	0.0028
VMI 4	-0.0375	0.0749	0.08	0.0749	0.198	0.0374	-0.0064	0.0030	0.0096	0.001	-0.006	0.001

Participating Laboratory	True mass 1 kg		Conv mass 1 kg		Conv mass 500 g		Conv mass 20 g		Conv mass 2 g		Conv mass 100 mg	
	Dev. from Nominal mass (mg)	uncer. k=1 ±(mg)	Dev. from Nominal mass (mg)	uncer. k=1 ±(mg)	Dev. from Nominal mass (mg)	uncer. k=1 ±(mg)	Dev. rom Nominal mass (mg)	uncer. k=1 ±(mg)	Dev. rom Nominal mass (mg)	uncer. k=1 ±(mg)	Dev. from Nominal mass (mg)	uncer. k=1 ±(mg)
<b>Loop B (M47384 B)</b>												
VMI 1	-0.107	0.0365	0.007	0.0365	0.148	0.0207	0.0005	0.0022	-0.004	0.001	0.0025	0.001
MUSSD	-0.172	0.26	0.018	0.26	0.1216	0.133	0.0182	0.013	-0.0049	0.007	-0.0026	0.0027
NBSM	0.466	0.402			-0.037	0.78	0.0198	0.036	0.0173	0.021		
NPLI	-0.031	0.021	0.082	0.021	0.191	0.041	0.0099	0.0035	-0.0017	0.0006	0.0034	0.0005
VMI 2	-0.14	0.0749	-0.025	0.075	0.139	0.0374	0.004	0.0041	-0.005	0.001	0.0028	0.001
NPSL			-1	1.63	1	1.6	0.112	0.08	0.001	0.01	0.002	0.006
KIM-LIPI	-1.63	0.03	-1.52	0.03	-4.38	0.031	0.009	0.0037	-0.0023	0.0015	0.0049	0.00066
Dom-MIME	-0.7	0.1	0	0.1	-0.1	0.1	0.1	0.02	-0.01	0.004	0.005	0.002
VMI 3	-0.297	0.0749	-0.183	0.075	-4.45	0.0374	0.011	0.0036	-0.004	0.001	0.0034	0.001

Table 5: Deviation from the KCRV (key comparison reference value of CCM.M-K1, CCM.M-K2) in milligrams and associated expanded uncertainty U (k=2) in milligrams for each participating laboratory.

	1kg			500g		20g		2g		100mg	
	Diff from KCRV (true)	Diff from KCRV (conv.)	Expanded Uncertainty k=2	Diff from KCRV	Expanded Uncertainty k=2	Diff from KCRV	Expanded Uncertainty k=2	Diff from KCRV	Expanded Uncertainty k=2	Diff from KCRV	Expanded Uncertainty k=2
VMI	-0.023	-0.022	0.073	-0.024	0.053	-0.0060	0.0133	-0.0027	0.0036	-0.0014	0.0035
CSIR	0.004	0.004	0.044	-0.067	0.252	-0.0003	0.0309	0.0001	0.0135	-0.0003	0.0062
NSCL	-0.001	-0.008	0.220	-0.037	0.222	0.0027	0.0205	-0.0017	0.0070	-0.0009	0.0043
NMIA	0.005	0.005	0.030	-0.009	0.042	-0.0037	0.0082	-0.0011	0.0022	0.0001	0.0011
ITDI	-0.003	-0.003	0.102	0.028	0.092	0.0067	0.0267	-0.0079	0.0203	0.0047	0.0184
NIMT	-0.004	-0.004	0.034	0.000	0.083	-0.0083	0.0170	-0.0027	0.0055	0.0068	0.0040
MASM	-0.065	-0.065	0.100	-0.032	0.068	-0.0055	0.0192	-0.0023	0.0041	0.0009	0.0038
NIS	-0.122	-0.122	0.078			-0.0243	0.0235	-0.0219	0.0145	-0.0007	0.0067
MUSSD	-0.137	-0.060	0.521	-0.050	0.268	0.0075	0.0311	-0.0031	0.0144	-0.0058	0.0063
NBSM	0.501		0.804	-0.209	1.560	0.0091	0.0740	0.0191	0.0421		
NPLI	0.004	0.004	0.034	0.019	0.089	-0.0008	0.0185	0.0001	0.0035	0.0002	0.0033
NPSL						0.1013	0.1609	0.0028	0.0203	-0.0012	0.0124
KIM-LIPI						-0.0017	0.0186	-0.0005	0.0045	0.0017	0.0034
Dom-MIME						0.0893	0.0435	-0.0082	0.0087	0.0018	0.0051

Table 6 Difference in assigned mass value between laboratory A and laboratory B and the expanded uncertainties for 1 kg (true mass) in milligrams

<b>1 kg true</b>											
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	NIS	MUSSD	NBSM	NPLI
VMI		-0.027	-0.022	-0.028	-0.020	-0.019	0.042	0.099	0.114	-0.524	-0.027
CSIR	0.027		0.005	-0.001	0.007	0.008	0.069	0.126	0.141	-0.497	0.000
NSCL	0.022	-0.005		-0.006	0.002	0.003	0.064	0.121	0.136	-0.502	-0.005
NMIA	0.028	0.001	0.006		0.008	0.009	0.070	0.127	0.142	-0.496	0.001
ITDI	0.020	-0.007	-0.002	-0.008		0.001	0.062	0.119	0.134	-0.504	-0.007
NIMT	0.019	-0.008	-0.003	-0.009	-0.001		0.061	0.118	0.133	-0.505	-0.008
MASM	-0.042	-0.069	-0.064	-0.070	-0.062	-0.061		0.057	0.072	-0.566	-0.069
NIS	-0.099	-0.126	-0.121	-0.127	-0.119	-0.118	-0.057		0.015	-0.623	-0.126
MUSSD	-0.114	-0.141	-0.136	-0.142	-0.134	-0.133	-0.072	-0.015		-0.638	-0.141
NBSM	0.524	0.497	0.502	0.496	0.504	0.505	0.566	0.623	0.638		0.497
NPLI	0.027	0.000	0.005	-0.001	0.007	0.008	0.069	0.126	0.141	-0.497	
<b>1kg true Unc (k=2)</b>											
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	NIS	MUSSD	NBSM	NPLI
VMI		0.085	0.232	0.078	0.125	0.080	0.123	0.106	0.526	0.808	0.080
CSIR	0.085		0.224	0.053	0.111	0.056	0.109	0.090	0.522	0.806	0.056
NSCL	0.232	0.224		0.222	0.242	0.223	0.242	0.233	0.565	0.834	0.223
NMIA	0.078	0.053	0.222		0.106	0.045	0.104	0.084	0.521	0.805	0.045
ITDI	0.125	0.111	0.242	0.106		0.108	0.143	0.128	0.530	0.811	0.108
NIMT	0.080	0.056	0.223	0.045	0.108		0.106	0.085	0.522	0.805	0.048
MASM	0.123	0.109	0.242	0.104	0.143	0.106		0.127	0.530	0.811	0.106
NIS	0.106	0.090	0.233	0.084	0.128	0.085	0.127		0.526	0.808	0.085
MUSSD	0.526	0.522	0.565	0.521	0.530	0.522	0.530	0.526		0.958	0.522
NBSM	0.808	0.806	0.834	0.805	0.811	0.805	0.811	0.808	0.958		0.805
NPLI	0.080	0.056	0.223	0.045	0.108	0.048	0.106	0.085	0.522	0.805	

Table 7 Difference in assigned mass value between laboratory A and laboratory B and the expanded uncertainties for 1 kg (conv. mass) in milligrams

<b>1kg conv</b>											
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	NIS	MUSSD	NPLI	
VMI		-0.026	-0.014	-0.027	-0.019	-0.018	0.043	0.100	0.038	-0.026	
CSIR	0.026		0.012	-0.001	0.007	0.008	0.069	0.126	0.064	0.000	
NSCL	0.014	-0.012		-0.013	-0.005	-0.004	0.057	0.114	0.052	-0.012	
NMIA	0.027	0.001	0.013		0.008	0.009	0.070	0.127	0.065	0.001	
ITDI	0.019	-0.007	0.005	-0.008		0.001	0.062	0.119	0.057	-0.007	
NIMT	0.018	-0.008	0.004	-0.009	-0.001		0.061	0.118	0.056	-0.008	
MASM	-0.043	-0.069	-0.057	-0.070	-0.062	-0.061		0.057	-0.005	-0.069	
NIS	-0.100	-0.126	-0.114	-0.127	-0.119	-0.118	-0.057		-0.062	-0.126	
MUSSD	-0.038	-0.064	-0.052	-0.065	-0.057	-0.056	0.005	0.062		-0.064	
NPLI	0.026	0.000	0.012	-0.001	0.007	0.008	0.069	0.126	0.064		
<b>1kg conv Unc (k=2)</b>											
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	NIS	MUSSD	NPLI	
VMI		0.085	0.232	0.078	0.125	0.080	0.123	0.106	0.526	0.080	
CSIR	0.085		0.224	0.053	0.111	0.056	0.109	0.090	0.522	0.056	
NSCL	0.232	0.224		0.222	0.242	0.223	0.242	0.233	0.565	0.223	
NMIA	0.078	0.053	0.222		0.106	0.045	0.104	0.084	0.521	0.045	
ITDI	0.125	0.111	0.242	0.106		0.108	0.143	0.128	0.530	0.108	
NIMT	0.080	0.056	0.223	0.045	0.108		0.106	0.085	0.522	0.048	
MASM	0.123	0.109	0.242	0.104	0.143	0.106		0.127	0.530	0.106	
NIS	0.106	0.090	0.233	0.084	0.128	0.085	0.127		0.526	0.085	
MUSSD	0.526	0.522	0.565	0.521	0.530	0.522	0.530	0.526		0.522	
NPLI	0.080	0.056	0.223	0.045	0.108	0.048	0.106	0.085	0.522		

Table 8 Difference in assigned mass value between laboratory A and laboratory B and the expanded uncertainties for 500 g in milligrams.

500g										
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	MUSSD	NBSM	NPLI
VMI		0.043	0.013	-0.015	-0.052	-0.024	0.008	0.026	0.185	-0.043
CSIR	-0.043		-0.030	-0.058	-0.095	-0.067	-0.035	-0.017	0.142	-0.086
NSCL	-0.013	0.030		-0.028	-0.065	-0.037	-0.005	0.013	0.172	-0.056
NMIA	0.015	0.058	0.028		-0.037	-0.009	0.023	0.041	0.200	-0.028
ITDI	0.052	0.095	0.065	0.037		0.028	0.060	0.078	0.237	0.009
NIMT	0.024	0.067	0.037	0.009	-0.028		0.032	0.050	0.209	-0.019
MASM	-0.008	0.035	0.005	-0.023	-0.060	-0.032		0.018	0.177	-0.051
MUSSD	-0.026	0.017	-0.013	-0.041	-0.078	-0.050	-0.018		0.159	-0.069
NBSM	-0.185	-0.142	-0.172	-0.200	-0.237	-0.209	-0.177	-0.159		-0.228
NPLI	0.043	0.086	0.056	0.028	-0.009	0.019	0.051	0.069	0.228	
500g Unc (k=2)										
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	MUSSD	NBSM	NPLI
VMI		0.254	0.225	0.066	0.097	0.089	0.075	0.069	0.269	1.561
CSIR	0.254		0.334	0.255	0.265	0.262	0.258	0.256	0.366	1.580
NSCL	0.225	0.334		0.226	0.237	0.234	0.229	0.227	0.346	1.576
NMIA	0.066	0.255	0.226		0.100	0.092	0.079	0.073	0.271	1.561
ITDI	0.097	0.265	0.237	0.100		0.116	0.107	0.102	0.280	1.563
NIMT	0.089	0.262	0.234	0.092	0.116		0.099	0.094	0.277	1.562
MASM	0.075	0.258	0.229	0.079	0.107	0.099		0.082	0.273	1.561
MUSSD	0.069	0.256	0.227	0.073	0.102	0.094	0.082		0.272	1.561
NBSM	0.269	0.366	0.346	0.271	0.280	0.277	0.273	0.272		1.583
NPLI	1.561	1.580	1.576	1.561	1.563	1.562	1.561	1.561	1.583	

Table 9 Difference in assigned mass value between laboratory A and laboratory B and the expanded uncertainties for 20 g in milligrams.

20 g														
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	NIS	MUSSD	NBSM	NPLI	NPSL	KIM-LIPI	Dom-MIME
VMI		-0.006	-0.009	-0.002	-0.013	0.002	-0.001	0.018	-0.013	-0.015	-0.005	-0.107	-0.004	-0.095
CSIR	0.006		-0.003	0.003	-0.007	0.008	0.005	0.024	-0.008	-0.009	0.001	-0.102	0.001	-0.090
NSCL	0.009	0.003		0.006	-0.004	0.011	0.008	0.027	-0.005	-0.006	0.004	-0.099	0.004	-0.087
NMIA	0.002	-0.003	-0.006		-0.010	0.005	0.002	0.021	-0.011	-0.013	-0.003	-0.105	-0.002	-0.093
ITDI	0.013	0.007	0.004	0.010		0.015	0.012	0.031	-0.001	-0.002	0.008	-0.095	0.008	-0.083
NIMT	-0.002	-0.008	-0.011	-0.005	-0.015		-0.003	0.016	-0.016	-0.017	-0.007	-0.110	-0.007	-0.098
MASM	0.001	-0.005	-0.008	-0.002	-0.012	0.003		0.019	-0.013	-0.015	-0.005	-0.107	-0.004	-0.095
NIS	-0.018	-0.024	-0.027	-0.021	-0.031	-0.016	-0.019		-0.032	-0.033	-0.023	-0.126	-0.023	-0.114
MUSSD	0.013	0.008	0.005	0.011	0.001	0.016	0.013	0.032		-0.002	0.008	-0.094	0.009	-0.082
NBSM	0.015	0.009	0.006	0.013	0.002	0.017	0.015	0.033	0.002		0.010	-0.092	0.011	-0.080
NPLI	0.005	-0.001	-0.004	0.003	-0.008	0.007	0.005	0.023	-0.008	-0.010		-0.102	0.001	-0.090
NPSL	0.107	0.102	0.099	0.105	0.095	0.110	0.107	0.126	0.094	0.092	0.102		0.103	0.012
KIM-LIPI	0.004	-0.001	-0.004	0.002	-0.008	0.007	0.004	0.023	-0.009	-0.011	-0.001	-0.103		-0.091
Dom-MIME	0.095	0.090	0.087	0.093	0.083	0.098	0.095	0.114	0.082	0.080	0.090	-0.012	0.091	
20 g conv Unc (k=2)														
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	NIS	MUSSD	NBSM	NPLI	NPSL	KIM-LIPI	Dom-MIME
VMI		0.030	0.019	0.014	0.025	0.015	0.017	0.022	0.029	0.073	0.015	0.161	0.015	0.042
CSIR	0.030		0.034	0.031	0.038	0.032	0.033	0.035	0.041	0.079	0.032	0.163	0.032	0.051
NSCL	0.019	0.034		0.021	0.030	0.021	0.023	0.027	0.034	0.075	0.023	0.161	0.023	0.045
NMIA	0.014	0.031	0.021		0.027	0.017	0.020	0.024	0.031	0.074	0.019	0.161	0.019	0.044
ITDI	0.025	0.038	0.030	0.027		0.027	0.029	0.032	0.038	0.077	0.028	0.162	0.028	0.048
NIMT	0.015	0.032	0.021	0.017	0.027		0.020	0.024	0.032	0.074	0.019	0.161	0.020	0.044
MASM	0.017	0.033	0.023	0.020	0.029	0.020		0.026	0.033	0.075	0.021	0.161	0.022	0.045
NIS	0.022	0.035	0.027	0.024	0.032	0.024	0.026		0.036	0.076	0.025	0.162	0.025	0.047
MUSSD	0.029	0.041	0.034	0.031	0.038	0.032	0.033	0.036		0.078	0.030	0.163	0.031	0.050
NBSM	0.073	0.079	0.075	0.074	0.077	0.074	0.075	0.076	0.078		0.074	0.176	0.074	0.084
NPLI	0.015	0.032	0.023	0.019	0.028	0.019	0.021	0.025	0.030	0.074		0.161	0.017	0.043
NPSL	0.161	0.163	0.161	0.161	0.162	0.161	0.161	0.162	0.163	0.176	0.161		0.161	0.166
KIM-LIPI	0.015	0.032	0.023	0.019	0.028	0.020	0.022	0.025	0.031	0.074	0.017	0.161		0.043
Dom-MIME	0.042	0.051	0.045	0.044	0.048	0.044	0.045	0.047	0.050	0.084	0.043	0.166	0.043	

Table 10 Difference in assigned mass value between laboratory A and laboratory B and the expanded uncertainties for 2 g in milligrams.

2g														
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	NIS	MUSSD	NBSM	NPLI	NPSL	KIM-LIPI	Dom-MIME
VMI		-0.0028	-0.0011	-0.0016	0.0052	0.0000	-0.0004	0.0192	0.0004	-0.0218	-0.0028	-0.0055	-0.0022	0.0055
CSIR	0.0028		0.0018	0.0012	0.0080	0.0028	0.0024	0.0220	0.0032	-0.0190	0.0000	-0.0027	0.0006	0.0083
NSCL	0.0011	-0.0018		-0.0006	0.0062	0.0010	0.0006	0.0202	0.0014	-0.0208	-0.0018	-0.0045	-0.0012	0.0066
NMIA	0.0016	-0.0012	0.0006		0.0068	0.0016	0.0012	0.0208	0.0020	-0.0202	-0.0012	-0.0039	-0.0006	0.0071
ITDI	-0.0052	-0.0080	-0.0062	-0.0068		-0.0052	-0.0056	0.0140	-0.0048	-0.0270	-0.0080	-0.0107	-0.0074	0.0003
NIMT	0.0000	-0.0028	-0.0010	-0.0016	0.0052		-0.0004	0.0192	0.0004	-0.0218	-0.0028	-0.0055	-0.0022	0.0056
MASM	0.0004	-0.0024	-0.0006	-0.0012	0.0056	0.0004		0.0196	0.0008	-0.0214	-0.0024	-0.0051	-0.0018	0.0060
NIS	-0.0192	-0.0220	-0.0202	-0.0208	-0.0140	-0.0192	-0.0196		-0.0188	-0.0410	-0.0220	-0.0247	-0.0214	-0.0137
MUSSD	-0.0004	-0.0032	-0.0014	-0.0020	0.0048	-0.0004	-0.0008	0.0188		-0.0222	-0.0032	-0.0059	-0.0026	0.0051
NBSM	0.0218	0.0190	0.0208	0.0202	0.0270	0.0218	0.0214	0.0410	0.0222		0.0190	0.0163	0.0196	0.0273
NPLI	0.0028	0.0000	0.0018	0.0012	0.0080	0.0028	0.0024	0.0220	0.0032	-0.0190		-0.0027	0.0006	0.0083
NPSL	0.0055	0.0027	0.0045	0.0039	0.0107	0.0055	0.0051	0.0247	0.0059	-0.0163	0.0027		0.0033	0.0110
KIM-LIPI	0.0022	-0.0006	0.0012	0.0006	0.0074	0.0022	0.0018	0.0214	0.0026	-0.0196	-0.0006	-0.0033		0.0077
Dom-MIME	-0.0055	-0.0083	-0.0066	-0.0071	-0.0003	-0.0056	-0.0060	0.0137	-0.0051	-0.0273	-0.0083	-0.0110	-0.0077	
2g conv Unc (k=2)														
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	NIS	MUSSD	NBSM	NPLI	NPSL	KIM-LIPI	Dom-MIME
VMI		0.013	0.007	0.004	0.020	0.005	0.004	0.014	0.014	0.042	0.003	0.020	0.004	0.008
CSIR	0.013		0.015	0.014	0.024	0.014	0.014	0.019	0.019	0.044	0.013	0.024	0.014	0.016
NSCL	0.007	0.015		0.007	0.021	0.008	0.007	0.016	0.016	0.043	0.007	0.021	0.007	0.010
NMIA	0.004	0.014	0.007		0.020	0.006	0.005	0.015	0.015	0.042	0.004	0.020	0.005	0.009
ITDI	0.020	0.024	0.021	0.020		0.021	0.020	0.025	0.025	0.047	0.020	0.028	0.020	0.022
NIMT	0.005	0.014	0.008	0.006	0.021		0.006	0.015	0.015	0.042	0.005	0.021	0.006	0.010
MASM	0.004	0.014	0.007	0.005	0.020	0.006		0.015	0.014	0.042	0.004	0.020	0.005	0.009
NIS	0.014	0.019	0.016	0.015	0.025	0.015	0.015		0.020	0.044	0.014	0.025	0.015	0.016
MUSSD	0.014	0.019	0.016	0.015	0.025	0.015	0.014	0.020		0.044	0.014	0.024	0.014	0.016
NBSM	0.042	0.044	0.043	0.042	0.047	0.042	0.042	0.044	0.044		0.042	0.047	0.042	0.043
NPLI	0.003	0.013	0.007	0.004	0.020	0.005	0.004	0.014	0.014	0.042		0.020	0.004	0.008
NPSL	0.020	0.024	0.021	0.020	0.028	0.021	0.020	0.025	0.024	0.047	0.020		0.020	0.022
KIM-LIPI	0.004	0.014	0.007	0.005	0.020	0.006	0.005	0.015	0.014	0.042	0.004	0.020		0.009
Dom-MIME	0.008	0.016	0.010	0.009	0.022	0.010	0.009	0.016	0.016	0.043	0.008	0.022	0.009	

Table 11 Difference in assigned mass value between laboratory A and laboratory B and the expanded uncertainties for 100 mg in milligrams.

100mg														
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	NIS	MUSSD	NPLI	NPSL	KIM-LIPI	Dom-MIME	
VMI		-0.0011	-0.0005	-0.0015	-0.0061	-0.0082	-0.0024	-0.0007	0.0044	-0.0016	-0.0002	-0.0031	-0.0032	
CSIR	0.0011		0.0006	-0.0004	-0.0050	-0.0071	-0.0012	0.0004	0.0055	-0.0005	0.0009	-0.0020	-0.0021	
NSCL	0.0005	-0.0006		-0.0010	-0.0056	-0.0077	-0.0018	-0.0002	0.0049	-0.0011	0.0003	-0.0026	-0.0027	
NMIA	0.0015	0.0004	0.0010		-0.0046	-0.0067	-0.0008	0.0008	0.0059	-0.0001	0.0013	-0.0016	-0.0017	
ITDI	0.0061	0.0050	0.0056	0.0046		-0.0021	0.0038	0.0054	0.0105	0.0045	0.0059	0.0030	0.0029	
NIMT	0.0082	0.0071	0.0077	0.0067	0.0021		0.0059	0.0075	0.0126	0.0066	0.0080	0.0051	0.0050	
MASM	0.0024	0.0012	0.0018	0.0008	-0.0038	-0.0059		0.0016	0.0068	0.0008	0.0022	-0.0007	-0.0008	
NIS	0.0007	-0.0004	0.0002	-0.0008	-0.0054	-0.0075	-0.0016		0.0051	-0.0009	0.0005	-0.0024	-0.0025	
MUSSD	-0.0044	-0.0055	-0.0049	-0.0059	-0.0105	-0.0126	-0.0068	-0.0051		-0.0060	-0.0046	-0.0075	-0.0076	
NPLI	0.0016	0.0005	0.0011	0.0001	-0.0045	-0.0066	-0.0008	0.0009	0.0060		0.0014	-0.0015	-0.0016	
NPSL	0.0002	-0.0009	-0.0003	-0.0013	-0.0059	-0.0080	-0.0022	-0.0005	0.0046	-0.0014		-0.0029	-0.0030	
KIM-LIPI	0.0031	0.0020	0.0026	0.0016	-0.0030	-0.0051	0.0007	0.0024	0.0075	0.0015	0.0029		-0.0001	
Dom-MIME	0.0032	0.0021	0.0027	0.0017	-0.0029	-0.0050	0.0008	0.0025	0.0076	0.0016	0.0030	0.0001		
100mg conv Unc (k=2)														
	VMI	CSIR	NSCL	NMIA	ITDI	NIMT	MASM	NIS	MUSSD	NPLI	NPSL	KIM-LIPI	Dom-MIME	
VMI		0.006	0.004	0.004	0.018	0.004	0.004	0.007	0.006	0.002	0.012	0.002	0.004	
CSIR	0.006		0.007	0.006	0.019	0.006	0.006	0.008	0.008	0.006	0.013	0.006	0.007	
NSCL	0.004	0.007		0.004	0.019	0.005	0.004	0.007	0.007	0.004	0.013	0.004	0.006	
NMIA	0.004	0.006	0.004		0.018	0.004	0.004	0.007	0.006	0.003	0.012	0.004	0.005	
ITDI	0.018	0.019	0.019	0.018		0.018	0.018	0.019	0.019	0.018	0.022	0.018	0.019	
NIMT	0.004	0.006	0.005	0.004	0.018		0.004	0.007	0.006	0.004	0.013	0.004	0.005	
MASM	0.004	0.006	0.004	0.004	0.018	0.004		0.007	0.006	0.003	0.012	0.004	0.005	
NIS	0.007	0.008	0.007	0.007	0.019	0.007	0.007		0.008	0.007	0.014	0.007	0.008	
MUSSD	0.006	0.008	0.007	0.006	0.019	0.006	0.006	0.008		0.006	0.013	0.006	0.007	
NPLI	0.002	0.006	0.004	0.003	0.018	0.004	0.003	0.007	0.006		0.012	0.002	0.004	
NPSL	0.012	0.013	0.013	0.012	0.022	0.013	0.012	0.014	0.013	0.012		0.012	0.013	
KIM-LIPI	0.002	0.006	0.004	0.004	0.018	0.004	0.004	0.007	0.006	0.002	0.012		0.004	
Dom-MIME	0.004	0.007	0.006	0.005	0.019	0.005	0.005	0.008	0.007	0.004	0.013	0.004		



Figure 1a: Mass values assigned by the participating laboratories with bars representing expanded uncertainties. Zero value corresponds to the KCRV of CCM.M-K1. The uncertainty of the reference value is 4.4  $\mu\text{g}$  ( $k=2$ ).

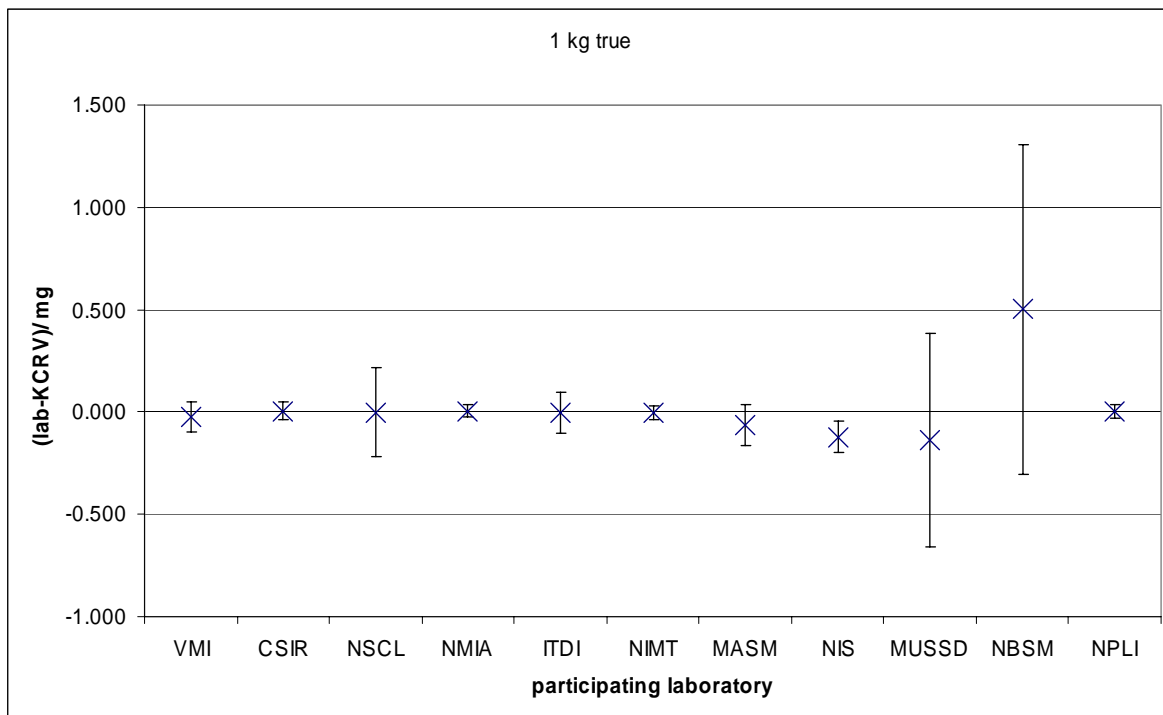


Figure 1b: Same as Figure 1a with scale reduced to correspond to the uncertainties of OIML E<sub>2</sub>

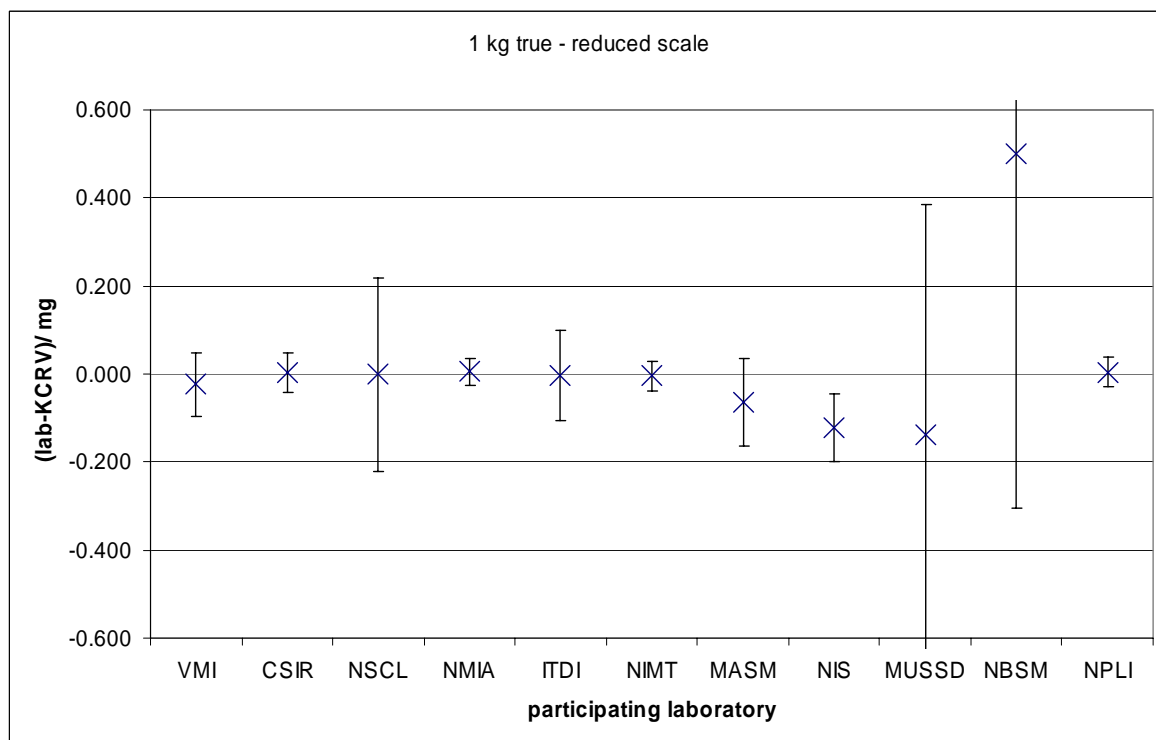


Figure 2: Mass values assigned by the participating laboratories with bars representing expanded uncertainties. Zero mass value corresponds to the key comparison reference value of CCM.M-K1. The uncertainty of the reference value is 4.4  $\mu\text{g}$  ( $k=2$ ).

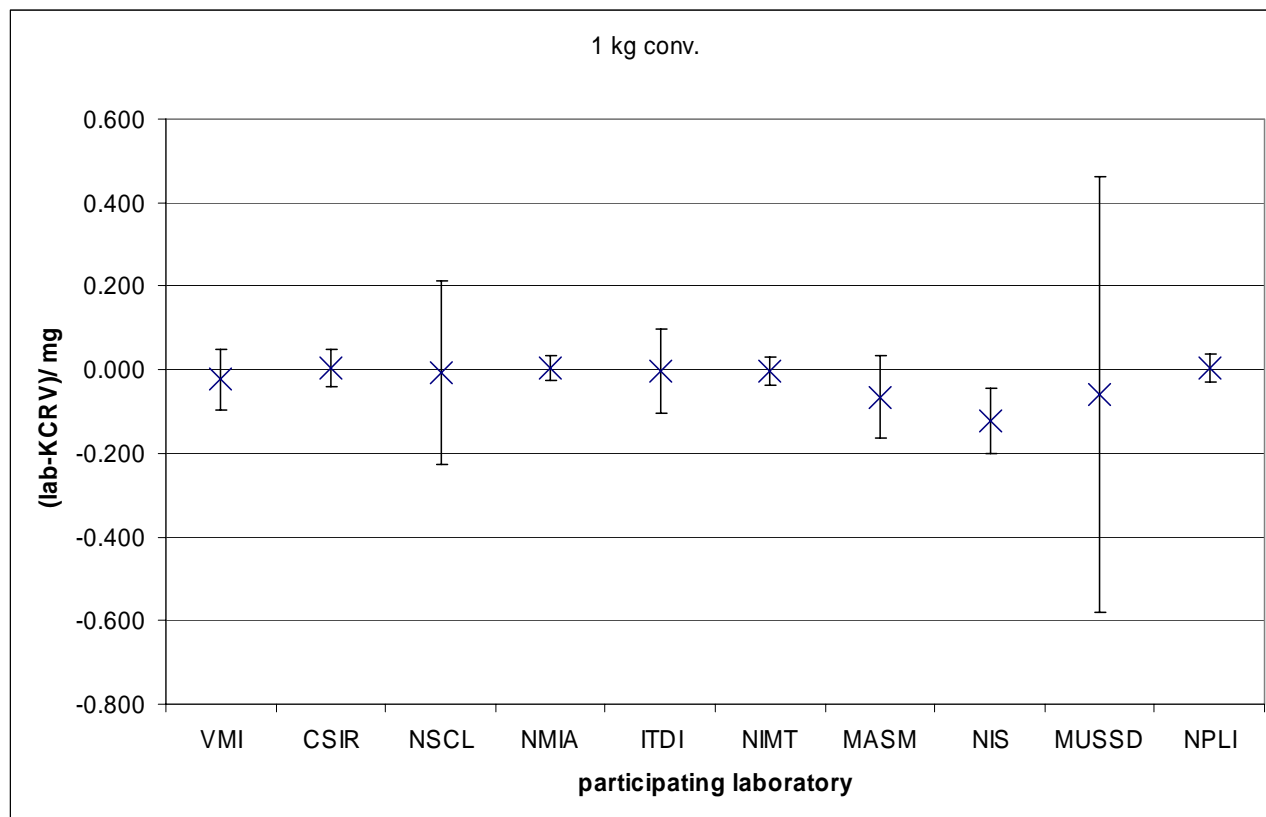


Figure 3a: Mass values assigned by the participating laboratories with bars representing expanded uncertainties. Zero mass value corresponds to the key comparison reference value of CCM.M-K2. The uncertainty of the reference value is 8  $\mu\text{g}$  ( $k=2$ ).

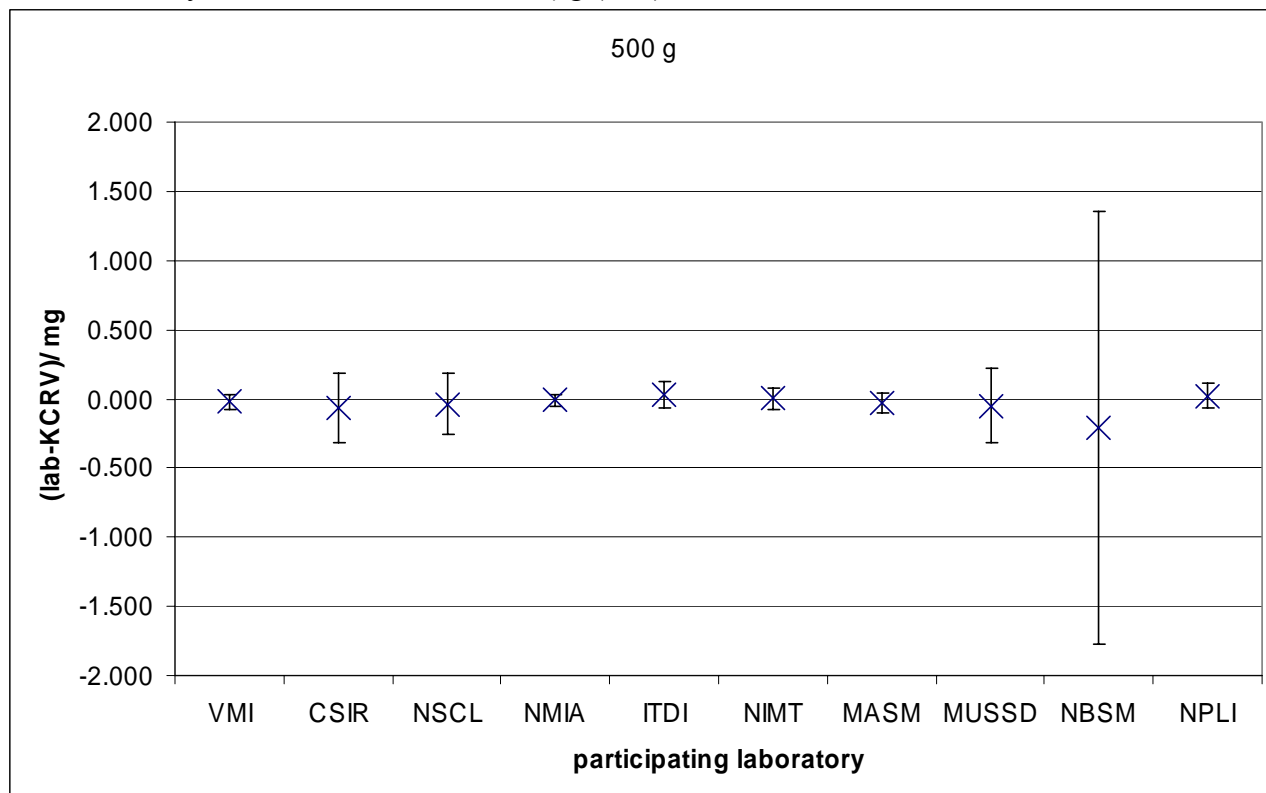


Figure 3b: Same as Figure 3a with scale reduced to correspond to the uncertainties of OIML E<sub>2</sub>

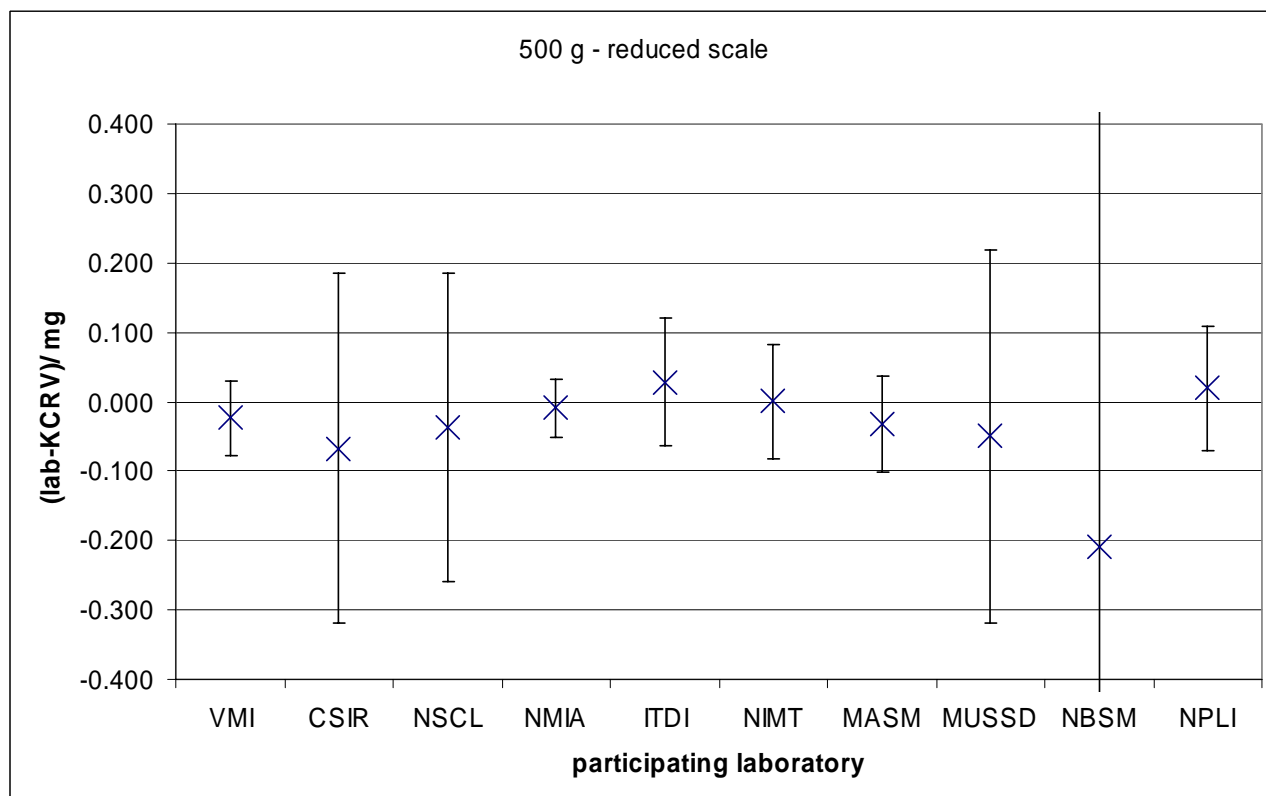


Figure 4a: Mass values assigned by the participating laboratories with bars representing expanded uncertainties. Zero mass value corresponds to the key comparison reference value of CCM.M-K2. The uncertainty of the reference value is 2.2  $\mu\text{g}$  ( $k=2$ ).

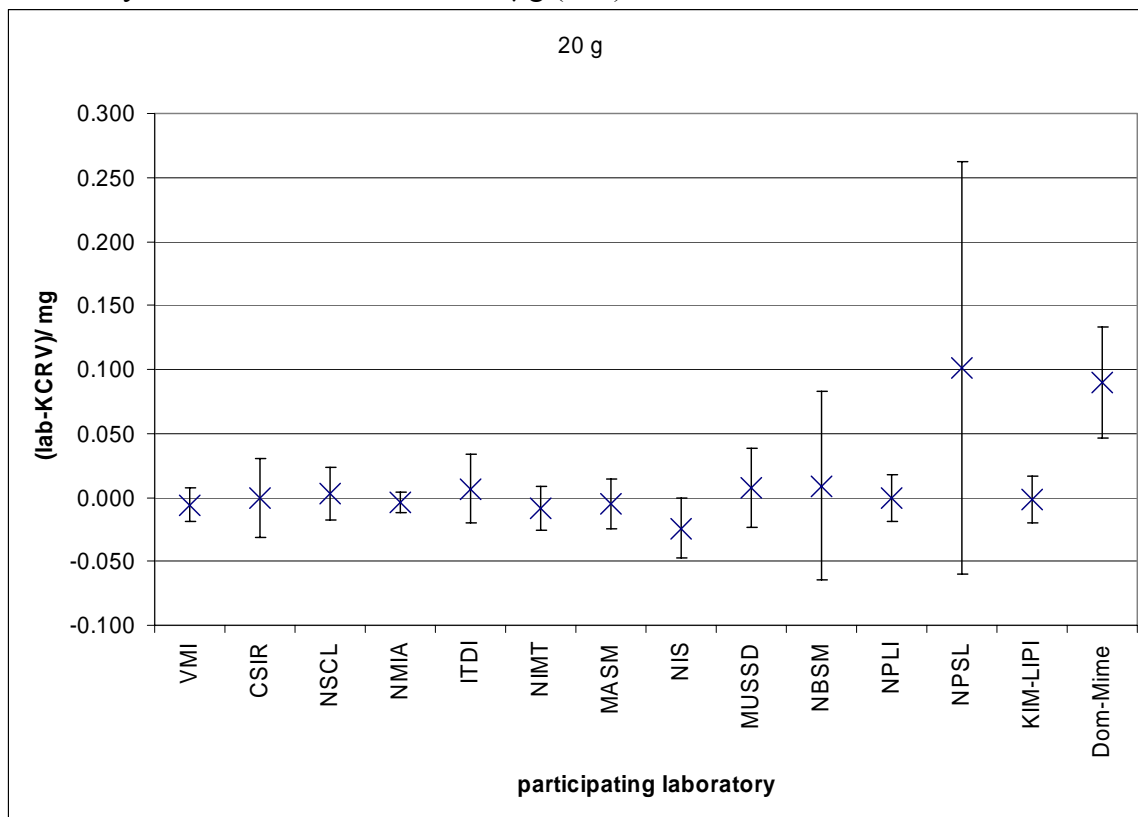


Figure 4b: Same as Figure 4a with scale reduced to correspond to the uncertainties of OIML E<sub>2</sub>

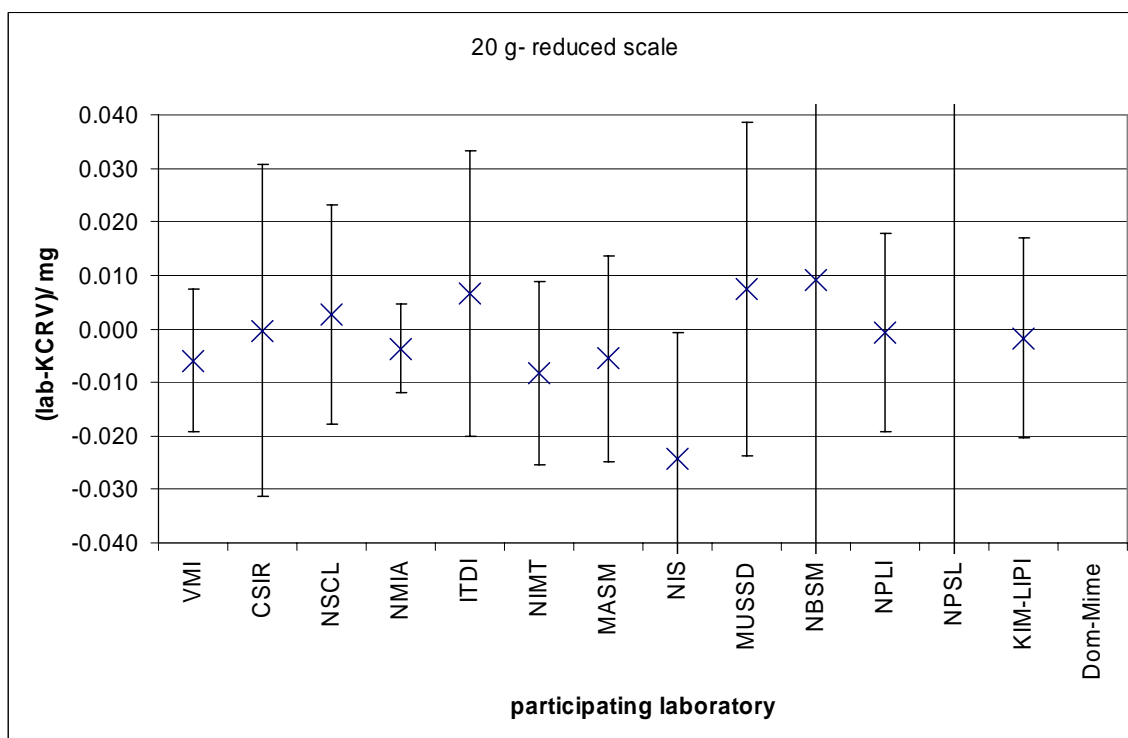


Figure 5a: Mass values assigned by the participating laboratories with bars representing expanded uncertainties. Zero mass value corresponds to the key comparison reference value of CCM.M-K2. The uncertainty of the reference value is 0.8  $\mu\text{g}$  ( $k=2$ ).

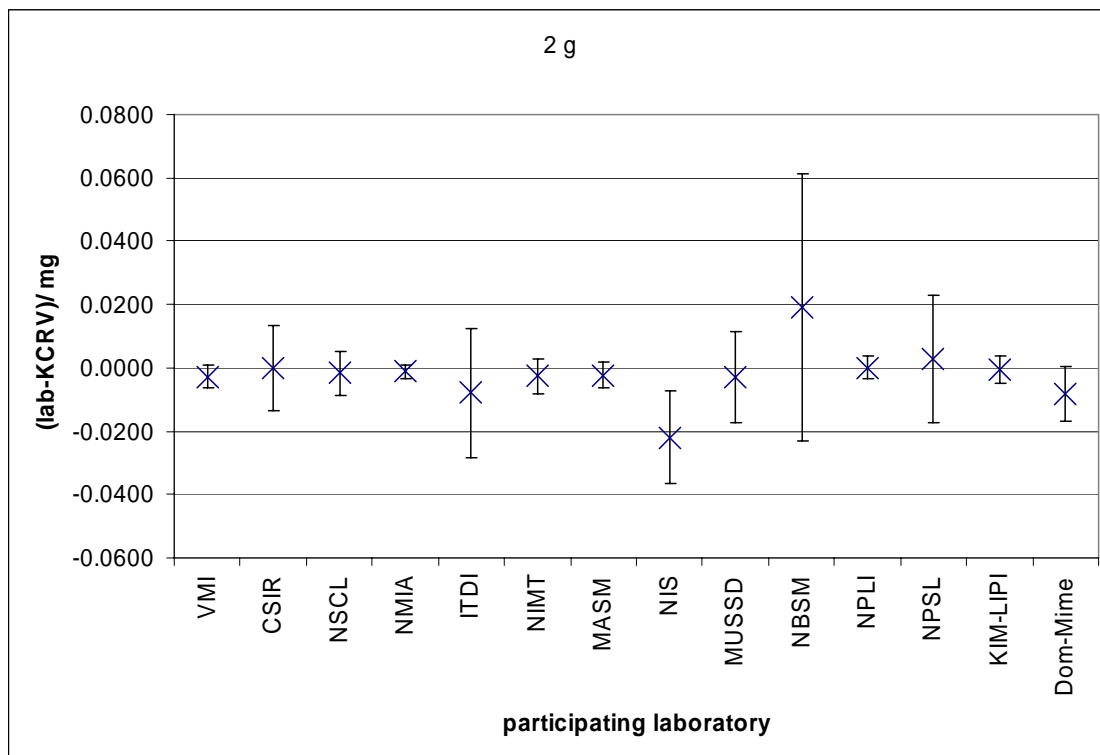


Figure 5b: Same as Figure 5a with scale reduced to correspond to the uncertainties of OIML E<sub>2</sub>

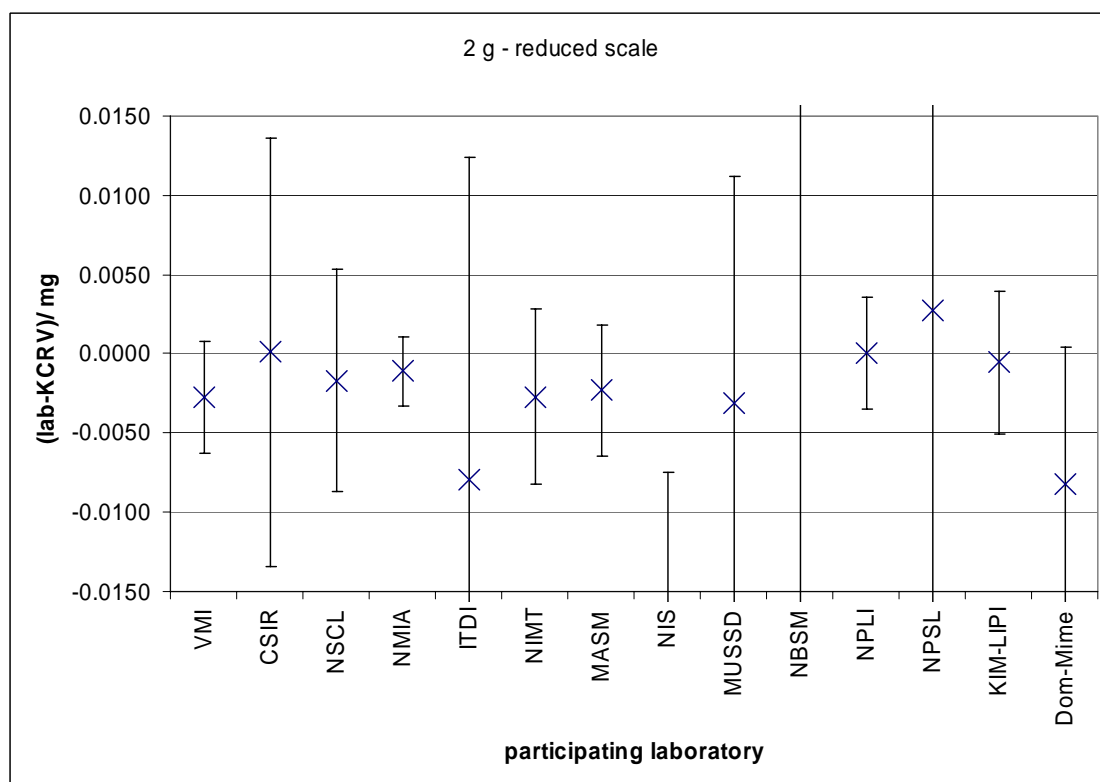


Figure 6a: Mass values assigned by the participating laboratories with bars representing expanded uncertainties. Zero mass value corresponds to the key comparison reference value of CCM.M-K2. The uncertainty of the reference value is  $0.4 \mu\text{g}$  ( $k=2$ ).

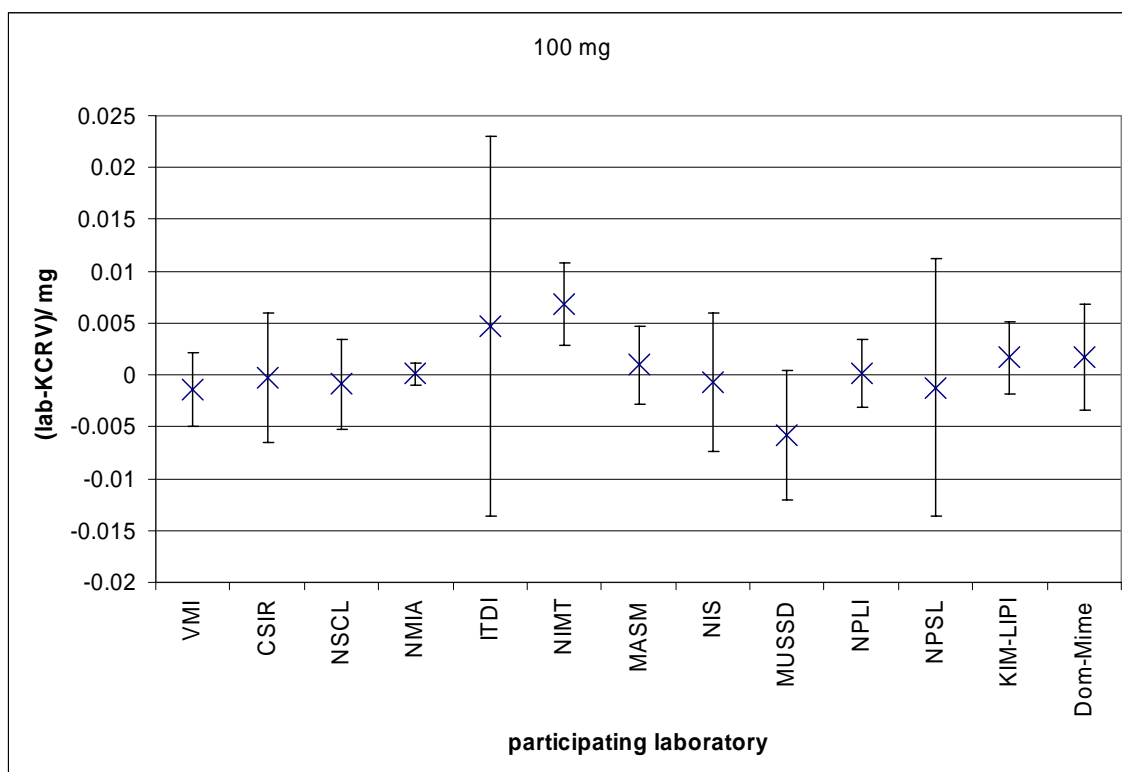


Figure 6b: Same as Figure 6a with scale reduced to correspond to the uncertainties of OIML E<sub>2</sub>

