

COOMET Project 257/Sk-a/02

**Key comparison of stainless steel 1 kg mass standards - COOMET.M.M-K1**

Comparison results

Robert Spurný, Irina Kolozinska,  
Viktor Snegov, Ludmila Evsievich,  
Michael Borys, Ilona Milkamanavičienė

Bratislava 2009

### List of participants

Laboratory	country	Contact person
Slovak Institute of Metrology (SMU) 63, Karloveská str. 84255 BRATISLAVA	Slovakia	Dr. Robert Spurný 004212 602 94 350 spurny@smu.gov.sk
National Scientific Centre “Institute of metrology” (NSC “IM”) Mironositskaya Str, 42, 61002, KHARKOV	Ukraine	Mrs. Irina Kolozinska + 38 057 704-97-22 + 38 057 700 34 47 metrology_mass@ukr.net
All-Russian Scientific Research Institute of Metrology named after D.I. Mendeleev (VNIIM) 19, Moscovsky prospect, 198005 Sankt-Petersburg, Russia	Russia	Dr. Viktor Snegov +7(812) 251 76 01 <a href="mailto:info@vniim.ru">info@vniim.ru</a>
Belarussian State Institute of Metrology (BelGIM) 93, Starovilensky trakt 220053, MINSK	Belorussia	Mrs. Ludmila Evsievich + 375 17 288 08 77 galat@belgim.by
Physikalish-Technische Bundesanstalt (PTB) Bundesallee 100 Braunschweig	Germany	Dr. Michael Borys <a href="mailto:Michael.Borys@PTB.de">Michael.Borys@PTB.de</a> +49(0) 531 592 1110
State Metrology Service (VMT) 31, Algirdo str. 2006 VILNIUS	Lithuania	MSc. Ilona Milkamanavičienė + 370 5 230 62 76 + 370 5 216 43 09 <a href="mailto:post@vmc.lt">post@vmc.lt</a>

### Timetable for circulation of weights

number	Laboratory	Date
1	SMU	March 2002
2	NSC IM	May 2002
3	VNIIM	June 2002
4	BelGIM	March 2003
5	PTB	May 2003
6	SMU	July 2003
7	VMC	February 2004
8	SMU	May 2004

## Mass standards

For international COOMET comparison were used two mass standards from SMU, marked 1 kg 04 and 1 kg 07.

SMU Standards from nonmagnetic stainless steel were produced in 1980.

Volumes of standards determined by hydrostatic weighing are

V 04 : 126,179 cm<sup>3</sup>,  $u_c = 0,002$  cm<sup>3</sup>

V 07 : 125,998 cm<sup>3</sup>,  $u_c = 0,002$  cm<sup>3</sup>

Mass of standards 04 and 07 was determined in SMU :

- in the year 2002 – comparing to the SMU standards 1 kg 02 and 1 kg E1. Standards 02 and E1 are calibrated by PtIr standard 1 kg No 65.

- in the year 2003 – comparing to the SMU standards 1 kg 02 and 1 kg E1. Standards 02 and E1 are calibrated by PtIr standard 1 kg No 65.

- in the year 2004 – comparing to the SMU standards 1 kg 02 and 1 kg E4. Standards 02 and E4 are calibrated by PtIr standard 1 kg No 65.

## Instruments used in participating laboratories r for Coomet comparison

Mass comparators	
SMU	Mettler AT 1006 (Max 1011 g, d = 0,001 mg)
NSC IM	Sartorius C1000S ( Max 1 kg, d = 0,002 mg)
VNIIM	Sartorius CC1000SL ( Max 1 kg, d = 0,001 mg)
BelGIM	Mettler AT 1005 ( Max 1109 g, d = 0,01 mg)
PTB	Mettler HK 1000 MC ( Max 1001,15 g, d = 0,0001 mg)
VMC	Mettler AT 1006 (Max 1011 g, d = 0,001 mg)

Device for air density determination	
SMU	Mettler Klimet A30
NSC IM	Temperature – Termopribor, TL-19, 0,1°C Pressure – GUGMC – CP-A, 0,1 mbar Humidity – Termopribor, MB-4M, 0,2°C
VNIIM	Temperature – VNIIM TCM 50, 0,02°C Pressure – MKRV Voschod, BOP-1, 0,01mbar Humidity – M-34, 2%
BelGIM	Temperature – RU VIT-1, 0,2°C Pressure Humidity – RU VIT-1, 1%
PTB	Temperature – glass thermometer, 0,01°C Pressure – Paroscientific 740-16B Humidity MBW DP3-D, 0,01 K
VMC	Mettler Klimet A30

## Traceability of mass standards

laboratory	Standard	mass	u <sub>c</sub> mg	Volume cm <sup>3</sup>
SMU	1 kg 02,	1 kg +0,250 mg	0,020	126,099
	1 kg E1	1 kg +3,535 mg	0,020	125,214
NSC IM	1kg UA2	1 kg +1,114 mg	0,015	125,505
VNIIM	1 kg No6	1 kg +3,486 mg	0,01	126,935
	1 kg No 12	1 kg +0,100 mg	0,0023	46,4082
BelGIM	1 kg No 5	1 kg +2,36 mg	0,02	126,454
PTB	1 kg G	1 kg -4,143 mg	0,013	124,4169
VMC	1 kg 154	1kg - 0,097 mg	0,05	124,85
	1 kg 21038	1 kg + 1,46 mg	0,05	125,63

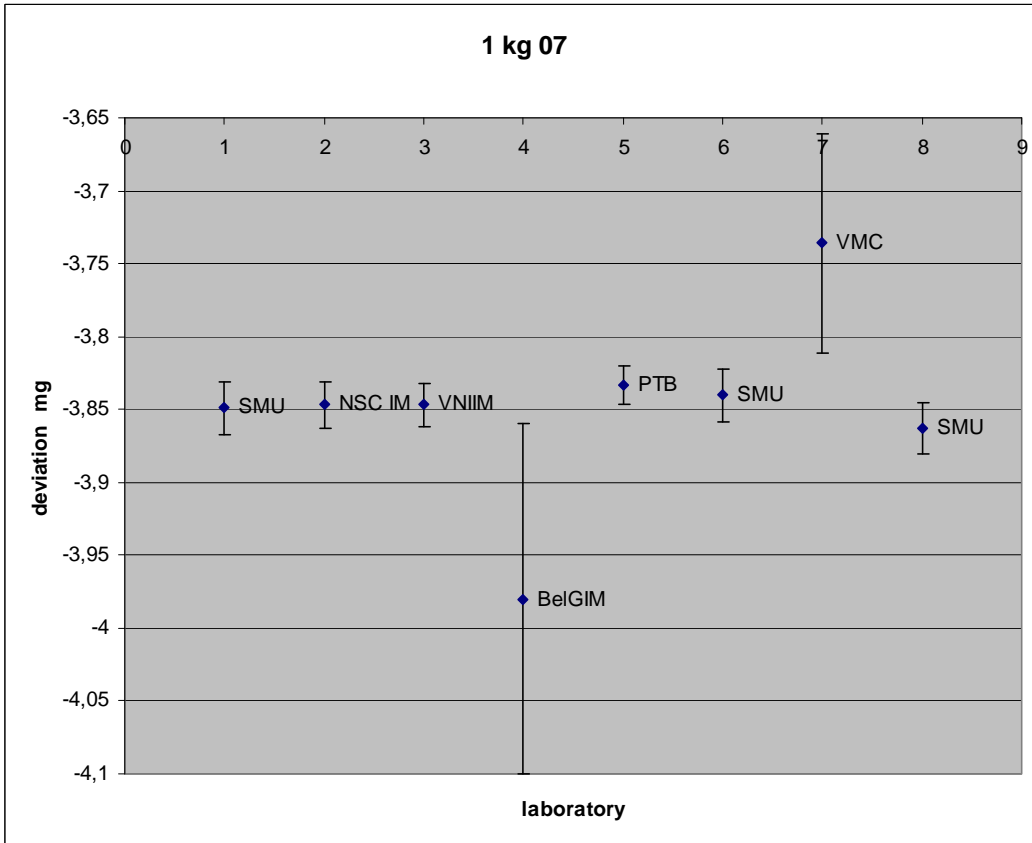
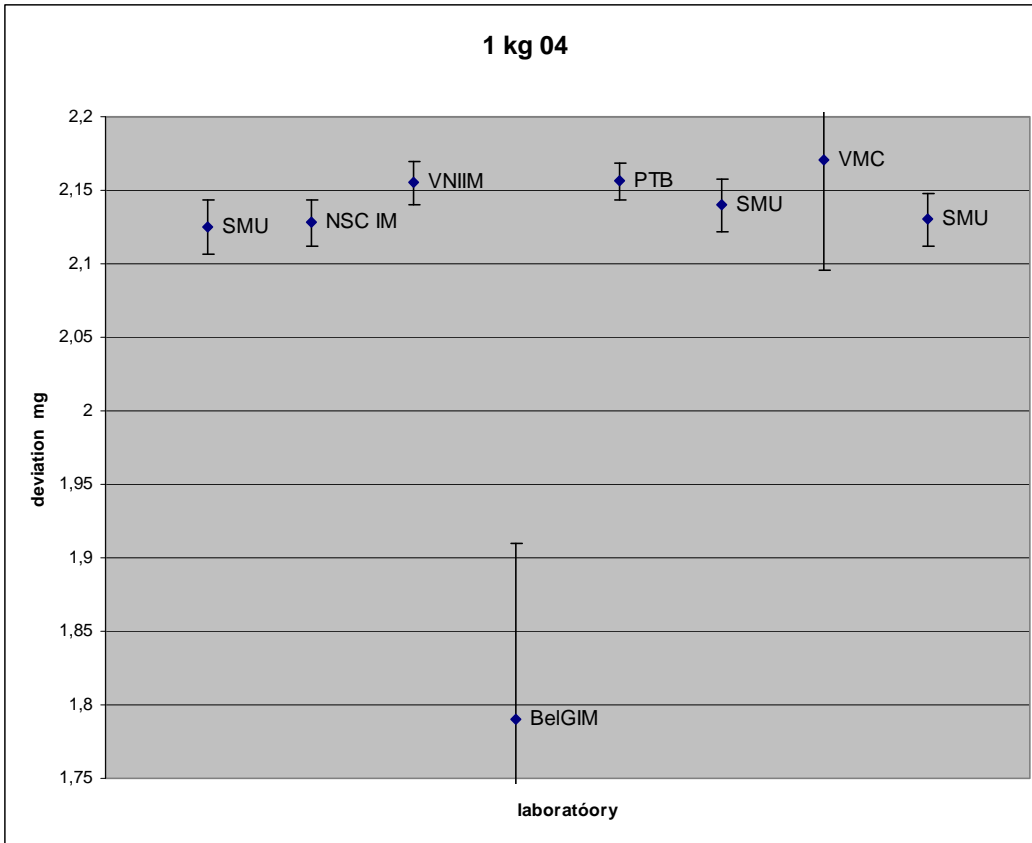
## Results of comparison presented by participating laboratories

### data of participating laboratories

#### COOMET 1 kg MASS STANDARDS COMPARISON

- deviations of mass standards 04 a 07 from nominal mass (mg)

	SMU march 02	Ukr may 02	VNIIM june 02	BelGIM mar 03	PTB may 03	SMU july 03	VMC febr 04	SMU may 04
1 kg 04	2,125	2,128	2,155	1,79	2,156	2,14	2,171	2,13
1 kg 07	-3,849	-3,847	-3,847	-3,98	-3,833	-3,84	-3,736	-3,863
uncert	0,018	0,016	0,015	0,046	0,013	0,018	0,075	0,018



Results of laboratories were evaluated by COOMET Recommendation R/GM/14:2006

## Key comparison reference value KCRV

Linking laboratory to CIPM (CCM M K1) measurement is PTB

KCRV – value of PTB :

PTB result of measurement in CCM M K1 :

difference from the reference value for PTB:  $x_{\text{ref}} = x^* = -1 \mu\text{g}$ ,  $u_{\text{C,PTB}} = 13 \mu\text{g}$

## Transformed data of participating laboratories

$$x_i' = x_i + \Delta, \text{ where}$$

$x_i'$  = transformed result of laboratory

$x_i$  = result of laboratory

$\Delta$  = additive correction – in Coomet project 257 case

$$\Delta = x^* - x_{\text{PTB}}, \quad x_{\text{PTB}} \text{ PTB result in Coomet 257}$$

$$u^2(\Delta) = 2 \cdot u_{\text{C,PTB}}^2$$

for mass standard 04 :  $x_{\text{PTB}} = 2,156 \text{ mg}$  :  $\Delta_{04} = (-0,001 - 2,156) \text{ mg} = -2,157 \text{ mg}$

for mass standard 07 :  $x_{\text{PTB}} = -3,833 \text{ mg}$  :  $\Delta_{07} = (-0,001 + 3,833) \text{ mg} = 3,832 \text{ mg}$

## Degrees of equivalence

$$d_i = x_i + \Delta - x_{\text{ref}}$$

As the KCRV value is for one linking laboratory

$$u^2(d_i) = u^2(x_i) + u^2(x_{\text{ref}})$$

## Pair degrees of equivalence

As there is no traceability among participants, there is  $\text{cov}(x_i, x_j) = 0$

Pair degrees of equivalence of the RMO KC

$$d_{ij} = d_i - d_j = x_i - x_j$$

$$u^2(d_{ij}) = u^2(x_i) + u^2(x_j)$$

Pair degrees of equivalence of the RMO KC and CIPM ( PTB)

$$d_{ij} = x_i + \Delta - x_j$$

$$u^2(d_{ij}) = u^2(x_i) + u^2(\Delta) + u^2(x_j)$$

## Evaluation of the results

In the following table of participant results is SMU taken as an arithmetic mean

Data of participating laboratories - Deviations from nominal masses (mg)

	SMU	NSC IM	VNIIM	BelGIM	PTB	VMC
1 kg 04	2,132	2,128	2,155	1,79	2,156	2,171
1 kg 07	-3,851	-3,847	-3,847	-3,98	-3,833	-3,736
uncert	0,018	0,016	0,015	0,12	0,013	0,075

Transformed data (mg)

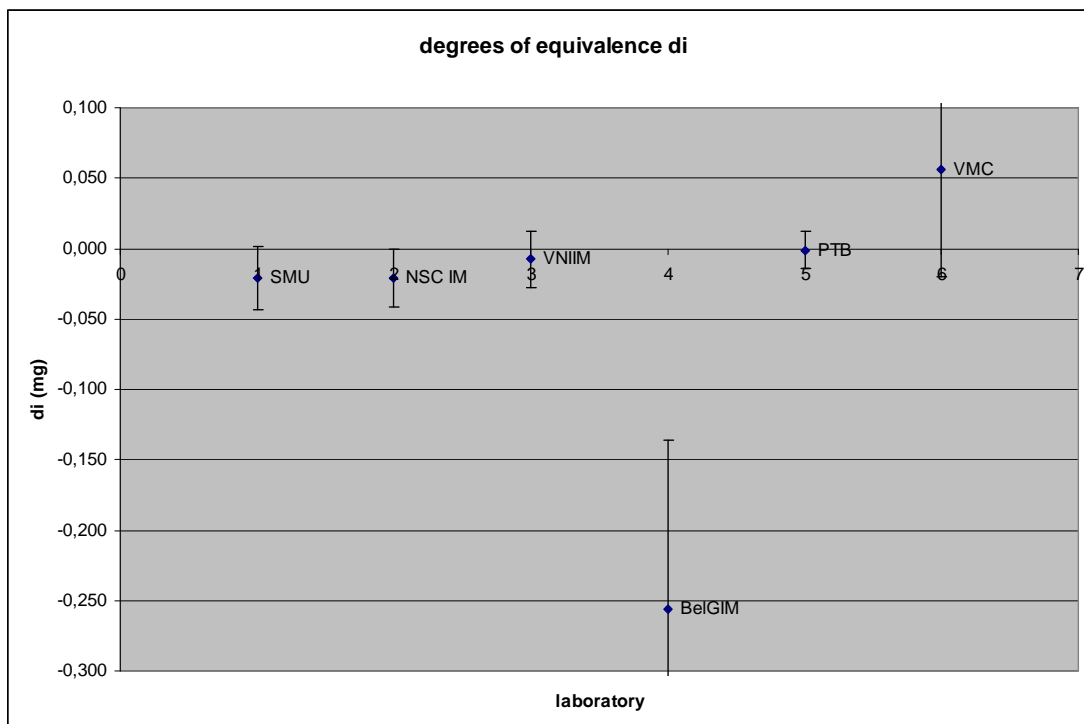
	SMU	NSC IM	VNIIM	BelGIM	PTB	VMC
1 kg 04	-0,025	-0,029	-0,002	-0,367	-0,001	0,014
1 kg 07	-0,019	-0,015	-0,015	-0,148	-0,001	0,096
uncert	0,018	0,016	0,015	0,12	0,013	0,075

Arithmetic mean of measurements for standards 04 and 07 (mg)

	SMU	NSC IM	VNIIM	BelGIM	PTB	VMC
$\bar{x}_i'$	-0,022	-0,022	-0,0085	-0,2575	-0,001	0,055
$u(\bar{x}_i')$	0,018	0,016	0,015	0,12	0,013	0,075

**Degree of equivalence  $d_i$  and uncertainties  $u(d_i)$ , (mg)**

	SMU	NSC IM	VNIIM	BelGIM	PTB	VMC
$d_i$	-0,021	-0,021	-0,008	-0,257	-0,001	0,056
$u(d_i)$	0,022	0,021	0,020	0,121	0,013	0,076



Pair degrees of equivalence  $d_{ij}$  for participants of RMO (mg)

	SMU	NSC IM	VNIIM	BelGIM	PTB	VMC
SMU	0,000	0,000	0,013	-0,236	0,020	0,077
Ukr	0,000	0,000	0,013	-0,236	0,020	0,077
VNIIM	-0,013	-0,013	0,000	-0,249	0,007	0,063
BelGIM	0,236	0,236	0,249	0,000	0,256	0,313
PTB	-0,020	-0,020	-0,007	-0,256	0,000	0,057
VMC	-0,077	-0,077	-0,063	-0,313	-0,057	0,000

Uncertainties  $u(d_{ij})$  (mg)

	SMU	NSC IM	VNIIM	BelGIM	PTB	VMC
SMU		0,030	0,030	0,123	0,026	0,079
Ukr	0,030		0,029	0,122	0,024	0,079
VNIIM	0,030	0,029		0,122	0,024	0,079
BelGIM	0,123	0,122	0,122		0,121	0,143
PTB	0,026	0,024	0,024	0,121		0,077
VMC	0,079	0,079	0,079	0,143	0,077	