

FINAL REPORT: COOMET.M.M-K5
«Key comparisons in the field of multiples and submultiples of the kilogram»
(COOMET 258/RU/02)

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December 2013

1. Introduction

This report summarizes the results of a comparison of Mass Standards conducted between four participating members of Euro-Asian Cooperation of National metrological Institutes (COOMET).

The COOMET key comparisons are usually carried out on those schemes that was proposed and implemented by the Consultative Committee for Mass and Related Quantities of the CIPM. Measurement comparisons bring the laboratories a confidence in the measurement standards and lead to the international acceptance of the measurement standards.

This comparison was arose from discussions at the 9th meeting of TC 1.6 "Mass and related quantities on 21-23 April, 2004, SMU, Slovakia. The comparison is internally identified as COOMET 258/RU/02 and KCDB identifier has been attributed by the BIPM as COOMET M.M-K5.

The purpose of the key comparison COOMET.M.M-K5 "Comparisons in the field of multiples and submultiples of the kilogram" is in comparing the results of measurements obtained by the participants. Two weights sets with five nominal mass values: 2 kg, 200 g, 50 g, 1 g and 200 mg (OIML Class E1) were used as transfer standards. These nominal values were chosen as they followed the second phase of comparison CCM.M-K5. All-Russian D.I. Mendeleev Research Institute for Metrology, VNIIM was the pilot laboratory as well as a link to the laboratory to the CCM comparisons. The comparison was carried out from May 2015 to July 2008. In 2007, measurements were carried out by Kazakhstan Institute of Metrology (RSE "KazInMetr") on his own initiative (letter № 18-05-01-3-2/6225 of 11/14/07).

2. Participants

Four National metrology institutes (NMIs) of COOMET Member- Countries took part in the comparison. They are listed in Table 1.

Table 1

Laboratory NMI	Country	Acronym
Russian Scientific Research Institute of Metrology DI Mendeleev (Pilot laboratory)	Russia	VNIIM
National Scientific Center "Institute of Metrology", Kharkov	Ukraine	NSC IM
Belarusian State Institute of Metrology	Belarus	BelGIM
Kazakhstan Institute of Metrology	Kazakhstan	KazInMetr

Measurements Schedule

No.	Name of NMI	Date of measurements
1	VNIIM	May 2005
2	BelGIM	September 2005
3	NSC IM	September 2006
4	KazInMetr	May 2008
5	VNIIM	July 2008

3 Transfer standards

3.1 Reference mass standards

Two weights sets with five nominal mass values: 2 kg, 200 g, 50 g, 1 g and 200 mg (OIML Class E1) were circulated among the participants. The transfer standards were provided by company "SARTOGOSM", St. Petersburg. Each of the transfer standard sets comprised five non-magnetic stainless steel weights and according to OIML, metrological and technical characteristics of them were not worse than Class E₁. Each set of transfer standards were placed in the weight boxes and then placed in a carton box. Transportation was undertaken by hand.

The metrological and technical characteristics of weights are presented in Table 2.

Table 2

Nominal value, g	Marking	Shape	Volume, cm ³	Density, g/cm ³	Susceptibility, χ or magnetization, μT
2000	«5»	Cylinder	253,630	7,8855	$\leq 0,02$
2000	None	Cylinder	253,810	7,8799	$\leq 0,02$
200	«*»	Cylinder	24,646	8,1149	$\leq 0,02$
200	None	Cylinder	25,409	7,8712	$\leq 0,02$
50	«*»	Cylinder	6,331	7,8976	$\leq 2,5$
50	«**»	Cylinder	6,328	7,9014	$\leq 2,5$
1	«1»	Knob	0,1265	7,9051	$\leq 2,5$
1	None	Cylinder	0,1266	7,8989	$\leq 2,5$
0,2	«*»	Sheet	0,0253	7,9051	$\leq 2,5$
0,2	None	Sheet	0,0253	7,9051	$\leq 2,5$

Notes: 1. Density values obtained from the sheet of material.

2. Temperature coefficient of thermal expansion was taken equal to $4,8 \cdot 10^{-5} \text{ } ^\circ\text{C}^{-1}$.

3.2 Packing

The transfer standards are packed in separate cases. They are shown in Fig. 1. This packing is usually used for precision weights class E.



Fig.1

Measuring instruments used by the participants

Balances – comparators	
VNIIM	CC2000 (Max= 2 kg, d=0,1 mg); CC1000S (Max=1000,5 g, d=0,001 mg); CC50 (Max=52 g, d=0,001 mg); UMX5 (Max=5,1 g, d=0,0001 mg)
BelGIM	VLO-5kg-1(Max= 5 kg, d=0,78 mg); AT1005 (Max= 1109 g, d=0,01 mg); AX 106 (Max=111 g, d=0,001 mg); C5S (Max=5,02 g, d=0,0001 mg)
KazInMetr	AX12004 (Max=12 kg, d=0,1 mg); AT1005 (Max=1109 g, d=0,01 mg); AT106/A (Max=111 g, d=0,001 mg); UMX5 (Max=5,1 g, d=0,0001 mg);
NSC IM	C5001 (Max=5100 g, d=0,5 mg); C1000S (Max=1000,5 g, d=0,02 mg) CC50 (Max=52 g, d=0,001 mg)
Devices for measuring the density of the air	
VNIIM	Thermometer - Multichannel digital thermometer, 0,02 °C Barometer – BOP-1, 0,5 hPa Hygrometer – Ratronik, 1%
BelGIM	Thermometer – BIT-2, 0,2 °C Barometer - BRC-1M-2, 0,03 hPa Hygrometer – BIT-2, 6 %
KazInMetr	Thermometer – Fluke 1620A, 0,04 °C Barometer – MES-200A, 2,9 hPa Hygrometer - Fluke 1620A, 0,5 %
NSC IM	Thermometer – TL-19, 0,1 °C Barometer – CP-A, 0,2 hPa Hygrometer – MB-4M, 5 %

NMI standards

The reference mass standards of participants which were used in measurements are shown in Table 3.

Table 3

NMI	Nominal	Marking	Mass	u_c , mg	Volume, cm ³
VNIIM	2 kg	No. 18325086/5	1 kg- 0,0007 mg	0,02	124,1495
		No. 31	1 kg- 0,2964 mg	0,02	125,3425
	200 g	No. 18325086/5	200,000575 g	0,008	25,450
	50 g	No. 18325086/5	50,000125 g	0,005	6,361
	1 g	No. 18325086/5	0,9999 mg	0,001	0,127
BelGIM	2 kg	KGRS-1 kg No. 5	1 kg + 2,24 mg	0,025	126,454
		1 kg E ₁ No.15918	1 kg + 0,23 mg	0,025	126,454
	200 g	RS-1110 No. 13	200,00048 g	0,01	25,291
	50 g	RS-1110 No. 13	50,000383 g	0,005	6,3227
	1 g	RS-1110 No. 13	1,000061 g	0,001	0,1265
KazInMetr	2 kg	RS 15935	1kg – 0, 23 mg	0,05	126,7905
		1 kg E1 No. 1593	1 kg + 0,041 mg	0,06	126,7495
	200 g	200 g No. 1593	200,00006 g	0,02	24,9619
	50 g	50 g No. 1593	50,000026 g	0,01	6,2416
	1 g	1 g No. 1593	1,000002 g	0,002	0,12506
NSC IM	2 kg	«1» knob	1 kg + 0,056 mg	0,020	124,10
		«1» cylinder	1 kg + 0,952 mg	0,016	125,458
	200 g	none	199,999993 g	0,010	25,092
		«*»	199,999957 g	0,010	25,094
	50 g	none	50,000007 g	0,002	6,273
		none	49,999943 g	0,002	6,273
	1 g	«/»	1,000002 g	0,0001	0,125
		«//»	0,999997 g	0,0002	0,125
	200 mg	none	0,199999 g	0,0002	0,025
		none	0,200002 g	0,0002	0,025

4. The results of comparisons reported by the participants

The comparisons results of the transfer standards are presented by the participants: the actual mass and the combined uncertainty are given in Tables 4 and 5. Here $m-m_0$ is a measured difference in mass of transfer standard from its nominal value, u_c - combined uncertainty ($k = 1$).

The results of the pilot laboratory VNIIM are also presented as the results of a laboratory.

Table 4

NMI	2 kg				200 g				50 g			
	«5»		None		«*»		None		«*»		«**»	
	$m - m_0$ mg	u_c mg	$m - m_0$ mg	u_c mg	$m - m_0$ mg	u_c mg	$m - m_0$ mg	u_c mg	$m - m_0$ mg	u_c mg	$m - m_0$ mg	u_c mg
VNIIM	6,06	0,10	5,64	0,10	-0,080	0,011	-0,288	0,011	0,121	0,005	0,134	0,005
BelGIM	5,83	0,22	5,69	0,22	-0,050	0,030	-0,258	0,030	0,070	0,005	0,090	0,005
KazInMetr	6,11	0,06	5,52	0,06	-0,083	0,004	-0,289	0,004	0,124	0,004	0,136	0,004
NSC IM	6,25	0,15	5,04	0,15	-0,081	0,011	-0,306	0,011	0,123	0,006	0,136	0,006

Table 5

NMI	1 g				200 mg			
	Cylinder		Knob		«*»		None	
	$m - m_0$ mg	u_c mg	$m - m_0$ mg	u_c mg	$m - m_0$ mg	u_c mg	$m - m_0$ mg	u_c mg
VNIIM	-0,0751	0,0005	0,0614	0,0005	-0,6500	0,0001	0,0011	0,0001
BelGIM	-0,0720	0,0018	0,0640	0,0018	-0,6493	0,0018	-0,0001	0,0018
KazInMetr	-0,0747	0,0008	0,0622	0,0008	-0,6491	0,0008	-0,0011	0,0008
NSC IM	-0,0750	0,0018	0,0620	0,0018	-0,6480	0,0018	0,0010	0,0018

4.1 Stability of the transfer standards

The changes in the mass of transfer standards that have occurred over the time of the comparisons have been measured in VNIIM, and they are shown in Table 6.

In general, these changes are small and have the order of the component uncertainty of measurement results estimated by type A.

Table 6

Nominal value, m_0 , g	Instability mass Δm , μg			u_c , μg
	With marking	Without marking	Standards	
2000	- 110	+ 90	-10	200
200	- 3	0	0	5
50	+ 3	+ 4	-1	5
1	+2	+4	- 0,3	0,5
0,2	- 0,7	+ 0,8	0,2	0,1

Table 7. Repeatability of the mass measurement results of transfer standards to VNIIM

Date	2 kg		200 g		50 g		1 g		200 mg	
	«5»	none	«*»	none	«*»	«**»	C	K	«*»	none
05.2005	6,06	5,59	-0,079	-0,284	0,119	0,131	-0,0752	0,061	-0,6496	0,0007
08.2007	6,03	5,67	-0,080	-0,288	0,122	0,134	-0,0749	0,061	-0,6500	0,0009
08.2008	5,95	5,69	-0,082	-0,292	0,123	0,136	-0,0747	0,061	-0,6502	0,0013
Average value	6,00	5,64	-0,080	-0,288	0,121	0,134	-0,0750	0,061	-0,6499	0,0010
$S(d)$	0,06	0,05	0,002	0,004	0,002	0,003	0,0003	0,000	0,0003	0,0003

4.3 KCRV

The equivalence degrees of VNIIM were calculated as per results of the CCM.M-K5 comparison as it is presented in Table 8. These degrees of equivalence of VNIIM were calculated using results 2 kg-Jx, 200 g-Jy, 1 g-Jy and 200 mg-Jy from the CCM.M-K5 comparison as presented in Table 8.

The VNIIM result for weight with the nominal value 50 g was not consistent with KCRV, and thus the results of measurements in this value have been excluded from the COOMET comparison report. This occurred due to changes in the laboratory of VNIIM. The mechanical mass comparator of VNIIM which had been used for measuring 50 g in the CIPM key comparison was replaced to an electronic comparator. Therefore the reference value of CIPM comparison in this value has not been calculated for RMO comparison.

Table 8

Nominal mass, m_0	Equivalence, D_{VNIIM} , mg	Expanded uncertainty, $U(D_{VNIIM})$, mg
2 kg-Jx	0,004	0,062
200 g-Jy	0,0026	0,0103
50 g-Jy	-0,0478	0,0144
1g-Jy	-0,00156	0,00195
200 mg-Jy	-0,00061	0,0019

The degree of equivalence

The standards equivalence degree for the participants was calculated according to the formula:

$$D_{ij} = (m_i - m_{0i})_j - (m_i - m_{0i})_{VNIIM} + \Delta_i, \quad (1)$$

where $\Delta_i = D_{iVNIIM}$ is the equivalence degree for the mass of the measurement standard with i -th of the nominal value of the results of CIPM comparisons.

This approach of linking the participants' results to the degrees of equivalence of the linking laboratory in CCM.M-K5 is different from the normal approach, which would be to use the results of the linking laboratory in both CCM.M-K5 and COOMET.M.M-K5 to relate the participants' results in COOMET.M.M-K5 to the KCRV of CCM.M-K5.

In case of using only one linking laboratory standard the uncertainty of the equivalence degree is calculated by the formula:

$$u_{ij}^2(D_{ij}) = u_{ij}^2(\Delta m_{ij}) + u_i^2(\Delta m_{iVNIIM}) + \frac{1}{4} U_i^2(D_{iVNIIM}), \quad (2)$$

where $u_{ij}(\Delta m_{ij})$ is the uncertainty of the measurement standard mass deviation from the nominal value for i -th standard of J -th institute;

$u_i(\Delta m_{iVNIIM})$ is the uncertainty of the measurement standard mass deviation from the nominal value for i -th standard obtained by VNIIM;

$U_i(D_{iVNIIM})$ is the extended uncertainty of the equivalence degree of the i -th mass standard obtained by VNIIM in CIPM comparison.

The equivalence degrees of the comparison participants are presented in Tables 9 and 10.

Table 9

NMI	2 kg «5»		2 kg None		200 g «*»		200 g None	
	D_j , mg	$U(m)$, mg	D_j , mg	$U(m)$, mg	D_j , mg	$U(m)$, mg	D_j , mg	$U(m)$, mg
BelGIM	-0,226	0,48	0,054	0,48	0,033	0,064	0,033	0,064
KazInMetr	0,054	0,24	-0,116	0,24	0,000	0,026	0,002	0,026
NSC IM	0,194	0,36	-0,596	0,36	0,002	0,032	-0,015	0,032

Table 10

NMI	1 g «C»		1 g «K»		200 mg «*»		200 mg None	
	D_j , mg	$U(m)$, mg	D_j , mg	$U(m)$, mg	D_j , mg	$U(m)$, mg	D_j , mg	$U(m)$, mg
BelGIM	0,0015	0,0042	0,0010	0,0042	0,0001	0,0040	-0,0018	0,0040
KazInMetr	-0,0012	0,0028	-0,0008	0,0028	0,0003	0,0024	-0,0028	0,0024
NSC IM	-0,0015	0,0042	-0,0010	0,0042	0,0014	0,0040	-0,0007	0,0040

The degrees of equivalence, D_j , of all the mass standards are presented at Figures 2 – 9.

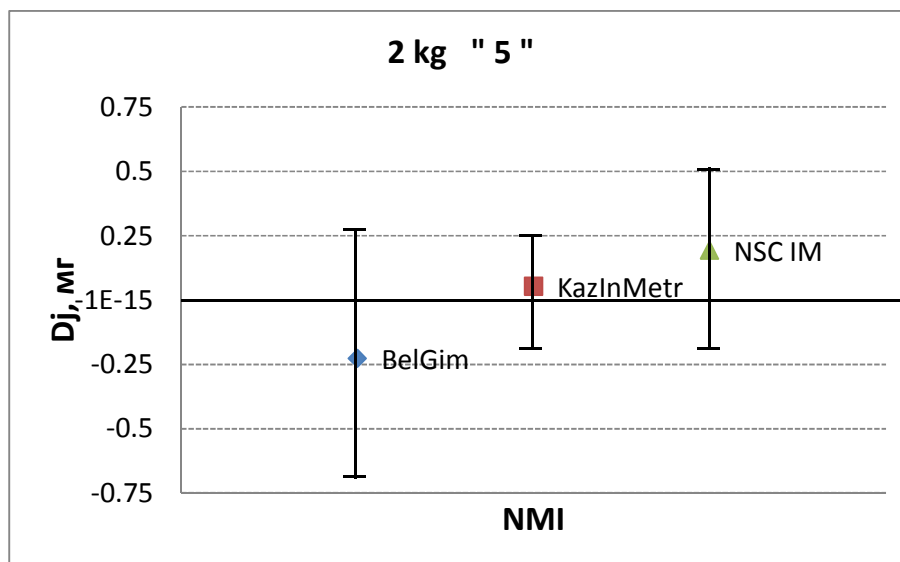


Fig. 2

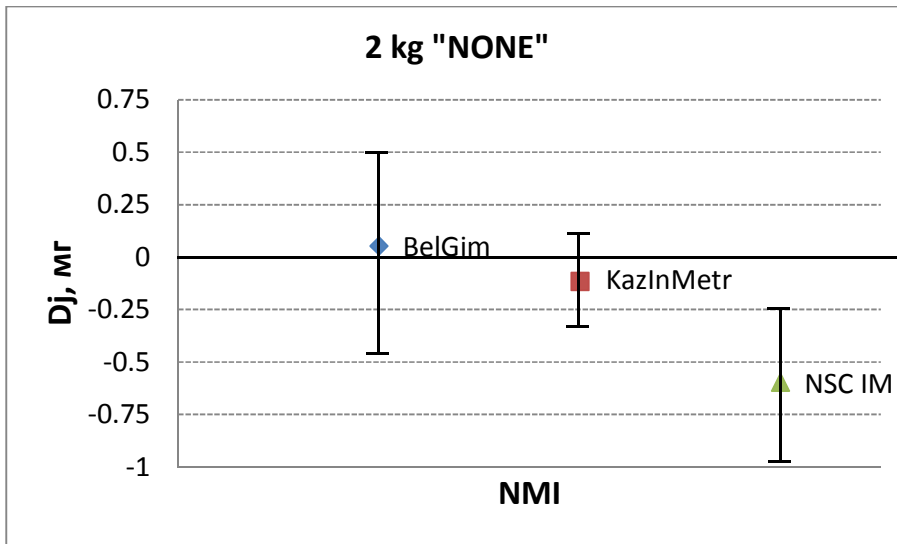


Fig. 3

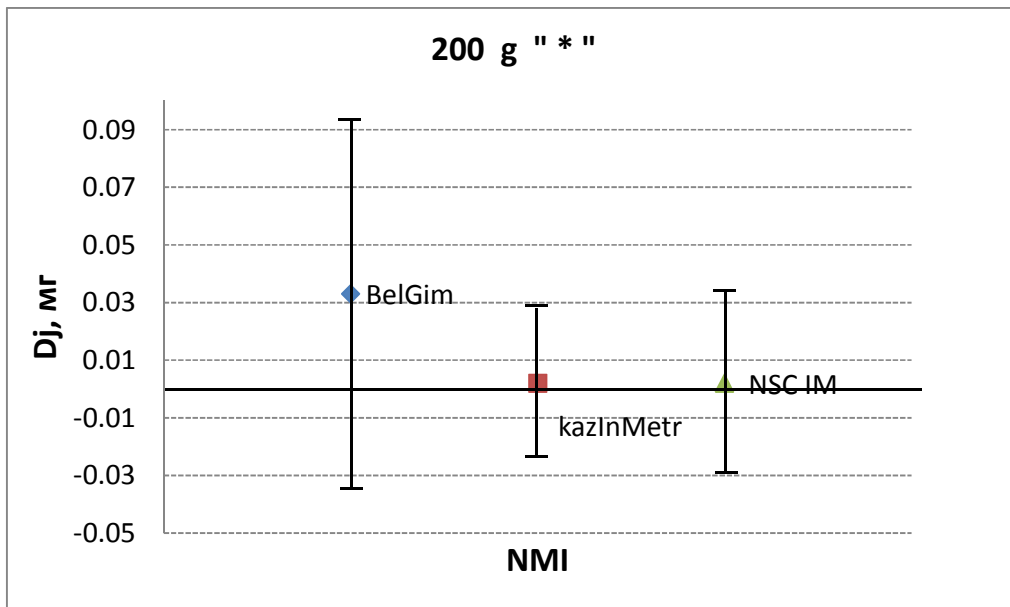


Fig. 4

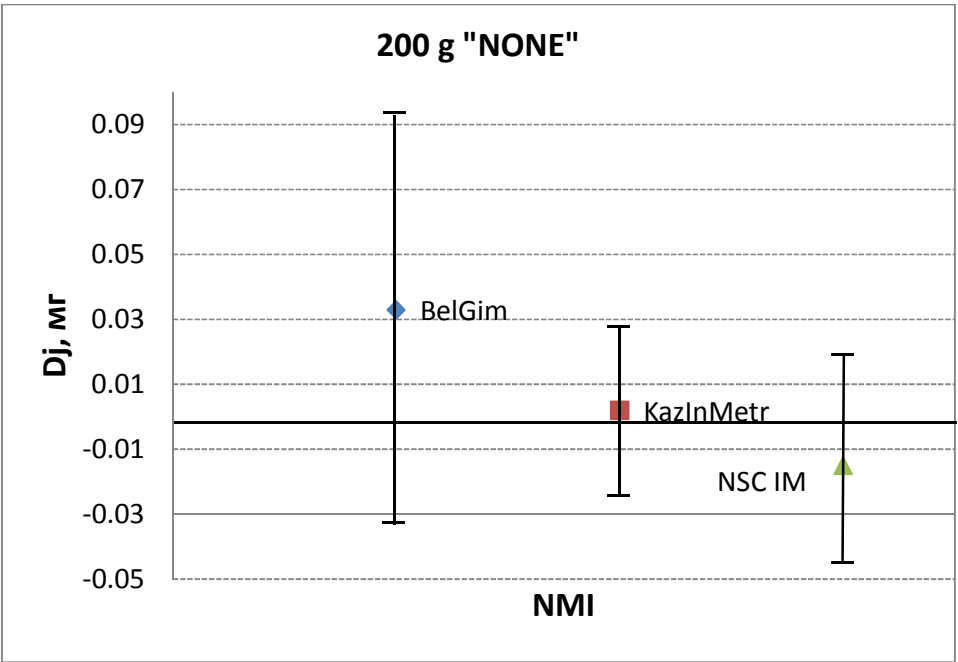


Fig. 5

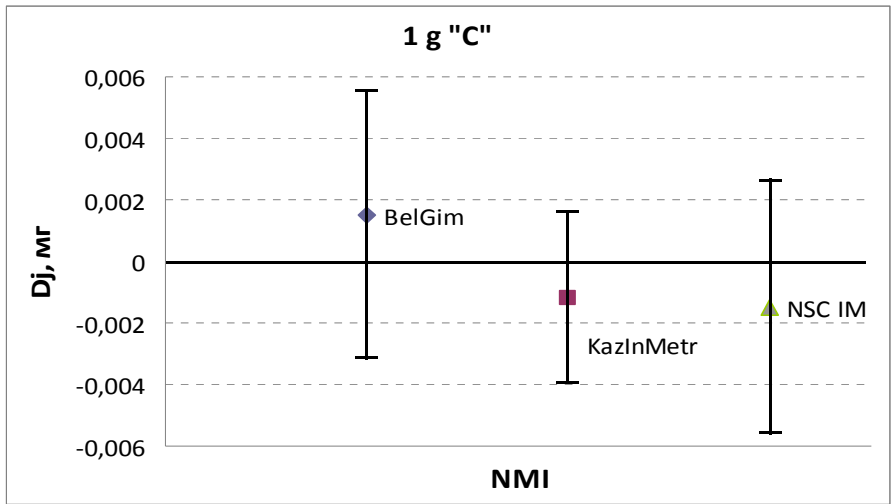


Fig. 6

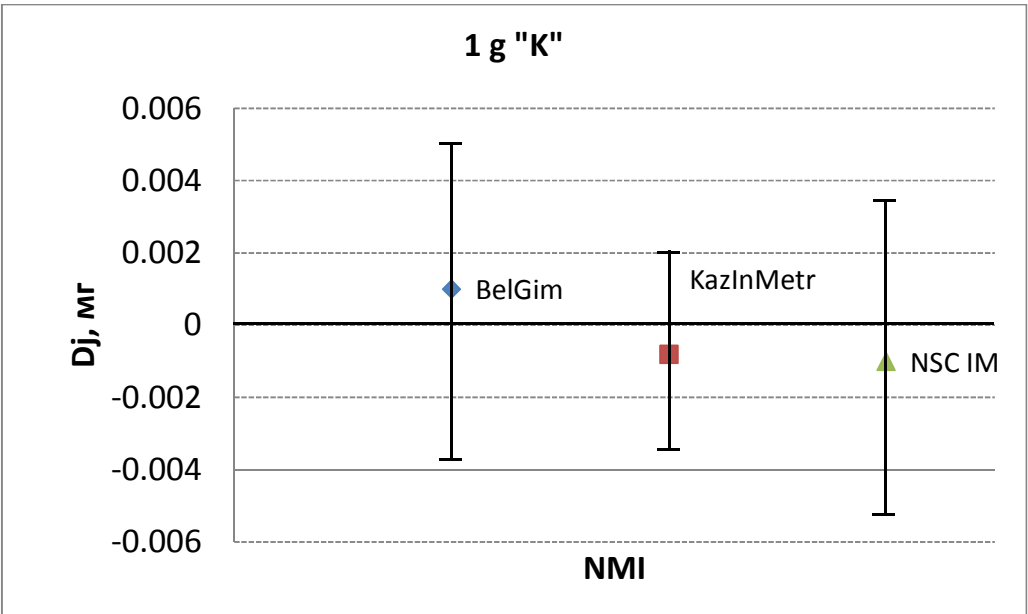


Fig. 7

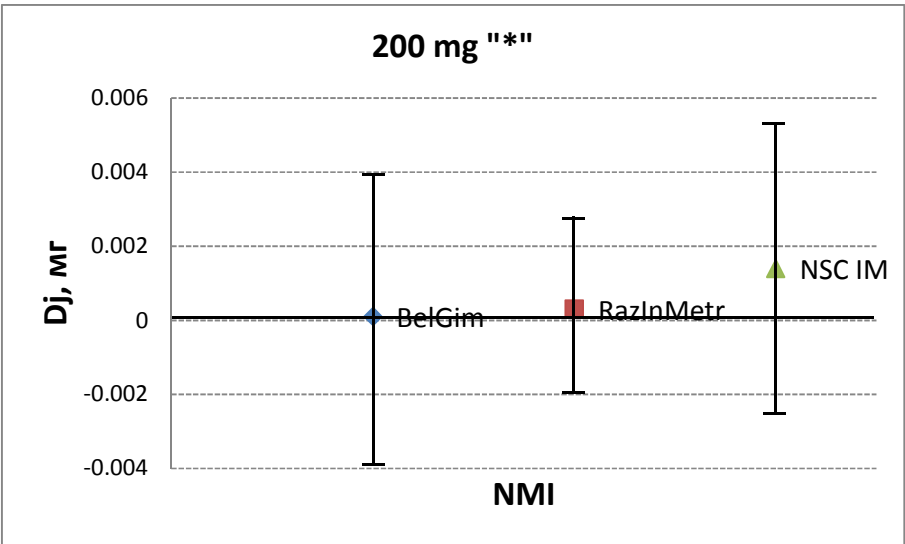


Fig.8

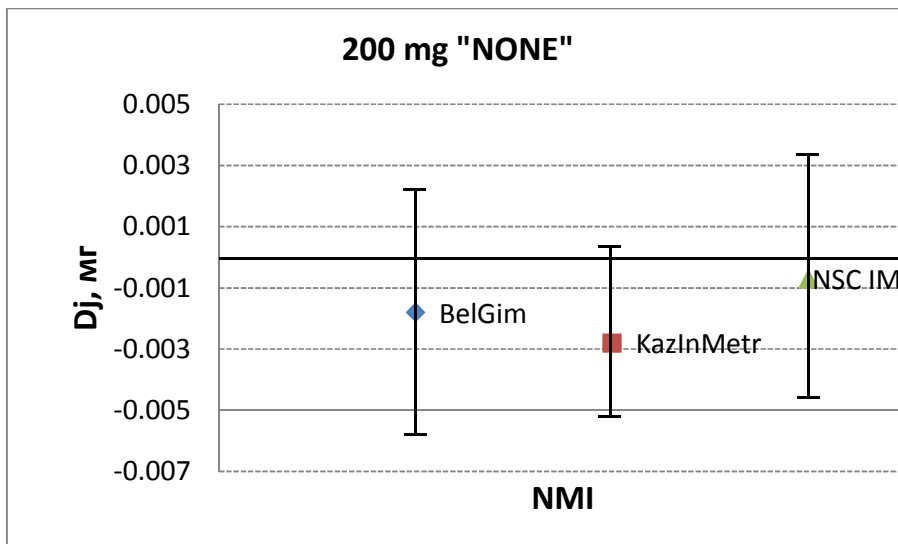


Fig. 9

5. Summary

Information on the degree of Equivalence between participants is shown below:

2 kg: Figures 2 and 3 show that all the values with the uncertainty bands except one participant intersect the reference line. For this participant, the average of the 2 kg “5” and 2 kg “NONE” results with the uncertainty band intersects the reference line.

200 g: Figures 4 and 5 show that all the values with the uncertainty bands intersect the reference line.

1 g: Figures 6 and 7 show that all the values with the uncertainty bands intersect the reference line.

200 mg: Figure 8 and 9 shows that all the values with the uncertainty bands intersect the reference line.

6. Acknowledgements

The authors would like to acknowledge the positive contribution of the following people, participated in organizing and carrying out the measurements in COOMET.M.M-K5 comparison: Irina Kolozinska, NSC “IM”, Ukraine; Evgeniy Galat and Lyudmila Evseevich, BelGIM, the Republic of Belarus, Chingis Kuanbaev and Dinara Mukasheva, KazInMetr, the Republic of Kazakhstan.