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Mass Comparison: 300 g laboratory balance

Kari Riski
Mittatekniikan keskus

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Centre for metrology and accreditation

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Abstract

A comparison of a 300 g laboratory balance (d = 0,1 mg) was carried out in December 2010 at the Centre for Metrology and Accreditation (MIKES). Seven participants; one from MIKES and six from four accredited calibration laboratories; took part in the comparison. Reference values were calculated as weighed means of all participants.

The measurements were made at MIKES. The loading points were given in advance by MIKES. Otherwise the participants calibrated the balance according to their own measurement procedures using their own weights. Measurement results of the laboratories were taken from calibration certificates.

The results were in agreement with the reference value.

Tiivistelmä

Mittatekniikan keskus (MIKES) järjesti joulukuussa 2010 massan vertailumittauksen. Vertailu tehtiin 300 g:n analyysivaa'alla (d = 0,1 mg). Vertailumittaukseen osallistui kuusi kalibroijaa neljästä akkreditoidusta kalibrointilaboratoriosta ja yksi kalibroija MIKESistä. Vertailun referenssiarvoina käytettiin osallistujien tulosten painotettua keskiarvoa.

Mittaukset tehtiin MIKESissä. Kuormauspisteet sovittiin etukäteen. Vertailuun osallistuneet laboratoriot tekivät mittaukset omien mittausmenetelmiensä mukaisesti käyttäen omia punnuksiaan. Mittaustulokset on otettu laboratorioiden antamista kalibrointitodistuksista.

Mittaustulosten ja referenssiarvon välillä oli hyvä yhteensopivuus.

Contents

1 Introduction

This mass comparison was carried out in December 2010 at the Centre for Metrology and Accreditation (MIKES). The comparison was made with a 300 g analytical balance.

The aim of the comparison was to compare measurement results. The loading points were given in advance. No other calibration instructions were given to the laboratories.

Six persons from four accredited mass calibration laboratories from Finland and one person from MIKES participated in the comparison.

2 Balance

The comparison was made with a standard laboratory balance: Sartorius R300S n/o 39040071. The capacity of the balance is 303 g and its resolution is 0,1 mg. The balance has internal adjusting weights. The balance was adjusted in the morning or/and at noon during the calibration period.

3 Pilot laboratory

The pilot laboratory of the comparison was MIKES. MIKES is the national standard laboratory for mass in Finland. The traceability of mass comes from BIPM.

4 Participants

The following laboratories participated in the comparison:

Oy G.W. Berg & Co Ab, K029, Vantaa,
Inspecta Oy, K004, Espoo
Lahti Precision OY, K019, Lahti,
MIKES, NMI, Espoo
Teopal Oy, K037, Espoo,

The measurements were made between 13 and 21 December 2010.

5 Stability measurements by MIKES

In the monitoring of the stability of the balance the following weights were used: P107 10 g, 20+10g and P112 50 g, 100 g, 200 g, 200+100 g. Both weight sets are of class OIML F_1 and has been calibrated by MIKES in 2009.

The stability results are given in table 1. The uncertainty due to stability u (*stab*) is the standard deviation of the values for a certain load.

Table 1, Stability monitoring results for loads 50 g, 100 g, 200 g and 300 g.

					50 g	100 g	200 g	300 g
Date	Time	t (°C)	p (hPa)	RH (%)	*I* – 50g (mg)	*I* -100g (mg)	*I* – 200g (mg)	*I* - 300g (mg)
15.12.2010	11.55	21,22	1021,6	45	0,35	0,4	0,5	0,35
15.12.2010	15.15	21,49	1019,9	45	0,35	0,55	0,7	0,5
16.12.2010	8.40	21,14	1002,7	45	0,3	0,55	0,55	0,35
17.12.2010	8.45	21,17	1006,4	45	0,4	0,6	0,6	0,5
17.12.2010	10.40	21,24	1007,9	45	0,4	0,55	0,75	0,55
21.12.2010	8.15	21,21	1000,7	45	0,35	0,55	0,65	0,5
21.12.2010	9.40	21,59	1001,5	45	0,4	0,65	0,7	0,6
				average	0,364	0,550	0,636	0,479
				u(*stab*)	0,038	0,076	0,090	0,095

I = indication with the load

6 Measurement instructions

The following information was given to the participants in advance:
1) Balance, Sartorius R300S, MAX = 303 g, d = 0,1 mg
2) No adjustment.
3) Loading points: 0 g, 1 g, 3 g, 5 g, 10 g, 30 g, 50 g, 100 g, 200 g ja 300 g.
4) The reference value will be the weighed mean of the participants

It was allowed to bring weights to MIKES in advance. No further instructions for the measurement method were given. The participants were asked to send their results as calibration certificates to MIKES after the measurements.

7 Results

The persons who made the calibrations are identified with randomly selected letters from A to G. In most cases they are called laboratories. MIKES is laboratory A. Table 2 gives measurement results and measurement uncertainties given by the participants. In all cases the coverage factor was two (k=2). Figures 1-7 shows the measurement results.

Figure 1 gives results at all loading points. Figures 2-7 show results with uncertainties at individual loads 10 g – 300 g.

Table 2, Results of the comparison, E = error of indication of the balance (mg), U = expanded uncertainty (mg)

LAB	A		B		C		D		E		F		G	
load (g)	E	U	E	U	E	U	E	U	E	U	E	U	E	U
0	0	0.13	0	0.22	0	0.13	0	0.16	0	0.5	0	0.48	0	0.38
1	-0.03	0.13	0	0.22	0	0.13	-0.1	0.16	0	0.5	-0.1	0.48	0	0.38
3	-0.04	0.13	0	0.22	0	0.13	-0.1	0.16	-0.1	0.5	0	0.48	0	0.38
5	-0.06	0.13	0	0.22	-0.1	0.18	-0.2	0.17	0	0.5	0	0.48	-0.1	0.38
10	-0.06	0.13	-0.1	0.23	-0.1	0.15	-0.3	0.17	0	0.5	0	0.48	0	0.39
30	0	0.14	0.1	0.25	0.1	0.2	0	0.18	0.1	0.5	0.1	0.49	0.1	0.39
50	0.22	0.16	0.3	0.28	0.3	0.27	0.2	0.2	0.4	0.5	0.3	0.5	0.4	0.4
100	0.48	0.22	0.5	0.42	0.6	0.49	0.4	0.23	0.6	0.5	0.7	0.51	0.7	0.42
200	0.55	0.37	0.6	0.68	0.8	0.86			0.8	0.5	0.7	0.54	0.9	0.46
300	0.35	0.54	0.5	0.68	0.8	0.86	0.1	0.42	0.6	0.5	0.5	0.58	0.8	0.5

All laboratories gave their results in calibration certificates. According to the certificates the uncertainties were estimated using the document EA-4/02 /1/.

The reference value y and its uncertainty $u(y)$ were calculated by the following formulae /2/:

$$y = \frac{\sum_{i=1}^{n} x_i / u^2(x_i)}{\sum_{i=1}^{n} 1/u^2(x_i)} \quad \text{(n=7)}$$

$$u(y) = \sqrt{\sum 1/u^2(x_i)}$$

where x_i is the result of laboratory i and $u(x_i)$ is the standard uncertainty of that result.

A consistency check was made by χ-test.

$$\chi^2_{obs} = \sum \frac{(x_i - y)^2}{u^2(x_i)}$$

If χ^2_{obs} is smaller than tabulated value (probability 5 %, n-1 degrees of freedom) the weighed mean can be used. In this case all χ values were below tabulate value 12,6 (n-1=6).

The reference values y and laboratory – reference values $d_i = x_i - y$ with uncertainties $u(y)$ and $u(d_i)$ are given in Table 3.

The standard uncertainties $u(d_i)$ were calculated in the following way:

$$u^2(d_i) = u^2(x_i) - u^2(y) + u^2(stab)$$

where $u(stab)$ is the uncertainty due to stability from Table 1.

Table 3, Reference values y , laboratory – reference values d_i and uncertainties given in mg.

Lab	ref		A		B		C		D		E		F		G	
LOAD (g)	*y*	*u (y)*	*d*	*u*	*d*	*u*	*d*	*u*	*d*	*u*	*d*	*u*	*d*	*u*	*d*	*u*
0	0.00	0.04	0.00	0.05	0.00	0.10	0.00	0.05	0.00	0.07	0.00	0.25	0.00	0.24	0.00	0.19
1	-0.03	0.04	0.00	0.05	0.03	0.10	0.03	0.05	-0.07	0.07	0.03	0.25	-0.07	0.24	0.03	0.19
3	-0.03	0.04	-0.01	0.05	0.03	0.10	0.03	0.05	-0.07	0.07	-0.07	0.25	0.03	0.24	0.03	0.19
5	-0.09	0.04	0.03	0.05	0.09	0.10	-0.01	0.08	-0.11	0.08	0.09	0.25	0.09	0.24	-0.01	0.19
10	-0.12	0.04	0.06	0.07	0.02	0.12	0.02	0.08	-0.18	0.09	0.12	0.25	0.12	0.24	0.12	0.20
30	0.04	0.04	-0.04	0.06	0.06	0.12	0.06	0.09	-0.04	0.08	0.06	0.25	0.06	0.24	0.06	0.19
50	0.26	0.05	-0.04	0.07	0.04	0.14	0.04	0.13	-0.06	0.10	0.14	0.25	0.04	0.25	0.14	0.20
100	0.51	0.06	-0.03	0.12	-0.01	0.22	0.09	0.25	-0.11	0.13	0.09	0.25	0.19	0.26	0.19	0.22
200	0.71	0.10	-0.16	0.18	-0.11	0.34	0.09	0.43			0.09	0.24	-0.01	0.26	0.19	0.22
300	0.47	0.10	-0.12	0.27	0.03	0.34	0.33	0.43	-0.37	0.21	0.13	0.25	0.03	0.29	0.33	0.25

Table 4 gives equivalence value (E_n - values) given as $E_n = d / U(d)$ where $U(d) = 2 * u(d)$.

Table 4, E_n values for the comparison

LAB Load (g)	A	B	C	D	E	F	G
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.02	0.15	0.29	-0.48	0.06	-0.14	0.08
3	-0.05	0.17	0.32	-0.46	-0.13	0.07	0.09
5	0.28	0.43	-0.07	-0.74	0.18	0.19	-0.03
10	0.44	0.08	0.12	-1.06	0.24	0.25	0.30
30	-0.36	0.25	0.33	-0.26	0.12	0.12	0.16
50	-0.24	0.16	0.17	-0.29	0.29	0.09	0.36
100	-0.11	-0.02	0.19	-0.43	0.18	0.37	0.45
200	-0.44	-0.16	0.11		0.19	-0.02	0.43
300	-0.22	0.05	0.39	-0.88	0.27	0.06	0.67

The laboratory result in an interlaboratory comparison is considered acceptable if the absolute values of the normalised errors E_n are less than 1. In this comparison all E_n values except 1 are below 1.

8 Measurement procedures and contents of certificates

All laboratories determined the loading curve with increasing and degreasing loads. They also determined repeatability and eccentric loading. The laboratories used OIML class E_2 weights /3/. Table 5 gives measured values for repeatability, eccentricity and hysteresis. In addition to these components the uncertainty of the error of indication contained components from weights and resolution of the balance.

Table 5, Measured repeatability, eccentricity and hysteresis, all values are in mg.

LAB	A	B	C	D	E	F	G
repeatability	0.04	0.1	0.05	0.07	0.1	0	0.05
eccentricity	0.3	0.3	0.4	0.3	0.4	0.4	0.3
hysteresis	0.1	0.1	0.2	0.4	0.2	0.1	0.1

As a rule the certificates of all participating laboratories were in accordance with the requirements of ISO/IEC 17025 /4/. The measurement methods were in accordance with EURAMET cg 18 /5/.

9 Conclusions

Four accredited mass calibration laboratories and MIKES participated in a comparison of 300 g laboratory balance. All results from the participating laboratories were in agreement with the reference values. One E_n value was 1,06 whereas the others were below 0,9.

10 References

1. “Expression of the Uncertainty of Measurement in Calibration”, EA-4/02 (www.european-accreditation.org)

2. M.G. Cox: “The evaluation of key comparison data”, *Metrologia*, 2002, **39**, 589-595

3. “Weights of Classes E_1, E_2, F_1, F_2, M_1, M_{1-2}, M_2, M_{2-3} and M_3 “, OIML R111, 2004 (www.oiml.org)

4. “General requirements for the testing and calibration laboratories”, SFS-ISO/IEC 17025, ISO, 2005

5. “Guidelines on the calibration of non-automatic weighing instruments”, EURAMET / cg-18 / v.02 , 2009, (www.euramet.org)

Figure 1. Results of the comparison (the standard uncertainty of the reference value is given)

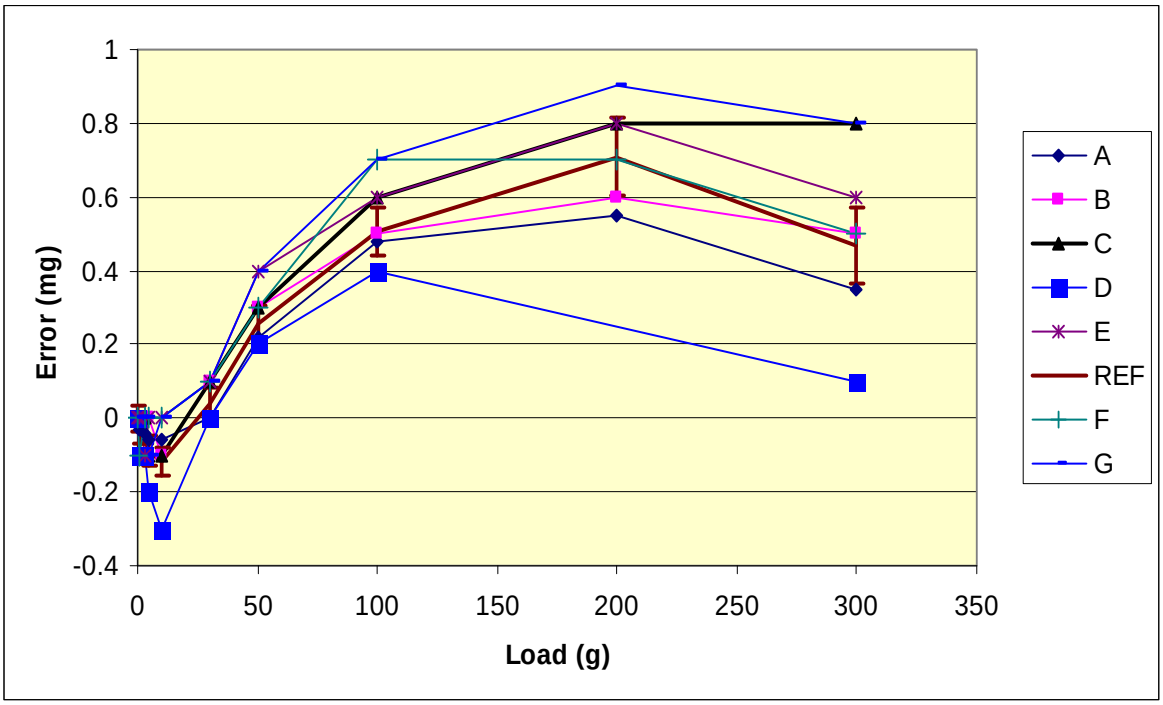


Figure 2. Measurement results at 10 g with expanded uncertainties.

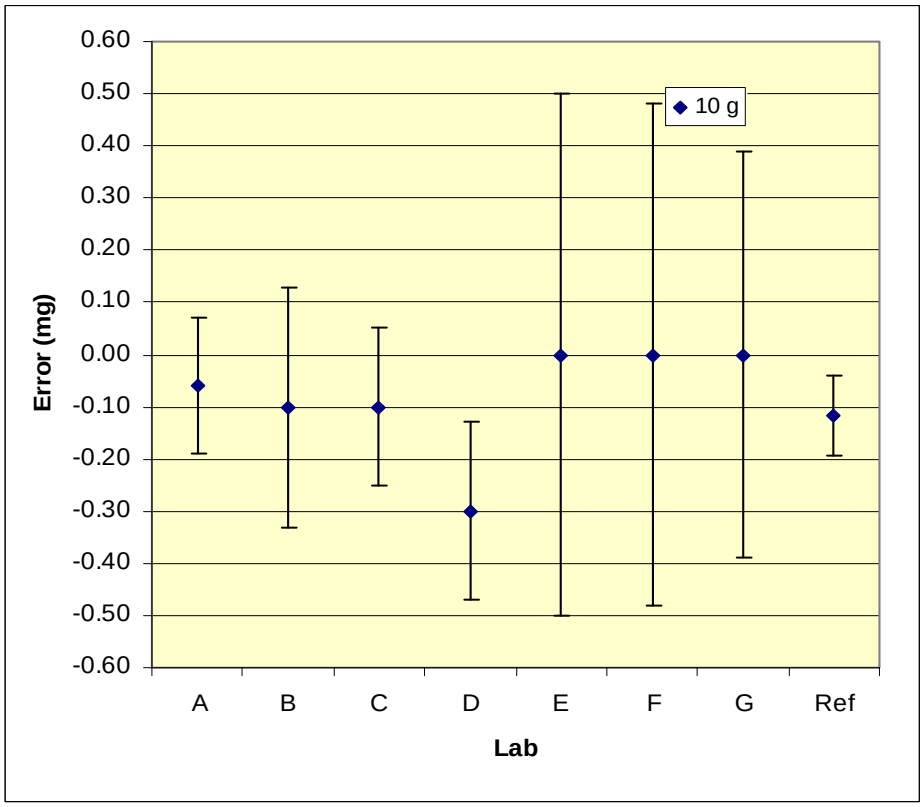


Figure 3. Measurement results at 30 g with expanded uncertainties.

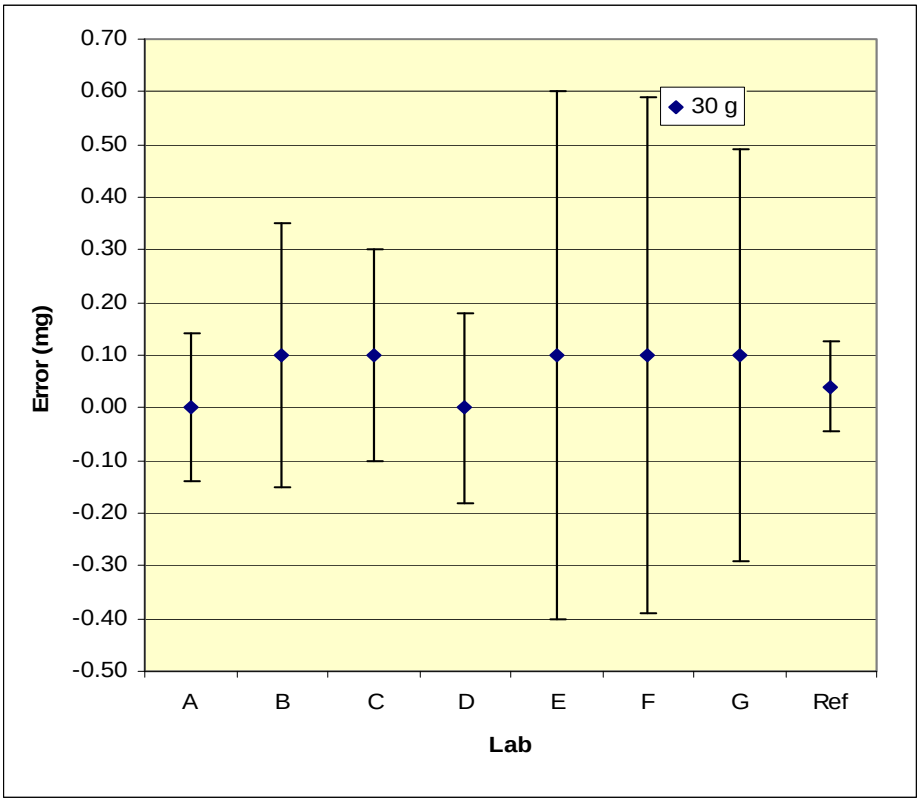


Figure 4. Measurement results at 50 g with expanded uncertainties.

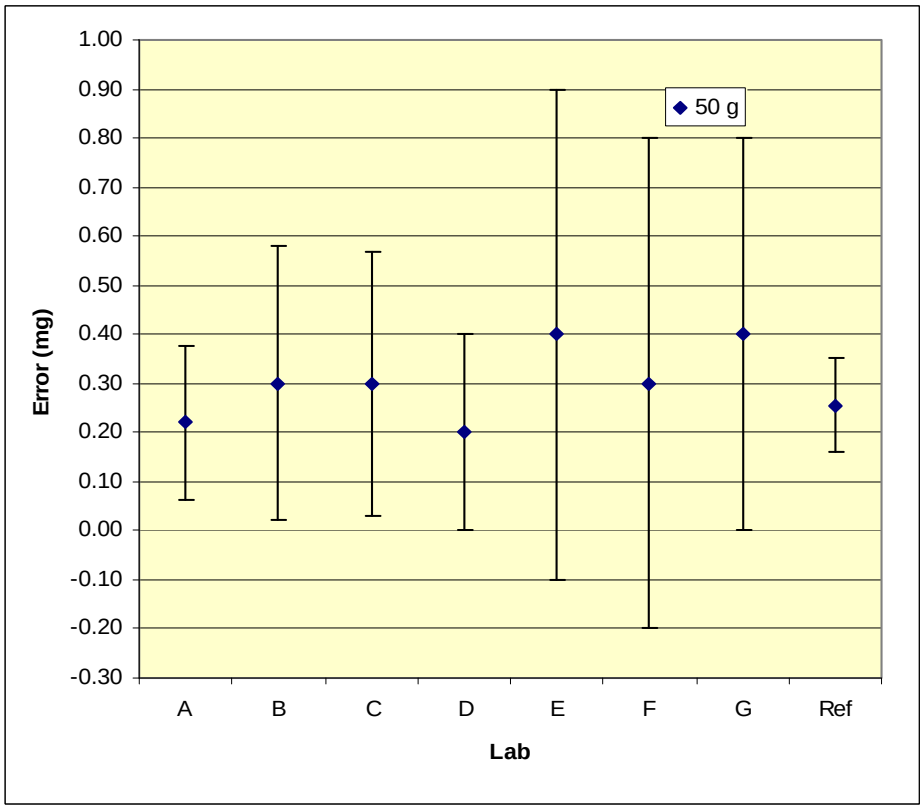


Figure 5. Measurement results at 100 g with expanded uncertainties.

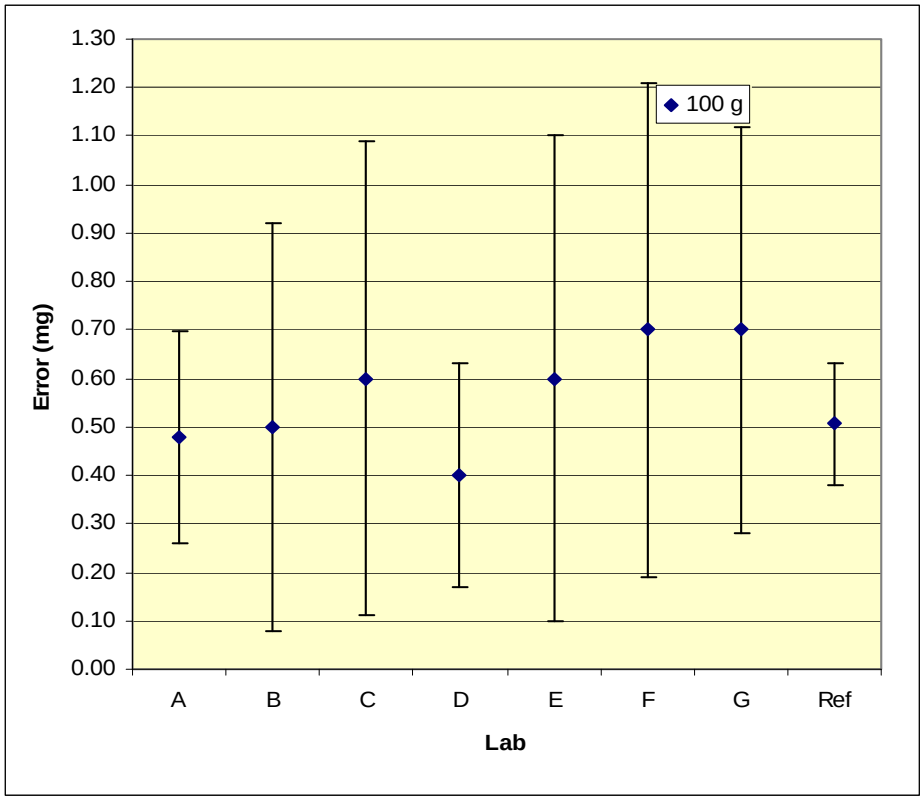


Figure 6. Measurement results at 200 g with expanded uncertainties.

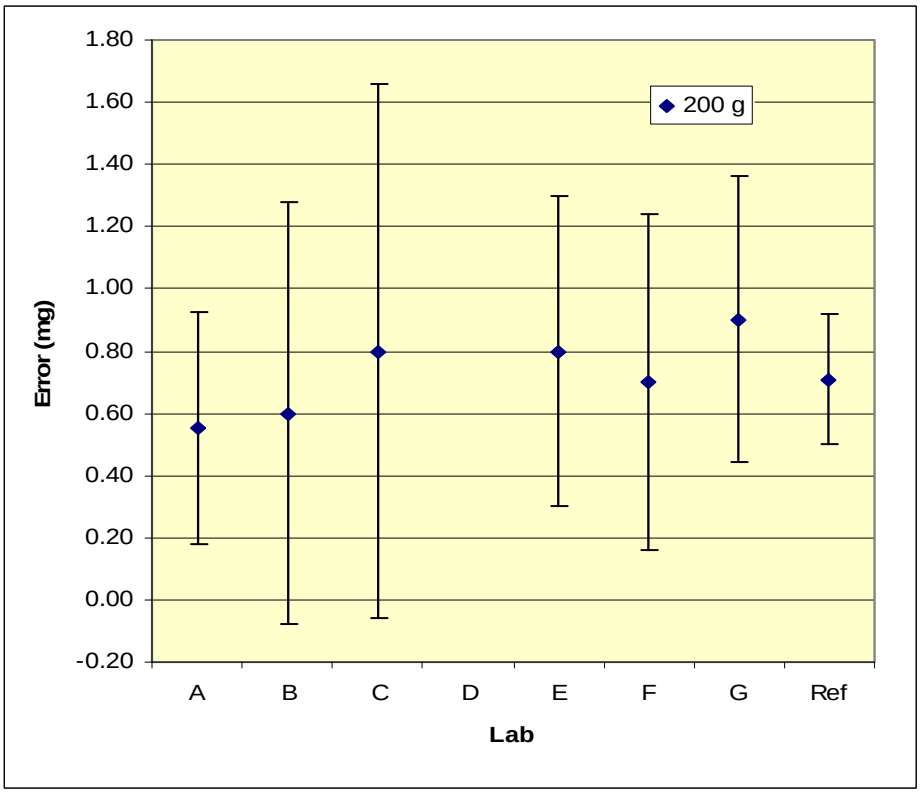
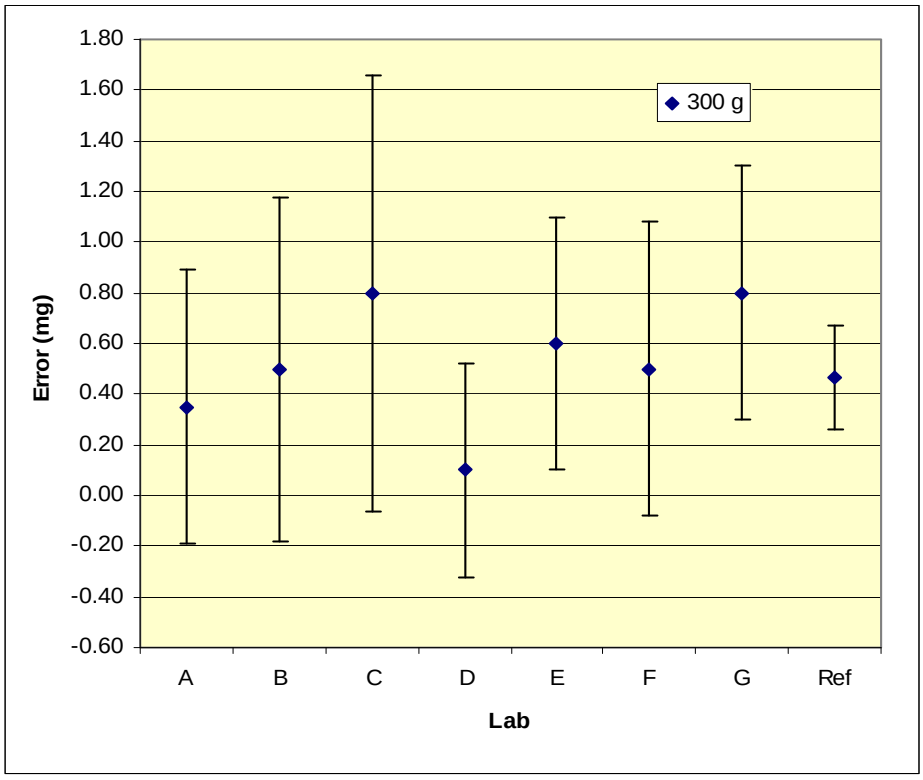


Figure 7. Measurement results at 300 g with expanded uncertainties.



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• P.O.Box 9, Tekniikantie 1, FI-02151 ESPOO, Finland
• Tel. +358 10 6054 000 • Fax +358 10 6054 299
• www.mikes.fi