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Mass Comparison: 200 g laboratory balance

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Centre for metrology and accreditation

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Abstract

A comparison of an analytical balance (MAX = 220 g, d = 0,01 mg) was carried out in November 2012 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 agreed in advance. 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 marraskuussa 2012 massan vertailumittauksen. Vertailu tehtiin analyysivaa'alla (MAX = 220 g, d = 0,01 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 November 2012 at the Centre for Metrology and Accreditation (MIKES). The comparison was made with an analytical balance.

The aim of the comparison was to compare measurement results. The loading points were agreed by the participants in advance.

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: Mettler AX205 No 1122180225. The capacity of the balance is 220 g and its resolution is 0,01 mg. The balance has internal adjusting weights. The balance was adjusted in the morning and if necessary 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 Tarkastus Oy, K055, Espoo
Lahti Precision OY, K019, Lahti,
Mittatekniikan keskus (MIKES), Espoo
Teopal Oy, K037, Espoo,

The measurements were made between 5 and 15 November 2012.

5 Stability measurements by MIKES

The stability of the balance was determined with the following weights: P13 50 g, 100 g and 200 g. Stability measurements were made before and after each comparison.

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.

Date	Time	RH (%)	p (hPa)	t (°C)	air density (kg/m^3)	Adjust-ment	*I* – 50g (mg)	*I* -100g (mg)	*I* – 200g (mg)
05.11.2012	8.42	45	1002.9	21.2	1.1822	yes	0.0697	0.093	-0.013
05.11.2012	13.48	45	1000	21.2	1.1789	no	0.0797	0.103	-0.003
06.11.2012	8.42	45	985	21.5	1.1599	yes	0.0797	0.103	-0.023
06.11.2012	12.45	45	985.4	21.2	1.1618	no	0.0897	0.103	-0.033
06.11.2012	12.48	45	985.4	21.2	1.1618	yes	0.0897	0.113	-0.013
06.11.2012	17.00	45	986.6	21.8	1.1605	no	0.0897	0.103	-0.003
15.11.2012	8.24	45	1003.2	21.1	1.1833	yes	0.0697	0.083	0.007
15.11.2012	11.15	45	1004.7	21.2	1.1845	yes			0.027
15.11.2012	13.30	45	1005.8	21.6	1.1841	no	0.0697	0.083	-0.013
						Std	0.0093	0.0107	0.0174

I = indication with the load

6 Measurement instructions

The following information was given to the participants in advance:
1) Balance, Mettler AX205, MAX = 220 g, d = 0,01 mg, serial number.
2) No adjustment.
3) Loading points: 0g, 1g, 3g, 5g, 10g, 20g, 30g, 50g, 100g, 150g and 200g.
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.

It was not mandatory to measure all loading points.

7 Results

The persons (outside MIKES) who made the calibrations are identified with randomly selected letters from A to F. Here they are called laboratories. Table 2 gives measurement results and measurement uncertainties given by the participants. In all cases the coverage factor was two (k=2). Figure 1 shows measurement results at all loading points without uncertainties. Figures 2-6 show measurement results at loads 10 g, 30 g, 50 g, 100 g and 200 g.

Table 2, Results of the comparison, E = error of indication of the balance, U = expanded uncertainty. Values are in mg.

LAB	MIKES		A		B		C		D		E		F	
Load (g)	E	U	E	U	E	U	E	U	E	U	E	U	E	U
0	0.00	0.05	0.00	0.094	0.00	0.052	0.00	0.052	0.00	0.063	0	0.129	0.00	0.14
1	-0.01	0.05	-0.03	0.094	-0.01	0.051	0.01	0.051	-0.01	0.061	0	0.130		
3	-0.02	0.05	0.01	0.096	-0.01	0.052			0.00	0.061	0	0.135	-0.01	0.14
5	0.02	0.05	-0.02	0.098	-0.02	0.052	0.01	0.053	0.00	0.061	0	0.143	0.01	0.14
10	0.04	0.05	-0.02	0.103	0.01	0.052	0.04	0.056	0.02	0.062	0.02	0.156	0.06	0.14
20	0.05	0.05			0.02	0.054	0.05	0.065	0.06	0.065	0.01	0.173		
30	0.10	0.06	0.08	0.116	0.03	0.080	0.04	0.080	0.07	0.080	0.07	0.212	0.11	0.15
50	0.11	0.06	0.05	0.135	0.08	0.080	0.08	0.112	0.14	0.086	0.12	0.242	0.15	0.2
100	0.13	0.07	0.08	0.182	0.10	0.150	0.15	0.209	0.15	0.150	0.14	0.278	0.22	0.2
150	0.08	0.09			0.05	0.300	0.08	0.300	0.16	0.300	0.12	0.316	0.10	0.2
200	0.04	0.10	0.07	0.287	-0.06	0.300	0.03	0.300	0.11	0.3	0.04	0.356	0.03	0.2

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 equations /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 the laboratory i and $u(x_i)=U(x_i)/k$ 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 the 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* with uncertainties *u(y)* are given in Table 3. The laboratory values – reference values

$d_i = x_i - y$

and their standard uncertainties $u(d_i)$ are given in Table 4.

The standard uncertainty of $u(d_i)$ was 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 and reference value uncertainties $u(y)$

LOAD (g)	y (mg)	$u(y)$ (mg)
0	0.000	0.012
1	-0.006	0.012
3	-0.008	0.014
5	0.001	0.013
10	0.026	0.013
20	0.041	0.014
30	0.069	0.017
50	0.103	0.018
100	0.134	0.025
150	0.089	0.035
200	0.036	0.038

Table 4, Laboratory – reference value d_i and uncertainties $u(d_i)$ given in mg.

Lab	MIKES		A		B		C		D		E		F	
LOAD (g)	*d*	*u*	*d*	*u*	*d*	*u*	*d*	*u*	*d*	*u*	*d*	*u*	*d*	*u*
0	0.000	0.023	0.000	0.046	0.000	0.025	0.000	0.025	0.000	0.030	0.000	0.064	0.000	0.070
1	-0.002	0.024	-0.024	0.046	-0.004	0.024	0.016	0.024	-0.004	0.029	0.006	0.064		
3	-0.010	0.023	0.018	0.047	-0.002	0.024			0.008	0.028	0.008	0.067	-0.002	0.069
5	0.018	0.024	-0.021	0.048	-0.021	0.025	0.009	0.025	-0.001	0.029	-0.001	0.071	0.009	0.069
10	0.014	0.024	-0.046	0.051	-0.016	0.024	0.014	0.027	-0.006	0.030	-0.006	0.077	0.034	0.069
20	0.004	0.024			-0.021	0.025	0.009	0.031	0.019	0.031	-0.031	0.086		
30	0.026	0.026	0.011	0.056	-0.039	0.038	-0.029	0.038	0.001	0.038	0.001	0.105	0.041	0.074
50	0.006	0.024	-0.053	0.066	-0.023	0.037	-0.023	0.054	0.037	0.040	0.017	0.120	0.047	0.099
100	-0.001	0.025	-0.054	0.088	-0.034	0.071	0.016	0.102	0.016	0.071	0.006	0.137	0.086	0.097
150	-0.006	0.028			-0.039	0.146	-0.009	0.146	0.071	0.146	0.031	0.154	0.011	0.094
200	0.001	0.039	0.034	0.139	-0.096	0.146	-0.006	0.146	0.074	0.146	0.004	0.175	-0.006	0.094

Equivalence values (E_n - values) given as $E_n = d / U(d)$ where $U(d) = 2 * u(d)$ are given in Table 5.

Table 5, E_n values of the comparison

LAB Load (g)	MIKES	A	B	C	D	E	F
1	-0.05	-0.26	-0.09	0.33	-0.07	0.05	
3	-0.21	0.19	-0.04		0.14	0.06	-0.01
5	0.37	-0.22	-0.43	0.18	-0.02	-0.01	0.06
10	0.30	-0.46	-0.03	0.01	-0.01	-0.01	0.23
20	0.09		-0.42	0.15	0.31	-0.18	
30	0.51	0.10	-0.52	-0.38	0.02	0.01	0.28
50	0.13	-0.41	-0.32	-0.22	0.46	0.07	0.24
100	-0.02	-0.31	-0.24	0.08	0.11	0.02	0.44
150	-0.12		-0.13	-0.03	0.24	0.10	0.06
200	0.01	0.12	-0.33	-0.02	0.25	0.01	-0.03

The laboratory results are considered acceptable if the absolute values of the normalised errors $|E_n|$ are less than 1. In this comparison all $|E_n|$ values are below 0,6.

8 Measurement procedures

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 or E_1 weights /3/. Table 5 gives measured values for repeatability, eccentricity and hysteresis. In addition to these the uncertainty of the error of indication contained components from air buoyancy, weights and resolution of the balance. It was not possible to trace all uncertainty components from some certificates. The measurement procedures were according to Ref 4.

Table 6, Measured repeatability, eccentricity and hysteresis, all values are in mg.

LAB	A	B	C	D	E	F	G
repeatability	0.013	0.026	0.025	0.025	0.03	0.016	0.03
eccentric loading	0.060	0.06	0.07	0.12	0.07	0.1	0.11
hysteresis	0.070	0.06	0.08	0.07	0.07	0.08	0.06

9 Conclusions

Four accredited mass calibration laboratories and MIKES participated in a comparison of 200 g laboratory balance. All results from the participating laboratories were in agreement with the reference values. The E_n values were below 0,6.

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. “Guidelines on the calibration of non-automatic weighing instruments”, EURAMET / cg-18 / v.03 , 2009, (www.euramet.org)

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

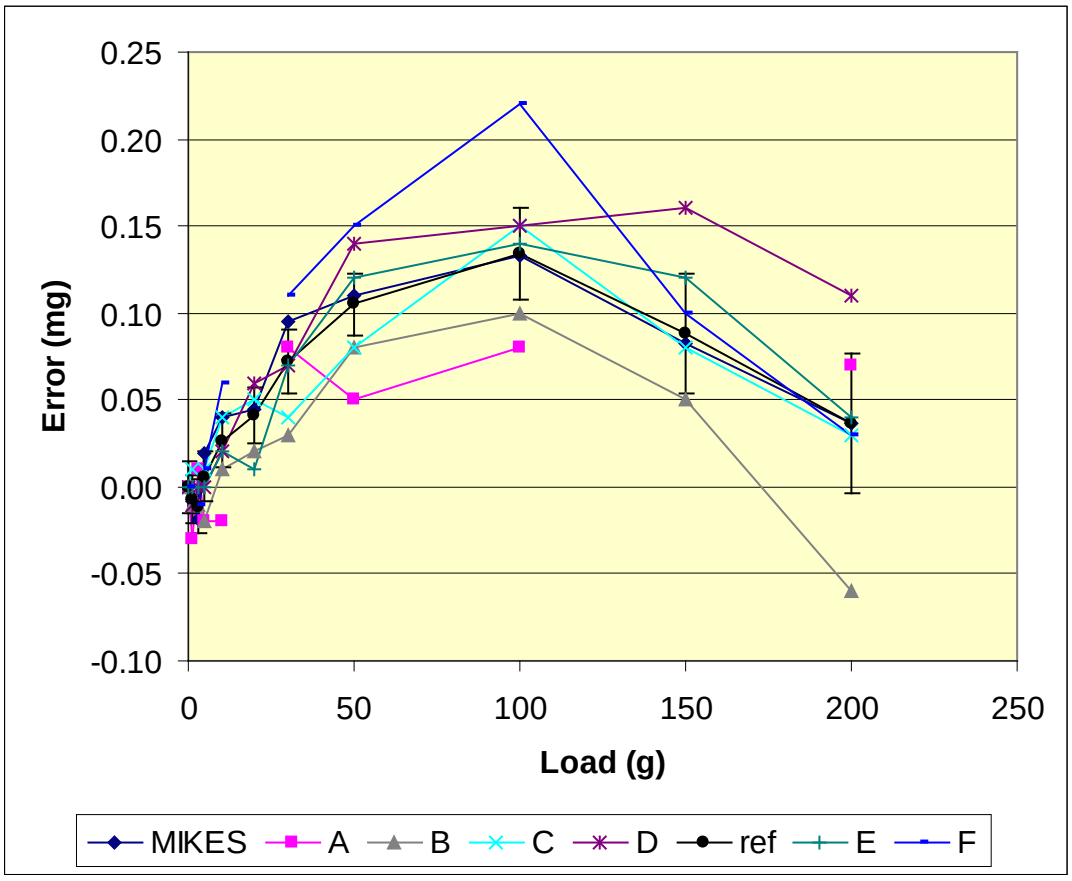


Figure 2. Measurement results at 10 g with expanded uncertainties.

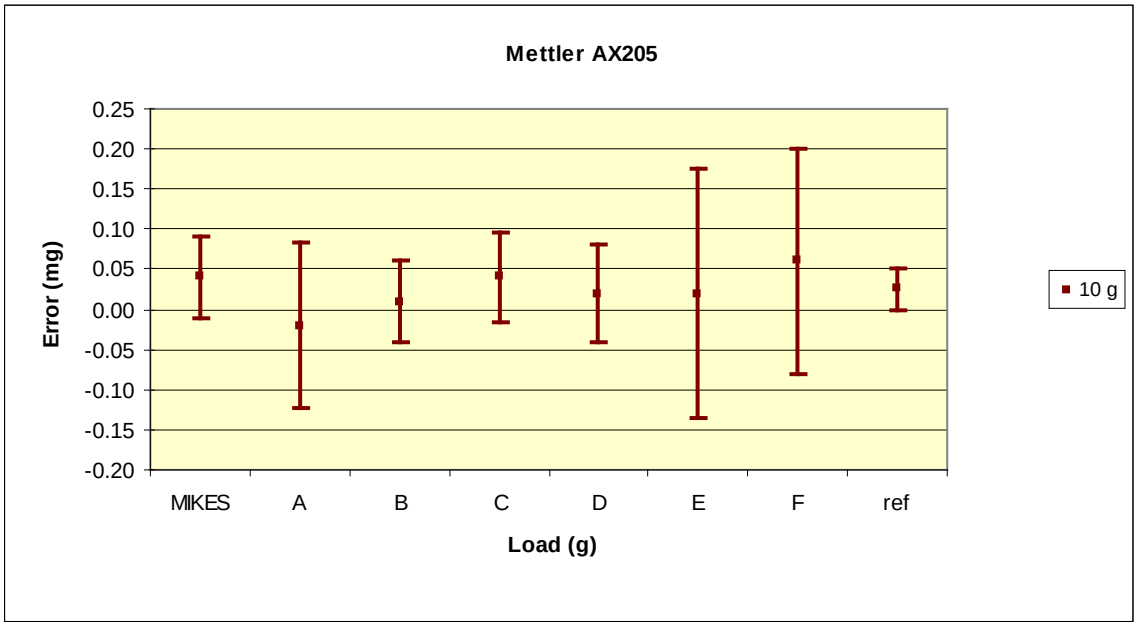


Figure 3. Measurement results at 30 g with expanded uncertainties.

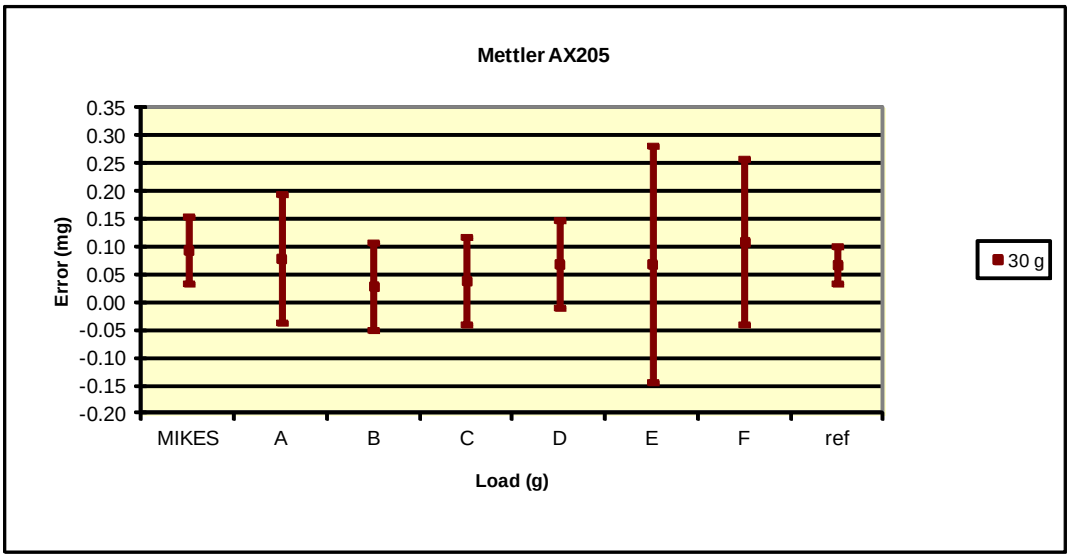


Figure 4. Measurement results at 50 g with expanded uncertainties.

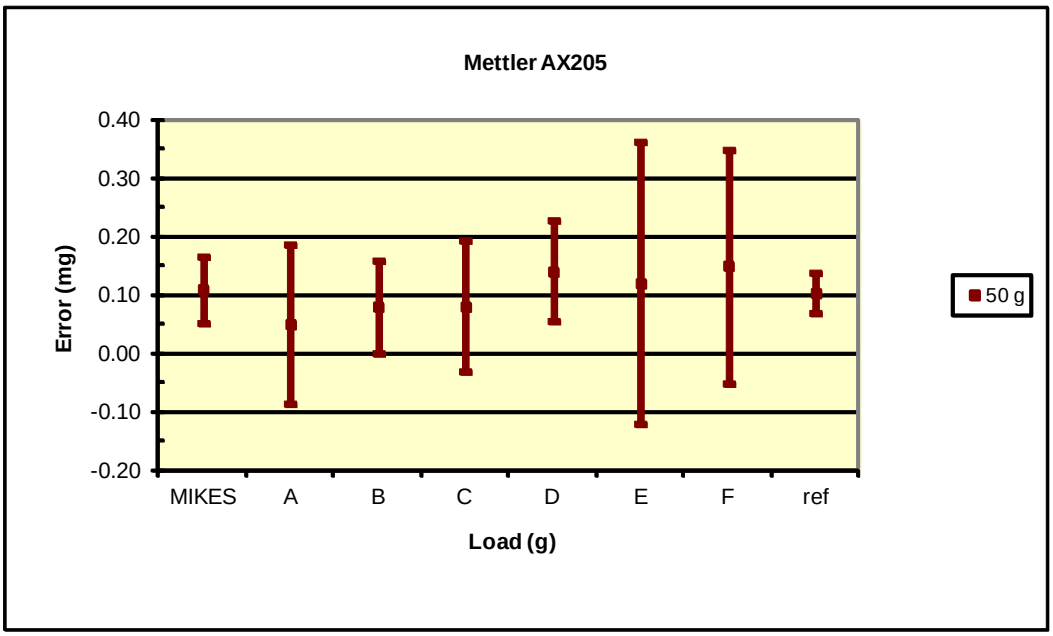


Figure 5. Measurement results at 100 g with expanded uncertainties.

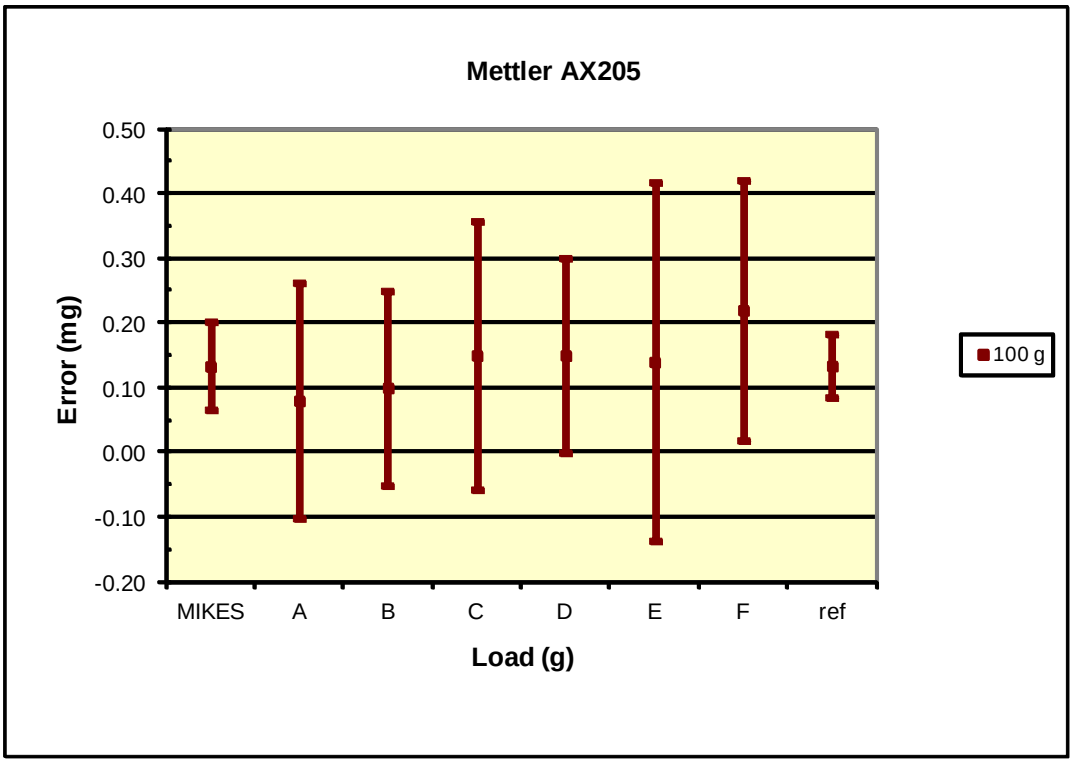
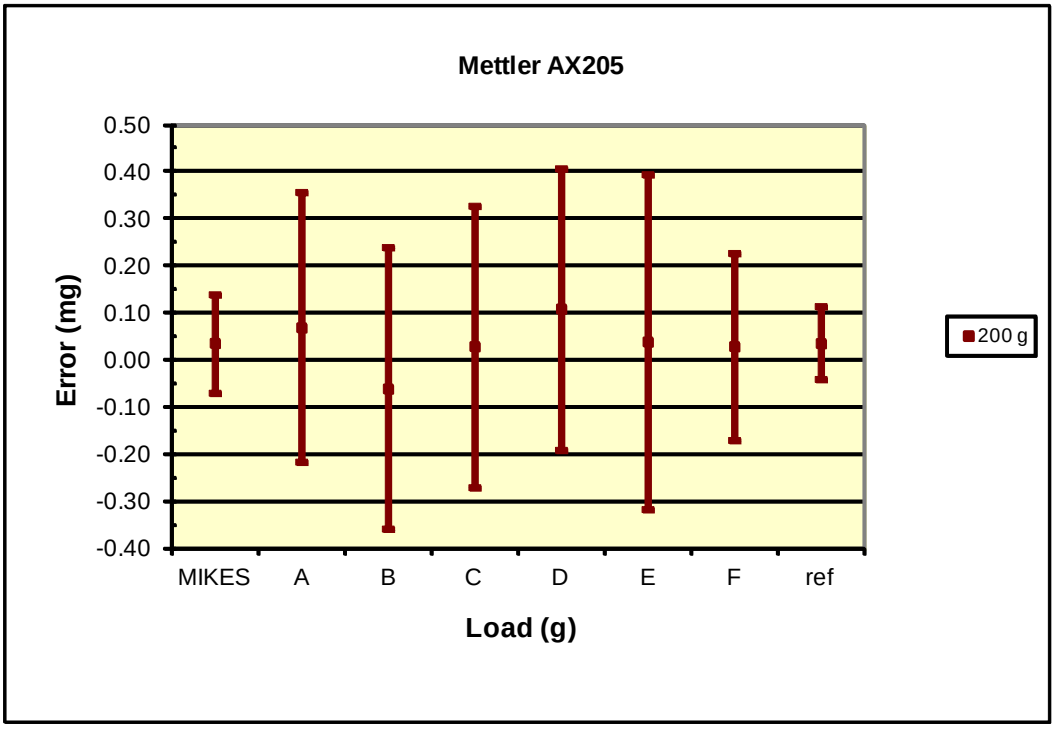


Figure 6. Measurement results at 200 g with expanded uncertainties.



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