Swedish Metrology and Quality AB

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ISO/IEC 17043

ilac-MRA

TO PARTICIPANTS

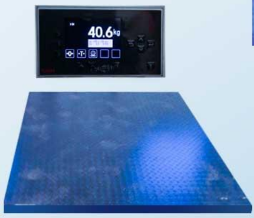
REPORT ON AN INTERLABORATORY COMPARISON (ILC)

ON THE CALIBRATION OF 3 INDUSTRIAL WEIGHING INSTRUMENTS BELOW.

INSTRUMENT NO.1
Max 30 kg d=0,05 g

INSTRUMENT NO.2
Max 1000 kg d=0,2 kg
Max 1500 kg d=0,5 kg

INSTRUMENT NO.3
Max 5000 kg d=1kg



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Content

Abstract

The object of this intercomparison was to organize a calibration of 3 different types of industrial weighing instruments in the range from 50 kg to 5000 kg having different types of load receptors.

The choice was a 5-ton instrument with a quadratic platform of 2,5*1,5 m and with a 1,5-ton capacity having a U-shaped platform with a construction designed for specific applications.

The 3rd instrument was planned to be a 50 kg industrial weighing instrument. As that was not available when the ILC started, we had to change to a more accurate 30 kg instrument. The details on that instrument were not properly informed to the participant before the ILC started.

All three instruments were placed in one room inside a building. For loading weighing instrument 2 and 3 a forklift was available to handle the 500 kg weights that were hired for this task.

In the case of the U-shaped platform of instrument 2 special interest was placed on the way laboratories would perform the eccentricity test.

During the exercise all together 25 calibrations (including SMQ's reference calibrations) were performed in 7 working days.

Some laboratories misunderstood that the CMC values in the description were the same as resolution of the instrument (d) and that caused some problems.

Results are demonstrating good confidence by the number of En-values as follows:

- 30 kg instrument   40 below 1 and 3 above 1
- 1500 kg instrument   22 below 1 and 2 above 1
- 5000 kg instrument   32 below 1 and 0 above 1

That gives confidence to most of the calibrations that the laboratories are doing.

The main concern is the effect of eccentricity on the 1500 kg instrument and that some laboratories document small uncertainties that give high En-values on the different instruments.

The reference laboratory did calibrations before and after the other laboratories and used those results in calculations of mean values and uncertainty as described in the report.

The organizer Swedish Metrology and Quality AB acted as organizer of the intercomparison as well as the reference laboratory according to the accreditation scope approved by Swedac.

Purpose and implementation of the comparison

This interlaboratory comparison serves as a tool to verify results from measurements carried out by calibration laboratories. It is an effective method to demonstrate technical capacity of the participants and serves as a technical base for accreditation as required by ISO/IEC 17025:2017 (SS-EN ISO/IEC 17025:2018) and specified in point 7.7.2.

The inter-comparison was supported by the company FLINTAB AB in Jönköping that provided the site at Arlöv Sweden and weighing instrument 2 and 3.

Further support came from METTLER TOLEDO Nordic that provided weighing instrument 1.

Logistic planning scheme for calibrations:

• **Date**	**Kl 8-12**	**Kl 13-17**
December 5	SMQ reference	Flintab
December 6	JH Analys	
December 7	JB Scales	
December 8	IKM Norge	Elastocon 13-15) Tillquist (15-17)
December 9	MyCal	OptiCal
Weekend		
December 12	RISE	Mettler Toledo
December 13	Vågkonsult	SMQ reference

All participants managed to perform the calibrations within the specified time.

Some of the participants calibrated all instruments, but some of them 1 or 2 instruments.

Some participants have an accreditation by SWEDAC or Norwegian Accreditation NA according to ISO/IEC on 17025:2017.

Principles on the calibration in general

Prior to each calibration by a participant the pilot laboratory informed about different matters like truck driver regulations and measuring points that should be included in the report.

Further it was checked that no significant change at some calibrated values had occurred before the next participant could start its calibration. That was done by the pilot laboratory by using one check weight for each instrument.

Weighing conditions during the measurement period

The weighing instruments used in this inter-comparison were situated indoors and any influence from the environment could be excluded.

Calibration instructions

The laboratories were allowed to use approximately 4 hours for calibrating the instruments. They were advised to use their own calibration procedures with focus on the points described below that were important for the inter-comparison outcome. They were not allowed to perform any type of adjustment on the weighing instruments themselves.
Using their own procedures also meant it was up to the laboratories which measurement points they would select if the following compulsory points were included.

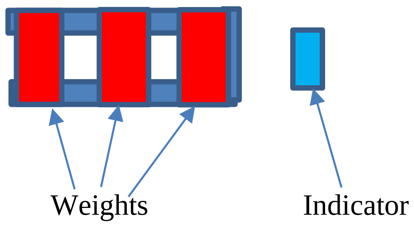
The laboratories were further encouraged to use the actual estimated uncertainty values even if those would differ from the CMC values in their accreditation scope.

Compulsory calibration points

	30 kg instrument	1500 kg instruments	5000 kg instruments
Capacity, Max resolution	Max 30 kg d= 0,05 g	Max 1500 kg d1= 0,2 kg d2 =0,5 kg	Max 5 000 kg d=1 kg
Point 1	2 kg	40 kg	40 kg
Point 2	5 kg	500 kg	500 kg
Point 3	10 kg	1 000 kg	2 000kg
Point 4	20 kg	1 500 kg	3 000 kg
Point 5	30 kg	Eccentricity	5 000 kg
Point 6		500 kg	

Specific eccentricity checks on the 1500 kg U-scale

The test of eccentricity should be done with a load of 500 kg according to the sketch below to calculate the performance of the eccentricity. The only eccentricity check that should be evaluated in the report was on the 1 500 kg instrument. This was decided by the organiser as there are different opinions internationally on how that test shall be done.



The explicit determination of eccentricity was in this report only asked for the U-instrument as that test is under discussion internationally on how it shall be performed.

It was found during the intercomparison that all laboratories had the described methodology according to the sketch above in their methods.

Planning and instruction details

The laboratories were asked to hand over original calibration data before leaving the site. The final calibration certificate and reports should then be sent to the organizer within one week, which most of them also managed to deliver. The evaluator used the principles of the ISO/IEC 17043:2010 Annex B equation B5 in the calculations of En values.

The participants should deliver calibration certificates which at least stated the measured values together with a belonging uncertainty for the points stated above. Several of them delivered data on further calibration points according to their procedures.

Administrative information

Site for calibrations	Address to send the reports:
FLINTAB Företagsvägen 29 building 6 Arlöv Sweden	Swedish Metrology and Quality AB Håkan Källgren Dragspelsgatan 21 Contact phone +46705774931 SE-504 72 Borås, Sweden e-mail: hakan.kallgren@smquality.se

Summary of the timeline planning:

- One week after the calibration/measurement send the calibration certificate to the evaluator of the inter-comparison exercise.
- A draft report will be sent to the participants within 4 weeks after receiving the last certificate.
- Comments on the draft report within 1 week
- Final report will be finalized within 2 weeks after receiving comments from all participants

Analysis of the calibration results

The information from the balance calibration used for the comparison is the “error of indication” (EoI). This error is simply the difference between the documented balance indication and the mass value of the used weights specified by the participants. For balance 1 all participants used their own weights (up to 30 kg). For balance 2 and 3 newly calibrated weights hired from Rise (National Swedish Metrology Institute) common to all were used except for FLINTAB that used their own weights. As seen in the various tables (column 2) always even weight values were documented. In the case of balance 2 and 3 the participants obviously summed up the weights nominal value.

In the case of balance 1, however, the even values seem to have a different explanation. The participants all used their computer-based documentation system entering the displayed value together with the identities of the weights placed on the balance. This should render uneven reference values in column 2 in the prepared excel-protocol for the comparison. With the found indication error the uneven weight reference was adjusted to an even value. With this adjusted difference and the previously noted error the balance indication was recalculated to present the found indication error both in the calibration certificate and the excel-protocol.

The quality of each individual measurement result is reviewed using the E_n – criteria. For each measurement point it is the distance of respective laboratory result to the corresponding reference value normalised with respect to the uncertainty in determining this difference.

$$E_n = \frac{x_i - x_{ref}}{\sqrt{U_i^2 + U_{ref}^2}} \qquad (1)$$

x_i: Single measurement result (error of indication); index i counts the various participants.

x_{ref}: Provided reference value (for each measurement point).

U_i: The estimated expanded uncertainty (k=2) stated by each laboratory for each calibration point.

U_{ref}: The estimated expanded uncertainty (k=2) of the reference value for the same calibration point.

Inter-comparison reference value

In every comparison the reference value is a crucial aspect. In this exercise SMQ acting as pilot laboratory performed a first calibration before the start and a second one after all participants had finished their work. This was complemented by a stability check for each balance before the next participant stared his work.

For the En-evaluation the reference value and its quality are of decisive importance. For each balance and every calibration point the corresponding reference value x_{ref} is calculated as the average from two complete calibration results x_{start} and x_{end}.

$$x_{ref} = \frac{x_{start} + x_{end}}{2} \qquad (2)$$

The uncertainty $\underline{U_{ref}}$ connected to it is the combined uncertainty of this average enlarged with half the difference (possible balance drift) between the two results.

$$U_{ref} = \frac{\sqrt{U_{start}^2 + U_{end}^2}}{\sqrt{2}} + \frac{1}{2}\left|x_{end} - x_{start}\right| \quad (3)$$

How the reference calibrations were performed and how the values and their respective uncertainties were calculated are described in greater detail in annex 2.

The reference values were then used to calculate the En values (equation (1)) according to ISO/IEC 17043:2010 annex B formula B5. An absolute value of $|E_n| \leq 1$ is often used as a criterion for an acceptable measurement quality.

Traceability for the pilot values at each point

Traceability for the reference values stated by SMQ is established by using weights that were calibrated immediately before usage.

Measuring results from the calibration of the three weighing instruments

The following tables and diagrams present the error of indication found by the participating laboratories along with the stated measurement uncertainty for each calibration point.

All tables have the same form. The left column assigns an identification number to each participating laboratory. The numbers are chosen randomly and not in timely order. The identity is the same for all three balances. A vacant row in a table therefore indicates that this participant did not take part in calibrating the actual balance or that point. Column 2 is aimed to report the reference load placed on the balance for the different calibration points. Column 3 should state the corresponding balance indication each participant had read off. The estimated calibration uncertainty for this point is contained in column 4. The bottom line in each table represents the reference i.e., the average from two calibrations provided by SMQ. The column to the right shows the En-value calculated according to equation (1).

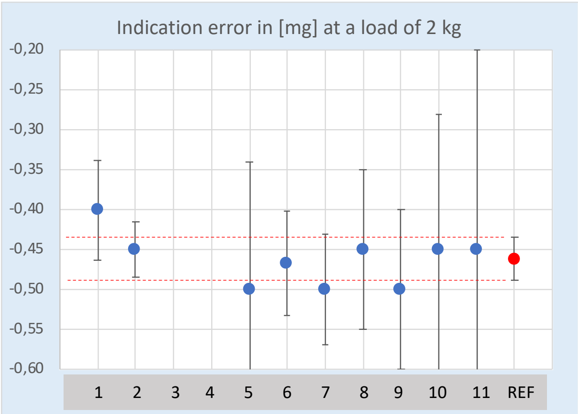
All diagrams are constructed in the same way. They present the found indication error for each participant from column 4 together with the "error staples" which are the uncertainty values stated in column 5.

For documenting the calibration results an excel-protocol was prepared in the way shown in the following tables. However, many participants used their own computer protocol and reported the asked information first in their calibration certificate. From there data was transferred into the excel-protocol on which the tables and diagrams are built.

Weighing instrument no. 1 - 30 kg

Table 1: Reported data from calibration point; 2 kg

Balance 1 - Load 2 kg					
Partici-pant	Applied Weights [g]	Balance indication [g]	Indication error [g]	Measurement uncertainty [g]	En-value
1	2000	1999,60	-0,40	0,062	**0,89**
2	2000	1999,55	-0,45	0,035	**0,24**
3					
4					
5	2000	1999,50	-0,50	0,16	**-0,24**
6	2000	1999,53	-0,47	0,066	**-0,09**
7	2000	1999,50	-0,50	0,069	**-0,53**
8	2000	1999,55	-0,45	0,10	**0,10**
9	2000	1999,50	-0,50	0,10	**-0,38**
10	2000	1999,55	-0,45	0,17	**0,06**
11	2000	1999,55	-0,45	0,25	**0,04**
REF	1999,999	1999,539	-0,461	0,027	

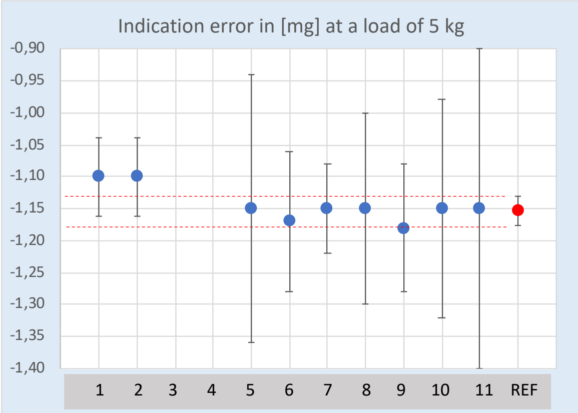


Comment: Column 2 displays even values except for the last row. In their calibration certificates all participants stated even values for the mass of applied weights.

For the reference calibration (last row) always the real mass values were reported, which is shown with several decimals in all following tables.

Table 2: Reported data from calibration point; 5 kg

Balance 1 - Load 5 kg					
Partici-pant	Applied Weights [g]	Balance indication [g]	Indication error [g]	Measurement uncertainty [g]	En-value
1	5000	4998,90	-1,10	0,062	**0,79**
2	5000	4998,90	-1,10	0,062	**0,79**
3					
4					
5	5000	4998,85	-1,15	0,21	**0,01**
6	5000	4998,83	-1,17	0,11	**-0,15**
7	5000	4998,85	-1,15	0,07	**0,04**
8	5000	4998,85	-1,15	0,15	**0,02**
9	5000	4998,82	-1,18	0,10	**-0,26**
10	5000	4998,85	-1,15	0,17	**0,02**
11	5000	4998,85	-1,15	0,25	**0,01**
REF	5000,001	4998,848	-1,153	0,024	



Comment: In the diagrams the reference value is accentuated by a different color. The doted lines represent an uncertainty band around the reference value which in most but not all cases is clearly lower than the values stated by the participants. Tendentially calibration uncertainty (absolute values) increases with increasing load, which is the case for most participant results and even for the reference calibration. Participants 1 and 2 do not quite follow this rule, which together with slightly higher indication errors leads to increasing En-value.

Table 3: Reported data from calibration point; 10 kg

Balance 1 - Load 10 kg					
Partici-pant	Applied Weights [g]	Balance indication [g]	Indication error [g]	Measurement uncertainty [g]	En-value
1	10000	9997,70	-2,30	0,062	**1,65**
2	10000	9997,65	-2,35	0,062	**1,09**
3					
4					
5	10000	9997,60	-2,40	0,33	**0,14**
6	10000	9997,62	-2,38	0,21	**0,31**
7	10000	9997,60	-2,40	0,069	**0,51**
8	10000	9997,65	-2,35	0,30	**0,32**
9	10000	9997,59	-2,41	0,20	**0,18**
10	10000	9997,65	-2,35	0,21	**0,44**
11	10000	9997,65	-2,35	0,25	**0,38**
REF	10000,0002	9997,5525	-2,448	0,064	

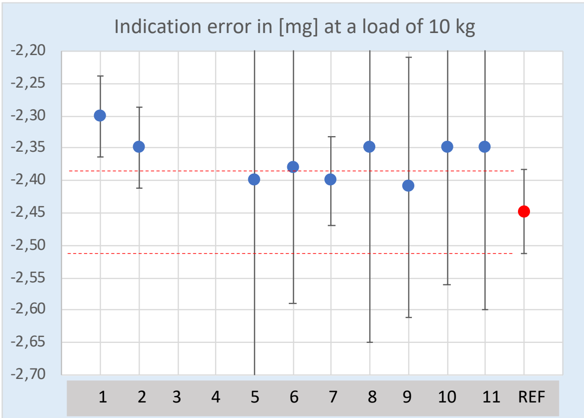
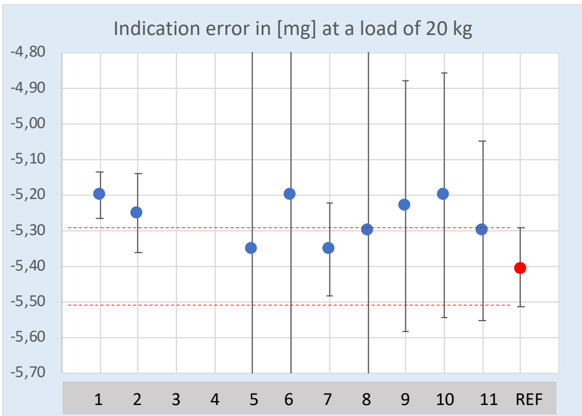


Table 4: Reported data from calibration point; 20 kg

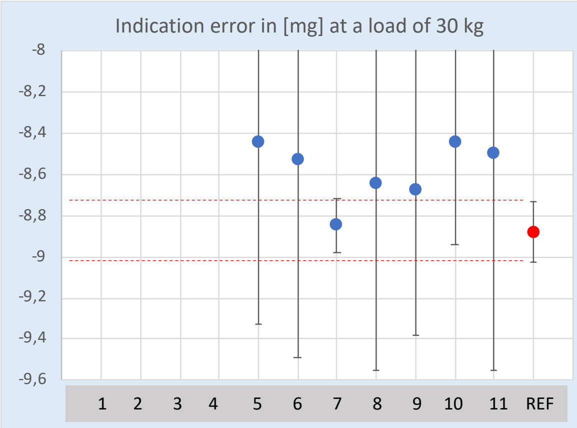
Balance 1 - Load 20 kg					
Partici-pant	Applied Weights [g]	Balance indication [g]	Indication error [g]	Measurement uncertainty [g]	En-value
1	20000	19994,80	-5,20	0,06	**1,59**
2	20000	19994,75	-5,25	0,11	**0,98**
3					
4					
5	20000	19994,65	-5,35	0,60	**0,08**
6	20000	19994,80	-5,20	0,69	**0,29**
7	20000	19994,65	-5,35	0,13	**0,30**
8	20000	19994,70	-5,30	0,60	**0,17**
9	20000	19994,77	-5,23	0,35	**0,47**
10	20000	19994,80	-5,20	0,34	**0,56**
11	20000	19994,70	-5,30	0,25	**0,37**
REF	20000,01	19994,61	-5,40	0,11	



Comment: It can be observed that some results are stated with roughly the same or even lower uncertainty than the reference uncertainty. It must be mentioned here that the displayed uncertainty of the reference values is totally dominated by the contribution due to the balance drift, i.e., the difference between the results of the first and last reference calibration. This aspect does not impinge the participants uncertainty budget. Thus, participant uncertainties lower than the presented reference uncertainties are not totally unreasonable. Larger reference uncertainty, however, leads to lower En-values.

Table 5: Reported data from calibration point; 30 kg

Balance 1 - Load 30 kg					
Partici-pant	Applied Weights [g]	Balance indication [g]	Indication error [g]	Measurement uncertainty [g]	En-value
1					
2					
3					
4					
5	30000,0	29991,55	-8,45	0,88	**0,48**
6	30000,0	29991,47	-8,53	0,96	**0,36**
7	30000,0	29991,15	-8,85	0,13	**0,14**
8	30000,0	29991,35	-8,65	0,90	**0,25**
9	29999,39	29990,71	-8,68	0,70	**0,28**
10	30000,0	29991,55	-8,45	0,49	**0,83**
11	30000,0	29991,50	-8,50	1,05	**0,36**
REF	30000,0127	29991,136	-8,877	0,146	



Observations on the tests:

The 30 kg instrument was manipulated by the organizer to a considerable error in advance. The purpose was to follow up the participants handling of that issue. There was no misunderstanding on that point by the participants even if some of them were a bit confused by the results.

It was observed during the reference calibrations that the stabilisation time before reading was an important for the result. The stabilisation time was approximately 30-40 seconds.

Two laboratories did not calibrate the 30 kg point, probably due to lack of suitable weights.

Weighing instrument no.2 - 1500 kg

The weights were handled by a fork lifter and some of the participants had license for that and did all handling themselves. Other laboratories hired a truck driver to move the weights.

The security requirements were followed strictly by the organizer.

The instrument is designed for 2000 kg but the organizer only asked for calibration points up to 1500 kg.

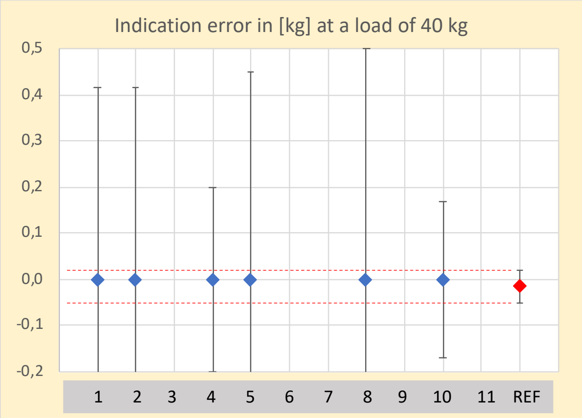
Most of the laboratories used 500 kg weights that were hired from (RISE Sweden)

The eccentricity test was included by the organizer to get some more facts on the handling of that

The implementation of how to do the eccentricity test was the same for all laboratories even if one laboratory used a higher load for the eccentricity test.

Table 6: Reported data from calibration point; 40 kg

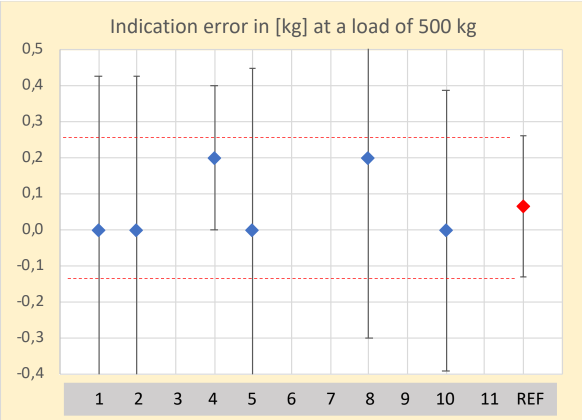
Balance 2 - Load 40 kg					
Partici-pant	Applied Weights [kg]	Balance indication [kg]	Indication error [kg]	Measurement uncertainty [kg]	En-value
1	40	40	0,0	0,42	**0,03**
2	40	40	0,0	0,42	**0,03**
3					
4	40	40	0,0	0,20	**0,07**
5	40	40	0,0	0,45	**0,03**
6					
7					
8	40	40	0,0	0,50	**0,03**
9					
10	40	40	0,0	0,17	**0,08**
11					
REF	40,000499	39,986	-0,0145	0,035	



Comment: In contrast to the reference calibration all participants used the weights nominal mass and standard resolution, which is probably reflected in a larger measurement uncertainty.

Table 7: Reported data from calibration point; 500 kg

Balance 2 - Load 500 kg					
Partici-pant	Applied Weights [kg]	Balance indication [kg]	Indication error [kg]	Measurement uncertainty [kg]	En-value
1	500	500	0,0	0,43	**-0,14**
2	500	500	0,0	0,43	**-0,14**
3					
4	500	500,2	0,2	0,20	**0,48**
5	500	500	0,0	0,45	**-0,13**
6					
7					
8	500	500,2	0,2	0,50	**0,25**
9					
10	500	500	0,0	0,39	**-0,15**
11					
REF	500,049	500,114	0,07	0,20	



Comment: The low standard resolution of 0,1 kg does not allow to reveal an indication error in the lower measuring range.

Table 8: Reported data from calibration point; 1000 kg

Balance 2 - Load 1000 kg					
Partici-pant	Applied Weights [kg]	Balance indication [kg]	Indication error [kg]	Measurement uncertainty [kg]	En-value
1	1000	1000,5	0,5	1,06	**0,01**
2	1000	1000,5	0,5	1,06	**0,01**
3					
4	1000	1000,5	0,5	0,50	**0,02**
5	1000	1000,5	0,5	0,45	**0,03**
6					
7					
8	1000	1000,5	0,5	0,50	**0,02**
9					
10	1000	1000,5	0,5	0,77	**0,02**
11					
REF	1000,061	1000,545	0,48	0,45	

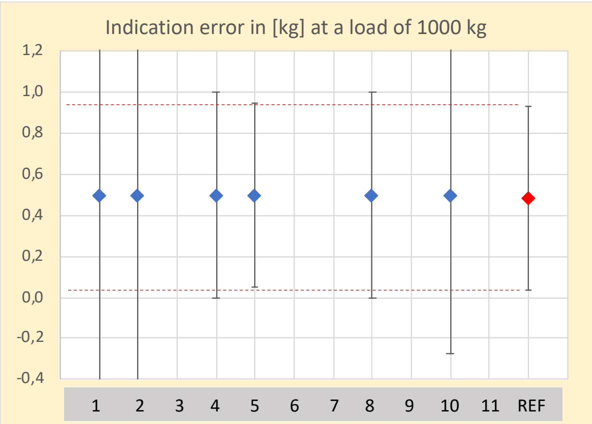
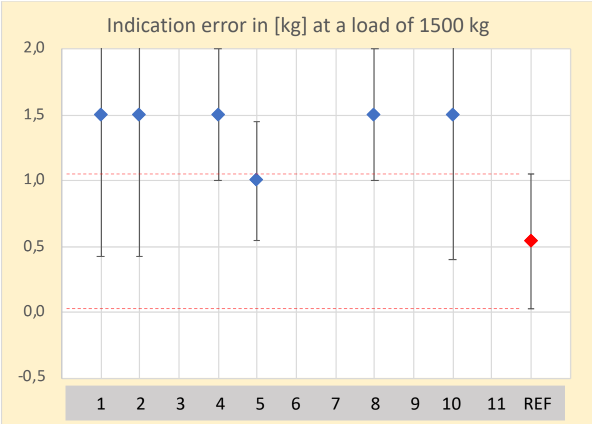


Table 9: Reported data from calibration point; 1500 kg

Balance 2 - Load 1500 kg					
Partici-pant	Applied Weights [kg]	Balance indication [kg]	Indication error [kg]	Measurement uncertainty [kg]	En-value
1	1500	1501,5	1,5	1,08	**0,80**
2	1500	1501,5	1,5	1,08	**0,80**
3					
4	1500	1501,5	1,5	0,50	**1,33**
5	1500	1501	1,0	0,45	**0,67**
6					
7					
8	1500	1501,5	1,5	0,50	**1,33**
9					
10	1500	1501,5	1,5	1,1	**0,79**
11					
REF	1500,07	1500,61	0,54	0,52	



Comment: At both 500 and 1500 kg the spread between all results is higher compared to 1000 kg. A probable explanation is the sensitivity to eccentricity which also was observed during the reference calibration (5 series). Very few centimeters out of the center had a distinct effect. It is obviously easier to place two 500 kg weights symmetrically than one or three of them. Concerning the deviation to the reference value - see explanation in annex 3. Two participants exceed the En-value of 1 due to optimistic uncertainty claims.

The sensitivity to positioning the weights became clear when the reference laboratory executed a specific repeatability test using 1500 kg by just lifting the weights up and down 14 times using a fork lifter trying not to change the position. The range (max – min) in this series was 0,1 kg (resolution 0,01 kg). During the calibration with 5 complete weighing series a range of 0,45 kg was observed.

Eccentricity in weighing instrument 2.

The determination of the eccentricity is standard procedure in balance calibration. For balance 2 with a U-shaped “platform” a large eccentricity can influence the repeatability and the uncertainty. Therefore, the eccentricity results are shown here explicitly.

In most calibrations 4 different points are checked; due to practical reasons here only 2 points outside the center.

The figure to the right shows these two positions where the 500 kg weights were placed. This balance contains 4 loadcells and one would expect that the eccentricity in position 1 should be less due to this construction.

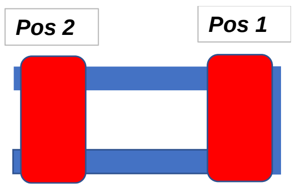
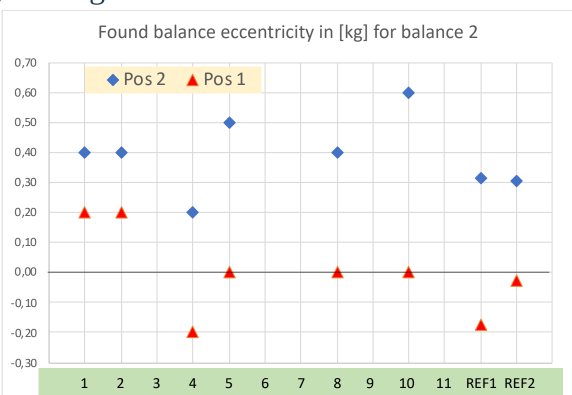


Table 10: Reported data from eccentricity test by 500 kg

Participant	Displayed values at			Maximal excentricity	excentricity
	Pos 2 [kg]	Centre [kg]	Pos 1 [kg]	Pos 2 [kg]	Pos 1 [kg]
1	500,4	500	500,2	0,40	0,2
2	500,4	500	500,2	0,40	0,2
3					
4	500,4	500,2	500,0	0,20	-0,2
5	1001,0	1000,5	1000,5	0,50	0
6					
7					
8	500,6	500,2	500,2	0,40	0
9					
10	500,6	500	500,0	0,60	0
11					
REF 1	500,42	500,105	499,93	0,31	-0,18
REF 2	500,35	500,045	500,02	0,31	-0,03

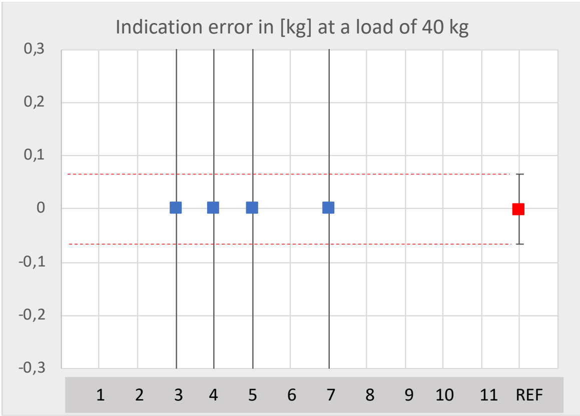


Comments: Usually this test is only performed once at each position. Table 10 shows the displayed values for both positions and the difference compared to the center position There are two results from the reference calibrations, each reflects the average of four repeated test in each position. As expected, position 1 is less sensitive to eccentricity effects than position 2. The range of 0,4 kg, however, is the same as also can be seen in the diagram.

Weighing instrument no. 3 - 5000 kg

Table 11: Reported data from calibration point; 40 kg

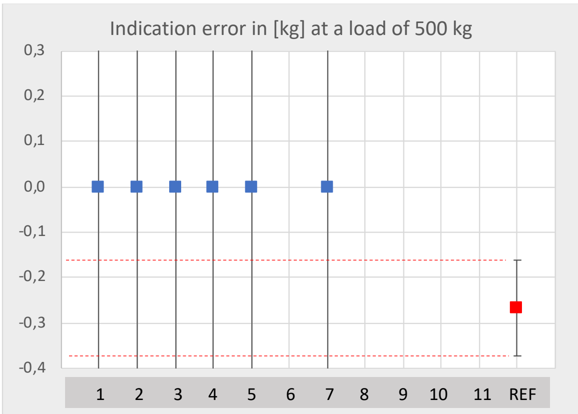
Balance 3 - Load 40 kg					
Partici-pant	Applied Weights [kg]	Balance indication [kg]	Indication error [kg]	Measurement uncertainty [kg]	En-value
1					
2					
3	40	40	0,0	0,65	**0,00**
4	40	40	0,0	1,00	**0,00**
5	40	40	0,0	0,76	**0,00**
6					
7	40	40	0,0	1,40	**0,00**
8					
9					
10					
11					
REF	40,000499	40	-0,0005	0,065	



Comment: With a resolution of 1 kg no indication error at such low load is expected. Due to several repetitions and an increased resolution a small indication error could be revealed. Participants 1 and 2 had probably no suitable weight available. Several of the calibration certificates do not expose if a repeatability test was done for this balance.

Table 12: Reported data from calibration point; 500 kg

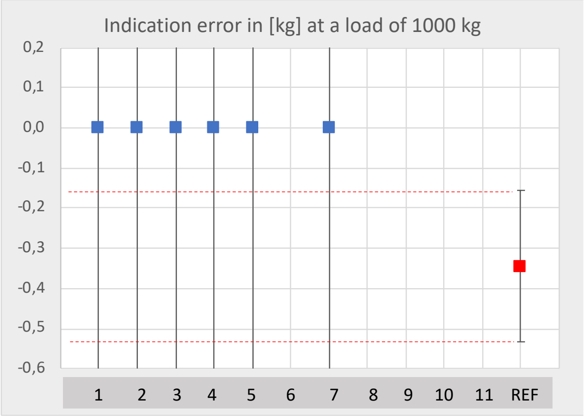
Balance 3 - Load 500 kg					
Partici-pant	Applied Weights [kg]	Balance indication [kg]	Indication error [kg]	Measurement uncertainty [kg]	En-value
1	500	500	0,0	0,59	**0,45**
2	500	500	0,0	0,59	**0,45**
3	500	500	0,0	0,66	**0,40**
4	500	500	0,0	1,0	**0,26**
5	500	500	0,0	0,76	**0,35**
6					
7	500	500	0,0	1,40	**0,19**
8					
9					
10					
11					
REF	500,049	499,78	-0,27	0,11	



It can be clearly seen in the results that the laboratories used the weights nominal values and not the calibrated mass value. Se annex 3.

Table 13: Reported data from calibration point; 1000 kg

Balance 3 - Load 1000 kg					
Partici-pant	Applied Weights [kg]	Balance indication [kg]	Indication error [kg]	Measurement uncertainty [kg]	En-value
1	1000	1000	0,0	0,61	**0,54**
2	1000	1000	0,0	0,61	**0,54**
3	1000	1000	0,0	0,68	**0,49**
4	1000	1000	0,0	1,0	**0,34**
5	1000	1000	0,0	0,76	**0,44**
6					
7	1000	1000	0,0	1,40	**0,24**
8					
9					
10					
11					
REF	1000,061	999,72	-0,34	0,19	

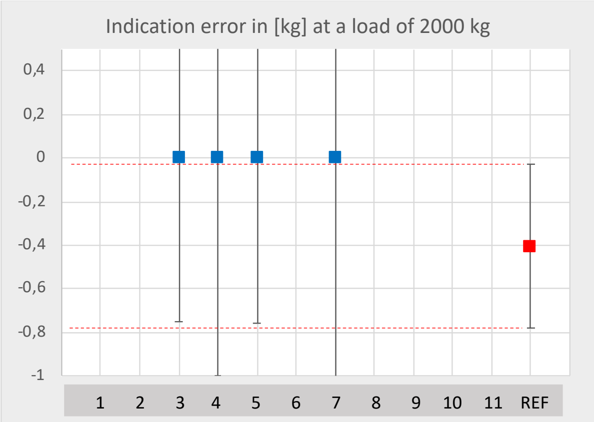


Comments: Only 6 participants performed this calibration. With the low balance resolution of 1 kg, the participants get the same results and an uncertainty roughly 6 times that of the reference value.

See comments related to nominal values in annex 3.

Table 14: Reported data from calibration point; 2000 kg

Balance 3 - Load 2000 kg					
Partici-pant	Applied Weights [kg]	Balance indication [kg]	Indication error [kg]	Measurement uncertainty [kg]	En-value
1					
2					
3	2000	2000	0,0	0,75	**0,48**
4	2000	2000	0,0	1,0	**0,38**
5	2000	2000	0,0	0,76	**0,48**
6					
7	2000	2000	0,0	1,4	**0,28**
8					
9					
10					
11					
REF	2000,08	1999,68	-0,40	0,38	



Comment: 2 of the laboratories did not perform the calibration at 2000 kg; may be that this point is not part of their routine. See comments related to nominal values in annex 3.

Table 15: Reported data from calibration point; 3000 kg

Balance 3 - Load 3000 kg					
Partici-pant	Applied Weights [kg]	Balance indication [kg]	Indication error [kg]	Measurement uncertainty [kg]	En-value
1	3000	3000	0,0	0,80	**0,32**
2	3000	3000	0,0	0,80	**0,32**
3	3000	3000	0,0	0,85	**0,30**
4	3000	3000	0,0	1,0	**0,27**
5	3000	3000	0,0	0,76	**0,33**
6					
7	3000	3000	0,0	1,40	**0,20**
8					
9					
10					
11					
REF	3000,10	2999,80	-0,30	0,50	

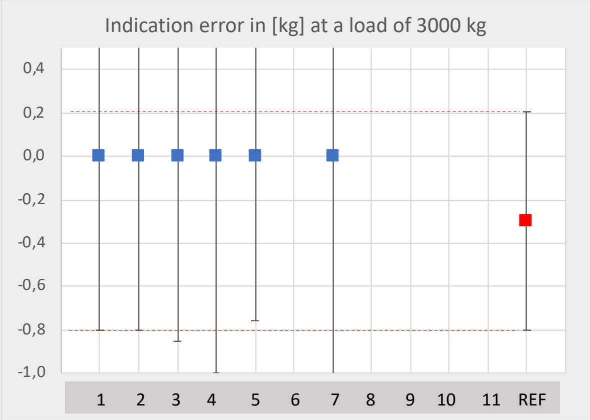
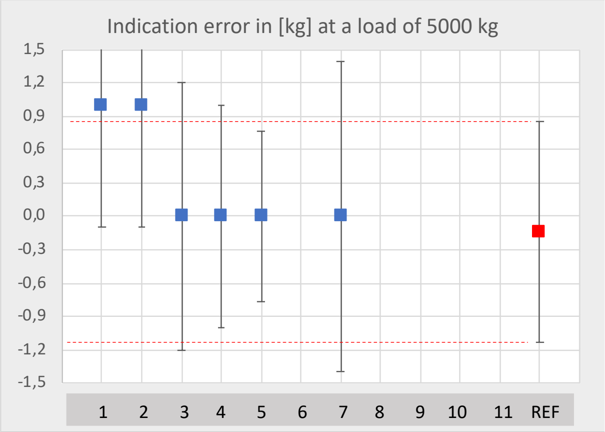


Table 16: Reported data from calibration point; 5000 kg

Balance 3 - Load 5000 kg					
Partici-pant	Applied Weights [kg]	Balance indication [kg]	Indication error [kg]	Measurement uncertainty [kg]	En-value
1	5000	5001	1,0	1,1	**0,77**
2	5000	5001	1,0	1,1	**0,77**
3	5000	5000	0,0	1,2	**0,09**
4	5000	5000	0,0	1,0	**0,10**
5	5000	5000	0,0	0,76	**0,11**
6					
7	5000	5000	0,0	1,4	**0,08**
8					
9					
10					
11					
REF	5000,19	5000,05	-0,14	0,99	



Comment: A credible explanation for the obvious grouping of results is related to the use of nominal values as described in annex 3.

General observations

(Not a part of the inter-comparison)

In this inter comparison 11 participating laboratories could demonstrate their capacity to calibrate the different instruments.

For an overall judgement of the outcome of this inter-comparison the following table summarizes a rough En-score with respect to the reference values for each instrument and all measurement points.

Weighing instrument	0 < |**En**| < 0,5	0,5 < |**En**| < 1	|**En**| > 1	Total No
1: 30 kg	32	8	3	43
2: 1500 kg	18	4	2	24
3: 5000 kg	28	4	0	32

All calibration results show a convincing capacity. The reason for the 5 unsatisfying En-values is not the found indication error but the underestimation of the belonging measurement uncertainty in the re-ported data.

For the specific eccentricity test no En-values were calculated. The results clearly show that position-ing of the weights is important in calibration and likewise för the use of the instrument.

The fact that the laboratories use the nominal weight load for instrument no. 2 and 3 leads to an offset.

Observations on the calibration certificates

The different calibration certificates nearly look the same except in one case where more details are documented.

Some facts are not explicitly stated; for example whether the laboratory performed repeatability tests on instrument 2 and 3 or not. On instrument no.1, however, most of the laboratories mentioned the number of repetitions that are in the range of 3 to 6.

One laboratory clearly declares that the uncertainty calculation is based on the EURAMET guide cg.18

Only one participant used the terms error or correction in the calibration certificate.

Some of the laboratories used their CMC values in the uncertainty declaration and some of them the calculated uncertainty values.

Acknowledgement

We gratefully thank:

- FLINTAB in Jönköping especially on arranging the facilities and 2 weighing instruments.
- METTLER TOLEDO Nordic for 1 weighing instrument
- RISE for arranging that the other participants could hire 500 kg weights.

Annex 1 project description

Documented on the web:

http://smquality.se/wp-content/uploads/2022/10/Description-of-ILC-weighing-instruments-2022-1.pdf

Annex 2 Uncertainty model for reference calibrations by SMQ

A prerequisite for making use of the En-criteria as a reliable estimation the reference values used must be of high quality i.e., their uncertainties should have low significance on the calculated En-values. Preferably the uncertainty should be about one third of that of the participants or better.

SMQ therefore performed for all three weighing instruments two complete calibrations, one before the comparison started and one after its end. In between a possible drift was monitored by checking one measurement point for each balance after each participant had finished its calibration. However, no drift beyond the uncertainty in the measurement was found.

For the reference calibrations by SMQ all weights were newly calibrated. They were different and had slightly lower uncertainties compared to those hired weights the participants used. Furthermore, at each measurement point the applied load was calculated as the sum of each individual mass value, which contrasted with most participants who used the sum of the weight's nominal values (balance 2 and 3). That difference in handling can clearly be seen in the tables for balance 3.

In the reference calibration therefore, the uncertainty contribution from the weights at each point also was based on their calibration uncertainty and not on their tolerances.

To achieve a distinct lower uncertainty for the reference values the SMQ-calibrations were performed with 10 complete repetitions for the 30 kg-balance and with 5 and 3 complete repetitions at all measurement points for balance 2 and 3 followed by at least 10 repetitions at one further measurement point.

For the analysis the following uncertainty model was used. It is valid for all three balances and based on the method designed by SMQ and validated according to EURAMET calibration guide No. 18

The indicated balance error E_{bal} is the difference between the balance indication I_{bal} and the conventional mass off the used weights M_w.

$$E_{bal} = \left\{ I_{bal} + \delta I_{rep} + \delta I_{res} + \delta I_{zero} + \delta B_{ecc} + \delta B_{zdrift} \right\} - \left\{ M_w + \delta M_{cal} + \delta M_{drift} \right\} \quad \text{(A1)}$$

The following seven uncertainty contributions are identified:

dI_{rep} Uncertainty due to spread in 10 repeated measurements (standard deviation of the mean)

dI_{res} Uncertainty due to readability, i.e., the balance resolution

dI_{zero} Uncertainty in perfect zeroing of the balance

dI_{ecc} Uncertainty due to eccentricity in not placing the weights mass centre at the balance centre

vdI_{zdrift} Uncertainty due to possible drift of the balance zero point during loading and unloading

dM_{cal} Uncertainty of the weights determined at their latest calibration

dM_{drift} Uncertainty due to eventual drift in weight mass

Each of the above uncertainty contributions d_i is judged and transformed to its standard uncertainty u_i and there after combined and expanded to a 95 % confidence interval according to the equation below.

$$U(E_{bal}) = 2 \times \sqrt{u_{rep}^2 + u_{res}^2 + u_{zero}^2 + u_{ecc}^2 + u_{zdrift}^2 + u_{mcal}^2 + u_{mdrift}^2} \quad \text{(A2)}$$

Further principal uncertainty components such as air buoyancy and convection effects are looked at but not included in the above model as they were found to be insignificant.

The uncertainty of the weights is taken from the different certificates and divided by the stated k-factor, always k = 2. The total weight uncertainty u_{mcal} is calculated as the root of the squared uncertainties of the individual weights, even considering possible correlation between weights of the same nominal value (500 kg weights).

For all three instruments and each calibration point two indication errors were measured (first and last calibration) and their average defined the best possible reference value – eq. (2). Due to differences in spread, eccentricity and zero-point drift between the calibration at start and end, also the uncertainties differed slightly between the two calibrations. Therefore, the uncertainty of the average indication error was calculated by combining both uncertainties - eq. (3) It was further enlarged by also considering the difference between the two corresponding results – adding linearly half of the difference.

The important uncertainty contributions differ from balance to balance and even between the measurement points. This is shown in the two graphs below.

As can be seen the weight uncertainty is not a real issue and neither is the eventual convection or air buoyancy effect, which both are calculated but not included in the above model. Concerning balance 1 it is the repeatability that dominates the uncertainty budget although it is based on the standard deviation of the mean from ten weighing series. As can be expected the resolution, despite it was increase to 0,01 kg, plays a major part influencing both the reading and the zeroing of the instruments, at least at the lower loads. For balance 2 and 3 the zero-point drift is the dominating contribution.

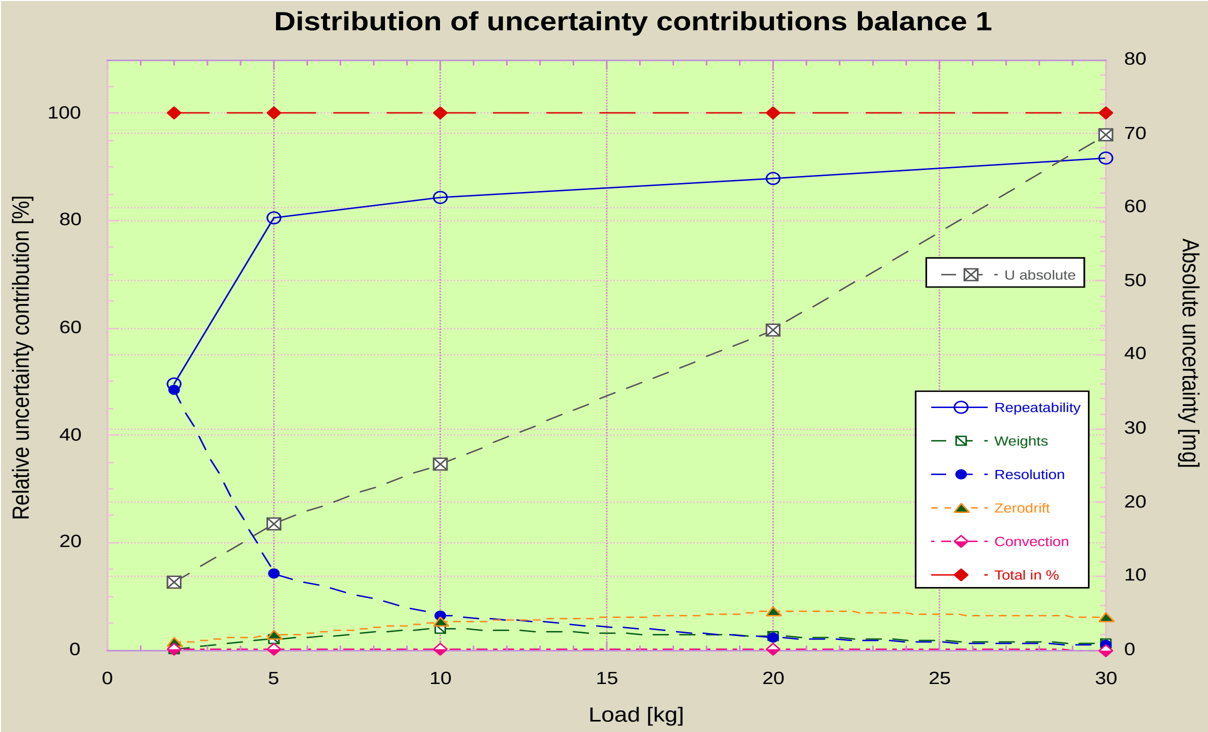


Diagram A2-1. The four most important uncertainty contributions for balance 1 and their varying importance with increasing load (left scale in % to the total uncertainty) together with the almost linear increase of the absolute uncertainty (right scale in mg).

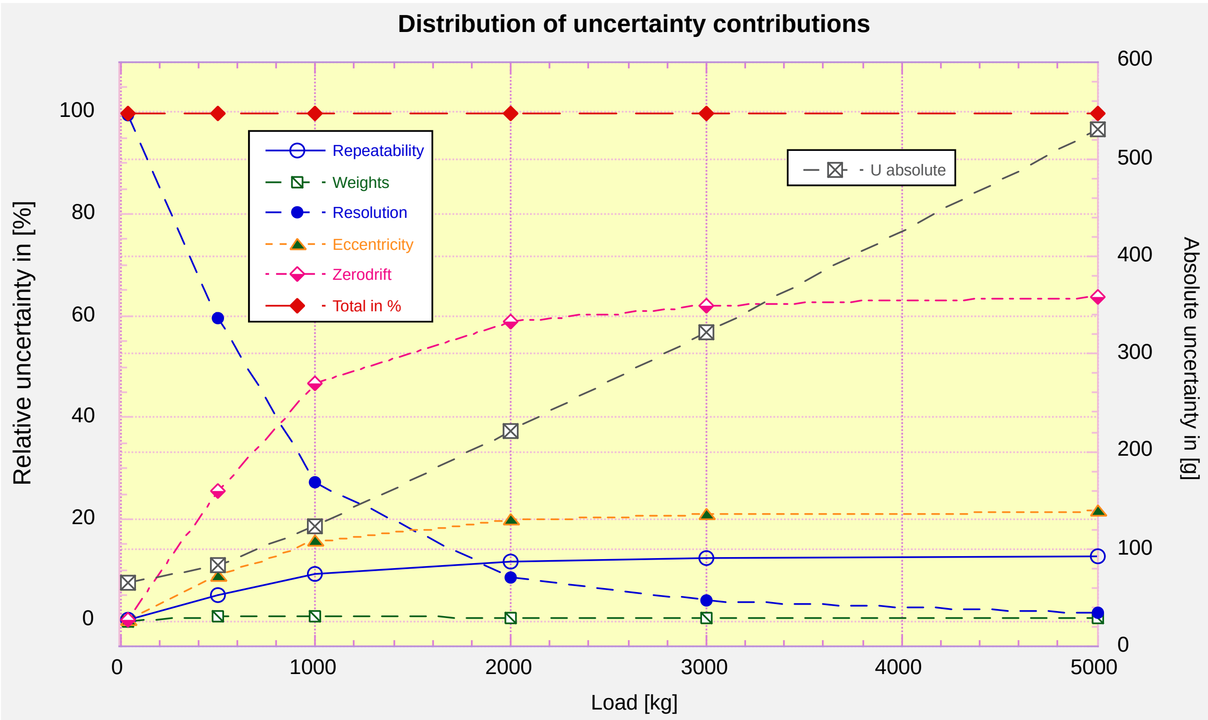


Diagram A2-2. Variation of the important uncertainty contributions for balance 3 and with increasing load (in % to the total uncertainty left scale) and the absolute uncertainty (in mg right scale) almost linearly increasing.

Annex 3 Effect of using nominal contra conventional mass values.

In the comparison for all three balances a certain pattern can be observed. With increasing load an increasing difference of the indication error can be seen in the diagrams between – on one side reported errors by the participants and on the other side from the reference calibration. For the later weights with somewhat lower uncertainty (1/3) were used whereas the participants all used hired weights for calibrating balance 2 and 3. The observed discrepancy, however, is not caused by different weights. The actual reason for the observed effect is twofold. First, in the reference calibration a clearly higher balance resolution could be used. Second and most important, the indication error was based on the difference between the balance indication and the weights conventional mass, not their nominal value as is practice for the participants. How this influences the reported indication error is shown in the table below for balance 3 ad a load of 3000 kg.

Table A3-1 effect of conventional contra nominal value in combination with resolution.

Reference weights:	Conventional value of weights [kg]	Balance indication [kg]	Indication error [kg]
SMQ-calibration	3000,10	2999,8 *	-0,3
Hired weights	3000,16	3000 **	-0,16
	Nominal weight value		
Hired weights	3000	3000 **	0

* Resolution 0,1 kg ** Resolution 1 kg

With limited resolution ** the difference in indication error became 0,3 kg (0-(-0,3)). With increased resolution * it could be 0,14 kg -0,16-(-0,3)) or even less.

As all weights had a conventional value higher than their nominal value their sum also tends to increase the indication error with larger loads as long as the limited resolution does not overturn the difference as was the case for two participants P1 and P2 at a load of 5000 kg. If SMQ had based its calibration on the weight's nominal value this increasing difference had not occurred, and the En-values would probably been lower.

It should in this context be mentioned that the hired 500 kg weights (RISE) that the participants had for their disposal all were newly calibrated (1 month earlier) and specified with their individual conventional values. However, no individual uncertainty only their tolerance was explicitly specified (80 g) – se a sample below.

Viktsatsklass (M1 - M3) : **M2**

VIKTDRIFT Malmö 601294 **(Samt N3000, M1M2 & M2M3)** *VIKTDRIFT.XLTX*

Vikt märkt	Nominell massa g	Tillåten tolerans mg	Massa 2020-05-04 g	Drift antal mätos	Massa 2021-05-18 g	Åt-gä rd	Massa efter trim /utbyte	Drift antal mätos	Massa 2022-11-08 g	Åt-gä rd
1	500000	80000	500041	1,16 G	500070	KÄ	500041	0,08 G	500039	G
2	500000	80000	500052	0,36 G	500043	G		0,72 G	500025	G
3	500000	80000	500045	0,40 G	500035	G		0,36 G	500044	G
4	500000	80000	500049	0,08 G	500051	G		1,56 G	500012	G
5	500000	80000	500039	0,04 G	500040	G		0,0 G	500040	G
6	500000	80000	500034	0,40 G	500024	G		0,96 G	500000	G
7	500000	80000	500052	0,20 G	500047	G		0,04 G	500048	G

Some comments on the true mass M, conventional mass CM and nominal mass value.

Balances indicate the mass of an object in units of kg. What is measured, however, is the force the earth gravitational field g_{loc} exerts on the object placed on the balance according to equation (A3).

$$F = M \cdot g_{loc} \qquad \text{(A3)}$$

Here M is the objects “true” mass, i.e. the amount of substance. Equation (A3) were only valid if there were no air around the object and balance. The surrounding air always exerts a certain lifting force opposite to the gravitational force, which is dependent on the density of the air r_a and the density of the weighed object r_o (Archimedes principle)

$$F = M \cdot \left(1 - \frac{\rho_a}{\rho_o}\right) \cdot g_{loc} \qquad \text{(A4)}$$

For transforming the force measuring instrument into a mass determining one it must be calibrated with sets of known weights at the actual place. But as (A4) indicates the calibration would only hold strictly for objects having the same density as were used during calibration and for the same air density conditions (air pressure, temperature, humidity, and gas composition). To round this problem a concept was introduced to apply standardized conditions for the object and air density (r_o = 8000 kg/m^3 and r_a = 1,2 kg/m^3) respectively. Thus, calibration weights should have this standard density and calibrations should be performed at such air conditions, which is utterly inconvenient. Only the best and most expensive weights have today a density close to 8000 kg/m^3. Most stainless-steel weights have densities in the range 7840 to 7950 kg/m^3. To overcome this problem the concept of a “conventional mass” was introduced. This means calibration laboratories first determine a weights true value in a very well-controlled environment and then “transform” this true mass into a “conventional mass value” using equation (A5).

$$CM_x = \frac{M_x\left(1 - \frac{\rho n}{\rho x}\right)}{\left(1 - \frac{\rho n}{\rho_{std}}\right)} \qquad \text{(A5)}$$

CM_x:	Conventional mass value of weight x
M_x:	True mass of weight x
r_n:	“Normal” air density = 1,2 kg/m^3
r_x:	Density of calibrated weight x (for example 7850 kg/m^3)
r_{std}:	Standard weight density 8000 kg/m^3

As all weighing is performed in air the use of a weights conventional mass for calibration is a practical and suitable concept. Even if this in practice means that the mass of objects with densities higher than the standard one is overestimated the large majority of objects with lower densities are underestimated. However, the difference is acceptable.

Calibrated weights come in various quality classes, which means their true mass and density are closer or further from the “nominal values” of even 1, 2, 5 and 10 mg, g or kg and their density also is closer or further from the standard one. This has also an impact on the uncertainty or how good a balance can be calibrated. When using several weights on a balance platform one can add their individual conventional values to a total load or one simply just add their nominal values. The later choice means the real load is further from the correct one. Calculating the load based on the individual weight values also means one can combine their uncertainties specified in the calibration certificates. When using the nominal values instead the uncertainty of the load must be based on the actual weight tolerances, which leads to much larger uncertainties.

Uncertainty example maximum load 5000 kg – balance 3:

The calibration weights (500 kg) used by SMQ had an uncertainty of 7,64 g each. This means for a total load from 10 weights the uncertainty is at least 24,2 g (quadratic combination). Also taking in consideration a correlation between them due to a common reference weight during their calibration the total load uncertainty is rather 37 g.

In comparison the hired RISE weights came with an uncertainty of 25 g (not explicitly stated). The comparable uncertainties thus were 79 g uncorrelated and more reasonably 121 g with correlation. This is a factor 3,2 larger than in the reference calibration. However, this would be based on the sum of the individual conventional values. As routinely only the nominal values were added the uncertainty should be based on the linear summation of the given weight tolerances of 80 g, which at a load of 5000 kg amounts to 800 g. Thus, this value would be the lower limit for the participants uncertainty claims for this situation. The stated uncertainties lied between 740 and 1600 g.

References:

- ISO/IEC 17043:2010 Conformity assessment – General requirements for proficiency testing
- ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories
- ISO 13528 Statistical methods for use in proficiency testing by interlaboratory comparison
- Evaluation of measurement data – Guide to the expression of uncertainty in measurement JCGM 100:2008/GUM:2010
- EA-4/02 M:2013 Evaluation of Uncertainty of Measurement in Calibration
- ILAC-P9:06/2014 ILAC policy for Participation in Proficiency Testing activities
- OIML R 76:1 edition 2006
- ISO 13548 corrected version 2016-10-15