THE PERFORMANCE EVALUATION OF LABORATORIES PERFORMING CALIBRATION OF NON-AUTOMATIC WEIGHING INSTRUMENTS (NAWI)

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Abstract – In 2014, a proficiency testing in the field of NAWI calibration was carried out at National Institute of Metrology (INM) from Romania. The accredited provider of this proficiency testing scheme was ROLAB Association. The subject of the comparison consisted in a weighing instrument having Max 6000 g and d = 0.01 g. The paper presents the results obtained by eleven participating laboratories in this proficiency testing scheme. All results were in agreement with the results of INM.

Keywords: non automatic weighing instrument (NAWI), normalized error, error of indication, uncertainty attributed to error of indication.

1. INTRODUCTION

ISO/IEC 17025 [1] requires "that laboratories have quality control procedures for monitoring the validity of tests and calibrations undertaken". This monitoring may include the participation in interlaboratory comparisons (ILCs) or proficiency testing (PT) programs.

An interlaboratory comparison (ILC) represents a valuable, collective exercise for evaluating laboratory proficiency and confirming claimed Calibration Measurement Capabilities (CMC) as measures of the metrological performance of the different actors which compose a country's national metrology system [2].

The goals of an ILC for determining laboratory performance include:

- evaluation and performance monitoring of laboratories for specific tests or measurements;
- identifying problems in laboratories and initiation of improvement actions;
- determining the effectiveness and comparability of tests or measurement methods;
- providing a reliable plus to laboratory's customers;
- training of participating laboratories based on the results of such comparisons.
- comparing own performance with other similar laboratories.

In 2014, for the first time, a proficiency test in the field of NAWI calibration was carried out in Romania, National Institute of Metrology (INM) acting both as pilot and reference laboratory.

The accredited provider of this proficiency testing scheme was ROLAB (Association of the Romanian Laboratories).

The main purpose of this proficiency test was to evaluate the performance of laboratories carrying out calibration of non-automatic weighing instruments.

Identity of participating laboratories was confidential and known only by those involved in the operation of proficiency testing scheme.

The participants calibrated at INM the balance using their own weights, in accordance with procedures given in [3].

Given the large number of participating laboratories, the provider considered necessary that the proficiency test be conducted in two rounds.

The paper presents the results obtained by eleven participating laboratories in the first round of the proficiency testing scheme. The results were analyzed using E_n (normalized error) values.

The aim of the comparison was not only to compare measurement results of the participant with those of PL/RL, but also to analyse measurement uncertainty, the choice of calibration points and the content of calibration certificates.

2. PROFICIENCY TEST ITEM

The subject of the comparison (the proficiency test item) consisted in a non-automatic weighing instrument, having the following characteristics.

- Max 6000g;
- d = 0.01g;
- temperature range: +15°C/+30°C
- digital indication;
- single weighing range;
- model PS 6000/C/.

3. PARTICIPATING LABORATORIES

For the presentation of measurement results were used codes (1 to 13) attributed to participating laboratories by PL / LR, which had the code "1".

Initially, 12 laboratories announced their participation in the comparison. Subsequently, one of them, namely, laboratory encoded with "8", announced its withdrawal from this proficiency test.

Also, laboratory encoded with "3" has not longer sent the final results of the measurements.

4. MEASUREMENT SCHEME OF PT

A scheme with sequential participation was used for the proficiency test.

The balance was calibrated by each participant at INM.

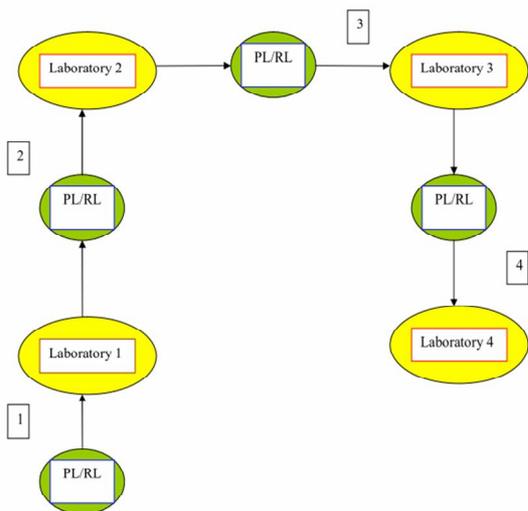The proficiency test was performed according to the scheme shown in Fig. 1:

Fig 1. Measurement scheme

The steps 1 to 4 are repeated for the other laboratories.

5. MEASUREMENTS PERFORMED BY PL/RL

5.1. Mass standards used for the calibration of NAWI

For the calibration, PL/RL used the sets of weights indicated in Table 1.

Table 1. Standards weights used by PL/RL

Set	OIML Class	Uncertainty	Calibration certificate
500g…500 mg, serial number: 002	F_1	(0,5…0,015) mg	02.01-302/2014
(5…1) kg, serial number: 158890-1	F_1	(5…1) mg	02.01-368/2013

5.2. Measurement method and test loads used by PL/RL

For the calibration of the balance, PL/RL used direct comparison method with standard weights having nominal mass and accuracy class presented in the Table 1.

Each load was placed only once, increasing by steps with unloading between the separate steps – corresponding to the majority of uses of the instruments for weighing single loads [3].

This procedure was applied up to the largest load. The test loads used for determining the errors of indication were: 0, 0.5g, 500g, 1000g, 1500g, 2000g, 2500g, 3000g, 3500g, 4000g, 4500g, 5000g, 5500g and 6000g. The results of average values obtained in different days were taken as reference values.

For other loads, reference values were calculated from a fourth order polynomial fit to the measurement results.

Also, eccentric errors at 2000 g, repeatability at 3000 g and 6000 g were measured.

The balance was calibrated with this method each day during the comparison, before the calibration of participating laboratories.

Environmental conditions were monitored during the proficiency test.

5.3. Measurement results of PL/RL

For a load j applied on the pan in an ascending way, the error of indication was calculated as follows [3]:

$$E_j = I_j - m_{cj} \qquad (1)$$

where I_j is the indication of the balance and m_{cj} is the conventional mass of the weights from the calibration certificate. Fig. 2 shows measurement results of INM.

In evaluating standard uncertainty associated with the error of indication, the following contributions were taken into account:
- reference standard,
- resolution of the weighing instrument;
- repetability of indications,
- effect of the air buoyancy,
- the effect of the load eccentrically placed.

Since the recommended minimum time for thermal stabilization of standard weights was complied with, the convection effects were neglected.
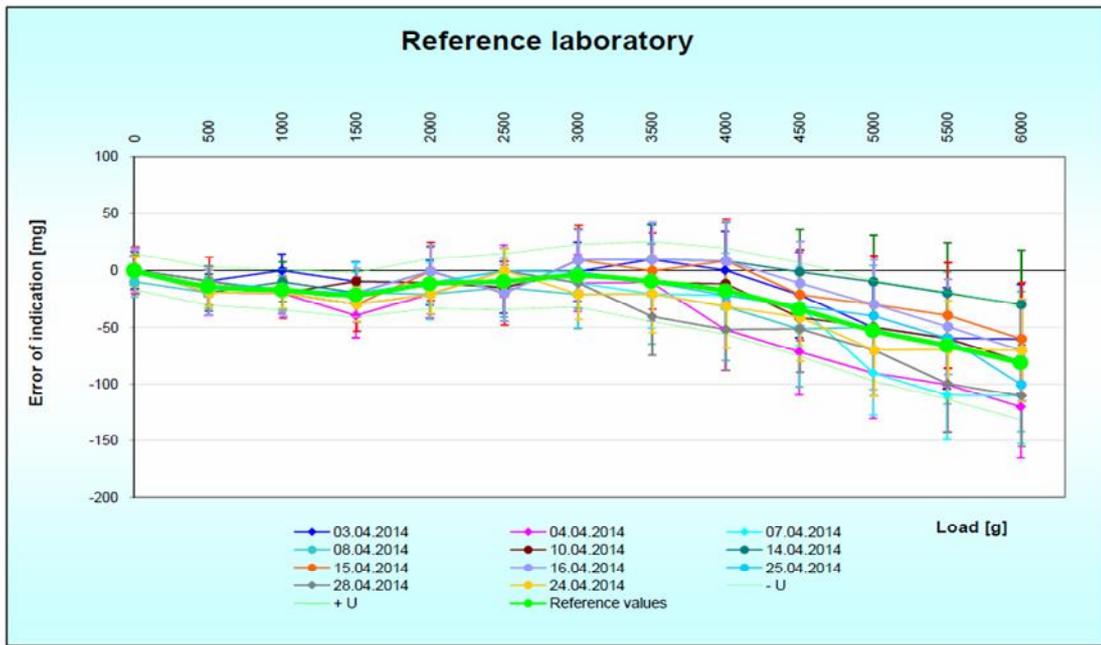
Fig. 2. Measurement results obtained by PL/RL

All uncertainty components can be graphically represented in an Ishikawa (Fishbone) diagram, as shown in Fig. 3.
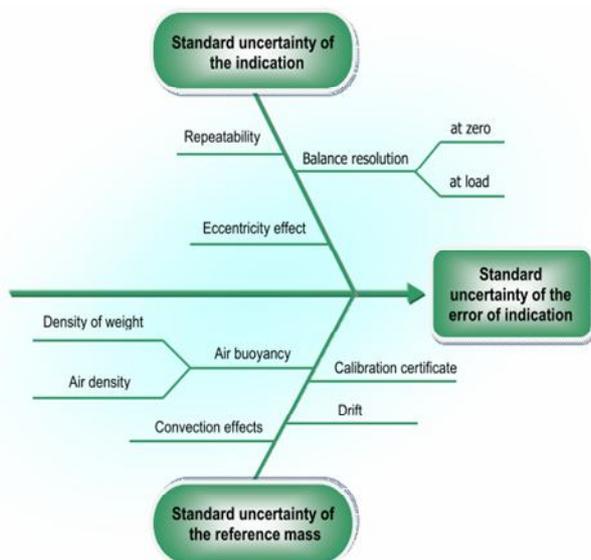

Fig. 3. Ishikawa diagram of uncertainty components in the calibration of the balance

6. MEASUREMENTS RESULTS OF PT

6.1. Generalities

Each laboratory has presented the final results in a calibration certificate, in accordance with the requirements of the technical protocol.

Laboratories have opted for placing the load only once, increasing by steps with unloading between the separate steps – corresponding to the majority of uses of the instruments for weighing single loads [3].

An exception was the lab „4" which applied the loads continuously, increasing and decreasing by steps.

The results were analyzed using E_n values (normalized error).

6.2. Results

In Table 2 are listed the results reported (errors of indication and uncertainty attributed to these errors) by each participant laboratory, including PL/RL.

Measurement uncertainty was estimated according to [3], with the following observations:

- uncertainty associated to limited resolution was estimated only once by the laboratories: 4, 9, 10, 11 and 13;

- laboratories 4, 9, 10 and 11 have not introduced in the uncertainty budget the component associated to air buoyancy;

- from uncertainty budget of the laboratory no. 4, it is not clear if repeatability was included in uncertainty calculation;

- laboratory no. 13 used for all test loads the same value for uncertainty associated with the load eccentrically placed;

- in the uncertainty budget of laboratory no.4 were some miscalculations regarding uncertainty associated to the load eccentrically placed, which makes this component undervalued (implicitly standard uncertainty associated to the error of indication);

- laboratory no. 5 considered negligible the effect of the load eccentrically placed, although from the calibration certificate issued, this is not apparent. In the table 3 are presented the uncertainty components reported by each participating laboratory.

Table 2. Errors of indication "E" and expanded uncertainty "U" (for k=2) associated to these errors, reported by each participating laboratory, including PL/RL

Load g	1 E mg	1 U mg	2 E mg	2 U mg	3 E mg	3 U mg	4 E mg	4 U mg	5 E mg	5 U mg	6 E mg	6 U mg	7 E mg	7 U mg	9 E mg	9 U mg	10 E mg	10 U mg	11 E mg	11 U mg	12 E mg	12 U mg	13 E mg	13 U mg
0	0	16			-	-							0	20	0	20	0	10	0	40	0	30		
0.5	0	16	-10	20	-	-	-10	30	0	68	0	20	-10	20	0	20	0	20	0	40	0	40	0	34
1	0	18	10	20	-	-	0	30	-10	68			-20	20	0	20	0	20						
2	0	18			-	-			0	68														
5	0	18	0	20	-	-			0	68														
10	0	18	-10	20	-	-	0	30	0	68			-20	20	0	20			0	40			0	34
20	0	18	0	20	-	-													0	40				
50	-2	18	-10	20	-	-	0	30	0	68	-10	20			0	20			-10	40			-10	34
100	-4	18			-	-	-10	30	-10	68	-10	20	-30	20	-10	20	0	20	0	40	-10	40		
200	-8	18	-10	20	-	-			-20	68					-10	20	-10	20	-10	40	-10	50		
250	-9	19			-	-																	-11	34
400	-13	19			-	-											-10	20						
500	-14	17	-20	20	-	-	-10	30	-20	68	-10	20	-10	20	-10	20			-10	40	-10	50	-12	34
1000	-17	18	-10	20	-	-	-10	40	0	68	0	20	-10	20	0	20	0	20	0	40	-10	60	-4	34
1500	-22	19			-	-																		
2000	-12	22	-10	40	-	-	-10	50	0	68	-10	30	-10	20	10	30	0	30	-10	40	-10	60	-7	34
2500	-10	25			-	-																		
3000	-5	27			-	-			40	68	-10	60	0	20					0	40	-10	60	-12	35
3500	-10	35			-	-																		
4000	-18	38			-	-			10	68	-20	70	-10	20	40	50	30	50			-20	80	-15	35
4500	-34	41			-	-																		
5000	-53	44	-50	100	-	-	-20	80	-20	68	-50	90	-50	20	-20	60	10	60	-20	60	-40	90	-20	35
5500	-66	47			-	-																		
6000	-81	50	-90	120	-	-	-30	90	-40	68	-60	110	-80	30	-10	70	10	80	-30	60	-50	100	-104	35

Table 3 Uncertainty components reported by each participating laboratory.

Lab	Resolution	Repeat-ability	Mass standards	Eccentricity	Buoyancy	Convection	Stability of indication	Hysteresis	Tare
2	X	X	X	X	X	-	-	-	X
3									
4	X	X	X	X	-	X	-	X	-
5	X	X	X	-	X	-	-	-	-
6	X	X	X	X	X	X	-	-	-
7	X	X	X	X	X	-	-	-	-
9	X	X	X	X	-	-	-	-	-
10	X	X	X	X	-	-	-	-	-
11	X	X	X	X	-	-	-	-	-
12	X	X	X	X	X	-	-	-	-
13	X	X	X	X	X	X	X	-	-

In Table 4 are presented the normalized errors E_n [4] of the reported values compared to reference values.

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

Where:
E_n = normalized error

x_{lab} = result of measurement carried out by a participant laboratory
x_{ref} = the comparison reference value of PL/RL
U_{ref} = measurement uncertainty of PL/RL
U_{lab} = measurement uncertainty reported by participant laboratory.

In Fig. 4 are presented the results of participating laboratories, including PL/RL.

Table 4. Normalized errors E_n of the reported values compared to reference values

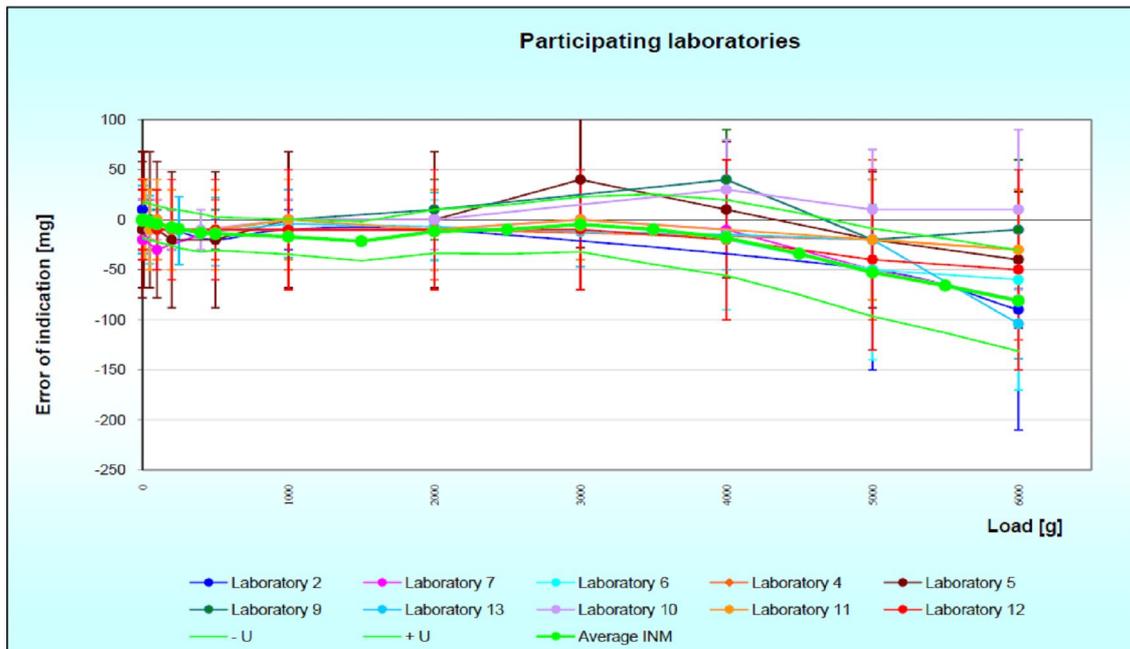| Load g	Participating laboratories										
	2	3	4	5	6	7	9	10	11	12	13
0						0	0	0	0	0	
0.5	-0.4		-0.3	0.0	0	-0.4	0	0	0	0	0
1	0.4		0	-0.1		-0.7	0	0			
2				0.0							
5	0			0.0							
10	-0.4		0	0.0		-0.7	0		0		0
20	0								0		
50	-0.3		0.1	0.0	-0.3		0.1		-0.2		-0.2
100			-0.2	-0.1	-0.2	-1.0	-0.2	0.2	0.1	-0.1	
200	-0.1			-0.2			-0.1	-0.1	-0.1	0	
250											0
400								0.1			
500	-0.2		0.1	-0.1	0.2	0.2	0.2		0.1	0.1	0
1000	0.3		0.2	0.2	0.6	0.3	0.6	0.6	0.4	0.1	0.3
1500											
2000	0		0	0.2	0	0.1	0.6	0.3	0	0	0.1
2500											
3000				0.6	-0.1	0.1			0.1	-0.1	-0.2
3500											
4000				0.4	0	0.2	0.9	0.8		0	0.1
4500											
5000	0		0.4	0.4		0.1	0.4	0.8	0.4	0.1	0.6
5500											
6000	-0.1		0.5	0.5	0.2	0	0.8	1.0	0.7	0.3	-0.4

Fig. 4. Results of participating laboratories, including PL/RL

To have a global image of the proficiency testing, it was made a centralization of results in the Table 5 (which contains normalized errors together with reported uncertainties for each participant).

Table 5. Centralization of normalized errors E_n and reported uncertainties

Laboratory	E_n values	Uncertainties
1	-	(16…50) mg
2	(-0.4…0.4) mg	(20…120) mg
3	-	-
4	(-0.3…0.5) mg	(20…90) mg
5	(-0.2…0.6) mg	68 mg
6	(-0.3…0.6) mg	(20…110) mg
7	(-1.0…0.3) mg	(20…30) mg
9	(-0.2…0.9) mg	(20…70) mg
10	(-0.1…1.0) mg	(10…80) mg
11	(-0.2…0.7) mg	(40…60) mg
12	(-0.1…0.3) mg	(30…100) mg
13	(-0.4…0.6) mg	(34…35) mg

7. CONCLUSIONS

Analyzing the results obtained in the proficiency test, it can be observed that all results were in agreement with the results of INM.

Laboratory "3" has not longer sent the final results of the measurements.

Although the uncertainty associated to the load eccentrically placed was correctly calculated, there were laboratories (2, 6, 9, 10 and 12) that have increased this component, because the balance had some obvious problems, related to this characteristic. But, lab "5" considered negligible this effect, although from the issued calibration certificate, this is not apparent. In this way, the expanded uncertainty was undervalued.

As a general observation, from the Table 2 and 4 it can be seen that most laboratories did not uniformly choose the calibration points, as is specified at the point 5.2 of [3].

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