INTERLABORATORY COMPARISON OF AN DIGITAL THERMOHYGROMETER IN SEVERAL ROMANIAN LABORATORIES

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This paper reports the results of measurements performed on a digital thermohygrometer by several metrology laboratories throughout Romania. The comparison began in 2013 and concluded in 2014. Temperature Laboratory of National Institute of Metrology (INM) acted as pilot laboratory (PL) and reference laboratory (RL) for the programme. The measurements were conducted at temperature integer values in the range of (10…30)° C. The results obtained in this comparison by participating laboratories are used to validate and transmitting traceability measurement according to quality management system.

Keywords: interlaboratory comparison, pilot laboratory, calibration

1. Introduction

This paper describes the conduct and results of interlaboratory comparison for calibration of a digital thermohygrometer- itinerant standard- with a range between -10 and +70 ° C [1] and the resolution value of 0,1 ° C, the comparison was performed during the period January 2013 to December 2014.

Initially, for this interlaboratory comparison, alongside the reference laboratory- RL-, the following 7 regional laboratories locations of the Romanian Bureau of Legal Metrology structure announced their participation: Bucuresti, Ploiesti, Pitesti, Craiova, Hunedoara, Cluj-Napoca, Timisoara and Iasi.

Subsequently, one of them, Cluj-Napoca laboratory, announced their withdrawal from this interlaboratory comparison.

The itinerant standard used in intercomparing was carefully selected by reference laboratory (RL), was initially calibrated by INM and then was

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transported between participating laboratories according to the circulation scheme of the standard, mentioned in the interlaboratory comparison guide. [2,3,4]

A pilot laboratory (PL) acts as coordinator for an interlaboratory comparison being responsible for preparing the transfer standards, for centralizing the results and also for preparing the final report of the intercomparing.

A reference laboratory (RL) establishes the reference values of the transfer standards at the beginning of the intercomparing, at the end, or when necessary.

For this interlaboratory comparison, Temperature Laboratory of National Institute of Metrology (INM) acted as pilot (PL) and also as reference laboratory (RL).

Measurement results, the modeling function and associated measurement uncertainty budget were presented in a calibration report by each participating laboratory. [4]

The results of interlaboratory comparisons is a way of monitoring the validity of results performed and provides confidence for customers requesting this type of calibration.

2. Measurement Instructions

Participating laboratories were organized into one group, the order being determined by location.

To perform the measurements, each participating laboratory has used the method and the routinely procedure when calibrating digital thermohygrometers.

Using digital thermohygrometer not raise special problems, other than those related to its fragility: special care was given to avoid its damage. In use, thermohygrometer was kept upright. Also avoided was subjected to shock, vibration and was not exposed to direct contact with water or other liquids.

According to the protocol established, each participant laboratory has conducted at least three different series of measurements at each temperature setting of 10, 20, 25 and 30 ºC.

Calibration was performed in thermostatic chambers by direct comparison method. As reference standards were used platinum resistance thermometers and digital thermometers, with calibration certificates available. According to calibration certificates, all standards used in comparison were traceable to national standards of Romania.

Measurements were performed at the inter values of the temperature in the range (0…30)º C. At each temperature point were performed at least three different series of measurements. The results of measurements modeling function and uncertainty of measurement budget were associated were presented in a calibration report by each participating laboratory.

Corrections determined by INM during the initial and final measurements mean corrections, which are the reference values (VR) of the comparison, as well as standard expanded uncertainties associated to the reference values are presented in the Table 1.

Table 1

Reference values of comparison

t_{90}/°C	Correction/°C	U/°C
10.00	-0.011	0.10
20.00	+0.075	0.10
25.00	+0.089	0.10
30.00	+0.095	0.10

3. Mathematical model of the measurement

The Correction, *C*, that must have added to indication of calibrated thermohygrometer, may be expressed as:

$$C = T_e - T_v + \delta T_1 + \delta T_2 + \delta T_3 + \delta T_4 + \delta T_5 + \delta T_6 + \delta T_7 + \delta T_8 \quad (1)$$

where :

T_e -standard (reference) thermohygrometer indication;

T_v -thermohygrometer under calibration indication;

δT_1-correction due to the finite resolution of standard thermometer;

δT_2 -correction due to calibration standard thermometer;

δT_3-correction due to drift between two successive calibrations of standard thermometer;

δT_4 -correction due to the influence of ambient conditions on thermometer standard (reference))

δT_5-correction due to the environmental uniformity comparison;

δT_6 -correction due to the influence of ambient conditions on calibrated thermohygrometer;

δT_7 -correction due to interpolation by thermohygrometer to be calibrated;

δT_8-correction due to interpolation by thermohygrometer to be calibrated;

To calculate the uncertainty associated with deviations against reference values using the modelling function:

$$\Delta C = C_{Labi} - C_{RL} + \delta C_{stab} \quad (2)$$

Combined standard uncertainty associated to deviation ΔC was calculated as follows: [5,6,7]

$$u_c(\Delta C) = [u_2(C_{Labi}) + u_2(C_{RL}) + u_2(\delta C_{stab})]^{1/2} \quad (3)$$

Table 2

Budget of measurement uncertainty for the temperature of 10ºC

Symbol of influence of the input quantity X_i	Estimation x_i (^oC)	Standard associated uncetainty $u(x_i)$ (^oC)	Probability distribution	The number of degrees of freedom v_i	Sensitivity coefficient c_i	Contribution $u_i(y) = C_{si} * u_i$ (^oC)
t_e	9.891	0.0037	normal	5	1	0.0000037
t_v	9.90	0.0245	normal	3	1	0.0000245
δT_1	0	0.000289	normal	∞	1	0.000289
δT_2	0	0.015	normal	∞	1	0.015
δT_3	0	0.005	rectangular	∞	1	0.00867052
δT_4	0	0.000289	rectangular	∞	1	0.00289
δT_5	0	0.0289	rectangular	∞	1	0.0289
δT_6	0	0.000289	rectangular	∞	1	0.0289
δT_7	0	0.0289	rectangular	∞	1	0.00289
δT_8	0	0.0289	rectangular	∞	1	0.0145
C	-0.011					
Combined standard uncertainty						0.05
The actual number of degrees of freedom						49.575
Expanded standard uncertainty						0.10

Expanded uncertainty $(k = 2)$ associated to deviations ΔC :[5,6,7]

$$U(\Delta C) = 2u_c(\Delta C) \quad (4)$$

4. Index of value calculation

For an as objective as possible analysis of the measurements results, the index of value was determined for each participating laboratory, index expressed by the equation [2, 3]:

$$E_i = \frac{x_i - x_{ref}}{U(\Delta C_i)} \quad (5)$$

where:

x_i - indication value of the itinerary standard at a given point of calibration, obtained by laboratory *„i”*;

x_{ref} – reference value;

$U(\Delta C_i) - \Delta C_i$ expanded uncertainty associated with deviation, uncertainty calculated using the modeling function.

For values of the index of value in the range [-1, +1], laboratory *„i”* is compatible with the reference laboratory and is considered able to perform measurements in this range with the declared uncertainty of measurement.

The indices of value for the 7 locations of participating laboratories are presented in Table 3.

Table 3

The Indices of value for participating laboratories

t_{90},[°C]	Participating laboratory code/ index of value					
	2	**3**	**4**	**5**	**6**	**7**
10	-0.32	-0.32	0.03	-0.37	0.35	0.75
20	-0.09	-0.10	-0.24	-0.45	0.21	0.30
25	-0.17	-0.15	0.00	-0.39	0.02	0.51
30	-0.24	-0.28	0.02	-0.62	0.17	0.25

5. Presentation of results

Each laboratory reported the measured temperature value that is assigned to itinerant standard, together with an expanded uncertainty. For all laboratories, the coverage factor was 2.

Differences between results obtained by participating laboratories and the reference and pilot laboratory are plotted in Figures 1- 4, for each calibration point. Vertical lines represent expanded uncertainty $U(k=2)$ associated with these differences.

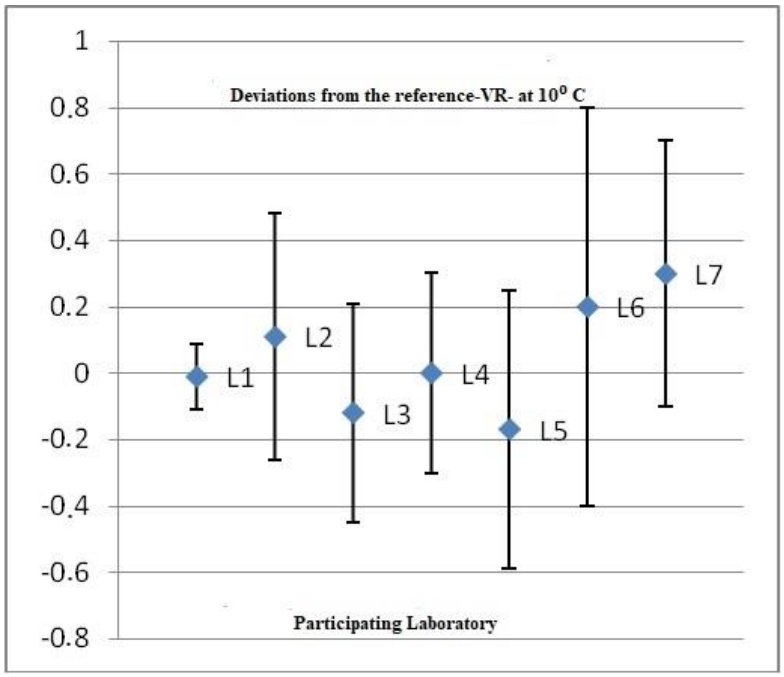

Fig. 1. Deviations from the reference-VR- values at 10^0 C obtained by participating laboratories

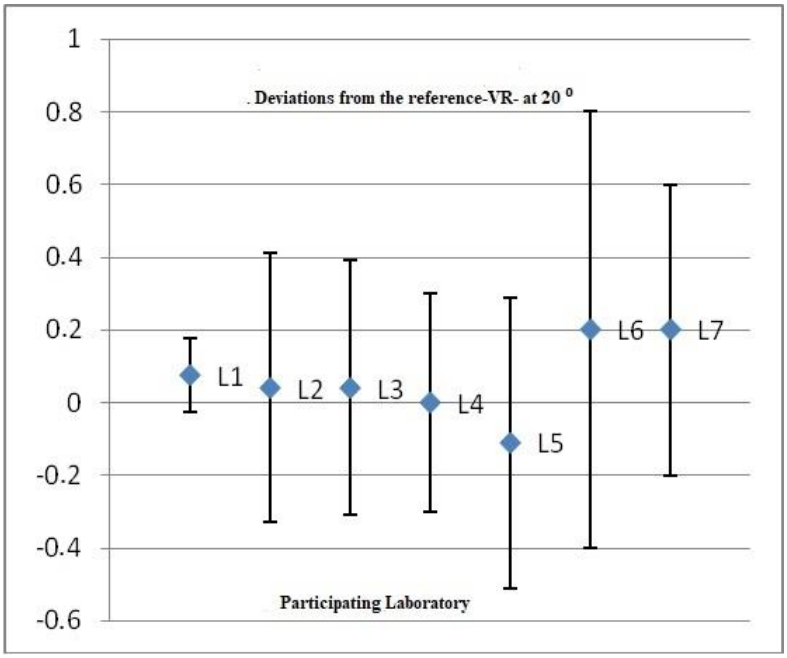

Fig. 2. Deviations from the reference-VR- values at 20º C obtained by participating laboratories

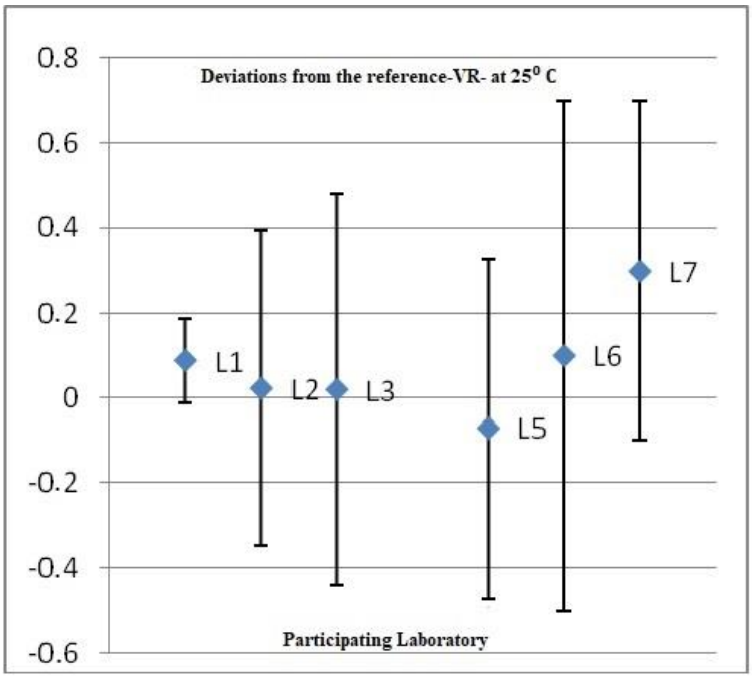

Fig. 3. Deviations from the reference-VR-
values at 25º C obtained by participating laboratories

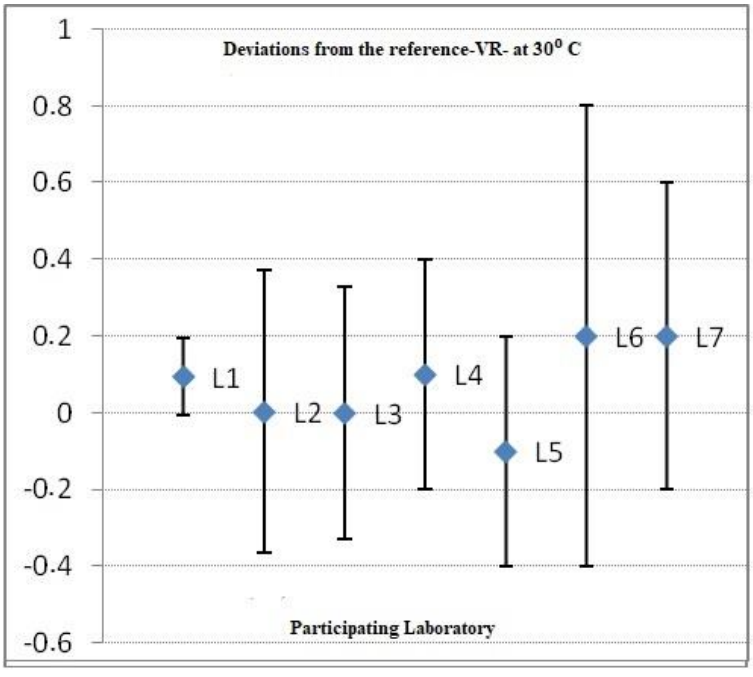

Fig. 4. Deviations from the reference-VR-
values at 30^0 C obtained by participating laboratories

6. Conclusions

Analyzing the results of interlaboratory comparison and associated uncertainties provided by the participating laboratories and the resulting values indices lead to the following conclusions:

- All laboratories participating in the interlaboratory comparison meet the acceptance criteria for all calibration points (except Laboratory no. 3 which has not made measurements at 25 ° C) with deviations somewhat lower or comparable to measurement uncertainty.

- These highlights once again the rigor and accuracy with which participating laboratories evaluated measurement uncertainty and conducted measurements.

The obtained results demonstrated well effects of variations in the heat transfer conditions air calibrations. [8,9]

The final results together with the associated uncertainties are reliable and applicable to the whole range of the itinerant standard, because in calculating the uncertainty is also taken into account the drift that the thermohygrometer can have at its extremities, respectively from -10 to +70 ° C.

The theme aimed to determine and monitor the ongoing performance of individual laboratories under BRML performing calibration, thus identifying potential problems that need to initiate corrective actions. The results obtained from interlaboratory comparisons are a way of monitoring the validity of calibrations performed, can be used to demonstrate the participating laboratory's measurement capability and the results provide confidence to customers and also in its own activity.

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