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INTERLABORATORY COMPARISON IN HUMIDITY AND TEMPERATURE

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Abstract: The aim of this paper is to present the results of an interlaboratory comparison in temperature and relative humidity, among eleven laboratories, that was coordinated by the National Institute of Metrology, Quality and Technology (Inmetro, Brazil). As transfer standard, a thermo-hygrometer was used. The intercomparison was carried out in the range from 20 %rh to 90 %rh (at 20 ºC and 30 ºC) and from 20 ºC to 40 ºC. The performance of the intercomparison was judged by calculating the normalized error. Results from the majority of the labs agreed well with those of Inmetro.

Keywords: Interlaboratory comparison, temperature, relative humidity, quality system.

1. INTRODUCTION

Temperature and humidity measurements are of great relevance in many research fields, once these quantities have influence on physical, chemical or biological processes. In industrial sectors, they can also represent a relevant factor in business costs, in the quality of goods and services, and for occupational safety and health at work. In the last decades, digital thermo-hygrometers have been widely used for these purposes. Hence, it is very important that the measurements performed by these instruments are reliable and traceable.

Interlaboratory comparison is a relevant tool to evaluate the performance and the quality of the results of the laboratories that carry out calibration services. The participation on it is one of the ways that an accredited lab has to fulfill the item 5.9 of ISO/IEC 17025 [1]. For not accredited labs or for those that intend to become accredited, the interlaboratory comparison program gives the laboratory the opportunity to evaluate its technical performance.

This is the second intercomparison program coordinated by Inmetro for relative humidity sensors and the first one in temperature for this kind of instrument (thermo-hygrometer). The previous relative humidity interlaboratory comparison was realized from October 2004 to March 2005 in the range from 30 %rh to 90 %rh at 20 ºC. Five labs participated on it and four of them had satisfactory results for all the points [2].

The aim of this paper is to present the results of an interlaboratory comparison in temperature and relative humidity among eleven laboratories. The intercomparison program was coordinated by the National Institute of Metrology, Quality and Technology (Inmetro, Brazil) with the support of the Technical Committee of Temperature and Humidity (CT-11) of the Laboratory Accreditation Division of the Institute.

2. INTERCOMPARISON PROGRAM

The measurements of the intercomparison program were started on April 2011 and the final report was issued on November 2011.

The Hygrometry Laboratory of the Thermal Metrology Division of Inmetro was the reference laboratory of the intercomparison. The laboratory started to render calibration services in 1998 and its calibration system is composed of a variety of equipment (climatic chambers, thermometers, cooled-mirror hygrometers, dew-point generator and others) to cover the range from –75 ºC to +75 ºC of dew/frost point temperatures. The humidity standard system had already been employed in bilateral comparisons to demonstrate its equivalence to humidity standards of other countries [3, 4, 5]. Also, the standard instruments are periodically compared to each other in order to assure the quality of the calibration and test results.

Eleven laboratories from eight different Brazilian cities participated of the interlaboratory comparison. All of them are accredited labs for the calibration of relative humidity and temperature sensors. To ensure the confidentiality of the results, each participating lab was identified and informed of a tag. So, the lab is only capable of identifying its result. The results and the tags of all the participants are only known by the organizing committee. They were fortuitously identified as 16, 17, 26, 45, 61, 62, 69, 72, 80, 83 and 86.

The participating labs should use their own calibration procedures, which are usually employed in the calibration services, and perform the calibrations points within their accreditation scope. They were informed that additional point should not be performed. The labs should also register their results in a spreadsheet prepared by the organizing committee and protect it with a password, which was considered as the signature of the lab, assuring the integrity of the data.

A digital thermo-hygrometer, belonged to Inmetro, was used as transfer standard of the intercomparison. The instrument has a thermistor and a capacitor as temperature and relative humidity sensors, respectively. A probe houses the sensors remotely from the principal body of the instrument, which does not offer the possibility to adjust its readings. The thermo-hygrometer has resolutions of 0.1 %rh

and 0.1 ºC and operating range from 0 %rh to 100 %rh and from –20 ºC to 125 ºC.

The transfer standard was calibrated by the reference laboratory before the interlaboratory comparison, by means of a climatic chamber and reference standards (cooled-mirror hygrometer and platinum resistance thermometer of 100 Ω). For all the calibration points, a correction value and an uncertainty were estimated. The uncertainty budget of the transfer standard was composed by several components, such as: calibration uncertainties, resolutions, repeatability of the readings, reproducibility, drift, curve fittings and thermal gradients of the climatic chamber. The uncertainties (combined and expanded) were then estimated according to the Guide to Expression of Uncertainty in Measurement [6].

The relative humidity calibration points selected for the comparison were: 20 %rh, 30 %rh, 40 %rh, 50 %rh, 60 %rh, 70 %rh, 80 %rh and 90 %rh measured at 20 ºC and 30 ºC. The temperature calibration points selected were: 20 ºC, 30 ºC and 40 ºC. The nominal points should be indicated by the participant's reference standard, after applying its correction.

3. RESULTS

The analysis of the results stated by the participants was executed by means of the normalized error. The normalized error (E_n), with respect to the uncertainty, is a convenient method to judge the quality of a measurement result. A measurement is considered acceptable when its E_n value is lower than one. The En value was calculated according to Eq. 1 below [7].

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

Where,

y_i Result of the participating lab
y_{ref} Result of the reference lab
U_i Uncertainty of the participating lab
U_{ref} Uncertainty of the reference lab

For relative humidity, not all the laboratories performed all the points of the intercomparison program. The following figures show the transfer standard's corrections obtained by the participants for the calibration points of relative humidity measured at 20 ºC and 30 ºC. The uncertainty bars were omitted on the figures for reason of clarity.

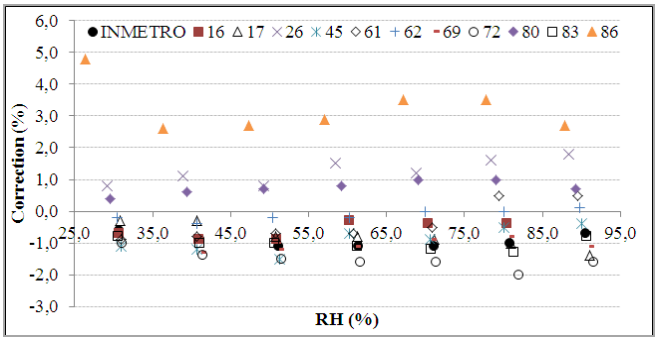

Figure 1 – Corrections of Relative Humidity at 20 ºC

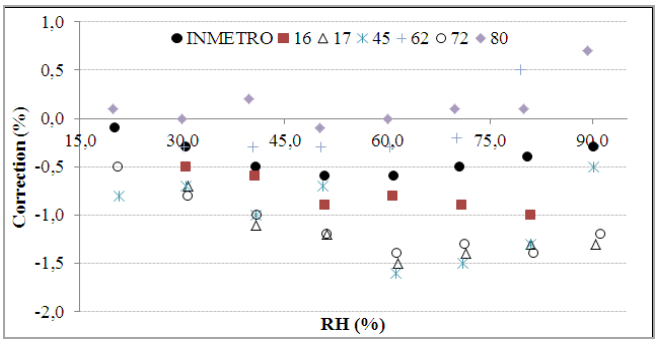

Figure 2 – Corrections of Relative Humidity at 30 ºC

Table 1 presents the corrections (*C*) and the expanded uncertainties (*U*) of the labs for the intercomparison points of relative humidity at 20 ºC.

Table 1 – Corrections and Uncertainties of RH at 20 ºC

		Relative Humidity (%)						
		30	**40**	**50**	**60**	**70**	**80**	**90**
I	***C***	-0.6	-0.9	-1.1	-1.1	-1.1	-1.0	-0.7
	U	0.7	0.9	1.0	1.2	1.4	1.6	1.7
16	***C***	-0.7	-0.9	-0.9	-0.3	-0.4	-0.4	-
	U	1.5	2.0	2.3	2.3	2.4	2.7	-
17	***C***	-0.3	-0.3	-0.8	-0.8	-0.9	-1.0	-1.4
	U	0.7	0.7	1.1	1.1	1.3	1.3	1.6
26	***C***	0.8	1.1	0.8	1.5	1.2	1.6	1.8
	U	1.8	1.8	2.5	2.5	3.0	3.6	3.6
45	***C***	-1.1	-1.2	-1.5	-0.7	-0.9	-0.5	-0.4
	U	1.3	1.3	1.5	1.7	1.9	2.1	2.3
61	***C***	-0.9	-0.8	-0.7	-0.7	-0.5	0.5	0.5
	U	2.0	2.0	2.4	2.4	2.8	2.8	3.4
62	***C***	-0.2	-0.4	-0.2	-0.2	0.0	0.0	0.1
	U	2.7	2.7	3.2	3.2	3.5	4.1	4.1
69	***C***	-	-1.3	-1.2	-1.1	-0.9	-0.8	-1.1
	U	-	1.8	1.9	2.1	2.3	2.6	2.8
72	***C***	-1.0	-1.4	-1.5	-1.6	-1.6	-2.0	-1.6
	U	1.0	1.0	1.3	1.3	1.6	1.6	1.9
80	***C***	0.4	0.6	0.7	0.8	1.0	1.0	0.7
	U	1.7	1.7	1.7	1.7	2.2	2.2	2.2
83	***C***	-0.8	-1.0	-1.0	-1.1	-1.2	-1.3	-0.8
	U	1.1	1.3	1.3	1.3	1.4	1.4	1.4
86	***C***	4.8	2.6	2.7	2.9	3.5	3.5	2.7
	U	2.4	2.4	2.6	2.6	3.0	2.4	2.4

Table 2 presents the corrections (*C*) and the expanded uncertainties (*U*) of the labs for the intercomparison points of relative humidity at 30 ºC.

Table 2 – Corrections and Uncertainties of RH at 30 ºC

		Relative Humidity (%)							
		20	**30**	**40**	**40**	**60**	**70**	**80**	**90**
I	***C***	-0.1	-0.3	-0.5	-0.6	-0.6	-0.5	-0.4	-0.3
	U	0.4	0.5	0.7	0.8	1.0	1.1	1.3	1.6
16	***C***	-	-0.5	-0.6	-0.9	-0.8	-0.9	-1.0	-
	U	-	1.4	1.9	2.0	2.3	2.4	2.7	-
17	***C***	-	-0.7	-1.1	-1.2	-1.5	-1.4	-1.3	-1.3
	U	-	0.7	0.7	1.1	1.1	1.3	1.3	1.6
45	***C***	-0.8	-0.7	-1.0	-0.7	-1.6	-1.5	-1.3	-0.5
	U	1.3	1.3	1.3	1.4	1.6	1.8	2.0	2.3
62	***C***	-	-0.3	-0.3	-0.3	-0.3	-0.2	0.5	-
	U	-	2.7	2.7	3.2	3.2	3.6	4.2	-
72	***C***	-0.5	-0.8	1.0	-1.2	-1.4	-1.3	-1.4	-1.2
	U	0.7	1.0	1.0	1.3	1.3	1.6	1.6	1.9
80	***C***	0.1	0.0	0.2	-0.1	0.0	0.1	0.1	0.7
	U	1.7	1.7	1.7	1.7	1.7	2.2	2.2	2.2

Figure 3 shows the transfer standard's corrections obtained by the participating laboratories for the calibration points of temperature. The uncertainty bars were omitted on the figures for reason of clarity. To avoid resolution loss of the graph, the results of the participant identified as 72 were also omitted because they are very far from the other labs (as it can be seen in Table 3).

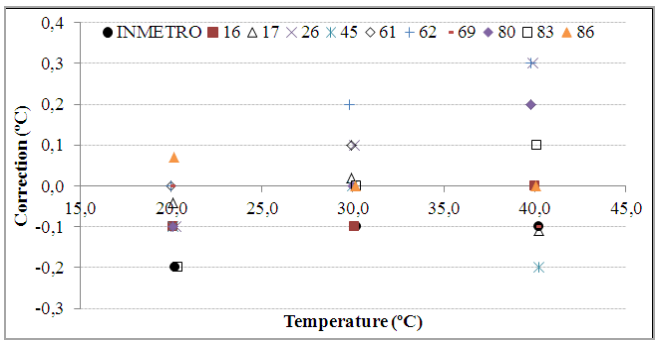

Figure 3 – Corrections of Temperature

Table 3 presents the corrections (*C*) and the expanded uncertainties (*U*) of the labs for the intercomparison points of temperature.

Table 3 – Corrections and Uncertainties of Temperature

		Temperature (°C)		
		20	**30**	**40**
I	***C***	-0.2	-0.1	-0.1
	U	0.3	0.3	0.3
16	***C***	-0.1	-0.1	0.0
	U	0.3	0.3	0.4
17	***C***	0.0	0.0	-0.1
	U	0.3	0.3	0.3
26	***C***	-0.1	0.1	0.3
	U	0.4	0.4	0.4
45	***C***	-0.1	0.0	-0.2
	U	0.3	0.3	0.3
61	***C***	0.0	0.1	0.2
	U	0.7	0.7	0.7
62	***C***	0.0	0.2	0.3
	U	0.5	0.5	0.5
69	***C***	0.0	0.0	-0.1
	U	0.3	0.3	0.3
72	***C***	20.1	30.2	40.3
	U	0.3	0.3	0.3
80	***C***	-0.1	0.0	0.2
	U	0.3	0.3	0.3
83	***C***	-0.2	0.0	0.1
	U	0.3	0.3	0.3
86	***C***	0.1	0.0	0.0
	U	0.7	0.8	0.8

Tables 4 and 5 present the E_n values for each participant for the intercomparison points of relative humidity (at 20 ºC and 30 ºC) and temperature, respectively.

Table 4 – E_n Values for RH Points at 20 ºC and 30 ºC

		E_n Values for RH (%) Points							
		20	**30**	**40**	**50**	**60**	**70**	**80**	**90**
16	**20 ºC**	-	-0.1	0.0	0.1	0.3	0.3	0.2	-
	30 ºC	-	-0.1	0.0	-0.1	-0.1	-0.2	-0.2	-
17	**20 ºC**	-	0.3	0.5	0.2	0.2	0.1	0.0	-0.3
	30 ºC	-	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.4
26	**20 ºC**	-	0.7	1.0	0.7	0.9	0.7	0.7	0.6
	30 ºC	-	-	-	-	-	-	-	-
45	**20 ºC**	-	-0.3	-0.2	-0.2	0.2	0.1	0.2	0.1
	30 ºC	-0.5	-0.3	-0.3	-0.1	-0.5	-0.5	-0.4	-0.1
61	**20 ºC**	-	-0.1	0.0	0.2	0.1	0.2	0.5	0.3
	30 ºC	-	-	-	-	-	-	-	-
62	**20 ºC**	-	0.1	0.2	0.3	0.3	0.3	0.2	0.2
	30 ºC	-	0.0	0.1	0.1	0.1	0.1	0.2	-
69	**20 ºC**	-	-	-0.2	0.0	0.0	0.1	0.1	-0.1
	30 ºC	-	-	-	-	-	-	-	-
72	**20 ºC**	-	-0.3	-0.4	-0.2	-0.3	-0.2	-0.4	-0.4
	30 ºC	-0.5	-0.4	-0.4	-0.4	-0.5	-0.4	-0.5	-0.4
80	**20 ºC**	-	0.5	0.8	0.9	0.9	0.8	0.7	0.5
	30 ºC	0.1	0.2	0.4	0.3	0.3	0.2	0.2	0.4
83	**20 ºC**	-	-0.2	-0.1	0.1	0.0	-0.1	-0.1	0.0
	30 ºC	-	-	-	-	-	-	-	-
86	**20 ºC**	-	2.2	1.4	1.4	1.4	1.4	1.6	1.2
	30 ºC	-	-	-	-	-	-	-	-

Table 5 – E_n Values for Temperature Points

	E_n Values for Temperature Points		
	20 ºC	**30 ºC**	**40 ºC**
16	0.2	0.0	0.2
17	0.4	0.3	0.0
26	0.2	0.4	0.8
45	0.2	0.2	-0.2
61	0.3	0.3	0.4
62	0.3	0.5	0.7
69	0.5	0.2	0.0
72	47.8	71.4	95.2
80	0.2	0.2	0.7
83	0.0	0.2	0.5
86	0.4	0.1	0.1

Table 6 summarises the number and the percentage of E_n values lower and higher than one for each point.

Table 6 – Number of E_n Values per Intercomparison Point

	Nº of Labs	**Points with $E_n \leq 1$**		**Points with $E_n > 1$**	
		Nº	**%**	**Nº**	**%**
30 %rh at 20 ºC	10	9	90	1	10
40 %rh at 20 ºC	11	10	91	1	9
50 %rh at 20 ºC	11	10	91	1	9
60 %rh at 20 ºC	11	10	91	1	9
70 %rh at 20 ºC	11	10	91	1	9
80 %rh at 20 ºC	11	10	91	1	9
90 %rh at 20 ºC	10	9	90	1	10
20 %rh at 30 ºC	3	3	100	0	0
30 %rh at 30 ºC	6	6	100	0	0
40 %rh at 30 ºC	6	6	100	0	0
50 %rh at 30 ºC	6	6	100	0	0
60 %rh at 30 ºC	6	6	100	0	0
70 %rh at 30 ºC	6	6	100	0	0
80 %rh at 30 ºC	6	6	100	0	0
90 %rh at 30 ºC	4	4	100	0	0
20 ºC	11	10	91	1	9
30 ºC	11	10	91	1	9
40 ºC	11	10	91	1	9
TOTAL	**151**	**141**	**93**	**10**	**7**

4. CONCLUSIONS

All the eleven labs participated of the intercomparison points of relative humidity measured at 20 ºC. However, the

labs 69 and 16 didn't perform the points 30 %rh and 90 %rh, respectively. Ten labs had $E_n \leq 1$ for all the points and one lab, identified as 86, had $E_n > 1$ for all the points.

Six labs (16, 17, 45, 62, 72 and 80) participated of the intercomparison points of relative humidity measured at 30 ºC. However, the labs 16, 17 and 62 didn't perform the point 20 %rh and the labs 16 and 62 didn't perform the point 90 %rh. All the labs had $E_n \leq 1$ for all the measured points.

All the eleven labs participated of the intercomparison points of temperature. Ten labs had $E_n \leq 1$ for all the points and one lab, identified as 72, had $E_n > 1$ for all the points.

If all the participating laboratories had performed all the calibration points, the intercomparison program should be composed of 198 points. However, as some participants didn't perform certain points because these were out of their scope, then 151 points were realized. From these, 141 (93%) had $E_n \leq 1$ and only 10 (7%) had $E_n > 1$.

In summary, one participant had unsatisfactory results for all the relative humidity calibration points and another had the same problem for temperature. However, all the others participants had satisfactory results for all the other points of relative humidity and temperature.

The participant that had unsatisfactory results for all the intercomparison points of temperature explained that the problem was caused by transcription error. The readings and the corrections were inadvertently changed when they were typed in the spreadsheet. The results would be satisfactory if this kind of mistake was not committed. Nevertheless, the laboratory has to implement preventive actions in order to avoid its happening again.

By means of the results previously presented, it can be concluded that the dissemination of the quantities relative humidity and temperature, concerning the calibration of a digital thermo-hygrometer, is well satisfactory. The final result of the interlaboratory comparison was also considered satisfactory by the organizers of the exercise, once ten of the eleven participants had E_n values lower than one for the relative humidity and temperature points, which means that more than 90% of all the performed intercomparison points are considered acceptable.

5. ACKNOWLEDGMENTS

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