Final Report

COOMET.T-S5

(COOMET project No: 826/MD/21)

COOMET Supplementary Comparison on Calibration of Relative Humidity Sensor

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2025

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1 Introduction

This report represents the results of comparison, in the context of international collaboration, which provides confidence in relative humidity measurements carried out in accordance with the Mutual Recognition Arrangement (MRA) of the International Committee for Weights and Measures (CIPM).

This comparison was organized by the following national metrology institutes: INM-MD (Republic of Moldova), MIKES (Finland) and BelGIM (Belarus). INM-MD was the pilot institute for this comparison. The travelling standard was provided by BelGIM. The INM-MD has been responsible for monitoring the performance of the standard, during the comparison, the evaluation and reporting of the comparison results. MIKES, which is the only participant in this comparison with published CMCs for relative humidity, also ensured that the results presented in this report were correlated with the results of other humidity comparisons.

Participants used their own calibration procedures to calibrate the transfer standard, along with some instructions provided in the technical protocol. In addition, participants were required to submit with the measurement results the respective uncertainties estimated according to their internal procedures and the Guide to Expressing Uncertainty in Measurement (GUM).

The comparison was conducted in accordance with the Technical Protocol of “Supplementary comparisons of standards for the relative humidity unit, COOMET project № 826/MD/21”, given in Appendix A, which was prepared by the INM-MD and approved by the participants.

This report presents the results of the relative humidity comparison performed by the participant NMIs, carried out by measuring a thermo-hygrometer ROTRONIC HP32-SET, which was used as a travelling standard instrument, in the relative humidity range from 10 %rh to 90 %rh, at air temperature values of 23 °C, 10 °C and 50 °C. The purpose of comparison was to establish the degree of equivalence between measurement standards of participant and to support CMCs.

2 Participants and organization of the comparison

2.1 Pilot Laboratory

The pilot institute for this comparison was INM-MD from Republic of Moldova. The pilot laboratory was responsible for preparing the technical protocol, determining the drift of the travelling standard, calculating the results and preparing the comparison report.

2.2 Participating Institutes

The participating institutes of the comparison and contact persons with their addresses are given are described in Table 1.

Table 1. List of Participants

Acronym of Institute	NMI	Address	Contact person
INM-MD	National Institute of Metrology	28, E. Coca Str, Chisinau, Republic of Moldova, MD-2064	Constantin Bordianu bordianuc@gmail.com Tel: (+373) 78 201 202
MIKES	VTT Technical Research Centre of Finland Ltd, Centre for Metrology	Tekniikantie 1 02150 Espoo, Finland	Richard Högström richard.hogstrom@vtt.fi Tel: (+358) 503 039 341
BelGIM	National Metrology Institute of Belarus	93, Starovilensky trakt, Minsk, 220053, Belarus	Alina Davidovschaia davidov@belgim.by Tel: +(375) 17 334 820

2.3 Comparison Schedule

The comparison scheme is presented in Figure 1.

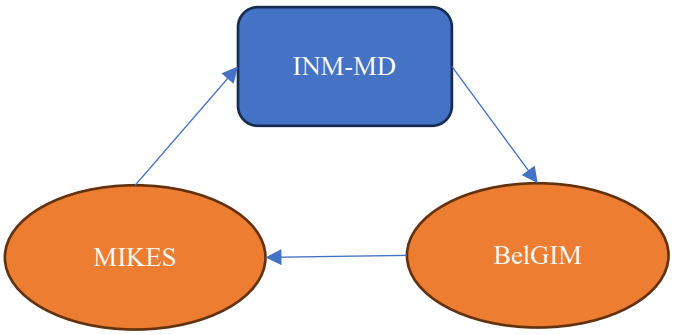

Figure 1. Scheme of the comparison

The time schedule for the comparison is given in Table 2. The circulation of the travelling standard was organized to monitor the performance of the travelling standard. Each laboratory had two weeks to carry out the measurements. The circulation of the travelling standards started in March 2021 and was completed in September 2021.

Table 2. The time schedule for the comparison

Participant	Country	Measurements Dates	
		from	to
INM-MD (Initial)	Republic of Moldova	15 March 2021	25 March 2021
BelGIM	Belarus	14 April 2021	27 April 2021
MIKES	Finland	10 June 2021	28 June 2021
INM-MD (Final)	Republic of Moldova	6 September 2021	17 September 2021

The performance of the travelling standard was monitored and analyzed at INM-MD from the measurements made at the beginning and the end of the circulation scheme.

3 Travelling Standard and Measurement Instructions

3.1 Description of the travelling standard

The travelling standard used was supplied by BelGIM. The photos and the general specifications are presented in Figure 2 and Table 3 respectively.

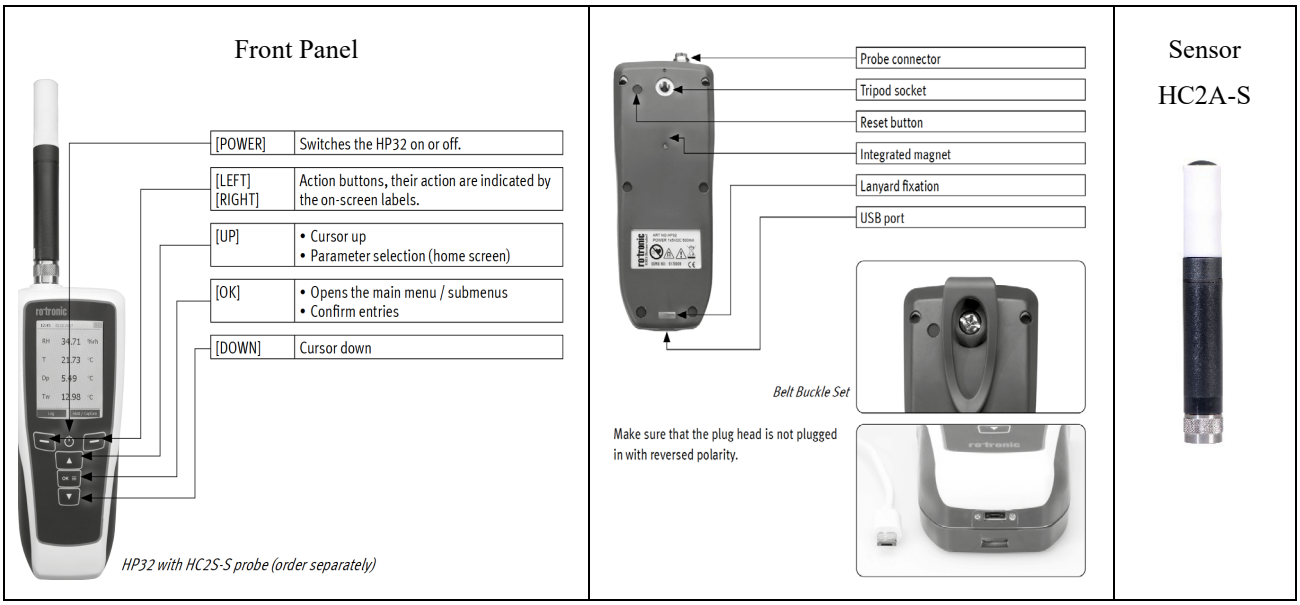

Figure 2. Travelling standard

Table 3. The general specifications of the transfer standard

Model:	**HP32-SET**
Measuring probe type:	HC2A-S
Manufacturer:	Rotronic AG
Owner	BelGIM
RH range:	0 %rh to 100 %rh
Temperature range:	-50 °C to 100 °C
Display operating temp:	-10 °C to 60 °C
Display resolution:	0.01 °C and %rh
Probe dimensions:	Φ11,6 mm x 7.84 mm
Probe cable length:	2.1 m
Electrical supply:	Battery, Lithium Polymer, 3.7 V, 1000 mAh

The instrument has relative humidity and temperature measurement ranges from 0 %rh to 100 %rh and -50 ºC to 100 ºC, respectively. For both quantities, the measurements were displayed with resolution of 0.01. Optionally, a software and USB connection cables were available with the instrument for transferring logged data and real time measurement data from the indicator to a personal computer.

3.2 Measurement Instructions

The measurement instructions, describing the operations to be performed on the travelling standard were given in the Technical Protocol given in Appendix A.

This supplementary comparison covers relative humidity values within the range from 10 %rh to 90 %rh at the temperatures of 23 °C, at 10 °C and 50 °C. The participating laboratories followed the technical protocol agreed between the participants before the start of the comparison, completing the calibration points in ascending order of relative humidity value. The following calibration points were defined: 10 %rh, 25 %rh, 50 %rh, 75 %rh and 90 %rh °C at 23 °C, 10 °C and 50 °C. Each laboratory was used its own normal set-up and processes.

The comparison was made by calibration of a travelling standard hygrometer, supplied by the BelGIM, the details of which are given in Table 3. The travelling standard was used to measure relative humidity of a sample of moist air produced by each participant's relative humidity standard.

An initial calibration of the hygrometer was performed by the pilot laboratory INM-MD before it was sent to BelGIM and MIKES. Upon completion of the MIKES calibration the travelling standard was returned to INM-MD to carry out a final calibration in order to check for instrument drift over the period of the comparison.

The measurements were performed according to participants' measurement procedure. It was agreed in the protocol that a set of ten measurements should be obtained for each comparison point. It was also agreed that the results of the measurements should be presented with the respective uncertainties assessed according to their internal procedures GUM [3].

3.3 Equipment used

The description of measuring instruments used in this comparison are given in Table 4.

Table 4. Parameters of equipments used

Laboratory		**INM**	**MIKES**	**BelGIM**
Humidity Generator / Climatic chamber	Manufacturer	Thunder Scientific	Heraeus-Industrietechnik GmbH	HygroGen
	Type	2500 ST	HC4020	2-XL
	Number	1206901	7064575	VCT-HG2-3027
Chilled Mirror Hygrometer	Manufacturer	MBW	MBW	MBW
	Type	373H	373LHX	473DPM
	Number	12-0406	08-1207	18-0912
	Traceability	CMI	MIKES	NPL
Thermometer	Manufacturer	Hart Scientific	Hart Scientific	MBW
	Type	CHUB-E4	CHUB-E4	SH2
	Number	A61077	A27255	3630
	Traceability	INM-MD	MIKES	NPL

Participants respected the prescribed sequence of temperature / RH set points to perform a rising series, to avoid possible hysteresis effects. The values of RH and temperature applied to the travelling standards were within ± 2.0 %rh and ± 2.0 °C, respectively, of the agreed nominal values for the comparison, and generally closer than this.

4 Drift of the transfer standard

The transfer standard was calibrated at INM-MD two times along the interlaboratory comparison, according to the dates described in Table 3. In all of them, the same calibration procedure, reference standards and equipment were used. The first comparison measurement was made at INM-MD in March 2021. Afterwards, the transfer standard hygrometer was sent to the participants (Table 3) so that to perform its comparison measurements. The hygrometer was returned to INM-MD and the second set of INM-MD comparison measurements was performed in September 2021. The results from the initial and final measurement are presented in Table 5.

Table 5. Drifts of the transfer standards

Nominal value		**Difference ($RH_{measured}$ - $RH_{applied}$), %rh**		**Drift, %rh**
Temperature	**Measurement Point, %rh**	**Initial measurement**	**Final measurement**	
23 °C	10	-0.29	-0.20	0.09
	25	-0.54	-0.49	0.05
	50	-0.72	-0.44	0.28
	75	-0.88	-0.80	0.08
	90	-0.85	-0.88	0.03
10 °C	10	-0.71	-0.45	0.26
	25	-0.90	-0.83	0.07
	50	-0.63	-0.72	0.09
	75	-0.41	-0.71	0.30
	90	-0.76	-1.01	0.25
50 °C	10	0.84	0.37	0.47
	25	0.51	0.21	0.30
	50	0.09	-0.15	0.24
	75	0.02	0.24	0.22
	90	-0.25	-0.68	0.43

The drift of the transfer standard was estimated for each comparison point as the difference between the comparisons performed in March 2021 and September 2021, by the pilot laboratory (INM-MD). This difference is shown in Figure 3.

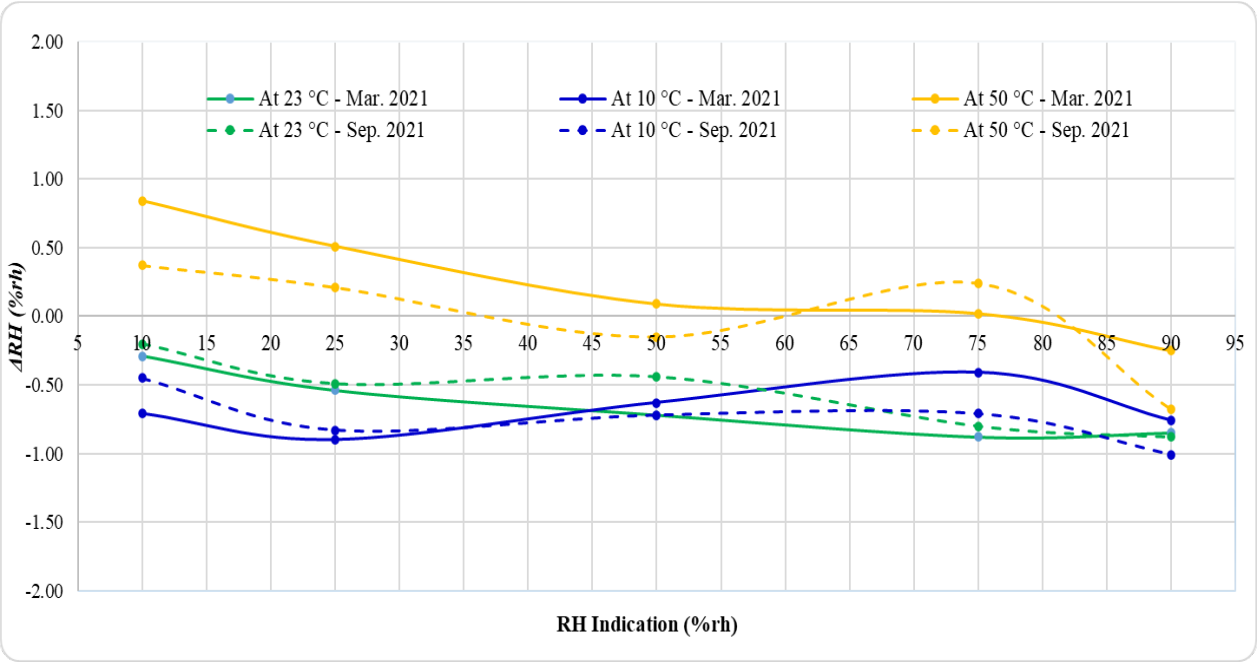

Figure 3. Calibration curves for transfer standard

For transfer standard, the absolute differences between the deviation of two successive measurements varied from 0.03 to 0.47. The observed deviation values from the mean value were in any case less than to the technical specification of the manufacturer, where the typical long-term stability, in relative humidity, for the probe HP32-SET, is better than 1,0 %rh/year. It can be concluded that the stability of the standards are considered to be satisfactory. Based on the low drifts, no additional correction factors were added to the participant's results in the process of obtaining the reference values. Instrument drift does not contribute uncertainty to the individual laboratory results, but needs to be taken into account in the assignment of CRV and in the calculations of equivalence. Therefore, a type B standard uncertainty component, due to the possibility of drift of the transfer standard, was added in the uncertainty budget, according to Equation (2) below.

$$u_{drift} = \frac{\Delta RH_1 - \Delta RH_2}{\sqrt{3}} \quad (1)$$

ΔRH_1 - results of initial measurement in the pilot laboratory;

ΔRH_2 - results of final measurement in the pilot laboratory;

5 Results of the Participating Institutes

The participants submitted the measurement results for transfer standard with the respective expanded uncertainties evaluated according to their internal calibration procedures and the GUM [3].

The measurement results of the participating institutes (x_i) and their expanded uncertainties ($U(x_i)$) are presented for each point in Table 6 to Table 8. Figures 4 to 6 show the results reported for each participant, together with their expanded uncertainties for a coverage factor k = 2, measured at 23 °C,

10 °C and 50 °C, grouped by relative humidity value (data points staggered in *x*-direction for visibility). Error bars show participant reported uncertainties (k = 2).

Table 6. Results of the participating institutes at 23 °C

Participating Institute	Measurement Point	Difference (DUT - ref. RH)	Expanded uncertainty
	%rh	%rh	%rh
INM-MD	10	-0.29	0.27
	25	-0.54	0.47
	50	-0.72	0.89
	75	-0.88	1.29
	90	-0.85	1.53
BELGIM	10	-0.35	0.30
	25	-0.48	0.36
	50	-0.63	0.48
	75	-0.64	0.63
	90	-0.70	0.79
MIKES	10	-0.61	0.41
	25	-0.74	0.64
	50	-0.65	0.91
	75	-0.80	1.20
	90	-1.10	1.40

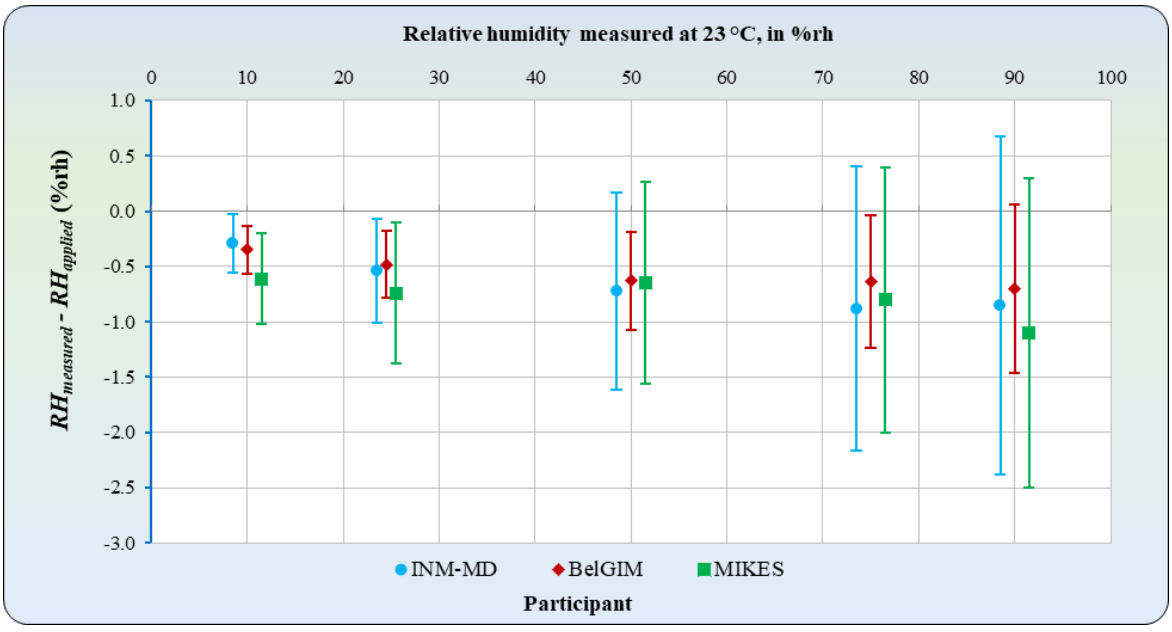

Figure 4. Results together with their expanded uncertainty (k = 2), measured at 23 °C (data points staggered in *x*-direction for visibility)

Table 7. Results of the participating institutes at 10 °C

Participating Institute	Measurement Point	Difference (DUT - ref. RH)	Expanded uncertainty
	%rh	%rh	%rh
INM-MD	10	-0.71	0.27
	25	-0.90	0.55
	50	-0.63	1.02
	75	-0.41	1.54
	90	-0.76	1.69
BELGIM	10	-0.91	0.30
	25	-1.32	0.36
	50	-1.41	0.48
	75	-1.28	0.63
	90	-1.50	0.79
MIKES	10	-0.86	0.40
	25	-1.27	0.60
	50	-1.43	0.91
	75	-1.30	1.20
	90	-1.40	1.40

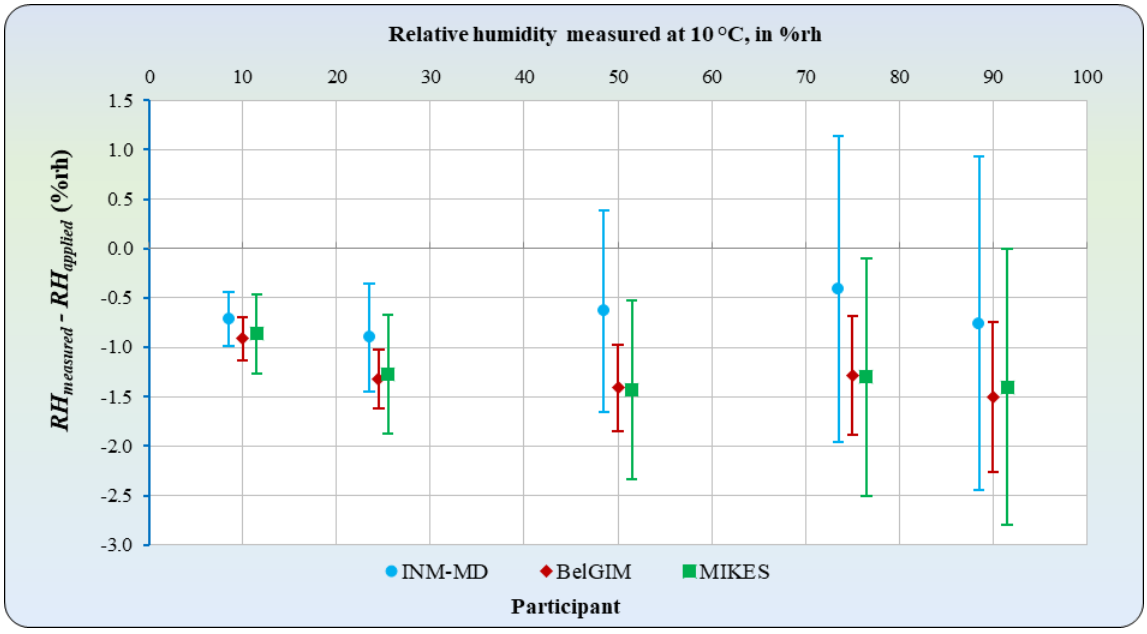

Figure 5. Results together with their expanded uncertainty (k = 2), measured at 10 °C (data points staggered in *x*-direction for visibility)

Table 8. Results of the participating institutes at 50 °C

Participating Institute	Measurement Point	Difference (DUT - ref. RH)	Expanded uncertainty
	%rh	%rh	%rh
INM-MD	10	0.84	0.26
	25	0.51	0.43
	50	0.09	0.73
	75	0.02	1.08
	90	-0.25	1.31
BELGIM	10	0.68	0.30
	25	0.61	0.36
	50	0.34	0.48
	75	0.71	0.63
	90	0.31	0.79
MIKES	10	0.43	0.39
	25	0.38	0.59
	50	0.28	0.92
	75	0.60	1.30
	90	-0.10	1.50

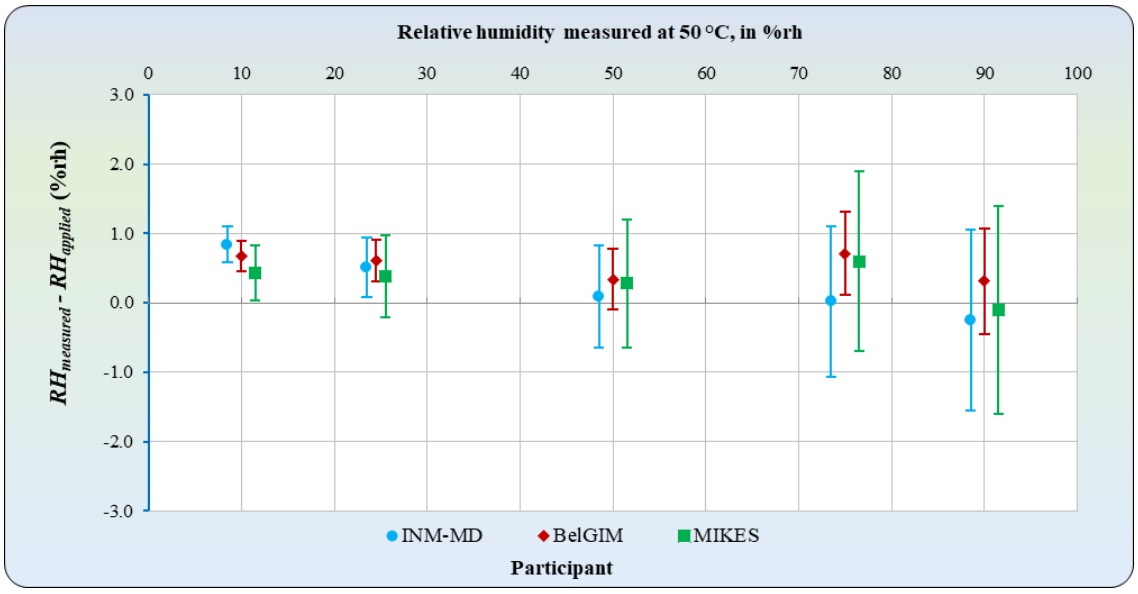

Figure 6. Results together with their expanded uncertainty (k = 2), measured at 50 °C (data points staggered in *x*-direction for visibility)

Participant data were reported for all humidity measurement points, separately reproduced at each of the four temperatures values. However just the first complete set of measurements at 23 °C was considered for the comparison was used. The detailed results by the participants are given in the comparison reports of the participants in Appendix B.

All participants provided their results together with the associated uncertainty budgets, estimated according to [3]. Uncertainty budgets for each participant are provided in Appendix C.

6 Analysis of comparison results

Analysis of comparison results were performed following the guidelines presented in [4]. The measurement results of each participating institute were compared to the Comparisons Reference Value, obtained according to [4].

6.1 The establishment of the Comparison Reference Value

The pilot laboratory on the basis of measurement results was calculated the Supplementary Comparisons Reference Value (CRV) – the traveling standard value assessment and corresponding uncertainty. The CRV was calculated separately for each measurement point and is considered as an estimation of the measurand according to the measurements provided by the participating laboratories. This estimation, x_{CRV}, was determined as a weighted mean of the provided results where the weights are the inverse values of the squares of the associated standard uncertainties.

$$x_{CRV} = \sum_{i=1}^{n} \frac{x_i}{u(x_i)^2} \Big/ \sum_{i=1}^{n} \frac{1}{u(x_i)^2} \tag{2}$$

where: x_i – results reported by the participants i of the supplementary comparison;

$u(x_i)$ – standard uncertainties ($k = 1$) reported by the participants i of the comparison;

n – the number of the participants of comparison;

x_{CRV} – the reference value of the supplementary comparisons.

The weights are computed from the standard uncertainties of individual measurements:

$$u\left(x_{ref}\right)^2 = 1 \Big/ \sum_{i=1}^{n} \frac{1}{u(x_i)^2} \tag{3}$$

The standard uncertainty of CRV, $u(x_{CRV})$, associated with the weighted mean was calculated as:

$$u(x_{CRV}) = \sqrt{u\left(x_{ref}\right)^2 + u\left(x_{drift}\right)^2} \tag{4}$$

where: $u(x_{CRV})$ – standard uncertainties of the reference value of the supplementary comparison;

$u(x_{drift})$ – is uncertainty value due to the drift of the comparison device.

As well as the uncertainty in weighted mean due to dispersion, calculating the comparison measurement uncertainties, the uncertainty values of the comparison device (obtained from the drift of the hygrometer during the comparison) given in Table 9 were taken into account (See Equation 4).

The expanded uncertainty of the Comparison Reference Values, $U(x_{CRV})$, was calculated by:

$$U(x_{CRV}) = 2 \cdot u(x_{CRV}) \tag{5}$$

The Comparison Reference Values (x_{CRV}), their corresponding standard uncertainties $u(x_{CRV})$ and expanded uncertainties $U(x_{CRV})$ are presented in Table 9 for each measurement point.

Table 9. Comparison Reference Values and corresponding uncertainties

Nominal value		x_{CRV}	$u(x_{ref})$	$u(x_{drift})$	$u(x_{CRV})$	$U(x_{CRV})$
Temperature	**Measurement Point**					
°C	**%rh**	**%rh**	**%rh**	**%rh**	**%rh**	**%rh**
23	10	-0.37	0.09	0.05	0.10	0.21
	25	-0.54	0.13	0.03	0.13	0.27
	50	-0.65	0.19	0.16	0.25	0.50
	75	-0.71	0.26	0.05	0.26	0.52
	90	-0.81	0.31	0.02	0.31	0.63
10	10	-0.81	0.09	0.15	0.17	0.35
	25	-1.21	0.13	0.04	0.14	0.28
	50	-1.30	0.20	0.05	0.20	0.41
	75	-1.18	0.26	0.17	0.31	0.63
	90	-1.37	0.32	0.14	0.35	0.70
50	10	0.70	0.09	0.27	0.29	0.57
	25	0.53	0.13	0.17	0.21	0.43
	50	0.27	0.18	0.14	0.23	0.46
	75	0.54	0.25	0.13	0.28	0.56
	90	0.12	0.31	0.25	0.40	0.79

6.2 Checking the comparisons data consistency

A χ^2 test is applied to carry out an overall consistency check of the results obtained (i.e., if all results can be regarded as belonging to the same statistical ensemble). For each measured point, the observed chi-squared value χ^2_{obs} was determined as:

$$\chi^2 = \sum_{i=1}^{n} \frac{(x_i - x_{CRV})^2}{u(x_i)^2} \tag{6}$$

where the degrees of freedom is: $v = n - 1$, for n results.

The consistency check is considered not fail if:

$$Pr\{\chi^2(v) > \chi^2_{obs}\} \geq 0.05 \tag{7}$$

where Pr denotes "probability of" and $\chi^2(v)$ is the inverse of the chi-square cumulative distribution function with degree of freedom specified by v for the probability of 0.05 (corresponding to the 95% level of confidence).

If the χ^2 consistency check fails, the institute with the highest value of χ^2_{obs} is excluded from the evaluation and a new reference value, reference standard uncertainty, and chi-squared values are calculated again without the excluded laboratory. If multiple outliers have been identified outliers are removed one-by-one with the largest normalized error (E_n) first.

For results included in weighted mean:

$$E_n = \frac{x_i - x_{CRV}}{2 \cdot \sqrt{u(x_i)^2 - u(x_{CRV})^2}} \quad (8)$$

For results excluded from weighted mean:

$$E_n = \frac{x_i - x_{CRV}}{2 \cdot \sqrt{u(x_i)^2 + u(x_{CRV})^2}} \quad (9)$$

The weighted mean is re-calculated until the consistency check does not fail. The criterion value, calculated in accordance with the data provided by NMIs, doesn't exceed the critical value χ^2, overage level 0.95 and the degrees of freedom $v = n - 1$:

$$\chi^2 < \chi^2_{0.95}(n - 1) \quad (10)$$

If the consistency check did not fail, then x_{CRV} was accepted comparison reference value and $U(x_{CRV})$ was accepted as the expanded uncertainty.

Therefore the data provided by different NMIs can be acknowledged as consistent, that is the objective confirmation of the announced uncertainties.

6.3 Degrees of Equivalence

There is at present no key comparison reference value (KCRV) for the humidity quantity of relative humidity and so the comparison reported can only demonstrate equivalence between the facilities of the participating institutes.

The results of the comparison are reported as the degree of equivalence (DoE), between the participant's result and the Comparison Reference Values (x_{CRV}). The degree of equivalence of each participant (D_i), was calculated according to Equation 11.

$$D_i = x_i - x_{CRV} \quad (11)$$

Where: x_{CRV} – is the CRV of the Supplementary Comparisons;

x_i – is the result of the participants.

The expanded uncertainty of the degree of equivalence for a participant's result $U(D_i)$ was calculated using Equation 12.

$$U(D_i) = 2 \cdot \sqrt{u(x_i)^2 - u(x_{CRV})^2} \quad (12)$$

Where: $u(x_i)$ – is the standard uncertainty of the result of the participant;

$u(x_{CRV})$ – is the standard uncertainty of the CRV.

The degrees of equivalence of the participants for each comparison point are presented in Table 10 to Table 12 and Figure 7 to Figure 9 where the limit lines demonstrate the calculated $U(D_i)$ at each relative humidity point.

Values of D_i are presented in Tables 10 and 12 below, using only the initial set of measurements conducted at INM-MD. The final set of INM-MD measurements was used only for estimating drift.

Table 10. The degrees of equivalence, D_i and its uncertainties $U(D_i)$ measured at 23 °C

Participating Institute	Measurement Point	D_i	$U(D_i)$
	%rh	%rh	%rh
INM-MD	10	0.08	0.34
	25	0.00	0.54
	50	-0.07	1.02
	75	-0.17	1.39
	90	-0.04	1.65
BELGIM	10	0.02	0.36
	25	0.06	0.45
	50	0.02	0.69
	75	0.07	0.82
	90	0.11	1.01
MIKES	10	-0.24	0.46
	25	-0.20	0.69
	50	0.00	1.04
	75	-0.09	1.31
	90	-0.29	1.53

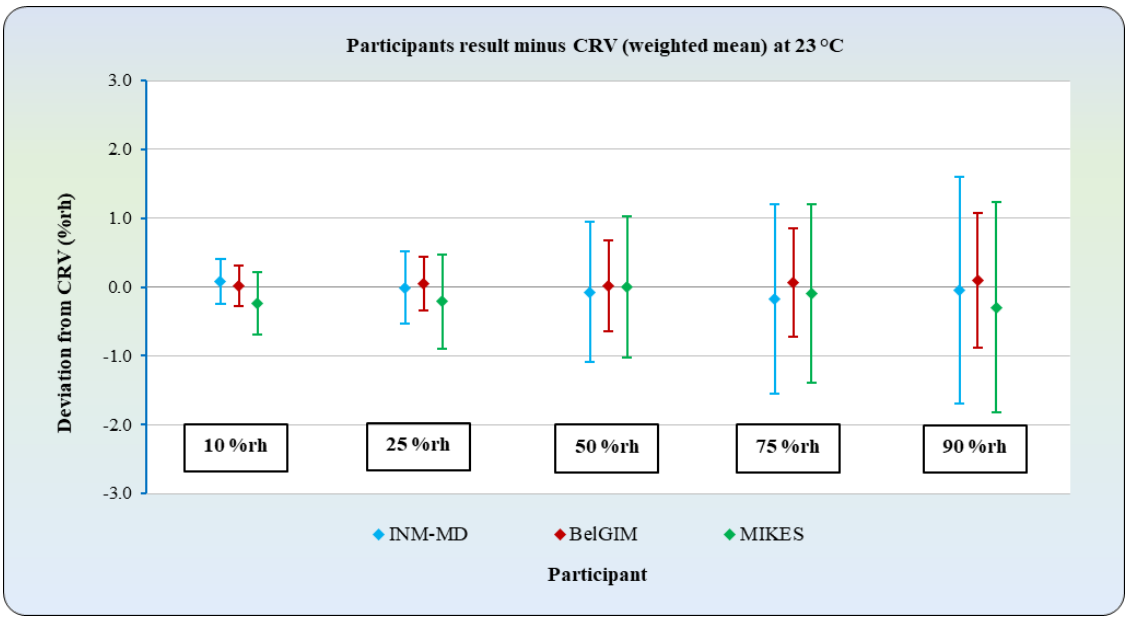

Figure 7. The degrees of equivalence, D_i and its uncertainties $U(D_i)$, measured at 23 °C

Table 11. The degrees of equivalence, D_i and its uncertainties $U(D_i)$ for 10 °C

Participating Institute	Measurement Point	D_i	$U(D_i)$
	%rh	%rh	%rh
INM-MD	10	0.10	0.44
	25	0.31	0.61
	50	0.67	1.10
	75	0.77	1.67
	90	0.61	1.83
BELGIM	10	-0.10	0.46
	25	-0.11	0.46
	50	-0.11	0.63
	75	-0.10	0.89
	90	-0.13	1.06
MIKES	10	-0.05	0.53
	25	-0.06	0.66
	50	-0.13	1.00
	75	-0.12	1.35
	90	-0.03	1.57

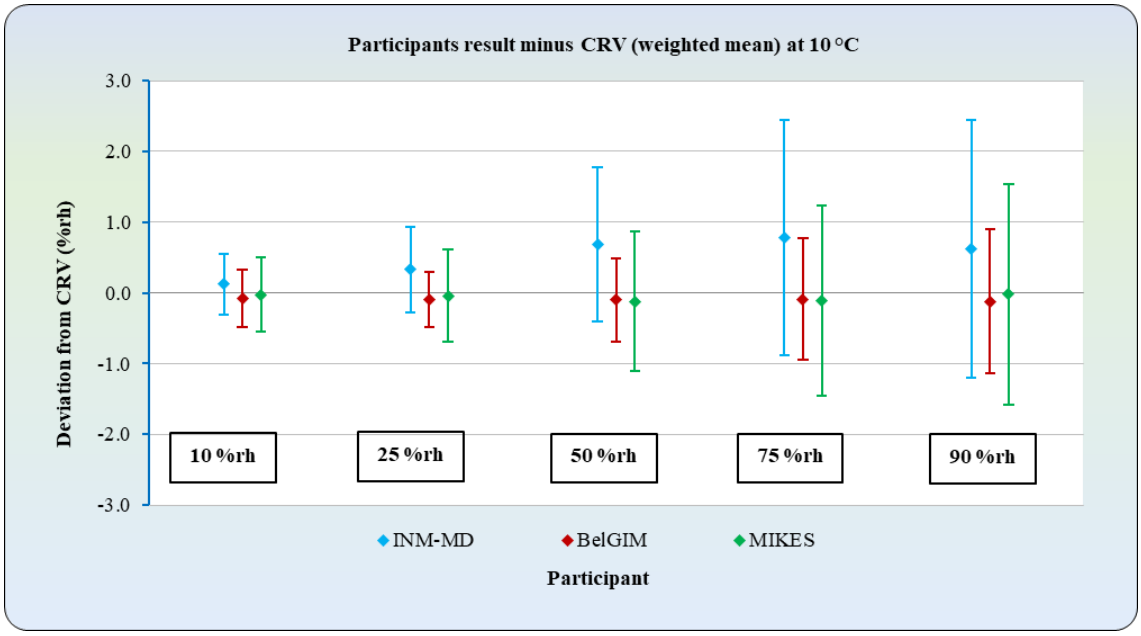

Figure 8. The degrees of equivalence, D_i and its uncertainties $U(D_i)$, measured at 10 °C

Table 12. The degrees of equivalence, D_i and its uncertainties $U(D_i)$ for 50 °C

Participating Institute	Measurement Point	D_i	$U(D_i)$
	%rh	%rh	%rh
INM-MD	10	0.14	0.63
	25	-0.02	0.61
	50	-0.18	0.87
	75	-0.52	1.22
	90	-0.37	1.53
BELGIM	10	-0.02	0.64
	25	0.08	0.56
	50	0.07	0.67
	75	0.17	0.84
	90	0.19	1.12
MIKES	10	-0.27	0.69
	25	-0.15	0.73
	50	0.01	1.03
	75	0.06	1.42
	90	-0.22	1.70

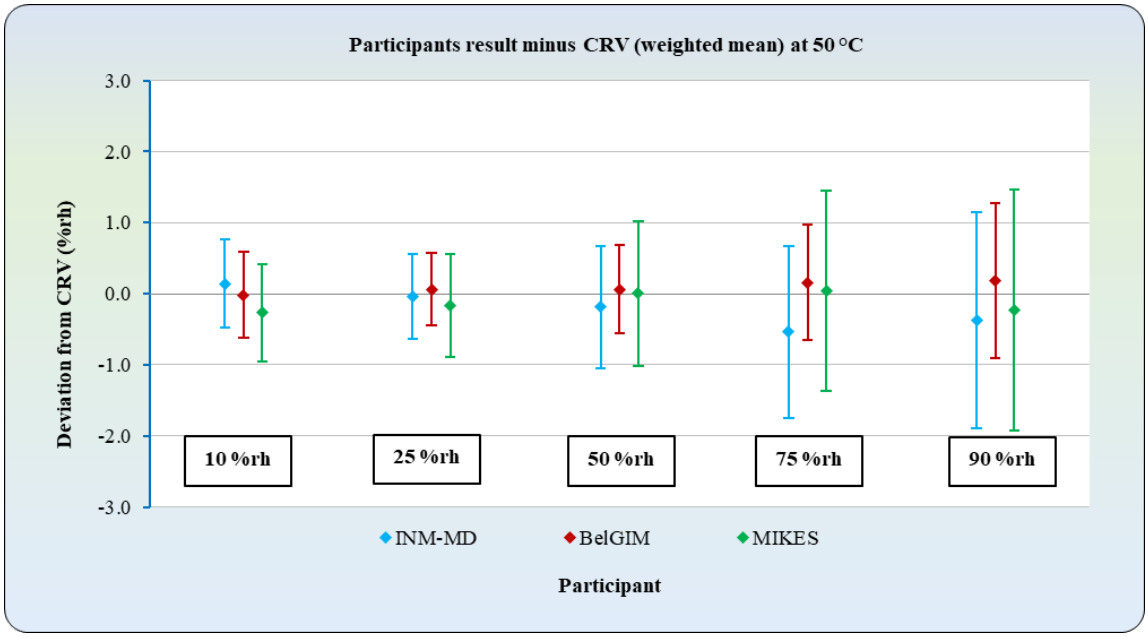

Figure 9. The degrees of equivalence, D_i and its uncertainties $U(D_i)$, measured at 50 °C

7 Conclusions

COOMET.T-S5 (COOMET project № 826/MD/21) comparison which aimed at evaluating the deviation from CRV of measurements of the standards for the relative humidity unit was conducted with 3 participants. The interlaboratory comparison of humidity standards was performed in five comparison points in the relative humidity range from 10 %rh to 90 %rh at 10 ºC, 23 ºC and 50 ºC. The comparison, carried out from March 2021 to September 2021, was coordinated by INM-MD. As transfer standard, a thermo-hygrometer with capacitive humidity sensors was used, and their drifts were estimated by means of the two calibrations of the instruments performed at INM-MD.

The CRV was determined by using the weighted mean of the measurement results of the participants. For the comparison results, all of the results supplied by the participants show good agreement with the CRV within the expanded uncertainty. The performance of the measurement results of each NMI with those of the CRV was analysed by means of the by the degree of equivalence. The thermo-hygrometer have shown an acceptable behavior throughout the comparison as Table 5 and Figure 3 show then, the results can be considered valid for comparing the measurement capabilities of the participant laboratories.

Following this comparison, equivalence between the participating laboratories was demonstrated for calibrating the relative humidity sensor in the range from 10% rh to 90% rh for relative humidity values, at temperature values from 10°C to 50°C.

8 References

[1] CIPM MRA-G-11 Measurement comparisons in the CIPM MRA. Guidelines for organizing, participating and reporting

[2] EURAMET Guide on Comparisons, EURAMET Guide No. 4, V1.1 (12/2016)

[3] JCGM 100:2008 Evaluation of measurement data – Guide to the expression of uncertainty in measurement, September 2008

[4] Recommendation COOMET R/GM/19:2016, Guideline on COOMET supplementary comparison evaluation, April 2016

[5] Guideline DKD-R 5-8 Calibration of hygrometers for the direct measurement of relative humidity, Edition 10/2019

Appendix A. Technical Protocol

COOMET project № 826/MD/21
Supplementary comparison

KCDB BIPM COOMET.T-S2

Supplementary comparisons of standards for the relative humidity unit

TECHNICAL PROTOCOL

National Institute of Metrology (INM-MD)
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Constantin Bordianu (coordinator)

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2021

1. Introduction

It is planned to organize a comparison on relative humidity realization in the Euro-Asian Cooperation of National Metrological Institutions (COOMET). The protocol is agreed by all participants.

The comparison will be performed by measuring a thermo-hygrometer - transfer standard instrument within the range from 10 %rh to 90 %rh relative humidity values at 23 °C, 50 °C, 10 °C and 23 °C air temperature values. The measurand for the comparison is relative humidity (RH).

INM-MD will be the pilot institute of this comparison. The travelling standard will be provided by participant laboratory. INM-MD will be responsible for monitoring the performance of the standard during the circulation and the evaluation and reporting of the comparison results.

The purpose of comparison is to demonstrate degree of equivalence and to support CMCs.

The comparison will be carried out in accordance with the "Measurement Comparisons in the CIPM MRA" and "EURAMET Guide on Comparisons". [1, 2].

2. Travelling Standard

The travelling standard, Rotronic HP32-SET model thermo-hygrometer (shown in Figure 1), has identification as follows:

Manufacturer: ROTRONIC AG, Swiss Model: HP32-SET Serial No: 5181786

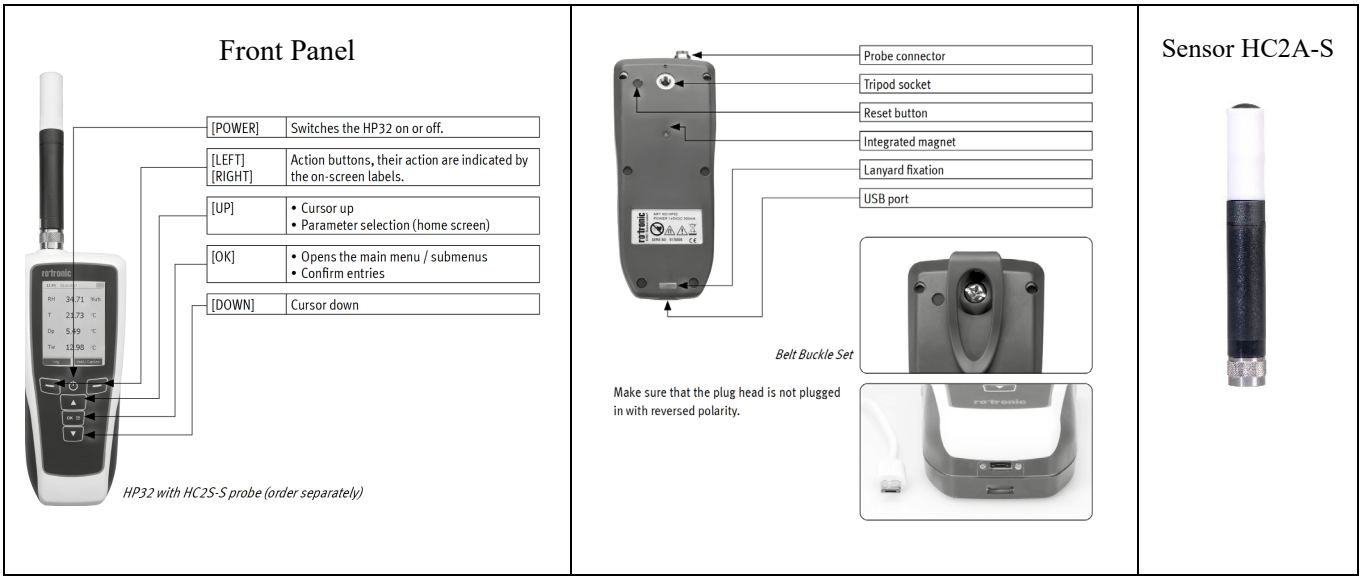

Figure 1. Travelling standard is a Rotronic HP32-SET Thermo-Hygrometer

The Rotronic HP32-SET thermo-hygrometer transfer standard instrument, henceforth denoted by the standard, has relative humidity range from 0 %rh to 100 %rh, and air temperature range from (-10) °C to

60 °C. Within the comparison, only the relative humidity values within the range from 10%rh to 90 %rh at 23 °C, 50 °C, 10 °C, and 23 °C air temperature values will be measured.

The travelling standard will be supplied by National Metrology Institute of Belarus. The general specifications of the transfer standard are given in Table 1.

Table 1. The general specifications of Rotronic HP32-SET Thermo-Hygrometer [1]

Model:	HP32-SET
Manufacturer:	ROTRONIC AG, Swiss
Owner:	National Metrology Institute of Belarus
Probe cable length:	2,1 m
Probe dimensions:	Φ11,6 mm x 78,84 mm
RH range:	0 %rh to 100 %rh
Temperature range (HC2A-S):	-50 °C to 100 °C
Display operating temperature:	-10 °C to 60 °C
Electrical supply:	Battery, Lithium Polymer, 3,7V, 1000 mAh
Accessories:	USB cable
Communication Interface:	Display, Micro USB, Logging software
Serial no.	5181786
Weight of the display together with sensor:	Appr. 2.0 kg
Insurance value:	2.000 EUR

3. Measurement Process

Participants should refer to the operating manuals for instructions and precautions for using the travelling standard. Participant may perform any initial checks of the operation of the thermo-hygrometer that would be performed for a normal calibration. In the case of an unexpected instrument failure at a participant institute, the pilot shall be informed as early as possible.

4. Operation of the travelling standard

Before any humidity measurements, follow the special instructions for using the Rotronic HP32-SET:

1) Read the operating instructions delivered by the manufacturer (a copy of the instructions is in the transport case or can be downloaded from the web page).
2) **Important**: The transfer standard use INM's default settings, which **MUST NOT be modified or adjusted** other than described in this document.
3) Measurements of RH, temperature and calculated dew-point can be read from the display with resolution of 0.01 %rh and 0.01 °C, respectively.

5. Data collection

RH readings used primarily in this comparison shall be obtained from the display and/or through the software.

Each measured value (incl. its experimental standard uncertainty) is obtained calculating the mean and standard deviation of at least 10 readings of the RH recorded during 10 to 20 minutes.

As a supporting measurement, the display readings and software readings of the temperature and (internally calculated) dew/frost point temperature in the travelling standard should be monitored. The mean and standard deviation of a set of at least 10 readings, taken over the same period as the RH measurements should be reported.

Values reported for RH produced or measured by a participant's standard should be the value applied to the instruments, after any allowances for pressure and temperature differences between the point of realization (laboratory standard generator or reference hygrometer) and the point of use (travelling standard).

6. Precautions and Additional Information

Participants should avoid lengthy additional measurements, except those necessary to give confidence in the results of this comparison.

The travelling standard used in this comparison must not be modified, adjusted or used for any purpose other than described in this document, nor given to any party.

The pilot will make an assessment of any drift in the travelling standard during the comparison, based on measurements at the pilot laboratory at the beginning and end of the comparison period. If drift is found, this will be taken into account in the final analysis of the comparison results.

7. Participant Laboratories

The pilot institute for this comparison is INM-MD (Moldova). The contact details of the coordinator are given below:

Pilot Institute	:	National Institute of Metrology (INM-MD)
Coordinator	:	Constantin BORDIANU Tel: (+373) 22 903 103 Fax: (+373) 22 903 111 E-mail: bordianuc@inm.gov.md

The participating institutes and contact persons with their addresses are given in Table 1.

Table 1. Participants

Country	Institute	Acronym	Shipping Address	Contact Person
Republic of Moldova	National Institute of Metrology	INM	Chisinau, MD2064 28, Eugen Coca Str.	Mr. Constantin BORDIANU bordianuc@inm.gov.md Tel: (+373) 22 903 103
Finland	VTT Technical Research Centre of Finland Ltd, Centre for Metrology MIKES	MIKES	Tekniikantie 1 02150 Espoo	Richard HÖGSTRÖM richard.hogstrom@vtt.fi Tel: (+358) 503 039 341
Belarus	National Metrology Institute of Belarus	BelGIM	93, Starovilensky trakt, Minsk, 220053	Alina DAVIDOVSCHAIA info@belgim.by davidov@belgim.by Tel: +(375) 17 334 820

By their declared intention to participate in this supplementary comparison, the laboratories accept the general instructions and the technical protocol written down in this document and commit themselves to follow strictly the procedures of this protocol as well as the version of the "Measurement Comparisons in the CIPM MRA", and "EURAMET Guide on Comparisons" in effect at the time of the initiation of the Supplementary Comparison. [1, 2]

Once the protocol and list of participants have been approved, no change to the protocol or list of participants may be made without prior agreement of all participants.

If for some reason, the measurement facility is not ready or customs clearance takes too much time in a country, the participating laboratory must contact the Pilot laboratory immediately. Exclusion of a participant's results from the report may occur if the results are not available in time to prepare the draft report.

8. Time Schedule

The time schedule for the comparison is given in the Appendix 3.

The performance of the travelling standard was monitored and analyzed at INM-MD from the measurements made at the beginning and end of the circulation scheme as given in Appendix 3.

Any deviation in the agreed plan should be approved by the pilot institute.

9. Transport Case

The travelling standard is packed in a transport case of size (40 x 40 x 32) cm and a total weight of 2 kg. The transport case can easily be opened for customs inspection.

The content of the transport case is given below:

1. Rotronic HP32-SET Transfer Standard Thermo-Hygrometer (Serial No: 5181786)
2. Rotronic HC2A-S Transfer Standard Thermo-Hygrometer Sensor (Serial No: 0000000018)
3. PC connection cable

4. Power cord
5. Software

10. Transportation of Travelling Standard

Each participant is responsible for the transportation of the travelling standard to the next participant.

After arrival in the participant's laboratory, the standard should be allowed to stabilize in a temperature and humidity-controlled environment for at least one day before use.

Each institute will have 60 days available. This includes the measurements and the transportation of the standard to the next participant.

11. Failure of Travelling Standard

In case of any damage or malfunction of the travelling standard, the Pilot institute (INM-MD) should be informed as soon as possible. The comparison will be carried out after the travelling standard is repaired, and additional check measurements carried out by the Pilot institute.

12. Financial aspects

Each participant institute is responsible for the cost of shipping to the next participant including any customs charges (or will be made on financial basis according to offer. Costs for transportation, customs and insurance will be included in the price).

Each participant institute is also responsible for its own costs for the measurements as well as any damage that may occur within its country.

Transportation and insurance are each laboratory's responsibility and cost. Each participating laboratory covers the costs for its own measurements, transportation and any customs charges. Each laboratory is responsible for any damage of the artefact from the point of receipt at their site until the artefact is signed for on receipt at the next laboratory. The insurance value of the artefact is 2.000 EUR. The overall costs for the organization, initial and interim measurements and the processing of results are covered by the pilot laboratory however any damage to or loss of either artefact must be paid for by the responsible participant. By their confirmation of participation, each laboratory agrees to be bound by these requirements.

13. Measurement Quantities and Points

Main quantity which must be measured is as follows:

- Relative humidity

The quantities to be measured and the measurement points are given in Table 3.

Each laboratory will be using its own normal set-up and processes.

Each participant should use their own stabilization times that they would normally use.

Table 3. Measurement quantities and points

Quantity	Measurement Points	
Relative humidity and air temperature	At 23 °C	10 %rh → 25 %rh → 50 %rh → 75 %rh → 90 %rh
	At 10 °C	10 %rh → 25 %rh → 50 %rh → 75 %rh → 90 %rh
	At 50 °C	10 %rh → 25 %rh → 50 %rh → 75 %rh → 90 %rh
	At 23 °C	10 %rh → 25 %rh → 50 %rh → 75 %rh → 90 %rh

Explanation of the RH set point underlined with dotted line:

For the measurements carried out using travelling standard, the first RH set point for each temperature sequence (underlined by dotted line) shall be maintained at least 1 hour and no longer than 5 hours before taking the measurements, must be applied.

If the prescribed sequence of set points would inevitably need to be stopped for more than 4 hours (overnight…), it is suggested to first end a RH sequence at current temperature level and then leave the sensor at ambient conditions (23 °C ± 3 °C and 50 %rh ± 20 %rh) in order to avoid a potential drift due to storage, i.e. drift due to dwell at extreme conditions. If even the RH sequence cannot be properly finished, then you should maintain the sensor at approximately 50 %rh at current temperature. The latter case is however **discouraged** to use.

If the scope/capability of a laboratory does not cover the whole range of this comparison, the laboratory is allowed to limit measurement values according to their capability. In this case, the Pilot institute (INM-MD) should be informed by the participant laboratory.

Laboratory records which must be measured are given below:

- Applied dew-point temperature values (measured by a dew-point hygrometer, or determined with some other method)
- If the reference instrument is a dew point hygrometer, the 2nd mirror PRT resistance at the dew-point temperature (if available)
- Resistance of the probe measuring the air temperature (if available)
- Ambient Pressure
- Head Pressure (measured from dew-point hygrometer, if applicable)

- Flow rate (measured from dew-point hygrometer, if applicable)
- Ambient temperature
- Ambient humidity

14. Calculation of the Comparison Reference Value

The Comparison Reference Value (CRV) for each measurement point x_{CRV} will be calculated using the weighted mean from the participating labs.

The pilot laboratory will make an assessment of any drift in the travelling standards during the comparison. The assessment will be based on initial and final measurements done by the pilot laboratory. If drift is found, this will be taken into account in the final analysis of the comparison results as an additional term u_{drift} in the uncertainty budget.

15. Measurement Instructions

Precautions and Initial Actions Prior to Comparison Measurements

- The values of RH and temperature applied to the travelling standards should be within ± 2 %rh and ± 2 °C, respectively, of the agreed nominal values for the comparison, and ideally closer than this. Deviations greater than this may increase the uncertainty in the comparison, for a particular result.
- Read the operating instructions delivered by the manufacturer (a copy of the instructions is in the transport case or can be downloaded from the web page).
- **Important**: The transfer standard use INM's default settings, which **MUST NOT be modified or adjusted** other than described in this document.
- Measurements of RH, temperature and calculated dew-point can be read from the display with resolution of 0.01 %rh and 0.01 °C, respectively.

Before the Measurements

- No initial tests are required.
- Check that the standard is functioning correctly that RH and temperature values are appear in the display.
- It should be allowed to stabilize in a temperature and humidity-controlled environment for at least 1 day before commencing measurements.

Environmental Conditions

- The ambient temperature and humidity must be measured. No corrections will be performed for temperature and humidity effects.
- Preferably, the measurements should be carried out at the ambient conditions given below;

  Temperature : (23 ± 3) °C

  Relative humidity : (50 ± 30) %rh

Method of measurement

- Participant institutes should use their own measurement methods for their laboratory standards.

16. Measurement Uncertainty

The uncertainty of measurement must be calculated according to the JCGM 100 “Guide to the Expression of Uncertainty in Measurement” [3] for the coverage probability of approximately 95%.

All contributions to the measurement uncertainty should be listed in the report submitted by each participant.

Even though the contributions to the uncertainty are specific to the measurement method used, it may be useful to consider the list of uncertainty sources given below.

1. The Type A standard uncertainty
2. The quoted uncertainty of the RH realization (applied RH)
3. The estimated uncertainty relating to the short-term stability of the travelling standard at the time of measurement
4. The estimated uncertainty relating to the hysteresis of the travelling standard at the time of measurement. (Difference between two consecutive measurements of mid-point, i.e. 50 %rh)
5. The estimated uncertainty in mean values due to dispersion of repeated results (reflecting the combined reproducibility of laboratory standard and travelling standards)
6. The estimated uncertainty due to non-linearity of the travelling standards in any case where measurements are significantly away from the agreed nominal value
7. The estimated covariance between applied (laboratory standard) and measured (travelling standard) values of RH (if found significant)
8. Any other components of uncertainty that are thought to be significant

This is not a complete list and should be extended with uncertainty contributions that are specific for the participant’s measurement system.

Each participant is required to submit detailed analyses of uncertainty for their RH standards. A list of the all significant components of the uncertainty budget should be evaluated, and should support the quoted uncertainties. Type B estimates of uncertainty may be regarded as having infinite degrees of freedom, or an alternative estimate of the number of degrees of freedom may be made following the methods in the ISO Guide. A template for reporting uncertainty of measurement will be in electronic form. Participants may add to the template any additional uncertainties they consider relevant.

The uncertainty budget stated by the participating laboratory should be referenced to an internal report (e.g. calibration instruction including uncertainty evaluation) and/or a published article.

17. Reporting Results

The results should be sent to the pilot institute at the latest six 5 weeks after completing the measurements. A template for reporting results will be provided in electronic form (see Appendix 4). Use

of this format, including calculations of means and differences, allows participants to see clearly the values and uncertainties of the parameters they are submitting for comparison.

Participants should report results to the pilot in terms of relative humidity (RH) at nominal temperature values stated in Table 3. The main measurement results comprise:

- Values of RH applied to the travelling standard at nominal temperature, and associated standard uncertainty
- Values of nominal temperatures
- Values measured using travelling standard (and their associated uncertainties derived from standard deviation of the set of readings)
- Values of difference between applied RH point and measured RH point.

From the data measured by the participants, results will be analysed in terms of differences between applied and measured RH at nominal temperatures.

The participants should report the conditions of realization and measurement, as background information to support the main results. These conditions should include:

- room conditions,
- placement of the temperature probe(s);
- set-up for simultaneous installation of the travelling standards;
- pressure difference between saturator or reference hygrometer and travelling standards;
- photo of the enclosure that affects the local flow rate around the sensor's probe;
- measurement traceability, and
- other items.

A template for reporting conditions of measurement will be provided in electronic form.

Participants should provide a description of the operation of their facilities used in the comparison.

Participants should also provide an example plot of equilibrium condition at a nominal RH/t set-points 90 %rh / 10 °C and 50 %rh / 23 °C, respectively, over at least one hour for the travelling standard.

However, results shall also be reported to the pilot institute. The report must contain at least:

- Details of participating institute
- The date and time of the measurements
- A detailed description of the method used
- The measurement standards used in the comparison measurements
- Software used in the comparison measurements
- The environmental conditions during the measurements
  - ambient temperature
  - relative humidity
  - ambient pressure (if applicable)
- Results of measurement

- A statement of traceability
- The Type A standard uncertainty;
- Detailed uncertainty budget with the different sources of uncertainty and their values, as;
  - The quoted uncertainty of the RH realization (applied RH)
  - The estimated uncertainty relating to the short-term stability of the travelling standard at the time of measurement
  - The estimated uncertainty due to any drift of the travelling standard over the period of the comparison (estimated by the pilot)
  - The estimated uncertainty in mean values due to dispersion of repeated results (reflecting the combined reproducibility of laboratory standard and travelling standard)
  - The estimated uncertainty due to non-linearity of the travelling standard in any case where measurements are significantly away from the agreed nominal value
  - The estimated covariance between applied (laboratory standard) and measured (travelling standard) values of RH (if found significant)
  - Any other components of uncertainty that are thought to be significant
- Expanded measurement uncertainty, estimated for the coverage probability of approximately 95 %.

18. Final Report of the Comparison

The pilot institute is responsible for the preparation of a comparison report.

The draft version of the comparison report will be issued within 12 weeks after receiving the last participant report by the pilot institute.

Draft report will be sent to each participant for discussion and approval. This draft will be confidential to the participants.

The participants will have four weeks to send their comments on Draft Report. After four-week, Draft Report will become the Final Report.

The Final Report will form the basis for the publication of results.

The supplementary Comparison Reference Value (CRV) will be calculated using the weighted mean from the participating labs.

The Final Report will provide the degrees of equivalence of the laboratories and their associated uncertainties.

19. References

[1] Measurement Comparisons in the CIPM MRA, MRA-D-05, V1.6

[2] EURAMET Guide on Comparisons, EURAMET Guide No. 4, V1.1 (12/2016)

[3] JCGM 100, “Guide to the Expression of Uncertainty in Measurement” (GUM), First edition, September 2008.

[4] Guideline on COOMET supplementary comparison evaluation, R/GM/19:2016, edition April 2016.

APPENDIX 1. Form for reporting on receipt of travelling standard

Participant must fax the Appendix 1 after receiving the travelling standard.
TO: (PILOT LABORATORY)

FAX:

FROM: (PARTICIPATING LABORATORY)

FAX:

We confirm having received the travelling standard with serial number …….

of the RH Comparison on: .....(date)

After visual inspection

☐ No damage has been noticed;

☐ The following damage must be reported

Has the hygrometer transportation package been opened during transit?
e.g., Customs ...

☐ No

☐ Yes: Please give details:

Is there any damage to the transportation package?

☐ No

☐ Yes: Please give details:

Are there any visible signs of damage to the instrument?

☐ No

☐ Yes: Please give details:

Do you believe the travelling standard is functioning correctly?

☐ Yes

☐ No: Please indicate your concerns:

PACKING LIST

Received	Items	Dispatched
	Rotronic hygrometer HP32-SET, s/n: 5181786	
	Sensor's probe HC2A-S (attached to HP32-SET)	
	Cable with UHB end for connection to a PC (attached to HP32-SET)	
	Logging software (CD)	
	Transport case	

Laboratory: ----------

Date: ---------- Signature: ----------

APPENDIX 2. Template for submission of results

The template for submission of results is available in electronic form only (Excel workbook). It will be sent to each participant during the comparison.

APPENDIX 3. Circulation time schedule

Acronym of Institute	Country	Starting Date	Time for measurement and transportation
BelGIM	Belarus	April 2021	30 days
MIKES	Finland	May-June 2021	60 days
INM-MD	Republic of Moldova	July 2021	30 days

Appendix B. Results of the participating institutes

Table B.1. Results and expanded uncertainties of the INM-MD

Nominal value		Applied Condition			Travelling Standard	Difference (RH_{Meas} - $RH_{Applied}$)	Expanded uncertainty
Temperature	Measurement Point	Reference temperature	Dew-point temperature	Reference RH	Measured RH		
°C	%rh	°C	°C	%rh	%rh	%rh	%rh
23 °C (Start)	10	22.86	-8.61	10.64	10.35	-0.29	0.27
	25	22.94	2.18	25.76	25.22	-0.54	0.47
	50	22.96	12.24	50.83	50.11	-0.72	0.89
	75	22.97	18.26	74.81	73.93	-0.88	1.29
	90	22.97	21.18	89.67	88.82	-0.85	1.53
10 °C	10	9.98	-17.45	10.82	10.11	-0.71	0.27
	25	10.02	-7.75	25.77	24.87	-0.90	0.55
	50	10.02	0.31	50.85	50.22	-0.63	1.02
	75	10.03	5.90	75.49	75.08	-0.41	1.54
	90	10.05	8.49	89.93	89.17	-0.76	1.69
50 °C	10	50.08	10.19	10.03	10.87	0.84	0.26
	25	50.06	24.60	24.98	25.49	0.51	0.43
	50	50.12	36.76	49.89	49.98	0.09	0.73
	75	50.15	44.45	74.93	74.95	0.02	1.08
	90	50.07	48.21	91.12	90.87	-0.25	1.31
23 °C (End)	10	22.86	-7.96	11.26	10.87	-0.39	0.39
	25	22.94	2.12	25.59	24.93	-0.66	0.51
	50	22.96	12.05	50.19	49.65	-0.54	0.77
	75	22.97	18.33	75.15	74.38	-0.77	1.09
	90	22.97	21.31	90.36	89.86	-0.50	1.26

Table B.2. Results and expanded uncertainties of the BelGIM

Nominal value		Applied Condition		Travelling Standard	Difference (RH_{Meas} - $RH_{Applied}$)	Expanded uncertainty
Temperature	Measurement Point	Reference temperature	Reference RH	Measured RH		
°C	%rh	°C	%rh	%rh	%rh	%rh
23 °C (Start)	10	23.00	10.19	9.84	-0.35	0.22
	25	23.00	24.71	24.23	-0.48	0.30
	50	23.00	49.77	49.14	-0.63	0.44
	75	23.00	74.86	74.22	-0.64	0.60
	90	23.00	90.01	89.31	-0.70	0.76
10 °C	10	10.00	10.37	9.46	-0.91	0.22
	25	10.00	24.78	23.46	-1.32	0.30
	50	10.00	49.52	48.11	-1.41	0.44
	75	10.00	74.38	73.10	-1.28	0.60
	90	10.00	90.44	88.94	-1.50	0.76
50 °C	10	50.00	10.42	11.10	0.68	0.22
	25	50.00	25.21	25.82	0.61	0.30
	50	50.00	50.37	50.71	0.34	0.44
	75	50.00	75.11	75.82	0.71	0.60
	90	50.00	90.82	91.13	0.31	0.76
23 °C (End)	10	23.00	10.28	9.78	-0.50	0.22
	25	23.00	24.90	24.15	-0.75	0.30
	50	23.00	50.02	49.23	-0.79	0.44
	75	23.00	75.17	74.16	-1.01	0.60
	90	23.00	90.23	89.24	-0.99	0.76

Table B.3. Results and expanded uncertainties of the MIKES

Nominal value		Applied Condition			Travelling Standard	Difference (RH_{Meas} - $RH_{Applied}$)	Expanded uncertainty
Temperature	Measurement Point	Reference temperature	Dew-point temperature	Reference RH	Measured RH		
°C	%rh	°C	°C	%rh	%rh	%rh	%rh
23 °C (Start)	10	23.11	-8.83	10.24	9.63	-0.61	0.41
	25	23.04	3.50	27.86	27.12	-0.74	0.64
	50	23.00	11.85	49.40	48.75	-0.65	0.91
	75	22.90	18.23	74.80	74.00	-0.80	1.20
	90	22.90	21.21	90.10	89.00	-1.10	1.40
10 °C	10	10.20	-18.35	9.70	8.84	-0.86	0.40
	25	10.19	-7.96	25.00	23.73	-1.27	0.60
	50	10.30	0.18	49.41	47.98	-1.43	0.91
	75	10.00	5.71	74.50	73.20	-1.30	1.20
	90	10.10	8.37	89.30	87.90	-1.40	1.40
50 °C	10	50.12	8.77	9.10	9.53	0.43	0.39
	25	50.08	24.14	24.27	24.65	0.38	0.59
	50	50.01	36.56	49.62	49.90	0.28	0.92
	75	49.90	44.25	75.10	75.70	0.60	1.30
	90	49.80	47.81	90.70	90.60	-0.10	1.50
23 °C (End)	10	23.09	-10.11	9.10	8.41	-0.69	0.39
	25	23.03	1.23	23.71	22.76	-0.95	0.58
	50	23.01	11.80	49.24	48.47	-0.77	0.91
	75	22.90	18.23	74.80	73.90	-0.90	1.20
	90	22.90	21.18	89.90	88.80	-1.10	1.40

Appendix C. Uncertainty budgets reported by the participating institutes

Uncertainty Budget of INM-MD

Uncertainty budget at 23 °C

Source of uncertainty	Distribution	Divisor	Uncertainty contribution, %rh				
	Measurement Point		10	25	50	75	90
Dew-point temperature in the measurement chamber							
Temporal variation of the standard hygrometer	Normal	1.000	0.0187	0.0373	0.0517	0.0583	0.0829
Calibration uncertainty	Normal	2.000	0.0419	0.0906	0.1673	0.2349	0.2752
Resolution of the standard hygrometer	Rectangular	1.732	0.0024	0.0052	0.0097	0.0136	0.0159
Interpolation between the calibration points	Rectangular	1.732	0.0097	0.0209	0.0386	0.0542	0.0636
Drift (Long-term instability)	Rectangular	1.732	0.0242	0.0523	0.0966	0.1356	0.1589
Air temperature in the measurement chamber							
Temporal variation of the standard thermometer	Normal	1.000	0.0051	0.0229	0.0459	0.0675	0.0809
Calibration uncertainty (sensor and indicator unit)	Normal	2.000	0.0064	0.0154	0.0308	0.0453	0.0543
Resolution (indicator unit)	Rectangular	1.732	0.0019	0.0044	0.0089	0.0131	0.0157
Interpolation between the calibration points	Rectangular	1.732	0.0074	0.0177	0.0355	0.0523	0.0627
Long-term instability (sensor and indicator unit)	Rectangular	1.732	0.0037	0.0089	0.0178	0.0262	0.0313
Self-heating of the standard thermometer	Rectangular	1.732	0.0112	0.0266	0.0533	0.0785	0.0940
Hysteresis of the standard thermometer	Rectangular	1.732	0.0037	0.0266	0.0178	0.0262	0.0313
Humidity generator							
Spatial inhomogeneity in the climatic chamber	Rectangular	1.732	0.0558	0.1330	0.2666	0.3923	0.4702
Temporal instability in the climatic chamber	Rectangular	1.732	0.0372	0.0887	0.1777	0.2615	0.3135
Radiation influences	Rectangular	1.732	0.0112	0.0266	0.0533	0.0785	0.0940
Saturation efficiency	Triangular	2.449	0.0143	0.0357	0.0714	0.1072	0.1286
Uncertainty due to formulae/calculations							
Saturation vapor pressure formula (ec)	Rectangular	1.732	0.0005	0.0013	0.0025	0.0037	0.0045
Saturation vapor pressure formula (ed)	Rectangular	1.732	0.0005	0.0013	0.0025	0.0037	0.0045
Calculation errors	Rectangular	1.732	0.0289	0.0144	0.0144	0.0144	0.0144
Device under calibration							
Temporal variation	Normal	1.000	0.0816	0.0149	0.0314	0.0458	0.0149

Resolution of the device under calibration	Rectangular	1.732	0.0029	0.0029	0.0029	0.0029	0.0029
Self-heating	Rectangular	1.732	0.0483	0.1046	0.1932	0.2712	0.3178
Hysteresis	Rectangular	1.732	0.0000	0.0000	0.0000	0.0000	0.0000
Combined uncertainty, %rh			**0.133**	**0.233**	**0.446**	**0.643**	**0.763**
Expanded uncertainty, %rh			**0.27**	**0.47**	**0.89**	**1.29**	**1.53**

Uncertainty budget at 10 °C

Source of uncertainty	**Probability Distribution**	**Divisor**	**Uncertainty contribution, %rh**				
	Measurement Point, %rh		**10**	**25**	**50**	**75**	**90**
Dew-point temperature in the measurement chamber							
Temporal variation of the standard hygrometer	Normal	1.000	0.0657	0.0602	0.1401	0.3108	0.1229
Calibration uncertainty	Normal	2.000	0.0463	0.1009	0.1857	0.2606	0.3034
Resolution of the standard hygrometer	Rectangular	1.732	0.0027	0.0058	0.0107	0.0150	0.0175
Interpolation between the calibration points	Rectangular	1.732	0.0107	0.0233	0.0429	0.0602	0.0701
Drift (Long-term instability)	Rectangular	1.732	0.0267	0.0583	0.1072	0.1505	0.1752
Air temperature in the measurement chamber							
Temporal variation of the standard thermometer	Normal	1.000	0.0259	0.0747	0.0523	0.0576	0.0888
Calibration uncertainty (sensor and indicator unit)	Normal	2.000	0.0073	0.0173	0.0344	0.0504	0.0599
Resolution (indicator unit)	Rectangular	1.732	0.0021	0.0050	0.0099	0.0146	0.0173
Interpolation between the calibration points	Rectangular	1.732	0.0084	0.0200	0.0397	0.0582	0.0691
Long-term instability (sensor and indicator unit)	Rectangular	1.732	0.0042	0.0100	0.0198	0.0291	0.0346
Self-heating of the standard thermometer	Rectangular	1.732	0.0126	0.0300	0.0595	0.0873	0.1037
Hysteresis of the standard thermometer	Rectangular	1.732	0.0042	0.0300	0.0198	0.0291	0.0346
Humidity generator							
Spatial inhomogeneity in the climatic chamber	Rectangular	1.732	0.0628	0.1500	0.2976	0.4365	0.5186
Temporal instability in the climatic chamber	Rectangular	1.732	0.0419	0.1000	0.1984	0.2910	0.3457
Radiation influences	Rectangular	1.732	0.0126	0.0300	0.0595	0.0873	0.1037
Saturator Efficiency	Triangular	2.449	0.0143	0.0357	0.0714	0.1072	0.1286
Calculation of the relative humidity							

Saturation vapor pressure formula (ec)	Rectangular	1.732	0.0005	0.0013	0.0026	0.0038	0.0045
Saturation vapor pressure formula (ed)	Rectangular	1.732	0.0005	0.0013	0.0026	0.0038	0.0045
Calculation errors	Rectangular	1.732	0.0144	0.0144	0.0144	0.0144	0.0144
Device under calibration							
Temporal variation	Normal	1.000	0.0298	0.0180	0.0050	0.0422	0.0422
Resolution of the device under calibration	Rectangular	1.732	0.0029	0.0029	0.0289	0.0029	0.0029
Self-heating	Rectangular	1.732	0.0535	0.1166	0.2144	0.3009	0.3503
Hysteresis	Rectangular	1.732	0.0000	0.0000	0.0000	0.0000	0.0000
Combined uncertainty			**0.135**	**0.273**	**0.511**	**0.772**	**0.845**
Expanded uncertainty			**0.27**	**0.55**	**1.02**	**1.54**	**1.69**

Uncertainty budget at 50 °C

Source of uncertainty	**Probability Distribution**	**Divisor**	**Uncertainty contribution, %rh**				
	Measurement Point, %rh		**10**	**25**	**50**	**75**	**90**
Dew-point temperature in the measurement chamber							
Temporal variation of the standard hygrometer	Normal	1.000	0.0294	0.0185	0.0415	0.0577	0.1191
Calibration uncertainty	Normal	2.000	0.0341	0.0747	0.1362	0.1934	0.2290
Resolution of the standard hygrometer	Rectangular	1.732	0.0020	0.0043	0.0079	0.0112	0.0132
Interpolation between the calibration points	Rectangular	1.732	0.0079	0.0172	0.0314	0.0447	0.0529
Drift (Long-term instability)	Rectangular	1.732	0.0197	0.0431	0.0786	0.1117	0.1322
Air temperature in the measurement chamber							
Temporal variation of the standard thermometer	Normal	1.000	0.0131	0.0261	0.0639	0.1107	0.1167
Calibration uncertainty of standard thermometer	Normal	2.000	0.0051	0.0124	0.0247	0.0371	0.0452
Resolution (indicator unit)	Rectangular	1.732	0.0015	0.0036	0.0071	0.0107	0.0130
Interpolation between the calibration points	Rectangular	1.732	0.0059	0.0143	0.0286	0.0429	0.0522
Long-term instability (sensor and indicator unit)	Rectangular	1.732	0.0029	0.0072	0.0143	0.0214	0.0261
Self-heating of the standard thermometer	Rectangular	1.732	0.0088	0.0215	0.0428	0.0643	0.0783
Hysteresis of the standard thermometer	Rectangular	1.732	0.0029	0.0215	0.0143	0.0214	0.0261
Humidity generator							

Spatial inhomogeneity in the climatic chamber	Rectangular	1.732	0.0439	0.1330	0.2142	0.3217	0.3914
Temporal instability in the climatic chamber	Rectangular	1.732	0.0293	0.0887	0.1428	0.2144	0.2609
Radiation influences	Rectangular	1.732	0.0088	0.0266	0.0428	0.0643	0.0783
Saturator Efficiency	Triangular	2.449	0.0143	0.0357	0.0714	0.1072	0.1286
Calculation of the relative humidity							
Saturation vapor pressure formula (ec)	Rectangular	1.732	0.0005	0.0012	0.0025	0.0037	0.0046
Saturation vapor pressure formula (ed)	Rectangular	1.732	0.0005	0.0012	0.0005	0.0037	0.0046
Calculation errors	Rectangular	1.732	0.0144	0.0144	0.0144	0.0144	0.0144
Device under calibration							
Temporal variation	Normal	1.000	0.0963	0.0333	0.0333	0.0316	0.0258
Resolution of the device under calibration	Rectangular	1.732	0.0029	0.0029	0.0029	0.0029	0.0029
Self-heating	Rectangular	1.732	0.0394	0.0862	0.1572	0.2233	0.2644
Hysteresis	Rectangular	1.732	0.0000	0.0000	0.0000	0.0000	0.0000
Combined uncertainty			**0.130**	**0.215**	**0.367**	**0.541**	**0.654**
Expanded uncertainty			**0.26**	**0.43**	**0.73**	**1.08**	**1.31**

Uncertainty Budget of MIKES

Example of uncertainty budget at 50 °C

Budjetti

Merkinnät viittaavat menet. ohjeen nro 9 liitteeseen 4. Markings refer to calibration instruction 9 Appendix 4.
Painelukemat Pascaleina ja lämpötilalukemat Celsius-asteina. Pressures in Pascal and temperatures in Celsius-degrees

Calibration certificate M-21H026
Calibration certificate of ref. M-21T020

	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN
1. Odotusarvo, Expexted value										
- Reference, Dw (g/m3)	7.605	7.639	20.333	20.261	41.357	41.364	62.261	62.305	74.746	74.665
- Reference, td	8.74	8.81	24.17	24.11	36.56	36.56	44.25	44.26	47.82	47.80
- Reference, tc	50.08573	50.15298	50.097198	50.072489	50.02024	50.00649	49.929402	49.87524	49.77669	49.75951
- Reference, RHR	9.09	9.10	24.30	24.24	49.60	49.64	74.99	75.23	90.67	90.64
RHR	9.09	9.10	24.23	24.17	49.47	49.51	74.87	75.11	90.59	90.56
PNc	101403	101430	101409	101435	101433	101433	101440	101437	101438	101440
PNd	101169	101195	101132	101177	101135	101148	101131	101156	101159	101158
delta PLc	0	0	0	0	0	0	0	0	0	0
delta PLd	0	0	0	0	0	0	0	0	0	0
tdN	8.761	8.83	24.182	24.126	36.568	36.573	44.254	44.27	47.831	47.808
delta tdc	-0.09052	-0.09052	-0.0889818	-0.0889874	-0.08774	-0.08774	-0.0869746	-0.08697	-0.08662	-0.08662
delta tdMS	0	0	0	0	0	0	0	0	0	0
delta tdMR	0	0	0	0	0	0	0	0	0	0
delta tdG	0	0	0	0	0	0	0	0	0	0
delta tdP	0.066428	0.066642	0.0750389	0.0712029	0.079184	0.076574	0.0813294	0.0757	0.075247	0.075836
tNc	50.08573	50.15298	50.097198	50.072489	50.02024	50.00649	49.929402	49.87524	49.77669	49.75951
delta tMcS	0	0	0	0	0	0	0	0	0	0
delta tMR	0	0	0	0	0	0	0	0	0	0
delta tGc	0	0	0	0	0	0	0	0	0	0
delta tcc	0	0	0	0	0	0	0	0	0	0
- Device under Cal, RHN										
RHN	9.517	9.543	24.576	24.724	49.736	50.066	75.534	75.95	90.861	90.839
L	9.517	9.543	24.576	24.724	49.736	50.066	75.534	75.95	90.861	90.839
delta CR	0	0	0	0	0	0	0	0	0	0
- Device under Cal, tNc										
tNc	49.98	50.05	50.05	50.02	49.95	49.93	49.87	49.82	49.90	49.89
Lt	49.98	50.05	50.05	50.02	49.95	49.93	49.87	49.82	49.90	49.89
delta CtR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Calibration correction, CRH										
CRHi	-0.42	-0.44	-0.28	-0.48	-0.13	-0.42	-0.55	-0.72	-0.19	-0.19
CRHRi	-0.43		-0.38		-0.28		-0.63		-0.19	
delta CRHi	0.01		0.21		0.29		0.17		0.00	
- Calibration correction, Ct										
Cti	0.10	0.11	0.05	0.05	0.07	0.07	0.06	0.06	-0.13	-0.13
CtRi	0.10		0.05		0.07		0.06		-0.13	
delta Cti	0.00		-0.01		0.00		0.01		0.00	

2. Standardi epävarmuus Standard Uncertainty	Sensitivit y Coeff	ui	ui	Sensitivit y Coeff	ui	ui	Sensitivity Coeff	ui	ui	Sensitivity Coeff	ui	ui	Sensitivity Coeff	ui	ui	Herkkyys kerroin
- Reference, Dw	1	0.1397	0.1377	1	0.1490	0.1465	1	0.2729	0.2821	1	0.3882	0.3877	1	0.4378	0.4443	1
unc tc	0.38	0.126	0.122	1.01	0.083	0.082	2.05	0.075	0.078	3.09	0.070	0.071	3.71	0.065	0.066	#REF!
unc RH	0.84	0.15711	0.155121	0.84	0.1472406	0.1445777	0.83	0.270854	0.277855	0.83	0.3874813	0.386134	0.82	0.443317	0.448898	#REF!
- Reference, RHR	1	0.15711	0.155121	1	0.1472406	0.1445777	1	0.270854	0.277855	1	0.3874813	0.386134	1	0.443317	0.448898	1
unc td	0.6155	0.24	0.24	1.4579	0.07	0.07	2.7120	0.07	0.07	3.8771	0.07	0.07	4.5695	0.07	0.07	#REF!
unc tc	0.4509	0.126	0.122	1.2049	0.083	0.082	2.4610	0.075	0.078	3.7230	0.070	0.071	4.5064	0.065	0.066	#REF!
- Reference, td	1	0.24	0.24	1	0.07	0.07	1	0.07	0.07	1	0.07	0.07	1	0.07	0.07	1
tdN	1	0.226831	0.224341	1	0.0138884	0.0026667	1	0.007424	0.01116	1	0.0083267	0.006498	1	0.005859	0.009866	1
delta tdc	1	0.035	0.035	1	0.035	0.035	1	0.035	0.035	1	0.035	0.035	1	0.035	0.035	1
delta tdMS	1	0.015588	0.015588	1	0.0155885	0.0155885	1	0.015588	0.015588	1	0.0155885	0.015588	1	0.015588	0.015588	1
delta tdMR	1	0.002887	0.002887	1	0.0028868	0.0028868	1	0.002887	0.002887	1	0.0028868	0.002887	1	0.002887	0.002887	1
delta tdG	1	0.057735	0.057735		0.057735	0.057735		0.057735	0.057735		0.057735	0.057735		0.057735	0.057735	
delta tdP	1	0.019176	0.019238	1	0.0216619	0.0205545	1	0.022859	0.022105	1	0.0234778	0.021853	1	0.021722	0.021892	1
- Reference, tc	1	0.126	0.122	1	0.083	0.082	1	0.075	0.078	1	0.070	0.071	1	0.065	0.066	1
tNc	1	0.025764	0.024647	1	0.0249917	0.0033221	1	0.004623	0.011454	1	0.0057708	0.00292	1	0.005967	0.008098	1
delta tMcS	1	0.0144	0.0144	1	0.0144	0.0144	1	0.0144	0.0144	1	0.0144	0.0144	1	0.0144	0.0144	1
delta tMR	1	0.0003	0.0003	1	0.0003	0.0003	1	0.0003	0.0003	1	0.0003	0.0003	1	0.0003	0.0003	1
delta tGc	1	0.1225	0.1188	1	0.0780	0.0806	1	0.0730	0.0762	1	0.0685	0.0689	1	0.0629	0.0640	1
delta tcc	1	0.0035	0.0035	1	0.0035	0.0035	1	0.0035	0.0035	1	0.0035	0.0035	1	0.0035	0.0035	1
- Device under Cal, RHN	1	0.1139	0.1180	1	0.0304	0.0293	1	0.0307	0.0301	1	0.0392	0.0360	1	0.0336	0.0465	1
L	1	0.1102	0.1144	1	0.0095	0.0050	1	0.0105	0.0085	1	0.0266	0.0216	1	0.0173	0.0365	1
delta CR	1	0.0289	0.0289	1	0.0289	0.0289	1	0.0289	0.0289	1	0.0289	0.0289	1	0.0289	0.0289	1
- Device under Cal, tNc	1	0.0302	0.0299	1	0.0327	0.0291	1	0.0292	0.0310	1	0.0291	0.0289	1	0.0292	0.0290	1
L	1	0.0090	0.0076	1	0.0153	0.0033	1	0.0045	0.0113	1	0.0033	0.0018	1	0.0045	0.0022	1
delta CR	1	0.0289	0.0289	1	0.0289	0.0289	1	0.0289	0.0289	1	0.0289	0.0289	1	0.0289	0.0289	1
- Calibration correction, CRH		0.1010			0.1606			0.2914			0.3915			0.4488		
CRHi	1	0.1009	0.0989	1	0.1492	0.1475	1	0.2722	0.2791	1	0.3883	0.3864	1	0.4439	0.4488	1
u(RHR,RHN)	-1	0.0137	0.0141	-1	0.0002	0.0000	-1	0.0001	0.0001	-1	0.0005	0.0006	-1	0.0003	0.0011	-1
delta CRHi	1	0.0040		1	0.0593		1	0.0836		1	0.0501		1	0.0009		1
- Calibration correction, Ct		0.1261			0.0870			0.0844			0.0763			0.0723		
Cti	1	0.1261	0.1258	1	0.0832	0.0870	1	0.0746	0.0844	1	0.0703	0.0762	1	0.0649	0.0723	1
delta CtRi	1	-0.0012		1	-0.0021		1	-0.0004		1	0.0018		1	-0.0002		1

	Measurement File
	h100621T50.xlsm
Measurement Quantity (RH, Td, Rho)?	RH
Meter or transmitter (M/L)?	M
Calibration certificate	M-21H026
Calibration certificate of ref. Thermometer	M-21T020

	UP		DOWN		UP		DOWN		UP		DOWN		UP		DOWN		UP		DOWN	
Result sheet	10y50		10a50		25y50		25a50		50y50		50a50		75y50		75a50		90y50		90a50	
Measurement file	h100621T50.xlsm		h100621T50.xlsm		h100621T50.xlsm		h100621T50.xlsm		h100621T50.xlsm		h100621T50.xlsm		h100621T50.xlsm		h100621T50.xlsm		h100621T50.xlsm		h100621T50.xlsm	
Start tab	q	28	q	28	q	28	q	28	q	28	q	28	q	28	q	28	q	28	q	28
	r		r		r		r		r		r		r		r		r		r	
Date	10.06.2021	[h100	10.06.2021	[h10	10.06.2021	[h10	11.06.2021	[h10	10.06.2021	[h100	11.06.2021	[h10	11.06.2021	[h100	11.06.2021	[h100	11.06.2021	[h100	11.06.2021	[h100
Ambient RH	42.4	[h100	42.6	[h10	42.2	[h10	42.2	[h10	42.4	[h100	42.2	[h10	42.4	[h100	42.4	[h100	42.3	[h100	42.2	[h100
Ambient T	21.4	[h100	21.4	[h10	21.4	[h10	21.5	[h10	21.4	[h100	21.6	[h10	21.4	[h100	21.5	[h100	21.5	[h100	21.5	[h100
Ambient P	1014.55	[h100	1014.83	[h10	1014.62	[h10	1014.86	[h10	1014.82	[h100	1014.84	[h10	1014.92	[h100	1014.87	[h100	1014.88	[h100	1014.91	[h100
Reference																				
Dew point mirror (Mich, MBW, EGG):	MBW373LHX	[h100	MBW373LHX	[h10	MBW373LHX	[h10	MBW373LHX	[h10	MBW373LHX	[h100	MBW373LHX	[h10	MBW373LHX	[h100	MBW373LHX	[h100	MBW373LHX	[h100	MBW373LHX	[h100
Relative humidity, RefRH (%):	9.087	[h100	9.099	[h10	24.227	[h10	24.169	[h10	49.470	[h100	49.510	[h10	74.867	[h100	75.110	[h100	90.587	[h100	90.562	[h100
Temperature, tNc (°C), uncorrected	50.086	[h100	50.153	[h10	50.097	[h10	50.072	[h10	50.020	[h100	50.006	[h10	49.929	[h100	49.875	[h100	49.777	[h100	49.760	[h100
tNc calibr. corr (°C)	0.000	[h100	0.000	[h10	0.000	[h10	0.000	[h10	0.000	[h100	0.000	[h10	0.000	[h100	0.000	[h100	0.000	[h100	0.000	[h100
Dew point temperature (Td), uncorrected	8.761	[h100	8.830	[h10	24.182	[h10	24.126	[h10	36.568	[h100	36.573	[h10	44.254	[h100	44.270	[h100	47.831	[h100	47.808	[h100
Td calibr. corr (°C)	-0.091	[h100	-0.091	[h10	-0.089	[h10	-0.089	[h10	-0.088	[h100	-0.088	[h10	-0.087	[h100	-0.087	[h100	-0.087	[h100	-0.087	[h100
Absolut humidity (g/m3):	7.60E+00	[h100	7.63E+00	[h10	2.03E+01	[h10	2.02E+01	[h10	4.12E+01	[h100	4.12E+01	[h10	6.21E+01	[h100	6.22E+01	[h100	7.47E+01	[h100	7.46E+01	[h100
dew point or ice point (k/j):	k		k		k		k		k		k		k		k		k		k	
Absolut humidity variation:	1.16E-01	[h100	1.16E-01	[h10	1.58E-02	[h10	3.21E-03	[h10	1.64E-02	[h100	2.43E-02	[h10	2.64E-02	[h100	2.12E-02	[h100	2.17E-02	[h100	3.64E-02	[h100
DP temperature (RefTd) variation:	0.2268	[h100	0.2243	[h10	0.0139	[h10	0.0027	[h10	0.0074	[h100	0.0112	[h10	0.0083	[h100	0.0065	[h100	0.0059	[h100	0.0099	[h100
Temperature (RefT) variation	0.0258	[h100	0.0246	[h10	0.0250	[h10	0.0033	[h10	0.0046	[h100	0.0115	[h10	0.0058	[h100	0.0029	[h100	0.0060	[h100	0.0081	[h100
RefRH variation	0.1305	[h100	0.1301	[h10	0.0206	[h10	0.0051	[h10	0.0149	[h100	0.0242	[h10	0.0304	[h100	0.0320	[h100	0.0308	[h100	0.0431	[h100
Chamber rel humidity (%RH):	10.000	[h100	10.000	[h10	25.050	[h10	25.010	[h10	50.000	[h100	49.990	[h10	75.000	[h100	75.050	[h100	90.070	[h100	89.940	[h100
Chamber temperature (°C):	49.690	[h100	49.730	[h10	49.710	[h10	49.700	[h10	49.700	[h100	49.740	[h10	49.700	[h100	49.700	[h100	49.700	[h100	49.700	[h100
Chamber measured temperature. tNcP (°C):	50.273	[h100	50.333	[h10	50.188	[h10	50.170	[h10	50.098	[h100	50.093	[h10	49.993	[h100	49.940	[h100	49.820	[h100	49.807	[h100
tNcP calibr. corr (°C)	0.000	[h100	0.000	[h10	0.000	[h10	0.000	[h10	0.000	[h100	0.000	[h10	0.000	[h100	0.000	[h100	0.000	[h100	0.000	[h100
Pressure in chamber, pTc (hPa)	1014.03	[h100	1014.30	[h10	1014.09	[h10	1014.35	[h10	1014.33	[h100	1014.33	[h10	1014.40	[h100	1014.37	[h100	1014.38	[h100	1014.40	[h100
Pressure in dew point mirror, pTd (hPa)	1011.69	[h100	1011.95	[h10	1011.32	[h10	1011.77	[h10	1011.35	[h100	1011.48	[h10	1011.31	[h100	1011.56	[h100	1011.59	[h100	1011.58	[h100
Dew point temperature pressure correction (°C):	0.066	[h100	0.067	[h10	0.075	[h10	0.071	[h10	0.079	[h100	0.077	[h10	0.081	[h100	0.076	[h100	0.075	[h100	0.076	[h100
Check	OK		OK		OK		OK		OK		OK		OK		OK		OK		OK	
RH-diff:	OK		OK		OK		OK		OK		OK		OK		OK		OK		OK	
T-diff:	OK		OK		OK		OK		OK		OK		OK		OK		OK		OK	

Device under calibration	ChubCH2	[h100	ChubCH2	[h10	ChubCH2	[h1	ChubCH2	[h10	ChubCH2	[h100	ChubCH2	[h10	ChubCH2	[h100	ChubCH2	[h100	ChubCH2	[h100	ChubCH2	[h100
Relative humidity, (%):	9.52	[h100	9.54	[h10	24.58	[h1	24.72	[h10	49.74	[h100	50.07	[h10	75.53	[h100	75.95	[h100	90.86	[h100	90.84	[h100
- Current or voltage output ():	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
Temperature (°C):	49.983	[h100	50.046	[h10	50.050	[h1	50.018	[h10	49.947	[h100	49.932	[h10	49.867	[h100	49.819	[h100	49.904	[h100	49.886	[h100
- Current or voltage output ():	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
Kastepistelämpötila (°C):	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
- Current or voltage output ():	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
Absolut humidty (g/m3):	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
- Current or voltage output ():	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
DUC reading variation (RH / %):	0.1102	[h100	0.1144	[h10	0.0095	[h1	0.0050	[h10	0.0105	[h100	0.0085	[h10	0.0266	[h100	0.0216	[h100	0.0173	[h100	0.0365	[h100
- Current or voltage output variation ():	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
- Covariance:	0.0137	[h100	0.0141	[h10	0.0002	[h1	0.0000	[h10	0.0001	[h100	0.0001	[h10	0.0005	[h100	0.0006	[h100	0.0003	[h100	0.0011	[h100
DUC reading variation (T / °C):	0.0090	[h100	0.0076	[h10	0.0153	[h1	0.0033	[h10	0.0045	[h100	0.0113	[h10	0.0033	[h100	0.0018	[h100	0.0045	[h100	0.0022	[h100
- Current or voltage output variation ():	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
DUC reading variation (Td / °C):	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
- Current or voltage output variation ():	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
- Covariance:	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
DUC reading variation (Dw / (g/m3))):	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
- Current or voltage output variation ():	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
- Covariance:	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
DUC resolution (rel. Humid.):	0.10	[h100	0.10	[h10	0.10	[h1	0.10	[h10	0.10	[h100	0.10	[h10	0.10	[h100	0.10	[h100	0.10	[h100	0.10	[h100
DUC resolution (temp.):	0.10	[h100	0.10	[h10	0.10	[h1	0.10	[h10	0.10	[h100	0.10	[h10	0.10	[h100	0.10	[h100	0.10	[h100	0.10	[h100
DUC resolution (dew point.):	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
DUC resolution (abs. hum):	--	[h100	--	[h10	--	[h1	--	[h10	--	[h100	--	[h10	--	[h100	--	[h100	--	[h100	--	[h100
RH rel to ice or water (v/j):	v		v		v		v		v		v		v		v		v		v	

Calibration results:

Relative Humidity

Reference value:		9.10	%RH		24.27	%RH		49.62	%RH		75.11	%RH		90.66	%RH					
DUC reading		9.53	%RH		24.65	%RH		49.90	%RH		75.74	%RH		90.85	%RH					
- Current or voltage output:	--		0.0000	--		0.0000	--		0.0000	--		0.0000	--		0.00					
Uncertainty (k=2) **		0.39	%RH		0.58	%RH		0.91	%RH		1.24	%RH		1.44	%RH					
Ref-Ind, RH (%):		-0.43	%RH		-0.38	%RH		-0.28	%RH		-0.63	%RH		-0.19	%RH					
CMC:		0.39	%RH		0.58	%RH		0.91	%RH		1.24	%RH		1.44	%RH					

Temperature

Reference value		50.12	°C		50.08	°C		50.01	°C		49.90	°C		49.77	°C					
DUC reading		50.01	°C		50.03	°C		49.94	°C		49.84	°C		49.90	°C					
- Current or voltage output:	--		0.0000	--		0.0000	--		0.0000	--		0.0000	--		0.00					
Uncertainty (k=2) **		0.30	°C		0.20	°C		0.20	°C		0.20	°C		0.20	°C					
Ref-Ind, T (°C):		0.10	°C		0.05	°C		0.07	°C		0.06	°C		-0.13	°C					

Uncertainty Budget of BelGIM

Uncertainty budget at 23 °C

Source of uncertainty	Distribution	Divisor	Uncertainty contribution, %rh				
	Measurement Point		10	25	50	75	90
Temporal variation of the standard hygrometer	Normal	1.000	0.0032	0.0032	0.0032	0.0045	0.0055
Calibration uncertainty of the standard hygrometer	Normal	2.000	0.1100	0.1500	0.2200	0.3000	0.3800
Drift (Long-term instability)	Rectangular	1.732	0.0577	0.0577	0.0577	0.0577	0.0577
Resolution of the standard hygrometer	Rectangular	1.732	0.0029	0.0029	0.0029	0.0029	0.0029
Temporal instability in the climatic chamber	Rectangular	1.732	0.0577	0.0577	0.0577	0.0577	0.0577
Spatial inhomogeneity in the climatic chamber	Rectangular	1.732	0.0577	0.0577	0.0577	0.0577	0.0577
Temporal variation of the device under calibration	Normal	1.000	0.0055	0.0032	0.0063	0.0037	0.0055
Resolution of the device under calibration	Rectangular	1.732	0.0029	0.0029	0.0029	0.0029	0.0029
Hysteresis	Rectangular	1.732	0.0000	0.0000	0.0000	0.0000	0.0000
Combined uncertainty, %rh			**0.15**	**0.18**	**0.24**	**0.32**	**0.39**
Expanded uncertainty, %rh			**0.30**	**0.36**	**0.48**	**0.63**	**0.79**

Uncertainty budget at 10 °C

Source of uncertainty	Distribution	Divisor	Uncertainty contribution, %rh				
	Measurement Point		10	25	50	75	90
Temporal variation of the standard hygrometer	Normal	1.000	0.0063	0.0075	0.0071	0.0086	0.0055
Calibration uncertainty of the standard hygrometer	Normal	2.000	0.1100	0.1500	0.2200	0.3000	0.3800
Drift (Long-term instability)	Rectangular	1.732	0.0577	0.0577	0.0577	0.0577	0.0577
Resolution of the standard hygrometer	Rectangular	1.732	0.0029	0.0029	0.0029	0.0029	0.0029
Temporal instability in the climatic chamber	Rectangular	1.732	0.0577	0.0577	0.0577	0.0577	0.0577
Spatial inhomogeneity in the climatic chamber	Rectangular	1.732	0.0577	0.0577	0.0577	0.0577	0.0577
Temporal variation of the device under calibration	Normal	1.000	0.0095	0.0055	0.0045	0.0032	0.0055
Resolution of the device under calibration	Rectangular	1.732	0.0029	0.0029	0.0029	0.0029	0.0029
Hysteresis	Rectangular	1.732	0.0000	0.0000	0.0000	0.0000	0.0000
Combined uncertainty, %rh			**0.15**	**0.18**	**0.24**	**0.32**	**0.39**
Expanded uncertainty, %rh			**0.30**	**0.36**	**0.48**	**0.63**	**0.79**

Uncertainty budget at 50 °C

Source of uncertainty	Distribution	Divisor	Uncertainty contribution, %rh				
	Measurement Point		10	25	50	75	90
Temporal variation of the standard hygrometer	Normal	1.000	0.0032	0.0045	0.0032	0.0055	0.0032
Calibration uncertainty of the standard hygrometer	Normal	2.000	0.1100	0.1500	0.2200	0.3000	0.3800
Drift (Long-term instability)	Rectangular	1.732	0.0577	0.0577	0.0577	0.0577	0.0577
Resolution of the standard hygrometer	Rectangular	1.732	0.0029	0.0029	0.0029	0.0029	0.0029
Temporal instability in the climatic chamber	Rectangular	1.732	0.0577	0.0577	0.0577	0.0577	0.0577
Spatial inhomogeneity in the climatic chamber	Rectangular	1.732	0.0577	0.0577	0.0577	0.0577	0.0577
Temporal variation of the device under calibration	Normal	1.000	0.0045	0.0063	0.0045	0.0055	0.0032
Resolution of the device under calibration	Rectangular	1.732	0.0029	0.0029	0.0029	0.0029	0.0029
Hysteresis	Rectangular	1.732	0.0000	0.0000	0.0000	0.0000	0.0000
Combined uncertainty, %rh			**0.15**	**0.18**	**0.24**	**0.32**	**0.39**
Expanded uncertainty, %rh			**0.30**	**0.36**	**0.48**	**0.63**	**0.79**