Hybrid Comparison METAS - INRiM Realization of Dew/Frost-Point from -30 °C to 70 °C

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I.N.RI.M. TECHNICAL REPORT

Sommario

Su richiesta dell'istituto elvetico METAS è stato organizzato e realizzato un confronto ibrido bilaterale per quanto riguarda la realizzazione del punto di rugiada/brina nel campo tra -30 °C e 70 °C. l'INRIM ha partecipato nella funzione di coordinatore del confronto e di ISSUING NMI ed il METAS come APPLICANT NMI.

La finalità del confronto è dimostrare la capacità del METAS nel generare un gas umido di temperatura di rugiada noto per ottenere le CMC per la grandezza umidità relativa. L'attuale presidente EURAMET TC-T Dott. Steffen Rudtsch ha accettato di agire come terza parte indipendente.

Il confronto ha avuto luogo per mezzo di un campione di trasferimento individuato nell'igrometro MBW 373HX SN 06-0102 di proprietà del METAS. Le misure iniziali e finali per la determinazione della stabilità del campione di trasferimento sono state eseguite dal METAS.

I responsabili del confronto sono per INRIM il Dott. Denis Smorgon, per METAS il Dott. Remo Senn e per il PTB Dott. Steffen Rudtsch. Il sig. Riccardo Salerno ha partecipato alle misure nelle attività di misura ed elaborazione dei risultati di taratura.

L'INRIM ha emesso il certificato 22-0723-01 del 2023-03-08.

Dal Report a cura di Remo Senn, Federal Institute of Metrology METAS del 16th of March 2023

No. 151.05/2023

Hybrid Comparison METAS - INRiM for Dew/Frost-Point Realization from -30 °C to 70 °C

Applicant NMI

Federal Institute of Metrology METAS
Remo Senn
Lindenweg 50
3003 Bern-Wabern
SWITZERLAND

Issuing NMI

ISTITUTO NAZIONALE DI RICERCA METROLOGICA INRiM
Denis Smorgon
Strada delle Cacce, 91
10135 Torino
ITALY

Independent Third Party

EURAMET TC-T Chair
Steffen Rudtsch
Physikalisch-Technische Bundesanstalt PTB
Abbestrasse 2-12
10587 Berlin

Introduction

To demonstrate the technical competence at METAS with respect to dew/frost-point realizations, a hybrid measurement comparison was performed with INRiM. The comparison took place simultaneously with the calibration of the METAS transfer standard (dew point mirror) for its realization of relative humidity.

The current EURAMET TC-T Chair was informed in advance about the project and agreed to act as the third independent party.

Sommario

1. Transfer Standard

Dew point mirror MBW 373HX SN 06-0102

2. Comparison Schedule/Communication

- Direct measurements at METAS from 28th of September to 25th October 2022
- Measurements at INRiM between 10th of November and 21st of December 2022
- Return measurements at METAS from 8th of February to 21st February 2023

During the whole time period above, the communication between METAS and INRiM was forwarded as a copy to the independent third party, the EURAMET TC-T Chair.

INRiM sent the measurement results to the third party on 31st of January 2023. METAS sent all the results of the direct and return measurements to the third party on 22nd of February 2023

On 22nd of February 2023 METAS and INRiM received the confirmation from the third party to share the results and further analysis of the data.

3. METAS System and Measurement Procedure

3.1 Humidity Generator

Thunder Scientific 2500 SN 0811713 with METAS traceable calibrated temperature and pressure sensors. The same system was also part of EURAMET.T-K8.

3.2 Measurement Procedure

The transfer standard was connected directly to the generator output by means of a tee. The conditioned air from the generator is thus fed directly into the measuring chamber of the generator and expanded to atmospheric pressure and, on the other hand, the conditioned air can be fed directly to the transfer standard without the measuring chamber having a direct influence. To achieve the necessary flow rate for the transfer standard, the internal pump and display of the transfer standard was used to set the flow rate to 0.5-0.6 l/min. The pressure difference between the atmosphere and the measuring head of the transfer standard was determined and applied as a correction to the measurement results.

For both measurement loops (direct/return), three complete cycles were performed over the entire range from -30 °C to 69.5 °C. The order of the measuring points was always in the following ascending order of -30 °C, -20 °C, -10 °C, 0 °C, 10 °C, 20 °C, 30 °C, 40 °C, 50 °C, 60 °C, 69.5 °C.

For the points -30 °C, -20 °C and -10 °C the definition over ice (frost point) was applied and for all remaining points the definition over water (dew point). The "Forced Frost Point" function below -5 °C was set and

activated on the transfer standard. In this way, it was ensured that all three points really correspond to the correct definition over ice.

The final results of both measurement loops (direct/return) are represented by the mean value and standard deviation of the three realized cycles. This standard deviation represents the repeatability and the larger value of both loops was directly included in the uncertainty calculation as type A uncertainty. The observed standard deviation during the measurement of single point was also taken into account, but has no dominant influence when combining both type A values. The complete uncertainty budget can be found in the appendix of this report.

4. INRiM System and Measurement Procedure

The transfer standard was connected to the primary frost/dew-point generator. The primary generator INRIM-01 and INRIM-02 are both single pressure recirculation type generators working at fixed pressure kept during the calibration session approx. at 1050 hPa. The UUT was fed with a gas flow-rate of 0.5/0.6 l/min, the pressure drop between the point of realization and the measurement head of the UUT was measured and considered as negligible.

Two complete session of measurements were performed over the entire range from -30 °C to 69.5 °C. The order of the measuring points was always in the following ascending order of -30 °C, -20 °C, -10 °C, 0 °C, 10 °C, 20 °C, 30 °C, 40 °C, 50 °C, 60 °C, 69.5 °C.

For the points -30 °C, -20 °C and -10 °C the definition over ice (frost point) was applied and for all remaining points the definition over water (dew point). The "Forced Frost Point" function below -5 °C was set and activated on the transfer standard. In this way, it was ensured that all three points really correspond to the correct definition over ice.

The final results released correspond to the second set of measurements. The estimated uncertainty include a minor contribution due to the reproducibility of the UUT in the forming of the mirror condensate. This is the reason why the INRIM calibration uncertainty does not correspond to the current published CMC on the KCDB.

5. Results

T_{NOM}	Phase	REF	UUT	UUT-REF	*U* (*k*=2)
°C		°C	°C	°C	°C
-30	Ice	-30.00	-29.98	0.020	0.034
-20	Ice	-20.00	-20.04	-0.033	0.040
-10	Ice	-10.00	-10.02	-0.020	0.037
0	Water	0.00	0.00	0.004	0.041
10	Water	10.00	10.01	0.013	0.047
20	Water	19.99	19.99	0.004	0.043
30	Water	30.00	30.01	0.007	0.042
40	Water	40.00	40.00	0.001	0.041
50	Water	50.00	50.01	0.002	0.048
60	Water	60.00	60.01	0.005	0.047
69.5	Water	69.50	69.54	0.039	0.050

Table 1: Direct Measurements METAS

T_{NOM}	Phase	REF	UUT	UUT-REF	*U* (*k*=2)
°C		°C	°C	°C	°C
-30	Ice	-30.00	-29.99	0.012	0.034
-20	Ice	-20.01	-20.04	-0.033	0.040
-10	Ice	-10.00	-10.02	-0.025	0.037
0	Water	0.00	0.00	0.000	0.041
10	Water	10.00	10.00	-0.005	0.047
20	Water	20.00	19.99	-0.014	0.043
30	Water	29.98	29.98	-0.002	0.042
40	Water	40.00	39.99	-0.005	0.041
50	Water	49.99	49.98	-0.007	0.048
60	Water	60.00	60.00	0.002	0.047
69.5	Water	69.50	69.54	0.031	0.050

Table 2: Return Measurements METAS

T_{NOM}	Phase	REF	UUT	UUT-REF	U (k=2)
°C		°C	°C	°C	°C
-30	Ice	-30.06	-30.06	0.00	0.06
-20	Ice	-20.07	-20.07	0.00	0.06
-10	Ice	-10.09	-10.09	0.00	0.06
0.1	Water	0.09	0.06	-0.03	0.06
10	Water	10.04	10.02	-0.02	0.06
20	Water	20.11	20.09	-0.02	0.06
30	Water	30.10	30.07	-0.03	0.06
40	Water	40.02	39.98	-0.04	0.06
50	Water	50.11	50.07	-0.04	0.06
60	Water	60.09	60.05	-0.04	0.06
68.5	Water	68.54	68.48	-0.06	0.06
69.5	Water	69.53	69.47	-0.06	0.06

Table 3: INRiM Measurements

T_{NOM}	Phase	$Drift_{Transfer}$
°C		°C
-30	Ice	-0.007
-20	Ice	0.000
-10	Ice	-0.004
0	Water	-0.004
10	Water	-0.017
20	Water	-0.017
30	Water	-0.009
40	Water	-0.007
50	Water	-0.010
60	Water	-0.004
69.5	Water	-0.008

Table 4: Drift of the Transfer Standard

5.1 Degree of Equivalence

The comparison results can now be easily expressed in terms of degree of equivalence:

- $T_{METAS} - T_{INRiM}$
- $U(T_{METAS} - T_{INRiM}) = 2 \cdot \sqrt{U^2{}_{METAS} + U^2{}_{INRiM} + \left(Drift_{Transfer} / \sqrt{3}\right)^2}$

T_{NOM}	Phase	$T_{METAS-INRiM}$	$U_{METAS-INRiM}$ (k=2)	En
°C		°C	°C	°C/°C
-30	Ice	0.020	0.073	0.24
-20	Ice	-0.033	0.074	0.41
-10	Ice	-0.020	0.070	0.26
0	Water	0.034	0.070	0.44
10	Water	0.033	0.077	0.42
20	Water	0.024	0.075	0.30
30	Water	0.037	0.072	0.49
40	Water	0.041	0.071	0.54
50	Water	0.042	0.075	0.55
60	Water	0.045	0.074	0.60
69.5	Water	0.099	0.076	1.29

Table 5: Degrees of equivalence and corresponding expanded uncertainty (k=2) for this comparison.

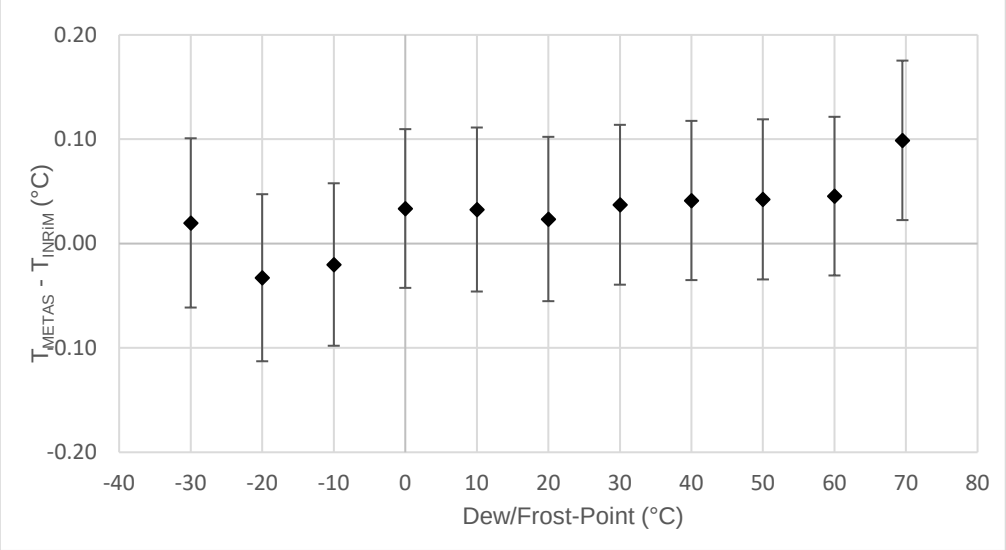

Figure 1: Degree of equivalence and corresponding expanded uncertainty (k=2) for each measurement point.

Attachment: METAS Uncertainty Budgets

Quantity (symbol)	Components	Standard uncertainty		Sensitivity coefficient		Uncertainty contribution
Q_i		$u_{(Qi)}$		c_i		u_i in °C
Frost point -30 °C						
Saturation temperature						
	Thermometer:					
	Calibration uncertainty (sensor and indicator unit)	0.005	°C	1	°C	0.005
	Long-term stability (sensor and indicator)	0.005	°C	1	°C	0.005
	Self-heating and residual heat fluxes (sensor)	0.001	°C	1	°C	0.001
	Resolution and linearity (indicator unit)	0.003	°C	1	°C	0.003
	Saturator:					
	Temperature homogeneity	0.005	°C	1	°C	0.005
	Temperature stability	0.002	°C	1	°C	0.002
Saturation pressure**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	1.386	°C/bar	0.0003
	Long-term stability (sensor and indicator)	0.0001	bar	1.386	°C/bar	0.0001
	Resolution and accuracy or linearity (indicator unit)	0.0001	bar	1.386	°C/bar	0.0001
	Linearity	0.0020	bar	1.386	°C/bar	0.0028
	Pressure differences in the saturator cell	0.0001	bar	1.386	°C/bar	0.0001
	Stability of the pressure	0.0002	bar	1.386	°C/bar	0.0003
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	1.386	°C/bar	0.0003
Gas pressure at the generator outlet**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	9.889	°C/bar	0.0021
	Long-term stability (sensor and indicator)	0.0001	bar	9.889	°C/bar	0.0010
	Resolution (indicator unit)	0.0001	bar	9.889	°C/bar	0.0010
	Linearity (over a range of ±10 hPa against the calibration point)	0.0004	bar	9.889	°C/bar	0.0040
	Stability of the pressure	0.0000	bar	9.889	°C/bar	0.0002
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	9.889	°C/bar	0.0020
Saturation efficiency						
	Saturation efficiency	0.006	°C	1		0.0060
Uncertainty due to formulae/calculations						
	Saturation vapour pressure formula(e)	0.006	°C	1	°C/°C	0.006
	Water vapour enhancement formula(e)	0.001	°C	1	°C/°C	0.001
Other uncertainties						
	Accuracy of the pressure drop correction DUT point of measurement	0.0001	bar	9.889	°C/bar	0.0010
	DUT Typ A Uncertainty	0.011	°C	1	°C/°C	0.011
Combined uncertainty						0.018
Expanded uncertainty						0.034

Quantity (symbol)	Components	Standard uncertainty		Sensitivity coefficient		Uncertainty contribution
Q_i		$u_{(Qi)}$		c_i		u_i in °C
Frost point -20 °C						
Saturation temperature						
	Thermometer:					
	Calibration uncertainty (sensor and indicator unit)	0.005	°C	1	°C	0.005
	Long-term stability (sensor and indicator)	0.005	°C	1	°C	0.005
	Self-heating and residual heat fluxes (sensor)	0.001	°C	1	°C	0.001
	Resolution and linearity (indicator unit)	0.003	°C	1	°C	0.003
	Saturator:					
	Temperature homogeneity	0.005	°C	1	°C	0.005
	Temperature stability	0.002	°C	1	°C	0.002
Saturation pressure**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	1.643	°C/bar	0.0003
	Long-term stability (sensor and indicator)	0.0001	bar	1.643	°C/bar	0.0002
	Resolution and accuracy or linearity (indicator unit)	0.0001	bar	1.643	°C/bar	0.0002
	Linearity	0.0020	bar	1.643	°C/bar	0.0033
	Pressure differences in the saturator cell	0.0001	bar	1.643	°C/bar	0.0002
	Stability of the pressure	0.0002	bar	1.643	°C/bar	0.0003
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	1.643	°C/bar	0.0003
Gas pressure at the generator outlet**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	10.778	°C/bar	0.0023
	Long-term stability (sensor and indicator)	0.0001	bar	10.778	°C/bar	0.0011
	Resolution (indicator unit)	0.0001	bar	10.778	°C/bar	0.0011
	Linearity (over a range of ±10 hPa against the calibration point)	0.0004	bar	10.778	°C/bar	0.0043
	Stability of the pressure	0.0000	bar	10.778	°C/bar	0.0002
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	10.778	°C/bar	0.0022
Saturation efficiency						
	Saturation efficiency	0.006	°C	1		0.0060
Uncertainty due to formulae/calculations						
	Saturation vapour pressure formula(e)	0.006	°C	1	°C/°C	0.006
	Water vapour enhancement formula(e)	0.001	°C	1	°C/°C	0.001
Other uncertainties						
	Accuracy of the pressure drop correction	0.0001	bar	10.778	°C/bar	0.0011
	DUT Typ A Uncertainty	0.014	°C	1	°C/°C	0.014
Combined uncertainty						0.020
Expanded uncertainty						0.040

Quantity (symbol)	Components	Standard uncertainty		Sensitivity coefficient		Uncertainty contribution
Q_i		$u_{(Qi)}$		c_i		u_i in °C
Frost point -10 °C						
Saturation temperature						
	Thermometer:					
	Calibration uncertainty (sensor and indicator unit)	0.005	°C	1	°C	0.005
	Long-term stability (sensor and indicator)	0.005	°C	1	°C	0.005
	Self-heating and residual heat fluxes (sensor)	0.001	°C	1	°C	0.001
	Resolution and linearity (indicator unit)	0.003	°C	1	°C	0.003
	Saturator:					
	Temperature homogeneity	0.005	°C	1	°C	0.005
	Temperature stability	0.002	°C	1	°C	0.002
Saturation pressure**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	2.407	°C/bar	0.0005
	Long-term stability (sensor and indicator)	0.0001	bar	2.407	°C/bar	0.0002
	Resolution and accuracy or linearity (indicator unit)	0.0001	bar	2.407	°C/bar	0.0002
	Linearity	0.0020	bar	2.407	°C/bar	0.0048
	Pressure differences in the saturator cell	0.0001	bar	2.407	°C/bar	0.0002
	Stability of the pressure	0.0002	bar	2.407	°C/bar	0.0005
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	2.407	°C/bar	0.0005
Gas pressure at the generator outlet**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	11.611	°C/bar	0.0024
	Long-term stability (sensor and indicator)	0.0001	bar	11.611	°C/bar	0.0012
	Resolution (indicator unit)	0.0001	bar	11.611	°C/bar	0.0012
	Linearity (over a range of ±10 hPa against the calibration point)	0.0004	bar	11.611	°C/bar	0.0046
	Stability of the pressure	0.0000	bar	11.611	°C/bar	0.0002
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	11.611	°C/bar	0.0023
Saturation efficiency						
	Saturation efficiency	0.006	°C	1	°C/°C	0.0060
Uncertainty due to formulae/calculations						
	Saturation vapour pressure formula(e)	0.006	°C	1	°C/°C	0.006
	Water vapour enhancement formula(e)	0.001	°C	1	°C/°C	0.001
Other uncertainties						
	Accuracy of the pressure drop correction	0.0001	bar	11.611	°C/bar	0.0012
	DUT Typ A Uncertainty	0.012	°C	1	°C/°C	0.012
Combined uncertainty						0.019
Expanded uncertainty						0.037

Quantity (symbol)	Components	Standard uncertainty		Sensitivity coefficient		Uncertainty contribution
Q_i		$u_{(Qi)}$		c_i		u_i in °C
Dew point 0 °C						
Saturation temperature						
	Thermometer:					
	Calibration uncertainty (sensor and indicator unit)	0.005	°C	1	°C	0.005
	Long-term stability (sensor and indicator)	0.005	°C	1	°C	0.005
	Self-heating and residual heat fluxes (sensor)	0.001	°C	1	°C	0.001
	Resolution and linearity (indicator unit)	0.003	°C	1	°C	0.003
	Saturator:					
	Temperature homogeneity	0.005	°C	1	°C	0.005
	Temperature stability	0.002	°C	1	°C	0.002
Saturation pressure**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	1.871	°C/bar	0.0004
	Long-term stability (sensor and indicator)	0.0001	bar	1.871	°C/bar	0.0002
	Resolution and accuracy or linearity (indicator unit)	0.0001	bar	1.871	°C/bar	0.0002
	Linearity	0.0020	bar	1.871	°C/bar	0.0037
	Pressure differences in the saturator cell	0.0001	bar	1.871	°C/bar	0.0002
	Stability of the pressure	0.0002	bar	1.871	°C/bar	0.0004
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	1.871	°C/bar	0.0004
Gas pressure at the generator outlet**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	14.222	°C/bar	0.0030
	Long-term stability (sensor and indicator)	0.0001	bar	14.222	°C/bar	0.0014
	Resolution (indicator unit)	0.0001	bar	14.222	°C/bar	0.0014
	Linearity (over a range of ±10 hPa against the calibration point)	0.0004	bar	14.222	°C/bar	0.0057
	Stability of the pressure	0.0000	bar	14.222	°C/bar	0.0003
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	14.222	°C/bar	0.0028
Saturation efficiency						
	Saturation efficiency	0.006	°C	1	°C/°C	0.0060
Uncertainty due to formulae/calculations						
	Saturation vapour pressure formula(e)	0.006	°C	1	°C/°C	0.006
	Water vapour enhancement formula(e)	0.001	°C	1	°C/°C	0.001
Other uncertainties						
	Accuracy of the pressure drop correction	0.0001	bar	14.222	°C/bar	0.0014
	DUT Typ A Uncertainty	0.014	°C	1	°C/°C	0.014
Combined uncertainty						0.021
Expanded uncertainty						0.041

Quantity (symbol)	Components	Standard uncertainty		Sensitivity coefficient		Uncertainty contribution
Q_i		$u_{(Qi)}$		c_i		u_i in °C
Dew point 10 °C						
Saturation temperature						
	Thermometer:					
	Calibration uncertainty (sensor and indicator unit)	0.005	°C	1	°C	0.005
	Long-term stability (sensor and indicator)	0.005	°C	1	°C	0.005
	Self-heating and residual heat fluxes (sensor)	0.001	°C	1	°C	0.001
	Resolution and linearity (indicator unit)	0.003	°C	1	°C	0.003
	Saturator:					
	Temperature homogeneity	0.005	°C	1	°C	0.005
	Temperature stability	0.002	°C	1	°C	0.002
Saturation pressure**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	4.157	°C/bar	0.0009
	Long-term stability (sensor and indicator)	0.0001	bar	4.157	°C/bar	0.0004
	Resolution and accuracy or linearity (indicator unit)	0.0001	bar	4.157	°C/bar	0.0004
	Linearity	0.0020	bar	4.157	°C/bar	0.0083
	Pressure differences in the saturator cell	0.0001	bar	4.157	°C/bar	0.0004
	Stability of the pressure	0.0002	bar	4.157	°C/bar	0.0008
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	4.157	°C/bar	0.0008
Gas pressure at the generator outlet**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	15.444	°C/bar	0.0032
	Long-term stability (sensor and indicator)	0.0001	bar	15.444	°C/bar	0.0015
	Resolution (indicator unit)	0.0001	bar	15.444	°C/bar	0.0015
	Linearity (over a range of ±10 hPa against the calibration point)	0.0004	bar	15.444	°C/bar	0.0062
	Stability of the pressure	0.0000	bar	15.444	°C/bar	0.0003
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	15.444	°C/bar	0.0031
Saturation efficiency						
	Saturation efficiency	0.006	°C	1	°C/°C	0.0060
Uncertainty due to formulae/calculations						
	Saturation vapour pressure formula(e)	0.006	°C	1	°C/°C	0.006
	Water vapour enhancement formula(e)	0.001	°C	1	°C/°C	0.001
Other uncertainties						
	Accuracy of the pressure drop correction	0.0001	bar	14.222	°C/bar	0.0014
	DUT Typ A Uncertainty	0.017	°C	1	°C/°C	0.017
Combined uncertainty						0.024
Expanded uncertainty						0.047

Quantity (symbol)	Components	Standard uncertainty		Sensitivity coefficient		Uncertainty contribution
Q_i		$u_{(Qi)}$		c_i		u_i in °C
Dew point 20 °C						
Saturation temperature						
	Thermometer:					
	Calibration uncertainty (sensor and indicator unit)	0.005	°C	1	°C	0.005
	Long-term stability (sensor and indicator)	0.005	°C	1	°C	0.005
	Self-heating and residual heat fluxes (sensor)	0.001	°C	1	°C	0.001
	Resolution and linearity (indicator unit)	0.003	°C	1	°C	0.003
	Saturator:					
	Temperature homogeneity	0.005	°C	1	°C	0.005
	Temperature stability	0.002	°C	1	°C	0.002
Saturation pressure**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	2.414	°C/bar	0.0005
	Long-term stability (sensor and indicator)	0.0001	bar	2.414	°C/bar	0.0002
	Resolution and accuracy or linearity (indicator unit)	0.0001	bar	2.414	°C/bar	0.0002
	Linearity	0.0020	bar	2.414	°C/bar	0.0048
	Pressure differences in the saturator cell	0.0001	bar	2.414	°C/bar	0.0002
	Stability of the pressure	0.0002	bar	2.414	°C/bar	0.0005
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	2.414	°C/bar	0.0005
Gas pressure at the generator outlet**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	16.667	°C/bar	0.0035
	Long-term stability (sensor and indicator)	0.0001	bar	16.667	°C/bar	0.0017
	Resolution (indicator unit)	0.0001	bar	16.667	°C/bar	0.0017
	Linearity (over a range of ±10 hPa against the calibration point)	0.0004	bar	16.667	°C/bar	0.0067
	Stability of the pressure	0.0000	bar	16.667	°C/bar	0.0003
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	16.667	°C/bar	0.0033
Saturation efficiency						
	Saturation efficiency	0.006	°C	1	°C/°C	0.0060
Uncertainty due to formulae/calculations						
	Saturation vapour pressure formula(e)	0.006	°C	1	°C/°C	0.006
	Water vapour enhancement formula(e)	0.001	°C	1	°C/°C	0.001
Other uncertainties						
	Accuracy of the pressure drop correction	0.0001	bar	16.667	°C/bar	0.0017
	DUT Typ A Uncertainty	0.015	°C	1	°C/°C	0.015
Combined uncertainty						0.022
Expanded uncertainty						0.043

Quantity (symbol)	Components	Standard uncertainty		Sensitivity coefficient		Uncertainty contribution
Q_i		$u_{(Qi)}$		c_i		u_i in °C
Dew point 30 °C						
Saturation temperature						
	Thermometer:					
	Calibration uncertainty (sensor and indicator unit)	0.005	°C	1	°C	0.005
	Long-term stability (sensor and indicator)	0.005	°C	1	°C	0.005
	Self-heating and residual heat fluxes (sensor)	0.001	°C	1	°C	0.001
	Resolution and linearity (indicator unit)	0.003	°C	1	°C	0.003
	Saturator:					
	Temperature homogeneity	0.005	°C	1	°C	0.005
	Temperature stability	0.002	°C	1	°C	0.002
Saturation pressure**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	4.786	°C/bar	0.0010
	Long-term stability (sensor and indicator)	0.0001	bar	4.786	°C/bar	0.0005
	Resolution and accuracy or linearity (indicator unit)	0.0001	bar	4.786	°C/bar	0.0005
	Linearity	0.0020	bar	4.786	°C/bar	0.0096
	Pressure differences in the saturator cell	0.0001	bar	4.786	°C/bar	0.0005
	Stability of the pressure	0.0002	bar	4.786	°C/bar	0.0010
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	4.786	°C/bar	0.0010
Gas pressure at the generator outlet**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	18.000	°C/bar	0.0038
	Long-term stability (sensor and indicator)	0.0001	bar	18.000	°C/bar	0.0018
	Resolution (indicator unit)	0.0001	bar	18.000	°C/bar	0.0018
	Linearity (over a range of ±10 hPa against the calibration point)	0.0004	bar	18.000	°C/bar	0.0072
	Stability of the pressure	0.0000	bar	18.000	°C/bar	0.0004
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	18.000	°C/bar	0.0036
Saturation efficiency						
	Saturation efficiency	0.006	°C	1	°C/°C	0.0060
Uncertainty due to formulae/calculations						
	Saturation vapour pressure formula(e)	0.006	°C	1	°C/°C	0.006
	Water vapour enhancement formula(e)	0.001	°C	1	°C/°C	0.001
Other uncertainties						
	Accuracy of the pressure drop correction	0.0001	bar	18.000	°C/bar	0.0018
	DUT Typ A Uncertainty	0.011	°C	1	°C/°C	0.011
Combined uncertainty						0.022
Expanded uncertainty						0.042

Quantity (symbol)	Components	Standard uncertainty		Sensitivity coefficient		Uncertainty contribution
Q_i		$u_{(Qi)}$		c_i		u_i in °C
Dew point 40 °C						
Saturation temperature						
	Thermometer:					
	Calibration uncertainty (sensor and indicator unit)	0.005	°C	1	°C	0.005
	Long-term stability (sensor and indicator)	0.005	°C	1	°C	0.005
	Self-heating and residual heat fluxes (sensor)	0.001	°C	1	°C	0.001
	Resolution and linearity (indicator unit)	0.003	°C	1	°C	0.003
	Saturator:					
	Temperature homogeneity	0.005	°C	1	°C	0.005
	Temperature stability	0.002	°C	1	°C	0.002
Saturation pressure**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	4.529	°C/bar	0.0010
	Long-term stability (sensor and indicator)	0.0001	bar	4.529	°C/bar	0.0005
	Resolution and accuracy or linearity (indicator unit)	0.0001	bar	4.529	°C/bar	0.0005
	Linearity	0.0020	bar	4.529	°C/bar	0.0091
	Pressure differences in the saturator cell	0.0001	bar	4.529	°C/bar	0.0005
	Stability of the pressure	0.0002	bar	4.529	°C/bar	0.0009
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	4.529	°C/bar	0.0009
Gas pressure at the generator outlet**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	19.444	°C/bar	0.0041
	Long-term stability (sensor and indicator)	0.0001	bar	19.444	°C/bar	0.0019
	Resolution (indicator unit)	0.0001	bar	19.444	°C/bar	0.0019
	Linearity (over a range of ±10 hPa against the calibration point)	0.0004	bar	19.444	°C/bar	0.0078
	Stability of the pressure	0.0000	bar	19.444	°C/bar	0.0004
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	19.444	°C/bar	0.0039
Saturation efficiency						
	Saturation efficiency	0.006	°C	1	°C/°C	0.0060
Uncertainty due to formulae/calculations						
	Saturation vapour pressure formula(e)	0.006	°C	1	°C/°C	0.006
	Water vapour enhancement formula(e)	0.001	°C	1	°C/°C	0.001
Other uncertainties						
	Accuracy of the pressure drop correction	0.0001	bar	19.444	°C/bar	0.0019
	DUT Typ A Uncertainty	0.009	°C	1	°C/°C	0.009
Combined uncertainty						0.021
Expanded uncertainty						0.041

Quantity (symbol)	Components	Standard uncertainty		Sensitivity coefficient		Uncertainty contribution
Q_i		$u_{(Qi)}$		c_i		u_i in °C
Dew point 50 °C						
Saturation temperature						
	Thermometer:					
	Calibration uncertainty (sensor and indicator unit)	0.005	°C	1	°C	0.005
	Long-term stability (sensor and indicator)	0.005	°C	1	°C	0.005
	Self-heating and residual heat fluxes (sensor)	0.001	°C	1	°C	0.001
	Resolution and linearity (indicator unit)	0.003	°C	1	°C	0.003
	Saturator:					
	Temperature homogeneity	0.005	°C	1	°C	0.005
	Temperature stability	0.002	°C	1	°C	0.002
Saturation pressure**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	8.222	°C/bar	0.0017
	Long-term stability (sensor and indicator)	0.0001	bar	8.222	°C/bar	0.0008
	Resolution and accuracy or linearity (indicator unit)	0.0001	bar	8.222	°C/bar	0.0008
	Linearity	0.0004	bar	8.222	°C/bar	0.0033
	Pressure differences in the saturator cell	0.0000	bar	8.222	°C/bar	0.0002
	Stability of the pressure	0.0002	bar	8.222	°C/bar	0.0016
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	8.222	°C/bar	0.0016
Gas pressure at the generator outlet**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	20.889	°C/bar	0.0044
	Long-term stability (sensor and indicator)	0.0001	bar	20.889	°C/bar	0.0021
	Resolution (indicator unit)	0.0001	bar	20.889	°C/bar	0.0021
	Linearity (over a range of ±10 hPa against the calibration point)	0.0004	bar	20.889	°C/bar	0.0084
	Stability of the pressure	0.0000	bar	20.889	°C/bar	0.0004
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	20.889	°C/bar	0.0042
Saturation efficiency						
	Saturation efficiency	0.006	°C	1	°C/°C	0.0060
Uncertainty due to formulae/calculations						
	Saturation vapour pressure formula(e)	0.006	°C	1	°C/°C	0.006
	Water vapour enhancement formula(e)	0.001	°C	1	°C/°C	0.001
Other uncertainties						
	Accuracy of the pressure drop correction	0.0001	bar	20.889	°C/bar	0.0021
	DUT Typ A Uncertainty	0.017	°C	1	°C/°C	0.017
Combined uncertainty						0.024
Expanded uncertainty						0.048

Quantity (symbol)	Components	Standard uncertainty		Sensitivity coefficient		Uncertainty contribution
Q_i		$u_{(Qi)}$		c_i		u_i in °C
Dew point 60 °C						
Saturation temperature						
	Thermometer:					
	Calibration uncertainty (sensor and indicator unit)	0.005	°C	1	°C	0.005
	Long-term stability (sensor and indicator)	0.005	°C	1	°C	0.005
	Self-heating and residual heat fluxes (sensor)	0.001	°C	1	°C	0.001
	Resolution and linearity (indicator unit)	0.003	°C	1	°C	0.003
	Saturator:					
	Temperature homogeneity	0.005	°C	1	°C	0.005
	Temperature stability	0.002	°C	1	°C	0.002
Saturation pressure**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	14.222	°C/bar	0.0030
	Long-term stability (sensor and indicator)	0.0001	bar	14.222	°C/bar	0.0014
	Resolution and accuracy or linearity (indicator unit)	0.0001	bar	14.222	°C/bar	0.0014
	Linearity	0.0004	bar	14.222	°C/bar	0.0057
	Pressure differences in the saturator cell	0.0000	bar	14.222	°C/bar	0.0003
	Stability of the pressure	0.0002	bar	14.222	°C/bar	0.0028
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	14.222	°C/bar	0.0028
Gas pressure at the generator outlet**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	22.333	°C/bar	0.0047
	Long-term stability (sensor and indicator)	0.0001	bar	22.333	°C/bar	0.0022
	Resolution (indicator unit)	0.0001	bar	22.333	°C/bar	0.0022
	Linearity (over a range of ±10 hPa against the calibration point)	0.0004	bar	22.333	°C/bar	0.0089
	Stability of the pressure	0.0000	bar	22.333	°C/bar	0.0004
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	22.333	°C/bar	0.0045
Saturation efficiency						
	Saturation efficiency	0.006	°C	1	°C/°C	0.0060
Uncertainty due to formulae/calculations						
	Saturation vapour pressure formula(e)	0.006	°C	1	°C/°C	0.006
	Water vapour enhancement formula(e)	0.001	°C	1	°C/°C	0.001
Other uncertainties						
	Accuracy of the pressure drop correction	0.0001	bar	22.333	°C/bar	0.0022
	DUT Typ A Uncertainty	0.015	°C	1	°C/°C	0.015
Combined uncertainty						0.024
Expanded uncertainty						0.047

Quantity (symbol)	Components	Standard uncertainty		Sensitivity coefficient		Uncertainty contribution
Q_i		$u_{(Qi)}$		c_i		u_i in °C
Dew point 69.5 °C						
Saturation temperature						
	Thermometer:					
	Calibration uncertainty (sensor and indicator unit)	0.005	°C	1	°C	0.005
	Long-term stability (sensor and indicator)	0.005	°C	1	°C	0.005
	Self-heating and residual heat fluxes (sensor)	0.001	°C	1	°C	0.001
	Resolution and linearity (indicator unit)	0.003	°C	1	°C	0.003
	Saturator:					
	Temperature homogeneity	0.005	°C	1	°C	0.005
	Temperature stability	0.002	°C	1	°C	0.002
Saturation pressure**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	23.333	°C/bar	0.0049
	Long-term stability (sensor and indicator)	0.0001	bar	23.333	°C/bar	0.0023
	Resolution and accuracy or linearity (indicator unit)	0.0001	bar	23.333	°C/bar	0.0023
	Linearity	0.0004	bar	23.333	°C/bar	0.0093
	Pressure differences in the saturator cell	0.0000	bar	23.333	°C/bar	0.0005
	Stability of the pressure	0.0002	bar	23.333	°C/bar	0.0047
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	23.333	°C/bar	0.0047
Gas pressure at the generator outlet**						
	Pressure gauge:					
	Calibration uncertainty (sensor and indicator unit)	0.0002	bar	23.778	°C/bar	0.0050
	Long-term stability (sensor and indicator)	0.0001	bar	23.778	°C/bar	0.0024
	Resolution (indicator unit)	0.0001	bar	23.778	°C/bar	0.0024
	Linearity (over a range of ±10 hPa against the calibration point)	0.0004	bar	23.778	°C/bar	0.0095
	Stability of the pressure	0.0000	bar	23.778	°C/bar	0.0005
	Effect of the tubing between the saturator and the pressure gauge	0.0002	bar	23.778	°C/bar	0.0048
Saturation efficiency						
	Saturation efficiency	0.006	°C	1	°C/°C	0.0060
Uncertainty due to formulae/calculations						
	Saturation vapour pressure formula(e)	0.006	°C	1	°C/°C	0.006
	Water vapour enhancement formula(e)	0.001	°C	1	°C/°C	0.001
Other uncertainties						
	Accuracy of the pressure drop correction	0.0001	bar	23.778	°C/bar	0.0024
	DUT Typ A Uncertainty	0.013	°C	1	°C/°C	0.013
Combined uncertainty						0.026
Expanded uncertainty						0.050

----------END OF THE DOCUMENT/FINE DEL DOCUMENTO----------

Appendix 1: INRIM Calibration Certificate 22-0723-01

Prot. n. 0004016 del 09/03/2023 - [UOR: 21 - Classif. III/9]

INRiM
ISTITUTO NAZIONALE
DI RICERCA METROLOGICA

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CERTIFICATO DI TARATURA

Certificate of Calibration

N. 22-0723-01 emesso il/*issued on* 2023-03-08

Oggetto *Item/Object*	DIGITAL HYGROMETER FOR MEASUREMENT OF THE DEW/FROST POINT
Modello/Tipo *Model/Type*	373HX
Identificazione *Serial number*	06-0102
Costruttore *Manufacturer*	MBW
Data ricevimento oggetto *Date of receipt of item*	2022-11-09
Data delle misure *Date of Measurements*	From 2022-11-14 to 2022-12-20
Procedura applicata *Applied procedure*	PT-T-3.1-01 Rev. 05
Registro di laboratorio *Laboratory record book*	1194
Committente *Customer*	Federal Institute of Metrology METAS
Indirizzo *Address*	Lindenweg 50, CH-3003 Berne-Wabern, Switzerland

CIPM MRA

Responsabile attività
Responsible for the activities

(Giulio Beltramino)

Autorizzato da
Authorized by
Metrologia applicata e ingegneria
Il Responsabile

PER (Michela Sega)

Il presente certificato attesta la riferibilità delle misure ai Campioni Nazionali (D.M. n. 591/1993) e alle unità di misura realizzate all'INRIM o in altri Istituti Metrologici Primari ai sensi della Legge n. 273/1991.
I risultati qui riportati si riferiscono esclusivamente agli oggetti descritti e alle condizioni di misura specificate.
L'autenticità del presente certificato è attestata dall'apposizione in originale delle firme e del timbro a secco.
La riproduzione del presente certificato è ammessa solo in copia conforme integrale; la riproduzione in copia conforme parziale è ammessa solo su autorizzazione scritta rilasciata dall'INRIM, da riportare con il numero di protocollo sulla riproduzione.

1. MISURANDO E METODO DI MISURA/*MEASURAND AND MEASUREMENT METHOD*

Il misurando è la temperatura di rugiada/brina generata dal generatore campione di riferimento INRIM 01 o INRIM 02. Lo strumento in taratura, collegato ad una delle uscite del generatore campione, è stato alimentato con una portata di gas umido ad una pressione di circa 1050 hPa. La taratura è avvenuta per metodo diretto confrontando la temperatura di rugiada/brina di riferimento prodotta dai generatori di gas umido con la lettura dello strumento in taratura.

The measurand is the dew/frost temperature generated by the primary generator INRIM 01 or INRIM 02. The unit under test (UUT), connected to one of the outputs of the primary generator, was fed with a humidified gas at a pressure of approx. 1050 hPa. The calibration took place by comparing the reference dew/frost temperature with the readings of the UUT.

2. RIFERIBILITÀ DELLE MISURE/*METROLOGICAL TRACEABILITY*

La riferibilità della temperatura di rugiada/brina di riferimento è garantita con i certificati:

The traceability of the reference dew/frost temperature is ensured with certificates:

Instrument	Identification	Certificate n.	Date of issue	Issued by
Numeral multimeter	2823A 07224	20-0714-01	03/11/2020	INRIM
Thermometric chain (PRT+Read-out)	90,92,93,94,95,96 + 443/25	19-0028-01	15/01/2019	INRIM
Numeral multimeter	11933	19-0699-01	10/04/2019	INRIM
Thermometric chain (PRT+Read-out)	86,87,88,89 +389/5	20-0059-01	22/01/2020	INRIM

3. LUOGO E CONDIZIONI DI MISURA/*SITE AND MEASUREMENT CONDITIONS*

Luogo svolgimento attività: / *Place of activity*:

INRIM – Hygrometry laboratory.

Condizioni di misura: / *Measurement conditions*:

Temperature:	**(25 ± 5)**	**[°C]**
Relative Humidity:	**na**	**[%UR]**

4. RISULTATI E INCERTEZZE DI MISURA/*RESULTS AND EXPANDED UNCERTAINTIES*

I risultati della taratura per la grandezza temperatura di rugiada/brina sono riportati nella tabella 1.

The results of the calibration for the dew temperature are reported in table 1

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Tabella 1: Risultati della taratura – Visore e Uscita digitale

Table 1: Calibration results – Display and Digital Output

N. ordine	*FASE*	t_{head} °C	Φ *l/min*	t_{RIF} (°C)	t_{UUT} (°C)	t_{UUT}-t_{RIF} (°C)	*U* (°C)	*NOTA*
#	*PHASE*	t_{head}	Φ	t_{REF}	t_{UUT}	t_{UUT}-t_{REF}	*U*	*NOTE*
1	Ice	28	0.5	-30.06	-30.06	0.00	0.06	A
2	Ice	23	0.5	-20.07	-20.07	0.00	0.06	A
3	Ice	26	0.5	-10.09	-10.09	0.00	0.06	A
4	Water	26	0.5	0.09	0.06	-0.03	0.06	A
5	Water	40	0.5	10.04	10.02	-0.02	0.06	A
6	Water	50	0.5	20.11	20.09	-0.02	0.06	A
7	Water	60	0.5	30.10	30.07	-0.03	0.06	A
8	Water	70	0.5	40.02	39.98	-0.04	0.06	A
9	Water	80	0.5	50.11	50.07	-0.04	0.06	A
10	Water	90	0.5	60.09	60.05	-0.04	0.06	A
11	Water	90	0.5	68.54	68.48	-0.06	0.06	B
12	Water	90	0.5	69.53	69.47	-0.06	0.06	B

Significato dei simboli:

FASE	=	fase del condensato sullo specchio dello strumento in taratura.
t_{head}	=	temperatura del corpo sensore letta dallo strumento in taratura.
Φ	=	portata di gas verso lo strumento in taratura.
t_{RIF}	=	temperatura di rugiada/brina di riferimento.
t_{UUT}	=	temperatura di rugiada/brina letta dallo strumento in taratura.
U	=	incertezza estesa di taratura.

Meaning of the symbols:

PHASE	=	*phase of the condensate on the mirror of the UUT.*
t_{head}	=	*temperature of the sensor body measured by the UUT.*
Φ	=	*gas flow-rate to the UUT.*
t_{REF}	=	*reference dew/frost temperature.*
t_{UUT}	=	*dew/frost temperature measured by the UUT.*
U	=	*expanded calibration uncertainty.*

Alla determinazione dell'incertezza di taratura concorrono l'incertezza nella determinazione delle condizioni applicate e la risoluzione, la ripetibilità e la riproducibilità dello strumento in taratura.
L'incertezza estesa di taratura *U* è espressa come l'incertezza tipo moltiplicata per il fattore di copertura $k = 2$, che per una distribuzione normale di probabilità corrisponde ad una copertura di circa il 95%.
Nella valutazione dell'incertezza di taratura, non è stata considerata la stabilità a lungo termine e la dello strumento in taratura.

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The calibration uncertainty was estimated considering the uncertainty contributions due to the determination of the applied conditions (t_{REF}), the resolution, the repeatability and the reproducibility of the UUT.

The expanded calibration uncertainty U is expressed as the standard uncertainty multiplied by the coverage factor k = 2, which for a normal probability distribution corresponds to a coverage of approximately 95%.

In the evaluation of the uncertainty, the long-term stability of the UUT was not considered.

5. NOTE/*NOTES*

Nota A - Questo certificato è coerente con le capacità di taratura e misura (CMCs) che sono incluse nell'appendice C dell'Accordo di Mutuo Riconoscimento (CIPM MRA) redatto dal Comitato Internazionale dei Pesi e Misure (CIPM). Nell'ambito del CIPM MRA, tutti gli Istituti partecipanti riconoscono reciprocamente la validità dei certificati di taratura e misura per le grandezze, i campi di misura e le incertezze specificate nel KCDB (per maggiori dettagli, vedere https://www.bipm.org/kcdb/).

Note A - This certificate is consistent with the capabilities (CMCs) that are included in Appendix C of the CIPM MRA drawn up by the CIPM. Under the CIPM MRA, all participating institutes recognize the validity of each other's calibration and measurement certificates for the quantities, ranges and measurement uncertainties specified in the KCDB (for details see https://www.bipm.org/kcdb/).

Nota B - Capacità di taratura e misura non inclusa nell'Accordo CIPM MRA.

Note B - Calibration and measurement capability is not included in the CIPM MRA Arrangement.

6. OSSERVAZIONI/*OBSERVATIONS*

Lo specchio dello strumento è stato deterso prima dell'avvio delle misure con acqua purificata e alcool etilico anidro.

The mirror of the instrument was cleaned before starting the measurements with purified water and anhydrous ethyl alcohol.

7. ALLEGATI/*ANNEXES*

ALLEGATO 1 AL CERTIFICATO DI TARATURA: Riferibilità delle misure ILAC-P10:07/2020, par. 2, punto 3a) – 2 pagine.

ANNEX 1 TO THE CALIBRATION CERTIFICATE: Traceability of measurements ILAC-P10:07/2020, par. 2, point 3a) – 2 pages.

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Traceability of measurements ILAC-P10:07/2020, par. 2, 3a)

1. Foreword

INRIM is a National Metrological Institute appointed by Legislative Decree no. 38, 21 January 2004, with role and objectives which includes those already assigned by the law n°273, 11 August 1991 "*Establishment of the National Calibration System.*"
INRIM participates in the *Mutual Recognition Agreement of National Measurement Standards and of Calibration and Measurement Certificates* (CIPM MRA) issued by the *National Metrology Institutes* (NMIs) since October ,14th, 1999. The *Calibration and Measurement Capabilities (CMCs) of INRIM are* included in the *Key Comparison Data Base* (KCDB, *http://kcdb.bipm.org/kcdb*) and published in the website of *Bureau International des Poids et Mesures* (BIPM, http://kcdb.bipm.org/ *kcdb*).

INRIM provides a comprehensive activity of calibration and measurement, and guarantees the metrological traceability of its measurements according to the criteria set out in paragraph 2, points 1) and 3a), of the document ILAC-P10:07/2020 "*ILAC Policy on the Traceability of Measurement Results*".
This document has the purpose to provide the evidences required in the mentioned document ILAC-P10:07/2020, Appendix A.
Please, note that in the following, "Technical document" is used to indicate both Calibration/Measurement Certificate and Test report.

2. Validation of calibration methods (UNI CEI EN ISO/IEC 17025:2018 par.7.2.2.4)

The criteria used for the selection of standardized measurement methods and the validation of measurement methods developed independently by INRIM are dealt with in the QMS General procedure RS05 *"Traceability of Measurements"* and are including participation in Interlaboratory Comparisons and Comparisons with different methods and/or standards.
The measurement method used in order to perform the activity to which this document refers, is described in the applied procedure, whose code is reported in the first page of the technical document.

Method validation was performed by participating in the following Interlaboratory comparisons:

TYPE OF ILC/PT	PARAMETERS/RANGE OF MEASUREMENTS	IDENTIFICATION OF ILC/PT*
Key comparison	Chilled mirror hygrometer (30 °C to 95 °C)	CCT-K8 (in progress)
Key comparison	Chilled mirror hygrometer (-50 °C to 20 °c)	EUROMET T-K6
Key comparison	Chilled mirror hygrometer (-50 °C to 20 °c)	CCT K6
Key comparison	Chilled mirror hygrometer (30 °C to 95 °C)	EURAMET T-K8 (in progress)
RMO comparison	Air temperature calibrations (-20 °C to 80 °C)	EURAMET P1061
RMO comparison	Relative humidity sensors (10% to 95 % and -10 °C to 70 °C)	EURAMET P1189

* Results of these comparisons can be consulted in the website http://kcdb.bipm.org.

3. Traceability of measurements (UNI CEI EN ISO IEC 17025:2018 par. 6.5)

The criteria used in order to guarantee the traceability of the measurements are managed by the procedure RS05 *"Measurement traceability"*. The traceability chain related to these measurements is identified in the mentioned procedure and /or reported in the technical document issued.

4. Evaluation of measurement uncertainty (UNI CEI EN ISO IEC 17025:2018 par. 7.6)

The evaluation of the measurement uncertainty is dealt with in the general procedure RQ01 "*Control of QMS documents*" and is carried out according to the guide JCGM 100:2008 "*Evaluation of measurement data - Guide to the expression of uncertainty in measurement*". The estimation of measurement uncertainty is reported in the applied procedure, the code of which is reported in the first page of the technical document.

5. Ensuring the validity of results (UNI CEI EN ISO IEC 17025:2018 par. 7.7)

The approach used by the INRIM QMS in order to assure the quality of the measurements results is defined in the procedure RP07 *"Ensuring the validity of results"*. It is based on the execution of ongoing activities (e.g.

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metrological confirmation of the standards and of the equipment, preliminary checks, repetition of measurements, statistical evaluation) and scheduled activities (e.g. use of other standards in the laboratory, and/or different methods, participation in ILCs).

6. Personnel (UNI CEI EN ISO IEC 17025:2018 par. 6.2)
The approach used by the INRIM QMS to ensure the competence of the staff responsible for carrying out the various activities is defined in the procedures RS02 *"Competences of the personnel"* and RS01 *"Organization and Operation"*. These procedures define the training needs, evaluation of the training carried out, maintaining records of the training carried out.

7. Facilities and environmental conditions (UNI CEI EN ISO IEC 17025:2018 par. 6.3)
The approach used by the INRIM QMS in order to guarantee the adequacy of the workplace and of the ambient conditions is defined in the procedure RS03 - *"Facilities and environmental conditions"*.
The ambient parameters that have influence on the quality of the results are monitored and recorded during the activities. The activities are suspended when the values of these parameters are out of the pre-defined limits.
The values of ambient conditions measured while performing the various activities are reported in the technical documents issued.

8.Equipment (UNI CEI EN ISO IEC 17025:2018 par. 6.4)
The methods adopted to manage the laboratory equipment are dealt with by the general procedure RS04 "Equipment". The equipment used for carrying out the activities (measuring instruments, reference samples, software, reference materials, etc.) comply with the requirements established for the application of the selected methods and to obtain the required measurement uncertainty. The equipment is under the permanent control of the laboratory.
Equipment that requires calibration or that have a defined period of validity are labeled and identified and are included in the calibration program updated periodically by the laboratory responsible. When necessary, intermediate checks are carried out in order to maintain confidence in the performance of the equipment.

9. Externally provided products and services (UNI CEI EN ISO/IEC 17025:2018 par. 6.6)
The processes defined by the INRIM QMS, for the purchase of supplies and services that have a critical influence on the quality of the calibration and measurement activities, are described in the procedure RS06 *"Externally provided products and services"*.
All goods and services purchased are tested by the same personnel who buy them, to verify its conformity to the requirements.
INRIM, as a public body, for amounts below the EU threshold, uses the Electronic Market of the (Italian) Public Administration (MEPA).

10. International Peer review and internal audits (UNI CEI EN ISO/IEC 17025:2018 par. 8.8)

INRIM participates in the EURAMET project no. 1123 *"On site peer review"*, with the NMIs of Spain (CEM *Centro Español de Metrologia*) and Portugal (IPQ, *Instituto Português da Qualidade*), a project promoted by the EURAMET TC-Q (Technical Committee for Quality). Within this project, Peer visits are carried out yearly to the laboratories and to the QMS.
The processes used by the INRIM-QMS to ensure that the operations carried out are continuously meeting the requirements of standard are described in the procedure RQ06 - *"Internal audits"*. Internal audits are planned yearly.
The laboratory that carried out the activity sustained the internal audit A06.2022 carried out on *2022/10/03*.

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Appendix 2: Studio della riproducibilità

Al fine di valutare la riproducibilità del campione di trasferimento (MBW 373) e dello strumento di controllo (MBW 573) sono state eseguite le misure ai punti del confronto in due sessioni separate (SET 1 e SET 2) a confronto con i generatori primari.