Georgian National Agency for Standards and Metrology

Metrology Institute

FINAL REPORT

COOMET project no. 768/GE/18

COOMET.T-S3 Supplementary comparison on Relative Humidity (RH) from 30 % rh to 90 % rh at 23 °C

Iuri Chelidze (GEOSTM)

Paul Carroll (NPL)

Laboratory-coordinator:
National Physical Laboratory (NPL) United Kingdom

Contact person:
National Physical Laboratory (NPL) United Kingdom

Address: G7-A7, Hampton Road, Teddington, Middlesex, TW11 0LW

Contact: Paul Carroll

Tel: +44 208 943 6732

E-mail: paul.carroll@npl.co.uk

October 2019

Contents

1. INTRODUCTION

This report describes the results of supplementary comparison COOMET.T-S3 (also known as supplementary comparison COOMET 768/GE/18) on Relative Humidity (RH) from 30 % rh to 90 % rh at 23 °C. The comparison was organised between the National Physical Laboratory (NPL) United Kingdom (Laboratory-coordinator) and Georgian National Agency for Standards and Metrology (GEOSTM), Georgia.

The purpose of this comparison is to perform a bilateral comparison NPL (UK) and GEOSTM - Georgia in order to compare their results and uncertainties in the calibration of hygrometers and to determine the bilateral degree of equivalence between the participating NMIs. The purpose of the comparisons conducted was to demonstrate the metrological technical competence of GEOSTM according to requirements of ISO/IEC 17025.

The GEOSTM relative humidity calibration laboratory started operating in the Temperature and Humidity Reference Division of the Metrology Institute of GEOSTM since 2016 and since then the laboratory has participated in several bilateral and/or pilot comparisons with other NMIs. The first comparison was conducted with the Czech Metrology Institute and another with the Polish National Metrology Institute. Both comparisons were successfully completed. As a next step there was a need to conduct comparison with an NMI which has CMC entries in the field of relative humidity, therefore this supplementary comparison was initiated and organized with NPL.

In 2018 on November 12 GEOSTM applied to COOMET for registration of the supplementary comparison– COOMET.T-S3 "NPL and GEOSTM inter-comparison of relative humidity realization. Relative Humidity from 30% RH to 90% RH at 23°C".

The procedures outlined in this document cover the technical procedure that was followed during measurement of the travelling standard. The procedure, which follows the guidelines established by the BIPM is based on current best practice in the use of relative humidity meters (hygrometers) and takes account of the experience gained from regional comparisons.

The results of this COOMET supplementary comparison will be used to support the CMC claims of GEOSTM in the field of humidity.

2. PARTICIPANTS OF THE COMPARISON

National Physical Laboratory (NPL) United Kingdom

Address: G7-A7, Hampton Road, Teddington, Middlesex, TW11 0LW

Contact: Paul Carroll

Tel: +44 208 943 6732

E-mail: paul.carroll@npl.co.uk

Georgian National Agency for Standards and Metrology (GEOSTM) Georgia

Address: 67 Chargali Street, Tbilisi 0178, Georgia

Contact: Iuri Chelidze

Tel: +995 32 2 613500

E-mail: iurichelidze.geostm@yahoo.com

3. SCHEDULE OF THE COMPARISON

NPL Initial: 25 July to 27 July 2018

GEOSTM: 15 August 2018

NPL Final: 17 September to 19 September 2018

4. DESCRIPTION OF THE TRAVELLING STANDARD

The travelling standard used in this comparison was provided by NPL. The description and characteristics of travelling standard are given in Table 1.

Table 1

Model:	HygroPalm HP32
Probe type:	HygroClip HC2A-S
Manufacturer:	Rotronic AG, Switzerland
Owner:	NPL, UK
RH range:	0 % rh to 100 % rh
Temperature range:	-50 °C to 100 °C

Display operating temp:	-10 °C to 60 °C
Probe dimensions:	Φ15 mm x 183 mm
Probe cable length:	1 m
Electrical supply:	Chargeable battery via USB cable
Accessories:	mini USB cable
Interface:	Display, software Rotronic HW4 Lite
Serial nos.:	Display: 5180315, Clip: 20238925

5. MEASUREMENT METHOD

This supplementary comparison covers relative humidity values of 30 %rh, 50 %rh and 90 %rh at a temperature of 23 °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 comparison was made by calibration of a travelling standard hygrometer, supplied by the pilot laboratory NPL, the details of which are given in Table 1. 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 NPL before it was sent to GEOSTM. Upon completion of the GEOSTM calibration the travelling standard was returned to NPL to carry out a final calibration in order to check for instrument drift over the period of the comparison.

At NPL the transfer standard hygrometer was calibrated inside a sub-chamber in a test chamber in the NPL humidity laboratory, by comparison against a reference standard chilled-mirror hygrometer and platinum resistance thermometers (PRTs). The two reference PRTs were mounted 58 mm apart in the sub-chamber with the transfer standard inserted in the space between them. Test gas of defined dew-point temperature was flowed into the sub-chamber from the NPL standard humidity generator and the dew-point measurement of gas exiting the sub-chamber was made by the reference standard chilled-mirror hygrometer.

The humidity measurements were traceable to the UK National Standard through calibration of the reference hygrometer against a standard humidity generator at NPL. The temperature measurements were traceable to the International Temperature Scale of 1990 (ITS-90) through calibration of the PRTs against NPL Temperature Standards. At each generated condition a time of not less than 60 minutes was allowed for temperature and relative humidity to equilibrate. A

set of 10 readings recorded at 2 minute intervals was then taken from the instrument under test. Measurements were carried out in the order reported.

GEOSTM started their calibration at the low humidity calibration point and proceeded until high humidity point. The reference thermo-hygrometer used by GEOSTM was calibrated by NPL prior to the comparison taking place. Relative humidity calibration at NPL is realized through humidity measurements made with a reference chilled-mirror hygrometer calibrated with traceability to the UK national standard humidity generator and air temperature measurements made with PRTs calibrated with traceability to the ITS-90. The sensors of the reference and travelling standards were placed in the middle of so-called useful volume of the climatic chamber close together (2 cm). The indications were recorded after the readings were stabilized. The stabilization criteria is deemed to be the moment when the change of the indication does not exceed the resolution. This moment occurs in 70-80 minutes approximately. The number of readings for each point is 10. The taking of readings lasts approximately 12-15 minutes. Uniformity of temperature in the useful volume of chamber was 0.04 °C

6. EQUIPMENT AND MEASURING CONDITIONS AT THE PARTICIPATING LABORATORIES

Each NMI described the equipment used in the comparison. The description and characteristics of measuring instruments used by GEOSTM in this comparison are given in Table 2.

Table 2

Title of measuring instruments used by GEOSTM	Characteristics of measuring instruments used by GEOSTM
1. Climatic Chamber	Kambic, Slovenia KK-190 CHLT Serial number: 16045126 Volume: 190 L Range of Temperature: -40 °C to +180 °C Range of humidity: 10 %rh to 98 %rh Temperature stability: ±0.1 °C Humidity stability: ±0,5 %rh
2. Reference Thermo-hygrometer (display unit with probe)	Rotronic, Hygrolog HL-NT3-DP; HC2A-S Serial number: 61716667; 20213103 Ranges: 10 %rh to 99 %rh -50 °C to +70 °C Calibrated by NPL UK, Calibration Certificate # 2018201255 (*NPL have*

	published CMCs in KCDB in relative humidity). Expanded uncertainty according to its certificate: ±0.5 %rh at 30 %rh ±0.9 %rh at 90 %rh ±0.1 °C at 23 °C
3. Temperature and Humidity data logger, used for registration of environmental conditions.	Rotronic, Hygrolog HL-NT3-DP Serial number: 61556859; 20068819. Calibrated by GEOSTM, Calibration Certificate GE/MI/09-00768-18 Ranges: 10 %rh to 99 %rh -50 °C to 70 °C

The description and characteristics of measuring instruments used by NPL in comparison are given in Table 3.

Table 3

Title of measuring instruments used by NPL	**Characteristics of measuring instruments used by NPL**
1. Climatic chamber - for temperature control.	Manufacturer: Montford Model: HC-500-R Serial number: 4877/K6822
2. Stainless steel sub-chamber - for housing test hygrometer inside climatic chamber.	NPL design
3. NPL Standard Humidity Generator 2 (SHG2) – for generation of gas with defined dew-point temperature.	NPL design [Stevens M and Bell, S A 1992 The NPL standard humidity generator: an analysis of uncertainty by validation of individual component performance, Meas. Sci. Technol. 3, pp 943-952.]
4. Chilled-mirror hygrometer – for measuring dew-point temperature of humidified test gas.	Manufacturer: MBW Model: 373HX Serial number: 16-0711
5. Two platinum resistance thermometers (PRTs) – for measurement of air temperature	Model: PT100 Serial numbers: SU120A, SU120B

in sub-chamber close to test hygrometer.	

The display unit of the hygrometer was kept outside the chamber at room conditions. Room conditions were recorded during the measurements using data logger and are shown in Table 4.

Measurements were carried out at the following nominal points of RH and temperature:

at 23 °C: → 30 %rh → 50 %rh→ 90 %rh

Participants respected the prescribed sequence of temperature/RH set points (marked with →) to perform a rising series, to avoid possible hysteresis effects.

The values of RH and temperature applied to the travelling standards were within ± 2 %rh and ± 0.5 °C, respectively, of the agreed nominal values for the comparison, and generally closer than this. Deviations greater than this may increase the uncertainty in the comparison for a particular result.

As much of the 1 metre cable as possible (at least 70 cm) from the sensor's head was thermalized at the same temperature as the sensor's head.

Both laboratories described the ambient conditions where the calibrations were performed. The data of ambient conditions of both NMIs are provided in table 4.

Table 4

NMI	Air Temperature (ºC)	Humidity (%rh)
NPL - Initial	23 ± 3	< 80
GEOSTM	22 to 24	56 to 59
NPL Final	23 ± 3	< 80

7. METHOD FOR REPORTING MEASUREMENT RESULTS

GEOSTM provided measurement results within two weeks after completing measurements.

The parameter to be compared between the participant NMIs laboratories in this comparison is the difference found between the travelling standard and the laboratory RH standard. The travelling standard was used simply as a comparator.

GEOSTM provided its results to the coordinator (pilot) laboratory in terms of RH at the specified temperature 23 °C. The main measurement results comprise of:

- values of air temperature and RH applied to the travelling standard at nominally 23 °C
- values of measured air temperature and RH logged from the transfer standard and associated expanded measurement uncertainty
- values of calculated dew/frost-point temperature logged from the transfer standard
- values of the difference between applied RH value and measured RH value.
- values of the difference between applied T value and measured T value.

From the data measured by each participant, results were analysed in terms of differences between applied and measured RH at the specified temperature 23 °C. The results of the difference between applied and measured air temperature were also analysed.

8. RESULTS OF THE COMPARISON

The results of this supplementary comparison are summarized in Tables 5-7 below.

The tables below show the transfer standard measurements observed at each participant NMI for each value of the realized relative humidity. The expanded uncertainty of each measurement is provided and the difference between realized and measured values of relative humidity and air temperature are shown in the last columns where:

$$\Delta RH = \text{realized RH} - \text{measured RH} \quad (1)$$

$$\Delta T = \text{realized temperature} - \text{measured temperature} \quad (2)$$

UNCERTAINTIES

The participant laboratories presented their uncertainty determination according to the GUM. The expanded measurement uncertainties reported are based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a coverage probability of approximately 95 %. Complete uncertainty budgets of the participants can be found in Appendix 1.

Table 5: NPL Initial Results 25 July to 27 July 2018:

Applied Condition			Travelling Standard					
Applied Temperature	Applied Dew Point	Calculated Relative Humidity	Measured Temperature	Expanded Uncertainty of the Temperature Measurement	Measured Relative Humidity	Expanded Uncertainty of the Relative Humidity Measurement	ΔRH	ΔT
°C	°C	%rh	°C	°C	%rh	%rh	%rh	°C
+23.04	+4.52	29.95	+23.14	±0.04	29.62	±0.28	0.33	-0.10
+23.01	+12.15	50.39	+23.12	±0.04	50.11	±0.40	0.28	-0.11
+23.01	+21.31	90.16	+23.12	±0.04	89.20	±0.64	0.96	-0.11

Table 6: GEOSTM Results 15 August 2018:

Applied Condition		Travelling Standard					
Applied Temperature	Applied Relative Humidity	Measured Temperature	Expanded Uncertainty of the Temperature Measurement	Measured Relative Humidity	Expanded Uncertainty of the Relative Humidity Measurement	ΔRH	ΔT
°C	%rh	°C	°C	%rh	%rh	%rh	°C
+23.32	32.07	+23.36	±0.13	31.40	±1.24	0.68	-0.04
+23.28	51.37	+23.34	±0.13	50.70	±1.31	0.68	-0.06
+23.18	89.80	+23.23	±0.13	88.84	±2.00	0.96	-0.05

Table 7: NPL Final Results 17 September to 19 September 2018:

Applied Condition			Travelling Standard					
Applied Temperature	Applied Dew Point	Calculated Relative Humidity	Measured Temperature	Expanded Uncertainty of the Temperature Measurement	Measured Relative Humidity	Expanded Uncertainty of the Relative Humidity Measurement	ΔRH	ΔT
°C	°C	%rh	°C	°C	%rh	%rh	%rh	°C
+23.01	+4.52	30.00	+23.12	±0.04	29.53	±0.28	0.47	-0.11
+23.01	+12.19	50.53	+23.13	±0.04	50.07	±0.40	0.46	-0.12
+23.01	+21.33	90.25	+23.12	±0.04	89.10	±0.64	1.15	-0.11

DISCUSSION

The final measurements at NPL revealed that the measurement error of the travelling standard instrument appeared to have drifted over the course of the comparison, under-reading more by between 0.14 %rh and 0.19 %rh across the relative humidity range measured. This is within the expected combined reproducibility of the NPL reference and the travelling standard.

BILATERAL DEGREE 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 bilateral equivalence between the facilities of the two participating institutes.

Bilateral equivalences for relative humidity and air temperature were calculated from differences $D_{GEOSTM/NPL}$, where:

$$D_{GEOSTM/NPL} = R_{GEOSTM} - R_{NPL} \quad (3)$$

where $R = \Delta$RH or ΔT as defined by equations 1 and 2.

The bilateral degree of equivalence (DoE) is determined as:

$$(D_{GEOSTM/NPL}, U_{GEOSTM/NPL}) = (D_{GEOSTM/NPL}, ku(D_{GEOSTM/NPL})) \quad (4)$$

where the coverage factor k =2 provides a coverage probability of 95 % for sufficiently large effective number of degrees of freedom of $u(D_{NPL/GEOSTM})$.

In this case,

$$u^2(D_{GEOSTM/NPL}) = u^2(R_{GEOSTM}) + u^2(R_{NPL}) + u^2{}_{drift} \quad (5)$$

where $u^2{}_{drift}$ is the uncertainty in the comparison due to drift of the transfer standard hygrometer at a given relative humidity value.

The results of the bilateral equivalence analysis are summarized in the following Tables 4 and 5. The uncertainty evaluation used the estimated drift between the initial and final NPL values at each relative humidity with a rectangular distribution.

Values of D are presented in Tables 8 and 9 below, using only the initial set of measurements conducted at NPL. The final set of NPL measurements is used only for estimating drift.

Table 8: Bilateral degree of equivalence between GEOSTM and NPL at relative humidities of 30 %rh, 50 %rh and 90 %rh at 23 °C.

Parameter: relative humidity

Nominal Temperature Value	Relative Humidity	$D_{GEOSTM/NPL}$	$U_{GEOSTM/NPL}$
°C	%rh	%rh	%rh
23	30	0.35	1.28
23	50	0.40	1.37
23	90	0.00	2.12

Table 9: Bilateral degree of equivalence between GEOSTM and NPL at temperatures of nominally 23 °C.

Parameter: air temperature

Nominal Temperature Value	Relative Humidity	$D_{GEOSTM/NPL}$	$U_{GEOSTM/NPL}$
°C	%rh	°C	°C
23	30	0.06	0.14
23	50	0.05	0.14
23	90	0.06	0.14

9. CONCLUSION

Bilateral equivalence is demonstrated between GEOSTM and NPL for realization of the parameters of relative humidity and air temperature through the results of this comparison.

The majority of the bilateral degree of equivalence values, $D_{GEOSTM/NPL}$, for the two participants are low compared to the uncertainty in the DoE, $U_{GEOSTM/NPL}$.

With this comparison the participant GEOSTM has demonstrated their technical competence for realization of relative humidities in the range 30 %rh to 90 %rh at 23 °C.

Date of issue: 22 February 2019 Signed:

Head of Temperature and humidity Reference Division

Name: Dr Iuri Chelidze

Measurements performed by:

Specialist of the division: Lasha Kvichidze

National Physical Laboratory (NPL)
Humidity Measurement and Standards

Measurements performed by:

Name: Paul Carroll

Appendix № 1

The Complete Uncertainty Budgets of the Participants

Uncertainty Budget of GEOSTM

Calibration Protocol

Used equipments: Hygrolog HL-NT3-DP type standard hygrometer, № 61716667, HC2A-S type HygroClip, № 20213103 which was calibrated by NPL in Great Britain, certificate number № 2018020125; KK-190 CHLT type testing climatic chamber, № 16045126.

Date of calibration: 15.08.2018
Customer: NPL
Identification: Thermo Hygrometer with HygroClip
Model: HP32; HygroClip: HC2A-S
Manufacturer: ROTRONIC AG, Switzerland
Serial No: 5180315; HygroClip: 20238925

Ranges: (-50 ÷ 100) °C
Resolution °C: 0.01
Number of measurements n: 10

Environmental conditions:
Temperature: 22 ÷ 24 °C
Pressure: -- mm Hg
Humidity: 56 ÷ 59 %

Control points: 23 °C, 30 % RH

1	2	3	4	5	6	7	8
№	Sources of uncertainty	Estimation, °C	Standard Uncertainty, °C	Distribution	Divisor, k	sensit. Coeff.	Standard Uncertainty component , °C
1	Real temperature inside the climatic chamber (calibration of the Standard)	23.324	0.1	Normal	2	1	0.05
2	Indication of the standard	-	0.006	Normal	1	1	0.006
3	Resolution of the Standard	-	0.01	Rectangular	1.73	1	0.006
4	Stability of the climatic chamber	-	0.050	Rectangular	1.73	1	0.029
5	Homogenity of the climatic chamber	-	0.040	Rectangular	1.73	1	0.023
6	Indication of the thermo hygrometer under calibration	23.364	0.005	Normal	1	1	0.005
7	Resolution of the thermo hygrometer under calibration	-	0.01	Rectangular	1.73	1	0.006
8	Short-term stability	-	0.000	Rectangular	1.73	1	0.000
9	-						
10	**Total correction**	**-0.040**					
Average	Total standard uncertainty	0.063					
ASD	**Expanded uncertainty**	**0.126**					

Control points: 23 °C, 50 % RH

1	2	3	4	5	6	7	8
№	Sources of uncertainty	Estimation, °C	Standard Uncertainty, °C	Distribution	Divisor, k	sensit. Coeff.	Standard Uncertainty component , °C
1	Real temperature inside the climatic chamber (calibration of the Standard)	23.283	0.1	Normal	2	1	0.05
2	Indication of the standard	-	0.007	Normal	1	1	0.007
3	Resolution of the Standard	-	0.01	Rectangular	1.73	1	0.006
4	Stability of the climatic chamber	-	0.050	Rectangular	1.73	1	0.029
5	Homogenity of the climatic chamber	-	0.040	Rectangular	1.73	1	0.023
6	Indication of the thermo hygrometer under calibration	23.339	0.002	Normal	1	1	0.002
7	Resolution of the thermo hygrometer under calibration	-	Resolution °C:	Rectangular	1.73	1	0.006
8	Short-term stability	-	0.000	Rectangular	1.73	1	0.000
9	-						
10	**Total correction**	**-0.056**					
Average	Total standard uncertainty	0.063					
ASD	**Expanded uncertainty**	**0.126**					

Control points: 23 °C, 90 % RH

1	2	3	4	5	6	7	8
№	Sources of uncertainty	Estimation, °C	Standard Uncertainty, °C	Distribution	Divisor, k	sensit. Coeff.	Standard Uncertainty component , °C
1	Real temperature inside the climatic chamber (calibration of the Standard)	23.179	0.1	Normal	2	1	0.05
2	Indication of the standard	-	0.004	Normal	1	1	0.004
3	Resolution of the Standard	-	0.01	Rectangular	1.73	1	0.006
4	Stability of the climatic chamber	-	0.050	Rectangular	1.73	1	0.029
5	Homogenity of the climatic chamber	-	0.040	Rectangular	1.73	1	0.023
6	Indication of the thermo hygrometer under calibration	23.226	0.005	Normal	1	1	0.005
7	Resolution of the thermo hygrometer under calibration	-	Resolution °C:	Rectangular	1.73	1	0.006
8	Short-term stability	-	0.000	Rectangular	1.73	1	0.000
9	-						
10	**Total correction**	**-0.047**					
Average	Total standard uncertainty	0.063					
ASD	**Expanded uncertainty**	**0.126**					

Control points: 23 °C, 50 % RH

1	2	3	4	5	6	7	8
№	Sources of uncertainty	Estimation, °C	Standard Uncertainty, °C	Distribution	Divisor, k	sensit. Coeff.	Standard Uncertainty component , °C
1	Real temperature inside the climatic chamber (calibration of the Standard)	23.278	0.1	Normal	2	1	0.05
2	Indication of the standard	-	0.004	Normal	1	1	0.004
3	Resolution of the Standard	-	0.01	Rectangular	1.73	1	0.006
4	Stability of the climatic chamber	-	0.05	Rectangular	1.73	1	0.029
5	Homogenity of the climatic chamber	-	0.04	Rectangular	1.73	1	0.023
6	Indication of the thermo hygrometer under calibration	23.324	0.003	Normal	1	1	0.003
7	Resolution of the thermo hygrometer under calibration	-	Resolution °C:	Rectangular	1.73	1	0.006
8	Short-term stability	-	0.000	Rectangular	1.73	1	0.000
9	-						
10	**Total correction**	**-0.046**					
Average	Total standard uncertainty	0.063					
ASD	**Expanded uncertainty**	**0.126**					

The person who has performed calibration: Specialist  L. Kvichidze

Checked by: Head of the Division  I. Chelidze

Calibration Protocol

Used equipments: Hygrolog HL-NT3-DP type standard hygrometer, № 61716667, HC2A-S type HygroClip, № 20213103 which was calibrated by NPL in Great Britain, certificate number № 2018020125; KK-190 CHLT type testing climatic chamber, № 16045126.

Date of calibration: 15.08.2018

Customer: NPL

Environmental conditions:

Identification: Thermo Hygrometer with HygroClip
Model: HP32; HygroClip: HC2A-S
Manufacturer: ROTRONIC AG, Switzerland
Serial No: 5180315; HygroClip: 20238925

Ranges: **(0 ÷ 100) % RH** **(-50 ÷ 100) °C**
Resolution: **% RH 0.01** **°C 0.01**

Temperature: 22 ÷ 24 °C
Pressure: -- mm Hg
Humidity: 56 ÷ 59 %

Control points: 30 % RH 23 °C

№	Ind. Std. Hyg. RHst. %	Ind. HUC, RHHUC. %	Ind. Std. Hyg. Correction RH %	Sources of uncertainty	Estimation, %	Std. Uncertainty, %	Unit	Distribution	Divisor, k	sensit. Coeff.	Uncertainty component, contribution, Ui
	1	2	3	4	5	6	7	8	9	10	11
1	31.81	31.43	0.3	Calibration of the standard	-	0.5	%	Normal	2	1	0.250
2	31.73	31.38		Indication of the standard	32.074	0.009	%	Normal	1	1	0.009
3	31.79	31.41		Interpolation of the standard	-	0.2	%	Rectangular	1.732	1	0.115
4	31.79	31.42		Drift of the standard	-	0.5	%	Rectangular	1.732	1	0.289
5	31.79	31.39		Resolution of the standard	-	0.01	%	Rectangular	1.732	1	0.006
6	31.76	31.39		Indication of hygrometer UC	31.397	0.006	%	Normal	1	1	0.006
7	31.76	31.38		Resolution of hygrometer UC	-	0.01	%	Rectangular	1.732	1	0.006
8	31.73	31.38		Stability of humidity inside the chamber	-	0.5	%	Rectangular	1.732	1	0.289
9	31.79	31.39		Homogenity of humidity inside the chambe	-	0.2	°C	Rectangular	1.732	1.816	0.210
10	31.79	31.40		Hysteresis of the standard	-	0.2	%	Rectangular	1.732	1	0.115
				Dynamic effect	-	0.5	%	Rectangular	1.732	1	0.289
Average	**31.774**	**31.397**		Total standard uncertainty	0.62						
ASD	**0.009**	**0.006**		Coverage factor	2						
				Expanded uncertainty	**1.238**			Normal			
				Correction	**0.677**						

Control points: 50 % RH 23 °C

	1	2	3	4	5	6	7	8	9	10	11
1	51.16	50.70	0.21	Calibration of the standard	-	0.5	%	Normal	2	1	0.250
2	51.13	50.71		Indication of the standard	51.370	0.009	%	Normal	1	1	0.009
3	51.16	50.72		Interpolation of the standard	-	0.2	%	Rectangular	1.732	1	0.115
4	51.13	50.70		Drift of the standard	-	0.5	%	Rectangular	1.732	1	0.289
5	51.22	50.72		Resolution of the standard	-	0.01	%	Rectangular	1.732	1	0.006
6	51.19	50.72		Indication of hygrometer UC	50.690	0.009	%	Normal	1	1	0.009
7	51.16	50.66		Resolution of hygrometer UC	-	0.01	%	Rectangular	1.732	1	0.006
8	51.16	50.66		Stability of humidity inside the chamber	-	0.5	%	Rectangular	1.732	1	0.289
9	51.13	50.64		Homogenity of humidity inside the chambe	-	0.17	°C	Rectangular	1.732	3.032	0.298
10	51.16	50.67		Hysteresis of the standard		0.2	%	Rectangular	1.732	1	0.115
				Dynamic effect	-	0.5	%	Rectangular	1.732	1	0.289
Average	**51.160**	**50.690**		Total standard uncertainty	0.65						
ASD	**0.009**	**0.009**		Coverage factor	2						
				Expanded uncertainty	**1.308**			Normal			
				Correction	**0.680**						

Control points: 90 % RH 23 °C

	1	2	3	4	5	6	7	8	9	10	11
1	89.17	88.82	0.43	Calibration of the standard	-	0.9	%	Normal	2	1	0.450
2	89.81	89.21		Indication of the standard	89.800	0.134	%	Normal	1	1	0.134
3	89.83	89.13		Interpolation of the standard	-	0.2	%	Rectangular	1.732	1	0.115
4	89.35	88.28		Drift of the standard	-	0.5	%	Rectangular	1.732	1	0.289
5	89.26	88.51		Resolution of the standard	-	0.01	%	Rectangular	1.732	1	0.006
6	88.88	88.19		Indication of hygrometer UC	88.842	0.135	%	Normal	1	1	0.135
7	89.88	89.30		Resolution of hygrometer UC	-	0.01	%	Rectangular	1.732	1	0.006
8	89.76	88.56		Stability of humidity inside the chamber	-	1.1	%	Rectangular	1.732	1	0.635
9	88.79	89.13		Homogenity of humidity inside the chambe	-	0.13	°C	Rectangular	1.732	5.452	0.409
10	88.97	89.29		Hysteresis of the standard		0.2	%	Rectangular	1.732	1	0.115
				Dynamic effect	-	0.5	%	Rectangular	1.732	1	0.289
Average	**89.370**	**88.842**		Total standard uncertainty	1.00						
ASD	**0.134**	**0.135**		Coverage factor	2						
				Expanded uncertainty	**2.003**			Normal			
				Correction	**0.958**						

Control points: 50 % RH 23 °C

	1	2	3	4	5	6	7	8	9	10	11
1	51.34	50.89	0.21	Calibration of the standard	-	0.5	%	Normal	2	1	0.250
2	51.34	50.87		Indication of the standard	51.556	0.006	%	Normal	1	1	0.006
3	51.34	50.86		Interpolation of the standard	-	0.2	%	Rectangular	1.732	1	0.115
4	51.34	50.85		Drift of the standard	-	0.5	%	Rectangular	1.732	1	0.289
5	51.31	50.84		Resolution of the standard	-	0.01	%	Rectangular	1.732	1	0.006
6	51.34	50.85		Indication of hygrometer UC	50.859	0.006	%	Normal	1	1	0.006
7	51.37	50.88		Resolution of hygrometer UC	-	0.01	%	Rectangular	1.732	1	0.006
8	51.37	50.87		Stability of humidity inside the chamber	-	0.5	%	Rectangular	1.732	1	0.289
9	51.37	50.85		Homogenity of humidity inside the chambe	-	0.17	°C	Rectangular	1.732	3.032	0.298
10	51.34	50.83		Hysteresis of the standard		0.2	%	Rectangular	1.732	1	0.115
				Dynamic effect	-	0.5	%	Rectangular	1.732	1	0.289
Average	**51.346**	**50.859**		Total standard uncertainty	0.65						
ASD	**0.006**	**0.006**		Coverage factor	2						
				Expanded uncertainty	**1.308**			Normal			
				Correction	**0.697**						

The person who has performed calibration: Specialist L. Kvichidze

Checked by: Head of the Division I. Chelidze

Uncertainty Budget of NPL

23 °C 30 % rh point

Temperature measurement uncertainties using an NPL chamber in the range -20 °C to 50 °C						
Source of uncertainty	**Value**	**Probability distributior**	**Unit**	**Divisor**	**Sens. Co-eff**	**Standard Uncertainty**
Uncertainties associated with PRTs						°C
Calibration uncertainty	0.01	Normal	°C	2.000	1.000	0.0050
Reproducibility	0.005	Rectangular	°C	1.732	1.000	0.0029
Drift	0.01	Rectangular	°C	1.732	1.000	0.0058
Non-linearity	0.005	Rectangular	°C	1.732	1.000	0.0029
Self heating (difference from calibration in fluid to use in air)	0.005	Rectangular	°C	1.732	1.000	0.0029
Hysteresis	0.005	Rectangular	°C	1.732	1.000	0.0029
Stem conduction	0.01	Rectangular	°C	1.732	1.000	0.0058
Uncertainties associated with resistance bridge						
Resistance bridge calibration	0.01	Normal	°C	2.000	1.000	0.0050
Bridge reproducibility	0.005	Rectangular	°C	1.732	1.000	0.0029
Bridge resolution	0.001	Rectangular	°C	1.732	1.000	0.0006
Bridge drift	0.01	Rectangular	°C	1.732	1.000	0.0058
Uncertainties associated with NPL chamber						
Chamber uniformity	0.0046	Rectangular	°C	1.732	1.000	0.0027
Chamber stability (worst case st dev 10 measurements)	0.0024	Normal	°C	3.162	1.000	0.0008
Effect of thermal radiation	0.015	Rectangular	°C	1.732	1.000	0.0087
Uncertainty of DUT						
DUT Resolution	0.01	Rectangular	°C	3.464	1.000	0.0029
DUT not reached end point	0.015	Rectangular	°C	1.732	1.000	0.0087
Standard uncertainty from standard deviation of 10 DUT measurements	0.0067	Normal	°C	3.162	1.000	0.0021
					Standard uncertainty	0.0190
					Expanded uncertainty using a coverage factor of k=2	0.0381

Dew point calibration uncertainty using an optical dew point hygrometer as the standard						
Source of uncertainty	**Value**	**Probability distributior**	**Unit**	**Divisor**	**Sens. Co-eff**	**Standard Uncertainty**
Uncertainties associated with reference chilled-mirror hygrometer						°C
Calibration uncertainty	0.05	Normal	°C	2.000	1.000	0.0250
Resolution of standard	0.01	Rectangular	°C	3.464	1.000	0.0029
Drift of standard	0.05	Rectangular	°C	1.732	1.000	0.0289
Repeatability	0.01	Normal	°C	1.000	1.000	0.0100
Standard error of regression	0.01	Normal	°C	1.000	1.000	0.0100
Contamination	0.01	Rectangular	°C	1.732	1.000	0.0058
Temperature gradients in condensate	0.01	Rectangular	°C	1.732	1.000	0.0058
Temperature gradients in mirror	0.01	Rectangular	°C	1.732	1.000	0.0058
Pressure difference	0.026	Rectangular	°C	1.732	1.000	0.0150
Mirror temperature fluctuations	0.01	Rectangular	°C	1.732	1.000	0.0058
Sampling including desorption	0.01	Rectangular	°C	1.732	1.000	0.0058
Standard deviation of readings	0.0069	Normal	°C	3.162	1.000	0.0022
					Standard uncertainty	0.0454
					Expanded uncertainty using a coverage factor of k=2	0.0908

Calculated Relative Humidity Uncertainty / %rh	Value	Probability distributior	Unit	Divisor	Sens. Co-eff	Standard Uncertainty
					%rh / °C	%rh
Generated air temperature uncertainty	0.0330	Normal	°C	2	1.876	0.0309
Dew-point temperature measurement uncertainty	0.0908	Normal	°C	2	2.163	0.0983
Vapour pressure equation uncertainty e (Sonntag 0.01 % of value)	0.0030	Normal	%rh	2	1	0.0015
Vapour pressure equations uncertainty es (Sonntag 0.01 % of value)	0.0030	Normal	%rh	2	1	0.0015
Instrument under test contributions						
Resolution	0.01	Rectangular	%rh	3.464	1.0000	0.0029
Short-term stability	0.0199	Normal	%rh	3.162	1.0000	0.0063
Measured value not reached end point	0.16	Rectangular	%rh	1.732	1.0000	0.0924
					Standard uncertainty	0.1386
				Expanded uncertainty using a coverage factor of k=2		0.2771

23 °C 50 %rh point

Temperature measurement uncertainties using an NPL chamber in the range -20 °C to 50 °C						
Source of uncertainty	**Value**	**Probability distributio**	**Unit**	**Divisor**	**Sens. Co-eff**	**Standard Uncertainty**
Uncertainties associated with PRTs						°C
Calibration uncertainty	0.01	Normal	°C	2.000	1.000	0.0050
Reproducibility	0.005	Rectangular	°C	1.732	1.000	0.0029
Drift	0.01	Rectangular	°C	1.732	1.000	0.0058
Non-linearity	0.005	Rectangular	°C	1.732	1.000	0.0029
Self heating (difference from calibration in fluid to use in air)	0.005	Rectangular	°C	1.732	1.000	0.0029
Hysteresis	0.005	Rectangular	°C	1.732	1.000	0.0029
Stem conduction	0.01	Rectangular	°C	1.732	1.000	0.0058
Uncertainties associated with resistance bridge						
Resistance bridge calibration	0.01	Normal	°C	2.000	1.000	0.0050
Bridge reproducibility	0.005	Rectangular	°C	1.732	1.000	0.0029
Bridge resolution	0.001	Rectangular	°C	1.732	1.000	0.0006
Bridge drift	0.01	Rectangular	°C	1.732	1.000	0.0058
Uncertainties associated with NPL chamber						
Chamber uniformity	0.0044	Rectangular	°C	1.732	1.000	0.0025
Chamber stability (worst case st dev 10 measurements)	0.0018	Normal	°C	3.162	1.000	0.0006
Effect of thermal radiation	0.015	Rectangular	°C	1.732	1.000	0.0087
Uncertainty of DUT						
DUT Resolution	0.01	Rectangular	°C	3.464	1.000	0.0029
DUT not reached end point	0.015	Rectangular	°C	1.732	1.000	0.0087
Standard uncertainty from standard deviation of 10 DUT measuremer	0.0097	Normal	°C	3.162	1.000	0.0031
					Standard uncertainty	0.0191
				Expanded uncertainty using a coverage factor of k=2		0.0383

Dew point calibration uncertainty using an optical dew point hygrometer as the standard						
Source of uncertainty	**Value**	**Probability distributio**	**Unit**	**Divisor**	**Sens. Co-eff**	**Standard Uncertainty**
Uncertainties associated with reference chilled-mirror hygrometer						°C
Calibration uncertainty	0.05	Normal	°C	2.000	1.000	0.0250
Resolution of standard	0.01	Rectangular	°C	3.464	1.000	0.0029
Drift of standard	0.05	Rectangular	°C	1.732	1.000	0.0289
Repeatability	0.01	Normal	°C	1.000	1.000	0.0100
Standard error of regression	0.01	Normal	°C	1.000	1.000	0.0100
Contamination	0.01	Rectangular	°C	1.732	1.000	0.0058
Temperature gradients in condensate	0.01	Rectangular	°C	1.732	1.000	0.0058
Temperature gradients in mirror	0.01	Rectangular	°C	1.732	1.000	0.0058
Pressure difference	0.026	Rectangular	°C	1.732	1.000	0.0150
Mirror temperature fluctuations	0.01	Rectangular	°C	1.732	1.000	0.0058
Sampling including desorption	0.01	Rectangular	°C	1.732	1.000	0.0058
Standard deviation of readings	0.0063	Normal	°C	3.162	1.000	0.0020
					Standard uncertainty	0.0454
					Expanded uncertainty using a coverage factor of k=2	0.0908

Calculated Relative Humidity Uncertainty / %rh	**Value**	**Probability distributio**	**Unit**	**Divisor**	**Sens. Co-eff**	**Standard Uncertainty**
					%rh / °C	%rh
Air temperature uncertainty	0.0331	Normal	°C	2	3.157	0.0522
Dew-point temperature measurement uncertainty	0.0908	Normal	°C	2	3.417	0.1552
Vapour pressure equation uncertainty e (Sonntag 0.01 % of value)	0.005	Normal	%rh	2	1	0.0025
Vapour pressure equations uncertainty es (Sonntag 0.01 % of value)	0.005	Normal	%rh	2	1	0.0025
Instrument under test contributions						
Resolution	0.01	Rectangular	%rh	3.464	1.0000	0.0029
Short-term stability	0.0195	Normal	%rh	3.162	1.0000	0.0062
Measured value not reached end point	0.2	Rectangular	%rh	1.732	1.0000	0.1155
					Standard uncertainty	0.2005
					Expanded uncertainty using a coverage factor of k=2	0.4010

23 °C 90 %rh point

Temperature measurement uncertainties using an NPL chamber in the range -20 °C to 50 °C						
Source of uncertainty	**Value**	**Probability distributio**	**Unit**	**Divisor**	**Sens. Co-eff**	**Standard Uncertainty**
Uncertainties associated with PRTs						°C
Calibration uncertainty	0.01	Normal	°C	2.000	1.000	0.0050
Reproducibility	0.005	Rectangular	°C	1.732	1.000	0.0029
Drift	0.01	Rectangular	°C	1.732	1.000	0.0058
Non-linearity	0.005	Rectangular	°C	1.732	1.000	0.0029
Self heating (difference from calibration in fluid to use in air)	0.005	Rectangular	°C	1.732	1.000	0.0029
Hysteresis	0.005	Rectangular	°C	1.732	1.000	0.0029
Stem conduction	0.01	Rectangular	°C	1.732	1.000	0.0058
Uncertainties associated with resistance bridge						
Resistance bridge calibration	0.01	Normal	°C	2.000	1.000	0.0050
Bridge reproducibility	0.005	Rectangular	°C	1.732	1.000	0.0029
Bridge resolution	0.001	Rectangular	°C	1.732	1.000	0.0006
Bridge drift	0.01	Rectangular	°C	1.732	1.000	0.0058
Uncertainties associated with NPL chamber						
Chamber uniformity	0.0046	Rectangular	°C	1.732	1.000	0.0027
Chamber stability (worst case st dev 10 measurements)	0.002	Normal	°C	3.162	1.000	0.0006
Effect of thermal radiation	0.015	Rectangular	°C	1.732	1.000	0.0087
Uncertainty of DUT						
DUT Resolution	0.01	Rectangular	°C	3.464	1.000	0.0029
DUT not reached end point	0.015	Rectangular	°C	1.732	1.000	0.0087
Standard uncertainty from standard deviation of 10 DUT measurements	0.0067	Normal	°C	3.162	1.000	0.0021
				Standard uncertainty		0.0190
				Expanded uncertainty using a coverage factor of k=2		0.0381

Dew point calibration uncertainty using an optical dew point hygrometer as the standard						
Source of uncertainty	**Value**	**Probability distributio**	**Unit**	**Divisor**	**Sens. Co-eff**	**Standard Uncertainty**
Uncertainties associated with reference chilled-mirror hygrometer						°C
Calibration uncertainty	0.05	Normal	°C	2.000	1.000	0.0250
Resolution of standard	0.01	Rectangular	°C	3.464	1.000	0.0029
Drift of standard	0.05	Rectangular	°C	1.732	1.000	0.0289
Repeatability	0.01	Normal	°C	1.000	1.000	0.0100
Standard error of regression	0.01	Normal	°C	1.000	1.000	0.0100
Contamination	0.01	Rectangular	°C	1.732	1.000	0.0058
Temperature gradients in condensate	0.01	Rectangular	°C	1.732	1.000	0.0058
Temperature gradients in mirror	0.01	Rectangular	°C	1.732	1.000	0.0058
Pressure difference	0.026	Rectangular	°C	1.732	1.000	0.0150
Mirror temperature fluctuations	0.01	Rectangular	°C	1.732	1.000	0.0058
Sampling including desorption	0.01	Rectangular	°C	1.732	1.000	0.0058
Standard deviation of readings	0.0078	Normal	°C	3.162	1.000	0.0025
				Standard uncertainty		0.0454
				Expanded uncertainty using a coverage factor of k=2		0.0909

Calculated Relative Humidity Uncertainty / %rh	Value	Probability distributio	Unit	Divisor	Sens. Co-eff	Standard Uncertainty
					%rh / °C	%rh
Air temperature uncertainty	0.0381	Normal	°C	2	5.648	0.1075
Dew-point temperature measurement uncertainty	0.0909	Normal	°C	2	5.680	0.2581
Vapour pressure equation uncertainty e (Sonntag 0.01 % of value)	0.009	Normal	%rh	2	1	0.0045
Vapour pressure equations uncertainty es (Sonntag 0.01 % of value)	0.009	Normal	%rh	2	1	0.0045
Instrument under test contributions						
Resolution	0.01	Rectangular	%rh	3.464	1.0000	0.0029
Short-term stability	0.0624	Normal	%rh	3.162	1.0000	0.0197
Measured value not at end point	0.26	Rectangular	%rh	1.732	1.0000	0.1501
				Standard uncertainty		0.3180
	Expanded uncertainty using a coverage factor of k=2					0.6360

Appendix № 2

NPL and GEOSTM inter-comparison of relative humidity realisations

Relative humidity from 30 % rh to 90 % rh

at 23 °C

Technical protocol

1. INTRODUCTION

1.1 GEOSTM of Georgia have requested that NPL pilot a comparison for relative humidity (RH) from 30 % rh to 90 % rh at 23 °C.

1.2 This technical protocol has been drawn up by NPL in consultation with GEOSTM.

1.3 The procedures outlined in this document cover the technical procedure to be followed during measurement of the travelling standard. The procedure, which follows the guidelines established by the BIPM[1] and EURAMET[2], is based on current best practice in the use of relative humidity meters (hygrometers) and takes account of the experience gained from regional comparisons.

1.4 This comparison is aimed at establishing the degree of equivalence between realisations of scales of RH at NPL and GEOSTM.

[1] T.J. Quinn, "Guidelines for key comparisons carried out by Consultative Committees," Appendix F to the MRA, BIPM, Paris.

[2] EUROMET Guide 3, EUROMET Guidelines on Conducting Comparisons

2. ORGANISATION

2.1 Method of comparison

2.1.1 The aim of this inter-comparison is to compare realisations of RH scales at the participating national measurement institutes NPL and GEOSTM.

2.1.2 The comparison will be made by calibration of a travelling standard (Rotronic HP32 s/n 5180315 with HygroClip HC2A-S s/n 20238925 owned by NPL, further details in section 3.1). The travelling standard will measure RH of a sample of moist gas produced by a participant's standard RH generator.

2.1.3 Measurements will start and end in the pilot laboratory NPL. GEOSTM will perform comparison measurements at the measurement points required after the initial NPL calibration. GEOSTM shall then return the travelling standard to the pilot to carry out final measurement in order to monitor instrument drift.

2.1.4 The GEOSTM results are to be communicated directly to NPL within two weeks of the completion of the measurements by the laboratory.

2.2 Handling of artefacts

2.2.1 The artefact should be examined immediately upon receipt at the laboratory. Participants are expected to follow all instructions in the operator's manual provided by the instrument manufacturer for proper unpacking and subsequent repacking. During packing and unpacking, all participants should check the contents with the packing list (Appendix 2) including the operator's manual.

2.2.2 Confirm receipt and condition upon arrival of the transfer standard via email to the pilot using the form in Appendix 2.

2.2.3 The travelling standard should only be handled by authorized persons and stored in such a way as to prevent damage.

2.2.4 During operation of the travelling standard, if there is any unusual occurrence, the pilot laboratory should be notified immediately before proceeding.

2.3 Transport of artefacts

2.3.1 The transportation process begins when the artefact leaves the sending laboratory and does not end until it reaches the destination laboratory. The participants should follow the following general guidelines:

(1) Plan the shipment well in advance. The recipient should be aware of any customs issues in their country that could delay the testing schedule. The shipping laboratory must be aware of any national regulations covering the travelling standard to be exported;

(2) Mark the shipping container "**FRAGILE SCIENTIFIC INSTRUMENTS" "TO BE OPENED ONLY BY LABORATORY STAFF**"; attach shock indicators if such devices are available;

(3) Determine the best way to ship the travelling standard to the next participant. In general transportation with an approved courier is preferred;

(4) Obtain the recipient's exact shipping address. If possible, have it shipped directly to the laboratory. Note the most up to date address details are listed in Appendix 1.

(5) Coordinate the shipping schedule with the recipient. The sending laboratory should provide the recipient with the details of the carrier, the tracking number, the exact travel mode, and the estimated time of arrival;

(6) Instruct the recipient to confirm receipt and condition upon arrival to the sender and the pilot. A form for reporting on the receipt of the travelling standards is shown in Appendix 2.

2.3.2 The travelling standard is supplied in a transportation case, in its original packaging. This is sent inside a further outer cardboard box, which is sufficiently robust to ensure safe transportation.

2.3.3 Each laboratory is responsible for the cost of shipping to the next participant including any customs charges and insurance. The insurance should be sufficient to cover the costs of the travelling standards and any damages that could occur.

3 Description of the travelling standard

3.1 Artefact

The travelling standard NPL will provide is manufactured by Rotronic:

Model:	HygroPalm HP32
Probe type:	HygroClip HC2A-S
Manufacturer:	Rotronic AG, Switzerland
Owner:	NPL, UK
Probe cable length:	1 m
Probe dimensions:	Φ15 mm x 183 mm
RH range:	0 % rh to 100 % rh
Temperature range:	-50 °C to 100 °C
Display operating temp:	-10 °C to 60 °C
Electrical supply:	Chargeable battery via USB cable
Accessories:	mini USB cable
Interface:	Display, software Rotronic HW4 Lite
Serial nos.:	Display: 5180315, Clip: 20238925

4 Measurement Instructions

4.1 Measurement process

4.1.1 The participants should refer to the operating manual for instructions and precautions for using the travelling standard. Participants may perform any initial checks of the operation of the 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 in order to revise the time schedule.

4.1.2 The display unit of the hygrometer shall be kept outside the chamber at room conditions. Room conditions should be limited so as to affect the readings.

4.1.3 Measurements shall be carried out at the following nominal points of RH and temperature:

at **23 °C**: → 30 %rh → 50 %rh→ 90 %rh

4.1.4 Participants should respect the prescribed sequence of temperature/RH set points (marked with →) to perform a rising series, minimising possible hysteresis effects.

4.1.5 The values of RH and temperature applied to the travelling standards should be within ± 2 %rh and ± 0.5 °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.

4.1.6 As much of the 1 metre cable as possible (at least 70 cm) from the sensor's head should be thermalized at the same temperature as the sensor's head.

4.1.7 Operation with the travelling standards

Before any humidity measurements, initial actions should be taken:

1) Read the operating instructions delivered by the manufacturer (a copy of the instructions is in the transport case or can be downloaded from their web page).

2) **Important:** The transfer standard uses the pilot's default settings, which **MUST NOT be modified** or adjusted other than described in this document.

3) Do not touch the sensor's head/filter with your fingers or any other object at any time. After you finish with the measurements, wait until sensor's head is cooled down and dried out to ambient conditions (approx. 23°C, 50%) before re-packing.

4) 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) The Rotronic sensor can be communicated through USB ports using downloadable software HW4 Lite from:

https://www.rotronic.com/en-gb/humidity_measurement-feuchtemessung-mesure_de_l_humidite/downloads-humidity-mr

6) Contact the pilot for the software product key (password).

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

4.1.9 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 other than the participants in the comparison.

4.1.10 The pilot will make an assessment of any drift in the travelling standards 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.

4.2 Data collection

4.2.1 RH readings used in this comparison can be obtained from the display and/or through the serial port.

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

4.2.3 Participants may apply their own criteria of stability for acceptance of measurements.

4.2.4 As a supporting measurement, the displayed readings and serial port readings of the temperature and (internally calculated) dew/frost point temperature of the travelling standards should be recorded. 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.

4.2.5 Values reported for RH either 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 realisation (laboratory standard generator or reference hygrometer) and the point of use (travelling standard) have been taken into consideration.

5 Reporting of Measurement results

5.1 GEOSTM must report their measurement results within two weeks after completing their measurements.

5.2 The parameter to be compared between the laboratories in this comparison is the difference found between the travelling standard and the laboratory RH standard. The travelling standard is used simply as a comparator.

5.3 GEOSTM should report results to the pilot in terms of RH at the specified temperature 23 °C. The main measurement results comprise of:

- values of RH applied to the travelling standard at the specified temperature 23 °C, and its associated standard uncertainty
- values of measured RH value by transfer standard and its associated standard uncertainty
- values of the difference between applied RH value and measured RH value.
- values of measured temperature
- The value of temperature applied to the sensor of relative humidity should be recorded
- values of internally calculated dew/frost point temperature

5.4 From the data measured by each participant, results will be analysed in terms of differences between applied and measured RH at the specified temperature 23 °C.

5.5 Participants should provide a description of the operation of their facilities used in the comparison as well as the traceability route.

6 Uncertainty of measurement

6.1 The uncertainty of the comparison results will be derived from:

- the quoted uncertainty of the RH realisation (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 pilots)
- the estimated uncertainty in mean values due to dispersion of repeated results (reflecting the combined reproducibility of laboratory standard and travelling standards)
- any other components of uncertainty that are thought to be significant

6.2 Participants are required to submit detailed analyses of uncertainty for their RH standards. Uncertainty analysis should be carried out according to the approach given in the ISO Guide to the Expression of Uncertainty of Measurement. 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.

6.3 The pilot laboratory creates an uncertainty budget template which will be applied by the parties.

6.4 The uncertainty budget stated by the participating laboratory should be referenced to an internal report and/or a published article if available.

7 Determination of the comparison reference value*

7.1 The outputs of the comparison are expected to be:

- Results of individual participants for comparison of the hygrometer against their RH reference in terms of mean values for the hygrometer at each measured value, estimated standard uncertainty of each mean result and estimated standard uncertainty of comparison process (e.g. effect of long-term stability and non-linearity of the travelling standard) if necessary.
- A comparison reference value (CRV) for each nominal value of RH in the comparison will be calculated. The CRV might be calculated as the mean of all valid results, or a weighted mean.
- Estimates of equivalence of each participant to the CRV for each nominal RH value. This might be expressed in terms of the Degree of Equivalence (DOE) given as a difference and its uncertainty ($\Delta \pm U$), in % rh.

7.2 The pilot will make an assessment of any drift in the travelling standards during the comparison. The assessment will be based on initial and final measurements completed by the pilot. If drift is found, this will be taken into account in the final analysis of the comparison results. If the drift is small compared with uncertainty values reported by the participants, an estimate for the drift may be set to zero with a standard uncertainty calculated according to the ISO Guide. In a case of a significant drift, it should be taken into account by assessment of uncertainty of determining of the equivalence's degrees.

* At the time of reporting the analysis was changed to determine the bilateral degree of equivalence between the facilities of the two participating institutes as described in section 8 of the final version of the report.

Appendix 1. DETAILS OF PARTICIPATING INSTITUTES

National Physical Laboratory (NPL) United Kingdom

Address: G7-A7, Hampton Road, Teddington, Middlesex, TW11 0LW
Contact: Paul Carroll

Tel: +44 208 943 6732

E-mail: paul.carroll@npl.co.uk

Georgian National Agency for Standards and Metrology (GEOSTM) Georgia

Address: 67 Chargali Street, Tbilisi 0178, Georgia
Contact: Lasha Kvichidze
Tel: +995 32 2 613500

E-mail: lashakvichidze@yahoo.com

Appendix 2. FORM FOR REPORTING ON DESPATCH / RECEIPT OF TRAVELLING STANDARDS

PACKING LIST

Despatched	Items	Dispatched
	Rotronic hygrometer HygroPalm HP32, s/n: 5180315	
	HygroClip with 1 m cable, s/n: 20238925	
	USB communication cable	
	Instruction Manual	
	Transport case	

Laboratory: _____

Date: _____ Signature: _____

PACKING LIST

Received	Items	Dispatched
	Rotronic hygrometer HygroPalm HP32, s/n: 5180315	
	HygroClip with 1 m cable, s/n: 20238925	
	USB communication cable	
	Instruction Manual	
	Transport case	

Laboratory: _____

Date: _____ Signature: _____