COMPARISON OF INMETRO AND INTI HUMIDITY STANDARDS

Final Report

Instituto Nacional de Metrologia, Qualidade e Tecnologia (INMETRO)
Instituto Nacional de Tecnología Industrial (INTI)

Contents

SIM.T-K6.4 – INMETRO / INTI
Final Report

COMPARISON OF INMETRO AND INTI HUMIDITY STANDARDS

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1. Abstract

The aim of this paper is to describe a bilateral comparison carried out by the hygrometry laboratories of the National Metrological Institutes of Brazil and Argentina, INMETRO and INTI, respectively. This comparison was planed and carried out as an informal comparison. But, in view of the lack and the need of humidity comparison reports in the region of the Inter American Metrology System (SIM), we decided to register this comparison as a bilateral key comparison of the regional metrology organization (RMO) , SIM.T-K6.4 – INMETRO / INTI. The comparison was performed in the range from –20 ºC to +60 ºC dew/frost point temperatures at 20 °C steps. This paper presents the calibration methods of the laboratories, the uncertainty analysis and the comparison results. The measurements results of the comparison are also presented in terms of the normalised error (E_n) as a function of the dew/frost point temperature.

Keywords: Comparison, Humidity, Normalised Error.

2. Introduction

At a meeting held in Paris on October 1999, the directors of the National Metrology Institutes (NMIs) of thirty-eight Member States of the Bureau International des Poids et Mesures (BIPM) and representatives of two international organizations signed a Mutual Recognition Arrangement (MRA) for national measurement standards and for calibration and measurement certificates issued by NMIs. A number of other institutes have signed since then. The MRA gives users reliable information on the comparability of national metrology services and provides the technical basis for arrangements negotiated for international trade, commerce and regulatory affairs [1]. Hence, comparison of reference standards between NMIs became very important.

In order to respond to the increasing needs for humidity sensors calibration in Brazil, the Thermal Metrology Division of the National Institute of Metrology, Quality and Technology (INMETRO) established a hygrometry laboratory which started to render calibration services in 1998. The laboratory's calibration system is composed of several equipments and instruments to cover the range from –75 ºC to +75 ºC of dew/frost point temperatures. The humidity standard system had already been employed in other bilateral comparisons to demonstrate its equivalence to humidity standards of other countries [2]. Also, the standard instruments are periodically compared to each other in order to assure the quality of the calibration and test results [3].

For several years INTI has carried out activities in order to meet the needs of humidity measurements in Argentina. Before the year 2006, INTI Física y Metrología rendered calibration services of humidity sensors in a reduced range. At that moment, INTI's humidity standard was an aspirate psychrometer traceable to Physikalisch - Technische Bundesanstalt (PTB) in relative humidity.

In the year 2006 a primary humidity generator was acquired. This is a commercial equipment of the brand Thunder Scientific model 2500 LT. This generator operates on the principle of the two - pressures method [4] and today it is INTI's humidity standard. The traceability to international system of units (SI) is achieved by calibration of pressure and temperature sensors at INTI labs without need of external calibrations. INTI's humidity lab covers the range between 10 %rh to 95 %rh at temperatures between –10 ºC to 70 ºC (approx.: –35 ºC to 65 ºC in dew point temperature). In the last five years, the generator has been checked with a capacitive humidity sensor traceable to an accredited laboratory. It is the first experience in a humidity comparison at INTI.

The aim of this work is to describe a bilateral comparison that was carried out by the hygrometry laboratories of INMETRO and INTI, and was piloted by INMETRO. The protocol applied was discussed previously by the authors. The protocol used in earlier comparisons by INMETRO with others countries [2] was used as base.
The comparison of the humidity standards was performed in the range from –20 ºC to +60 ºC of dew/frost point temperatures at 20 °C steps. A total of five dew/frost point temperatures were used for the comparison.

As transfer standard, a chilled-mirror hygrometer (CMH) was used. CMHs, considered as one of the most accurate and reliable methods of measuring dew/frost point temperatures, have been widely used as reference standards in calibration laboratories and as transfer standards in comparisons of humidity national standards.

The measurements started at INMETRO by comparison of the transfer standard readings with those indicated by the standards CMHs. The air samples were generated by a working humidity generator equipped with a climatic chamber where the sensor of the transfer standard was positioned. The transfer standard was then hand-carried to INTI, where it was also calibrated inside the climatic chamber of the primary humidity generator. After returning to INMETRO's laboratory, measurements were repeated in order to check the CMH stability and to obtain a larger data sample since the beginning of the calibration.

This paper presents the calibration methods of both laboratories, the uncertainty analysis and the comparison results. The measurements results of the comparison are presented in terms of the normalised error (E_n) as a function of the dew/frost point temperature.

3. Facilities of the Laboratories

The humidity laboratory of INMETRO has four standard CMHs of which two are calibrated abroad, they are: *i)* a Michell S4000, identified as PR 001, traceable to the National Physical Laboratory (NPL, UK) in the dew/frost point temperature range from –75 ºC to +20 ºC; and *ii)* a MBW 373, identified as PR 002, traceable to the Centre Technique des Industries Aérauliques et Thermiques (CETIAT, France) in the dew/frost point temperature range from –40 ºC to +75 ºC.

For the generation of air samples, the humidity laboratory of INMETRO uses three commercial humidity generators: *i)* a Michell divided-flow generator, model DG-4, which works in the dew/frost point temperature range from –75 ºC to +20 ºC. In this equipment, dried gas is divided into two streams of which one passes through a water saturator and is mixed with the other stream to produce a certain gas sample. Dew/frost point temperatures can be selected via a front panel keypad, through factory pre-set values, or by manually mixing the wet and dry gases by means of metering valves mounted on its front panel; and *ii)* two Weiss Technik climatic chambers, models SB2-300 and WK3-340/40, that have a relative humidity operating range from 10 %rh to 98 %rh in the range from 10 ºC to 95 ºC.

The humidity standard of INTI is a two pressure primary humidity generator. It is a commercial equipment, Thunder Scientific 2500 LT, serial number 0607577 humidity range is 10 %rh to 95 %rh and temperature range is -10 ºC to 70 ºC. This is approximately -35 ºC to 65 ºC in dew point temperature. The two pressures principle for generating humidity air samples is a process that involves, first the saturation of an air sample at one pressure and then the decompression of this sample to produce an air sample with less humidity [5, 6].

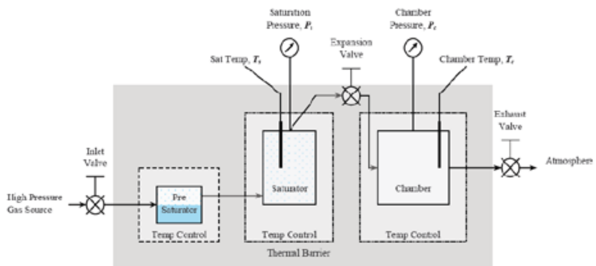

Figure 1 – Principle of INTI's Humidity Standard

The humidity value of the generated air sample is determined by the measurements of saturator pressure, sample chamber pressure, saturator temperature and sample chamber temperature using equation (1) or (2) [5, 6, 7].

$$RH(\%) = \left(\frac{f(P_s, t_s) \cdot e_w(t_s) \cdot P_c}{f(P_c, t_c) \cdot e_w(t_c) \cdot P_s} \right) \cdot 100 \qquad (1)$$

$$f\left(P_c, t_{dew}\right) \cdot e_w\left(t_{dew}\right) = \frac{f\left(P_s, T_s\right) \cdot e_w\left(T_s\right)}{P_s} \cdot P_c \qquad (2)$$

Where,
$RH(\%)$ – Relative humidity;
t_{dew} – Dew point temperature;
$e_w\ (t)$ – Vapor pressure;
$f\ (P,\ t)$ – Enhancement factor;
P_x – Pressure ($x = s$: saturator, c: chamber);

t_x – Pressure (x = s: saturator, c: chamber).

The Thunder Scientific 2500 LT is commanded via a front panel or via RS232 port by software 2500 ControlLog for control and data acquisition. In this generator it is only possible to control the saturator pressure and the saturator temperature. The sample chamber is at atmospheric pressure and at the same temperature as the saturator. The value of the relative humidity or dew point temperature is showed in the front panel or via software. The pressure and temperature measurements are traceable to SI. Both sensors are calibrated at INTI with traceability at the temperature and pressure national standard, see Appendix 1: CMCs Mass and Related Quantities and Appendix 2: CMCs Thermometry of INTI.

The INTI humidity lab also has two instruments as secondary standards and a climatic chamber: a Vaisala HM70 with a probe HMP77B capacitive hygrometer, an Almemo FNA846 aspirate psychrometer, and a Weiss SB1/300/40 climatic chamber. These are used in the calibration services and tests.

4. Transfer Standard

As transfer standard, a Michell Optidew Vision CMH, serial number 118931, property of INMETRO, which can operate in the range from –60 ºC to +90 ºC of dew/frost point temperature, was used for the comparison. The hygrometer control unit is separated from the dew point sensor head. The latter can thus be mounted in several ways to suit the purpose. An application software allows its control and the data acquisition. In order to prevent any loss of measurement accuracy due to mirror contamination, the hygrometer uses an automatic compensation system based on a self-learning prediction algorithm which adjusts the operating conditions in order to achieve optimal performance at all times.
The decision to use this instrument as transfer standard was based on the following considerations: (*i*) we found it more interesting to use this one than INTI´s RH sensor (Vaisala); (*ii*) it was used before for this same purpose with satisfactory results [2] and (*iii*) it is a dew-point hygrometer that has moderate accuracy, simple operation and easy transportation.
It is necessary to say that registering this comparison was not among our initial objectives. It was planed as a first approach.

5. Measuring Procedures

At both institutes, for all the five comparison points, four measurement runs were carried out in order to quantify the effect of any irreproducibility of the transfer standard. For each run, the condensate was cleared and re-formed and ten measurements were acquired at intervals of 1 min.

In order to avoid any complication in the measurement due to the phase change between water and ice, the nominal value of 0 ºC was changed to +1 °C.

Measurements at INMETRO

For this bilateral comparison, the air samples generated by one of the chambers (WK3-340/40) and the reference values indicated by the standard hygrometer PR 002 were used. However, several times, the standard hygrometer PR 001 and another hygrometer (PR 040), which was calibrated by the manufacturer, whose lab is accredited in its country, were used in parallel to PR 002. Some points were also repeated using hygrometers PR 001 and/or PR 040. In every case, the results found using hygrometers PR 001 and/or PR 040 were equivalent to the results obtained using hygrometer PR 002.

For all the comparison points, the transfer standard sensor was positioned near the centre of the climatic chamber. Air samples from the climatic chamber were brought to the measurement head of the standard hygrometer PR 002 by means of its internal diaphragm pump, or by an external suction pump, and a heated hose. The hose inlet was placed near the transfer standard sensor head. The gas flow rate in the standard hygrometer was set to approximately 0.5 l/min. For the dew/frost points of –20 ºC and 1 ºC, the hose, the internal tubing and the measurement head of the standard hygrometer PR 002 were kept at room temperature (21 ºC). For the dew points of 20 ºC, 40 ºC and 60 ºC, in order to prevent any condensation, the devices were heated about 20 ºC above the actual dew point temperature.

The frost point temperature of –20 ºC was repeated with the transfer standard sensor head outside the climatic chamber housed into a stainless-steel sampling device. Stainless-steel tubes were used for connecting the device to the chamber. The gas flow rate was set to approximately 1.0 l/min. The system operated in the open circuit mode. The transfer standard sensor head was cooled to –3 ºC by means of a water/ethanol mixture supplied by a thermostatic bath. Before performing the measurements, the acquisition system was purged for about 4 hours. The results found with this measurement procedure were equivalent to the ones obtained when the transfer standard sensor head was inserted directly in the centre of the chamber, without cooling and pumping.

Figure 2 – Transfer Standard Sensor Connected at INMETRO Climatic Chamber and Cooled at –3 ºC

Measurements at INTI

The measurements were performed in the chamber of the generator. All points were measured with a sensor transfer placed in the center of the chamber and a chamber temperature sensor placed beside it. Several positions of the sensor transfer were tested in order to avoid the effects of the high flux of air over the mirror. The air flux of generator was tested at 10 l/min, 15 l/min and 20 l/min, and no differences were found. The air flux wasn't measured at the instrument; these were different operating conditions of the generator.

In all cases the saturator temperature, that is approximately the same as the chamber temperature, was set at 5 ºC or more over the dew point temperature of the generated sample to avoid any kind of condensation.

Only the raw measurements of saturator pressure, chamber pressure and saturator temperature were used. The reference values of dew point temperature were calculated with a home made software. This software was validated satisfactorily with Control Log and other commercial softwares. The uncertainty of dew point reference temperature was calculated by classical uncertainty propagation and checked by simulation of distributions [6, 7, 8]

Figure 3 – Transfer Standard Sensor Inside of the Chamber of INTI Primary Generator

6. Results

For each nominal comparison point, the mean values of the reference standard (*RS*) and transfer standard (*TS*) readings were calculated for each run. Table 1 shows these values for INMETRO and INTI.

INMETRO					
-20	***RS***	-19.91	-19.80	-19.84	-19.91
	TS	-19.60	-19.32	-19.40	-19.42
0	***RS***	+0.96	+0.96	+0.89	+0.93
	TS	+1.09	+1.08	+1.03	+1.08
+20	***RS***	+19.97	+19.98	+19.86	+20.01
	TS	+20.12	+20.15	+20.04	+20.20
+40	***RS***	+40.17	+40.25	+40.21	+40.17
	TS	+40.36	+40.43	+40.39	+40.33
+60	***RS***	+60.16	+60.21	+60.00	+59.99
	TS	+60.32	+60.38	+60.21	+60.19
INTI					
-20	***RS***	-19.90	-19.90	-19.91	-19.89
	TS	-19.49	-19.49	-19.49	-19.49
0	***RS***	+1.19	+1.19	+1.18	+1.18
	TS	+1.20	+1.20	+1.29	+1.30
+20	***RS***	+19.92	+19.92	+19.92	+19.89
	TS	+19.89	+19.88	+19.68	+19.63
+40	***RS***	+40.02	+40.02	+40.02	+40.01
	TS	+40.18	+40.15	+40.13	+40.12
+60	***RS***	+59.95	+59.95	+59.95	+59.95
	TS	+60.24	+60.21	+60.21	+60.18

Table 1 – Mean Values of the Measurements for the 4 Runs (in °C)

The average difference (D) of the four runs, performed at each laboratory, was used for the comparison. Table 2: shows the overall mean values (mean of the mean values of the four runs) and the mean differences for both institutes.

T	INMETRO			INTI		
	RS	***TS***	***D***	***RS***	***TS***	***D***
-20	-19.87	-19.44	-0.43	-19.90	-19.49	-0.41
0	+0.94	+1.07	-0.13	+1.19	+1.25	-0.06
20	+19.95	+20.13	-0.17	+19.91	+19.77	+0.14
40	+40.20	+40.38	-0.18	+40.02	+40.15	-0.13
60	+60.09	+60.28	-0.19	+59.95	+60.21	-0.26

Table 2 – Mean Values of Both Runs and Differences (in °C)

Based on the Guide to the Expression of Uncertainty in Measurement [9], the laboratories calculated the measurement uncertainty at each point. The combined standard uncertainty (u_c) was calculated using equation (3) below:

$$u_c = \sqrt{\sum_{i=1}^{4} u_i^2} \qquad (3)$$

Where,
u_1 – Standard uncertainty associated with the reference standard (based on a normal distribution);
u_2 – Standard uncertainty due to the resolution of the transfer standard (based on a rectangular distribution);
u_3 – Standard uncertainty associated with transfer standard repeatability (based on a normal distribution);
u_4 – Standard uncertainty associated with transfer standard reproducibility (based on a normal distribution).

At INTI, the reference standard uncertainty is derived from the uncertainty of the primary generator.
See Appendix 3: Uncertainty budget for INTI Standard.
At INMETRO, the reference standard uncertainty combines the calibration uncertainty of the reference hygrometer, its resolution, the drift between successive calibrations and an uncertainty contribution associated with the polynomial correction.
See Appendix 4: Uncertainty budget for INMETRO Standard.

At both institutes, for the transfer standard, the uncertainty associated with repeatability was estimated as the average of the mean standard deviations of the four runs, and the uncertainty associated with reproducibility was estimated as the standard deviation of the four differences. In the case of INMETRO, the reproducibility of transfer standard takes into consideration measurements realized before and after measurements realized in INTI. Therefore, the drift of transfer standard is being considered within the reproducibility of transfer standard. We mean the reproducibility of transfer standard takes into consideration the drift of transfer standard.Table 3: shows the uncertainty sources and the combined uncertainties for both institutes.

INMETRO					
T	u_1	u_2	u_3	u_4	u_c
-20	0.063	0.029	0.007	0.081	**0.107**
0	0.048	0.029	0.013	0.013	**0.059**
+20	0.048	0.029	0.012	0.018	**0.060**
+40	0.048	0.029	0.014	0.011	**0.059**
+60	0.048	0.029	0.012	0.025	**0.062**
INTI					
T	u_1	u_2	u_3	u_4	u_c
-20	0.105	0.029	0.04	0.008	**0.116**
0	0.051	0.029	0.03	0.059	**0.088**
+20	0.054	0.029	0.03	0.125	**0.142**
+40	0.055	0.029	0.03	0.024	**0.073**
+60	0.053	0.029	0.03	0.021	**0.071**

Table 3 – Uncertainty Contributions and Combined Standard Uncertainty (in °C)

The measurement expanded uncertainty (*U*) was calculated by multiplying the combined standard uncertainty (u_c) by a coverage factor *k*=2, which corresponds to a confidence interval of approximately 95%.

Table 4 shows the uncertainties at the comparison points for each participating laboratory.

T	**INMETRO**			**INTI**		
	u_c	***k***	***U***	u_c	***k***	***U***
-20	0.107	2.0	0.21	0.116	2.0	0.23
0	0.059	2.0	0.12	0.088	2.0	0.18
+20	0.060	2.0	0.12	0.142	2.0	0.28
+40	0.059	2.0	0.12	0.073	2.0	0.15
+60	0.062	2.0	0.12	0.071	2.0	0.14

Table 4 – Measurement Uncertainty (in °C)

Figure 4 compares the differences found at INMETRO and at INTI. The vertical error bar associated with each measurement point represents the expanded uncertainty listed in the above Table 4.

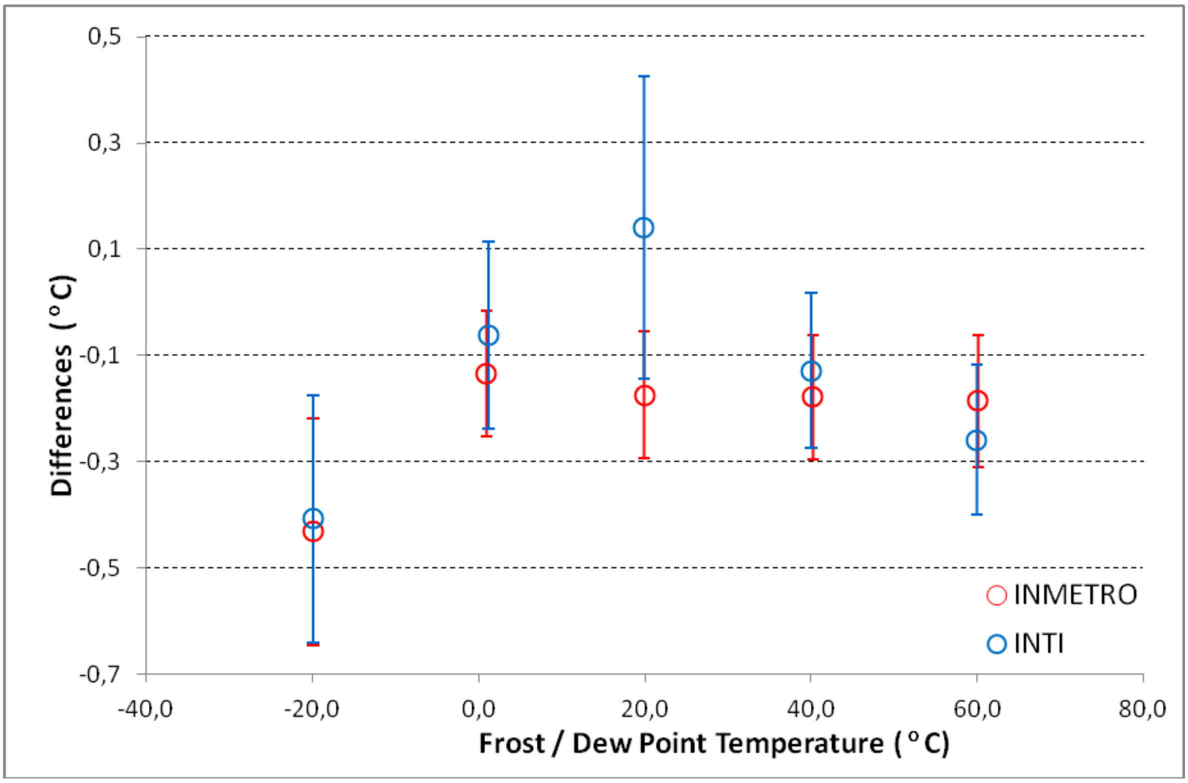

Figure 4 – Measurement Differences and associated Expanded Uncertainty

The compatibility of the measurements was analysed by means of the normalised error (E_n). A comparison measurement is satisfactory when its E_n is equal or lower than one [10]. E_n numbers were calculated according to the equation (4) below.

$$E_n = \left| \frac{D_{INMETRO} - D_{INTI}}{\sqrt{(U_{INMETRO})^2 + (U_{INTI})^2}} \right| \quad (4)$$

Where,
$D_{INMETRO}$ – Difference found for INMETRO measurements;
D_{INTI} – Difference found for INTI measurements;
$U_{INMETRO}$ – Expanded uncertainty calculated at INMETRO;
U_{INTI} – Expanded uncertainty calculated at INTI.

Table 5 below presents the E_n numbers of all comparison points for INMETRO and INTI.

T	$D_{INMETRO}$ - D_{INTI}	$U_{INMETRO}$	U_{INTI}	$\sqrt{(U_{INMETRO})^2 + (U_{INTI})^2}$	E_n
-20	-0.02	0.21	0.23	0.31	0.08
0	-0.07	0.12	0.18	0.22	0.34
+20	-0.32	0.12	0.28	0.30	1.02
+40	-0.05	0.12	0.15	0.19	0.26
+60	+0.07	0.12	0.14	0.18	0.39

Table 5 – E_n Numbers

7. Conclusion

A bilateral comparison of the humidity standards of the hygrometry labs of INMETRO and INTI in the dew/frost point temperature range from –20 °C to +60 °C was presented. The calibration methods, the uncertainty analysis and the comparison results were also discussed.

The highest difference among the differences found by the laboratories was observed in the comparison dew point temperature of 20 °C. For this point, the E_n number was slightly higher than one. The laboratories have discussed about the reason for this difference, but no objective evidence was found.

The measurement of the 20 ºC dew point temperature carried out at INTI shows low repeatability and the difference does not follow the tendencies of the other measured points. During the data acquisition process, the measurements and control parameters of the generator did not show any anomalies. The transfer standard is also a well-known instrument which has been exhaustively calibrated in the last years. So, the incompatibility in this point does not seem to have anything to do with the generator or the transfer standard. An operational problem seems to be the most probable cause. Although several and careful cleaning processes were performed, the possibility of some occasional contamination of the sensor mirror surface cannot be totally dismissed. The possibility that the air speed and its profile within the chamber have affected the condensate formation on the sensor mirror surface cannot be dismissed either.

However, as reported in Table 5, the normalised errors show that the E_n numbers are lower than one for the other comparison points. So, it can be concluded that, except for the 20 ºC dew point temperature, INMETRO and INTI measurements agreed to within their expanded uncertainties with a confidence level of approximately 95%.

8. References

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Appendix 1: CMCs Mass and Related Quantities, INTI AR

Mass and Related Quantities, Argentina, INTI (Instituto Nacional de Tecnologia Industrial)

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty						
Class	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Comments	NMI Service Identifier
Mass	Mass standard	Subdivision method	1	1	mg	Temperature	((18 to 22) ± 0.5) °C	0.0007	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	2	2	mg	Temperature	((18 to 22) ± 0.5) °C	0.0007	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	5	5	mg	Temperature	((18 to 22) ± 0.5) °C	0.0008	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	10	10	mg	Temperature	((18 to 22) ± 0.5) °C	0.0008	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	20	20	mg	Temperature	((18 to 22) ± 0.5) °C	0.0008	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	50	50	mg	Temperature	((18 to 22) ± 0.5) °C	0.001	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	100	100	mg	Temperature	((18 to 22) ± 0.5) °C	0.001	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	200	200	mg	Temperature	((18 to 22) ± 0.5) °C	0.0015	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	500	500	mg	Temperature	((18 to 22) ± 0.5) °C	0.002	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	1	1	g	Temperature	((18 to 22) ± 0.5) °C	0.0025	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	2	2	g	Temperature	((18 to 22) ± 0.5) °C	0.0025	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	5	5	g	Temperature	((18 to 22) ± 0.5) °C	0.0045	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							

Mass and Related Quantities, Argentina, INTI (Instituto Nacional de Tecnologia Industrial)

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty						
Class	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Comments	NMI Service Identifier
Mass	Mass standard	Subdivision method	10	10	g	Temperature	((18 to 22) ± 0.5) °C	0.008	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	20	20	g	Temperature	((18 to 22) ± 0.5) °C	0.008	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	50	50	g	Temperature	((18 to 22) ± 0.5) °C	0.01	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	100	100	g	Temperature	((18 to 22) ± 0.5) °C	0.02	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	200	200	g	Temperature	((18 to 22) ± 0.5) °C	0.035	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	500	500	g	Temperature	((18 to 22) ± 0.5) °C	0.08	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	1	1	kg	Temperature	((18 to 22) ± 0.5) °C	0.15	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	2	2	kg	Temperature	((18 to 22) ± 0.5) °C	0.5	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Subdivision method	5	5	kg	Temperature	((18 to 22) ± 0.5) °C	0.8	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Mass comparator, dissemination	10	10	kg	Temperature	((18 to 22) ± 0.5) °C	1.5	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Direct comparison	20	20	kg	Temperature	((18 to 22) ± 0.5) °C	10	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Direct comparison	50	50	kg	Temperature	((18 to 22) ± 0.5) °C	25	mg	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Direct comparison	100	100	kg	Temperature	((18 to 22) ± 1.5) °C	2	g	2	95%	No		
						Humidity	((40 to 60) ± 7) %							

Mass and Related Quantities, Argentina, INTI (Instituto Nacional de Tecnologia Industrial)

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty						
Class	**Instrument or Artifact**	**Instrument Type or Method**	**Minimum value**	**Maximum value**	**Units**	**Parameter**	**Specifications**	**Value**	**Units**	**Coverage Factor**	**Level of Confidence**	**Is the expanded uncertainty a relative one?**	**Comments**	**NMI Service Identifier**
Mass	Mass standard	Direct comparison	200	200	kg	Temperature	((18 to 22) ± 1.5) °C	3	g	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Direct comparison	500	500	kg	Temperature	((18 to 22) ± 1.5) °C	8	g	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Direct comparison	1000	1000	kg	Temperature	((18 to 22) ± 1.5) °C	15	g	2	95%	No		
						Humidity	((40 to 60) ± 7) %							
Mass	Mass standard	Direct comparison	5000	5000	kg	Temperature	((15 to 25) ± 3) °C	150	g	2	95%	No		
						Humidity	((40 to 60) ± 20) %							
Density of solid	Volume of mass standard 1 g	Hydrostatic weighing by weight comparison	0.104	0.145	cm^3	Water temperature	20 °C	0.0008	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 2 g	Hydrostatic weighing by weight comparison	0.225	0.275	cm^3	Water temperature	20 °C	0.0008	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 5 g	Hydrostatic weighing	0.594	0.6562	cm^3	Water temperature	20 °C	0.0015	cm^3	2	95%	No		

Mass and Related Quantities, Argentina, INTI (Instituto Nacional de Tecnologia Industrial)

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty						
Class	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Comments	NMI Service Identifier
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 10 g	Hydrostatic weighing	1.208	1.292	cm^3	Water temperature	20 °C	0.0015	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 20 g	Hydrostatic weighing	2.448	2.551	cm^3	Water temperature	20 °C	0.002	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 50 g	Hydrostatic weighing	6.188	6.313	cm^3	Water temperature	20 °C	0.002	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 100 g	Hydrostatic weighing	12.396	12.604	cm^3	Water temperature	20 °C	0.0035	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 200 g	Hydrostatic weighing	24.792	25.208	cm^3	Water temperature	20 °C	0.0069	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 500 g	Hydrostatic weighing	61.981	63.02	cm^3	Water temperature	20 °C	0.017	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 1 kg	Hydrostatic weighing	123.962	126.04	cm^3	Water temperature	20 °C	0.035	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 2 kg	Hydrostatic weighing	247.924	252.08	cm^3	Water temperature	20 °C	0.069	cm^3	2	95%	No		

Mass and Related Quantities, Argentina, INTI (Instituto Nacional de Tecnologia Industrial)

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty						
Class	**Instrument or Artifact**	**Instrument Type or Method**	**Minimum value**	**Maximum value**	**Units**	**Parameter**	**Specifications**	**Value**	**Units**	**Coverage Factor**	**Level of Confidence**	**Is the expanded uncertainty a relative one?**	**Comments**	**NMI Service Identifier**
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 5 kg	Hydrostatic weighing	619.81	630.2	cm^3	Water temperature	20 °C	0.17	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 10 kg	Hydrostatic weighing	1239.62	1260.4	cm^3	Water temperature	20 °C	0.35	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 20 kg	Weighing of the displaced liquid	2479.24	2520.8	cm^3	Water temperature	20 °C	0.5	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of solid	Volume of mass standard 50 kg	Weighing of the displaced liquid	6198.09	6301.99	cm^3	Water temperature	20 °C	1	cm^3	2	95%	No		
						Air temperature	((18 to 22) ± 0.5) °C							
						Humidity	((40 to 60) ± 7) %							
Density of liquid	Hydrometers	Cuckow method, weighing hydrostatic	0.65	2	g/cm^3	Water temperature	15 °C to 20 °C	0.0001	g/cm^3	2	95%	No		
						Air temperature	20 °C							
						Humidity	40% to 60%							
Absolute Pressure	Pressure gauge	Gas medium	1,5E+03	4,0E+04	Pa			4	Pa	2	95%	No	Approved on 12 February 2009	
Absolute Pressure	Pressure gauge	Gas medium	4,0E+04	7,0E+06	Pa			(2.0 + 5E-05*p*), *p* pressure in Pa	Pa	2	95%	No	Approved on 12 February 2009	
Absolute Pressure	Pressure gauge	Gas medium	7,1E+06	1,21E+07	Pa			6E-05*p* , *p* pressure in Pa	Pa	2	95%	No	Approved on 12 February 2009	

Mass and Related Quantities, Argentina, INTI (Instituto Nacional de Tecnologia Industrial)

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty						
Class	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Comments	NMI Service Identifier
Absolute Pressure	Pressure gauge	Oil medium	2,0E+05	1,0E+08	Pa			(30 + 5E-05*p*), *p* pressure in Pa	Pa	2	95%	No	Approved on 12 February 2009	
Absolute Pressure	Pressure gauge	Oil medium	1,0E+08	4,0E+08	Pa			(4E-05*p* + 2.1E-13p^2), *p* pressure in Pa	Pa	2	95%	No	Approved on 12 February 2009	
Gauge Presure	Pressure gauge	Gas medium	-1,0E+05	-5,0E+03	Pa			(1 + 4E-05*p*), *p* absolute value of the gauge pressure in Pa	Pa	2	95%	No	Approved on 12 February 2009	
Gauge Presure	Pressure gauge	Gas medium	-5,0E+03	-1,5E+03	Pa			2	Pa	2	95%	No	Approved on 12 February 2009	
Gauge Presure	Pressure gauge	Gas medium	-1,5E+03	1,5E+03	Pa			0.03	Pa	2	95%	No	Approved on 12 February 2009	
Gauge Presure	Pressure gauge	Gas medium	1,5E+03	5,0E+03	Pa			2	Pa	2	95%	No	Approved on 12 February 2009	
Gauge Presure	Pressure balance, pressure gauge	Gas medium	5,0E+03	7,0E+06	Pa			(1 + 4E-05*p*), *p* pressure in Pa	Pa	2	95%	No	Approved on 12 February 2009	
Gauge Presure	Pressure balance, pressure gauge	Gas medium	7,0E+06	1,20E+07	Pa			5E-05*p* , *p* pressure in Pa	Pa	2	95%	No	Approved on 12 February 2009	
Gauge Presure	Pressure balance, pressure gauge	Oil medium	1,0E+05	1,0E+08	Pa			(30 + 4E-05*p*), *p* pressure in Pa	Pa	2	95%	No	Approved on 12 February 2009	
Gauge Presure	Pressure balance, pressure gauge	Oil medium	1,0E+08	4,0E+08	Pa			(4E-05*p* + 2.1E-13p^2), *p* pressure in Pa	Pa	2	95%	No	Approved on 12 February 2009	
Force, tension and compression	Force measuring device	Direct comparison	500	1000	N	Temperature		0.0004		2	95.45%	Yes		
Force, tension and compression	Force measuring device	Direct comparison	1	2.5	kN	Temperature		0.0004		2	95.45%	Yes		

Mass and Related Quantities, Argentina, INTI (Instituto Nacional de Tecnologia Industrial)

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty						
Class	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Comments	NMI Service Identifier
Force, tension and compression	Force measuring device	Direct comparison	2.5	5	kN	Temperature		0.0004		2	95.45%	Yes		
Force, tension and compression	Force measuring device	Direct comparison	5	10	kN	Temperature		0.0003		2	95.45%	Yes		
Force, tension and compression	Force measuring device	Direct comparison	10	20	kN	Temperature		0.0005		2	95.45%	Yes		
Force, tension and compression	Force measuring device	Direct comparison	20	50	kN	Temperature		0.0001		2	95.45%	Yes		
Force, tension and compression	Force measuring device	Direct comparison	50	110	kN	Temperature		0.0001		2	95.45%	Yes		
Force, tension and compression	Force measuring device	Direct comparison	110	150	kN	Temperature		0.0003		2	95.45%	Yes		
Force, tension and compression	Force measuring device	Direct comparison	150	200	kN	Temperature		0.0003		2	95.45%	Yes		
Force, tension and compression	Force measuring device	Direct comparison	200	500	kN	Temperature		0.0004		2	95.45%	Yes		
Force, tension and compression	Force measuring device	Direct comparison	500	999	kN	Temperature		0.0003		2	95.45%	Yes		
Volume of liquids	Glassware (pycnometers, pipettes, buretes, flasks)	Gravimetric, distilled and deaerated water	10	100	ml	Temperature	19 ºC to 21 ºC	0.05	%	2	95%	Yes	Approved on 13 February 2012	102.04.05.00.00 4
Volume of liquids	Glassware (pycnometers, pipettes, buretes, flasks)	Gravimetric, distilled and deaerated water	0.1	1	l	Temperature	19 ºC to 21 ºC	0.03	%	2	95%	Yes	Approved on 13 February 2012	102.04.05.00.00 4
Volume of liquids	Volumetric test measures (graduated neck type)	Gravimetric, distilled and deaerated water	5	40	l	Temperature	ambient	0.015	%	2	95%	Yes	Approved on 13 February 2012	102.04.05.00.00 5
Volume of liquids	Volumetric test measures (graduated neck type)	Gravimetric	100	5000	l	Temperature	ambient	0.015	%	2	95%	Yes	Approved on 13 February 2012	102.04.05.00.00 5

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Appendix 2: CMCs Thermometry, INTI AR

Thermometry, Argentina, INTI (Instituto Nacional de Tecnologia Industrial)

Calibration or Measurement Services			Measurand Level or Range			Measurement Conditions/Independent variables		Expanded Uncertainty						
Quantity	Instrument or artifact	Instrument Type or Method	Minimum value	Maximum value	units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	NMI Service Identifier	Comments
Temperature	PRT	Comparison with SPRT	-25	10	°C	Bath	temperature controlled ethylene glycol and water bath	0.1	°C	2	95%	No	PEC08 or PEC13	Hysteresis uncertainty for each IPRT must be added to the combined uncertainty quoted in the Calibration Report Approved on 12 July 2007
Temperature	PRT	Comparison with SPRT	10	80	°C	Bath	temperature controlled water bath	0.02	°C	2	95%	No	PEC08 or PEC13	Hysteresis uncertainty for each IPRT must be added to the combined uncertainty quoted in the Calibration Report Approved on 12 July 2007
Temperature	PRT	Comparison with SPRT	80	200	°C	Bath	temperature controlled siliconed oil bath	0.03	°C	2	95%	No	PEC08 or PEC13	Hysteresis uncertainty for each IPRT must be added to the combined uncertainty quoted in the Calibration Report Approved on 12 July 2007

Thermometry, Argentina, INTI (Instituto Nacional de Tecnologia Industrial)

Calibration or Measurement Services			Measurand Level or Range			Measurement Conditions/Independent variables		Expanded Uncertainty						
Quantity	Instrument or artifact	Instrument Type or Method	Minimum value	Maximum value	units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	NMI Service Identifier	Comments
Temperature	PRT	Comparison with SPRT	200	400	°C	Bath	temperature controlled alumina powder-in air fluid bath	0.1	°C	2	95%	No	PEC08 or PEC13	Hysteresis uncertainty for each IPRT must be added to the combined uncertainty quoted in the Calibration Report Approved on 12 July 2007
Temperature	Mercury-in-glass thermometer 0.1 °C graduation	Total immersion, comparison with SPRT	-25	10	°C	Bath	temperature controlled ethylene glycol and water bath	0.1	°C	2	95%	No	PEC10	Approved on 12 July 2007
Temperature	Mercury-in-glass thermometer 0.1 °C graduation	Total immersion, comparison with SPRT	10	80	°C	Bath	temperature controlled water bath	0.04	°C	2	95%	No	PEC10	Approved on 12 July 2007
Temperature	Mercury-in-glass thermometer 0.1 °C graduation	Total immersion, comparison with SPRT	80	200	°C	Bath	temperature controlled siliconed oil bath	0.05	°C	2	95%	No	PEC10	Approved on 12 July 2007
Temperature	Mercury-in-glass thermometer 0.2 °C graduation	Total immersion, comparison with SPRT	-25	10	°C	Bath	temperature controlled ethylene glycol and water bath	0.12	°C	2	95%	No	PEC10	Approved on 12 July 2007
Temperature	Mercury-in-glass thermometer 0.2 °C graduation	Total immersion, comparison with SPRT	10	80	°C	Bath	temperature controlled water bath	0.07	°C	2	95%	No	PEC10	Approved on 12 July 2007
Temperature	Mercury-in-glass thermometer 0.2 °C graduation	Total immersion, comparison with SPRT	80	200	°C	Bath	temperature controlled siliconed oil bath	0.07	°C	2	95%	No	PEC10	Approved on 12 July 2007
Temperature	Mercury-in-glass thermometer 0.5 °C graduation	Total immersion, comparison with SPRT	-25	10	°C	Bath	temperature controlled ethylene glycol and water bath	0.2	°C	2	95%	No	PEC10	Approved on 12 July 2007

Thermometry, Argentina, INTI (Instituto Nacional de Tecnologia Industrial)

Calibration or Measurement Services			Measurand Level or Range			Measurement Conditions/Independent variables		Expanded Uncertainty						
Quantity	**Instrument or artifact**	**Instrument Type or Method**	**Minimum value**	**Maximum value**	**units**	**Parameter**	**Specifications**	**Value**	**Units**	**Coverage Factor**	**Level of Confidence**	**Is the expanded uncertainty a relative one?**	**NMI Service Identifier**	**Comments**
Temperature	Mercury-in-glass thermometer 0.5 °C graduation	Total immersion, comparison with SPRT	10	80	°C	Bath	temperature controlled water bath	0.2	°C	2	95%	No	PEC10	Approved on 12 July 2007
Temperature	Mercury-in-glass thermometer 0.5 °C graduation	Total immersion, comparison with SPRT	80	200	°C	Bath	temperature controlled siliconed oil bath	0.2	°C	2	95%	No	PEC10	Approved on 12 July 2007
Temperature	Type E thermocouple	Comparison with thermocouples	0	900	°C	Isothermal block in temperature controlled furnace		[0.5 + 0.0009 *t* /(°C)]	°C	2	95%	No	PEC09	Pre-determined value of inhomogeneity included in the CMC entry Approved on 12 July 2007
Temperature	Type J thermocouple	Comparison with thermocouples	0	700	°C	Isothermal block in temperature controlled furnace		[0.5 + 0.0009 *t* /(°C)]	°C	2	95%	No	PEC09	Pre-determined value of inhomogeneity included in the CMC entry Approved on 12 July 2007
Temperature	Type K or N thermocouple	Comparison with thermocouples	0	1100	°C	Isothermal block in temperature controlled furnace		[0.5 + 0.0009 *t* /(°C)]	°C	2	95%	No	PEC09	Pre-determined value of inhomogeneity included in the CMC entry Approved on 12 July 2007
Temperature	Type T thermocouple	Comparison with thermocouples	0	400	°C	Isothermal block in temperature controlled furnace		[0.5 + 0.0009 *t* /(°C)]	°C	2	95%	No	PEC09	Pre-determined value of inhomogeneity included in the CMC entry Approved on 12 July 2007

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Appendix 3: Uncertainty budget for INTI Standard

Uncertainty of one dew point formation One dew point formation = 1 run composed of 10 readings taken at each 1 minute	
The uncertainty in dew point temperature was calculated by propagation of the uncertainties and by propagation of distributions of the following components, in the formula of dew point temperature in function of saturator pressure, chamber pressure and saturator temperature. The applied formulae were obtained of the Industrial Research Limited Report Nº988: Uncertainty Analysis for Humidity Generators - Jeremy Lovell - Smith	
Uncertainty of saturator pressure measurement (u Ps)	
average between 10 readings	
pressure resolution	(traducer range / 25000)*0.5/√(3)
pressure calibration INTI report OTI NºFM-102-090-unico	sensor low pressure < 344500 Pa U=68,94757 Pa - sensor high pressure > 344500 Pa U=689,4757 Pa
Uncertainty of chamber pressure measurement (u Pc)	
of average between 10 readings	
pressure resolution	(traducer range / 25000)*0.5/√(3)
pressure calibration INTI report OTI NºFM-102-090-unico	sensor low pressure < 344500 Pa U=68,94757 Pa - sensor high pressure > 344500 Pa U=689,4757 Pa
Uncertainty of saturator temperature measurement (u Ts)	
of average between 10 readings	
temperature resolution	0,01*0,5/(√(3))
temperature calibration INTI report FM-102-PCC-036	(U=0,02 ºC)
Saturator efficiency, saturator bath uniformity, contamination of supply gas and water	(U=0,104 ºC)
Formulae uncertainty	
Uncertainty of vapor pressure formula (u ew)	bibliographic data: Industrial Research Limited Report Nº988: Uncertainty Analysis for Humidity Generators - Jeremy Lovell - Smith
Uncertainty of enhancement factor formula (u fw)	bibliographic data: Industrial Research Limited Report Nº988: Uncertainty Analysis for Humidity Generators - Jeremy Lovell - Smith

Ps:	Saturator pressure
uP:s	Uncertainty of saturator pressure measurement
Pc:	Chamber pressure
uPc:	Uncertainty of chamber pressure measurement
Ts:	Saturator temperature
uTs:	Uncertainty of saturator temperature measurement

Ps [Pa]	uPs [Pa]	Pc [Pa]	uPc [Pa]	Ts [°C]	uTs [°C]	Dew Point Ref [°C]	U Dew Point Ref [°C], k=2
710139	347	101067	35	5,00	0,05	-19,9	0,21
710157	347	101058	35	5,00	0,05	-19,9	0,21
710166	346	100971	35	5,00	0,05	-19,9	0,21
710109	349	101142	35	5,00	0,05	-19,9	0,20
358516	345	101331	35	20,00	0,05	1,2	0,10
358532	345	101333	35	20,00	0,05	1,2	0,10
358526	345	101295	35	19,99	0,05	1,2	0,10
358504	345	101285	35	19,99	0,05	1,2	0,10
138030	35	101303	35	24,99	0,05	19,9	0,10
138031	35	101289	35	24,99	0,05	19,9	0,11
138028	35	101277	35	24,99	0,05	19,9	0,11
137596	35	100791	35	24,99	0,05	19,9	0,10
131033	49	101009	35	44,97	0,05	40,0	0,10
131021	35	100990	35	44,97	0,05	40,0	0,11
131018	35	100983	35	44,97	0,05	40,0	0,11
131062	49	100974	35	44,97	0,05	40,0	0,11
158133	35	100913	35	69,94	0,05	60,0	0,10
158119	40	100912	35	69,94	0,05	60,0	0,10
158145	36	100898	35	69,94	0,05	59,9	0,10
158142	35	100888	35	69,94	0,05	59,9	0,11

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Appendix 4: Uncertainty budget for INMETRO Standard.

Uncertainty budget for INMETRO Standard:

<table>
<tr><th></th><th>Cal.</th><th>Res.</th><th>Fitting[1]</th><th>Drift[2]</th><th>Rep.[2]</th><th>u_1</th></tr>
<tr><td>-20</td><td>0,1/2</td><td rowspan="5">0,01 /√12</td><td rowspan="5">0,013 /1</td><td rowspan="5">0,06/√(3)</td><td>0,007</td><td>0,063</td></tr>
<tr><td>0</td><td rowspan="4">0,06/2</td><td>0,008</td><td>0,048</td></tr>
<tr><td>20</td><td>0,002</td><td>0,048</td></tr>
<tr><td>40</td><td>0,006</td><td>0,048</td></tr>
<tr><td>60</td><td>0,004</td><td>0,048</td></tr>
</table>

[1] Fitting of the correction curve

[2] Repeatability – average of the mean standard deviations of the measurements of the four runs