Final Report

SIM.T-S5

Report on the comparison of the calibration of 100 Ω Platinum Resistance Thermometers

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1. INTRODUCTION

The object of this report is to present the final results of the comparison of the calibration of 100 Ω (at 0 ºC) platinum resistance thermometers coordinated by the Centro Español de Metrología (CEM).

This interlaboratory comparison was carried out under the European project of quality support and application of sanitary and phytosanitary measures in Central America (PRACANS).

The purpose of the comparison is to check the equivalency between the participant laboratories in the calibration of platinum resistance thermometers by comparison in the range from -38,8 ºC up to 250 ºC. CEM acts as the pilot laboratory and provides the comparison reference values. The Centro Nacional de Metrología (CENAME) was not able to perform the measurements.

The final circulation scheme was as follows:

NMI	Country	Starting of measurements
CEM	Spain	2013-08-20
LACOMET	Costa Rica	2013-10-03
CEHM	Honduras	2013-10-22
LANAMET	Nicaragua	2013-11-18
CENAMEP	Panama	2013-12-15
CENAME	Guatemala	---
CIM	El Salvador	2014-01-30
CEM	Spain	2014-03-05

Table 1. Circulation scheme

Temperature values are referred to the International Temperature Scale of 1990 (ITS-90).

In the comparison it was planned to perform additional measurements in fixed points to be used by the participants for internal purposes, but finally no measurements were performed due to the tight schedule.

2. MEASUREMENT METHODOLOGY

The protocol of the comparison (see annex 2) was prepared by CEM and agreed with the participant laboratories in August 2013. It was approved by the CCT-WG7 in December 2013. The modifications introduced in the protocol, following the CCT-WG7 requests, did not involve critic changes in the measurement procedure so it was not necessary to repeat any measurements after the CCT-WG7 protocol acceptance. It was agreed to make the comparison using the *W* of each laboratory at 1 mA current. The *W* values are defined as the quotient between the resistance value of the thermometer at the calibration point and the resistance value at the triple point of water.

In order to maintain as much control as possible over the travelling PRTs and checking the influence of transport and, where appropriate, to correct possible accidents, it was requested to report to CEM the PRTs measured resistance values at the triple point of water or at the ice point prior to the calibration.

3. DESCRIPTION OF THERMOMETERS

The PRTs used as travelling thermometers were chosen to provide enough stability to allow the comparison of the results. Table 2 provides a summary of the main features of the PRTs used.

Manufacturer	Fluke	
Model	5626	
Serial number	3473	3481
Temperature range	-200 °C to 661 °C	
Resistance at 0 º C	100 Ω (± 1 Ω)	
Stability	± 0.003 °C	

Table 2. PRTs characteristics

4. THERMOMETERS CHARACTERIZATION

The PRTs were previously characterized by CEM. Two studies were performed:

- Heat conduction
- Hysteresis

4.1. Heat conduction study

A heat conduction study was carried out for both thermometers in order to determine the proper immersion depth for each PRT. The study was performed in the extreme temperatures of calibration: -38 ºC and 250 ºC, and consisted in full immersion of the PRTs and then decreasing the immersion depth centimeter by centimeter taking readings of the PRT resistance value in each position. Figure 1 summarizes the results obtained where the good immersion depth characteristics for both thermometers are shown. The measurements were carried out in the same (alcohol and oil) liquid baths than the ones listed in table 5.

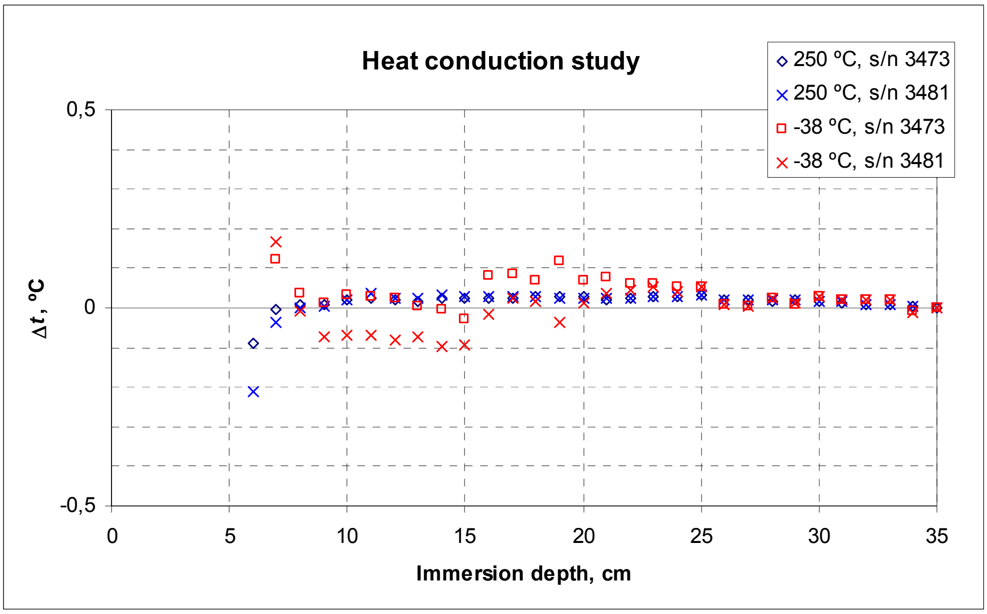


Figure 1. PRTs heat conduction study

4.2. Hysteresis study

Both PRTs were subjected to five temperature cycles, each of them consisting of:

1. Cooling to -38 ºC for at least 10 minutes.
2. Air heating to room temperature.
3. Determination of *R* (0 ºC).
4. Heating to 250 ºC for at least 10 minutes.
5. Air cooling to room temperature.
6. Determination of *R* (0 ºC).

This hysteresis study was performed twice, one before the first calibration at CEM and the other one before the last calibration at CEM. Figures 2 and 3 show the results obtained, where the odd-numbered points are after cooling to -38 °C and even-numbered points are after heating to 250 °C. The thermometer with s/n 3473 has shown an overall stability of 2 mK while the stability s/n 3481 is a bit worse, around 3 mK along the whole hysteresis study. However it is difficult to distinguish clearly if the causes of the instabilities are due to the thermometer hysteresis. The differences observed in *R* (0 ºC) values are mainly due to short time stabilities of the thermometers.

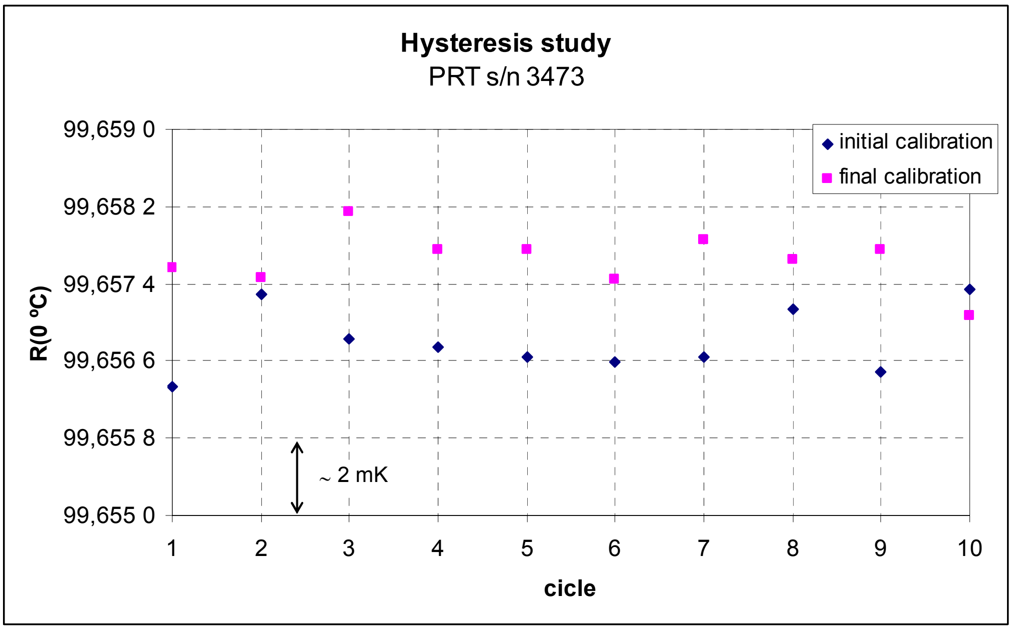


Figure 2. PRT s/n 3473 hysteresis study

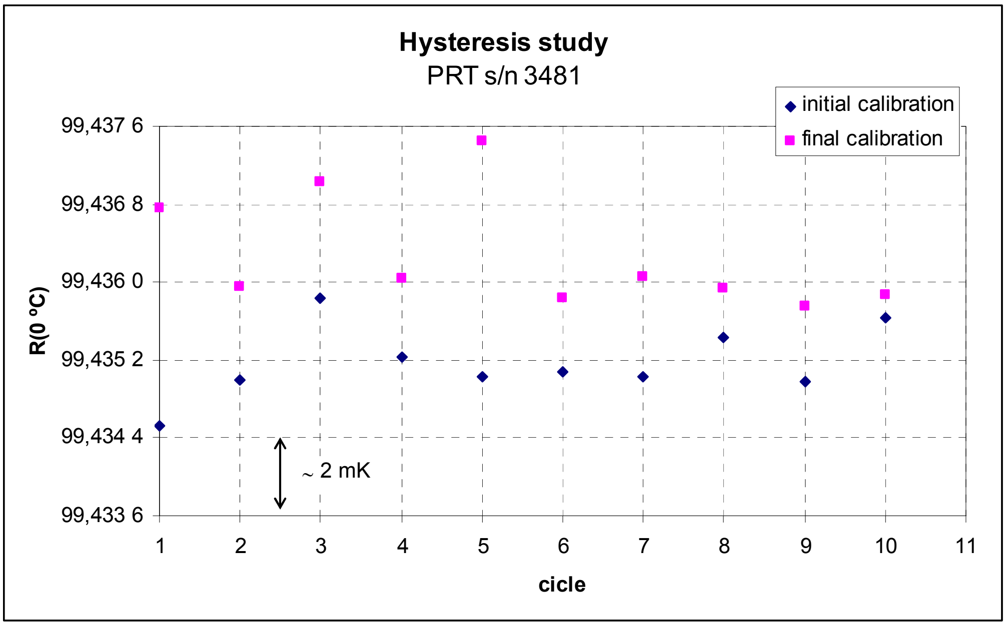


Figure 3. PRT s/n 3481 hysteresis study

4.3. Thermometers self-heating

CEM performed measurements of the thermometers selfheating in an ice point during the initial and the final calibrations. The selfheating was estimated by measuring the thermometers resistance at two electrical currents: 1 mA and $\sqrt{2}$ mA.

LACOMET and CENAMEP also measured the thermometers selfheating. Table 3 summarizes the results:

Laboratory	PRT s/n 3473 mΩ	PRT s/n 3481 mΩ	Isothermal media used
CEM initial calibration	0,4	0,4	Ice point
LACOMET	0,5	0,5	Ice point
CENAMEP	0,7	0,7	Liquid bath
CEM final calibration	0,4	0,4	Ice point

Table 3. Summary of the selfheating measurements.

As it can be seen in table 3 the selfheating was in all cases lower that 2 mK.

5. STABILITY OF THE THERMOMETERS

The comparison protocol specified the measurement of *R*(0 ºC) as receiving and send the results immediately to CEM. This data let to check the thermometer status after the successive displacements and, if significant changes were detected, let to take appropriate actions.

R(0 ºC) measurements were performed by the laboratories at the water triple point or at the ice bath. In order to standardize the results and comparing them, the resistance values were extrapolated to the water triple point temperature 0,01 ºC. The results obtained for both thermometers are given in Tables 4 and 5 and graphically in figures 4 and 5. The uncertainties showed are those supplied by the laboratories in the reception formats. No significant drifts were observed during the comparison.

Laboratory	Date	*t* / ºC	R_t / Ω	*R*(0,01 ºC) / Ω	*U* / ºC
CEM	06/09/2013	0,001	99,658 00	99,661 39	0,0070
LACOMET	25/09/2013	-0,001	99,656 60	99,661 01	0,0028
CEHM	17/10/2013	0,005	99,658 00	99,659 99	0,0200
LANAMET	07/11/2013	0,010	99,660 20	99,660 20	0,0075
CENAMEP	15/12/2013	0,010	99,660 49	99,660 49	0,0030
CIM	23/01/2014	0,00	99,663 00	99,666 58	0,10
CEM	05/03/2014	0,000	99,657 69	99,661 66	0,0070

Table 4. Control measurements at the water triple point, PRT s/n 3473

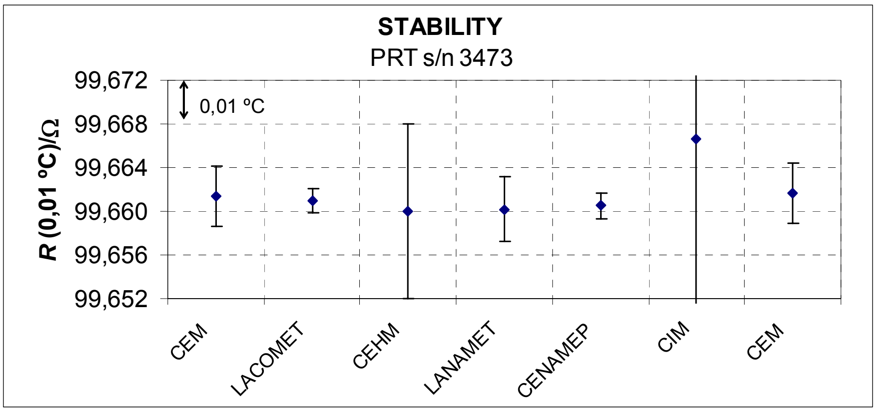


Figure 4. Control measurements at the water triple point, PRT s/n 3473

Laboratory	Date	*t* / °C	R_t / Ω	*R*(0,01 °C) / Ω	*U* / °C
CEM	06/09/2013	0,001	99,436 00	99,439 38	0,0070
LACOMET	25/09/2013	-0,001	99,435 30	99,439 70	0,0028
CEHM	17/10/2013	0,005	99,436 00	99,437 98	0,0200
LANAMET	07/11/2013	0,01	99,438 90	99,438 90	0,0075
CENAMEP	15/12/2013	0,01	99,439 37	99,439 37	0,0300
CIM	23/01/2014	0,00	99,444 20	99,447 77	0,100
CEM	05/03/2014	0,000	99,435 98	99,439 95	0,0070

Table 5. Control measurements at the water triple point, PRT s/n 3481

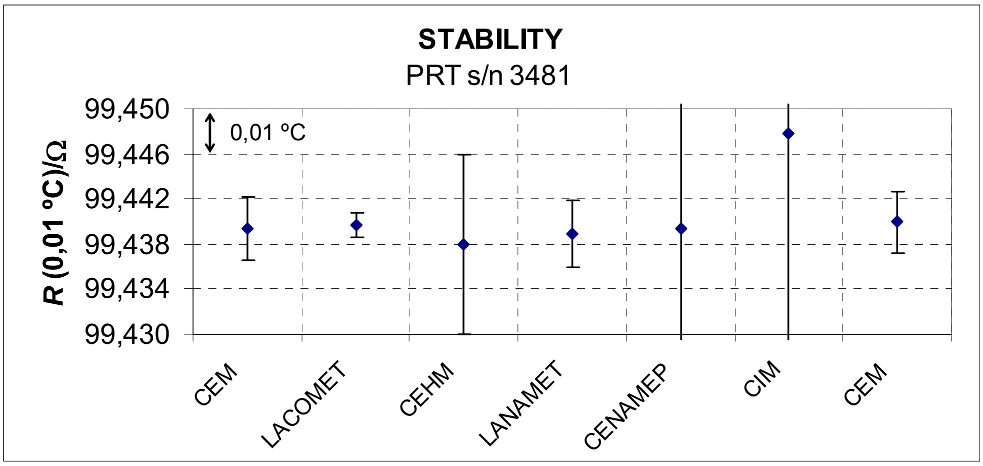


Figure 5. Control measurements at the water triple point, PRT s/n 3481

6. CALIBRATION METHOD AND INSTRUMENTATION USED

The calibration method to be used was comparison, in isothermal media, against previously calibrated reference standards.

The annex 2 of this report includes the comparison protocol, which describes the process and measurement points. The procedure used by each laboratory was the one used in routine calibrations.

Table 6 shows a summary of the instrumentation used by the participants.

	CEM	LACOMET	CEHM	LANAMET	CENAMEP	CIM
Standard thermometers						
Description	PRT	PRT	PRT	PRT	PRT	PRT
Manufacturer	Isotech	Isotech	Fluke	Fluke	Hart Scientific	Fluke
Model	670 SQ	909H-033	5626	5626	5681	5626
Traceability	CEM	LACOMET	LACOMET	LACOMET	INTI	CENAM
Measurement equipment						
Description	Bridge	Bridge	Temperature readout	Temperature readout	Bridge	Multimeter
Manufacturer	ASL	Isotech	Fluke / Isotech	Fluke	Hart Scientific	Keithley
Model	F700	MicroK400	Chub-E4 / TTI plus	1529	1590	2001
Traceability	CEM	LACOMET	ICE	LACOMET	---	CENAM
Standard Resistor						
Description	External	Internal	---	---	External	---
Manufacturer	Tinsley	---	---	---	Hart Scientific	---
Model	5685 A	---	---	---	5420/25	---
Traceability	CEM	NRC	---	---	INTI	---
Isothermal enclosures						
Description	*Alcohol bath*	*Liquid bath*	*Liquid bath*	*Liquid bath*	*Liquid bath*	*Liquid bath*
Manufacturer	Heto	Isotech	Isotech	Giussani	Hart Scientific	Giussani I
Model	KB 25	915C	ORION 796 M	TB300	7312	BK 40
Description	*Water bath*	*Oil bath*	*Liquid bath*	*Liquid bath*	*Liquid bath*	*Liquid bath*
Manufacturer	Heto	Tamson	Isotech	Fluke	Hart Scientific	GIUSSANI
Model	KB 216	TV7000	ORION 796 H	7341	7381	TB 300
Description	*Oil bath*	*Furnace*	---	---	*Furnace*	---
Manufacturer	Heto	Isotech	---	---	Fluke	---
Model	KB 12	ITL17703	---	---	9260	---
Triple point of water cell						
Manufacturer	---	Isotech	---	Fluke	Isotech	---
Model	---	A11-50-270	---	5901B-G	A11-50-270	---
Traceability	---	NIST	---	INRiM	NIST	---

Table 6. Summary of the instrumentation used

7. ANALYSIS OF RESULTS

In order to compare the results, the data sent by each laboratory were extrapolated to the reference temperatures given in the protocol. For this purpose, sensitivity coefficients (defined as the resistance change of each PRT with temperature) were used. They were calculated using the fitting curves obtained in the CEM initial calibration. A least squares fitting to the differences between the measured values and the ITS-90 reference functions were made. The deviation equation used in the complete range was:

$$W_{\mathrm{d}} = a \cdot (W - 1) + b \cdot (W - 1)^2 \quad (1)$$

The evaluation of the results was made in terms of the reduced resistance W_{t} in each calibration point in order to eliminate possible PRTs instabilities. The last measured value by each laboratory in the triple point of water or ice point was used for W_t calculation (tables 10 and 11).

7.1 Uncertainty calculation of the reference values

The reference values for each calibration point was taken as the mean between the first and last CEM calibration because the thermometers shown enough stability throughout the comparison and also because CEM has Calibration Measurement Capabilities (CMCs) approved for calibration of industrial platinum resistance thermometers by comparison with uncertainties from 0,01 ºC to 0,02 ºC in the temperature range (-80 to 250) ºC.

For calculating the uncertainty of the reference value, the following mathematical model was considered:

$$W_{\mathrm{ref.},\,t} = (W_{\mathrm{CEM1},\,t} + W_{\mathrm{CEM2},\,t}) / 2 + \delta W_{\mathrm{est.},\,t} + \Delta W_{\mathrm{ext.},t} \quad (2)$$

where:

- $W_{\mathrm{ref.},\,t}$: W reference value of the comparison at the calibration point t.
- $W_{\mathrm{CEM1},\,t}$ and $W_{\mathrm{CEM2},t}$: W values at the calibration point t measured at he first and the last calibration at CEM respectively.
- $\delta W_{\mathrm{est.},\,t}$: correction due to lack of stability at the calibration point t of the PRT.
- $\Delta W_{\mathrm{ext.},\,t}$: correction due to the interpolation value to the nominal value of the calibration point.

Taken into account that the uncertainties corresponding to the first and final CEM calibrations are highly correlated, applying the law of propagation of uncertainties to (2):

$$u^2(W_{\text{ref.},\,t}) = u^2(W_{\text{CEM}}) + u^2(\delta W_{\text{est.},\,t}) + u^2(\Delta W_{\text{ext},\,t}) \quad (3)$$

where:

- $u(W_{\text{ref.},\,t})$: standard uncertainty of the *W* reference value at the calibration point *t*.
- $u(W_{\text{CEM}})$: CEM calibration standard uncertainty at the calibration point *t*.
- $u(\delta W_{\text{est.},\,t})$: standard uncertainty due to the lack of stability of the PRT throughout the comparison. It was calculated considering the difference between the first and the last calibration of the PRT at the point *t* as the maximum value for this cause and assuming a rectangular probability distribution.
- $u(\Delta W_{\text{ext.},\,t})$: standard uncertainty due to the interpolation of the measured values to the nominal value of the calibration point. It was considered a value of 0,0015 ºC corresponding to the standard deviation of the fitting residues.

The uncertainties in *W* are calculated by using the corresponding uncertainty in *R* and the calculated thermometers sensitivity coefficients as they appear in tables 12 to 22.

The values of $u(\delta W_{\text{est.},\,t})$ and $u(\Delta W_{\text{ext.},\,t})$ are small and have little influence on the uncertainty of the reference value $u(W_{\text{ref.},\,t})$. The uncertainty value $u(\Delta W_{\text{ext.},\,t})$ was quadratically composed with the one of the calibration of each laboratory in order to account for the interpolation of the measured values to the nominal values of the calibration points as an additional source of uncertainty.

7.2 Standardized Deviation Coefficients calculation

In order to asses the results of the participant laboratories, the standardized deviation coefficients were calculated at each calibration point and for each laboratory. They are defined as:

$$E_{\text{L}t} = \frac{|W_{\text{L}t} - W_{\text{R}t}|}{\sqrt{U_{\text{L}t}^2 + U_{\text{R}t}^2}} \quad (4)$$

where:

- $U_{\text{L},\,t,}$: Calibration expanded uncertainty of the laboratory L at the temperature *t*.
- $U_{\text{R},\,t,}$: Calibration expanded uncertainty of the pilot laboratory at the temperature *t*.

7.3 Results

Below the results are presented in tabular and graphical form for both PRTs at each calibration point.

In the tables 7 to 12, each column is:

- Column 1: identification of the participants.

- Column 2: $\boldsymbol{t}$, reference measured temperatures reported by the participants.
- Column 3: $\boldsymbol{R(t)}$, measured resistance values reported by the participants.
- Column 4: $\boldsymbol{R(t_{cp})}$, PRT resistance values interpolated to the nominal value of the calibration point t_{cp}.
- Column 5: $\boldsymbol{E_L}$ standardized deviation coefficient calculated by means of (4) but using the resistance values measured at the calibration point (0 ºC) instead of the *W* values.
- Column 6: $\boldsymbol{U}$ calibration expanded uncertainty for $\boldsymbol{R(t)}$, in ºC, reported by the participants.
- Column 7: $\boldsymbol{U\ (t_{cp})}$ calibration expanded uncertainty for $\boldsymbol{R(t_{cp})}$, in ºC, calculated by combining the expanded uncertainty reported by the laboratories and the uncertainty of the interpolation. A coverage factor *k*=2 has been considered.
- Column 8: immersion depth of the thermometer in the calibration point.

In the tables 13 to 24, each column is:

- Column 1: identification of the participants.
- Column 2: $\boldsymbol{t}$, reference measured temperatures reported by the participants.
- Column 3: $\boldsymbol{R(t)}$, measured resistance values reported by the participants.
- Column 4: $\boldsymbol{R(t_{cp})}$, PRT resistance values interpolated to the nominal value of the calibration point t_{cp}.
- Column 5: $\boldsymbol{W(t_{cp})}$, calculated *W* values at the nominal value of the calibration point t_{cp}. The *R*(0,01 ºC) used is the one calculated for each participant at the end of the calibration (tables 10 and 11)
- Column 7: $\boldsymbol{E_L}$ standardized deviation coefficient.
- Column 8: $\boldsymbol{U}$ calibration expanded uncertainty for $\boldsymbol{R(t)}$, in ºC, reported by the participants.
- Column 9: $\boldsymbol{U\ (t_{cp})}$ calibration expanded uncertainty for $\boldsymbol{R(t_{cp})}$, in ºC, calculated by combining the expanded uncertainty reported by the laboratories and the uncertainty of the interpolation $u(\Delta W_{ext.,\,t})$. A coverage factor *k*=2 has been considered.
- Column 8: immersion depth of the thermometer in the calibration point.

In the corresponding values for CEM, it is included too the values of the differences and the standardized deviation coefficients in order to show the PRTs stability throughout the comparison and the repeatability of the calibrations performed.

CIM performed no hysteresis study so the uncertainties reported did not take into account this component.

The interpolated results obtained at each calibration, with their corresponding uncertainties, are plotted in figures 6 to 14 where three solid lines represents the reference values and the upper and lower limits of their expanded uncertainty. A coverage factor *k*=2 has been considered.

Calibration point, t_{cp} = 0,010 **ºC** **Beginning of the calibration** **s/n 3473**

PRT sensitivity coefficient = 0,397 5 **Ω / ºC**

Laboratory	***t*** ºC	***R*(*t*)** Ω	***R*(t_{cp})** Ω	***E*** E_L	U_t ºC	U_{tcp} ºC	**Immersion** cm
CEM	-0,001	99,656 4	99,660 7	0,13	0,007	0,008	36
LACOMET	0,001	99,657 5	99,661 0	0,11	0,007	0,008	30
CEHM	0,002	99,671 0	99,674 2	0,36	0,089	0,089	20
LANAMET	0,010	99,660 2	99,660 1	0,28	0,008	0,008	12,5
CENAMEP	0,010	99,660 5	99,660 5	0,23	0,003	0,005	27
CIM	0,001	99,662 8	99,666 4	0,13	0,100	0,100	17
CEM	0,000	99,657 7	99,661 8	0,13	0,007	0,008	36

R_{ref} = 99,661 3 U_{ref} = 0,0033

Table 7.

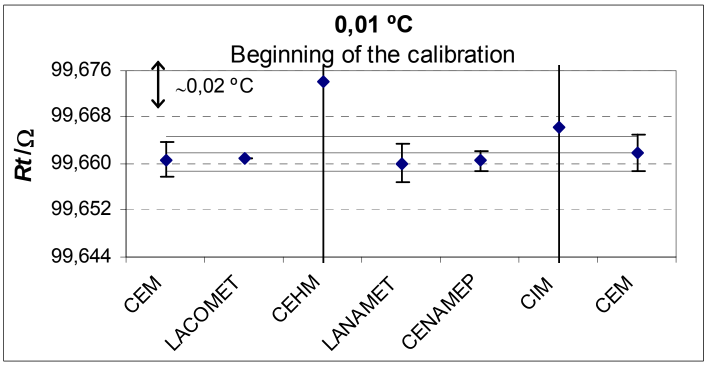
Calibration point, t_{cp} = 0,010 **ºC** **Beginning of the calibration** **s/n 3481**

PRT sensitivity coefficient = 0,396 6 **Ω / ºC**

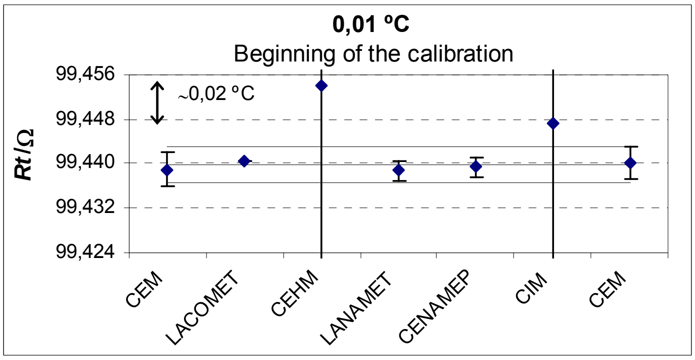
Laboratory	***t*** ºC	***R*(*t*)** Ω	***R*(t_{cp})** Ω	E_L	U_t ºC	U_{tcp} ºC	**Immersion** cm
CEM	-0,001	99,434 7	99,439 0	0,13	0,007	0,008	35
LACOMET	0,001	99,437 0	99,440 5	0,28	0,007	0,008	30
CEHM	0,002	99,451 0	99,454 2	0,42	0,088	0,088	20
LANAMET	0,010	99,438 9	99,438 7	0,19	0,008	0,008	12,5
CENAMEP	0,010	99,439 4	99,439 4	0,05	0,003	0,004	27
CIM	0,001	99,443 8	99,447 4	0,20	0,100	0,100	17
CEM	0,000	99,436 0	99,440 1	0,13	0,007	0,008	35

R_{ref} = 99,439 6 U_{ref} = 0,0033

Table 8.



a) PRT s/n 3473



b) PRT s/n 3481

Figure 6.

Calibration point, t_{cp} = 0,010 **ºC** **Mid-point of the calibration**

PRT sensitivity coefficient = 0,397 5 **Ω / ºC** s/n 3473

Laboratory	***t*** ºC	***R*(*t*)** Ω	***R*(t_{cp})** Ω	**E_L**	**U_t** ºC	**U_{tcp}** ºC	**Immersion** cm
CEM	0,000	99,656 2	99,660 2	0,19	0,007	0,008	35
LACOMET	0,002	99,657 6	99,660 9	0,03	0,007	0,008	30
CEHM	-0,002	99,656 0	99,660 8	0,01	0,089	0,089	20
LANAMET	0,010	99,660 7	99,660 6	0,10	0,009	0,010	12,5
CENAMEP	0,010	99,660 8	99,660 8	0,07	0,003	0,005	27
CIM	0,002	99,665 0	99,668 2	0,18	0,100	0,100	17
CEM	0,000	99,657 7	99,661 9	0,19	0,007	0,008	35

R_{ref} = 99,661 1 **U_{ref} =** 0,0036

Table 9.

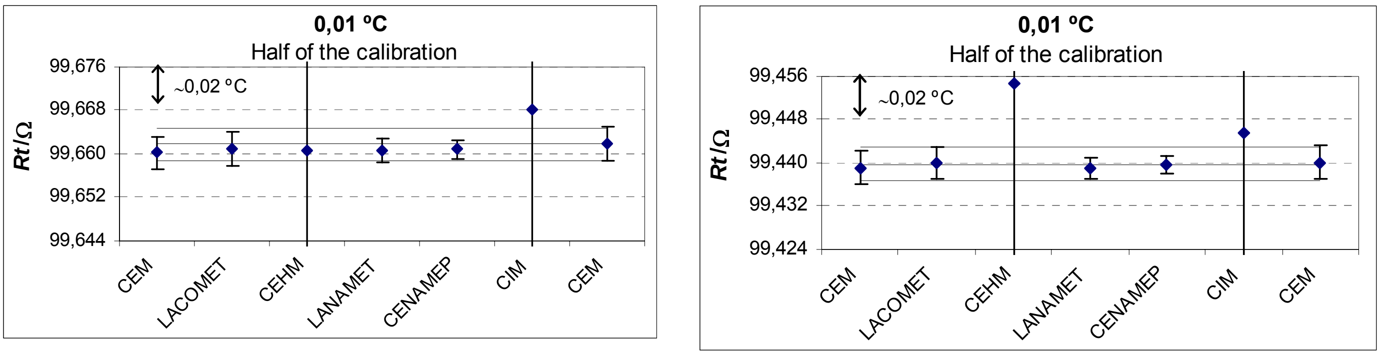
Calibration point, t_{cp} = 0,010 **ºC** **Mid-point of the calibration**

PRT sensitivity coefficient = 0,396 6 **Ω / ºC** s/n 3481

Laboratory	***t*** ºC	***R*(*t*)** Ω	***R*(t_{cp})** Ω	**E_L**	**U_t** ºC	**U_{tcp}** ºC	**Immersion** cm
CEM	0,000	99,435	99,439 1	0,11	0,007	0,008	35
LACOMET	0,002	99,436 7	99,440 0	0,09	0,007	0,008	30
CEHM	-0,002	99,450 0	99,454 8	0,43	0,089	0,089	20
LANAMET	0,010	99,439 3	99,439 1	0,11	0,008	0,008	12,5
CENAMEP	0,010	99,439 6	99,439 6	0,00	0,003	0,004	27
CIM	0,001	99,442 0	99,445 6	0,15	0,100	0,100	17
CEM	0,000	99,436 0	99,440 1	0,11	0,007	0,008	35

R_{ref} = 99,439 6 **U_{ref} =** 0,0032

Table 10.



a) PRT s/n 3473 b) PRT s/n 3481

Figure 7.

Calibration point, t_{cp} = 0,010 **ºC** **End of the calibration**

PRT sensitivity coefficient = 0,397 5 **Ω / ºC** s/n 3473

Laboratory	***t*** ºC	***R*(*t*)** Ω	***R*(t_{cp})** Ω	**E_L**	**U_t** ºC	**U_{tcp}** ºC	**Immersion** cm
CEM	0,001	99,658 4	99,661 8	0,01	0,007	0,008	35
LACOMET	0,002	99,657 7	99,660 9	0,21	0,007	0,008	30
CEHM	0,001	99,666 0	99,669 6	0,22	0,089	0,089	20
LANAMET	0,010	99,659 9	99,659 8	0,45	0,008	0,008	12.5
CENAMEP	0,010	99,660 6	99,660 6	0,34	0,003	0,005	27
CIM	0,004	99,664 8	99,667 2	0,14	0,100	0,100	17
CEM	0,000	99,657 6	99,661 7	0,01	0,007	0,008	35

R_{ref} = 99,661 8 **U_{ref} =** 0,0030

Table 11.

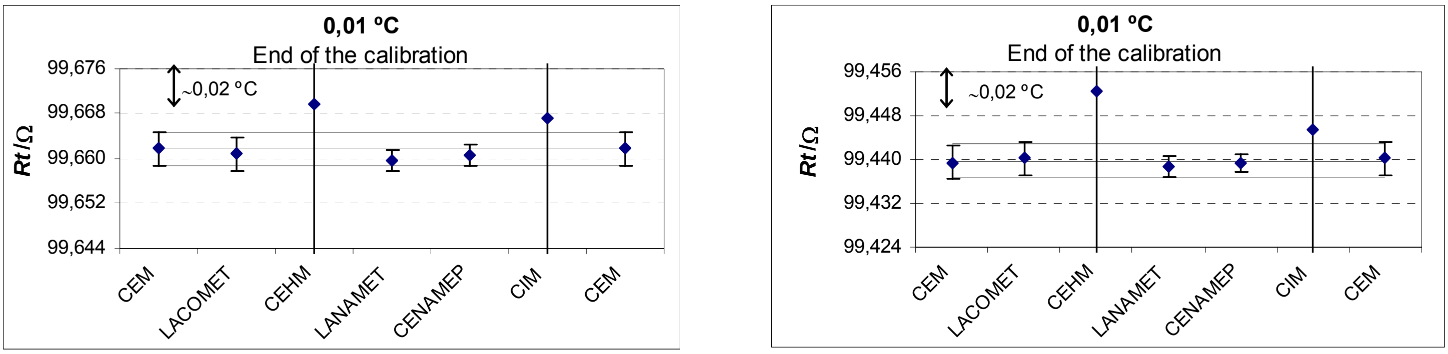
Calibration point, t_{cp} = 0,010 **ºC** **End of the calibration**

PRT sensitivity coefficient = 0,396 6 **Ω / ºC** s/n 3481

Laboratory	***t*** ºC	***R*(*t*)** Ω	***R*(t_{cp})** Ω	**E_L**	**U_t** ºC	**U_{tcp}** ºC	**Immersion** cm
CEM	0,001	99,436 0	99,439 4	0,09	0,007	0,008	35
LACOMET	0,002	99,437 0	99,440 2	0,08	0,007	0,008	30
CEHM	0,001	99,449 0	99,452 6	0,36	0,088	0,088	20
LANAMET	0,010	99,438 9	99,438 7	0,25	0,008	0,008	12,5
CENAMEP	0,010	99,439 4	99,439 4	0,11	0,003	0,004	27
CIM	0,001	99,442 0	99,445 6	0,14	0,100	0,100	17
CEM	0,000	99,436 1	99,440 2	0,09	0,007	0,008	35

R_{ref} = 99,439 8 **U_{ref} =** 0,0032

Table 12.



a) PRT s/n 3473 b) PRT s/n 3481

Figure 8.

Calibration point, t_{cp} = -38,8 **ºC**

PRT sensitivity coefficient = 0,402 3 **Ω / ºC** s/n 3473

Laboratory	***t*** ºC	***R*(*t*)** Ω	***R*(t_{cp})** Ω	***W*(t_{cp})** Ω/Ω	**E_L**	**U_t** ºC	**U_{tcp}** ºC	**Immersion** cm
CEM	-38,857	84,124 3	84,147 0	0,844 326	0,05	0,011	0,011	35
LACOMET	-38,463	84,282 9	84,147 4	0,844 338	0,15	0,008	0,009	30
CEHM	-38,757	84,176 0	84,158 7	0,844 377	0,14	0,086	0,086	20
LANAMET	-38,805	84,146 1	84,148 1	0,844 354	0,23	0,024	0,024	18
CENAMEP	-38,804	84,145 1	84,146 8	0,844 334	0,08	0,006	0,007	27
CEM	-38,825	84,137 7	84,147 6	0,844 332	0,05	0,011	0,011	35

W_{ref} = 0,844 329 U_{ref} = 0,012

Table 13.

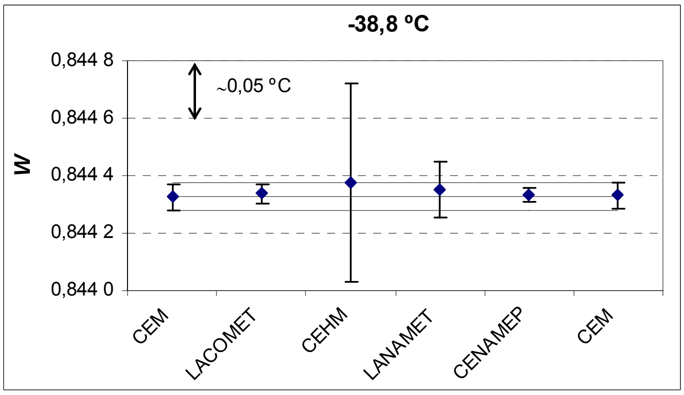
Calibration point, t_{cp} = -38,8 **ºC** s/n 3481

PRT sensitivity coefficient = 0,401 4 **Ω / ºC**

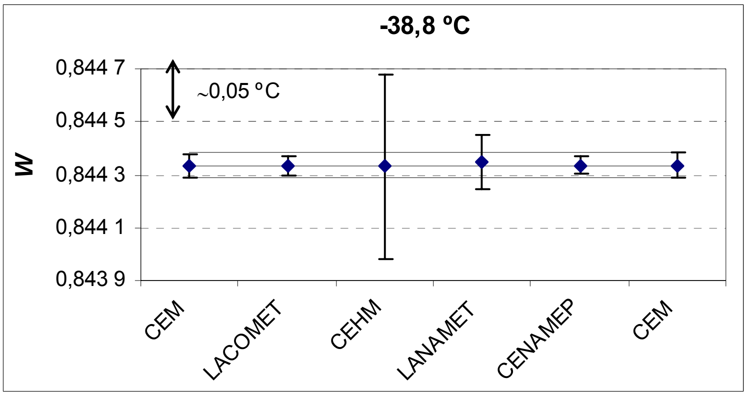
Laboratory	***t*** ºC	***R*(*t*)** Ω	***R*(t_{cp})** Ω	***W*(t_{cp})** Ω/Ω	**E_L**	**U_t** ºC	**U_{tcp}** ºC	**Immersio n** cm
CEM	-38,857	83,937 5	83,960 2	0,844 335	0,01	0,011	0,011	35
LACOMET	-38,463	84,095 7	83,960 6	0,844 332	0,05	0,008	0,009	30
CEHM	-38,757	83,988 0	83,970 7	0,844 330	0,02	0,086	0,086	20
LANAMET	-38,808	83,957 9	83,961 0	0,844 349	0,13	0,025	0,025	18
CENAMEP	-38,805	83,958 3	83,960 1	0,844 334	0,02	0,008	0,008	27
CEM	-38,825	83,951 0	83,960 9	0,844 336	0,01	0,011	0,011	35

W_{ref} = 0,844 335 U_{ref} = 0,012

Table 14.



a) PRT s/n 3473



b) PRT s/n 3481

Figure 9.

Calibration point, t_{cp} = -20 **°C**

PRT sensitivity coefficient = 0,399 9 **Ω / °C** s/n 3473

Laboratory	***t***	***R*(*t*)**	***R*(t_{cp})**	***W*(t_{cp})**	**E_L**	**U_t**	**U_{tcp}**	**Immersion**
	°C	**Ω**	**Ω**	**Ω/Ω**		**°C**	**°C**	**cm**
CEM	-19,994	91,687 8	91,685 4	0,919 965	0,04	0,011	0,011	35
LACOMET	-19,954	91,703 8	91,685 4	0,919 974	0,10	0,008	0,009	30
CEHM	-20,009	91,690 0	91,693 6	0,919 976	0,02	0,086	0,086	20
LANAMET	-19,992	91,687 9	91,684 6	0,919 976	0,05	0,031	0,031	18
CENAMEP	-20,005	91,683 0	91,684 8	0,919 970	0,04	0,008	0,008	27
CIM	-19,940	91,721 2	91,697 2	0,920 034	0,16	0,100	0,100	17
CEM	-20,058	91,662 9	91,685 9	0,919 971	0,04	0,011	0,011	35
			W_{ref} =	0,919 968		**U_{ref} =**	0,012	

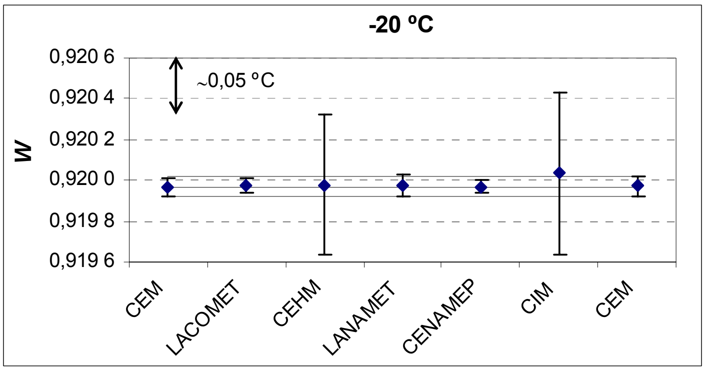
Table 15.

Calibration point, t_{cp} = -20 **°C** s/n 3481

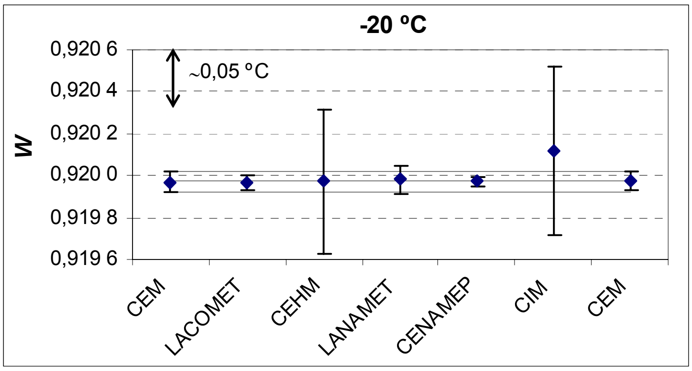
PRT sensitivity coefficient = 0,399 1 **Ω / °C**

Laboratory	***t***	***R*(*t*)**	***R*(t_{cp})**	***W*(t_{cp})**	**E_L**	**U_t**	**U_{tcp}**	**Immersion**
	°C	**Ω**	**Ω**	**Ω/Ω**		**°C**	**°C**	**cm**
CEM	-19,944	91,503 7	91,481 3	0,919 970	0,01	0,011	0,011	35
LACOMET	-19,954	91,500 1	91,481 8	0,919 968	0,05	0,008	0,009	30
CEHM	-20,009	91,490 0	91,493 6	0,919 972	0,00	0,086	0,086	20
LANAMET	-20,000	91,481 4	91,481 6	0,919 979	0,06	0,030	0,030	18
CENAMEP	-20,004	91,479 9	91,481 4	0,919 971	0,01	0,006	0,007	27
CIM	-19,950	91,521 6	91,501 6	0,920 118	0,36	0,100	0,100	16
CEM	-20,058	91,459 2	91,482 2	0,919 972	0,01	0,011	0,011	35
			W_{ref} =	0,919 971		**U_{ref} =**	0,012	

Table 16.



a) PRT s/n 3473



b) PRT s/n 3481

Figure 10.

Calibration point, t_{cp} = 29,8 **ºC**

PRT sensitivity coefficient = 0,393 9 **Ω / ºC** s/n 3473

Laboratory	***t***	***R*(*t*)**	***R*(t_{cp})**	***W*(t_{cp})**	**E_L**	**U_t**	**U_{tcp}**	**Immersion**
	ºC	**Ω**	**Ω**	**Ω/Ω**		**ºC**	**ºC**	**cm**
CEM	29,726	111,415 1	111,444 4	1,118 226	0,01	0,007	0,008	35
LACOMET	29,847	111,462 8	111,444 4	1,118 236	0,21	0,008	0,009	30
CEHM	29,802	111,453 0	111,452 2	1,118 217	0,02	0,090	0,090	20
LANAMET	29,832	111,454 6	111,442 1	1,118 225	0,00	0,036	0,036	18
CENAMEP	29,792	111,440 5	111,443 7	1,118 232	0,13	0,009	0,010	27
CIM	27,720	110,630 6	111,449 9	1,118 221	0,02	0,060	0,060	17
CEM	29,844	111,461 7	111,444 3	1,118 226	0,01	0,007	0,008	35

W_{ref} = 1,118 226 U_{ref} = 0,008

Table 17.

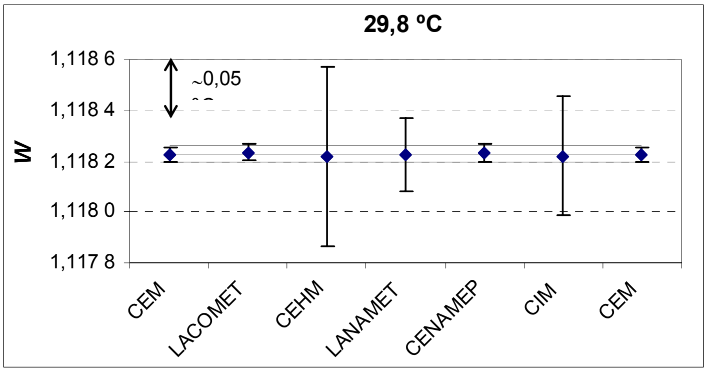
Calibration point, t_{cp} = 29,8 **ºC** s/n 3481

PRT sensitivity coefficient = 0,393 0 **Ω / ºC**

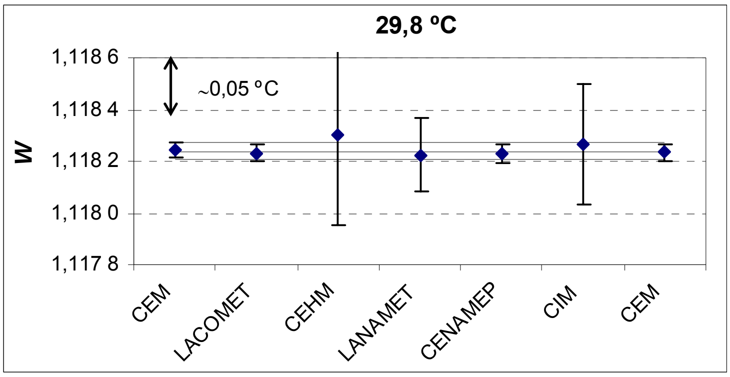
Laboratory	***t***	***R*(*t*)**	***R*(t_{cp})**	***W*(t_{cp})**	**E_L**	**U_t**	**U_{tcp}**	**Immersion**
	ºC	**Ω**	**Ω**	**Ω/Ω**		**ºC**	**ºC**	**cm**
CEM	29,726	111,168 0	111,197 3	1,118 241	0,08	0,007	0,008	35
LACOMET	29,847	111,215 6	111,197 2	1,118 232	0,11	0,008	0,009	30
CEHM	29,802	111,219 0	111,218 2	1,118 304	0,19	0,089	0,089	20
LANAMET	29,822	111,203 4	111,194 8	1,118 224	0,09	0,036	0,036	18
CENAMEP	29,795	111,194 2	111,196 1	1,118 230	0,15	0,009	0,009	27
CIM	27,700	110,381 2	111,206 5	1,118 265	0,12	0,060	0,060	16
CEM	29,844	111,214 7	111,197 4	1,118 233	0,08	0,007	0,008	35

W_{ref} = 1,118 237 U_{ref} = 0,008

Table 18.



a) PRT s/n 3473



b) PRT s/n 3481

Figure 11.

Calibration point, t_{cp} = 156,7 **°C**

PRT sensitivity coefficient = 0,378 8 **Ω / °C** s/n 3473

Laboratory	***t*** °C	***R*(*t*)** Ω	***R*(t_{cp})** Ω	***W*(t_{cp})** Ω/Ω	***E*$_L$**	***U$_t$*** °C	***U$_{tcp}$*** °C	**Immersion** cm
CEM	156,631	160,423 1	160,449 1	1,609 936	0,08	0,014	0,014	35
LACOMET	156,675	160,440 1	160,449 6	1,609 956	0,19	0,011	0,011	25
CEHM	156,645	160,386 0	160,406 8	1,609 386	1,53	0,095	0,095	20
LANAMET	156,633	160,418 8	160,444 1	1,609 919	0,16	0,035	0,035	18,4
CENAMEP	156,710	160,454 3	160,450 5	1,609 970	0,25	0,025	0,025	17
CIM	156,580	160,422 8	160,468 3	1,610 041	0,42	0,060	0,060	17
CEM	156,704	160,451 7	160,450 3	1,609 949	0,08	0,014	0,014	35

***W*$_{ref}$ =** 1,609 942 ***U*$_{ref}$ =** 0,015

Table 19.

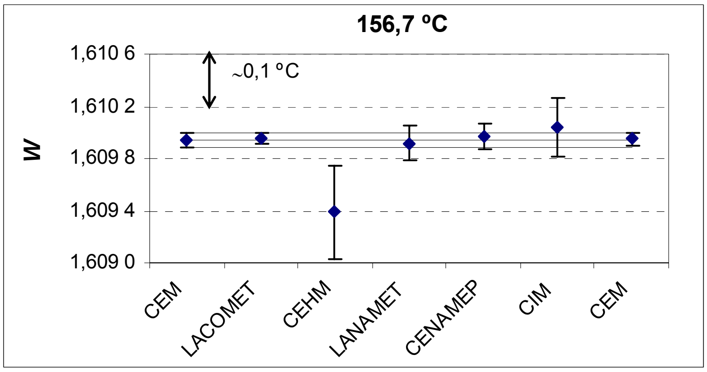
Calibration point, t_{cp} = 156,7 **°C** s/n 3481

PRT sensitivity coefficient = 0,378 0 **Ω / °C**

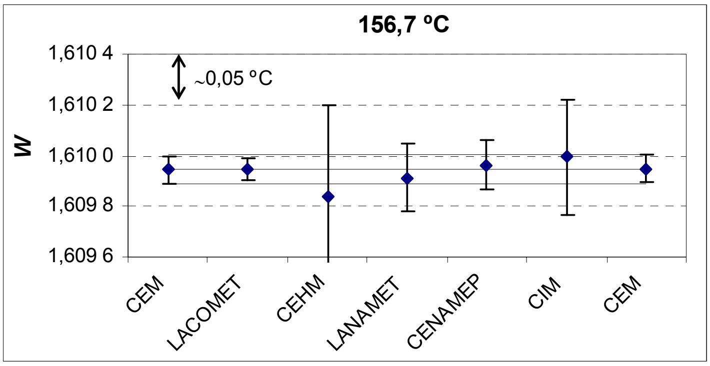
Laboratory	***t*** °C	***R*(*t*)** Ω	***R*(t_{cp})** Ω	***W*(t_{cp})** Ω/Ω	***E*$_L$**	***U$_t$*** °C	***U$_{tcp}$*** °C	**Immersion** cm
CEM	156,631	160,066 1	160,092 0	1,609 945	0,02	0,014	0,014	35
LACOMET	156,675	160,083 6	160,093 1	1,609 944	0,04	0,011	0,011	30
CEHM	156,645	160,082 0	160,102 8	1,609 841	0,29	0,09	0,094	20
LANAMET	156,633	160,062 2	160,087 6	1,609 912	0,24	0,035	0,035	18,4
CENAMEP	156,726	160,103 7	160,093 9	1,609 963	0,15	0,026	0,026	17
CIM	156,590	160,065 4	160,107 0	1,609 996	0,21	0,06	0,060	16
CEM	156,704	160,095 0	160,093 5	1,609 947	0,02	0,014	0,014	35

***W*$_{ref}$ =** 1,609 946 ***U*$_{ref}$ =** 0,015

Table 20.



a) PRT s/n 3473



b) PRT s/n 3481

Figure 12.

Calibration point, t_{cp} = 232,3 **°C**

PRT sensitivity coefficient = 0,370 0 **Ω / °C**

s/n 3473

Laboratory	***t*** °C	***R*(*t*)** Ω	***R*(t_{cp})** Ω	***W*(t_{cp})** Ω/Ω	**E_L**	**U_t** °C	**U_{tcp}** °C	**Immersion** cm
CEM	231,906	188,595 6	188,741 5	1,893 820	0,05	0,014	0,014	35
LACOMET	232,368	188,765 7	188,740 6	1,893 828	0,04	0,022	0,022	25
CEHM	232,300	188,763 0	188,763 0	1,893 888	0,17	0,10	0,102	20
LANAMET	232,243	188,718 1	188,739 4	1,893 837	0,07	0,045	0,045	18,4
CENAMEP	232,000	188,631 6	188,742 6	1,893 854	0,23	0,031	0,031	17
CIM	232,200	188,734 2	188,771 2	1,894 016	0,84	0,060	0,060	17
CEM	232,319	188,749 2	188,742 2	1,893 828	0,05	0,014	0,014	35

W_{ref} = 1,893 824 U_{ref} = 0,015

Table 21.

Calibration point, t_{cp} = 232,3 **°C**

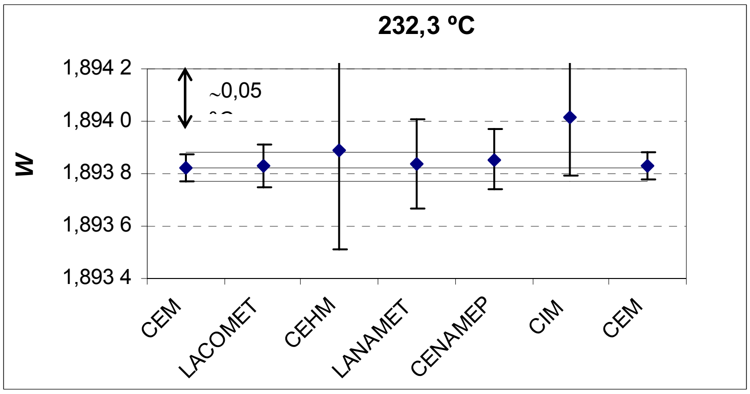
s/n 3481

PRT sensitivity coefficient = 0,369 1 **Ω / °C**

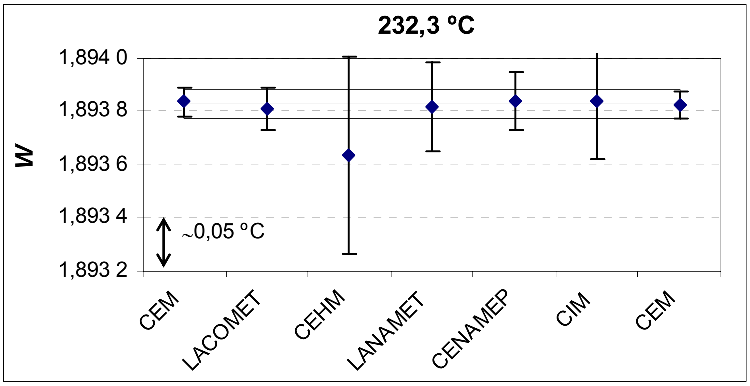
Laboratory	***t*** °C	***R*(*t*)** Ω	***R*(t_{cp})** Ω	***W*(t_{cp})** Ω/Ω	**E_L**	**U_t** °C	**U_{tcp}** °C	**Immersion** cm
CEM	231,906	188,176 5	188,322 1	1,893 837	0,08	0,014	0,014	35
LACOMET	232,368	188,345 9	188,320 8	1,893 810	0,21	0,022	0,022	25
CEHM	232,300	188,327 0	188,327 0	1,893 636	0,52	0,10	0,100	20
LANAMET	232,265	188,305 9	188,318 7	1,893 817	0,08	0,045	0,045	18,4
CENAMEP	232,018	188,218 4	188,322 5	1,893 841	0,08	0,029	0,029	17
CIM	232,200	188,297 2	188,334 1	1,893 841	0,04	0,060	0,060	16
CEM	232,319	188,329 4	188,322 4	1,893 825	0,08	0,014	0,014	35

W_{ref} = 1,893 831 U_{ref} = 0,015

Table 22.



a) PRT s/n 3473



b) PRT s/n 3481

Figure 13.

Calibration point, t_{cp} = 250 **ºC**

PRT sensitivity coefficient = 0,367 9 **Ω / ºC**

s/n 3473

Laboratory	***t*** ºC	***R*(*t*)** Ω	***R*(t_{cp})** Ω	***W*(t_{cp})** Ω/Ω	***E*$_L$**	***U$_t$*** ºC	***U$_{tcp}$*** ºC	**Immersion** cm
CEM	250,646	195,506 8	195,269 2	1,959 319	0,05	0,014	0,014	36
LACOMET	249,937	195,244 9	195,268 1	1,959 326	0,03	0,022	0,022	30
CEHM	249,994	195,279 0	195,281 2	1,959 286	0,10	0,102	0,102	20
LANAMET	250,001	195,266 1	195,265 9	1,959 325	0,01	0,047	0,047	18,4
CENAMEP	249,991	195,266 6	195,269 9	1,959 350	0,19	0,037	0,037	17
CIM	249,970	195,290 2	195,301 2	1,959 534	0,93	0,060	0,060	17
CEM	250,124	195,315 6	195,269 9	1,959 326	0,05	0,014	0,014	36

***W*$_{ref}$ =** 1,959 322 ***U*$_{ref}$ =** 0,015

Table 23.

Calibration point, t_{cp} = 250 **ºC**

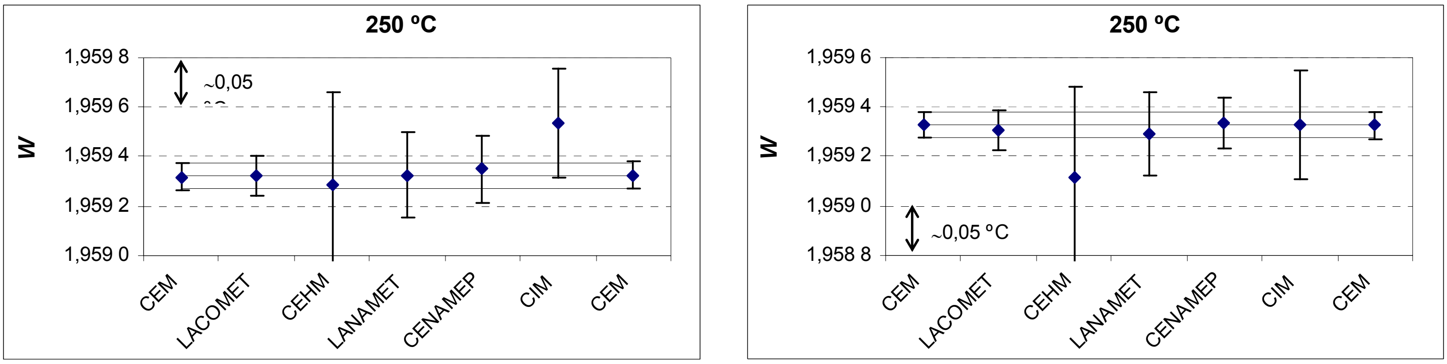
s/n 3481

PRT sensitivity coefficient = 0,367 1 **Ω / ºC**

Laboratory	***t*** ºC	***R*(*t*)** Ω	***R*(t_{cp})** Ω	***W*(t_{cp})** Ω/Ω	***E*$_L$**	***U$_t$*** ºC	***U$_{tcp}$*** ºC	**Immersion** cm
CEM	250,646	195,071 8	194,834 7	1,959 331	0,03	0,014	0,014	35
LACOMET	249,937	194,810 8	194,834 0	1,959 308	0,20	0,022	0,022	25
CEHM	249,994	194,837 0	194,839 2	1,959 117	0,57	0,10	0,100	20
LANAMET	249,986	194,824 2	194,829 6	1,959 293	0,20	0,046	0,046	18,4
CENAMEP	250,014	194,840 4	194,835 3	1,959 336	0,07	0,027	0,027	17
CIM	249,970	194,835 8	194,846 8	1,959 331	0,01	0,060	0,060	16
CEM	250,124	194,881 5	194,835 8	1,959 326	0,03	0,014	0,014	35

***W*$_{ref}$ =** 1,959 328 ***U*$_{ref}$ =** 0,015

Table 24.



a) PRT s/n 3473

b) PRT s/n 3481

Figure 14.

8. CONCLUSIONS

The thermometers have shown an acceptable behavior throughout the comparison as figures 4 and 5 show then, the results can be considered valid for comparing the measurement capabilities of the participant laboratories.

Except in one calibration point (156,7 ºC) for CEHM, the equivalence between the participant laboratories in the calibration of platinum resistance thermometers by comparison in the range from -38,8 ºC up to 250 ºC has been demonstrated.

ANNEX 1. PARTICIPANT LABORATORIES UNCERTAINTY BUDGETS

A1.1. CEM Uncertainty Budget

Description	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution			Units
Uncertainties of the calibration system				**-80 °C a 0 °C**	**0 °C a 90 °C**	**90 °C a 250 °C**	
Bridge reading	1,00E-06 /√3	rectangular	$R_s/\sqrt{2}s_p$	0,000 1	0,000 1	0,000 1	°C
Bridge calibration	3,52E-06	normal	$R_s/\sqrt{2}s_p$	0,000 6	0,000 6	0,000 6	°C
Standard resistor calibration	2,80E-04 /2	normal	$L_p/\sqrt{2}s_p$	0,000 5	0,000 5	0,000 5	°C
Standard resistor drift	1,00E-04 /√3	rectangular	$L_p/\sqrt{2}s_p$	0,000 2	0,000 2	0,000 2	°C
SPRTs calibration	0,0024 /2	normal	1	0,001 2	0,001 2	0,001 2	°C
SPRTs drift	0,002 4 /√3	rectangular	1	0,000 7	0,000 7	0,000 7	°C
Stability of isothermal enclosure	0,0024	rectangular	1	0,002 4			°C
	0,0017	rectangular	1		0,001 7		°C
	0,0031	rectangular	1			0,003 1	°C
Uniformity of isothermal enclosure	0,0043	rectangular	1	0,004 3 °C			°C
	0,0025	rectangular	1		0,002 5		°C
	0,0059	rectangular	1			0,005 9	°C
t_{ref}			s_x	**0,002 0**	**0,001 3**	**0,002 7**	Ω
DUT uncertainties							
Bridge reading	1,00E-06 /√3	rectangular	R_s	**0,000 1**	**0,000 1**	**0,000 1**	Ω
Bridge calibration	3,52E-06	normal	R_s	**0,000 4**	**0,000 4**	**0,000 4**	Ω
Standard resistor calibration	2,80E-04 /2	normal	L_x	**0,000 3**	**0,000 3**	**0,000 3**	Ω
Standard resistor drift	1,00E-04 /√3	rectangular	L_x	**0,000 1**	**0,000 1**	**0,000 1**	Ω
PRT hysteresis	0,00027	normal	1	**0,000 3**	**0,000 3**	**0,000 3**	Ω
			$u(R_x)$=	0,002 1	0,001 4	0,002 7	Ω
R_s : standard resistor value			$U(R_x)(k = 2)$=	0,004	0,003	0,005	°C
s_p :SPRTs sensitivity coefficient			$\boldsymbol{U(t_x)(k = 2)}$=	**0,011**	**0,007**	**0,014**	°C
L_p and L x : SPRTs and DUT reading							

A1.2. LACOMET Uncertainty Budget

Calibration Point/s: -38,8 °C

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Standard deviation of 20 reading	0,0005	rectangular	1	0,0005	°C
Calibration of standards	Certificated	0,0020	Normal	1	0,002	°C
Drift of standards	Control chart	0,0010	rectangular	1	0,0010	°C
Stability of isothermal enclosure	Characterization of the isothermal enclosure	0,0012	rectangular	1	0,0012	°C
Uniformity of isothermal enclosure	Characterization of the isothermal enclosure	0,0017	rectangualr	1	0,0017	°C
Reading of thermometer under calibration	Standard deviation of 20 reading	0,0001	rectangular	1	0,0001	°C
Hysteresis of the thermometer under calibration	Difference at 156 °C between 5 cycles in the ca	0,0018	rectangular	1	0,0018	°C
Self heating correction of the thermometer under calibration	Estimated from measurements at 0,5 mA, 1 mA and 1,4 mA	0,0002	rectangular	1	0,0002	°C
Self heating correction of the standard	Estimated from measurements at 0,5 mA, 1 mA	0,0002	rectangular	1	0,0002	°C
Immersion error of the thermometer under calibration	Evaluation at 2,5 cm and 5 cm from de maximu	0,0005	rectangular	1	0,0005	°C
Immersion error of the standard	Evaluation at 2,5 cm and 5 cm from de maximu	0,0005	rectangular	1	0,0005	°C
Insulation and oxidation / reduction state resistance of the thermometer under calibration	Estimation from manufactures specification	0,0017	rectangular	1	0,0017	°C
Insulation and oxidation / reduction state resistance of the standard	Estimation from manufactures specification	0,0010	rectangular	1	0,0010	°C
				Combined standard uncertainty =	0,0041	°C
				Combined standard uncertainty, in ºC =	0,0041	ºC
				Expanded standard uncertainty, in ºC =	0,008	ºC

Calibration Point/s: -20 °C

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Standard deviation of 20 reading	0,0005	rectangular	1	0,0005	°C
Calibration of standards	Certificated	0,0020	Normal	1	0,002	°C
Drift of standards	Control chart	0,0010	rectangular	1	0,0010	°C
Stability of isothermal enclosure	Characterization of the isothermal enclosure	0,0012	rectangular	1	0,0012	°C
Uniformity of isothermal enclosure	Characterization of the isothermal enclosure	0,0012	rectangualr	1	0,0012	°C
Reading of thermometer under calibration	Standard deviation of 20 reading	0,0001	rectangular	1	0,0001	°C
Hysteresis of the thermometer under calibration	Difference at 156 °C between 5 cycles in the ca	0,0018	rectangular	1	0,0018	°C
Self heating correction of the thermometer under calibration	Estimated from measurements at 0,5 mA, 1 mA and 1,4 mA	0,0002	rectangular	1	0,0002	°C
Self heating correction of the standard	Estimated from measurements at 0,5 mA, 1 mA	0,0002	rectangular	1	0,0002	°C
Immersion error of the thermometer under calibration	Evaluation at 2,5 cm and 5 cm from de maximu	0,0005	rectangular	1	0,0005	°C
Immersion error of the standard	Evaluation at 2,5 cm and 5 cm from de maximu	0,0005	rectangular	1	0,0005	°C
Insulation and oxidation / reduction state resistance of the thermometer under calibration	Estimation from manufactures specification	0,0017	rectangular	1	0,0017	°C
Insulation and oxidation / reduction state resistance of the standard	Estimation from manufactures specification	0,0010	rectangular	1	0,0010	°C
				Combined standard uncertainty =	0,0040	°C
				Combined standard uncertainty, in ºC =	0,0040	ºC
				Expanded standard uncertainty, in ºC =	0,008	ºC

Calibration Point/s: 0 °C

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Standard deviation of 20 reading	0,0003	rectangular	1	0,0003	°C
Calibration of standards	Certificated	0,0010	Normal	1	0,001	°C
Drift of standards	Control chart	0,0010	rectangular	1	0,0010	°C
Stability of isothermal enclosure	Characterization of the isothermal enclosure	0,0010	rectangular	1	0,001	°C
Uniformity of isothermal enclosure	Characterization of the isothermal enclosure	0,0012	rectangualr	1	0,0012	°C
Reading of thermometer under calibration	Standard deviation of 20 reading	0,0001	rectangular	1	0,0001	°C
Hysteresis of the thermometer under calibration	Difference at 156 °C between 5 cycles in the ca	0,0018	rectangular	1	0,0018	°C
Self heating correction of the thermometer under calibration	Estimated from measurements at 0,5 mA, 1 mA and 1,4 mA	0,0002	rectangular	1	0,0002	°C
Self heating correction of the standard	Estimated from measurements at 0,5 mA, 1 mA	0,0002	rectangular	1	0,0002	°C
Immersion error of the thermometer under calibration	Evaluation at 2,5 cm and 5 cm from de maximu	0,0005	rectangular	1	0,0005	°C
Immersion error of the standard	Evaluation at 2,5 cm and 5 cm from de maximu	0,0005	rectangular	1	0,0005	°C
Insulation and oxidation / reduction state resistance of the thermometer under calibration	Estimation from manufactures specification	0,0017	rectangular	1	0,0017	°C
Insulation and oxidation / reduction state resistance of the standard	Estimation from manufactures specification	0,0010	rectangular	1	0,0010	°C
				Combined standard uncertainty =	0,0035	°C
				Combined standard uncertainty, in ºC =	0,0035	ºC
				Expanded standard uncertainty, in ºC =	0,007	ºC

Calibration Point/s: 29,8 °C

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Standard deviation of 20 reading	0,0005	rectangular	1	0,0005	°C
Calibration of standards	Certificated	0,0020	Normal	1	0,002	°C
Drift of standards	Control chart	0,0010	rectangular	1	0,0010	°C
Stability of isothermal enclosure	Characterization of the isothermal enclosure	0,0012	rectangular	1	0,0012	°C
Uniformity of isothermal enclosure	Characterization of the isothermal enclosure	0,0012	rectangualr	1	0,0012	°C
Reading of thermometer under calibration	Standard deviation of 20 reading	0,0001	rectangular	1	0,0001	°C
Hysteresis of the thermometer under calibration	Difference at 156 °C between 5 cycles in the ca	0,0018	rectangular	1	0,0018	°C
Self heating correction of the thermometer under calibration	Estimated from measurements at 0,5 mA, 1 mA and 1,4 mA	0,0002	rectangular	1	0,0002	°C
Self heating correction of the standard	Estimated from measurements at 0,5 mA, 1 mA	0,0002	rectangular	1	0,0002	°C
Immersion error of the thermometer under calibration	Evaluation at 2,5 cm and 5 cm from de maximu	0,0005	rectangular	1	0,0005	°C
Immersion error of the standard	Evaluation at 2,5 cm and 5 cm from de maximu	0,0005	rectangular	1	0,0005	°C
Insulation and oxidation / reduction state resistance of the thermometer under calibration	Estimation from manufactures specification	0,0017	rectangular	1	0,0017	°C
Insulation and oxidation / reduction state resistance of the standard	Estimation from manufactures specification	0,0010	rectangular	1	0,0010	°C
				Combined standard uncertainty =	0,0040	°C
				Combined standard uncertainty, in ºC =	0,0040	ºC
				Expanded standard uncertainty, in ºC =	0,008	ºC

Calibration Point/s: 156,7 °C

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Standard deviation of 20 reading	0,0008	rectangular	1	0,0008	°C
Calibration of standards	Certificated	0,0030	Normal	1	0,003	°C
Drift of standards	Control chart	0,0010	rectangular	1	0,0010	°C
Stability of isothermal enclosure	Characterization of the isothermal enclosure	0,0017	rectangular	1	0,0017	°C
Uniformity of isothermal enclosure	Characterization of the isothermal enclosure	0,0029	rectangualr	1	0,0029	°C
Reading of thermometer under calibration	Standard deviation of 20 reading	0,0001	rectangular	1	0,0001	°C
Hysteresis of the thermometer under calibration	Difference at 156 °C between 5 cycles in the ca	0,0018	rectangular	1	0,0018	°C
Self heating correction of the thermometer under calibration	Estimated from measurements at 0,5 mA, 1 mA and 1,4 mA	0,0002	rectangular	1	0,0002	°C
Self heating correction of the standard	Estimated from measurements at 0,5 mA, 1 mA	0,0002	rectangular	1	0,0002	°C
Immersion error of the thermometer under calibration	Evaluation at 2,5 cm and 5 cm from de maximu	0,0010	rectangular	1	0,001	°C
Immersion error of the standard	Evaluation at 2,5 cm and 5 cm from de maximu	0,0010	rectangular	1	0,001	°C
Insulation and oxidation / reduction state resistance of the thermometer under calibration	Estimation from manufactures specification	0,0017	rectangular	1	0,0017	°C
Insulation and oxidation / reduction state resistance of the standard	Estimation from manufactures specification	0,0010	rectangular	1	0,0010	°C
				Combined standard uncertainty =	0,0056	°C
				Combined standard uncertainty, in ºC =	0,0056	ºC
				Expanded standard uncertainty, in ºC =	0,011	ºC

Calibration Point/s: 232,3 °C

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Standard deviation of 20 reading	0,0010	rectangular	1	0,001	°C
Calibration of standards	Certificated	0,0035	Normal	1	0,0035	°C
Drift of standards	Control chart	0,0010	rectangular	1	0,0010	°C
Stability of isothermal enclosure	Characterization of the isothermal enclosure	0,0029	rectangular	1	0,0029	°C
Uniformity of isothermal enclosure	Characterization of the isothermal enclosure	0,0046	rectangualr	1	0,0046	°C
Reading of thermometer under calibration	Standard deviation of 20 reading	0,0001	rectangular	1	0,0001	°C
Hysteresis of the thermometer under calibration	Difference at 156 °C between 5 cycles in the ca	0,0018	rectangular	1	0,0018	°C
Self heating correction of the thermometer under calibration	Estimated from measurements at 0,5 mA, 1 mA and 1,4 mA	0,0010	rectangular	1	0,001	°C
Self heating correction of the standard	Estimated from measurements at 0,5 mA, 1 mA	0,0010	rectangular	1	0,001	°C
Immersion error of the thermometer under calibration	Evaluation at 2,5 cm and 5 cm from de maximu	0,0058	rectangular	1	0,0058	°C
Immersion error of the standard	Evaluation at 2,5 cm and 5 cm from de maximu	0,0058	rectangular	1	0,0058	°C
Insulation and oxidation / reduction state resistance of the thermometer under calibration	Estimation from manufactures specification	0,0017	rectangular	1	0,0017	°C
Insulation and oxidation / reduction state resistance of the standard	Estimation from manufactures specification	0,0010	rectangular	1	0,0010	°C
				Combined standard uncertainty =	0,0110	°C
				Combined standard uncertainty, in ºC =	0,0110	ºC
				Expanded standard uncertainty, in ºC =	0,022	ºC

Calibration Point/s: 250 °C

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Standard deviation of 20 reading	0,0010	rectangular	1	0,001	°C
Calibration of standards	Certificated	0,0035	Normal	1	0,0035	°C
Drift of standards	Control chart	0,0010	rectangular	1	0,0010	°C
Stability of isothermal enclosure	Characterization of the isothermal enclosure	0,0029	rectangular	1	0,0029	°C
Uniformity of isothermal enclosure	Characterization of the isothermal enclosure	0,0046	rectangualr	1	0,0046	°C
Reading of thermometer under calibration	Standard deviation of 20 reading	0,0001	rectangular	1	0,0001	°C
Hysteresis of the thermometer under calibration	Difference at 156 °C between 5 cycles in the ca	0,0018	rectangular	1	0,0018	°C
Self heating correction of the thermometer under calibration	Estimated from measurements at 0,5 mA, 1 mA and 1,4 mA	0,0010	rectangular	1	0,001	°C
Self heating correction of the standard	Estimated from measurements at 0,5 mA, 1 mA	0,0010	rectangular	1	0,001	°C
Immersion error of the thermometer under calibration	Evaluation at 2,5 cm and 5 cm from de maximu	0,0058	rectangular	1	0,0058	°C
Immersion error of the standard	Evaluation at 2,5 cm and 5 cm from de maximu	0,0058	rectangular	1	0,0058	°C
Insulation and oxidation / reduction state resistance of the thermometer under calibration	Estimation from manufactures specification	0,0017	rectangular	1	0,0017	°C
Insulation and oxidation / reduction state resistance of the standard	Estimation from manufactures specification	0,0010	rectangular	1	0,0010	°C
				Combined standard uncertainty =	0,0110	°C
				Combined standard uncertainty, in ºC =	0,0110	ºC
				Expanded standard uncertainty, in ºC =	0,022	ºC

A1.3. CEHM Uncertainty Budget

Calibration Point/s: 0 ºC, s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,0007	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0055	normal	1	0,0055	ºC
Drift of standards	Type B	0,0143	rectangular	1	0,0143	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0029	rectangular	1	0,0029	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatibility of standards	Type A	0,0027	normal	1	0,0027	ºC
				Combined standard uncertainty, in ºC =	0,044	ºC
				Expanded standard uncertainty, in ºC =	0,088	ºC

Calibration Point/s: 0 ºC, s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,0007	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0025	normal	1	0,0025	ºC
Drift of standards	Type B	0,0143	rectangular	1	0,0143	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0087	rectangular	1	0,0087	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatibility of standards	Type A	0,0027	normal	1	0,0027	ºC
				Combined standard uncertainty, in ºC =	0,044	ºC
				Expanded standard uncertainty, in ºC =	0,089	ºC

Calibration Point/s: ice point

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,0007	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0055	normal	1	0,0055	ºC
Drift of standards	Type B	0,0143	rectangular	1	0,0143	ºC
Stability of isothermal enclosure	Type B		rectangular	1	0,0000	ºC
Uniformity of isothermal enclosure	Type B		rectangular	1	0,0000	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B		rectangular	1	0,0000	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatibility of standards	Type A	0,0022	normal	1	0,0022	ºC
				Combined standard uncertainty, in ºC =	0,016	ºC
				Expanded standard uncertainty, in ºC =	0,031	ºC

Calibration Point/s: 250 ºC, s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,000735	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0025	normal	1	0,0025	ºC
Drift of standards	Type B	0,0287	rectangular	1	0,0287	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0029	rectangular	1	0,0029	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatibility of standards	Type A	0,0022	normal	1	0,0022	ºC
				Combined standard uncertainty, in ºC =	0,050	ºC
				Expanded standard uncertainty, in ºC =	0,100	ºC

Calibration Point/s: 250 ºC, s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,0007	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0025	normal	1	0,0025	ºC
Drift of standards	Type B	0,0287	rectangular	1	0,0287	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0087	rectangular	1	0,0087	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatibility of standards	Type A	0,0022	normal	1	0,0022	ºC
				Combined standard uncertainty, in ºC =	0,051	ºC
				Expanded standard uncertainty, in ºC =	0,102	ºC

Calibration Point/s: 232 ºC, s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,000735	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0025	normal	1	0,0025	ºC
Drift of standards	Type B	0,0287	rectangular	1	0,0287	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0029	rectangular	1	0,0029	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatability of standards	Type A	0,0022	normal	1	0,0022	ºC
				Combined standard uncertainty, in ºC =	0,050	ºC
				Expanded standard uncertainty, in ºC =	0,100	ºC

Calibration Point/s: 232 ºC, s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,0007	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0025	normal	1	0,0025	ºC
Drift of standards	Type B	0,0287	rectangular	1	0,0287	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0087	rectangular	1	0,0087	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatability of standards	Type A	0,0022	normal	1	0,0022	ºC
				Combined standard uncertainty, in ºC =	0,051	ºC
				Expanded standard uncertainty, in ºC =	0,102	ºC

Calibration Point/s: 156 ºC, s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,000735	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0025	normal	1	0,0025	ºC
Drift of standards	Type B	0,0228	rectangular	1	0,0228	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0029	rectangular	1	0,0029	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatability of standards	Type A	0,0022	normal	1	0,0022	ºC
				Combined standard uncertainty, in ºC =	0,047	ºC
				Expanded standard uncertainty, in ºC =	0,094	ºC

Calibration Point/s: 156 ºC, s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,0007	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0025	normal	1	0,0025	ºC
Drift of standards	Type B	0,0228	rectangular	1	0,0228	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0087	rectangular	1	0,0087	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatability of standards	Type A	0,0022	normal	1	0,0022	ºC
				Combined standard uncertainty, in ºC =	0,048	ºC
				Expanded standard uncertainty, in ºC =	0,095	ºC

Calibration Point/s: 29,6 ºC, s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,000735	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0025	normal	1	0,0025	ºC
Drift of standards	Type B	0,0170	rectangular	1	0,0170	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0029	rectangular	1	0,0029	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatability of standards	Type A	0,0022	normal	1	0,0022	ºC
				Combined standard uncertainty, in ºC =	0,044	ºC
				Expanded standard uncertainty, in ºC =	0,089	ºC

Calibration Point/s: 29,6 ºC, s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,0007	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0025	normal	1	0,0025	ºC
Drift of standards	Type B	0,0170	rectangular	1	0,0170	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0087	rectangular	1	0,0087	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatability of standards	Type A	0,0022	normal	1	0,0022	ºC
				Combined standard uncertainty, in ºC =	0,045	ºC
				Expanded standard uncertainty, in ºC =	0,090	ºC

Calibration Point/s: -38,8 ºC, s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,000735	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0025	normal	1	0,0025	ºC
Drift of standards	Type B	0,0098	rectangular	1	0,0098	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0029	rectangular	1	0,0029	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatibility of standards	Type A	0,0022	normal	1	0,0022	ºC
				Combined standard uncertainty, in ºC =	0,042	ºC
				Expanded standard uncertainty, in ºC =	0,084	ºC

Calibration Point/s: -38,8 ºC, s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	Type B	0,0007	rectangular	1	0,0007	ºC
Calibration of standards	Type B	0,0025	normal	1	0,0025	ºC
Drift of standards	Type B	0,0098	rectangular	1	0,0098	ºC
Stability of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Uniformity of isothermal enclosure	Type B	0,0289	rectangular	1	0,0289	ºC
Reading of thermometer under calibration	Type B	0,0007	rectangular	1	0,0007	ºC
Hysteresis of the thermometer under calibration	Type B	0,0087	rectangular	1	0,0087	ºC
Thermal Fluxes	negligible				0,0000	ºC
Repeatibility of standards	Type A	0,0022	normal	1	0,0022	ºC
				Combined standard uncertainty, in ºC =	0,043	ºC
				Expanded standard uncertainty, in ºC =	0,086	ºC

A1.4. LANAMET Uncertainty Budget

Calibration Point/s: **1st TPW, sn 3481**

Description	Method of estimation	Standard uncertainty, Ω	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Bridge reading	Bridge calibration certificate	0,000 250 0	Tipo B; normal	1	0,000 25	Ω
Bridge accuracy	Bridge accuracy	0,000 028 9	Tipo B; rectangular	1	0,000 03	Ω
Temperature variations on the standard resistor	Temperature changes during the measurement days	0,001 435 3	Tipo B; rectangular	1	0,001 44	Ω
Standard resistor drift	Calibration history.	0,000 195 0	Tipo B; rectangular	1	0,000 19	Ω
Lack of stability of the SPRT in the triple point of water	Differences between the two last measurements	0,000 052 0	Tipo B; rectangular	1	0,000 05	Ω
Heat conduction	Measurements during calibration	0,000 332 0	Tipo B; rectangular	0,4	0,000 13	Ω
Hydrostatic head correction	2 cm of maximum error	0,000 008 4	Tipo B; rectangular	0,4	0,000 00	Ω
TPW temperature	TPW callibration certificate	0,000 206 6	Tipo B; normal	0,4	0,000 08	Ω
TPW drift	Manufacturer certificate	0,000 034 6	Tipo B; rectangular	0,4	0,000 01	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
TPW instabilities	Maximum values	0,000 115 5	Tipo B; rectangular	0,4	0,000 05	Ω
				Combined standard uncertainty =	0,001 48	Ω
				Expanded standard uncertainty =	0,002 96	Ω
				Expanded standard uncertainty in ºC =	0,0076	ºC

Calibration Point/s: **250 °C** s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,000 704 0	normal	1	0,000 70	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,004 917 7	Trectangular	1	0,004 92	Ω
Bridge drift	Calibration history	0,000 925 3	normal	1	0,000 93	Ω
Calibration of standards	SPRTs certificates	0,002 354 6	normal	1	0,002 35	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,005 853 6	normal	1	**0,005 85**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,000 676 1	normal	- 1	0,000 68	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,004 870 6	rectangular	- 1	0,004 87	Ω
Bridge drift	Calibration history	- 0,000 920 5	normal	- 1	0,000 92	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	- 0,000 530 0	rectangular	- 1	0,000 53	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	0,002 655 8	rectangular	- 1	0,002 66	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,002 655 8	rectangular	- 1	0,002 66	Ω
				Combined standard uncertainty =	0,008 59	Ω
				Expanded standard uncertainty =	0,017 17	Ω
				Expanded standard uncertainty in ºC =	0,046	ºC

Calibration Point/s: 232,3 °C s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,001 210 9	normal	1	0,001 21	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,004 753 1	Trectangular	1	0,004 75	Ω
Bridge drift	Calibration history	0,000 928 3	normal	1	0,000 93	Ω
Calibration of standards	SPRTs certificates	0,002 257 3	normal	1	0,002 26	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,005 761 9	normal	1	**0,005 76**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,001 106 0	normal	- 1	0,001 11	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,004 707 7	rectangular	- 1	0,004 71	Ω
Bridge drift	Calibration history	- 0,000 843 8	normal	- 1	0,000 84	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	- 0,000 530 0	rectangular	- 1	0,000 53	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	0,002 899 4	rectangular	- 1	0,002 90	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,002 380 6	rectangular	- 1	0,002 38	Ω
				Combined standard uncertainty =	0,008 47	Ω
				Expanded standard uncertainty =	0,016 94	Ω
				Expanded standard uncertainty in ºC =	0,045	ºC

Calibration Point/s: 156,7 °C s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,000 256 0	normal	1	0,000 26	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,004 040 2	Trectangular	1	0,004 04	Ω
Bridge drift	Calibration history	0,000 941 5	normal	1	0,000 94	Ω
Calibration of standards	SPRTs certificates	0,001 954 7	normal	1	0,001 95	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,004 927 5	normal	1	**0,004 93**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,000 218 3	normal	- 1	0,000 22	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,004 001 6	rectangular	- 1	0,004 00	Ω
Bridge drift	Calibration history	- 0,000 511 1	normal	- 1	0,000 51	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	- 0,000 530 0	rectangular	- 1	0,000 53	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	0,000 863 3	rectangular	- 1	0,000 86	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,001 655 3	rectangular	- 1	0,001 66	Ω
				Combined standard uncertainty =	0,006 67	Ω
				Expanded standard uncertainty =	0,013 33	Ω
				Expanded standard uncertainty in ºC =	0,035	ºC

Calibration Point/s: 29,8 °C s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,001 419 5	normal	1	0,001 42	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,002 806 9	Trectangular	1	0,002 81	Ω
Bridge drift	Calibration history	0,000 964 3	normal	1	0,000 96	Ω
Calibration of standards	SPRTs certificates	0,001 253 7	normal	1	0,001 25	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,003 947 1	normal	1	**0,003 95**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,001 476 8	normal	- 1	0,001 48	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,002 780 1	rectangular	- 1	0,002 78	Ω
Bridge drift	Calibration history	0,000 064 3	normal	- 1	0,000 06	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	- 0,000 530 0	rectangular	- 1	0,000 53	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	- 0,000 341 1	rectangular	- 1	0,000 34	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,004 994 1	rectangular	- 1	0,004 99	Ω
				Combined standard uncertainty =	0,007 13	Ω
				Expanded standard uncertainty =	0,014 27	Ω
				Expanded standard uncertainty in ºC =	0,036	ºC

Calibration Point/s: 2nd TPW, sn 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Bridge reading	Bridge calibration certificate	0,000 250 0	Tipo B; normal	1	0,000 25	Ω
Bridge accuracy	Bridge accuracy	0,000 028 9	Tipo B; rectangular	1	0,000 03	Ω
Temperature variations on the standard resistor	Temperature changes during the measurement days	0,001 435 3	Tipo B; rectangular	1	0,001 44	Ω
Standard resistor drift	Calibration history.	0,000 195 0	Tipo B; rectangular	1	0,000 19	Ω
Lack of stability of the SPRT in the triple point of water	Differences between the two last measurements	0,000 230 9	Tipo B; rectangular	1	0,000 23	Ω
Heat conduction	Measurements during calibration	0,000 649 5	Tipo B; rectangular	0,4	0,000 26	Ω
Hydrostatic head correction	2 cm of maximum error	0,000 008 4	Tipo B; rectangular	0,4	0,000 00	Ω
TPW temperature	TPW callibration certificate	0,000 206 6	Tipo B; normal	0,4	0,000 08	Ω
TPW drift	Manufacturer certificate	0,000 034 6	Tipo B; rectangular	0,4	0,000 01	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
TPW instabilities	Maximum values	0,000 115 5	Tipo B; rectangular	0,4	0,000 05	Ω
				Combined standard uncertainty =	0,001 51	Ω
				Expanded standard uncertainty =	0,003 03	Ω
				Expanded standard uncertainty in ºC =	0,0078	ºC

Calibration Point/s: -20 °C s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,000 496 4	normal	1	0,000 50	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,002 309 0	Trectangular	1	0,002 31	Ω
Bridge drift	Calibration history	0,000 899 0	normal	1	0,000 90	Ω
Calibration of standards	SPRTs certificates	0,001 159 3	normal	1	0,001 16	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,003 303 7	normal	1	**0,003 30**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,000 497 4	normal	- 1	0,000 50	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,002 287 0	rectangular	- 1	0,002 29	Ω
Bridge drift	Calibration history	0,000 176 5	normal	- 1	0,000 18	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	0,000 810 0	rectangular	- 1	0,000 81	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	- 0,000 012 6	rectangular	- 1	0,000 01	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,004 503 3	rectangular	- 1	0,004 50	Ω
				Combined standard uncertainty =	0,006 12	Ω
				Expanded standard uncertainty =	0,012 23	Ω
				Expanded standard uncertainty in ºC =	0,030	ºC

Calibration Point/s: -38,8 °C s/n 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,000 812 2	normal	1	0,000 81	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,002 119 1	Trectangular	1	0,002 12	Ω
Bridge drift	Calibration history	0,000 828 5	normal	1	0,000 83	Ω
Calibration of standards	SPRTs certificates	0,001 401 3	normal	1	0,001 40	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,003 314 3	normal	1	**0,003 31**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,000 866 3	normal	- 1	0,000 87	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,002 098 9	rectangular	- 1	0,002 10	Ω
Bridge drift	Calibration history	0,000 159 1	normal	- 1	0,000 16	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	0,000 810 0	rectangular	- 1	0,000 81	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	0,000 290 5	rectangular	- 1	0,000 29	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,002 886 8	rectangular	- 1	0,002 89	Ω
				Combined standard uncertainty =	0,005 03	Ω
				Expanded standard uncertainty =	0,010 06	Ω
				Expanded standard uncertainty in ºC =	0,025	ºC

Calibration Point/s: 3rd TPW, sn 3481

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Bridge reading	Bridge calibration certificate	0,000 250 0	Tipo B; normal	1	0,000 25	Ω
Bridge accuracy	Bridge accuracy	0,000 028 9	Tipo B; rectangular	1	0,000 03	Ω
Temperature variations on the standard resistor	Temperature changes during the measurement days	0,001 435 3	Tipo B; rectangular	1	0,001 44	Ω
Standard resistor drift	Calibration history.	0,000 195 0	Tipo B; rectangular	1	0,000 19	Ω
Lack of stability of the SPRT in the triple point of water	Differences between the two last measurements	0,000 046 2	Tipo B; rectangular	1	0,000 05	Ω
Heat conduction	Measurements during calibration	0,000 200 0	Tipo B; rectangular	0,4	0,000 08	Ω
Hydrostatic head correction	2 cm of maximum error	0,000 008 4	Tipo B; rectangular	0,4	0,000 00	Ω
TPW temperature	TPW callibration certificate	0,000 206 6	Tipo B; normal	0,4	0,000 08	Ω
TPW drift	Manufacturer certificate	0,000 034 6	Tipo B; rectangular	0,4	0,000 01	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
TPW instabilities	Maximum values	0,000 115 5	Tipo B; rectangular	0,4	0,000 05	Ω
				Combined standard uncertainty =	0,001 48	Ω
				Expanded standard uncertainty =	0,002 95	Ω
				Expanded standard uncertainty in ºC =	0,0076	ºC

Calibration Point/s: **1st TPW, sn 3473**

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Bridge reading	Bridge calibration certificate	0,000 250 0	Tipo B; normal	1	0,000 25	Ω
Bridge accuracy	Bridge accuracy	0,000 028 9	Tipo B; rectangular	1	0,000 03	Ω
Temperature variations on the standard resistor	Temperature changes during the measurement days	0,001 438 5	Tipo B; rectangular	1	0,001 44	Ω
Standard resistor drift	Calibration history.	0,000 195 5	Tipo B; rectangular	1	0,000 20	Ω
Lack of stability of the SPRT in the triple point of water	Differences between the two last measurements	0,000 005 8	Tipo B; rectangular	1	0,000 01	Ω
Heat conduction	Measurements during calibration	0,000 230 9	Tipo B; rectangular	0,4	0,000 09	Ω
Hydrostatic head correction	2 cm of maximum error	0,000 008 4	Tipo B; rectangular	0,4	0,000 00	Ω
TPW temperature	TPW callibration certificate	0,000 206 6	Tipo B; normal	0,4	0,000 08	Ω
TPW drift	Manufacturer certificate	0,000 034 6	Tipo B; rectangular	0,4	0,000 01	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
TPW instabilities	Maximum values	0,000 115 5	Tipo B; rectangular	0,4	0,000 05	Ω
				Combined standard uncertainty =	0,001 48	Ω
				Expanded standard uncertainty =	0,002 96	Ω
				Expanded standard uncertainty in ºC =	0,0076	ºC

Calibration Point/s: **250 °C** s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,000 937 7	normal	1	0,000 94	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,004 917 8	Trectangular	1	0,004 92	Ω
Bridge drift	Calibration history	0,000 925 3	normal	1	0,000 93	Ω
Calibration of standards	SPRTs certificates	0,002 354 7	normal	1	0,002 35	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,005 886 4	normal	1	**0,005 89**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,001 021 1	normal	- 1	0,001 02	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,004 881 7	rectangular	- 1	0,004 88	Ω
Bridge drift	Calibration history	- 0,000 925 7	normal	- 1	0,000 93	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	- 0,000 425 0	rectangular	- 1	0,000 43	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	0,002 655 8	rectangular	- 1	0,002 66	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,002 655 8	rectangular	- 1	0,002 66	Ω
				Combined standard uncertainty =	0,008 64	Ω
				Expanded standard uncertainty =	0,017 29	Ω
				Expanded standard uncertainty in ºC =	0,047	ºC

Calibration Point/s: **232,3 °C** s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,000 702 2	normal	1	0,000 70	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,004 752 9	Trectangular	1	0,004 75	Ω
Bridge drift	Calibration history	0,000 928 3	normal	1	0,000 93	Ω
Calibration of standards	SPRTs certificates	0,002 257 2	normal	1	0,002 26	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,005 676 6	normal	1	**0,005 68**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,000 744 9	normal	- 1	0,000 74	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,004 718 0	rectangular	- 1	0,004 72	Ω
Bridge drift	Calibration history	- 0,000 848 6	normal	- 1	0,000 85	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	- 0,000 425 0	rectangular	- 1	0,000 43	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	0,002 899 4	rectangular	- 1	0,002 90	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,002 380 6	rectangular	- 1	0,002 38	Ω
				Combined standard uncertainty =	0,008 37	Ω
				Expanded standard uncertainty =	0,016 74	Ω
				Expanded standard uncertainty in ºC =	0,045	ºC

Calibration Point/s: **156,7 °C** s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,000 264 1	normal	1	0,000 26	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,004 040 2	Trectangular	1	0,004 04	Ω
Bridge drift	Calibration history	0,000 941 5	normal	1	0,000 94	Ω
Calibration of standards	SPRTs certificates	0,001 954 7	normal	1	0,001 95	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,004 928 0	normal	1	**0,004 93**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,000 263 2	normal	- 1	0,000 26	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,004 010 5	rectangular	- 1	0,004 01	Ω
Bridge drift	Calibration history	- 0,000 515 3	normal	- 1	0,000 52	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	- 0,000 425 0	rectangular	- 1	0,000 43	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	0,000 863 3	rectangular	- 1	0,000 86	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,001 655 3	rectangular	- 1	0,001 66	Ω
				Combined standard uncertainty =	0,006 67	Ω
				Expanded standard uncertainty =	0,013 33	Ω
				Expanded standard uncertainty in ºC =	0,035	ºC

Calibration Point/s: 29,8 °C s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,001 248 8	normal	1	0,001 25	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,002 807 0	Trectangular	1	0,002 81	Ω
Bridge drift	Calibration history	0,000 964 3	normal	1	0,000 96	Ω
Calibration of standards	SPRTs certificates	0,001 253 7	normal	1	0,001 25	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,003 889 0	normal	1	**0,003 89**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,001 478 2	normal	- 1	0,001 48	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,002 786 4	rectangular	- 1	0,002 79	Ω
Bridge drift	Calibration history	0,000 061 4	normal	- 1	0,000 06	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	- 0,000 425 0	rectangular	- 1	0,000 43	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	- 0,000 341 1	rectangular	- 1	0,000 34	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,004 994 1	rectangular	- 1	0,004 99	Ω
				Combined standard uncertainty =	0,007 10	Ω
				Expanded standard uncertainty =	0,014 20	Ω
				Expanded standard uncertainty in ºC =	0,036	ºC

Calibration Point/s: 2nd TPW, sn 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Bridge reading	Bridge calibration certificate	0,000 250 0	Tipo B; normal	1	0,000 25	Ω
Bridge accuracy	Bridge accuracy	0,000 028 9	Tipo B; rectangular	1	0,000 03	Ω
Temperature variations on the standard resistor	Temperature changes during the measurement days	0,001 438 5	Tipo B; rectangular	1	0,001 44	Ω
Standard resistor drift	Calibration history.	0,000 195 5	Tipo B; rectangular	1	0,000 20	Ω
Lack of stability of the SPRT in the triple point of water	Differences between the two last measurements	0,000 225 2	Tipo B; rectangular	1	0,000 23	Ω
Heat conduction	Measurements during calibration	0,002 424 9	Tipo B; rectangular	0,4	0,000 97	Ω
Hydrostatic head correction	2 cm of maximum error	0,000 008 4	Tipo B; rectangular	0,4	0,000 00	Ω
TPW temperature	TPW callibration certificate	0,000 206 6	Tipo B; normal	0,4	0,000 08	Ω
TPW drift	Manufacturer certificate	0,000 034 6	Tipo B; rectangular	0,4	0,000 01	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
TPW instabilities	Maximum values	0,000 115 5	Tipo B; rectangular	0,4	0,000 05	Ω
				Combined standard uncertainty =	0,001 78	Ω
				Expanded standard uncertainty =	0,003 56	Ω
				Expanded standard uncertainty in ºC =	0,0091	ºC

Calibration Point/s: -20 °C s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,001 295 2	normal	1	0,001 30	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,002 309 1	Trectangular	1	0,002 31	Ω
Bridge drift	Calibration history	0,000 899 1	normal	1	0,000 90	Ω
Calibration of standards	SPRTs certificates	0,001 159 2	normal	1	0,001 16	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,003 513 7	normal	1	**0,003 51**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,001 224 2	normal	- 1	0,001 22	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,002 292 2	rectangular	- 1	0,002 29	Ω
Bridge drift	Calibration history	0,000 177 0	normal	- 1	0,000 18	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	0,000 420 0	rectangular	- 1	0,000 42	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	- 0,000 012 6	rectangular	- 1	0,000 01	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,004 503 3	rectangular	- 1	0,004 50	Ω
				Combined standard uncertainty =	0,006 30	Ω
				Expanded standard uncertainty =	0,012 59	Ω
				Expanded standard uncertainty in ºC =	0,031	ºC

Calibration Point/s: -38,8 °C s/n 3473

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	SPRT repeatability	0,000 527 8	normal	1	0,000 53	Ω
Bridge calibration	Bridge certificate	0,000 250 0	normal	1	0,000 25	Ω
Bridge stability	Manufacturer information	0,002 119 1	Trectangular	1	0,002 12	Ω
Bridge drift	Calibration history	0,000 828 5	normal	1	0,000 83	Ω
Calibration of standards	SPRTs certificates	0,001 401 3	normal	1	0,001 40	Ω
Drift of standards	Calibration history	0,001 766 7	rectangular	1	0,001 77	Ω
Bridge/SPRT accuracy	Manufacturer information	0,000 028 9	rectangular	1	0,000 03	Ω
SPRTs corrected measurements	**Quadratic sum of components**	0,003 256 3	normal	1	**0,003 26**	**Ω**
DUT reading (resistance or temperature)	DUT repeatability	0,000 548 9	normal	- 1	0,000 55	Ω
Correction to DUT readings	Bridge certificate	0,000 250 0	normal	- 1	0,000 25	Ω
DUT accuracy	DUT accuracy	0,000 028 9	rectangular	- 1	0,000 03	Ω
DUT stability	Manufacturer information	0,002 103 6	rectangular	- 1	0,002 10	Ω
Bridge drift	Calibration history	0,000 159 5	normal	- 1	0,000 16	Ω
DUT hysteresis	Reproducibility of the DUT in the reference point	0,000 420 0	rectangular	- 1	0,000 42	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
Stability of isothermal enclosure	Previous characterization study	0,000 290 5	rectangular	- 1	0,000 29	Ω
Uniformity of isothermal enclosure	Previous characterization study	0,002 886 8	rectangular	- 1	0,002 89	Ω
				Combined standard uncertainty =	0,004 90	Ω
				Expanded standard uncertainty =	0,009 80	Ω
				Expanded standard uncertainty in ºC =	0,024	ºC

Calibration Point/s: **2rd TPW, sn 3473**

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Bridge reading	Bridge calibration certificate	0,000 250 0	Tipo B; normal	1	0,000 25	Ω
Bridge accuracy	Bridge accuracy	0,000 028 9	Tipo B; rectangular	1	0,000 03	Ω
Temperature variations on the standard resistor	Temperature changes during the measurement days	0,001 438 5	Tipo B; rectangular	1	0,001 44	Ω
Standard resistor drift	Calibration history.	0,000 195 5	Tipo B; rectangular	1	0,000 20	Ω
Lack of stability of the SPRT in the triple point of water	Differences between the two last measurements	0,000 052 0	Tipo B; rectangular	1	0,000 05	Ω
Heat conduction	Measurements during calibration	0,000 259 8	Tipo B; rectangular	0,4	0,000 10	Ω
Hydrostatic head correction	2 cm of maximum error	0,000 008 4	Tipo B; rectangular	0,4	0,000 00	Ω
TPW temperature	TPW callibration certificate	0,000 206 6	Tipo B; normal	0,4	0,000 08	Ω
TPW drift	Manufacturer certificate	0,000 034 6	Tipo B; rectangular	0,4	0,000 01	Ω
Thermal fluxes	Immersion test	negligible			0,000 00	Ω
TPW instabilities	Maximum values	0,000 115 5	Tipo B; rectangular	0,4	0,000 05	Ω
				Combined standard uncertainty =	0,001 48	Ω
				Expanded standard uncertainty =	0,002 96	Ω
				Expanded standard uncertainty in ºC =	0,0076	ºC

A1.5. CENAMEP Uncertainty Budget

Calibration Point/s: -38.7 °C s/n 3473

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,00089	°C	0,00089	normal	1	0,00089	°C
SPRT calibration	certificate	0,001	°C	0,001	normal	1	0,001	°C
SPRT drift	internal study	0,000216	Ω	0,00022	normal	9,7	0,0021	°C
Standard resistor calibration	certificate	0,000043	Ω	0,000043	normal	9,7	0,0004	°C
Standard resistor drift	internal study	0,00011	Ω	0,00003	rectangular	9,7	0,0003	°C
Isothermal enclosure stability	internal study	0,0015	°C	0,00043	rectangular	1	0,0004	°C
Isothermal enclosure uniformity	internal study	0,0015	°C	0,00043	rectangular	1	0,0004	°C
DUT reading	statistic study	0,0004	Ω	0,0004	normal	2,5	0,001	°C
DUT histeresys	evauated during calibration	0,0012	Ω	0,00035	rectangular	2,5	0,00087	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	certificate	0,00017	Ω	0,00017	normal	2,5	0,00042	°C
Standard resistor drift	internal study	0,00042	Ω	0,00012	rectangular	2,5	0,00030	°C
						Combined standard uncertainty, in ºC =	0,0030	ºC
						Expanded standard uncertainty, in ºC =	0,0060	ºC

Calibration Point/s: -20.0 °C s/n 3473

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,0015	°C	0,0015	normal	1	0,0015	°C
SPRT calibration	certificate	0,001	°C	0,001	normal	1	0,001	°C
SPRT drift	internal study	0,000236	Ω	0,00024	normal	9,7	0,0023	°C
Standard resistor calibration	certificate	0,000047	Ω	0,000047	normal	9,7	0,0005	°C
Standard resistor drift	internal study	0,00012	Ω	0,00003	rectangular	9,7	0,0003	°C
Isothermal enclosure stability	internal study	0,0015	°C	0,00043	rectangular	1	0,0004	°C
Isothermal enclosure uniformity	internal study	0,0015	°C	0,00043	rectangular	1	0,0004	°C
DUT reading	statistic study	0,00084	Ω	0,00084	normal	2,5	0,0021	°C
DUT histeresys	evauated during calibration	0,0012	Ω	0,00035	rectangular	2,5	0,00087	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	certificate	0,00018	Ω	0,00018	normal	2,5	0,00046	°C
Standard resistor drift	internal study	0,00046	Ω	0,00013	rectangular	2,5	0,00033	°C
						Combined standard uncertainty, in ºC =	0,0038	ºC
						Expanded standard uncertainty, in ºC =	0,0077	ºC

Calibration Point/s: 0.01 °C s/n 3473

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Calibration of the standard (TPW cell)	Certificate	0,0001	°C	0,0001	normal	1	0,0001	°C
Reproducibility of the TPW cell	internal study	0,001	°C	0,001	normal	1	0,001	°C
Drift of the triple point of water cell	Manufacturer	0,0001	°C	0,00010	rectangular	1	0,0001	°C
DUT reading	statistic study	0,00033	Ω	0,00033	normal	2,5	0,00083	°C
DUT histeresys	evauated during calibration	0,0012	Ω	0,00035	rectangular	2,5	0,00087	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	Certificate	0,00020	Ω	0,00020	normal	2,5	0,00050	°C
Standard resistor drift	internal study	0,00050	Ω	0,00014	rectangular	2,5	0,00036	°C
						Combined standard uncertainty, in ºC =	0,0017	ºC
						Expanded standard uncertainty, in ºC =	0,0034	ºC

Calibration Point/s: 29.8 °C s/n 3473

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,0019	°C	0,0019	normal	1	0,0019	°C
SPRT calibration	certificate	0,001	°C	0,001	normal	1	0,0010	°C
SPRT drift	internal study	0,000287	Ω	0,00029	normal	9,7	0,0028	°C
Standard resistor calibration	certificate	0,000057	Ω	0,000057	normal	9,7	0,0006	°C
Standard resistor drift	internal study	0,00014	Ω	0,00004	rectangular	9,7	0,0004	°C
Isothermal enclosure stability	internal study	0,002	°C	0,00058	rectangular	1	0,0006	°C
Isothermal enclosure uniformity	internal study	0,002	°C	0,00058	rectangular	1	0,0006	°C
DUT reading	statistic study	0,00092	Ω	0,00092	normal	2,6	0,0024	°C
DUT histeresys	evauated during calibration	0,0012	Ω	0,00035	rectangular	2,6	0,0009	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	certificate	0,00022	Ω	0,00022	normal	2,6	0,0006	°C
Standard resistor drift	internal study	0,00056	Ω	0,00016	rectangular	2,6	0,0004	°C
						Combined standard uncertainty, in ºC =	0,0045	ºC
						Expanded standard uncertainty, in ºC =	0,0091	ºC

Calibration Point/s: 156.7 °C s/n 3473

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,0034	°C	0,0034	normal	1	0,0034	°C
SPRT calibration	certificate	0,0015	°C	0,0015	normal	1	0,0015	°C
SPRT drift	internal study	0,000412	Ω	0,00041	normal	10,1	0,0042	°C
Standard resistor calibration	certificate	0,000082	Ω	0,000082	normal	10,1	0,0008	°C
Standard resistor drift	internal study	0,00021	Ω	0,00006	rectangular	10,1	0,0006	°C
Isothermal enclosure stability	internal study	0,02	°C	0,00577	rectangular	1	0,0058	°C
Isothermal enclosure uniformity	internal study	0,03	°C	0,00866	rectangular	1	0,0087	°C
DUT reading	statistic study	0,0016	Ω	0,0016	normal	2,7	0,0043	°C
DUT histeresys	evauated during calibration	0,0012	Ω	0,00035	rectangular	2,7	0,0009	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	certificate	0,00032	Ω	0,00032	normal	2,7	0,0009	°C
Standard resistor drift	internal study	0,00080	Ω	0,00023	rectangular	2,7	0,0006	°C
						Combined standard uncertainty, in ºC =	0,013	ºC
						Expanded standard uncertainty, in ºC =	0,025	ºC

Calibration Point/s: 232.3 °C s/n 3473

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,0069	°C	0,0069	normal	1	0,0069	°C
SPRT calibration	certificate	0,0015	°C	0,0015	normal	1	0,0015	°C
SPRT drift	internal study	0,000485	Ω	0,00049	normal	10,1	0,0049	°C
Standard resistor calibration	certificate	0,000097	Ω	0,000097	normal	10,1	0,0010	°C
Standard resistor drift	internal study	0,00024	Ω	0,00007	rectangular	10,1	0,0007	°C
Isothermal enclosure stability	internal study	0,02	°C	0,00577	rectangular	1	0,0058	°C
Isothermal enclosure uniformity	internal study	0,03	°C	0,00866	rectangular	1	0,0087	°C
DUT reading	statistic study	0,0027	Ω	0,0027	normal	2,7	0,0073	°C
DUT histeresys	evauated during calibration	0,0012	Ω	0,00035	rectangular	2,7	0,0009	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	certificate	0,00038	Ω	0,00038	normal	2,7	0,0010	°C
Standard resistor drift	internal study	0,00094	Ω	0,00027	rectangular	2,7	0,0007	°C
						Combined standard uncertainty, in ºC =	0,015	ºC
						Expanded standard uncertainty, in ºC =	0,031	ºC

Calibration Point/s: 250 °C s/n 3473

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,011	°C	0,011	normal	1	0,0110	°C
SPRT calibration	certificate	0,0015	°C	0,0015	normal	1	0,0015	°C
SPRT drift	internal study	0,000503	Ω	0,00050	normal	10,1	0,0051	°C
Standard resistor calibration	certificate	0,000101	Ω	0,000101	normal	10,1	0,0010	°C
Standard resistor drift	internal study	0,00025	Ω	0,00007	rectangular	10,1	0,0007	°C
Isothermal enclosure stability	internal study	0,02	°C	0,00577	rectangular	1	0,0058	°C
Isothermal enclosure uniformity	internal study	0,03	°C	0,00866	rectangular	1	0,0087	°C
DUT reading	statistic study	0,0032	Ω	0,0032	normal	2,7	0,0087	°C
DUT histeresys	evauated during calibration	0,0012	Ω	0,00035	rectangular	2,7	0,0009	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	certificate	0,00039	Ω	0,00039	normal	2,7	0,0011	°C
Standard resistor drift	internal study	0,00098	Ω	0,00028	rectangular	2,7	0,0008	°C
						Combined standard uncertainty, in ºC =	0,018	ºC
						Expanded standard uncertainty, in ºC =	0,037	ºC

Calibration Point/s: -38.7 °C s/n 3481

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,0015	°C	0,0015	normal	1	0,0015	°C
SPRT calibration	certificate	0,001	°C	0,001	normal	1	0,001	°C
SPRT drift	internal study	0,000216	Ω	0,00022	normal	9,7	0,0021	°C
Standard resistor calibration	certificate	0,000043	Ω	0,000043	normal	9,7	0,0004	°C
Standard resistor drift	internal study	0,00011	Ω	0,00003	rectangular	9,7	0,0003	°C
Isothermal enclosure stability	internal study	0,0015	°C	0,00043	rectangular	1	0,0004	°C
Isothermal enclosure uniformity	internal study	0,0015	°C	0,00043	rectangular	1	0,0004	°C
DUT reading	statistic study	0,00095	Ω	0,00095	normal	2,5	0,002375	°C
DUT histeresys	evauated during calibration	0,00038	Ω	0,00011	rectangular	2,5	0,00027	°C
Standard resistor calibration	certificate	0,00017	Ω	0,00017	normal	2,5	0,00042	°C
Standard resistor drift	internal study	0,00042	Ω	0,00012	rectangular	2,5	0,00030	°C
						Combined standard uncertainty, in ºC =	0,0038	ºC
						Expanded standard uncertainty, in ºC =	0,0076	ºC

Calibration Point/s: -20.0 °C s/n 3481

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,00088	°C	0,00088	normal	1	0,00088	°C
SPRT calibration	certificate	0,001	°C	0,001	normal	1	0,001	°C
SPRT drift	internal study	0,000236	Ω	0,00024	normal	9,7	0,0023	°C
Standard resistor calibration	certificate	0,000047	Ω	0,000047	normal	9,7	0,0005	°C
Standard resistor drift	internal study	0,00012	Ω	0,00003	rectangular	9,7	0,0003	°C
Isothermal enclosure stability	internal study	0,0015	°C	0,00043	rectangular	1	0,0004	°C
Isothermal enclosure uniformity	internal study	0,0015	°C	0,00043	rectangular	1	0,0004	°C
DUT reading	statistic study	0,0003	Ω	0,0003	normal	2,5	0,000753769	°C
DUT histeresys	evauated during calibration	0,00038	Ω	0,00011	rectangular	2,5	0,00028	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	certificate	0,00018	Ω	0,00018	normal	2,5	0,00046	°C
Standard resistor drift	internal study	0,00046	Ω	0,00013	rectangular	2,5	0,00033	°C
						Combined standard uncertainty, in ºC =	0,0029	ºC
						Expanded standard uncertainty, in ºC =	0,0059	ºC

Calibration Point/s: 0.01 °C s/n 3481

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Calibration of the standard (TPW cell)	Certificate	0,0001	°C	0,0001	normal	1	0,0001	°C
Reproducibility of the TPW cell	internal study	0,001	°C	0,001	normal	1	0,001	°C
Drift of the triple point of water cell	Manufacturer	0,0001	°C	0,0001	rectangular	1	0,0001	°C
DUT reading	statistic study	0,00033	Ω	0,00033	normal	2,5	0,00083	°C
DUT histeresys	evauated during calibration	0,00038	Ω	0,00011	rectangular	2,5	0,00028	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	Certificate	0,00020	Ω	0,00020	normal	2,5	0,00050	°C
Standard resistor drift	internal study	0,00050	Ω	0,00014	rectangular	2,5	0,00036	°C
						Combined standard uncertainty, in ºC =	0,0015	ºC
						Expanded standard uncertainty, in ºC =	0,0029	ºC

Calibration Point/s: 29.8 °C s/n 3481

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,0018	°C	0,0018	normal	1	0,0018	°C
SPRT calibration	certificate	0,001	°C	0,001	normal	1	0,0010	°C
SPRT drift	internal study	0,000287	Ω	0,00029	normal	9,7	0,0028	°C
Standard resistor calibration	certificate	0,000057	Ω	0,000057	normal	9,7	0,0006	°C
Standard resistor drift	internal study	0,00014	Ω	0,00004	rectangular	9,7	0,0004	°C
Isothermal enclosure stability	internal study	0,002	°C	0,00058	rectangular	1	0,0006	°C
Isothermal enclosure uniformity	internal study	0,002	°C	0,00058	rectangular	1	0,0006	°C
DUT reading	statistic study	0,00083	Ω	0,00083	normal	2,6	0,0022	°C
DUT histeresys	evauated during calibration	0,00038	Ω	0,00011	rectangular	2,6	0,0003	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	certificate	0,00022	Ω	0,00022	normal	2,6	0,0006	°C
Standard resistor drift	internal study	0,00056	Ω	0,00016	rectangular	2,6	0,0004	°C
						Combined standard uncertainty, in ºC =	0,0043	ºC
						Expanded standard uncertainty, in ºC =	0,0086	ºC

Calibration Point/s: 156.7 °C s/n 3481

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,0037	°C	0,0037	normal	1	0,0037	°C
SPRT calibration	certificate	0,0015	°C	0,0015	normal	1	0,0015	°C
SPRT drift	internal study	0,000412	Ω	0,00041	normal	10,1	0,0042	°C
Standard resistor calibration	certificate	0,000082	Ω	0,000082	normal	10,1	0,0008	°C
Standard resistor drift	internal study	0,00021	Ω	0,00006	rectangular	10,1	0,0006	°C
Isothermal enclosure stability	internal study	0,02	°C	0,00577	rectangular	1	0,0058	°C
Isothermal enclosure uniformity	internal study	0,03	°C	0,00866	rectangular	1	0,0087	°C
DUT reading	statistic study	0,0018	Ω	0,0018	normal	2,7	0,0048	°C
DUT histeresys	evauated during calibratior	0,00038	Ω	0,00011	rectangular	2,7	0,0003	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	certificate	0,00032	Ω	0,00032	normal	2,7	0,0009	°C
Standard resistor drift	internal study	0,00080	Ω	0,00023	rectangular	2,7	0,0006	°C
						Combined standard uncertainty, in ºC =	0,013	ºC
						Expanded standard uncertainty, in ºC =	0,026	ºC

Calibration Point/s: 232.3 °C s/n 3481

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,0058	°C	0,0058	normal	1	0,0058	°C
SPRT calibration	certificate	0,0015	°C	0,0015	normal	1	0,0015	°C
SPRT drift	internal study	0,000485	Ω	0,00049	normal	10,1	0,0049	°C
Standard resistor calibration	certificate	0,000097	Ω	0,000097	normal	10,1	0,0010	°C
Standard resistor drift	internal study	0,00024	Ω	0,00007	rectangular	10,1	0,0007	°C
Isothermal enclosure stability	internal study	0,02	°C	0,00577	rectangular	1	0,0058	°C
Isothermal enclosure uniformity	internal study	0,03	°C	0,00866	rectangular	1	0,0087	°C
DUT reading	statistic study	0,0024	Ω	0,0024	normal	2,7	0,0065	°C
DUT histeresys	evauated during calibratior	0,00038	Ω	0,00011	rectangular	2,7	0,0003	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	certificate	0,00038	Ω	0,00038	normal	2,7	0,0010	°C
Standard resistor drift	internal study	0,00094	Ω	0,00027	rectangular	2,7	0,0007	°C
						Combined standard uncertainty, in ºC =	0,015	ºC
						Expanded standard uncertainty, in ºC =	0,029	ºC

Calibration Point/s: 250 °C s/n 3481

Description	Method of estimation	*U* value	Units	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards	statistic study	0,0044	°C	0,0044	normal	1	0,0044	°C
SPRT calibration	certificate	0,0015	°C	0,0015	normal	1	0,0015	°C
SPRT drift	internal study	0,000503	Ω	0,00050	normal	10,1	0,0051	°C
Standard resistor calibration	certificate	0,000101	Ω	0,000101	normal	10,1	0,0010	°C
Standard resistor drift	internal study	0,00025	Ω	0,00007	rectangular	10,1	0,0007	°C
Isothermal enclosure stability	internal study	0,02	°C	0,00577	rectangular	1	0,0058	°C
Isothermal enclosure uniformity	internal study	0,03	°C	0,00866	rectangular	1	0,0087	°C
DUT reading	statistic study	0,0018	Ω	0,0018	normal	2,7	0,0049	°C
DUT histeresys	evauated during calibratior	0,00038	Ω	0,00011	rectangular	2,7	0,0003	°C
Thermal fluxes	Immersion test	negñigibñe					0,00000	°C
Standard resistor calibration	certificate	0,00039	Ω	0,00039	normal	2,7	0,0011	°C
Standard resistor drift	internal study	0,00098	Ω	0,00028	rectangular	2,7	0,0008	°C
						Combined standard uncertainty, in ºC =	0,014	ºC
						Expanded standard uncertainty, in ºC =	0,027	ºC

A1.6. CIM Uncertainty Budget

Calibration Point/s: (250.0 ,232.3, 156.7,27.8)°C

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards		0,001	Normal	1	0,001	°C
Calibration of standards		0,002	Normal	1	0,002	°C
Drift of standards		0,010	Rectangular	1	0,010	°C
Stability of isothermal enclosure		0,024	Rectangular	1	0,024	°C
Uniformity of isothermal enclosure		0,011	Rectangular	1	0,011	°C
Reading of thermometer under calibration		0,001	Rectangular	1	0,001	°C
Thermal fluxes	Negligible				0,000	°C
Hysteresis of the thermometer under calibration	No evaluation performed	-				
				Combined standard uncertainty =		
				Combined standard uncertainty, in ºC =	0,03	ºC
				Expanded standard uncertainty, in ºC =	0,06	ºC

Calibration Point/s: 0 °C a -20 °C

Description	Method of estimation	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution	Units
Reading of standards		0,001	Normal	1	0,001	°C
Calibration of standards		0,001	Normal	1	0,001	°C
Drift of standards		0,004	Rectangular	1	0,004	°C
Stability of isothermal enclosure		0,001	Rectangular	1	0,001	°C
Uniformity of isothermal enclosure		0,051	Rectangular	1	0,051	°C
Reading of thermometer under calibration		0,001	Rectangular	1	0,001	°C
Thermal fluxes	Negligible				0,000	°C
Hysteresis of the thermometer under calibration	No evaluation performed					
				Combined standard uncertainty =		
				Combined standard uncertainty, in ºC =	0,05	ºC
				Expanded standard uncertainty, in ºC =	0,10	ºC

ANNEX 2. COMPARISON PROTOCOL

1. OBJECTIVE

This document sets out the instructions for carrying out the comparison of the calibration of 100 Ω (at 0 ºC) platinum resistance thermometers coordinated by the Centro Español de Metrología (CEM).

The purpose of the comparison is to check the equivalency between the participant laboratories (see Annex 1) in the calibration of platinum resistance thermometers by comparison in the range from -38,8 ºC up to 250 ºC. The results of this comparison could be use by the participants to support their calibration by comparison of platinum resistance thermometers CMCs in this range.

2. INTRODUCTION

The calibration method of the traveling standards will be by comparison in stable isothermal enclosures against the reference standards of the laboratory and using their own procedures.

Temperature values will be referred to the International Temperature Scale of 1990 (ITS-90).

The coordinator will:
prepare the comparison protocol,
follow the CIPM-MRA procedures to include the comparison in the BIPM-KCDB,
characterize and calibrate the two thermometers at the beginning and at the end of the comparison,
collect the information from all participants and,
perform the analysis of the comparison data and elaborate the final report one month after the last participant report was received.

Each participant laboratory should:
perform the measurements according to the rules of this protocol,
hand-carried the thermometers to the next participant in due time,
send to the coordinator a report using the templates included in the excel spreadsheet attached to this report 15 days after the completion of its measurements.

If a participant had troubles for meeting the deadlines, it must notify the affected laboratories and the coordinator, remaining the responsibility of the coordinator laboratory for reorganizing new deadlines.

3. TRAVELLING STANDARDS AND TRANSPORT METHOD

The traveling standards are two 100 Ω (at 0ºC) platinum resistance thermometers from Hart Scientific, model 5626, serial numbers 3473 and 3481.

It is the responsibility of each participating laboratory the thermometers transportation up to the next laboratory. The costs are covered by the European project PRACAMS. The receiving laboratory will send by e-mail to the pilot laboratory the format shown in annex 2 once the first measurement at 0 ºC has been done. The thermometers have to be transported using the packing provided by the manufacturer.

The packing and unpacking of the thermometers should be carefully performed and only by authorized staff of the thermometry laboratory.

4. CIRCULATION SCHEME

The circulation scheme (see figure 1) will be a single loop. The measurements will start and end at CEM.

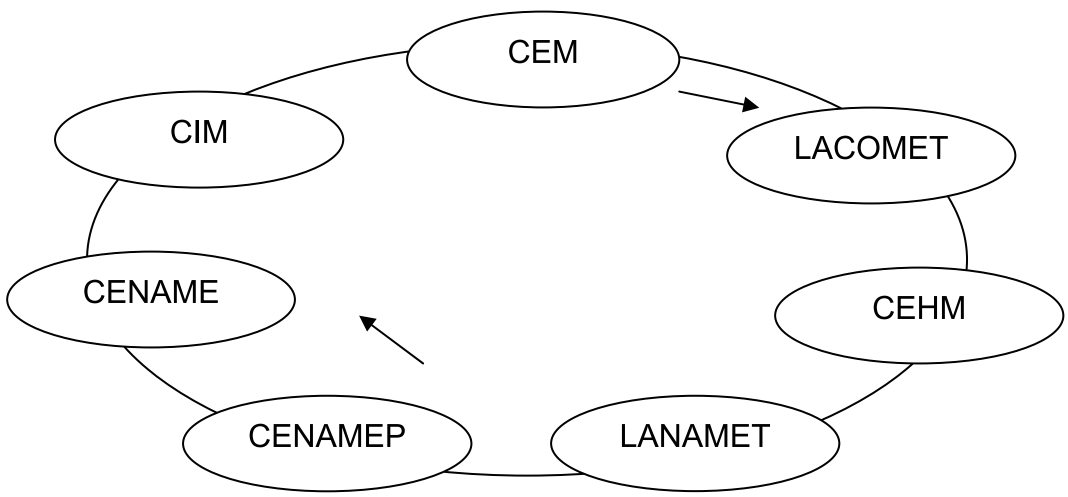


Figure 1. Circulation scheme

The maximum time allowed to each laboratory for calibration of the two thermometers will be 2 weeks plus 1 additional week for shipping and receiving for the next laboratory (see table 1)

NMI	Starting of measurements	Delivery date of equipments
CEM	2013-08-21	2013-09-06
LACOMET	2013-09-30	2013-10-18
CEHM	2013-10-21	2013-11-08
LANAMET	2013-11-11	2013-11-29
CENAMEP	2013-12-02	2013-12-20
CENAME	2014-01-06	2014-01-24
CIM	2014-01-27	2014-02-14
CEM	2014-02-17	2014-02-27

Table 1. Comparison Schedule

5. MEASUREMENT PROCEDURE

5.1. Calibration by comparison

The measurand will be the electrical resistance of the thermometer, with four terminals at the temperatures shown below.

0 ºC; 250 ºC; 232,3 ºC; 156,7 ºC; 29,8 ºC; 0 ºC; -20 ºC; -38,8 ºC; 0 ºC

The participants will report the results of their measurements at the temperatures as close as possible to the above calibration points, no calibration curves should be used to interpolate the results.

Correct immersion depths for the thermometers during calibration have to be assured. It is common practice to test it by immersing the thermometers at the maximum depth allowed by the isothermal enclosure used and withdrawing them several centimeters. If no significant differences in the readings are recorded, then it can be concluded that a correct immersion depth is achieved. If significant differences are found, then a source of uncertainty due to thermal fluxes has to be taken into account.

Each laboratory must follow their own procedures, using the equipments to get their best measurement capability for the calibration of platinum resistance thermometers by comparison.

The calibration points will be done in the order shown, from the highest temperature to the lowest.

No heat treatment will be performed to the thermometers.

The electrical resistance measurement will be performed with four terminals with 1 mA current. If other current were used, it must be specified and if possible the self heating determined.

The first resistance value of the thermometers at 0 ºC should be measured by each participant upon reception and its result send to the coordinator laboratory by e-mail using the format shown in annex 2.

The values of resistance of the traveling thermometers at 0 ºC could be determined by each laboratory at the water triple point or at the ice point. In the latter case, the ice bath temperature must be measured with their working standards.

The self-heating of the thermometer will be determined at 0 ºC.

5.2. Additional measurements at fixed points

As additional measurements to that described in point 5.1. the participants could perform measurements in the fixed points of Hg, Ga, In and Sn. Measurements at the fixed points should be performed in order of decreasing temperatures alternating with a measurement at the triple point of water.

The laboratories that decide to perform these additional measurements have to follow their normal practice when realizing the ITS-90. For each fixed point the value of the reduced resistance W=RT / RTPW is calculated, being RTPW the triple point of water resistance value obtained immediately after the measurement of RT. RT and RTPW should have been corrected for hydrostatic head and if any the pressure effect. At least 2 different phase transitions will be performed. The different values will be delivered together with the calculated mean according to the excel spreadsheet template.

These results could be used by the laboratory for internal purposes and will be included in an annex to the final report.

6. EXPRESSION OF RESULTS

Each participant laboratory will send a report by e-mail to the pilot laboratory within two weeks once the calibration is completed, following the excel spreadsheet format attached to this report.

7. CALCULATION OF UNCERTAINTIES

Each participant laboratory must complete the excel format for calculation of uncertainties. At least, the causes given below shall be quantified:

Calibration by comparison
Reading of standards,
Calibration of standards,
Drift of standards,
Stability of isothermal enclosure,
Uniformity of isothermal enclosure,
Reading of thermometer under calibration,
Hysteresis of the thermometer under calibration,
Thermal fluxes

The participants are reminded that thermal hysteresis results in different resistance values at the same temperature point, depending on whether the temperature was increasing or decreasing so it experiments a maximum around the midpoint of the calibration range. The participants are asked to evaluate the hysteresis of the thermometers using their own methods.

Calibration in fixed points
Phase transition repeatability
Chemical impurities and isotopic composition for the TPW
Hydrostatic-head errors
Bridge measurement errors:
Uncertainty propagated from the TPW
SPRT self heating errors
Heat flux-immersion errors
Errors in gas pressure
Errors in the choice of freezing point value from plateau of the freezing curve
SPRT internal Insulation leakage (if any)

8. EVALUATION OF RESULTS

The values measured by CEM at the beginning and at the end of the comparison will be used to calculate the reference value of the comparison and the drift of the standards. In order to compare the results, the data sent by each laboratory will be extrapolated to the reference temperatures given in the protocol. For this purpose, sensitivity coefficients (defined as the resistance change of each PRT with temperature) were used. They were given by the fitting curves got in the last calibration at CEM. For the fitting, the reference functions of the ITS-90 will be used. Equations of the following type, fitted by least squares method, were applied to the differences between the measured values and the reference ones:

$$W_{\mathrm{d}} = a \cdot (W - 1) + b \cdot (W - 1)^2 \qquad (1)$$

Evaluation of the results will be made in terms of the reduced resistance Wt in each calibration point in order to eliminate possible PRTs instabilities. For each laboratory the last measured value of resistance at the water triple point will be used for Wt calculation.

Also for each laboratory in each calibration point the value of its standardized deviation coefficient will be calculated. It is defined as:

$$E_{\mathrm{L}t} = \frac{|W_{\mathrm{L}t} - W_{\mathrm{R}t}|}{\sqrt{U_{\mathrm{L}t}^2 + U_{\mathrm{R}t}^2}} \qquad (2)$$

where:

$U_{\mathrm{L},\,t}$: Expanded uncertainty of laboratory L at temperature t.

$U_{R,\,t}$: Expanded uncertainty of the reference laboratory at temperature t

The degrees of equivalence between the laboratories will be also determined.

ANNEX 1. PARTICIPANT LABORATORIES

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ANNEX 2. RECEPTION FORMAT

In order to have information about the progress of the comparison and, if were necessary to take appropriate corrective actions, please the receiving laboratory will send by e-mail this form to the pilot laboratory, once the first measurement at 0 ºC be done and will communicate the date of receipt to the coordinator laboratory.

Thanks for your collaboration.

The traveller thermometers were received ____________________

There were no signs of damage in transport

Observed damages:

Are they serious? Yes/No

Is it probably that the thermometers are still valid for use? Yes/No

Measurements at 0 ºC:

Temperature:________________________ ºC

Resistance:__________________________

Uncertainty: _________________________ ºC

Comments:

Participant:

E-mail: