#### BILATERAL COMPARISON OF TEMPERATURE STANDARDS

**Instituto Nacional de Metrologia, Qualidade e Tecnologia (Inmetro), Brazil**

**Trinidad and Tobago Bureau of Standards (TTBS), Trinidad and Tobago**

#### Standard Platinum Resistance Thermometers from the Hg Triple Point to the Zn Freezing Point

**TECHNICAL PROTOCOL**

January/2020, revised May/2020

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# INTRODUCTION

* 1. Under the Mutual Recognition Arrangement (MRA)[[1]](#footnote-1) the metrological equivalence of national measurement standards will be determined by a set of key comparisons chosen and organized by the Consultative Committees of the CIPM working closely with the Regional Metrology Organizations (RMOs).
	2. This document describes the technical protocol of a bilateral comparison of temperature standards between Instituto Nacional de Metrologia, Qualidade e Tecnologia (INMETRO), Brazil, and Trinidad and Tobago Bureau of Standards (TTBS), Trinidad and Tobago.
	3. This technical protocol has been prepared and approved by the two participants indicated above.
	4. The procedures outlined in this document cover the technical procedure to be followed during measurement of two transfer standards. The procedure, which follows the guidelines established by the BIPM[[2]](#footnote-2), is based on current best practices in the use of standard platinum resistance thermometers and takes account of the experience gained from the research and calibration activities of the participants over the years.
	5. This comparison is aimed at checking the degree of equivalence between fixed point calibration results of standard platinum resistance thermometers (SPRT) in the range between the triple point of mercury (-38.8344 °C) and the freezing point of zinc (419.527 °C).

# ORGANIZATION

## Participants

* + 1. Details of mailing and electronic addresses are given in Appendix 1. The participating institutes are:
* Instituto Nacional de Metrologia, Qualidade e Tecnologia (Inmetro) – Brazil
* Trinidad and Tobago Bureau of Standards (TTBS) – Trinidad and Tobago
	+ 1. Inmetro is the pilot of this bilateral comparison, taking main responsibility for running comparison.
		2. By their declared intention to participate in this bilateral comparison, the laboratories accept the general instructions and the technical protocol written down in this document and commit themselves to follow strictly the procedures of this protocol as well as the version of the "Guidelines for Key Comparisons" in effect at the time of the initiation of the Bilateral Comparison.
		3. Once the protocol and list of participants have been approved, no change to the protocol or list of participants may be made without prior agreement of all participants.
		4. The participants must be able to submit an uncertainty budget of their temperature measurements according to section 3.4.
	1. **Transfer Standard**
		1. Each laboratory will provide a SPRT as transfer standards, as described below:

|  |  |  |
| --- | --- | --- |
| Laboratory | INMETRO | TTBS |
| SPRT ID | SPRT #1 | SPRT #2 |
| Manufacturer | Rosemount | Isotech |
| Model | 162CE | 670Q |
| Serial number | 3713 | 234 |
| Nominal resistance at 0 °C | 25  | 25  |
| Number of wires | 4 | 4 |

* 1. **Handling of the Artefact**
		1. The artefact should only be handled by authorized persons and stored in such a way as to prevent damage.
		2. During measurements, if there is any unusual occurrence, the pilot laboratory should be notified immediately before proceeding.
	2. **Transport of Artefact**
		1. Both Inmetro and TTBS will be in charge to transport the transfer to the other laboratory.
	3. **Timetable**

|  |  |  |
| --- | --- | --- |
| Activity | **Start Month** | **Provisional date** |
| Submission of a technical protocol to participants for unanimous approval | January 2020 |  |
| Submission of revised technical protocol to SIM/ WG3 (thermometry WG) for approval. | January 2020 |  |
| Travelling of SPRT #1 to TTBS | January 2020 |  |
| Completion of the measurements of both standards at TTBS | January 2020 |  |
| Travelling of both standards to Inmetro | January 2020 |  |
| Completion of the measurements of both standards at Inmetro |  | March 2020 |
| Draft A ready to both participants |  | July 2020 |
| Deadline for comments on Draft A |  | August 2020 |
| Draft B ready and submitted to SIM/WG3 |  | September 2020 |
| Paper submission |  | October 2020 |

# MEASUREMENT INSTRUCTIONS

* 1. **Measurand**
		1. The measurand of this comparison are the *W(t90)* measured values, where

|  |  |
| --- | --- |
| $$W\left(t\_{90}\right)=\frac{R(t\_{90})}{R(TPW)}$$ | (1) |

where *R(t90)* and *R(TPW)* are, respectively, the values of electrical resistance of the SPRT measured at the fixed points, and the resistance at the triple point of water (TPW).

* + 1. With the measured values of *W(t90)*, the differences between both laboratories are given as follows:

|  |  |
| --- | --- |
| $$∆t\_{90}=\frac{W\_{TTBS}\left(t\_{90}\right)-W\_{Inmetro} (t\_{90})}{dW(t\_{90})/dt\_{90}}$$ | (2) |
| Where *dW(t90)/dt90* is the first derivative of *W* with relation to the temperature. |  |

* 1. **Preliminary checks**
		1. The artefact should be examined when received by the participant laboratory, before the start of measurements, to check if the PRT has any kind of damage. If the artefact has no damage, the laboratory will proceed with the measurements.
	2. **Measurement process**
		1. Each participant will measure the electrical resistances of the SPRT using four wires connection.
		2. All the measured electrical resistances must be corrected to null current (0 mA).
		3. Each participant will follow its own procedure while calibrating the SPRTs.
		4. The first point to be measured is the TPW, immediatelyafter receiving the SPRTs. This value will be reported, in order to identify any drift due to transportation.
		5. The calibration then will proceed from higher to lower temperatures. The SPRTs shall be calibrated at the zinc freezing point (Zn FP, 419.527 °C), tin freezing point (Sn FP, 231.928 °C), gallium melting point (Ga MP, 29.7646 °C) and mercury triple point (Hg TP, -38.8344 °C). Before and after each calibration point, the *RTPW* value of the SPRTs must be measured.

* + 1. The transfer standards used in this comparison must not be modified, adjusted or used for any purpose other than described in this document, nor given to any party other than the participants of this comparison.
		2. If unacceptable performance or failure of the transfer standard is detected, the participants will discuss the situation and agree a course of action.
	1. **Uncertainties**
		1. Each participant will calculate, for each calibration point, the measurement uncertainties, according to Appendix 3, which must include at least, but not excluding other components:
1. Repeatability of the test thermometer’s readings;
2. Fixed point cell uncertainty;
3. Resistance readout system uncertainty;
4. Self-heating correction’s uncertainty;
5. Hydrostatic head correction’s uncertainty;
6. Gas pressure correction’s uncertainty, if applicable;
7. Heat flux uncertainty;
8. Uncertainty of the TPW measurement.

* 1. **Reporting of measurement results**
		1. Participants will report their measurement results in a period of time not exceeding three weeks after completion of measurements. The measurement report is given in Appendix 2, and must include the following information:
1. Initial and final *R(TPW)* measured values;
2. For each calibration point, *W(t90)* and expanded uncertainty;
3. Measurement system (fixed point cells, isothermal medias and electrical resistance readouts);
4. Uncertainty analysis.
	* 1. Measurement uncertainties will be reported in terms of temperature, by converting the *W(t90)* uncertainties values with the appropriate value of *dW(t90)/dt90*.
		2. The participants should not disclose their measurement results to a third party. The participants will exchange their measurement results after all the measurements are completed.
5. **RESULTS OF THE COMPARISON**
	1. The pilot laboratory will analyze the results of participant laboratories. The results of the comparison are:
		1. The bilateral differences, as described in eq. 2;
		2. The Standard Error (SE), given by:

|  |  |
| --- | --- |
| $$SE=\frac{\left|Δt\_{90}\right|}{\sqrt{U(W\_{TTBS}(t\_{90}))^{2}+U(W\_{Inmetro}(t\_{90}))^{2}}}$$ | (3) |

 where *t90* is given in eq. 2, and *U* is the expanded uncertainty of *W(t90)* in terms of temperature for a confidence level of approximately 95%.

1. **COMPARISON REPORT**
	1. The pilot laboratory will prepare the Draft A, which will be available for observations in a period of time no longer than two weeks.
	2. The pilot laboratory will then prepare the Draft B, which will be submitted to SIM/WG3 for approval.

**APPENDIX 1**

**DETAILS OF PARTICIPATING INSTITUTES**

**Instituto Nacional de Metrologia, Qualidade e Tecnologia – INMETRO**

Address: Laboratório de Termometria (Prédio 04) – Av. Nossa Senhora das Graças, 50

Xerém – Duque de Caxias – RJ – Brasil – CEP: 25250-020

Contact: Klaus Natorf Quelhas

Phone: +55 21 2145 3113

E-mail: knquelhas@inmetro.gov.br

**Trinidad and Tobago Bureau of Standards – TTBS**

Address: 1-2 Century Drive, Trincity Industrial Estate, Macoya, Tunapuna

 Trinidad and Tobago

Contact: Francis Hamilton

Phone: +1 868 662-8827 ext 2311

E-mail: Francis.Hamilton@ttbs.org.tt

# APPENDIX 2

# MEASUREMENT REPORT

Identification

|  |  |
| --- | --- |
| Laboratory : |  |
| Contact : |  |
| e-mail : |  |

Transfer standard information :

|  |  |
| --- | --- |
| SPRT ID : |  |
| Manufacturer : |  |
| Model : |  |
| Serial number : |  |
| Date of transfer standard arrival : |  |
| Initial value of *R(TPW)* () : |  | ± |  |
| Final value of *R(TPW)* () : |  | ± |  |

Calibration results :

|  |  |  |  |
| --- | --- | --- | --- |
| Fixed point | *W(t90)* | Expanded uncertainty(°C) | Effective Degrees of Freedom |
| Zn |  |  |  |
| Sn |  |  |  |
| Ga |  |  |  |
| Hg |  |  |  |

# Measurement system information

Standards :

|  |  |  |  |
| --- | --- | --- | --- |
| Description | Manufacturer | Model | Traceability |
|  |  |  |  |
|  |  |  |  |
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|  |  |  |  |
|  |  |  |  |

Electrical resistance readouts :

|  |  |  |  |
| --- | --- | --- | --- |
| Description | Manufacturer | Model | Traceability |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

Isothermal media :

|  |  |  |
| --- | --- | --- |
| Description | Manufacturer | Model |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

**APPENDIX 3**

# UncertaintY analysis

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Fixed Point :** |  |  |  |  |  |  |  |  |  |
| **Description** | **Estimate***xi* | **Unit** | **Probability distribution** | **Standard uncertainty***uxi* | **Sensitivity coefficient***ci* | **Unit** | **Contribution to uncertainty***ci · uxi* | **Degrees of freedom***i* |
| Repeatability of test thermometer |  |  |  |  |  |  |  |  |
| Fixed point cell |  |  |  |  |  |  |  |  |
| Resistance readout |  |  |  |  |  |  |  |  |
| Self-heating correction |  |  |  |  |  |  |  |  |
| Hydrostatic head correction |  |  |  |  |  |  |  |  |
| Gas pressure correction |  |  |  |  |  |  |  |  |
| Heat flux |  |  |  |  |  |  |  |  |
| TPW measurement |  |  |  |  |  |  |  |  |
| TPW stability |  |  |  |  |  |  |  |  |
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|  |  |  |  |  |  |  |
|  |  |  |  | **Combined** **uncertainty** = |  |  |
|  |  |  |  | **Effective degrees of freedom** =  |  |  |
|  |  |  |  | *k* =  |  |  |
|  |  |  |  | **Expanded** **uncertainty** = |  |  |

1. MRA, Mutual Recognition Arrangement, BIPM, 1999. [↑](#footnote-ref-1)
2. Measurement comparisons in the CIPM MRA, CIPM MRA-D-05 version 1.6, BIPM, Paris. [↑](#footnote-ref-2)