BIPM Capacity Building & Knowledge Transfer Programme

2018 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Investigation of self-heating effect for Pt100 thermometer in a Liquid bath and in a Climatic chamber at different temperatures
Description	The self-heating effect for Pt100 thermometer when calibrated in a Liquid bath and in a Climatic chamber was determined at different temperatures and at currents ranging from 0.5 mA to 2√2 mA
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Motivation & Introduction

My motivation to participate in this project was due to a number of publications I read related to the Self-Heating of Platinum Resistance Thermometers (PRTs) during calibration. Each was aimed at estimating the errors associated with this phenomenon which has the potential to influence the uncertainty of measurement. This craved my interest, but I faced limitations in equipment and resources to carry out the investigation. This project placement, therefore, came as an opportunity. As Ghana is in the process of establishing a fully-fledged National Metrology Institute (NMI), qualified and experienced metrologists will be required to man its activities, even at the yet to be established Accreditation body. My participation therefore gives me an additional knowledge in temperature metrology research and an opportunity to aspire for higher learning in Metrology.

During calibration, all the PRT resistance measurements can be performed with the same measuring current, usually 0.5 mA, and the results in the certificate are then given for this current. The subsequent use of the calibrated thermometer by the customer requires the measurement in *situ* of its resistance by means of a digital multi-meter working at the same measuring current of 0.5 mA. The resulting self-heating error is negligible if the medium used is similar to that used during calibration. If the medium to be used is different, the self-heating effect may differ from that of calibration.

This investigation is therefore aimed at estimating the errors that can be expected due to varied excitation currents when calibrations are done in a liquid bath and in a climatic chamber, hence the description of my project.

Research

PRTs of the Pt100 type are widely used in industry. Measurement with resistance thermometers involve passing a current through the thermometer sensing element, which gives rise to Joule heating. The amount of dissipated power in this case is proportional to the square of the current. As a matter of fact, there is no way to assure that the current used to excite the PRT during calibration is the same as that which is used by the customer. It is also not assured that the medium of calibration is the same medium of measurement applied by the customer. In this investigation, the error that can be expected due to this difference in excitation currents, in different calibration media, was estimated in the temperature range of -30 °C to 150 °C. Measurements were done in liquid baths and in a climatic chamber with air circulation and the results evaluated over the whole range.

Equipment and Method

All measurements were performed using the same facilities used by TUBITAK UME in the calibration of PRTs and humidity measuring devices. The sample PRTs were also supplied by TUBITAK UME.

In the investigation, four Pt100 thermometers with different dimensions and unknown sensitivity coefficients were excited with several current values in the range of 0.5 mA to 2√2 mA and the resistance measured via a four-wire connection with an Analogue-to-Digital-Convertor (ADC) Thermometer Bridge with 0.001 mK resolution and better than 0.03 ppm accuracy value. Equivalent temperatures were determined using ITS-90 algorithm and the self-heating effects evaluated for the whole range. This range of current was selected because it is typical for industrial PRT applications.

Table 1: Details of Pt100 thermometers used for the investigation

	PRT-1	PRT-2	PRT-3	PRT-4 (short)
Manufacturer	Fluke	Fluke	VNIIM	TURKEY
Model	5626	5626	3TC-100	Nil
Serial Number	2433	32077	99-10	Nil
Diameter (mm)	6.4	6.4	5.3	5.9
Length (mm)	300	300	535	100
Submersion depth (mm)	240	240	240	Complete

The PRTs used for the investigation were first annealed at 180 °C for 2 hours (after attaining stability) in a 3-zone furnace. Ice point values were determined before and after annealing in an ice bath with distilled water in two phases (liquid and solid) in thermal equilibrium. This test was to determine the stability of the PRTs before commencement of measurements. The short sample PRT did not go through this test because of its short length. All the PRTs and a reference SPRT (used to determine stability of medium) were connected to an Isotech MicroK Thermometer Bridge. They were immersed in a Heto CB 217 stirred alcohol bath for measurement at -30 °C, immersed in Isotech 796m stirred distilled water bath for measurement at 50 °C and in a Fluke 6024 stirred Oil bath at 100 °C and 150 °C. Measurement at 0 °C was, however, done in an ice bath. The immersion depth in liquid and in ice baths was 24 cm. All measurements were carried out in an ascending order. The selected excitation currents were 0.5 mA; 0.5√2 mA; 1 mA; 1√2 mA; 2 mA; and 2√2 mA.

This procedure was repeated in a Weiss WKL100 climatic chamber with air circulation. 20 cm length of each thermometer was immersed in the chamber through an inlet port, except for the short length which was completely immersed. The waiting time for each excitation current, after stability, was 60 minutes in chamber and 10 minutes in the liquid bath. This was due to the good thermal conductivity in liquid, which is more than ten times lower in air.

Results and Discussion

At the end of investigation in liquid baths, it was realized that the resistance of the PRT appreciated as the current was increased for each temperature point. This was similar in climatic chamber and typical with all PRTs. Stability was better in liquid bath than in air (i.e. up to 0.1 mK for liquid bath and 3 mK in Chamber).

Results for PRT no. 2433 self-heating at 0.5 mA and 2 mA are as indicated in Table 2. The trend was same for the remaining PRTs.

Table 2: Result for PRT no. 2433 self-heating at 0.5 mA and 2 mA

set point	*Heating-effect in liquid*	*Heating-effect in air*		*set point*	*Heating-effect in liquid*	*Heating-effect in air*
°C	mK	mK		°C	mK	mK
-30	1.1	4.0		*-30*	7.7	6.0
0	0.3	6.0		*0*	4.9	12.0

50	1.3	16.0
100	0.4	6.0
150	0.3	52.0

50	6.2	21.0
100	8.6	18.0
150	10.5	10.0

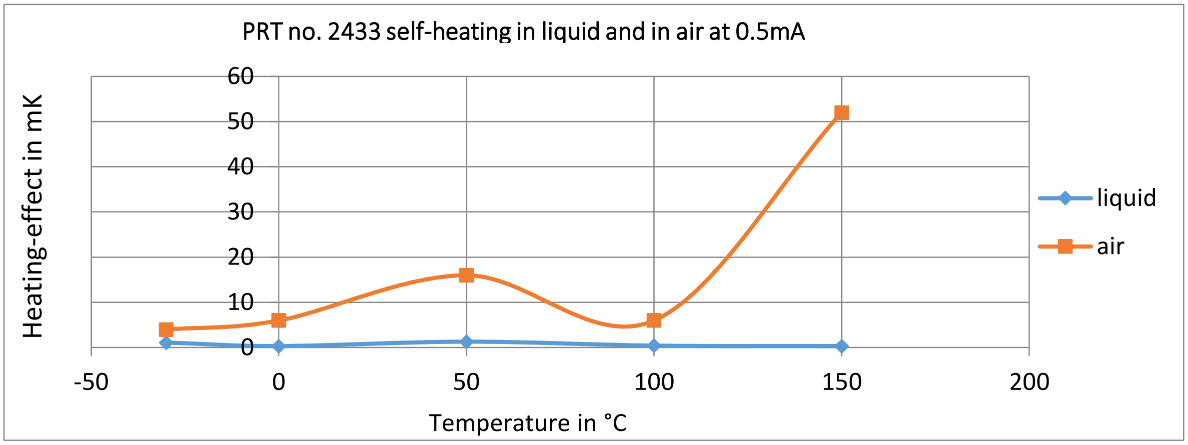

Fig. 1: Self-heating of PRT in liquid bath and in climatic chamber at 0.5 mA

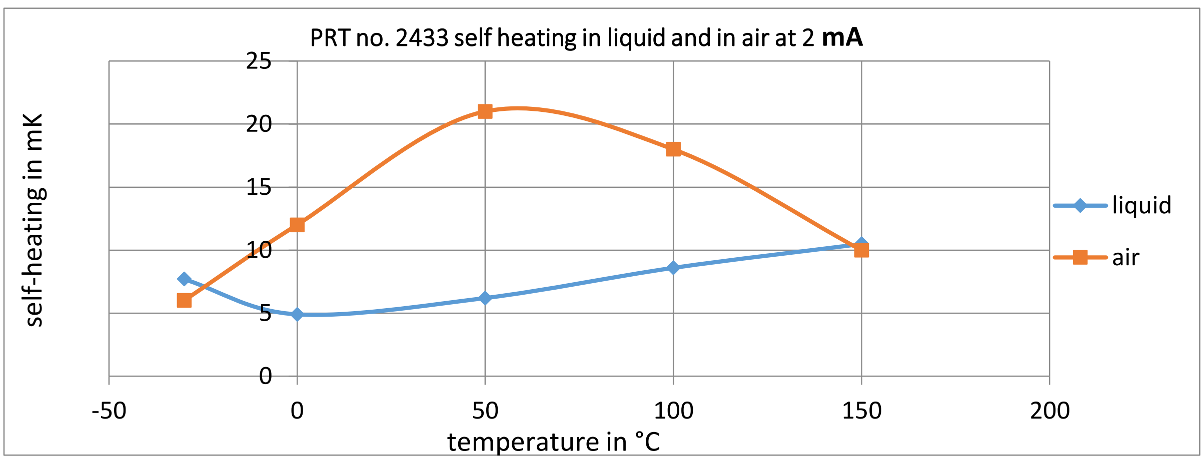

Fig. 2: Self-heating of PRT in liquid bath and in climatic camber at 2 mA

Considering the temperature range of -30 °C to 150 °C for this investigation, self-heating for Pt100 in liquid was found to be about 1 mK at 0.5 mA current excitation and of a maximum of 10 mK at 2 mA. These values were however higher in the climatic chamber, ranging from 52 mK down to 21 mK at 0.5 mA and 2 mA respectively. Highest value was recorded at 150 °C for an excitation current of 0.5 mA.

CIPM MRA Lectures

In course of the training, a two-day lecture was given on the Global Quality Infrastructure and a perspective of the CIPM MRA. It was meant to give an overview of some activities of the BIPM to participants. Resource persons were from BIPM and TUBITAK UME. There was a wide range of topics including the CIPM MRA quality systems and requirements on CMC submission. Also of interest was a discussion on the importance of a National Quality Infrastructure which relies on Metrology, Standardization Accreditation Conformity Assessment and Market Surveillance. The lecture was very educating and of high relevance.

Conclusions and Future Work

From the results for self-heating effect in liquid and in air, it is evident that the medium of application of the PRT should always be considered during calibration. This is due to the high values of self-heating effect recorded for measurement in air. It is possible to determine the amount of uncertainty contribution due to Joule self-heating effect in PRT measurement. This procedure can be applied to any PRT which mW/°C coefficient is unknown, in order to evaluate the uncertainty due to different excitation currents.

Despite the findings and conclusions of this investigation, it does not presuppose a final recommendation. It only reflects the results of this investigation so far. It is work in progress and hopefully, the final paper will be submitted at an international platform for approval and/or acceptance.

Acknowledgements

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