BIPM Capacity Building & Knowledge Transfer Programme

2019 BIPM-TÜBİTAK UME Project Placement

REPORT

Project Name	Assessment of the Impact of Stability of Calibration Medium to the Uncertainty of Measurement
Description	The research project placement was aimed at investigating the effect of the 'stability factor' of the medium used in calibration of digital thermometers in calculating the uncertainty of measurement. The study was conducted by medium stability comparison measurements using dry blocks and liquid baths (as heat enclosures), with a digital thermometer as the device under calibration and a standard platinum resistance thermometer (SPRT) as a reference thermometer.
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Date	1 March to 22 April 2019

MOTIVATION & INTRODUCTION.

Uncertainty of measurement is attributed by several factors or contributors depending on the particular type of measurement experiment.

Some contributions to measurement uncertainty originate from the instruments being measured and others from the reference materials or standards. Sometimes the environment or the medium in which the measurement processes are carried out influence the measurement results.

My project, 'Assessment of Impact of ***Stability of Medium*'** to measurement uncertainty aimed at analyzing how different media stabilities can influence measurement uncertainty.

The study was carried out by using liquid baths (oil, alcohol and water baths), dry blocks, a digital thermometer and a standard platinum resistant thermometer. The same device under calibration (DUC) which was a digital thermometer, and the same standard platinum resistance thermometer (SPRT) as a reference thermometer were used in all media so as to have a controlled experimental study.

As a designated National Metrology Institute, the Tanzania Bureau of Standards through its Metrology Department, is mandated to provide traceability in various fields of measurement across the country. This goes hand in hand with the bureau's capability in meeting the demand of the customers' accuracy specifications for calibrations, and hence, to foster and facilitate industrial growth and trade within the country and globally. Currently, the TBS temperature laboratory Calibration Measurement Capability (CMC) for calibration of digital thermometers is 0.05^{0}C, a value which is relatively higher than what many of the customers would demand for traceability of their equipment. The objective of my study was to use the obtained results towards improving our laboratory CMC for digital thermometers and to pave the way towards revalidating a new method on calibration of digital thermometers by determining the most appropriate heat source (with better stability), and therefore minimum uncertainty of measurement, with the ultimate result of the improvement of our laboratory CMC in calibration of digital thermometers.

RESEARCH

The study started with reading and understanding "Guidelines on the Calibration of Temperature Block Calibrators", a EURAMET Calibration Guide No. 13, Version 4.0 (09/2017). Prior to calibration of a digital thermometer by dry blocks, thermal properties (dry block characterization) of dry blocks were investigated and finally their measurement uncertainties were calculated. The equipment used in the measurement experiments are as shown in the Table 1 below.

Table 1. Equipment used

Equipment	**Manufacturer**	**Model No.**	**Serial No.**
1.Dry Block	FLUKE	9170	B18613
2.Dry Block	ISOTECH	VENÜS	381662/1
3.Oil Bath	FLUKE	6020	ASA246
4.Water Bath	ISOTECH	796m	3416411
5.Alcohol Bath	HETO	01DBT200	93030924
6.Digital Thermometer(PT-100)	FLUKE	5626	2434
7.Standard Platinum Resistance Thermometer(SPRT)	FLUKE	5680	1137
7.Precision Thermometry Bridge.	ISOTECH	Micro K Gold	371230/1
8.PT-100 Display	FLUKE	1529-R	B05220

Two new dry blocks were characterized and calibrated as shown in the photographs below.

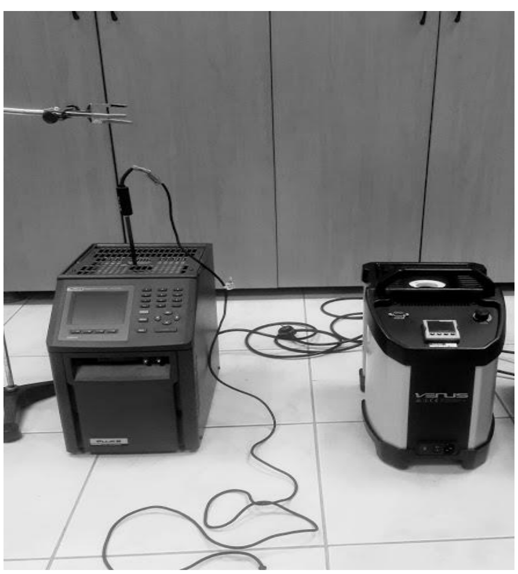

Figure1.Dry blocks

Figure2. Dry block Characterization

The operating temperature ranges of the two dry blocks were similar, i.e. -45 ^{0}C to 140 ^{0}C. Thermal characterizations were done at temperature points -30 ^{0}C, 60 ^{0}C and 130 ^{0}C and their respective uncertainties were calculated as shown in table 2.

Table2. Calibration results and uncertainties of dry blocks

Type of Dry Block	**Point Calibrated(^{0}C)**	**Reference Reading (^{0}C)**	**Dry Block/DUC Reading(^{0}C)**	**Deviation (^{0}C)**	**Uncertainty (^{0}C) ±**
A	-30	-30.003	-30.000	+0.003	0.007
B	-30	-29.9	-30.0	-0.1	0.052
A	60	59.998	60.000	+0.002	0.024
B	60	59.96	60.00	+0.04	0.060
A	130	129.963	130.000	+0.037	0.024
B	130	129.7	130.0	+0.3	0.317

Upon the calibration and quantification of the dry blocks' uncertainties, the digital thermometer was first calibrated by using the dry blocks and then again by using the liquid baths. The uncertainties of the liquid baths were obtained from their previous certificates of calibration.

Oil Bath *Water Bath*

Figure 3. Calibration of digital thermometer by Oil and Water Bath respectively

The uncertainties of the dry blocks and the digital thermometer were calculated from their respective budgets. Tables 3 and 4 illustrate the uncertainty budgets for dry blocks A and B at 60^{0}C and for the digital thermometer at 100^{0}C

Table3.*Uncertainties budget for Block A and Block B at 60^{0}C*

	Definition of uncertainty component	Block A Value	Block B Value
	Reference Thermometer		
	Certificate	0.000001	0.000001
	Drift	1.34E-06	1.34E-06
	Reference Display		
	Certificate	6.25E-08	6.25E-08
	Drift	2.09E-08	2.09E-08
	Dry Block		
	Repeatability	1.12E-08	2.95E-07
	Resolution	8.35E-08	8.35E-08
	Temperature differences between the borings	3.69E-06	0.000423
	Axial inhomogeneity	0.000136	0.00048
	Loading of the block with other thermometers	8.35E-08	8.35E-08
	Stability in time	3.08E-10	7.54E-07
	Hysteresis	0	0
TOTAL VARIANCES	u_{tref}^2 =	***1.42E-04***	***9.06E-04***
Standard Uncertainty	u_{tref} =	***0.012***	***0.030***
Expanded Uncertainty (k=2, %95)	U_{tref} =	***0.024***	***0.060***

Table 4.Uncertainty budget of digital thermometer calibration by oil bath and dry blocks at 100⁰C

	Definition of uncertainty component	Liquid bath	Block A	Block B
		Value	**Value**	**Value**
	Reference Thermometer			
	Certificate	0.000001	0.000001	0.000001
	Drift	1.3365E-06	1.3365E-06	1.3365E-06
	Reference Display			
	Certificate	6.3E-08	6.25E-08	6.25E-08
	Drift	2.1E-08	2.08828E-08	2.08828E-08
	Temperature Source			
	Uncertainty of Temperature Source	3.00712E-06	0.000192455	0.014734873
	Uncertainty of Ice point	***3.00712E-06***	3.00712E-06	3.00712E-06
	Device Under Calibration			
	Repeatability	***1.0E-07***	2.12222E-08	3.03444E-07
	Resolution	***8.4E-10***	8.3531E-08	8.3531E-10
	Hysteresis	***3.2E-07***	3.94241E-08	1.84599E-06
	Interpolation	***5.0E-07***	5.62628E-08	7.38801E-08
TOTAL VARIANCES	u_{tref}^2 =	***9.36E-06***	***1.98E-04***	***1.47E-02***
Standard Uncertainty	u_{tref} =	***0.003***	***0.014***	***0.121***
Expanded Uncertainty (k=2, %95)	U_{tref} =	***0.006***	***0.028***	***0.243***

The calibration results and the uncertainties by both methods were presented in a comparison manner as per table 5.

Table 5. Results of measurements

Method	Point Calibrated (⁰C)	Reference Reading(⁰C)	Digital Thermometer/DUC Reading(⁰C)	Deviation (⁰C)	Uncertainty (⁰C) ±
1.Dry Blocks (i)Block A	-30	-30.034	-30.034	0.000	0.009
	10	9.979	9.978	-0.001	0.018
	60	59.981	59.979	-0.002	0.028
	100	99.963	99.960	-0.003	0.028
	130	129.972	129.969	-0.003	0.028
	-30	-29.816	-29.840	-0.024	0.061
	10	10.076	10.065	-0.011	0.065
	60	59.864	59.875	+0.011	0.070
	100	99.799	99.820	+0.021	0.243
(ii)Block B	130	129.656	129.664	+0.008	0.370

Method	Point Calibrated (^0C)	Reference Reading(^0C)	Digital Thermometer/DUC Reading(^0C)	Deviation (^0C)	Uncertainty (^0C) ±
2.Liquid Baths (i)Alcohol Bath	-30 10	-30.142 10.021	-30.145 10.021	-0.003 0.000	0.006 0.005
(ii)Water Bath	60	60.057	60.056	-0.001	0.009
(iii)Oil Bath	100 130	100.003 130.012	100.002 130.010	-0.001 -0.002	0.006 0.006
3.Ice Point	0	-0.002	0.006	+0.008	0.006

CONCLUSION AND FUTURE WORK

As it is observed from the calibration results in table 5, the deviations of digital thermometer readings from the reference thermometer readings for liquid baths are the smallest in comparison to the dry blocks deviations. Likewise, the uncertainties of the digital thermometer for the given calibrated points were found to be minimal for liquid baths. It was concluded that, liquid baths are the better heat enclosures for calibration of digital thermometers than dry blocks as a result of their stability. However, it was found that the dry block A had better stability than dry block B. As stipulated in my objective, the research work outcomes would lead into employing them in validating a new method of digital thermometers calibration which could assure an improved CMC for our temperature laboratory in my institute. The work would facilitate and pave the way towards our participation and conformity with CIPM MRA requirements and hence, a reduction of Technical Barriers to Trade.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to the BIPM and TÜBİTAK-UME for this programme initiative of its kind. Many thanks to Mr.Andy Henson and Mr.Chingis Kuanbayev for their incredible coordination pertaining the programme. Appreciation for all time concern and care we received from the TÜBİTAK-UME Department of International Relations under Mr. Ömer Altan, not forgetting Ms Hanen TIR and Ms. M̈uge ATAM. On the other hand, I dedicate my special thanks to my supervisors during my project study at temperature laboratory, starting with Dr. Murat KALEMCİ (Head of Laboratory), Mr. Ali UYTUN and Mr. Mücahit KORKMAZ for their maximum time devotion in assuring that I meet and achieve my study expectations. Finally, many thanks go to the Director General of Tanzania Bureau of Standards, Dr. Yusuf A. Ngenya, for his support and authorization of my attendance to this esteemed programme.