BIPM Capacity Building & Knowledge Transfer Programme
2023 BIPM - TÜBİTAK UME Project Placement
REPORT

Project Name	Knowledge Transfer And Capacity Building In Radiation Thermometry, Humidity And Air Temperature Measurements
Description	Calibration and uncertainty calculation Radiation thermometers, Humidity and air temperature measuring equipment according to their specific guidelines/standards and generating reports meeting the requirements of ISO/IEC 17025 standard.
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Motivation & Introduction

Kenya Bureau of Standards (KEBS) is the premier government agency for the provision of Standards, Metrology and Conformity Assessment (SMCA) in the Kenya. The Metrology Directorate is the designated National Metrology Institute in Kenya whose mandate is the realization, maintenance and dissemination of SI units.

KEBS Metrology provides metrological traceability for measurements needed by industries, food and health sectors, research and development among others. There is critical need for measurement traceability for radiation thermometers including infrared thermometers and thermal cameras especially in the health care system and heavy industrial applications such as steel mills.

Humidity measurements by chilled mirror hygrometers and dew point meters are used extensively in pharmaceutical industries and food and agricultural sectors. As such, these two parameters are key pillars to supporting the economy of the country.

Currently, KEBS has already acquired standards and equipment required to perform the calibration of radiation thermometers and humidity meters. The equipment/ standards include; black body sources, standard infrared thermometers, standard thermo-hygrometers and an environmental chamber. However, the relevant personnel carrying out these services have limited technical know-how and experience in these two measurement areas.

In order to better serve the East African market KEBS thermometry Laboratory had sought to expand its accreditation to humidity and radiation thermometry by DAkkS (Deutsche Akkreditierungsstelle) under the terms of 17025, but due to shortcomings of training in personnel it has not been possible to achieve this.

Therefore, the BIPM-TUBITAK UME placement was a perfect opportunity to help equip the KEBS personnel with the much needed skills, hands-on calibration experience and technical proficiency in measurements of radiation thermometers and humidity, requisite for industry and economy support.

Project Objectives

The research objectives of the research were;

1. To understand the principles and master the use of Blackbody sources, Thermal cameras, Fixed point black body cells, Reference radiation thermometers, Dew point thermo-hygrometer.
2. To Perform **calibrations and measurements** in radiation thermometry and humidity/ air temperature measurements.
3. To develop **measurement uncertainties budgets** in radiation thermometry, humidity and air temperature measurements.

Project Methodology

The project was undertaken through a combination of lectures and hands-on laboratory excersises. The team in the UME Thermodynamics Laboratory had a very intensive and well planned training schedule for us. All concepts were first taught through interactive classroom sessions that allowed us to understand the basics and principles behind every activity. Questions were adequately tackled and the knowledge gained was invaluable.

The second part of each lesson involved the practical sessions in which we actively participated in the laboratory activities. We set up different measurements, took readings and carried out analysis with the help of the Laboratory staff.

The section below will outline some of the activities that were carried out during the study period briefly;

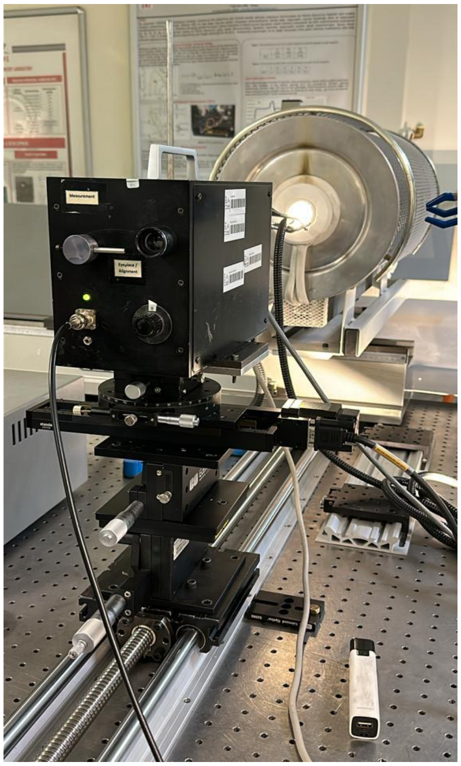
a.) ITS-90 & Realization of Zinc Fixed Point Melting and Freezing Plateaus

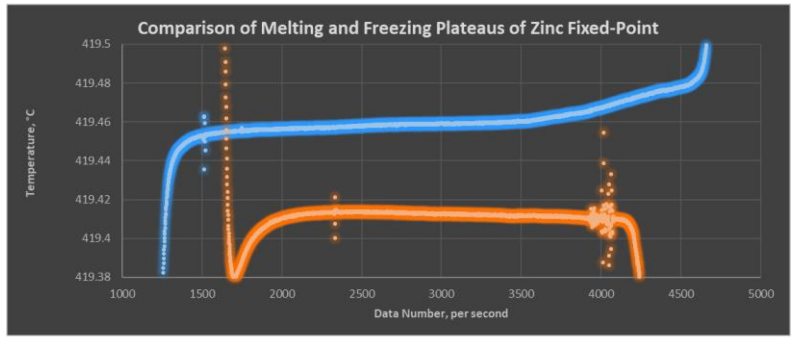
The International Temperature Scale of 1990 (ITS-90) is an internationally recognized temperature scale established to provide a standard reference for temperature measurements. It is used in various fields, including physics, chemistry, and engineering. One of the applications of ITS-90 is in the field of radiation thermometry.

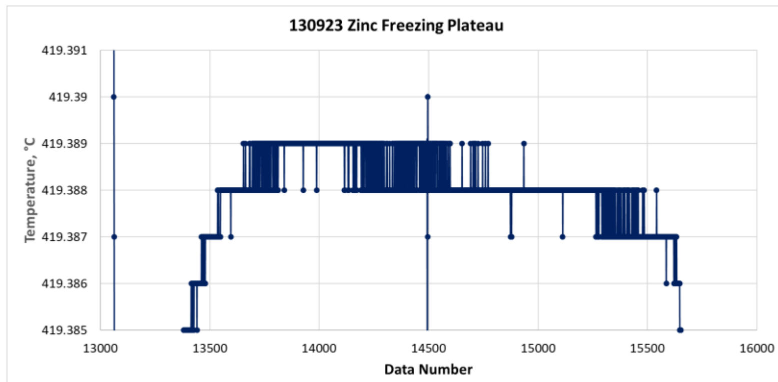
Radiation thermometry involves measuring temperatures by detecting and analyzing the thermal radiation emitted by an object. The scale is particularly relevant for high-temperature measurements where traditional contact thermometry methods may not be practical or accurate.

ITS-90 relies on defined fixed points, including the triple point of water (0.01°C), Zinc, Aluminum, Silver, Gold and Copper. These fixed points provide well-defined and reproducible temperatures.

This scale serves as a standard temperature scale for radiation thermometry, providing a basis for calibrating instruments used to measure temperatures based on the thermal radiation emitted by objects. The fixed points and principles of blackbody radiation ensure traceability and consistency in high-temperature measurements across different laboratories and applications.



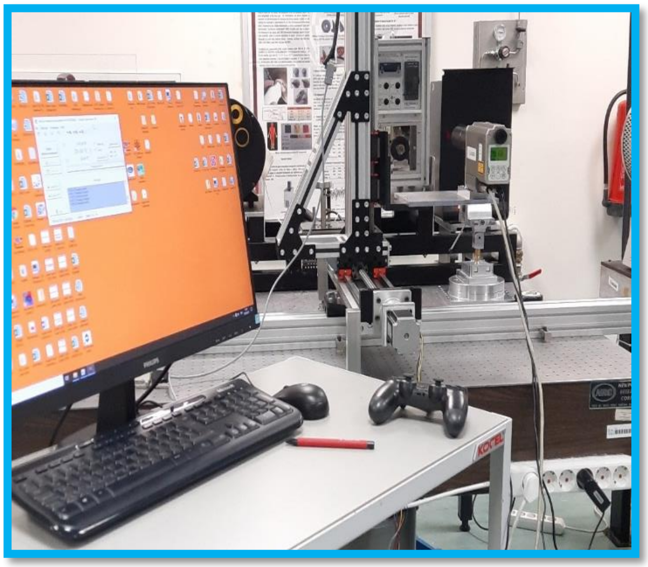




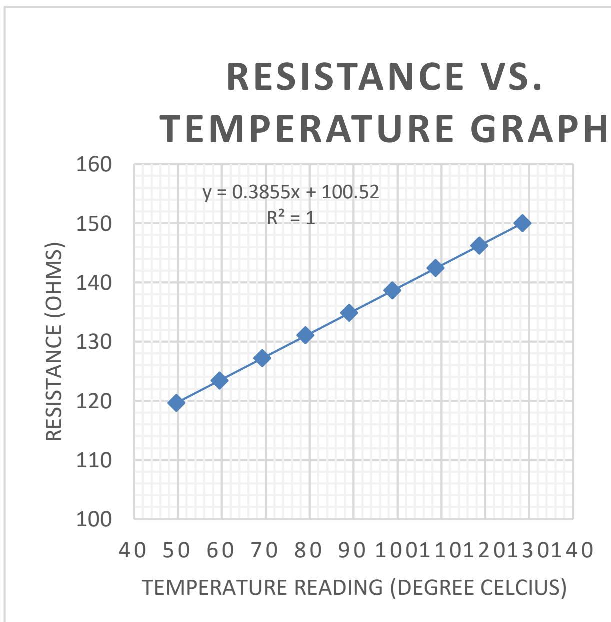
The zinc freezing point (Zn FP) is one of the fixed points on the International Temperature Scale of 1990 (ITS-90). It is used for the calibration of radiation thermometers, especially those operating at high temperatures. Realizing the zinc freezing point involves creating a stable and reproducible temperature reference by carefully controlling the phase transition of high-purity zinc.

b.) **Calibration of Heitronics Pyrometer against Reference standard PT 100 by Comparison**

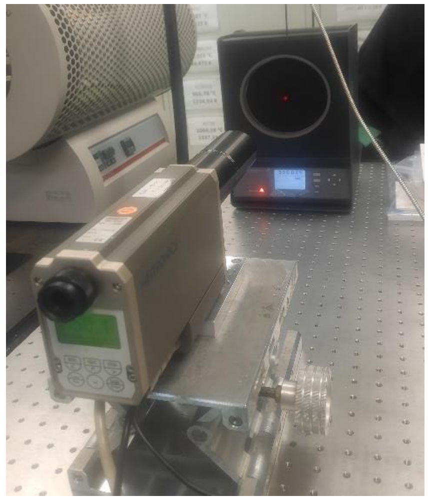
Below 400 degrees Celsius, radiation thermometers can be reliably calibrated against a traceable contact thermometer. In our case, we used a PT100 reference thermometer to calibrate a heitronics pyrometer. This measurement also allowed us to see the relationship between the temperature measurement and resistance in PT100.



		E =0.998	E= 0.999
Set Point	Reference Thermometer Reading (Ohms)	UUC Reading(Degree Celcius)	UUC Reading(Degree Celcius)
50	119.579	49.613	49.59
60	123.404	59.433	59.418
70	127.2296	69.217	69.156
80	131.0507	79.102	79.048
90	134.851	88.965	88.895
100	138.6541	98.816	98.76
110	142.4384	108.7	108.6
120	146.2296	118.6	118.5
130	149.9857	128.5	128.4



c.) **Calibration of Fluke Flat Infrared Calibrator (Black Body Source) against Heitronics Reference Thermometer**



Reference Standard - Heitronics Reference Thermometer
Unit Under Calibration – Fluke 4181 Flat Black body Calibrator

Customer Request: Calibration at 35, 100, 200 and 500 Degree Celcius
UUT had no prior emissivity calibration and hence manufacturer value for emissivity was used E = 0.95. Ideally calibrators should be calibrated for emissivity at least once annually.

Procedure

Visual inspection

Inspect the UUT visually. Look out for obvious damage. Then check for dust. If dusty you can blow the surface to clean it. Check also for scratches. If there are any major scratches take photos and inform the client.

Functional check

Power the UUT up and confirm that it switches on correctly.
In case of prominent scratches conduct a thermal imaging check to if the equipment's functionality is severely affected.

Calibration

Reference thermometer was aligned correctly to the UUC at focal distance = 39 cm
Emissivity values of UUT and ref. thermometer set to 0.95
Calibrator set to 35 Degree Celsius and allowed to stabilize.
Stability can be observed by checking that the reference thermometer Reading does not fluctuate much. However, at temperatures above 50 degrees Celsius, keep the reference thermometer away and shielded from the radiation area of the Calibrator. An Aluminum Plate can be used for this.

Take Readings at E = 0.95 (Both UUT and Ref standard). Change E= 0.94 and take readings again.
Perform SSE
For this; move the Ref thermometer from the center by a distance about R/2 (R= Radius of the black body aperture.)
Move UP and record the standard temperature difference from average std reading at E= 0.95. Repeat the same for DOWN, LEFT, RIGHT and BACK/FRONT. The uncertainty contributor will be the maximum of all six divided by 2.
Take back the alignment back to the original set up. Take the new reading. The difference between this reading and the average standard reading is the repeatability.

Undo the configuration and have a second person realign it to get the reproducibility just like the repeatability above.

d.) Uncertainty Budgets

An uncertainty budget outlines the contributions of individual sources of uncertainty and their impact on the overall measurement accuracy. This involves identifying and quantifying sources of error, estimating their uncertainties, and combining them to determine the overall uncertainty associated with a measurement result.
The table below shows the uncertainty calculation of a radiation thermometer for one of the measurements done at the laboratory during the training.

Model Equation	$t_{ref} + \delta t_{ref} = t_{cal} + \delta t_{cal\text{-}stab} + \delta t_{ref\text{-}stab} + \delta t_{res.} + \delta t_{emiss.} + \delta t_{SSE} + \delta t_{interpol.} + \delta t_{repeatability} + \delta t_{reproducibility}$

Symbol	Description	Estimated Value	Value	Distribution	Divisor	Uncertainty Contribution	Sensitivity Coefficient	Total Uncertainty
t_{ref}	Standard Reading	501.20	_					
t_{cal}	UUC Reading	499.60	_					
δt_{ref}	Standard Uncertainty	0.00	0.10	Normal	1	0.10	1.00	0.10
$\delta t_{cal\text{-}stab}$	Ref standard thermometer stability	0.00	0.05	Normal	1	0.05	1.00	0.05
$\delta t_{ref\text{-}stab}$	UUC thermometer stability	0.00	0.05	Normal	1	0.05	1.00	0.05
$\delta t_{resolution}$	UUC thermometer Resolutiom	0.00	0.05	Rectangular	1.732051	0.03	1.00	0.03
δt_{emiss}	Emissivity contributor	0.00	0.78	Rectangular	1.732051	0.45	1.00	0.45
δt_{SSE}	Positioning Error	0.00	0.50	Rectangular	1.732051	0.29	1.00	0.29
$\delta t_{Interpolation}$	Interpolation Error	0.00	0.00	Rectangular	1.732051	0.00	1.00	0.00
$\delta t_{Repeatability}$	Repeatability	0.00	0.10	Rectangular	1.732051	0.06	1.00	0.06
$\delta t_{Reproducibility}$	Reproducibility	0.00	0.15	Rectangular	1.732051	0.09	1.00	0.09
$u(T_{cal})$	Declared Uncertainty (K=2)	1.12		Total Uncertainty			$u(T_{cal})$	0.56
				Expanded Uncertainty			$u(T_{cal})$	1.12
				Declared Uncertainty (K=2)			$u(T_{cal})$	1.12

e.) Air temperature measurements and Humidity Calibrations

Humidity is water vapor admixed with air or any other dry gas. It is often expressed as Relative Humidity even though it can also be measured as absolute Humidity. Hygrometers are the instruments used for measurement of humidity. Relative Humidity is the amount of water vapor in a gas to the maximum amount possible at the same temperature.

During the placement period, I was trained on the equations related to relative humidity and I interacted extensively with the equipment used for hygrometer calibration. The Humidity Laboratory is well equipped with several humidity generators, a conditioning chamber and standard dew point hygrometers.

I was trained on the calibration of hygrometers by use of the conditioned chambers and humidity generators. I was also taken through the uncertainty calculations for both the air temperature and the relative humidity components. I was actively engaged throughout the training period.

CIPM MRA Training

During my UME training, I had the privilege of receiving additional instruction from BIPM representatives concerning the CIPM MRA and its significance in the field of metrology. I gained insights into the origins of the CIPM MRA, its launch rationale, and its overarching functions and objectives. This encompassed a comprehensive understanding of how a National Metrology Institute (NMI) can engage in comparisons within the CIPM MRA framework, ensuring the publication of its calibration measurement capabilities (CMCs) in the BIPM key comparison database (KCDB). Furthermore, I delved into the procedural aspects, including the requisite peer reviews—namely, intra-regional assessments and inter-regional reviews conducted by the Joint Committee for Traceability in Metrology (JCRB).
Additionally, it became evident that NMIs are mandated to establish and sustain a quality management system (QMS) aligned with CIPM MRA requirements. The approval and ongoing monitoring of this QMS are entrusted to the respective regional metrology organizations (RMOs). Emphasis was also placed on the paramount importance of maintaining metrological traceability and the strategies employed to uphold it.

Conclusions and Future Work

This training has been very instrumental in shaping my understanding of radiation thermometry air temperature and Relative Humidity. I gained the requisite knowledge required to transform our measurement capability at KEBS to a globally recognized level. The ties I made at the Laboratory are promising and I look forward to fostering the relationship between our laboratory and UME TUBITAK's laboratories with the aim of improving our capabilities.

I was able to not only achieve my intended technical objectives, but also gained important soft and skills. I was highly impressed by the dedication and the work ethic of the team at UME TUBITAK. Throughout the period I was there, the team was engaged in various Research Projects that they worked tirelessly on. They put in extra hours and came up with innovative ways of dealing with challenges faced. The team had custom made solutions that suited their applications perfectly. These are things that I hope to take back with me back to KEBS.

In the near future, we hope to increase our accreditation scope to include the three measurands covered during the placement project. The process has already begun and we hope to complete it within the next two years.

Acknowledgements

This has been an experience of a lifetime. I will live to cherish the moments that I spent in Turkey during this wonderful opportunity. The technical knowledge gained is invaluable not only to me but to Kenya at large.

I would like to express my heartfelt gratitude first to the wonderful time at UME TUBITAK Radiation and Humidity Laboratories. They put in extra effort to help me understand the concepts, and sacrificed their time to help me with my research project. Their hospitality was far beyond my expectation and I truly cannot thank them enough.

I would also like to thank BIPM and the management of UME TUBITAK for providing the chance to attend this training. This opportunity to train with world leaders is critical in helping to develop Metrology and grow capacity in different parts of the world. I hope and pray that they continue with the good work to keep empowering young Metrologists around the world.

Lastly I thank God for enabling to get this opportunity and to complete it successfully!