BIPM Capacity Building & Knowledge Transfer Programme

2023 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Capacity Building on Primary Level Mass Calibration Service
Description	The project mainly aims to capacitate the trainee with the primary-level mass calibration (class E1 or higher) by gaining ample knowledge and experience about the calibration procedure, auxiliary measurements, and calculation of the effects of relevant factors. Mainly, the trainee aims to focus on the volume and density determination of solid bodies. This will be a single step towards the longstanding pursuit for the establishment of primary-level mass calibration in the National Metrology Laboratory of the Philippines.
Author, NMI	Argielou Flores, National Metrology Laboratory of the Philippines (NMLPhil)
Mentor at TÜBİTAK UME	Dr. Beste Korutlu, Mass Laboratory, TUBITAK-UME, Turkiye
Date	4 September to 2 October 2023

Motivation & Introduction

To date, the National Metrology Laboratory of the Philippines (NMLPhil) is only capable of calibrating up to OIML class E_2 weights. Taking a step higher in terms of capability will be more attainable if the NMLPhil has more personnel with first-hand experience in primary-level mass calibration and its auxiliary measurements. The need for this upgrade is strengthened by the emerging local test weight and weighing instrument manufacturers in the Philippines. And, as the de facto National Metrology Institute of the country, it is the institute's responsibility to make traceability in the SI unit of mass accessible for these manufacturers.

In this project, Mr. Flores aims to be able to (i) measure mass standard volume and density; (ii) evaluate and prepare uncertainty budgets for these measurements (iii) familiarize the calculation of correction factor due to the variation of the center of gravity and air buoyancy; and (iv) familiarize with weighing by subdivision method.

The volume and density determination of solids are two of the most critical auxiliary measurements in carrying out the calibration class E1 weights (or higher). Mr. Flores plans to establish these measurements in his home institute: to offer measurement services and proficiency testing to the public. These will be particularly interesting for research and development institutes, local calibration laboratories, and test weight manufacturers.

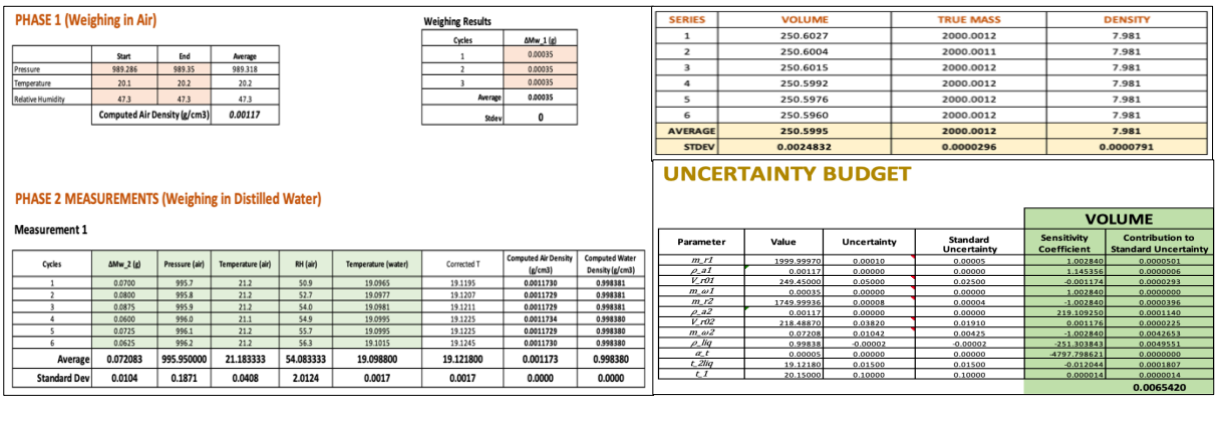
Research

The volume and density measurement of a solid body in the Mass laboratory of TUBITAK-UME is done through the hydrostatic technique. The laboratory has two separate measurement systems: a commercially available system for the low-capacity measurement of weights (1 g to 1 kg) and a developed system for the high-capacity measurement of weights (2 kg to 50 kg). The hydrostatic technique can be performed through three methods: first is weighing two different reference weights, the second is the weighing of reference weights in air and in the liquid, and the third is direct weighing. The system for low-capacity measurement works with the principle of the third method and the high-capacity works with that of the first method.

The trainee under this project planned to adopt the same setup for his home institute. The trainee was able to operate the two systems, with the supervision of TUBITAK UME staff, in determining the volume and density of sample test weights. The experience helped the trainee to have a deeper grasp of the concept of the hydrostatic technique and the mechanisms of the two systems.

Figure 1: The trainee operating the high-capacity measure volume and density measurement system of TUBITAK-UME

A thorough discussion on the theoretical aspect of the hydrostatic technique was conducted by Dr. Beste Korutlu. The discussion focused on the derivation of the model equation for the volume and density calculation. From the model equation, the trainee derived the individual equations for each uncertainty component with guidance from reference documents provided by Dr. Beste. The equations were then implemented in Microsoft Excel. The Excel file was created so that the user will only input the environmental conditions and the weighing results and it will calculate directly the volume and density values of the subjected test weight and its associated uncertainty.



PHASE 1 (Weighing in Air)

	Start	End	Average
Pressure	989.286	989.35	989.318
Temperature	20.1	20.2	20.2
Relative Humidity	47.3	47.3	47.3
	Computed Air Density (g/cm3)		*0.00117*

Weighing Results

Cycles	ΔMw_1 (g)
1	0.00035
2	0.00035
3	0.00035
Average	0.00035
Stdev	0

PHASE 2 MEASUREMENTS (Weighing in Distilled Water)

Measurement 1

Cycles	ΔMw_2 (g)	Pressure (air)	Temperature (air)	RH (air)	Temperature (water)	Corrected T	Computed Air Density (g/cm3)	Computed Water Density (g/cm3)
1	0.0700	995.7	21.2	50.9	19.0965	19.1195	0.0011730	0.998381
2	0.0800	995.8	21.2	52.7	19.0977	19.1207	0.0011729	0.998381
3	0.0875	995.9	21.2	54.0	19.0981	19.1211	0.0011729	0.998381
4	0.0600	996.0	21.1	54.9	19.0995	19.1225	0.0011734	0.998380
5	0.0725	996.1	21.2	55.7	19.0995	19.1225	0.0011729	0.998380
6	0.0625	996.2	21.2	56.3	19.1015	19.1245	0.0011730	0.998380
Average	0.072083	995.950000	21.183333	54.083333	19.098800	19.121800	0.001173	0.998380
Standard Dev	0.0104	0.1871	0.0408	2.0124	0.0017	0.0017	0.0000	0.0000

SERIES	VOLUME	TRUE MASS	DENSITY
1	250.6027	2000.0012	7.981
2	250.6004	2000.0011	7.981
3	250.6015	2000.0012	7.981
4	250.5992	2000.0012	7.981
5	250.5976	2000.0012	7.981
6	250.5960	2000.0012	7.981
AVERAGE	250.5995	2000.0012	7.981
STDEV	0.0024832	0.0000296	0.0000791

UNCERTAINTY BUDGET

Parameter	Value	Uncertainty	Standard Uncertainty	VOLUME Sensitivity Coefficient	VOLUME Contribution to Standard Uncertainty
m_{r1}	1999.99970	0.00010	0.00005	1.002840	0.0000501
ρ_{a1}	0.00117	0.00000	0.00000	1.145356	0.0000006
V_{r01}	249.45000	0.05000	0.02500	-0.001174	0.0000293
m_{w1}	0.00035	0.00000	0.00000	1.002840	0.0000000
m_{r2}	1749.99936	0.00008	0.00004	-1.002840	0.0000396
ρ_{a2}	0.00117	0.00000	0.00000	219.109250	0.0001140
V_{r02}	218.48870	0.03820	0.01910	0.001176	0.0000225
m_{w2}	0.07208	0.01042	0.00425	-1.002840	0.0042653
ρ_{liq}	0.99838	-0.00002	-0.00002	-251.303843	0.0049551
α_t	0.00005	0.00000	0.00000	-4797.798621	0.0000000
t_{2liq}	19.12180	0.01500	0.01500	-0.012044	0.0001807
t_1	20.15000	0.10000	0.10000	0.000014	0.0000014
					0.0065420

Figure 2: The Excel file created to compute for mass standard's volume and density with uncertainty

A discussion about factors affecting weight calibration such as the center of gravity and buoyancy was conducted. The discussion went on to the calculation of the correction factor contributed by these two factors and how these affect the true mass of the calibrated weight. The figure below illustrates the effect and shows the formula for calculating these corrections.

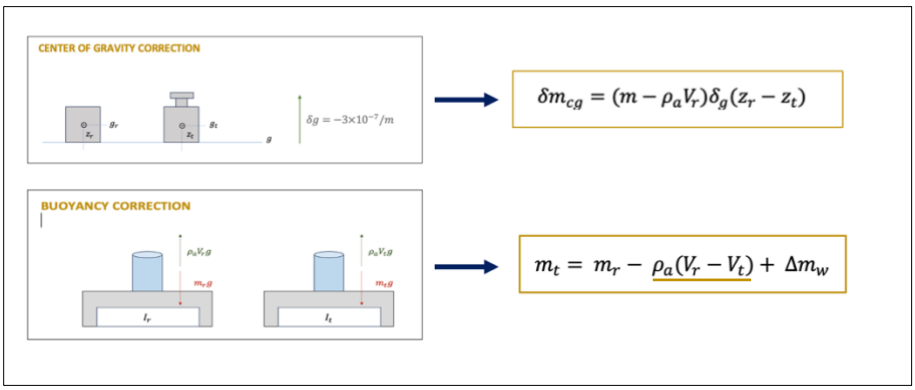


Figure 3: Illustration and the formula for calculating the correction factors for the center of gravity and buoyancy

Dr. Beste also discussed the weighing by subdivision method, a topic personally requested by the trainee. This is because of the current setup of the NMLPhil where the institute spends a large amount of money just to send at least two 30-pc sets of mass standards abroad. To add to that, the possibility of losing and damaging the whole two sets of weights during transit is a risk that the institute cannot afford. The weighing by subdivision method is a helpful technique where you can calibrate other test weights with different nominal values using one known/calibrated test weight. With this technique, the NMLPhil can now only send at least two pieces of weights abroad for recalibration. With the subdivision method, the NMLPhil can use the recalibrated artifacts to perform in-house calibration for the remaining mass standards: this would allow the institute to save money and prevent the risk of losing and damaging a whole set of weights. This is a method that the institute is planning to adopt after procuring mass comparators appropriate for this application.

The whole program of the project placement also includes a discussion and online crash course on the CIPM-MRA. As someone new to the field of metrology, attending an orientation hosted by experts from BIPM and TUBITAK themselves is a significant milestone. The online modules contain all the information needed to know about procedures and relevant organizations in the processing and publication of comparisons and CMCs.

Conclusions and Future Work

The project placement has been very productive. The trainee, with the help of his technical supervisors, was able to achieve the objectives especially the performance of volume and density measurement and drafting of the uncertainty budget. Familiarization with the effect of center of gravity and buoyancy and the weighing by subdivision method were also achieved.

All of the objectives in this project were accomplished. The knowledge and experience gained by the trainee in volume and density measurements will be of good use in drafting a project proposal on the establishment of such measurement services in his home institute. The familiarization with the weighing by subdivision method is a helpful feat in addressing the concerns of the NMLPhil in the recalibration of their mass standards abroad. On the way to the establishment of primary-level mass calibration in his country, the trainee could also share all his learnings, including that of the CIPM-MRA, with interested stakeholders as he regularly conducts internal and external training on mass metrology and calibration guidelines in his country.

Acknowledgements

I would like to extend my sincerest gratitude to the organizers of the project placement. This project placement is an instrumental opportunity for developing National Metrology Institutes (NMIs) to connect with other NMIs, capacitate their staff, expand their technical services and expertise, and upgrade the status of their institutes. Special mention to Ms. Muge Atam and Mr. Chingis Kuanbayev, thank you for facilitating this joint initiative from the start until the end. We appreciate your efforts in conveying announcements and information regarding the program to ensure that everything will go smoothly and everyone will be safe and secure. To my technical supervisor, Dr. Beste Korutlu, I am very blessed to have worked with you and witnessed your dedication to your job. Despite your hectic schedule, you still managed to find time to personally train me and answer my questions. To the whole team of the Mass laboratory, Dr. Beste, Dr. Ozlem, and Gokhan, I am so grateful to know the three of you. Your hospitality and enthusiasm in sharing your expertise made my stay comfortable and worthwhile. To my co-trainees from different NMIs, it is an honor to connect with you on a deeper level even only after a short time.

The world of metrology is not so big, I am optimistic that I will have the chance to see you all again in the future.