Short Report on CCM Activities at TÜBİTAK Ulusal Metroloji Enstitüsü

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Introduction

This report is prepared to acknowledge the Consultative Committee of Mass and Related Quantities (CCM) with the related activities pursued in the National Metrology Institute (UME) of Turkey. The report summarizes the status of national standards, as well as highlights the recent activities within the framework of the CIPM MRA and R&D in the fields covered by the CCM.

Organization

TÜBİTAK Ulusal Metroloji Enstitüsü (UME) is the national metrology institute and the highest technical authority in Turkey for the field of scientific metrology. The work of TÜBİTAK UME is committed to excellence in measurement and testing for the benefit of industries and consumers alike. TÜBİTAK UME operates as a national reference laboratory in metrology under the auspices of the Scientific and Technological Research Council of Turkey (TÜBİTAK) placed under the Ministry of Industry and Technology. It meets the requirements for calibration and testing laboratories as defined in the ISO/IEC 17025 standard. It is a fundamental task of TÜBİTAK UME to realize and maintain the standards of the measurement units in compliance with the International System of Units (SI) and to disseminate them, above all within the framework of legal and industrial metrology as well as persuading its scientific and technological development to anticipate new measurement and testing requirements in the areas of energy, safety, health, and environmental protection. TÜBİTAK UME provides government authorities and key economic players with the technical assistance they require to draft new regulations and standards at the national level.

It is worth to mention, that activities in the fields of mass and related quantities are shared by 8 laboratories of TÜBİTAK UME. They are the following: Acoustics Laboratory, Electrodynamics Laboratory, Fluid Mechanics Laboratory, Force Laboratory, Mass Laboratory, Pressure Laboratory, Vacuum Laboratory, Volume, Density and Viscosity Laboratory.

Status of National Standards

Being responsible for the realization, maintenance and dissemination of units TÜBİTAK UME have

the following calibration and measurement set-ups in the Mass and Related Quantities (MRQ) field:

- Vacuum calibration from $1 \cdot 10^{-4}$ Pa to $5 \cdot 10^{3}$ Pa
- Pressure calibration from $5 \cdot 10^{3}$ Pa Pa to 500 MPa both in hydraulic and pneumatic media
- Helium Leak rate detection in vacuum ($2 \cdot 10^{-5}$ mbarl/s - $2 \cdot 10^{-6}$ mbarl/s)
- Determination of volume or density of solids in the range of 1 g – 50 kg
- Calibration of 1 mg to 50 kg E1 and E2 (over 50 kg) mass standards
- Determination of kinematic viscosity of Newtonian liquids in the range from 0,5 mm^2/s to 100000 mm^2/s
- Determination of dynamic viscosity of Newtonian liquids in the range 0,5 mPa·s - 100 000 mPa·s
- Calibration of tension and compression type force transducers up to 3 MN
- Calibration of water flowmeter from 0,01 m^3/h to 2000 m^3/h
- Absolute gravimeters

In addition, TÜBİTAK UME has in use the various set-ups for a wide range of calibration services to customers. Some of them are listed below:

- Calibration vacuum gauges (CDG, SRG, Pirani, etc.)
- Helium Leak rate detection in vacuum
- Calibration of pressure balances (determination of the effective area of the piston-cylinder unit)
- Dynamic pressure calibration
- Calibration of gauge and absolute pressure calibrators
- Calibration of 1 mg to 50 kg E1 and E2 (over 50 kg) mass standards
- Calibration and type approval testing for non-automatic weighing instruments
- Determination of reference liquid densities
- Calibration of hydrometers
- Calibration of the digital density meters
- Determination of kinematic and dynamic viscosity of Newtonian liquids
- Calibration of rotational viscometers
- Calibration of tension and compression type force transducers
- Dynamic calibration of force measuring devices
- Calibration of Rockwell, Brinell and Vickers hardness reference blocks
- Determination of density of solids
- Calibration of torque transducers and hand torque tools
- Calibration of water flowmeters

Overview of the Current Infrastructure

Density and Viscosity

Determination of density of liquids is performed by using the primary level hydrostatic weighing system. The measurement range of the system is for density from 600 kg/m^3 to 1700 kg/m^3 in the temperature range from 5° C to 60° C and enables perform the measurements with uncertainty from 0,01 kg/m^3 to 0,05 kg/m^3. A homemade primary level hydrostatic weighing system for density determinations and primary level viscosity measuring system is shown in Fig. 1 and Fig. 2 respectively.

Fig. 1. Primary level hydrostatic weighing system for density determinations designed and developed at TÜBİTAK UME

Fig. 2. Primary level viscosity measuring system

TÜBİTAK UME provides traceability to values that correspond to the kinematic and dynamic viscosity values of twice distilled water at normal atmospheric pressure (0.101325 MPa) with a density of 0.99820 g/cm³ at 20 ° C. The work in the field of viscosity is carried out by the Volume, Density and Viscosity Laboratory.

Fluid Flow

The TÜBİTAK UME Water Flow Laboratory has been built to cover the full range of industrial needs for water flow rate measurements in Turkey. The capacity of the measurement lines and primary reference systems allows coverage of a flow rate range from 0.01 m^3/h to 2000 m^3/h with an uncertainty of less than 0.06 % (k=2). 1-ton mass water flow measuring system and Piston prover are given in Fig. 3 and Fig. 4 respectively.

Fig. 3. 1-ton mass water flow measuring system with deadweight test mechanism

Fig. 4. Piston prover

Force and Torque

TÜBİTAK UME has the capabilities to perform force and torque measurement at the primary level. The systems established at the Force Laboratory of the institute are: Deadweight Force standard machine from 0.5 N to 110 kN, Lever Amplification Deadweight Force standard machine from 20 kN to 1100 kN and Built-up type force standard machine from 50 kN to 3 MN are available. Torque measurements are performed up to 1 kN·m by using the 1 kN·m torque standard machine designed and constructed by TÜBİTAK UME. Force standards machines with different mechanism are presented in Fig. 5-7, while 1 kN·m torque standard machine is shown in Fig. 8.

Fig. 5. Deadweight Force standard machine designed and constructed by TÜBİTAK UME

Fig. 6. Lever Amplification Deadweight Force standard machine

Fig. 7. Built-up type force standard machine

Fig. 8. 1 kN·m torque standard machine designed and constructed by TÜBİTAK UME

Gravimetry

Measurements of gravity of acceleration are performed by absolute gravimeters, Microg LaCoste models FG5-X-254 with an uncertainty of 2 µGal (1 Gal = 1 cm/s²) and A10-005, A10-044 with an uncertainty of 10 µGal in the laboratory environment. The absolute gravimeters FG5-X and A10s and FG5-X are shown in Fig. 9a Fig. 9b respectively.

Fig. 9a. Absolute gravimeter FG5-X

Fig. 9b. Absolute gravimeters A10 and FG5-X

Hardness

Calibrations of hardness reference blocks in Rockwell, Brinell and Vickers scales are performed by deadweight hardness standard machines. Besides, calibration of hardness diamond indenters is performed in Rockwell and Vickers methods.

Hardness measurement systems are presented in Fig. 10 and Fig. 11

Fig.10. Rockwell, Brinell and Vickers scale deadweight hardness standards designed and constructed by TÜBİTAK UME

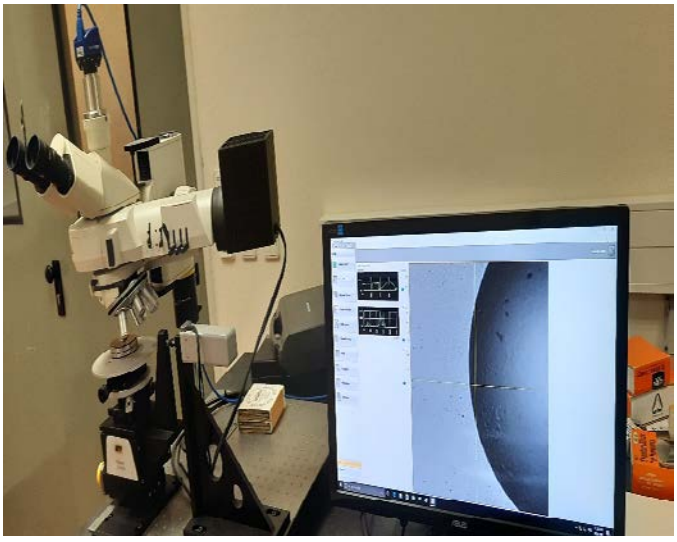

Fig. 11. Brinell, Vickers and Knoop hardness indentation measurement system

Mass

Currently, UME Kibble Balance-3 (UME KB-3) system is installed for realizing kilogram via the Planck constant. The distinctive features of the UME KB-3 experiment regarding its design and operation are given below:

- Novel dynamical measurement procedure
- Local vacuum around the cubic mirror on the top of the moving magnet for determination of the displacement of the magnetic circuit concerning the coil with sufficient accuracy
- Compact design including a moving magnetic circuit and a stationary coil
- Simultaneous testing of Faraday's Law of Induction and Ampere's Law of Force

The current relative uncertainty $7.7 \cdot 10^{-8}$.

The results of research on the establishment of the Kibble Balance system at TÜBİTAK UME were published in peer-reviewed journals as paper such as Metrologia, IEEE Transactions on Instrumentation and Measurement, Acta IMEKO (for details, see the chapter "Publications" of this report).

TÜBİTAK UME Kibble Balance setup is presented in Fig. 12.

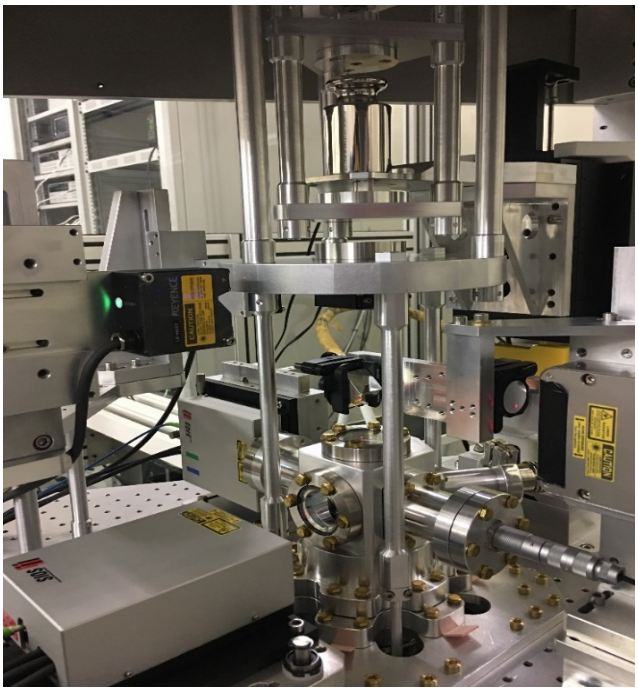

Fig.12. TÜBİTAK UME Kibble Balance setup

Pressure and Vacuum

Pneumatic pressure measurements cover a range from 20 Pa to 100 MPa using 20 deadweight testers with an uncertainty of 25 ppm to 44 ppm. Hydraulic measurements cover a range from $8 \cdot 10^5$ Pa to 500 MPa using 15 deadweight testers with an uncertainty of 49 ppm to 110 ppm.

Vacuum measurements are performed using by homemade Primary Static Expansion System from $3 \cdot 10^{-4}$ Pa to $1 \cdot 10^3$ Pa by applying the cascade method.

Pressure and vacuum standards are given in Fig. 13 and Fig. 14 respectively.

Fig.13. Primary pressure balance standards

Fig.14. Primary Vacuum Static Expansion System designed and constructed by TÜBİTAK UME

Staff

CCM related activities have been carried out by 33 employees working at 8 different laboratories of TÜBİTAK UME. Furthermore, 10 out of 33 people have PhD degree. The work experience of the senior staff working in the field of Mass and Related Quantities metrology is more than 17 years.

Calibration/ Testing Services

Calibration and measurement capabilities (CMCs) of TÜBİTAK UME in the fields of Mass and related quantities (MRQ) covers the sub-fields of mass standards, force, pressure, density, hardness, torque, gravity and viscosity. Currently, TÜBİTAK UME has 86 CMC entries in the MRQ field with their breakdown on measurement quantities as presented in Table 1.

Table 1. Number of CMC entries per measurement quantity

Quantity	Number of CMC entries	Quantity	Number of CMC entries
Pressure	12	Gas flow speed	1
Dynamic viscosity	21	Volume gas flowrate	3
Kinematic viscosity	26	Volume of solid	3
Force	6	Volume of liquid	5
Mass	8	Volume water flowrate	1

On average TÜBİTAK UME annually performs about 1200 calibrations in the MRQ field for customers. The great majority of these calibrations are calibrations of pressure balances, pressure calibrators, vacuum gauges, mass and balance standards, gravimetric measurements, density and viscosity determinations of liquids, density determinations of solids, hardness measurements of blocks, load cells and torques cells, gas and liquid flowmeter instruments. Around 50% of certificates issued by TÜBİTAK UME bears the CIPM MRA logo.

As more than 100 accredited calibration laboratories became operational in Turkey during the past ten years, a slight decrease in the number of calibrations performed by TÜBİTAK UME for customers occurred. These laboratories are accredited mainly for calibration of mass, pressure, force, torques, hardness, density and viscosity calibrations.

Comparisons

TÜBİTAK UME has a total of 62 comparison records on the BIPM Key Comparisons Database (KCDB), 42 of which are key and 20 of them are supplementary comparisons. 4 RMO key and 9 supplementary comparisons piloted by TÜBİTAK UME. The breakdown of the participating comparisons according to their types and subject fields is presented in Table 2.

Table 2. Statistics of the participating comparisons in the framework of the CIPM MRA

Type of comparison	Density	Force	Fluid Flow	Gravity	Viscosity	Hardness	Mass standards	Pressure and Vacuum
CIPM key	1	4	3	2	5			
EURAMET key	5	1	3	1		2	3	9 (1)
EURAMET supplementary			4		1	1	3 (1)	4 (2)
COOMET key								1 (1)
COOMET supplementary							1	1 (1)
GULFMET key							2 (2)	
GULFMET supplementary		2 (2)					2 (2)	1 (1)
Total / key	6	5	6	3	5	2	5	10
Total / supplementary		2	4		1	1	6	6

The number of comparisons piloted by TÜBİTAK UME is presented in Table 2 in brackets. The following key comparisons are piloted by TÜBİTAK UME: COOMET.M.P-K15, EURAMET.M.P-K13, GULFMET.M.M-K4, GULFMET.M.M-K7. Furthermore the supplementary comparisons piloted by TÜBİTAK UME are COOMET.M.P-S2, EURAMET.M.M-S3, EURAMET.M.P-S11, EURAMET.M.P-S13, GULFMET.M.F-S1, GULFMET.M.F-S2, GULFMET.M.M-S1, GULFMET.M.M-S2, GULFMET.M.P-S1.

As TÜBİTAK UME important responsibility for the contribution of national quality infrastructure, the institute regularly organizes bilateral and multilateral comparisons for accredited laboratories inside the country in the field of mass and related quantities.

Research and Other Projects

Besides providing calibration services, TÜBİTAK UME is strongly involved in research work in all sub-fields falling into the CCM scope. R&D projects are the most important field of activities of the institute. TÜBİTAK UME plans and aligns its activities in line with priorities described in the CCM

WG Strategy Document (https://www.bipm.org/utils/en/pdf/CCM-strategy-document.pdf) and EURAMET Strategic Research Agenda (https://www.euramet.org/publications-media-centre/documents/). Furthermore, TÜBİTAK UME has placed a growing emphasis on research activities that cross into areas that are outside its traditional remit as a national metrology institute. It is worth mentioning that TÜBİTAK UME is one of the active partners in joint research projects under European Metrology Research Programmes managed by EURAMET and jointly funded by European Commission and participating states.

A summary of few selected R&D projects is presented below.

16RPT03 inTENSE "Developing research capabilities for traceable intraocular pressure (IOP) measurements".

The aim of the joint research project in the framework of the European Metrology Programme for Innovation and Research (EMPIR) is to develop the metrological infrastructure and to develop traceable measurement and research capabilities at CMI for IOP measurements using common contact and non-contact tonometer types in the physiological and pathophysiological range of 10 mmHg – 80 mmHg.

TÜBİTAK UME took an active part in the identification of the existing legal status of metrological checks of medical devices with a measuring function in general and IOP metrology in particular, especially giving contribution by a detailed analysis of the established regulations, practices and training programmes for those taking part in the mentioned medical metrology application in Turkey, setting a case study that would contribute to both the established centre for IOP metrology and to the comparison to the existing and future EU and other relevant national legislation.

More details about the projects can be found on the project website (http://intense.cmi.cz/).

17IND12 Met4FoF "Metrology for the Factory of the Future"

The aim of the joint research project in the framework of the EMPIR Programme is to establish the metrological infrastructure required for quality assurance and traceability in the factory of the future (FoF) by consistently taking into account measurement uncertainty from the traceable calibration of individual sensors through to machine learning (ML) data aggregation methods.

In this project, TÜBİTAK UME contributed to the work within the work packages related to dynamic pressure measurements. TÜBİTAK UME was responsible for investigation of a commercial dynamic digital pressure sensor for experimental measurements with DTI (Digital Transducer Interface) output for the project. Development of measurement protocol as well as planning for measurements to be performed were the major contributions of TÜBİTAK UME.

More details about the projects can be found on the project website (https://www.ptb.de/empir2018/met4fof/home/).

17IND07 DynPT "Development of measurement and calibration techniques for dynamic pressures and temperatures"

The aim of the joint research project in the framework of the EMPIR Programme is to improve the accuracy and reliability of dynamic pressure and temperature measurements that are widely performed as part of manufacturing, product and safety testing, and research and development activities.

TUBİTAK UME is the work package 2 (WP2) leader in the project. Besides, a dynamic pressure calibration standard was developed up to 500 MPa and dynamic pressure interlaboratory comparisons were planned from 50 MPa to 400 MPa. Research on the effect of the different pressure transmission media (oils) on dynamic pressure sensors performance was another responsibility under the project for TÜBİTAK UME. The dynamic pressure calibration standard developed at UME is given in Fig. 15 as an example of outcomes of the project.

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More details about the projects can be found on the project website (www.dynamic-prestemp.com).

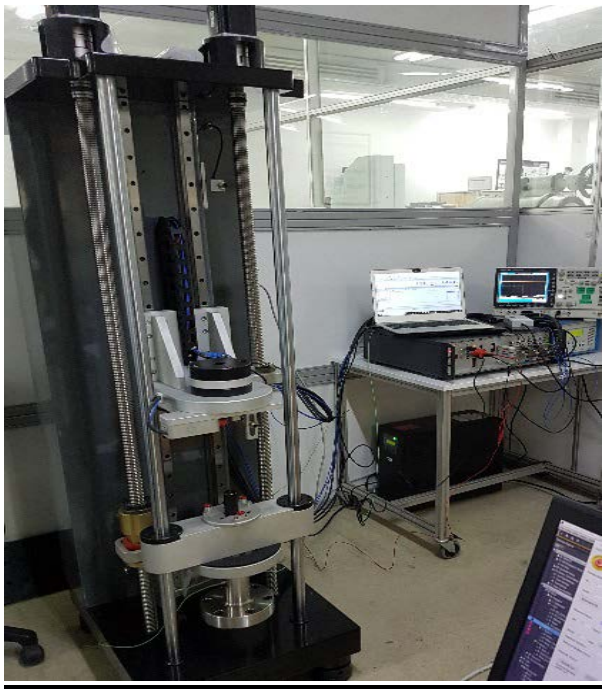

Fig. 15. The dynamic pressure calibration standard

17RPT02 RhoLiq "Establishing traceability for liquid density measurements"

The aim of the joint research project in the framework of the EMPIR Programme is to improve the measurement capabilities for liquid density measurements, the realization of density measurement at the primary level with hydrostatic weighing system and secondary level with oscillation type density meters.

Being the leader of one of the work packages within the project, TÜBİTAK UME developed primary-level liquid density measurement capabilities using the hydrostatic weighing method and secondary-level liquid density measurement capabilities using oscillation-type density meters.

TÜBİTAK UME has also joined two diagnostic and two consolidation comparison measurements under the project. Developing new guidance inside the project is another contribution of TÜBİTAK UME within the project.
More details about the projects can be found on the project website (https://rholiq.org).

17IND13 "Metrowamet - Metrology for real-world domestic water metering"

The aim of the joint research project in the framework of the EMPIR Programme is to establish a metrological infrastructure that will enable an integral characterization of domestic water meter performance close to real-world conditions and not at laboratory conditions as presently done.

TÜBİTAK UME recorded the time-dependent water consumption in the houses and extracted the consumption characteristics using obtained data. The test rig was developed for water meter assessment under dynamic load changes. A profile determined and the comparison is made under dynamic load changes. The test rig was developed for testing domestic water meters under specific conditions (e.g. hardness, pH and suspended particles). The performance tests were carried out for domestic water meters under real conditions.

More details about the projects can be found on the project website (https://www.ptb.de/empir2018/de/metrowamet/the-project/).

18SIB08 ComTraForce "Comprehensive Traceability for Force Metrology Services".

The aim of the joint research project in the framework of the EMPIR Programme is to provide calibration services, in the field of mechanical and material testing, with the methods and guidelines needed for comprehensive traceability of static, continuous and dynamic force measurements. TÜBİTAK UME contributes to the project by developing infrastructure for continuous and dynamic force measurements under all work packages.

More details about the projects can be found on the project website (https://www.ptb.de/empir2019/comtraforce/home/)

20IND13 SAFEST "Sustainable advanced flow meter calibration for transport sector"

The project will start in June 2021. The aim of the joint research project in the framework of the EMPIR Programme is to provide the foundation for advanced flow metrology in the transport sector ensuring reliable fuel consumption measurements as needed in road and maritime transport. By enabling characterizations of flow meters closer to operational conditions and a better consideration of the impact of the fuel properties on the flow measurement innovation in the transport sector will be fostered and the increased deployment of sustainable alternative transport fuels supported. Moreover, the results will contribute to appropriate emission calculations.

TÜBİTAK UME will realize the density and viscosity measurements within the capability of its laboratory. Of particular relevance for this project is TÜBİTAK UME's long-term experience in density and viscosity measurements of a broad range of liquids which was further expanded by 17RPT02 RhoLiq project and its know-how and capabilities of measurements at temperatures up to 100 °C for viscosity and 200 °C for density, and insights into the realization of density measurements at high pressures.

20NRM2 MFMET "Establishing metrology standards in microfluidic devices"

The project will start in June 2021. The aim of the joint research project in the framework of the EMPIR Programme is to establishing metrology standards in microfluidic devices. Microfluidics is concerned with fluid-handling in the nano-to-millilitre scale and has major applications in biomedical and chemical analysis however global standards are lacking. ISO/TC48/WG3 has been set up to develop microfluidic standards covering metrology for the methodologies and fabrication processes that are essential to ensure measurement accuracy and traceability of devices. The goal of this project is to contribute to the development of globally accepted standards for microfluidics and disseminate them to end-users in the industry (health, pharmaceutical) and academia.

TÜBİTAK UME will contribute to the project for the development of flow control concepts, terms and components to be used in microfluidics. The flow quantities and liquid properties to be used for development of test protocols will be identified and prioritized. The test protocols for at least 3 flow-related quantities (such as flow rate, flow speed, liquid volume) relevant to microfluidic devices and at least 3 liquid properties (such as density, viscosity, refractive index) will be developed.

Renovation and Further Development of TÜBİTAK UME Research Infrastructure

The investment project funded by the Department of Strategy and Budget under the Presidency of the Turkish Republic has been started in 2017 and currently is in progress. The main objective of the project is an establishment of an infrastructure for the manufacturing and fabrication of semiconductors and superconductors-based quantum devices to be used for the realization of primary standards mainly of electrical quantities. Infrastructure will also include the establishment of various set-ups for the characterization of manufactured devices. In addition, the project covers further development of infrastructure of existing TÜBİTAK UME laboratories for an extension of calibration and measurement capabilities in traditional metrology fields such as optics, time and frequency, acoustics, voltage, vacuum, etc. The full project consists of 22 work packages and 17 of them were successfully completed in 2020. Two work packages within the project were concerning with activities in the field of vacuum measurements. They are the following: "Development of Primary level "Constant Pressure Flowmeter" system" and "Upgrade of the existing primary static expansion system". View of new systems developed within the framework of these work packages is presented in Fig. 16.

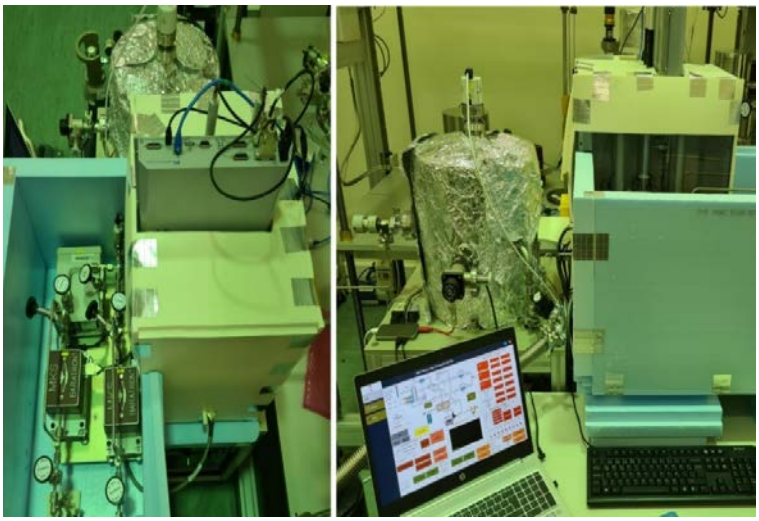

Fig. 16. Constant pressure flowmeter

Turkey Height Modernization and Improvement of Gravity System Infrastructure Project

The project was funded by the Department of Strategy and Budget under the Presidency of the Turkish Republic. It was started in 2015 and completed successfully in 2020.

This project aimed to determine the priorities of civil and military users in real time and in any weather conditions that could make possible an accuracy of a few centimetres in height information for them to physically produce high resolution and accuracy Turkey's geoid model. For this purpose, absolute gravity values were measured and mapped at 100 points throughout Turkey with a uncertainty of about 10 µg using the micro-g A10 (#044) absolute gravimeter device. This activity also constituted realization of national gravity network based on values measured by TÜBİTAK UME, and further distributed to thousands of other points by using relative gravimeters.

Other Activities

BIPM-TÜBİTAK UME project placements

TÜBİTAK UME is running a joint training together with the BIPM entitled “BIPM-TÜBİTAK UME project placements” for transferring knowledge and experience to young metrologists from the BIPM Member States or Associates. Lectures are delivered by experts both from UME and BIPM and the participants have the opportunity to enrich their technical skills via the training in the laboratories of UME. In the overall, 27 participants from 18 countries took part in the initiative. 6 participants passed training in various TÜBİTAK UME laboratories involved in activities in the fields covered by mass and related quantities.

Information about participants of the first three cycles of the program is summarized in Table 3. The figures in the Table 5 are limited to participants worked in the MRQ fields.

Table 3. Information about participants of the BIPM-TÜBİTAK UME project placements

Year	Participant’s Institute	Country	Laboratory
2018	Kazakhstan Institute of Standardization and Metrology (KazStandard)	Kazakhstan	Pressure
	Institute of Metrology of Bosnian and Herzegovina (IMBIH)	Bosnia and Herzegovina	Fluid Flow
	National Metrology Institute of Ethiopia (NMIE)	Ethiopia	Mass
2019	Kenya Bureau of Standards (KEBS)	Kenya	Pressure
	Uzbek National Institute of Metrology (UzNIM)	Uzbekistan	Mass
2020	Saudi Standard, Metrology and Quality Organization – the National Calibration and Measurement Center (SASO-NMCC)	Saudi Arabia	Force

The applications for the 4th cycle of the placements will be collected until the 30th of April 2021 and “The 2021 Project Placement” training will start on 6th September 2021.

Publications

The list of major publications of TÜBİTAK UME in Mass and Related Quantities in the period from 2019 to 2020 is presented below.

[1] Dlamini, S., Sibisi, M., Matosse, J., Aydemir, B., Vatan, C., Dizdar, H. "NMISA's New 5 kN Deadweight Force Standard Machine", Acta IMEKO, 9:5 (2020): 85-87

[2] Kozin, A., Shapovalov, V., Ahmedov, H., Demir, A., Korutlu, B., Shabalin, A., "Study of the Effect of Argon Pressure on the Temperature of a Hot Target", Journal of Physics: Conference Series, 1713:1 (2020): 1-4

[3] Kuzu, C., Germak, A., Origlia, C., Pelit, E., "Preliminary Results of EURAMET Rockwell Comparison Between INRIM and UME (EURAMET.M.H-S1.A.B.C)", Acta IMEKO, 9:5 (2020): 256-260

[4] Kuzu, C., Pelit, E., Meral, I., "A New Design of Rockwell-Brinell-Vickers Hardness Standard Machine at UME", Acta IMEKO, 9:5 (2020): 230-234

[5] Kuzu, C., Pelit, E., "Design and Development of High Load Brinell Hardness Standard Machine at UME", Acta IMEKO, 9:5 (2020): 226-229

[6] Jousten, K., Bock, T., Elkatmis, A., Kangi, R., Phanakulwijit, S., Setina, J. "Key comparison Euramet.M.P-K15.1 in the pressure range from $3 \cdot 10^{-4}$ Pa to 1 Pa", Metrologia, 57:1A (2020): 07031

[7] Jousten, K., Bock, T., Elkatmis, A., Kangi, R., Phanakulwijit, S., Setina, J., "Final Report on Key Comparison EURAMET.M.P-K15.1 in the Pressure Range from $3 \cdot 10^{-4}$ Pa to 1 Pa", Metrologia, 57:1A (2020): 1-30

[8] Kozin, A.A., Shapovalov, V.I., Ahmedov, H., Demir, A., Korutlu, B., "Study of Argon Pressure Effect on Hot Target Temperature", XVII International Scientific and Technical Conference "Rapid Solidification Materials and Coatings" (RSMC 2020), Moscow (20-21/10/2020): 5 p.

[9] Durgut, Y., Yilmaz, R., Hamarat, A., Meral, I., Uslukilic, U., "Traceable Dynamic Pressure Measurements from 50 MPa to 400 MPa (in Turkish)", Academic Perspective Procedia, 3:1 (2020): 658-664

[10] Ahmedov, H., Celik, M., Orhan, R., Korutlu, B., Hamid, R., Sahin, E., "A UME Kibble Balance Displacement Measurement Procedure", Acta IMEKO, 9:3 (2020): 11-16

[11] Ahmedov, H., Korutlu, B., Dorosinskiy, L., Orhan, R., Tuncel, O., "External Magnetic Field Measurements in the UME Kibble Balance", Acta IMEKO, 9:3 (2020): 33-39

[12] Korutlu, B., Mitsas, C., Malengo, A., Wuthrich, C., Lee, S., Alqarni, S., Al-Abdulhadi, A., Al-Qattan, A.I., Mahmoud, K.S., "GULFMET.M.M.K4 "Key Comparison of 1 kg Stainless Steel Mass Standards", Metrologia, 57:1A (2020): 1-18

[13] Bettin, H., Borys, M., Firlus, M., Buchner, C., Zelenka, Z., Medina, N., Parlić-Risović, T., Bejzak, M., Mitsas, C., Lefkopoulos, A., Lenard, E., Popa, G.F., Malengo, A., Madec, T., Beaudoux, F., Fuchs, P., Marti, K., Wuthrich, C., Kajastie, H., Eltawil, A., Fujii, K., Kuramoto,

N., Waseda, A., Perkin, M., Akcadag, U.Y., "EURAMET Key Comparison 1031 (EURAMET.M.D-K1.1) Solid Density Comparison", Metrologia, 57:1A (2020): 1-45

[14] Ahmedov, H., Korutlu, B., Orhan, R., Tuncel, O., "Seasonal Effects in Gravity", Conference on Precision Electromagnetic Measurements (CPEM 2020), Denver, 24-28 August 2020, 2020:DOI: 10.1109/CPEM49742.2020.9191842 (2020): Article number 9191842

[15] Ahmedov, H., Orhan, R., Korutlu, B., Tuncel, O., "AC Voltage Measurements in UME Kibble Balance", Conference on Precision Electromagnetic Measurements (CPEM 2020), Denver, 24-28 August 2020, 2020:DOI: 10.1109/CPEM49742.2020.9191793 (2020): Article number 9191793

[16] Ahmedov, H., Korutlu, B., Orhan, R., Tuncel, O., Babayigit Askin, N. "Local Vacuum in UME Kibble Balance", Conference on Precision Electromagnetic Measurements (CPEM 2020), Denver, 24-28 August 2020, 2020:DOI: 10.1109/CPEM49742.2020.9191912 (2020): Article number 9191912

[17] Ahmedov, H., Korutlu, B., Orhan, R., Tuncel, O., Dogan, C., "Design of UME Kibble Balance-3", Conference on Precision Electromagnetic Measurements (CPEM 2020), Denver, 24-28 August 2020, 2020:DOI: 10.1109/CPEM49742.2020.9191798 (2020): Article number 9191798

[18] Wu, S., Feng, J., Li, C., Su, D., Wang, Q., Hu, R., Hu, L., Xu, J., Ji, W., Ulrich, C., Pálinkáš, V., Kostelecký, J., Bilker-Koivula, M., Näränen, J., Merlet, S., Le Moigne, N., Mizushima, S., Francis, O., Choi, I., Kim, M., Kirbas, C., Coskun, I., "The Results of CCM.G-K2.2017 Key Comparison Absolute Gravimeters", Metrologia, 57:1A (2020) : Article number 07002.

[19] R. Falk, V. Pálinkáš, H. Wziontek, A. Rülke, M. Val'ko, Ch. Ullrich, H. Butta, J. Kostelecký, M. Bilker-Koivula, J. Näränen, A. Prato, F. Mazzoleni, C. Kirbaş, Coşkun, M. Van Camp, S. Castelein, J. D. Bernard, A. Lothhammer, M. Schilling, L. Timmen, D. Lacovone, G. Nettis, F. Greco, A. Messina, R. Reudink, M. Petrini, P. Dykowski, M. Sękowski, J. Janák, J. Papčo, A. Engfeldt and H. Steffen, “EURAMET.M.G-K3 regional comparison of absolute gravimeters”, Metrologia, Volume 57, Number 1A, Article number 07019.

[20] Turk, A., Hamarat, A., Karaboce, B., "Comparison of Manual and Automated Pressure Calibration Methods of Medical Pressure Calibrator", 15th IEEE International Symposium on Medical Measurements and Applications (MeMeA 2020), Bari, 1-3 June 2020, DOI: 10.1109/MeMeA49120.2020.9137288 (2020): Article number 9137288

[21] Durgut, Y., Vámossy, C., Petrovski, N., Kacarski, V., Tomcini, B., Djurić, P., Vulić, A., Al-Jattal, N., Justice, B., Alotaibi, H., Alanazi, N., Dapkeviciene, K., Brzozowski, A., Setina, J., Bermanec, L., "Final report on Supplementary Comparison in Hydraloic Media in the Range from 10 MPa to 100 MPa at Gauge Mode", Metrologia, 57:1A (2020): Article number 07020

[22] Altintas, A., Kocas, I., Durgut, Y., Bartolo, J., Bergoglio, M., Bermanec, L., Bošnjaković, A., Burzić, S., Condereys, A., Dobre, M., Farar, P., Hetherington, P., Medina, N., Sabuga, W., Ott, O., Konczak, T., Sandu, I., Setina, J., Steindl, D., Vámossy, C., Waller, B., Wuethrich,

C., Brzozowski, A., Geel, J., Saxholm, S., "Final Report on Key Comparison EURAMET.M.P-K1.c in the Range 0.7 MPa to 7.0 MPa of Gas Gauge Pressure", Metrologia, 57:1A (2020): Article number 07022

[23] Elkatmis, A., Kangi, R., Becker, U., Jousten, K., Mari, D., Boineau, F., Vicar, M., Ruiz, S., Setina, J., "Time Stability Characterization of Quadrupole Mass Spectrometers", Measurement, 165:December (2020): Article number 108143

[24] Aydemir, B., Tascan, H., "Effects of Sample Shapes on Tensile Test Results in Stretch Film Materials", 3. International Conference on Materials Science, Mechanical and Automotive Engineerings and Technology (IMSMATEC'20), İstanbul (24-26/06/2020): 4 p.

[25] Altintas, A., Kocas, I., Durgut, Y., Bartolo, J., Bergoglio, M., Medina, N., Sabuga, W., Setina, J., Wuethrich, C., Arrhen, F., "Final Report on Key Comparison EURAMET.M.P-K1.c in the Range 0.7 MPa to 7.0 MPa of Gas Gauge Pressure" (2020) : 43 p.

[26] Durgut, Y., Vámossy, C., Petrovski, N., Kacarski, V., Tomcini, B., Al-Jattal, N., Justice, B.K., Alotaibi, H.M., Setina, J., Saxholm, S., Altintas, A., Hetherington, P., "Final Report on Supplementary Comparison in Hydraulic Media in the Range From 10 MPa To 100 MPa at Gauge Mode" (2020): 52 p.

[27] Durgut, Y., Ganioglu, O., Aydemir, B., Turk, A., Yilmaz, R., Hamarat, A., Bagci, E., "Improvement of dynamic pressure standard for calibration of dynamic pressure transducers", 19th International Congress of Metrology, EDP Sciences, https://doi.org/10.1051/metrology/201927009 (2019): 27009

[28] Yilmaz, R., Durgut, Y., Hamarat, A., "Calibration of Digital Dynamic Pressure Sensors", AMA Association for Sensors and Measurement, DOI 10.5162/SMSI2020/E3.4 (2020): 376-377

[29] Germak, A., Kuzu, C., Origlia, C., Pelit, E., "EURAMET Supplementary Comparison Between INRIM and UME in Rockwell Hardness Scales (Hra-Hrbw-hrc)-EURAMET.M.H-S1.a.b.c", Metrologia, 57:1A (2020): Article number 07018

[30] Turk, A., Hamarat, A., Karaboce, B., "Comparison of Manual and Automated Pressure Calibration Methods of Medical Pressure Calibrator", IEEE International Symposium on Medical Measurements and Applications (MeMeA 2020), Bari (01-03/06/2020): 6 p.

[31] Dizdar, H., Aydemir, B., Vatan, C., "Investigation of Different Compression Apparatus Usage Effects in Calibration Process of Strain Cylinders", MAPAN - Journal of Metrology Society of India, 35:3 (2020): 359-364

[32] Durgut, Y., Yilmaz, R., Justice, B., Alotaibi, H., Alanazi, N., "Supplementary Pressure Comparison from (0.7 to 7) MPa in Gas Media at Gauge Mode", Metrologia, 57: Technical Supplement 1A (2020): Article number 07014

[33] Alisic, S., Gutfeldt, B., Beaudoux, F., Bezjak, M., Coenegrachts, M., Davidson, S., Grgić, G., Hanrahan, R., Geel, J., Kacmaz, S., Mangutova-Stoilkovska, B., Miteva, M., Navrozidis, G., Neuvonen, P., Nielsen, L., Ojanen-Saloranta, M., Pantić, D., Pärn, A., Popa, G., Snopko, L.;

"Final Report on EURAMET Comparison on 1 kg Stainless Steel Mass Standards", Metrologia, 57:Technical Supplement 1A (2020): Article number 07011

[34] Ahmedov, H., Celik, M., Orhan, R., Korutlu, B., Hamid, R., Sahin, E., "Displacement Measurements in UME Oscillating-Magnet Kibble Balance", 23rd IMEKO TC4 International Symposium on Electrical and Electronic Measurements Promote Industry 4.0; Xi'an; 17-20 September 2019, 52-56

[35] Ahmedov, H., Korutlu, B., Dorosinskiy, L., Orhan, R., "Measurement Procedure for External Magnetic Field in UME Kibble Balance", 23rd IMEKO TC4 International Symposium on Electrical and Electronic Measurements Promote Industry 4.0; Xi'an; 17-20 September 2019, 87-92

[36] Korutlu, B., Mitsas, C., Malengo, A., Wuthrich, C., Alqarni, S., Al-Abdulhadi, A., Al-Qattan, A.I., "Final Report for GULFMET.M.M-K7: Key Comparison of 5 kg, 100 g, 10 g, 5 g and 500 mg Mass Standards", Metrologia, 57:Technical Supplement 1A (2020): Article number 07005

[37] Aydemir, B., Vatan, C., Dizdar, H., Binown, A., "Bilateral Comparison on Force Standard Machines Between TÜBİTAK UME and SASO-NMCC", Metrologia, 57:Technical Supplement 1A (2020): Article number 07007

[38] Aydemir, B., Vatan, C., Dizdar, H., Binown, A., Mitsas, C., Justice, B., Zarouni, M., Shehhi, K., "Comparison of Force Standard Machines in The Range of 100 kN and 1000 kN", Metrologia, 57:Technical Supplement 1A (2020): Article number 07006

[39] Ahmedov, H., "Displacement Measurements in UME Oscillating-Magnet Kibble Balance", 23rd IMEKO TC4 International Symposium on Electrical and Electronic Measurements Promote Industry 4.0; Xi'an; 17-20 September 2019

[40] Ünsal, B., "A Mass Flow Rate Measurement Technique Based on Exact Analytical Solution of Time-Dependent Pipe Flows", Workshop on Dynamic Measurements Methods for Water Metering, 13-14 November 2019, Lyon

[41] Kangi, R., Elkatmis, A., Gorobei, V., Chernyshenko, A., "The Preliminary Results of the Regional Key Comparison COOMET.M.P-K15 in the Pressure Range from 0.3 mPa to 0.9 Pa", Journal of Physics: Conference Series, 26th International Conference on Vacuum Technique and Technology (VTT 2019), 1313:1 (2019): 012027

[42] Kangi, R., "Development of a Temperature-Controlled Container for High Accuracy Capacitance Manometers", Journal of Physics: Conference Series, 26th International Conference on Vacuum Technique and Technology (VTT 2019), 1313:1 (2019): 012026

[43] Kacmaz, S., Amal, A., Mitsas, C., Almusawi, K., Alyousefi, R., Jattal, N., Sultan, N.J., "GULFMET M.M-S1: Comparison of Mass Standards in Multiples and Sub-Multiples of the Kilogram", Metrologia, 56:Technical Supplement 1A (2019): Article number 07007

[44] Kacmaz, S., Kangi, L., M Alqarni, S., A Aljuwyr, A., "GULFMET M.M-S2: Bilateral Comparison of Mass Standards Between TÜBİTAK UME and SASO NMCC", Metrologia, 56: Technical Supplement 1A (2019): Article number 07008

[45] Durgut, Y., Ganioglu, O., Aydemir, B., Turk, A., Yilmaz, R., Hamarat, A., Bagci, E., "Improvement of Dynamic Pressure Standard for Calibration of Dynamic Pressure Transducers", International Metrology Congress (CIM 2019), Paris (24-26/09/2019): 1 p.

[46] Kangi, R., Elkatmis, A., Chernyshenko, A., "The Preliminary Results of the Regional Key Comparison COOMET.M.P-K15 in the Pressure Range from 0.3 mPa to 0.9 Pa", 26th Vacuum Technique and Technology Conference (BTT-2019), St. Petersburg (18-20/06/2019): 5 p.

[47] Unsal, B., Akselli, B., Saci, S., Aksel, E., "Initial Results on the Flow Dynamics of Household Water Consumption", 18th International Flow Measurement Conference (Flomeko 2019), Lisbon (26-28/06/2019): 6 p.

[48] Gersl, J., Busche, P., Huu, M., Pachinger, D., Muller, H., Knabben, D., Bertasiene, A., Vilbaste, M., Care, I., Kaykisizli, H., Haack, S., Maar, L., "Comparison of Calibrations of Wind Speed Meters with a Large Blockage Effect", 18th International Flow Measurement Conference (Flomeko 2019), Lisbon (26-28/06/2019): 9 p.

[49] Hogstrom, R., Saxholm, S., Sarraf, C., Spasito, A., Sutton, G., Wynands, R., Jonsson, G., Durgut, Y., Peruzzi, A., Fateev, A., Liverts, M., Adolfse, C., Oster, A., "Measurement and Calibration Techniques for Dynamic Pressures and Temperatures", International Symposium on Temperature and Thermal Measurement in Industry and Science, Chengdu (10-14/06/2019): 1 p.

[50] Ahmedov, H., Korutlu, B., Orhan, R., "Optimization Procedure for the Determination of Faraday's Voltage in UME Kibble Balance (July 2018)", IEEE Transactions on Instrumentation and Measurement, 68:6 (2019): 2172-2175

[51] Elkatmis, A., Kangi, R., "Remarks Concerning About the Characteristics of the Extractor Vacuum Gauge and the Quadrupole Mass Spectrometer", Measurement, 131 (2019): 269-276