KRISS Korea Research Institute of Standards and Science

Progress Report of KRISS Mass-Related Quantities Metrology

(19th meeting of the CCM, May 2023)

This report gives a brief summary of the main activities in the area of Mass-Related Quantities at KRISS since the last CCM meeting (May 2023).

1. Mass Metrology

Contact: Dr. Kwang-Cheol Lee (kclee@kriss.re.kr)

KRISS started a project to build a new Kibble balance, KB-II. KB-II has the following differences from the first KRISS Kibble balance, KB-I. The weighing cell is fixed in both weighing and moving modes. The mass pan and coil suspension are joined through an overlapped flexure. A spring is located between the weighing cell and coil suspension. The coil suspension can be moved vertically by pushing or pulling the spring by electromagnetic actuators. The coil temperature is maintained by flowing a current through auxiliary coil.

The permanent magnet assembly was delivered in March. The magnet was manufactured by a US company, Electron Energy Coperation. The magnet is made of Gd-doped SmCo which shows good temperature stability. The radial B-field is 0.4 T at the air gap of 15 mm wide.

2. Force and Torque Standards

2.1 Deadweight Force Machines

Contact: Dr. Minseok Kim (minsk@kriss.re.kr)

KRISS joined the small force comparison in the range of 200 N and 500 N, which is piloted by METAS and coded as CCM.F-K23, using the 200 N and 2 kN force machines in 2020. The final report is ready for publication and the equivalence of KRISS force standards in the range of 200 N and 500 N is confirmed.

2.2 Hydraulic/Build-up Force Machines

Contact: Dr. Minseok Kim(minsk@kriss.re.kr)

The commissioning of the KRISS hydraulic force standard machine of 5.5 MN capacity is about to begin. The target calibration and measurement uncertainty is 0.01% and was verified through an intra-laboratory comparison with the KRISS 1 MN deadweight force machine in 2022. We are planning to conduct a bilateral comparison in the range of 2 MN and 4 MN with one of NMIs who has the CMC better than 0.01% in the force range.

2.3 Deadweight Torque Machines

Contact: Dr. Minseok Kim (minsk@kriss.re.kr)

KRISS is developing a deadweight torque machine with 22 kN·m capacity and target relative uncertainty of 5×10^{-5}. The characterization and improvement will continue in the year of 2023.

3. Pressure and Vacuum Metrology

3.1 Pressure Standards

Contact: Dr. Sam-Yong Woo (sywoo@kriss.re.kr)

A new compact and space-efficient impulse pressure generator based on a shock accelerometer is being developed and improved. The shock acceleration exciter is known to be used for an impact standard that generally consists of pneumatic exciter, air-borne hammer and anvil. An optical interferometer has been installed in order to obtain the displacement of the piston in the dynamic pressure standard. Since the 2nd derivative of the piston displacement could be very noisy, a new way based on the density change determination by using the piston displacement information is being considered, which could be traceable to SI units. From the known density change according to the volume change which is proportional to the piston displacement, the pressure inside test chamber can be estimated.

As an applied research topic, KRISS has researched on multi-capillary pressure drop standards using the differential pressure standard under the constant flow condition. KRISS researched a technology that measures the pressure change through filters.

3.2 Vacuum Standards

Contact: Dr. Han-Wook Song (hanugi16@kriss.re.kr)

KRISS started to develop a new vacuum standard for the pressure range from 1 Pa to 100 kPa using an optical method (one of 'new realizations of the pascal') since 2018. KRISS designed a Fabry–Perot (FP) cavity structure having two channels and fabricated a single-mode (SM) He–Ne laser with the wavelength of 633 nm as the light source. Currently, Hardware construction for KRISS optical pressure standard system has been completed. As the first step, KRISS has calculated the standard pressure using the beating frequencies between the two channels in the pressure range of 1 Pa to 10 kPa. KRISS are also studying theoretically the second and third virial constants for He gas by ab initio molecular dynamics (MD) computation. Using the measured beating frequency, KRISS determined the internal pressure in the cavity considering the refractive index virial coefficients (A_R, B_R and C_R) and density virial coefficients (A_p, B_p and C_p), the Boltzmann constant k_B, and the thermodynamic temperature. The uncertainty is currently in evaluation considering the uncertainty factors for the range from 1 Pa to 10 kPa and comparisons are in the process between the new standard and the FPG using CDGs as a transfer standard.

As the applied research topics, KRISS has researched on a new standard leak element (SLE). This study used a unique, cost-effective material of micro-scale capillary tubing to develop a conductance-type SLE. The characteristics of SLE are under the evaluations. As another topic, KRISS investigated the possibility of a quartz tuning fork (QTF) as a small economic vacuum sensor. The frequency change characteristics according to the pressure change were investigated using an QTF.

4. Gravity Standards

Contact: Dr. In-Mook Choi (mookin@kriss.re.kr)

A superconducting gravimeter (iGrav-055, GWR Instruments) has been installed at an absolute gravity observatory to monitor gravity changes precisely. This work was accomplished through cooperation between KRISS and NGII (National Geographic Information Institute).

Furthermore, the development of a SQUID-based superconducting gravimeter (SSG) is currently ongoing. The components for the superconducting gravimeter have been fabricated, and performance tests have been conducted. After optimizing each component, the entire system has been integrated as planned. Initially, the gravity change due to Earth tide was successfully measured. To enhance its performance, the SSG is currently undergoing upgrades.

The atomic gravimeter, being developed in the time and frequency group, is now fully operational and has been compared with the conventional gravity standard, FG5X-104

5. Hardness Standards

Contact: Contact: Mr. Nae-Hyung Tak (nhtak@kriss.re.kr)

The measuring system for the Rockwell and Vickres hardness indenter will be set up by LTF SpA Italy in June. In addition, KRISS measurement of the APMP.M.H-5(Brinell hardness) and APMP.M.H-6(Vickers hardness) were finished and its results were reported.

6. Fluid Flow Standards

6.1 Gas Flow Metrology

Contact: Dr. Woong Kang (woong.kang@kriss.re.kr)

In high-pressure gas flow standard system in KRISS, a compressed air flow system has been used for the primary standard gravimetric system with in CMC in BIPM. KRISS is cooperating with KOGAS, a governmental company for the nation's import and supply of natural gas in Korea. KOGAS has the natural gas flow calibration facility related to KRISS high-pressure gas flow standard system. Key Comparison for high-pressure gas flow, CCM.FF-K5.2021 is planned by a pilot lab (PTB). KRISS and KOGAS will participate in CCM.FF-K5.2021 with air and natural gas flow facility in 2023, respectively.

6.2 Liquid(Water) Flow Metrology

Contact: Dr. Sejong Chun (sjchun@kriss.re.kr)

Two key comparisons (APMP.M.FF-S1, CCM.FF-K1.2015) were approved by BIPM to be published at KCDB on 22nd January and 22nd July, 2022, respectively. KRISS also participated in a round robin test for APMP.M.FF.K1.1.2022 from 8th to 17th August 2022. Its measurement results have been already submitted to the pilot laboratory (CMS-ITRI).

The 6th Peer Review was held from 4th to 5th July 2022 under the supervision of Dr. Shaw from CMS-ITIR as a technical assessor. Measurement equivalence based on the two key comparison results, published at KCDB, was reviewed by the technical assessor. As a result, a CMC table, which contains the lowest flow rate of 10 L/h, the largest flow rate of 2000 m^3/h, and the measurement uncertainty of 0.06 % (k = 2), has been approved by the technical assessor. At present, APMP QS Review is being undertaken. In addition, KRISS wants to participate in a new key comparison, which is related to CCM.FF-K1 for large-capacity flow measurement, in due course.

At KRISS, a micro liquid flow standard system was constructed, and the peer review process was completed in 2022. The flow rate range of the micro flow standard system is 2 mL/h to 200 mL/h, with a maximum uncertainty of 0.7% (*k*=2). In 2019, KRISS organized the international comparison of microflow standard systems through the APMP TCI project, and the results confirmed the international equivalence of microflow standard systems among all participating institutions. Additionally, KRISS participated in the MeDD II project of EURAMET's EMPIR, contributing to research on calibrating drug delivery devices using micro flow standard systems.

6.3 Liquid (Hydrocarbon) Flow Metrology

Contact: Dr. Seok Hwan Lee (seokhwan.lee@kriss.re.kr)

In the light oil flow standard system (Viscosity: 3.6 cSt @ 20 °C), the KRISS and PTB oil flow standard systems were compared using a Coriolis flowmeter. The calibration values of the Coriolis flowmeter in KRISS and PTB were 0.21–0.23 % (*U*=0.08 %, *k*=2) and 0.18–0.24 % (*U*=0.05 %, *k*=2), respectively, for Re number range between 35,000 and 145,000. Furthermore, we participated in the APMP international comparison (APMP.M.-FF-K2.2021) organized by NIMJ, and we have completed all the calibrations and are currently awaiting the results report. In heavy oil flow standard system (viscosity: 20 cSt @ 20 °C), recently a level retaining device in the oil reservoir was added and the flow control valve was replaced. Improvements to the heavy oil flow standard system reduced the measurement uncertainty from 0.11 % to 0.08 % (*k*=2) in the flow rate range from 2 to 22 m^3/h. The peer review of the liquid hydrocarbon flow system was completed in 2022. Currently, the light oil has completed CMC registration, while the heavy oil is undergoing evaluation for CMC registration.

6.4 Air Speed Metrology

Contact: Dr. Woong Kang (woong.kang@kriss.re.kr)

KRISS has improved the air flow standard system to calibrate three-dimensional velocity probe with the non-nulling method for the gas flow velocity measurement in the smoke-stack. The flow velocity distributions in the smoke-stack of the domestic power plant are measured by three-dimensional probes with KRISS on-site stack gas velocity field measurement system. The greenhouse gas flowrate national test bed is constructing to simulate the smoke-stack in the industrial and power plant of Korea. Furthermore, we participated in the APMP international comparison (APMP.M.-FF-K3.2020) organized by ITRI/CMS, and we have completed all the calibrations and are currently awaiting the results report (Draft A).

7. KC and MRA

7.1 Comparison Activities since 2021

- CCM.F-K23 (Low force; 200 N, 500 N), Final Report in progress
- APMP.M.D-K4 (hydrometer; 640 kg m^{-3} ~ 1 320 kg m^{-3}), published
- APMP.M.P-K4 (Vacuum 1 Pa to 10 kPa), Draft A in progress
- CCM.P-K16, K17, K18 (Gauge pressure, 0.25 kPa ~ 350MPa, Absolute Pressure, 0.25 kPa~ 350 kPa, Gauge pressure, 0.7 MPa ~ 7 MPa), Measurement in progress
- CCM.G-K2.2023 (Absolute Gravity), Technical protocol in progress
- APMP.M.FF-K6.2018 (Low-Pressure Gas Flow 10 to 100 m3/h), Draft A in progress
- CCM.FF-K6.2017 (Low-Pressure Gas Flow 2 to 10 mL/min), Draft B in progress
- APMP.M.FF-S1 (Water Flow between 300 m^3/h and 1200 m^3/h), Published in Metrologia Tech. Suppl.
- CCM.FF-K2.2011 (Hydrocarbon between 5 kg/min and 60 kg/min)/, Draft B in progress
- CCM.FF-K1.2015 (Water between 30 m^3/h and 200 m^3/h), Published in Metrologia Tech. Suppl.
- APMP.M.FF-K3 (Air speed 2 m/s to 20 m/s), Draft A in progress
- APMP.M.FF-K2 (Hydrocarbon between 60 m3/h and 150 m3/h), Measurement phase
- APMP.M.FF.K1.1.2022 (Water Flow between 5 kg/min and 60 kg/min), Measurement completed

7.2 MRA Activities in 2023

N/A

8. List of publications

[1] K.-C. Lee *et al*. Report on the APMP key comparison of hydrometer calibrations APMP.M.D-K4, Metrologia 60(1A), 07007, 2023

[2] H. W. Song *et al*. Preliminary results of KRISS optical pressure standard system, Measurement: Sensors, No. 18, 100169-1, 2021

[3] T. J. Kwon *et al*. The accurate estimation of the third virial coefficients for helium using three-body neural network potentials, BULLETIN OF THE KOREAN CHEMICAL SOCIETY, Volume 43, No. 5, 612-619, 2022

[4] Gracia Kim *et al*, "Design and Fabrication of a Heat Switch for a SQUID-Based Superconducting Gravimeter", Physica C, 598, 1354064, 2022

[5] Gracia Kim *et al*, "Design, Fabrication and Experimental Demonstration of a Highly Sensitive SQUID-based Accelerometer", Superconductor science and technology, 35 (10), 105014, 2002

[6] S.H Lee *et al*., Performance tests of flowmeters for fuel consumption measurements in fishing vessels, Flow Measurement and Instrumentation, Volume 80, pp 101959, 2021

[7] Y.M Choi *et al*., Revisit the Pitot static tubes in the standards, Flow Measurement and Instrumentation, Volume 82, pp 102074, 2021

[8] D.T. Nguyen *et al*. Calibration process and uncertainty estimation for 3D pitot tubes to enhance greenhouse gas emission measurements in smokestacks, Metrologia, Volume 59(4),

045004, 2022
[9] W. Kang *et al*. Investigation of a Calibration Method of Coriolis Mass Flowmeters by Density-and Pressure-Matching Approaches for Hydrogen Refueling Stations, Applied Sciences, Volume 12(24), 12609, 2022
[10] S. Chun, Time-series analysis of differential pressure and flow velocity signals by means of weighted statistics, Measurement, 190, 110682, 2022
[11] S.H Lee *et al*., Development of infrared absorption-based flow sensor for in-situ measurement of dispenser discharge amount, Optics and Lasers in Engineering, pp 107334, 2023
[12] S. Im *et al*., Smokestack gas velocity measurements using 3D pitot tubes in a coal-fired power plants, Flow Measurement and Instrumentation, Volume 91, pp 102347, 2023

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