

Measurement Standards Laboratory of New Zealand (MSL)

Activity report for the 19th meeting of Consultative Committee for Mass and Related Quantities (CCM)

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1. Main research and development activities related to CCM activities

Kibble balance

MSL Kibble balance is the main research project for the MSL mass and related quantities standards. This Kibble balance has a distinct working principle in which it utilizes twin pressure balances and can be operated in oscillatory moving mode. Some technologies used for this Kibble balance can contribute to the development and capability extension in mass, pressure flow and force standards. The development of this novel Kibble balance continues to be largely focussed on providing research opportunities for newer metrologists, with a few key components being constructed and evaluated as separate research/development projects. The current progress in the MSL Kibble balance can be summarized as the following:

- A vacuum chamber to house the system has been manufactured and the chamber has passed acceptance tests carried out in our laboratory with new vacuum pumps.
- We have installed a prototype coil with an interferometer in the magnet system to investigate the moving mode and its uncertainties with focus on the synchronicity of the induced AC voltage and velocity measurements for an oscillatory coil movement. We have developed an initial measurement model and are currently setting up the experiments.
- An optical table has been installed for the continued development of the interferometer based on Zeeman stabilized laser and experiments on non-linearity errors. The system now includes a time interval analyzer for high-speed displacement data acquisition.
- Progress continues to be made on the conversion of each of the two pressure balances to a rotating cylinder configuration, with preparations now being made for bearing and piston runout measurements on one prototype.
- We are investigating methods to control the coil position using syringe pump and mass flow controller. The syringe pump method has been published and has the potential to be applied in low flow calibrations.
- A measurement model for the weighing mode that uses twin pressure balance as the force comparator has been developed.

Mass

As part of the ongoing equipment and measurement capability improvements, MSL mass standards has continued its focus on renewing and upgrading laboratory equipment. This is achieved by acquiring new mass comparators, enhancing calibration software and facilities.

- Our novel automated weight changer system for a 500 g commercial mass comparator (XPE505C) is now fully commissioned for automated routine calibrations of 200 g to 500 g weights.
- We have acquired a 6 g mass comparator (XPR6U) and acquisition of an automated 100 g mass comparator (AX107H) is expected to be completed soon.
- Further improvements have been made in our mass calibration program written in Python that runs circular weighing with automated weight changers or manual loading. The program is now in use for routine calibrations.
- We have upgraded our large mass-lifting hoists to improve the safety of measurements for the mass build-up to 500 kg and to reduce positioning error, with the aim of participating in a large mass comparison.

Pressure

MSL pressure standards has been mainly focusing on commissioning new standards while working on the twin pressure balance of MSL Kibble balance. There is also initial work in progress to investigate temperature and magnetism effects on the standards.

- We are in the process of moving to a new piston cylinder unit as our primary pressure standard that can be reserved for scale realisation activities. Dimensional measurements have been completed and are being analysed with improved analysis methods.
- We have begun the assembly of the new oil-operated pressure standards to replace our older standards and improve our capability in the range 11 MPa to 270 MPa.
- We have acquired a commercial magnetic susceptometer (YSZ01C) for weights from 2 g to 50 kg for investigation of magnetism effects from pressure balance weights.
- An uncertainty analysis for temperature gradient across primary standard is under development.

2. Participation in relevant comparisons

- 1 APMP.M.D-K4 (hydrometers): Final report has been published.
- 2 APMP.M.M-K5 (mass: 200 mg, 1 g, 50 g, 200 g and 2 kg): Final report has been published.

3. Recent publications

- 1 Y. H. Fung, F. Messerli, R. Hawke and M. Clarkson, "Experiments on oscillatory moving mode for the MSL Kibble balance", Conference on Precision Electromagnetic Measurements (CPEM) 2022 Digest, Wellington, December 2022.

- 2 R. J. Hawke, M. T. Clarkson, "Position control for the MSL Kibble balance coil using a syringe pump", *Acta IMEKO*, Volume 11, Number 4, 1- 7, December 2022.
- 3 K-C Lee, Y. J. Lee, F. Inoue, K. Toda, K. Fujii, F.M. Nor, V. Tulasombut, R. Steyn, K. Fen and C. Sutton, "Report on the APMP key comparison of hydrometer calibrations APMP.M.D-K4", *Metrologia*, Volume 60, Number 1A, 07007, March 2023.
- 4 M. Clarkson, "A twin pressure balance as the force comparator for the MSL Kibble balance", 2021 Kibble Balance Technical Meeting (KBTM), online meeting hosted by UME, November 2021.
- 5 Y. H. Fung, "MSL Kibble balance progress update", 2021 Kibble Balance Technical Meeting (KBTM), online meeting hosted by UME, November 2021.
- 6 Y. H. Fung, "Optics and metrology", Metrology Society of Australasia Conference 2023, Wellington, February 2023.
- 7 P. D. McDowall, "International trends in realisation of the pascal", Metrology Society of Australasia Conference 2023, Wellington, February 2023.