CAL LAB

THE INTERNATIONAL JOURNAL OF METROLOGY

Customer Technical Qualification in Analyzing of the Accreditation Scopes of Calibration Laboratories

An Intercomparison Between Primary High-Pressure Gas Flow Standards with Sub-Permille Uncertainties

Enhancing the Accuracy of a Power and Energy Standard

2020
OCTOBER
NOVEMBER
DECEMBER

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CAL LAB
THE INTERNATIONAL JOURNAL OF METROLOGY

Volume 27, Number 4

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FEATURES

DEPARTMENTS

ON THE COVER: Engineer Michal Sitta using a Radian Research RX-33 to characterize the Meatest M133 calibrator at the Meatest calibration lab in Brno, Czech Republic.

CALENDAR

UPCOMING CONFERENCES & MEETINGS

The following event dates and delivery methods are subject to change. Visit the event URL provided for the latest information.

Feb 22-26, 2021 The International Systems of Units in FAIR Digital Data. Virtual CIPM Meeting. The International Committee for Weights and Measures (CIPM), which directs all metrological work the parties to the Metre Convention decide to carry out in common, now takes the lead to transform the SI into the digitized world via its Task Group on the "Digital SI". The Task Group is now organizing a virtual workshop to bring together leading experts and groups in digitalization related to metrology and data science in order to exchange ideas about first steps to proceed in this direction aiming at agreeing on basic standards for a "Digital SI" framework. https://www.bipm.org/en/conference-centre/bipm-workshops/digital-si/

May 3-6, 2021 SMSI. Nuremberg, Germany. Held in conjunction with SENSOR+TEST, Sensor and Measurement Science International will be a hybrid face-to-face and virtual event. The SMSI brings scientists and researchers from all concerned scientific fields together to secure the success of these ideas in the future. https://www.smsi-conference.com/

May 4-6, 2021 SENSOR+TEST. Nuremberg, Germany. From 4 to 6 May 2021 experts will be meeting again for an in-depth exchange on the worldwide most important industrial fair for sensor and measuring technology. www.sensor-test.com

May 17-21, 2021 IEEE I2MTC. Virtual. The IEEE I2MTC – International Instrumentation and Measurement Technology Conference – is the flagship conference of the IEEE Instrumentation and Measurement Society and is dedicated to advances in measurement methodologies, measurement systems, instrumentation and sensors in all areas of science and technology. These features make I2MTC a unique event and one of the most important conferences in the field of instrumentation and measurement. https://i2mtc2021.ieee-ims.org/

May 25-27, 2020 IEEE SGSMA. Virtual Event. The Second IEEE International Conference on Smart Grid Synchronized Measurement and Analytics provides a leading forum for disseminating the latest research in Synchronized Measurements and Analytics. The theme of the conference will be focused particularly on synchronized sampling and synchrophasors. http://www.sgsma2021.org/

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Correction: In the "Automation Corner," on page 44, of the Jul-Sep 2020 issue, the last name of author Miguel Marques was misspelled as Margus. Marques is the correct spelling.

EDITOR'S DESK

The Written Word

World and national events are so much more *diverse* and *informative* when read from (drum roll please)… a newspaper. Being informed is a much less exhaustive proposition when ingesting current events through words on a piece of paper. It's actually kind of meditative. Your focus is on the meaning of the words instead of dramatic video clips repeated over and over. It takes time to read a whole story instead of just highlights given in an "AP News Minute," so your perspective becomes broader; your mind is busy in the digestion of details of the story rather than in the forming of an opinion or superficial impression.

Everyone perceives and processes information differently, but I personally find the slower processing of information through the written word to be more meaningful. It's gratifying to be able to contribute to the medium through Cal Lab Magazine.

Each paper or article is an exercise in presentation and comprehension. As a non-technical person, I have to be able to judge each contributed paper by how effectively the author tells their "story," which is a super challenge. For example, how well does the author, 1) organize the elements of the paper, 2) stay on topic, and 3) provide relevance for the reader? I've had contributions that were well organized and focused, but provided little substance or meat. On the other hand, I've seen highly engaging content that lacked structure and focus. Every literate person can be a writer, but it takes a little discipline and *a lot of practice* to do it well, so I appreciate each and every paper contribution we get; they are no small task to complete and represent years of knowledge wrapped up in a tidy package.

To start off in this issue we present a proceedings paper from the 19th International Metrology Congress (CIM), held every other year in France. "Customer Technical Qualification in Analyzing of the Accreditation Scopes of Calibration Laboratories," by Suelí Fischer Beckert and Renan Ednan Flôres of the Federal University of Santa Catarina in Brazil, examines the need for customers to understand the CMC criteria specific to their laboratory, and not just rely on the accredited laboratory's interpretation of calibration results.

With kind permission of TEKNA and the authors, we are able to reprint in this issue a 2019 North Sea Flow Measurement Workshop paper titled "An Intercomparison Between Primary High-Pressure Gas Flow Standards with Sub-Permille Uncertainties." Traditionally, Cal Lab Magazine reprinted intercomparisons more regularly, so we were fortunate to find such a paper. We found this paper in the Measurement Library (http://www.measurementlibrary.com/), which is a vast collection of measurement papers freely available online.

And finally, our last paper is written by our publisher Mike Schwartz and co-authored by Jack Somppi, titled "Enhancing the Accuracy of a Power and Energy Standard." They show how measurement accuracies can be improved using a three phase energy source paired with a more accurate energy standard, bypassing the need for a lab to continually upgrade their sources as requirements get tighter. Power quality articles like this are more important than ever as utilities around the world work to update their power grid infrastructure.

Flow and power measurement is much less attention grabbing than the news videos we've all been bombarded with of late, but no less important! So I extend a big heartfelt THANK YOU to our readers, for taking the time to stop and read, because the act of reading and writing go hand in hand.

Happy Measuring,

Sita Schwartz
Editor

Jun 6-11, 2021 IMS2021. Atlanta, GA. You are cordially invited join us in Atlanta, 6-11 June 2021 at the intersection of communications, aerospace, automotive, IoT and other emerging technologies to learn the latest developments in MHz-to-THz theory, techniques, devices, systems and applications at the International Microwave Symposium (IMS). IMS2021 is the centerpiece of Microwave Week 2021 comprised of three conferences including the RFIC Symposium (www.rfic-ieee.org) and the ARFTG Conference (www.arftg.org). https://ims-ieee.org/ims2021

Jun 7-9, 2021 IEEE MetroInd4.0&IoT. Rome, Italy. The International Workshop on Metrology for Industry 4.0 & IoT aims to discuss the contributions both of the metrology for the development of Industry 4.0 and IoT and the new opportunities offered by Industry 4.0 and IoT for the development of new measurement methods and apparatus. MetroInd4.0&IoT aims to gather people who work in developing instrumentation and measurement methods for Industry 4.0 and IoT. Attention is paid, but not limited to, new technology for metrology-assisted production in Industry 4.0 and IoT, Industry 4.0 and IoT component measurement, sensors and associated signal conditioning for Industry 4.0 and IoT, and calibration methods for electronic test and measurement for Industry 4.0 and IoT. http://www.metroind40iot.org/

Jun 21-24, 2021 NEWRAD. Boulder, CO. The 14th International Conference on New Developments and Applications in Optical Radiometry Conference covers all aspects of optical radiation measurements and a wide range of topics will be presented during our four day program, including Earth remote sensing observations and Quantum optics technologies. https://www.nist.gov/news-events/events/2021/06/14th-international-conference-new-developments-and-applications-optical

Jun 23-25, 2021 IEEE MetroAerospace. Naples, Italy. The 8th International Workshop on Metrology for AeroSpace aims to gather people who work in developing instrumentation and measurement methods for aerospace. Attention is paid, but not limited to, new technology for metrology-assisted production in aerospace industry, aircraft component measurement, sensors and associated signal conditioning for aerospace, and calibration methods for electronic test and measurement for aerospace. http://www.metroaerospace.org/

Jul 19-22, 2021 MSC Training Symposium. Anaheim, CA. The MSC Training Symposium takes place annually in Orange County, California and is celebrating 50 years of educational training. The Symposium provides measurement professionals the opportunity to provide a training session of related subjects within the measurement industry and share the knowledge gained through education or on-the-job training. https://msc-conf.com/

Aug 1-4, 2021 A2LA Tech Forum. Chantilly, VA. A2LA is committed to providing a dynamically educational experience to help you navigate the waters of accreditation. The A2LA Tech Forum has grown to become one of the largest, multidiscipline events in the accreditation industry, attracting attendees from over 12 different industries, including automotive, environmental, pharmaceutical, calibration, and more. https://www.a2la.org/tech-forum

Aug 21-26, 2021 NCSL International Workshop & Symposium. Orlando, FL. NCSL International provides the best opportunities for the world's measurement science professionals to network and exchange information, to promote measurement education and skill development and to develop a means to resolve measurement challenges. https://www.ncsli.org

Aug 30-Sep 2, 2021 AUTOTESTCON. National Harbor, MD. AUTOTESTCON is the world's premier conference that brings together the military/aerospace automatic test industry and government/military acquirers and users to share new technologies, discuss innovative applications, and exhibit products and services. Event URL: https://autotestcon.com/

Aug 30-Sep 3, 2021 The XXIII IMEKO World Congress. Yokohama, Japan. For all people working in metrology and measurement science coming either from academia or industry, from scientists to engineers, from mathematicians to chemists and physicists, from instrumentation designers to measuring techniques developers, to exchange and share information. http://www.imeko2021.org/

Sep 7-9, 2021 CIM. Lyon, France. The 20th International Metrology Congress is a showcase for industrial applications, advances in R&D and prospects dedicated to measurements, analysis and testing processes. https://www.cim2021.com/

Sep 29-Oct 1, 2021 IEEE AMPS. Cagliari, Italy. The 11th International Workshop on Applied Measurements for Power Systems deals with all the aspects related to measurement applications in current power systems and in future Smart Grids and has the main goal of encouraging discussion on these topics among experts coming from academia, industry and utilities. https://conferences.ieee.org/conferences_events/conferences/conferencedetails/50177

CALENDAR

SEMINARS & WEBINARS: Dimensional

Feb 10-11, 2021 Gage Calibration & Repair. Virtual Training. IICT Enterprises. This 2-day training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair and adjustments of micrometers, calipers, indicators height gages, etc. https://www.calibrationtraining.com/schedule

Feb 23-24, 2021 Gage Calibration & Repair. Madison, WI. IICT Enterprises. This 2-day training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair and adjustments of micrometers, calipers, indicators height gages, etc. https://www.calibrationtraining.com/schedule

Mar 2, 2021 Dimensional Measurement User. Bristol, UK. INSPHERE Ltd. In this training course, learners will be introduced to dimensional metrology and the importance of good measurement practice and the right measurement behaviors. This is an EAL approved qualification. https://training.npl.co.uk/course/dimensional-measurement-user/

Mar 9-10, 2021 Gage Calibration & Repair. Des Moines, IA. IICT Enterprises. This 2-day training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair and adjustments of micrometers, calipers, indicators height gages, etc. https://www.calibrationtraining.com/schedule

Mar 23-24, 2021 Gage Calibration & Repair. Indianapolis, IN. IICT Enterprises. This 2-day training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair and adjustments of micrometers, calipers, indicators height gages, etc. https://www.calibrationtraining.com/schedule

Mar 25-26, 2021 Gage Calibration & Repair. Schaumburg, IL. IICT Enterprises. This 2-day training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair and adjustments of micrometers, calipers, indicators height gages, etc. https://www.calibrationtraining.com/schedule

Mar 30, 2021 Dimensional Measurement Applier. Bristol, UK. INSPHERE Ltd. The Dimensional Measurement Applier course provides knowledge and expertise in the application of measurement. It will encourage a planning culture, enabling organizations to save time and money through the implementation of best measurement practice. https://training.npl.co.uk/

Apr 14-15, 2021 Gage Calibration & Repair. Atlanta, GA. IICT Enterprises. This 2-day training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair and adjustments of micrometers, calipers, indicators height gages, etc. https://www.calibrationtraining.com/schedule

May 12-13, 2021 Gage Calibration & Repair. Dallas, TX. IICT Enterprises. This 2-day training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair and adjustments of micrometers, calipers, indicators height gages, etc. https://www.calibrationtraining.com/schedule

May 26-27, 2021 Dimensional Measurement. Port Melbourne, VIC. Australia NMI. This two-day course (9 am to 5 pm) presents a comprehensive overview of the fundamental principles in dimensional metrology and geometric dimensioning and tolerancing. https://shop.measurement.gov.au/collections/physical-metrology-training

Jun 9-10, 2021 Gage Calibration & Repair. Las Vegas, NV. IICT Enterprises. This 2-day training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair and adjustments of micrometers, calipers, indicators height gages, etc. https://www.calibrationtraining.com/schedule

SEMINARS & WEBINARS: Electrical

Feb 22-25, 2021 MET-101 Basic Hands-On Metrology. Everett, Washington. Fluke Calibration. A four-day "how to" course that introduces basic measurement concepts, basic electronics related to measurement instruments, and math used in calibration. https://us.flukecal.com/training

Jun 21-24, 2021 MET-101 Basic Hands-On Metrology. Everett, Washington. Fluke Calibration. A four-day "how to" course that introduces basic measurement concepts, basic electronics related to measurement instruments and math used in calibration. https://us.flukecal.com/training

SEMINARS & WEBINARS: Flow

Mar 22-25, 2021 Gas Flow Calibration Using molbloc/molbox. Phoenix, Arizona. Fluke Calibration. A four-day course on the operation and maintenance of a Fluke Calibration molbloc/molbox system. https://us.flukecal.com/training

SEMINARS & WEBINARS: General

Jun 21-25, 2021 Fundamentals of Metrology. Gaithersburg, MD. The 5-day Fundamentals of Metrology seminar introduces participants to the concepts of measurement systems, units, measurement uncertainty, measurement assurance, traceability, basic statistics and how they fit into a laboratory Quality Management System. https://www.nist.gov/pml/weights-and-measures/about-owm/calendar-events

SEMINARS & WEBINARS: Industry Standards

Feb 8-11, 2021 Auditing Your Laboratory to ISO/IC 17025:2017 (AUD 102W). Virtual. A2LAWPT. This course will introduce participants to ISO/IEC 19011, the guideline for auditing management systems as applied to ISO/IEC 17025:2017. The participant will learn about auditing principles and develop skills for performing higher-value internal audits. https://www.a2lawpt.org/events

CALENDAR

Feb 10-11, 2021 Internal Auditing for all Standards. Webinar. IAS. This 2-day Training Course examines auditing principles and techniques and facilitates the practice of required internal audit skills. It is based on internationally-recognized approaches to conducting conformant internal audits. The techniques learned by participants promote the involvement of all types of staff as auditors and auditees. The course includes easy-to-implement methods for risk-based thinking, continual improvement, and closing out findings through the analysis of root causes aimed at their elimination. https://www.iasonline.org/training/

Feb 22-26, 2021 Forensic ISO/IEC 17025:2017 Internal Auditor. Live Online. ANAB. This course provides a detailed review of ISO/IEC 17025:2017 and the related ANAB accreditation requirements for forensic service providers (AR 3125) as well as a review of ISO 19011, Guidelines for Auditing Management Systems. https://anab.ansi.org/training/public-course-schedule

Mar 1-2, 2021 Understanding ISO/IEC 17025:2017 for Testing & Calibration Laboratories (MS 111W). Virtual. A2LAWPT. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2lawpt.org/events

Mar 1-2, 2021 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Webinar. IAS. This 2-day Training Course examines structural components of the standard. Quality system and technical requirements are grouped in a manner that makes them clear and understandable. https://www.iasonline.org/training/

Mar 3-4, 2021 Auditing Your Laboratory to ISO/IEC 17025:2017 (AUD 102W). Virtual. A2LAWPT. This course will introduce participants to ISO/IEC 19011, the guideline for auditing management systems as applied to ISO/IEC 17025:2017. The participant will learn about auditing principles and develop skills for performing higher-value internal audits. https://www.a2lawpt.org/events

Apr 6-7, 2021 Understanding ISO/IEC 17025:2017 for Testing & Calibration Laboratories (MS 111W). Virtual. A2LAWPT. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2lawpt.org/events

Apr 7-8, 2021 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Webinar. IAS. Course objective is to learn about ISO/IEC 17025 from one of its original authors. To learn its

Principles and what it requires of laboratory staff. https://www.iasonline.org/training/

Apr 8-9, 2021 Auditing Your Laboratory to ISO/IEC 17025:2017 (AUD 102W). Virtual. A2LAWPT. This course will introduce participants to ISO/IEC 19011, the guideline for auditing management systems as applied to ISO/IEC 17025:2017. The participant will learn about auditing principles and develop skills for performing higher-value internal audits. https://www.a2lawpt.org/events

Apr 14-15, 2021 Internal Auditing for all Standards. Webinar. IAS. This 2-day Training Course examines auditing principles and techniques and facilitates the practice of required internal audit skills. It is based on internationally-recognized approaches to conducting conformant internal audits. The techniques learned by participants promote the involvement of all types of staff as auditors and auditees. The course includes easy-to-implement methods for risk-based thinking, continual improvement, and closing out findings through the analysis of root causes aimed at their elimination. https://www.iasonline.org/training/

Apr 26-30, 2021 Lead Assessor Intensive Training (ISO/IEC 17025 or ISO/IEC 17020). Washington, DC. ANAB has redesigned its Lead Assessor Intensive Training course to an exercise-based approach to better support and develop the competencies required of a lead assessor. The course was developed in response to the recent change of focus on competence within laboratory-related accreditation standards. https://anab.ansi.org/public-course-schedule

Apr 28-30, 2021 Internal Auditing to ISO/IEC 17025:2017 (en Espanol). Vivir en linea. ANAB. Attendees will learn how to coordinate a quality management system audit to ISO/IEC 17025:2017 and collect audit evidence and document observations, including techniques for effective questioning and listening. https://anab.ansi.org/public-course-schedule

May 17-19, 2021 Internal Auditing to ISO/IEC 17025:2017. Live Online. ANAB. Attendees will learn how to coordinate a quality management system audit to ISO/IEC 17025:2017 and collect audit evidence and document observations, including techniques for effective questioning and listening. https://anab.ansi.org/public-course-schedule

May 17-20, 2021 Forensic ISO/IEC 17025:2017 Internal Auditor. Cary, NC. ANAB. This course provides a detailed review of ISO/IEC 17025:2017 and the related ANAB accreditation requirements for forensic service providers as well as a review of ISO 19011, Guidelines for Auditing Management Systems. https://anab.ansi.org/training/public-course-schedule

CALENDAR

May 19-20, 2021 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Webinar. IAS. Course objective is to learn about ISO/IEC 17025 from one of its original authors. To learn its Principles and what it requires of laboratory staff. https://www.iasonline.org/training/

Jun 28-Jul 2, 2021 Forensic ISO/IEC 17025:2017 Internal Auditor. Live Online. ANAB. This course provides a detailed review of ISO/IEC 17025:2017 and the related ANAB accreditation requirements for forensic service providers (AR 3125) as well as a review of ISO 19011, Guidelines for Auditing Management Systems. https://anab.ansi.org/training/public-course-schedule

SEMINARS & WEBINARS: Management & Quality

Feb 24-25, 2021 Documenting Your ISO/IEC 17025 Management System. Webinar. A2LA WorkPlace Training. During this course, the participant will gain an understanding of the basic concepts of management system documentation structure, content, and development. https://www.a2lawpt.org/events

Mar 2-3, 2021 Validation and Verification of Analytical Methods. Live Online. ANAB. This course provides an introduction to validation and verification of analytical methods. The common elements of a validation/verification plan and a general approach to performing a validation or verification are presented. The pertinent requirements in ISO/IEC 17025 and ISO/IEC 17020 for method validation and verification are also reviewed. https://anab.ansi.org/training/public-course-schedule

Mar 4, 2021 Document Control and Record Keeping. Webinar. NIST. This 2-hour webinar will introduce the fundamentals of Laboratory Management System Document Control and Record Keeping that are necessary to successfully implement ISO/IEC 17025:2017. https://www.nist.gov/pml/weights-and-measures/about-owm/calendar-events

SEMINARS & WEBINARS: Measurement Uncertainty

Feb 11-12, 2021 Understanding Measurement Uncertainty. Live Online. ANAB. Attendees of the two-day Fundamentals Measurement Uncertainty training course will learn a practical approach to measurement uncertainty applications, based on fundamental practices. https://anab.ansi.org/public-course-schedule

Mar 3-4, 2021 Uncertainty of Measurement. Webinar. IAS. The training includes case studies and discussions, with application of statistical components in practical examples that are frequently encountered by testing laboratories. https://www.iasonline.org/training/

Mar 16, 2021 Introduction to Measurement Uncertainty. Virtual. A2LA WorkPlace Training. This course is a suitable introduction for both calibration and testing laboratory participants, focusing on the concepts and mathematics of the measurement uncertainty evaluation process. https://www.a2lawpt.org/events/

KIHOMAC

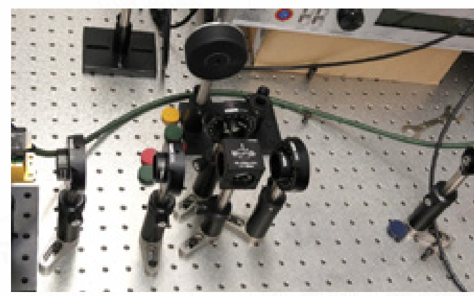
POSITIONS AVAILABLE

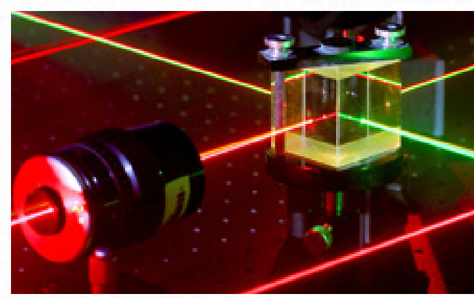
Test & Measurement Engineering

KIHOMAC is currently seeking mid-career level software and hardware engineering professionals and technical leaders for our team.

In aerospace and defense, *technology* is the platform, and KIHOMAC delivers it. Come and join our team supporting Naval Aviation weapon system acquisition, research, development, test, and evaluation.

We offer competitive salaries, outstanding benefits, and a customer oriented, positive and authentic culture. Our medical, dental, and vision coverage are first rate with low employee contributions.





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Apr 12, 2021 Introduction to Measurement Uncertainty. Virtual. A2LA WorkPlace Training. This course is a suitable introduction for both calibration and testing laboratory participants, focusing on the concepts and mathematics of the measurement uncertainty evaluation process. https://www.a2lawpt.org/events/

Apr 13-14, 2021 Applied Measurement Uncertainty for Calibration Laboratories. Webinar. A2LA WorkPlace Training. During this course, the participant will be introduced to several tools and techniques that can be applied in the calibration laboratory environment to efficiently and effectively create measurement uncertainty budgets which comply with ISO/IEC 17025 requirements. https://www.a2lawpt.org/events

Apr 13-15, 2021 Measurement Uncertainty: Practical Applications. Live Online. ANAB. This course reviews the basic concepts and accreditation requirements associated with measurement traceability, measurement assurance, and measurement uncertainty as well as their interrelationships. A basic process for the effective evaluation of a calibration service supplier or reference material producer will be discussed and participants will apply the process through a practical exercise. https://anab.ansi.org/training/public-course-schedule

Apr 26-27, 2021 Understanding Measurement Uncertainty (en Espanol). Vivir en Linea. ANAB. Attendees of the two-day Fundamentals Measurement Uncertainty training course will learn a practical approach to measurement uncertainty applications, based on fundamental practices. https://anab.ansi.org/public-course-schedule

May 20, 2021 Basic Uncertainty Concepts. Webinar. NIST. This 2-hour webinar provides a very basic introduction to uncertainty calculations and reporting using the 8-step process published in NIST SOP 29 (NISTIR 6969), beginning with some definitions and concepts from the Guide to the Expression of Uncertainty in Measurement (GUM) and includes some simple calculations. https://www.nist.gov/news-events/events/2021/05/5710-basic-uncertainty-concepts

May 20-21, 2021 Understanding Measurement Uncertainty. Live Online. ANAB. Attendees of the two-day Fundamentals Measurement Uncertainty training course will learn a practical approach to measurement uncertainty applications, based on fundamental practices. https://anab.ansi.org/public-course-schedule

Jun 9-10, 2021 Uncertainty of Measurement for Labs. Webinar. IAS. The training includes case studies and discussions, with application of statistical components in practical examples that are frequently encountered by testing laboratories. https://www.iasonline.org/training/

SEMINARS & WEBINARS: Pressure

Mar 29-Apr 2, 2021 Principles of Pressure Calibration. Phoenix, Arizona. Fluke Calibration. A five-day training course on the principles and practices of pressure calibration using digital pressure calibrators and piston gauges (pressure balances). https://us.flukecal.com/training

Apr 19-23, 2021 Advanced Piston Gauge Metrology. Phoenix, Arizona. Fluke Calibration. A five-day course focusing on the theory, use and calibration of piston gauges and deadweight testers. https://us.flukecal.com/training

Jun 23-24, 2021 Pressure Measurement. Port Mebourne, VIC. Australia NMI. This two-day course (9 am to 5 pm each day) covers essential knowledge of the calibration and use of a wide range of pressure measuring instruments, their principles of operation and potential sources of error — it incorporates extensive hands-on practical exercises. https://shop.measurement.gov.au/collections/physical-metrology-training

SEMINARS & WEBINARS: RF & Microwave

May 4-6, 2021 VNA Tools Training Course. Federal Institute of Metrology METAS. Bern-Wabern, Switzerland. VNA Tools is a free software developed by METAS for measurements with the Vector Network Analyzer (VNA). The software facilitates the tasks of evaluating measurement uncertainty in compliance with the ISO-GUM and vindicating metrological traceability. The software is available for download at www.metas.ch/vnatools. The three day course provides a practical and hands-on lesson with this superior and versatile software. https://www.metas.ch/metas/en/home/dl/kurse---seminare.html

Jun 29-Jul 1, 2021 VNA Tools Training Course. Federal Institute of Metrology METAS. Bern-Wabern, Switzerland. VNA Tools is a free software developed by METAS for measurements with the Vector Network Analyzer (VNA). The software facilitates the tasks of evaluating measurement uncertainty in compliance with the ISO-GUM and vindicating metrological trace-ability. The software is available for download at www.metas.ch/vnatools. The three day course provides a practical and hands-on lesson with this superior and versatile software. https://www.metas.ch/metas/en/home/dl/kurse---seminare.html

CALENDAR

SEMINARS & WEBINARS: Software

Feb 8-12, 2021 TWB 1051 MET/TEAM® Basic Web-Based Training. Fluke Calibration. This web-based course presents an overview of how to use MET/TEAM® Test Equipment and Asset Management Software in an Internet browser to develop your asset management system. You will learn a systematic approach to recording the information you need to manage your lab assets routinely, consistently and completely. http://us.flukecal.com/training

Mar 8-12, 2021 MC-206 Basic MET/CAL® Procedure Writing. Everett, Washington. Fluke Calibration. A five-day course to familiarize you with traceability and procedure writing in the MET/CAL® software environment. http://us.flukecal.com/training

Apr 8-22, 2021 Software Verification and Validation. Webinar. NIST. These two 2-hour sessions on Software Verification and Validation will focus on the use of Microsoft Excel in calibration laboratories and examine the ISO/IEC 17025:2017 requirements related to software. Session I will provide guidance and resources for ensuring software quality assurance, documenting evidence of verification and validation, and provide the tools for ongoing software evaluation. https://www.nist.gov/pml/weights-and-measures/about-owm/calendar-events

Apr 26-30, 2021 TWB 1051 MET/TEAM® Basic Web-Based Training. Fluke Calibration. This web-based course presents an overview of how to use MET/TEAM® Test Equipment and Asset Management Software in an Internet browser to develop your asset management system. You will learn a systematic approach to recording the information you need to manage your lab assets routinely, consistently and completely. http://us.flukecal.com/training

May 3-7, 2021 TWB 1031 MET/CAL® Procedure Development Web-Based Training. Fluke Calibration. A five-day (2-hour sessions), instructor-led web-based training, course on creating procedures with the latest version of MET/CAL®. http://us.flukecal.com/training

May 10-14, 2021 MC-207 Advanced MET/CAL® Procedure Writing. Everett, Washington. Fluke Calibration. A five-day course for advanced users of MET/CAL® calibration software. http://us.flukecal.com/training

Jun 7-11, 2021 MC-205 MET/TEAM® Asset Management. Everett, Washington. Fluke Calibration. A five-day course on the use of MET/TEAM software to manage and report on your assets in the calibration metrology lab. http://us.flukecal.com/training

SEMINARS & WEBINARS: Temperature & Humidity

Feb 26, 2021 Testing Temperature Controlled Enclosures - Online Delivery. Australia NMI. This one day course (9 am to 5 pm) is for people involved in routine performance testing of temperature controlled enclosures (oven, furnace, refrigerator and fluid bath). It incorporates an extensive overview of AS 2853 requirements and common industry practice and it also includes hands-on practical demonstrations. https://www.industry.gov.au/client-services/training-and-assessment

Mar 23-25, 2021 Temperature Measurement. Malaga WA, Australia. NMI. This three-day course (9 am to 5 pm) covers the measurement of temperature and the calibration of temperature measuring instruments. It incorporates extensive hands-on practical exercises. https://www.industry.gov.au/client-services/training-and-assessment

Apr 12-14, 2021 Practical Temperature Calibration. American Fork, Utah. Fluke Calibration. A three-day course designed to help calibration technicians and engineers get a solid base of temperature calibration fundamentals. https://us.flukecal.com/training

Apr 15-16, 2021 Infrared Calibration. American Fork, Utah. Fluke Calibration. A two-day course on the basics of infrared temperature metrology to help begin or sustain an infrared temperature calibration program. https://us.flukecal.com/training

May 10, 2021 Temperature Measurement and Calibration (with optional practical day). Teddington, UK. NPL. This is a 2-3 day course, covering the range –200 °C to 3000 °C, the course will concentrate on those methods of measurement which are of greatest technological and industrial importance. https://training.npl.co.uk/course/temperature-measurement-and-calibration-with-optional-practical-day/

May 13, 2021 Humidity Measurement and Calibration. Teddington, UK. NPL. This is a 2 day course covering dew point, relative humidity and other humidity quantities, the course will concentrate on methods of measurement which are of greatest technological relevance to attendees. https://training.npl.co.uk/course/humidity-measurement-and-calibration/

SEMINARS & WEBINARS: Volume

Jun 6-11, 2021 Volume Metrology Seminar. Gaithersburg, MD. The 5-day OWM volume metrology seminar is designed to enable metrologists to apply fundamental measurement concepts to volume calibrations. A large percentage of time is spent on hands-on measurements, applying procedures and equations discussed in the classroom. https://www.nist.gov/pml/weights-and-measures/about-owm/calendar-events

Jun 14-18, 2021 Volume Metrology Seminar. Gaithersburg, MD. The 5-day OWM volume metrology seminar is designed to enable metrologists to apply fundamental measurement concepts to volume calibrations. A large percentage of time is spent on hands-on measurements, applying procedures and equations discussed in the classroom. https://www.nist.gov/pml/weights-and-measures/about-owm/calendar-events

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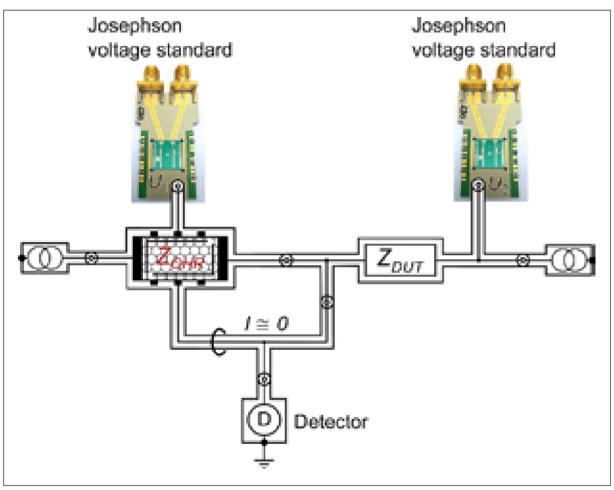
Quantum-Based Impedance Bridges

PTBnews 3.2020 – Within the scope of a European metrology research project, PTB is investigating the utilizability of novel quantum Hall resistance standards based on graphene for impedance metrology. The activities aim to develop quantum-based impedance bridges to simplify the calibration of electrical AC voltage quantities for practice-oriented, flexible and efficient use, e.g. in calibration laboratories or in industry. The first measurements performed have already shown very good reproducibility and demonstrated the new method's potential.

Today, realizing electrical units – or rather calibrating electrical quantities – in the AC voltage regime (i.e. impedances) is mostly done by means of calculable, conventional artefacts or via DC-AC voltage transfer based on quantum resistance standards exploiting the quantum Hall effect. The bridges used for this purpose are based on inductive voltage dividers and achieve excellent measurement uncertainties in the range of only a few parts in a billion. The use of such bridges is, however, limited with regard to the realizable voltage ratios, phase angles and frequencies; moreover, they are complex and require manual operation, thus making them accessible to experts only.

To overcome these limitations, PTB, together with 10 other partner institutes, is developing flexible and more easily automatable impedance bridges within the scope of a European metrology research project titled "Graphene impedance quantum standards (GIQS)". Hereby, modern quantum voltage sources based on pulse-driven Josephson voltage standards are used instead of inductive voltage dividers to generate the bridge voltages. These so-called Josephson impedance bridges allow the flexible and accurate realization of AC voltages at different frequencies, with any phase angles, and with high stability over time. Combined with a quantum Hall resistor, these bridges allow nearly any random impedance to be calibrated accurately.



Schematic diagram (strongly simplified) of a Josephson impedance bridge combined with a quantum Hall resistor (QHR). The current for the measurement is supplied by two current sources (left and right); voltage is measured in a quantum-based way via two pulse-operated Josephson voltage standards (U1 and U2). After aligning the bridge by adjusting the voltage ratios and phase angles, the voltage measured by the detector is zero; thus, the ratio of the impedances of the device under test (ZDUT) to those of the quantum Hall impedance standard (ZQHR) is equal to the ratio between the two bridge voltages U1 and U2 which is very precisely known. Credit: PTB.

The aim pursued by PTB, which consists in developing a quantum Hall resistor made of graphene, offers even more advantages for the practice-oriented use of Josephson impedance bridges. Conventional quantum Hall resistors made of semiconducting heterogeneous structures must typically be operated at high magnetic fields and low temperatures, which makes expensive and complex cryogenic magnetic systems and the supply with liquid helium indispensable. In contrast to this, the particular properties of graphene enable use in less cost-intensive and more easily operable magnetic systems with small cooling units.

However, the graphene circuits used for this purpose still have to be further optimized. The high accuracy of the Josephson impedance bridge provides ideal preconditions for these investigations. The first measurements performed at PTB on a 10 nF capacitance standard have already shown very good reproducibility of the results in the range of a few parts in 108 and have thus confirmed the great potential of this new measurement method. Further optimization of the bridge measuring technology and of the graphene standard resistors is currently being worked on.

Scientific publication: S. Bauer, Y. Pimsut, R. Behr, O. Kieler, M. Kruskopf, L. Palafox, J. Lee, J. Schurr: AC quantum Hall resistance combined with a four-terminal pair pulse-driven Josephson impedance bridge. Accepted for publication in *IEEE Trans. Instrum. Meas.* (2020)

Source: https://www.ptb.de/cms/en/presseaktuelles/journals-magazines/ptb-news.html

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NMIs Demonstrate High Accuracy Reference Measurement System for SARS-CoV-2 Testing

Twenty-one National Metrology Institutes and expert laboratories from sixteen countries have demonstrated that highly accurate measurements of the amount of the SARS-CoV-2 viral RNA can be achieved worldwide using reverse transcription-digital PCR (RT-dPCR). The ability to accurately measure the amount of the viral cause of COVID-19 with global equivalence will considerably improve testing confidence and support countries in effectively tackling the pandemic.

The comparison study (CCQM-P199.b) organized by the CCQM Working Group on Nucleic Acid Analysis (CCQM-NAWG), and coordinated by the National Measurement Laboratory at LGC (UK), NIM (China), NIBSC (UK) and NIST (US), required quantification of the same viral genetic sequences targeted by many of the diagnostic tests. The

RT-dPCR results were found to agree very well with each other and different SI-traceable non-molecular orthogonal methods; most values were within +/-40% of mean. The reproducibility of the method is unprecedented for absolute molecular measurements, where orders of magnitude of spread in reported copy numbers can be found using conventional molecular diagnostic methods. This work, made possible by over a decade of CCQM led collaborative efforts within the bio-metrology community, represents the most comprehensive example of highly reproducible and sensitive measurement of RNA and opens the possibility for SI-traceable quantification of viral genes. The methods and results are already being used by National Metrology Institutes to value assign reference materials that underpin the quality of SARS-CoV-2 diagnostic tests. The comparison was conducted under an accelerated timeline, with the worldwide comparison completed in under six months, and the final report expected in early 2021.

In the longer term, these capabilities have far wider implications as they can provide a global foundation for ensuring the accuracy of associated molecular methods whether applied to COVID-19, as preparation for any future global pandemic or for wider diagnostic uses such as in testing for antibiotic resistance or cancer.

Source: https://www.bipm.org/en/news/full-stories/2020-12-nmi-covid.html

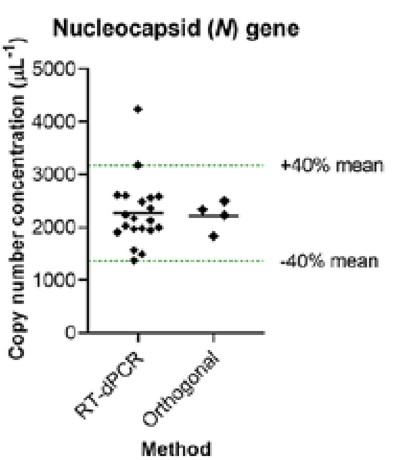


Figure illustrating results from part of the study demonstrating that laboratories performing molecular RT-dPCR methods are able to perform with good agreement with each other and the SI-traceable orthogonal methods (isotope-dilution mass spectrometry and single molecule flow cytometry), the latter providing the basis for the RT-dPCR method's claimed accuracy. The RT-dPCR results were compared with orthogonal methods using different concentrations of the same RNA material. The different concentrations were prepared using gravimetric dilution. Diamonds show individual laboratories' results with solid black line (mean) and dotted green lines +/-40% of mean value. Credit: BIPM.

NIST's SAMURAI Measures 5G Communications Channels Precisely

NIST News, August 10, 2020 – Engineers at the National Institute of Standards and Technology (NIST) have developed a flexible, portable measurement system to support design and repeatable laboratory testing of fifth-generation (5G) wireless communications devices with unprecedented accuracy across a wide range of signal frequencies and scenarios.

The system is called SAMURAI, short for Synthetic Aperture Measurements of Uncertainty in Angle of Incidence. The system is the first to offer 5G wireless measurements with accuracy that can be traced to fundamental physical standards — a key feature because even tiny errors can produce misleading results. SAMURAI is also small enough to be transported to field tests.

Mobile devices such as cellphones, consumer Wi-Fi devices and public-safety radios now mostly operate at electromagnetic frequencies below 3 gigahertz (GHz) with antennas that radiate equally in all directions. Experts predict 5G technologies could boost data rates a thousandfold by using higher, "millimeter-wave" frequencies above 24 GHz and highly directional, actively changing antenna patterns. Such active antenna arrays help to overcome losses of these higher-frequency signals during transmission. 5G systems also send signals over multiple paths simultaneously — so-called spatial channels — to increase speed and overcome interference.

Many instruments can measure some aspects of directional 5G device and channel performance. But most focus on collecting quick snapshots over a limited frequency range to provide a general overview of a channel, whereas SAMURAI provides a detailed portrait. In addition, many instruments are so physically large that they can distort millimeter-wave signal transmissions and reception.

Described at the 95th ARFTG Microwave Measurement Conference on August 7, 2020, SAMURAI is expected to help resolve many unanswered questions surrounding 5G's use of active antennas, such as what happens when high data rates are transmitted across multiple channels at once. The system will help improve theory, hardware and analysis techniques to provide accurate channel models and efficient networks.

"SAMURAI provides a cost-effective way to study many millimeter-wave measurement issues, so the technique will be accessible to academic labs as well as instrumentation metrology labs," NIST electronics engineer Kate Remley said. "Because of its traceability to standards, users can have confidence in the measurements. The technique will allow better antenna design and performance verification, and support network design."

SAMURAI measures signals across a wide frequency range, currently up to 50 GHz, extending to 75 GHz in the coming year. The system got its name because it measures received signals at many points over a grid or virtual "synthetic aperture." This allows reconstruction of incoming energy in three dimensions — including the angles of the arriving signals — which is affected by many factors, such as how the signal's electric field reflects off of objects in the transmission path.

SAMURAI can be applied to a variety of tasks from verifying the performance of wireless devices with active antennas to measuring reflective channels in environments where metallic objects scatter signals. NIST researchers are currently using SAMURAI to develop methods for testing industrial Internet of Things devices at millimeter-wave frequencies.

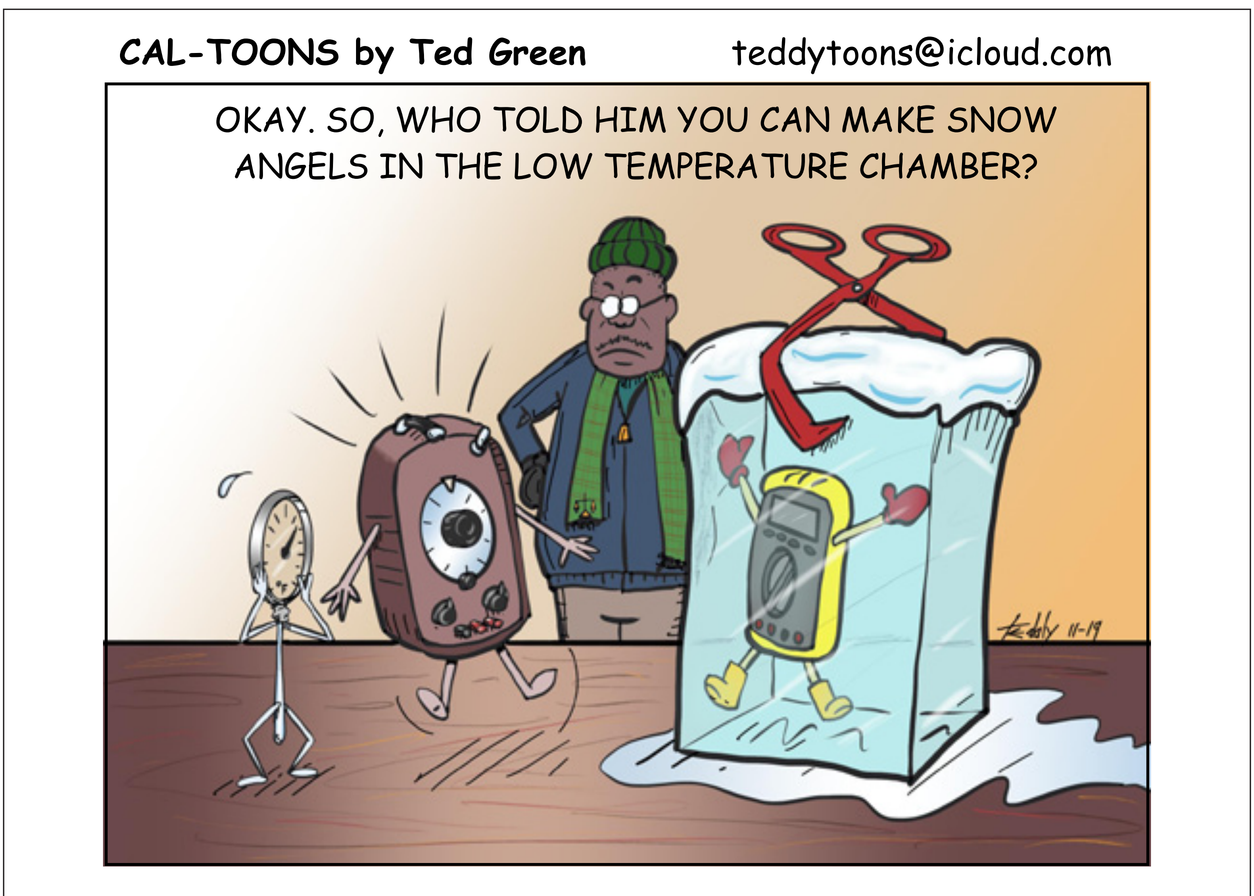
The basic components are two antennas to transmit and receive signals, instrumentation with precise timing synchronization to generate radio transmissions and analyze reception, and a six-axis robotic arm that positions the receive antenna to the grid points that form the synthetic aperture. The robot ensures accurate and repeatable antenna positions and traces out a variety of reception patterns in 3D space, such as cylindrical and hemispherical shapes. A variety of small metallic objects such as flat plates and cylinders can be placed in the test setup to represent buildings and other real-world impediments to signal transmission. To improve positional accuracy, a system of 10 cameras is also used to track the antennas and measure the locations of objects in the channel that scatter signals.

The system is typically attached to an optical table measuring 5 feet by 14 feet (1.5 meters by 4.3 meters). But the equipment is portable enough to be used in mobile field tests and moved to other laboratory settings. Wireless communications research requires a mix of lab tests — which are well controlled to help isolate specific effects and verify system performance — and field tests, which capture the range of realistic conditions.

Measurements can require hours to complete, so all aspects of the (stationary) channel are recorded for later analysis. These values include environmental factors such as temperature and humidity, location of scattering objects, and drift in accuracy of the measurement system.

The NIST team developed SAMURAI with collaborators from the Colorado School of Mines in Golden, Colorado. Researchers have verified the basic operation and are now incorporating uncertainty due to unwanted reflections from the robotic arm, position error and antenna patterns into the measurements.

Source: https://www.nist.gov/news-events/news/2020/08/nists-samurai-measures-5g-communications-channels-precisely



Precision Metrology Certificate Program

UNC Charlotte, William States Lee College of Engineering News, August 11, 2020 – To provide engineers with advanced coursework about dimensional measurement, The William States Lee College of Engineering's Mechanical Engineering Department and Center for Precision Metrology offer the Graduate Certificate in Precision Metrology Program. The four-course program is designed with working professionals in mind, offering study topics important to industrial engineering careers through both distance-learning and in-class options.

"There is an awareness problem when it comes to metrology," said Dr. Ed Morse, deputy director of the Center for Precision Metrology. "A lot of engineering students graduate without having studied metrology, or even knowing what it is. Then they get into jobs where metrology is important, and there is a gap in the engineering knowledge they need."

The Graduate Certificate in Precision Metrology Program (https://metrologycertificate.uncc.edu/home/program-description) is designed to fill that knowledge gap. The program provides students with a broader understanding of metrology, and exposes them to advanced techniques in dimensional measurement and data analysis.

"The purpose of the certificate is to teach dimensional metrology and its application to industry," Dr. Morse said. "Our target students are engineers who feel they need more knowledge and ability in metrology, but don't want to go for a full master's degree."

There are 10 students in the current cohort of the program. They include full-time students in Charlotte, and industry professional in other parts of the country.

Certificate program student Taylor Ritchie lives in Colorado, where he is a staff mechanical engineer at Woodward Inc. Ritchie graduated from Colorado State University in 2008, where he studied mechanical engineering, but had very little instruction in metrology.

"My job demands an in-depth knowledge of metrology and how that applies to component design, processing, wear and failure," Ritchie said, "UNC Charlotte has one of the most comprehensive precision engineering programs in the country. And the remote-learning aspect of it was important to me."

Ritchie is now in his second year of the program. He takes his classes remotely, using a computer to view and participate in the live lectures. "I like the live session," he said, "because I can ask questions in real time and hear the questions other students are asking."

For the laboratory portion of the courses, Ritchie has worked out arrangements with professors and lab managers to come to the UNC Charlotte campus for a few days or a week each semester and do all the lab work during that time.

"The program is absolutely giving me the experience I'm looking for," Ritchie said. "It's been very beneficial for my career. I think it's great."

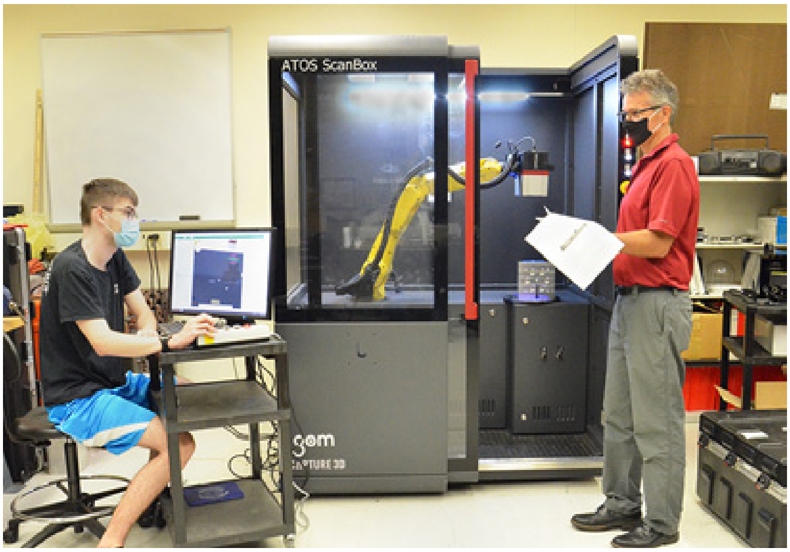
The coursework for the metrology certificate includes four graduate-level classes (12 credit hours) of precision metrology courses, taken either in the classroom or remotely. Students must take two required courses, MEGR 6181 Engineering Metrology and MEGR 7182 Machine Tool Metrology. They then select take two addition courses from the list below:

- MEGR 7183 – Precision Machine Design
- MEGR 7185 – Gear Manufacturing and Metrology
- MEGR 7186 – Data Analysis and Uncertainty
- MEGR 7187 – Flexures
- MEGR 7191 – Introduction to Optical Fabrication and Testing
- MEGR 7283 – Advanced Coordinate Metrology
- MEGR 7284 – Advanced Surface Metrology

Applicants must have a degree in engineering or a closely related field, but there is no GRE requirement. Applicants should submit a written description of any relevant and significant work experience, especially as it pertains to metrology.

More information on program requirements and the Graduate School application forms are here: https://mygradschool.uncc.edu/.

Source: https://engr.uncc.edu/news/2020-08-11/precision-metrology-certificate-program



Undergraduate Research Assistant Ryan Gorman, left and Dr. Ed Morse working with a new ATOS ScanBox optical measuring machine. Credit: Photo courtesy of UNC Charlotte

Customer Technical Qualification in Analyzing of the Accreditation Scopes of Calibration Laboratories

Suelí Fischer Beckert[1] and Renan Ednan Flôres
Federal University of Santa Catarina, Brazil

In the context of metrological confirmation, calibration is an essential process in all quality assurance efforts. Several organizations choose to outsource this activity to accredited laboratories in accordance with the requirements set forth in ISO/IEC 17025: 2017. Organizations understand that accredited laboratory has formal recognition of its technical competence to perform the services within its scope of accreditation. The document ILAC P14: 2020 sets out the requirements for the statement of Calibration and Measurement Capabilities (CMCs) and for the evaluation of measurement uncertainty in calibration certificates or reports. However, when analyzing the scope of accredited laboratories in some national calibration bodies, it is possible to observe that, for the same instrument and the same measuring range, different values are attributed to CMC. If the CMC should result from normal calibration operations on the best existing device, what causes this dispersion? How can the customer make effective use of the information contained in accreditation scopes? Yes, organizations can even outsource calibration activities. But the selection of the service provider and the interpretation of the calibration results remain the customer's responsibility. This paper presents an analysis of accreditation scopes of different national calibration bodies and discusses the qualification of those in charge of metrology management, regarding the knowledge and skills required for activity.

1. Introduction

Conformity assessment based on the product specification and the measurement evaluation is important for the quality assurance of manufactured products and for the stability of production processes [1]. In this sense, providing quality measurements is necessary to ensure that measures can be used to make correct decisions. Among the main factors that impact on the quality of measurements, the measuring instruments have a direct influence on the results obtained. In the latest version of ISO 9001: 2015 [3], the requirement related to the control of measurement resources was divided into two parts: one aimed at the management of measurement processes; and another part directed to the control of the measuring instruments, an activity that ISO 10012: 2003 [3] defines as Metrological Confirmation.

Metrological Confirmation is the set of operations required to ensure that the measuring equipment conforms to the requirements of its intended use. Required requirements include range, resolution and maximum permissible errors.

ISO 14978: 2018 [4] define the maximum permissible errors for a metrological characteristic (MPE) as the extreme values of a metrological characteristic permitted by specifications, regulations, etc. for measuring equipment. This standard considers that the definition of the maximum permissible errors can be made by the manufacturer or by the user. Therefore, it is possible to observe in some ISO standards related to geometric specification instruments that the MPEs for the metrological characteristics were excluded.

But some countries such as United Kingdom, Germany and Japan have maintained national standards setting the maximum permissible errors for commercially recognized equipment. Table 1 shows the international standards for calipers and micrometers and the respective national standards of the previously mentioned countries.

In the last revision of ISO/IEC 17025 [5] in 2017 it is possible to show an orientation for calibration laboratories to meet customers' requirements (5.4, 7.1.1.d, 7.2.1.4, 7.2.1.6 and 7.8.12). This could mean that customers could establish abusive MPEs for metrological characteristics of measuring equipment. And consequently, calibration laboratories could be accredited with alternative calibration methods with higher measurement uncertainties.

It seems, at first, that calibration laboratories, even accredited, would be allowed to use inappropriate methods, as long as those accepted by customers.

This paper aims to perform an analysis of the accreditation scopes available in different accreditation bodies and to provide guidelines for users of calibration services performed by external providers to make appropriate requests. For this, calibration activity of calipers and micrometers were used as a case study.

1 Corresponding author: sueli.f@ufsc.br

International Standard	National Standard
ISO 13385-1:2019 Metrological characteristics for Calipers: • Partial surface contact error, *E* • Scale shift error, *S* • Line contact error, *L* • Full surface contact error, *J* • Error due to crossed knife-edge distance, *K* • Repeatability of partial surface contact error, *R*	• DIN 862 (2015) • BS 887 (2008) • JIS B 7507 (2016)
ISO 3611:2010 Metrological characteristics for Micrometers for external measurements: • Full surface contact error, *J* • Repeatability, *R* • Partial surface contact error, *E*	• DIN 863 (2017) • BS 870 (2008) • JIS B 7502 (2016)

Table 1. Standards for calipers and micrometers.

2. Analysis of Accreditation Scopes

Document P14: 2020 [6], issued by the International Laboratory Accreditation Cooperation (ILAC) is a policy that sets out the requirements and guidelines for the estimation and statement of uncertainty, in order to ensure a harmonised interpretation of the GUM and the consistent use of CMC.

CMC is a calibration and measurement capability available to customers under normal conditions as described in the laboratory's scope of accreditation. Also, according to ILAC P14: 2013, there shall be no ambiguity on the expression of the CMC on the scopes of accreditation and, consequently, on the smallest uncertainty of measurement that can be expected to be achieved by a laboratory during a calibration or a measurement.

Several accreditation bodies have developed complementary normative documents to guide calibration laboratories in presenting their Measurement and Calibration Capabilities. Among them: P104 issued by A2LA [7], M3003 issued by UKAS [8] and NIT-DICLA-021 issued by CGCRE [9]. The European Community uses EA 4/02 M: 2013 [10] as a reference for the measurement uncertainty evaluation and consequently also for CMC.

SAC-SINGLAS in 2019 [11] considers that CMC is one of the essential pieces of information to be used by potential customers to judge the suitability of a laboratory to carry out particular calibration work at the laboratory or on-site.

To evaluate the form and declared values of CMCs in the accreditation scopes, four accreditation bodies were consulted. The data collection of CMCs from the accreditation scopes focused on the dimensional area. More specifically, the calibration and measurement capabilities for micrometers and calipers were analysed. For external micrometers, lengths of 25 mm and 300 mm were considered. As for calipers, evaluated lengths were 150 mm and 600 mm.

The query was performed in the databases provided by A2LA [12] RBC [13] UKAS [14] and DAkkS [15] and the total of laboratories evaluated is presented in Table 2.

It was evidenced that the forms of presentation of CMC follow the models suggested in document ILAC P14: 2013

Measuring Instrument	Accreditation Body	Total Laboratories Evaluated
Micrometer	Association for Laboratory Accreditation (A2LA)	174
	Rede Brasileira de Calibração (RBC)	75
	United Kingdom Accreditation Service (UKAS)	57
	Deutsche Akkreditierungsstelle GmbH (DakkS)	25
Caliper	Association for Laboratory Accreditation (A2LA)	54
	Rede Brasileira de Calibração (RBC)	46
	United Kingdom Accreditation Service (UKAS)	34
	Deutsche Akkreditierungsstelle GmbH (DakkS)	19

Table 2. Accreditation bodies consulted on the presentation of the CMC.

Format	Example
A single value	1.0 µm 0.008 mm
A range	0.8 µm to 2 µm 0.01 mm to 0.06 mm
An explicit function	[10 + (L/50)] µm, L in meters (0.6R + 13L) µin, L in inches

Table 3. Forms of CMC presentation in accreditation scopes.

(Table 3), being the most common:

a) A single value, which is valid throughout the measurement range.

b) A range. In this case, a calibration laboratory should have proper assumption for the interpolation to find the uncertainty at intermediate values.

c) An explicit function of the measurand or a parameter.

In the verified accreditation bodies, it was observed that only A2LA presented the CMC in function of resolution, which was not observed in the other networks. On the other hand, DAkkS and UKAS present greater uniformity in form and declared CMC values.

Tables 4 and 5 present the minimum and maximum values shown in the accreditation scopes consulted.

The variation detected in the accreditation scopes requires that the user of the calibration services pay attention to their real needs and make the appropriate choice of the external provider. It should be noted that CMC represents the lowest uncertainty the laboratory can obtain, considering the best equipment available. Therefore, depending on the measuring instrument that will be subject to calibration, the measurement uncertainty obtained may be different from that established for CMC. This implies that there may still be an increase in the expanded uncertainty presented in the calibration certificate because the resolution directly impacts the measurement uncertainty. It is also important to note that the CMC declared is for the best method that laboratory performs. If there are more calibration methods, there may be an increase in uncertainty.

In a careful analysis, uniformity in the presentation of CMCs was expected, especially when it comes to measuring instruments used on a large scale. It is a fact that ISO standards wanted not to establish the maximum permissible errors for geometric specification equipment. But several countries have specific standards setting these limits. It is also observed homogeneity in MPEs established by different manufacturers for the same type of measuring instrument.

Although some ISO standards do not yet specify MPEs, they relate the metrological characteristics to be evaluated in the instruments and suggest the standards to be used. Thus, if the laboratories were using normative documents and observed the maximum permissible errors established by the manufacturers or standards, greater uniformity in CMCs could be obtained.

Table 6 presents an example of measurement uncertainty balance for the metrological characteristic full surface contact error, evaluated in a digital micrometer at 25 mm with 0.001 mm for resolution, considering normal calibration conditions and main sources of uncertainties. For this evaluation, three measurement cycles were considered. The standard uncertainties related to temperature are calculated as shown in Supplement (S4) of EA 4/02 guideline [10].

Based on Table 6, some simulations were made for different measurement conditions. The results are shown in Table 7.

In comparison with the CMCs declared in the calibration scopes (Table 4), it is clear that there is a real possibility of minimizing the existing variations.

Length	CMC	CGCRE	A2LA	UKAS	DAKKS
25 mm	Lowest value (µm)	0.3	0.2	0.9	1.4
	Highest value (µm)	3.0	14	1.6	3.8
300 mm	Lowest value (µm)	0.8	0.3	1.7	6.0
	Highest value (µm)	14	22	3.4	12

Table 4. Extreme values of CMC extracted from the accreditation scopes for micrometer.

Length	CMC	CGCRE	A2LA	UKAS	DAKKS
150 mm	Lowest value (µm)	1.0	1.6	11	34
	Highest value (µm)	30	29	19	34
600 mm	Lowest value (µm)	4.0	2.50	14	48
	Highest value (µm)	37	33	33	78

Table 5. Extreme values of CMC extracted from the accreditation scopes for calipers.

Simulations were also carried out to evaluate the expanded uncertainty of the metrological characteristic partial surface contact error in calibration of calipers. The results are shown in Table 8.

Since the accreditation process of calibration laboratories is voluntary, CMC is an agreement between the laboratory and the Accreditation Body. As the accreditation process for calibration laboratories is voluntary, the CMC is an agreement between the laboratory and the accreditation body. In view of the flexibility of ISO/IEC 17025 for the laboratory to develop its own procedures, it is the client's responsibility to critically assess the scope of accreditation and,

Source of Uncertainty	Value	Divisor	$u(x_i)$	Probability Distribution	c_i	$u_i(y)$ (µm)	υ_i / υ_{eff}
Repeatability	s_{REP}= 0 µm	√3	0	T	1	0	2
Uncertainty Calibration of the reference standard (gauge block)	U_{GB}= 0.2 µm	2	0.1	N	1	0.1	∞
Length variation of gauge block	E_{GB} = 0.2 µm	√3	0.12	R	1	0.12	∞
Micrometer resolution	Res = 0.5 µm	√3	0.29	R	1	0.29	∞
Temperature difference between micrometer and gauge block	δTemp = 0.2°C	√3	0.12	R	25000 µm x 11.5 ×10^{-6}°C^{-1}	0.03	∞
Temperature other than 20°C degrees	Δ_{Temp} x δa = 1°C x 2 × 10^{-6}°C^{-1}	√3x √6	0.47×10^{-6}°C^{-1}	---	25000 µm	0.01	∞
	Combined Uncertainty u (y)					0.33	>50
	Expanded Uncertainty U					**0.7**	k = 2.00

Table 6. Measurement Uncertainty Balance for Micrometer.

in particular, to agree with the laboratory the calibration methods that meet the inspection and process requirements.

3. Qualification of the Metrological Function

ISO 10012: 2003 (and also ISO 9000: 2015 [16]) defines the metrological function as the functional unit with technical and administrative responsibility to define and implement the measurement management system, which is a set of interrelated or interactive elements necessary for the metrological conformation and control of measurement processes.

It is a fact that metrological confirmation directly affects the control of measurement processes, since instruments are devices used to monitor and measure manufacturing processes and products, respectively. Maybe that's why organizations use the tolerance of products as basis for defining the MPEs for measuring instruments. However, this should not be the order of the activity's execution. And yes, from the metrological confirmation, the equipment should be selected for the measurement tasks. Even because the measurement processes are subject to other sources of variation, such as the measurand itself, operator, environmental conditions, etc. To analyze the quality of measurement processes, statistical methods as set out in MSA [17] or VDA 5 [18] manuals are widely used. And for application of these methods, verified measuring instruments should be selected. More advanced studies also operate with probabilistic calculations to estimate the risks of incorrect inspections [1] [19,20].

Length (mm)	s_{REP} (µm)	U_{GB} (k = 2) (µm)	E_{GB} (µm)	Res (µm)	δ_{Temp} (°C)	Δ_{Temp}≠20°C (°C)	U (µm)	k
25	0	0.2	0.2	0.5	0.2	1	0.7	2.00
	1	0.5	1	0.5	1	3	2.0	2.23
	0	0.2	0.2	1	0.2	1	1.2	2.00
	1	0.5	1	1	1	3	2.2	2.13
	0	0.2	0.2	2	0.2	1	2.3	2.00
	1	0.5	1	2	1	3	2.9	2.00
300	0	0.2	0.9	0.5	0.2	1	1.5	2.00
	1	0.5	3	0.5	1	3	5.5	2.01
	0	0.2	0.9	1	0.2	1	1.8	2.00
	1	0.5	3	1	1	3	5.6	2.01
	0	0.2	0.9	2	0.2	1	2.7	2.00
	1	0.5	3	2	1	3	6.0	2.00

Table 7. Expanded uncertainty estimated for different measurement conditions (micrometer).

Length (mm)	s_{REP} (mm)	U_{GB} (k = 2) (µm)	E_{GB} (µm)	Res (mm)	δ_{Temp} (°C)	$\Delta_{Temp} \neq 20°C$ (°C)	U (mm)	k
150	0	0.2	0.8	0.005	0.2	1	0.01	2.00
	0.01	2	5	0.005	1	3	0.02	2.87
	0	0.2	0.8	0.01	0.2	1	0.02	2.00
	0.01	2	5	0.01	1	3	0.02	2.28
	0	0.2	0.8	0.025	0.2	1	0.03	2.00
	0.01	2	5	0.025	1	3	0.04	2.02
600	0	0.3	1.3	0.005	0.2	1	0.01	2.00
	0.01	2	8	0.005	1	3	0.02	2.25
	0	0.3	1.3	0.01	0.2	1	0.02	2.00
	0.01	2	8	0.01	1	3	0.03	2.13
	0	0.3	1.3	0.025	0.2	1	0.03	2.00
	0.01	2	8	0.025	1	3	0.04	2.00

Table 8. Expanded uncertainty estimated for different measurement conditions (caliper).

In metrological confirmation activities, the calibration and verification of the measuring instruments are fundamental. Verification is defined in VIM [21] and ISO 9001 [2] as the objective proof that a given item satisfies the specified requirements. Verification after calibration compares calibration results with established MPEs for metrological characteristics. In an internal process, it is up to the metrological function to define these limits [4]. For definition of MPEs, the specifications given by manufacturers and normative documents should be considered. This is because the design characteristics are set to meet a certain level of accuracy of the equipment. Applications of measuring instruments should be taken into account in the MPEs definition, allowing longer equipment life and less intervention for adjustments. But care should be taken in adopting larger MPEs. Values well beyond those specified by manufacturers may lead the instrument to operate at levels for which it was not built, and may also negatively compromise the organization's metrological culture.

In order to define the maximum permissible errors, the following qualifications of the metrological function are required: to know principles of operation of measuring system and the measurement processes in which it will be used. A common practice is not to apply acceptance criteria for measuring instruments already in use that are more than twice the MPEs established by manufacturers or normative documents.

Once the maximum permissible errors are defined, the next step is to evaluate how they should be compared to the calibration results.

The complete result of a calibration shows values obtained for the metrological characteristics together with the measurement uncertainty. The measurement uncertainty corresponds to the confidence interval within true value can be assigned, with a confidence level of approximately 95%. Higher uncertainty values can make metrological verification process unfeasible if the main sources of variation are due to the calibration process itself and not to the equipment being evaluated.

In this step, a fundamental requirement in metrological verification should be considered: the selection of external provider to carry out the calibration. Unless the organization has technical support of its supplier and has credibility in the information passed by him, the metrological function shall be technically qualified in terms of calibration methods and measurement uncertainty. Then, the metrological function may perform a critical analysis of the CMCs declared by the calibration laboratories. Typical sources of measurement uncertainty in calibration are repeatability, the uncertainty of the gauge used and the measuring instrument resolution. In dimensional area, uncertainty sources of temperature variation may also impact the calibration results, especially when it comes to longer lengths. It is important to note that CMCs declared in accreditation scopes usually have been calculated considering the best existing equipment, unless the reference gauge fails to meet this condition.

In practical terms, the organization can estimate a measurement uncertainty for a given piece of equipment from the declared CMC. Two sources of uncertainty that can directly impact on the expanded uncertainty are repeatability and resolution. Equation (1) calculates an estimate for the measurement uncertainty of calibration, when the instrument does not fit as the best existing device. This equation is also applicable to cases where contributions to the uncertainty from the device are not included in the CMC presented in the scope of the laboratory's accreditation.

$$U = 2\sqrt{\left(\frac{CMC}{2}\right)^2 + \left(\frac{Res}{q\sqrt{3}}\right)^2 + (s_{REP})^2} \quad (1)$$

where
Res is the resolution of the measuring instrument, used during calibration (apply q=1 for analog instruments and q=2 for digital instruments); and
s_{REP} is the repeatability standard deviation.

It is important to note that in analog instruments, the resolution can be a fraction of the value of the division indicated on the instrument. For example, in a micrometer with the lowest indicated division of 0.01mm, the laboratory may adopt a resolution of 0.001 mm or 0.002 mm in the calibration. For digital instruments, the resolution corresponds to the digital increment.

Another relevant way to obtain consistent information is to request the external supplier to discriminate in a budget the least possible uncertainty to be obtained, considering the specific metrological characteristics of the measuring instrument and the procedure that will effectively be used in the calibration.

Having clarity about the information passed on by the external provider, it is possible to compare them with the organization-defined MPEs and thus to be able to select the calibration service provider appropriately.

4. Conclusion

This paper sought to contextualize the variations existing in the presentations of accreditation scopes. In order to promote greater homogeneity among laboratories, it is important that customers request calibration procedures compatible with the functional and metrological characteristics of measuring instruments, established in standards or by manufacturers.

In this sense, it is necessary for the metrological function in companies to have technical knowledge about the functionality of the measuring instruments, the metrological characteristics that need to be checked, the definition of maximum permissible errors, calibration method and associated uncertainties, interpretation of accreditation scopes and calibration certificates.

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An Intercomparison Between Primary High-Pressure Gas Flow Standards with Sub-Permille Uncertainties

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1. Introduction

Currently, state-of-the-art commercial calibrations of high-pressure gas flowmeters are performed with uncertainties that range between 0.13% and 0.25%, depending on pressure and flowrate. These measurement capabilities are traceable to primary standards using several steps in which the flowrate range and pressures are increased. For the primary high-pressure calibration facilities in Western Europe these traceability chains are described in [1]. In France a pVTt tank is used, in The Netherlands, Germany and Denmark piston provers are used. The National Metrology Institutes and Designated Institutes of these countries cooperate with the high-pressure calibration laboratories in the EuReGa consortium (European References for Gas).

Every three years, after recalibration of the participants' high-pressure gas flow laboratories, EuReGa organizes an intercomparison at the level where commercial calibrations are performed. These results are used to average the traceability chains of the laboratories, which also results in lower uncertainties. This process is called harmonization and the procedure and data processing is described in [2]. The results of the harmonization exercises are reported by EuReGa [3]. In the past 20 years of harmonization, the differences between the laboratories have diminished and the uncertainties have improved [2].

After the success of 20 years of intercomparisons, EuReGa extends the intercomparisons to the level of the primary standards. These are operated with sub-permille uncertainties, i.e. with expanded uncertainties ($k = 2$) better than 0.1%. Unfortunately, the French colleagues cannot participate. Their primary pVTt tank operates at variable pressure. For the pVTt tank critical flow Venturi nozzles (sonic nozzles) are suitable as intercomparison devices as their mass flowrate does not depend on the downstream pressure. An intercomparison between LNE-LADG, PTB, NIM and NIST using sonic nozzles [4], demonstrated the equivalence of the French and the German primary standards.

The two DN100 turbine gasmeters used in this comparison have been used in previous EuReGa intercomparisons. The last time in 2017 – 2018 [3]. In this paper these results will be compared with the present results utilizing piston provers.

2. Piston Provers

The characteristics of the piston provers are listed in Table 1. VSL uses a 24″ gas-oil Piston Prover (GOPP). The prover is filled with oil on one side and gas on the other side of the free moving piston. The maximum flowrate is 230 m³/h. PTB uses a 10″ gas-gas Piston Prover (HPPP), it consists of a honed 250 mm diameter in which a piston can travel at a maximum speed of 3 m/s (approx. 480 m³/h) over a length of 6 m with an effective measurement length of 3 m. Finally, FORCE Technology uses a 26″ Twin gas-gas Piston Prover with two parallel cylinders with bidirectional pistons inside them. The actuated pistons can displace up to 400 m³/h. The bottom row of Table 1 shows the CMC uncertainties, which range between 0.065% and 0.086%.

Institute Country	**VSL** The Netherlands	**PTB** Germany	**FORCE** Denmark
Primary device	24” Gas Oil Piston Prover (GOPP)	10” Piston Prover (HPPP)	26” Twin Piston Prover
Piston	Passive	Passive	Active
Nominal diameter	600 mm	250 mm	660 mm
Absolute operating pressure	1 – 62 bar	8 – 51 bar	1 – 66 bar
Piston stroke	12 m	6 m	2.8 m
Effective piston stroke	6.5 m	3 m	0.6 – 2.7 m
Flowrate range	3 – 230 m³/h	3 – 480 m³/h	2 – 400 m³/h
Maximum piston speed	0.25 m/s	3 m/s	0.17 m/s
CMC (k = 2)	0.070 – 0.086 %	0.065 %	0.080 %

Table 1. Characteristics of the piston provers of the participants.

3. Meter Packages and Test Protocol

The turbine gasmeters used in this intercomparison, are part of a so-called meter package. Each meter package consists of a flow conditioner, an inlet spool, a G250 turbine gasmeter and an outlet spool with thermowell. The package is shipped and stored in its entirety. The meter packages are labelled EuReGa DN100 M1 and EuReGa DN100 M2, which will be denoted in the rest of this paper by M1 and M2, respectively.

The packages are calibrated individually, not in series like in the previous intercomparisons. The meters are calibrated at flowrates 25, 40, 65, 100, 160, 250 and 400 m³/h at absolute pressures of 8, 20 and 50 bar. At each flowrate the laboratories report the meter deviation e, which is the average of four or five successive measurements, and its expanded measurement uncertainty. PTB and Force cover the entire range while VSL covers the range up to 200 m³/h. In addition, VSL calibrated only the M2 package [5].

The long-term performance of the intercomparison packages was reviewed in 2013 [6]. In a period of 6 years in which 5 intercomparison rounds were performed, the DN100 meters showed a random drift of approximately 0.1%.

The calibration results obtained by the piston provers is compared with the results of the previous intercomparison [3], performed in 2017-2018 using the same pressures and flowrates as above. Force and LNE-LADG performed the calibrations at all pressures and flowrates. LNE used air instead of natural gas. PTB cannot perform routinely calibrations at 8 bar and the M1 and M2 meter packages are too small for calibration by VSL. The data of the previous intercomparison were reprocessed in the same way as the calibration results obtained with the piston provers. In addition, PTB calibrated both meters in the Braunschweig flow facility with atmospheric air. Table 2 presents a schematic overview of the calibration data included in the present study.

4. Data Processing and the PTB Turbine Gasmeter Model

The data processing is done identically to [8], [7]. For each combination of pressure and flowrate, the weighted average of the laboratories' results is calculated with the associated uncertainty. These are fitted in the Reynolds domain by a least-squares approximation.

Up till the present intercomparison, the calibration data were fitted using the formula

$$e_{Re} = \sum_{j=0}^{n} a_j \,[\log(Re/10^6)]^j \qquad (1)$$

		Piston prover intercomparison		2017-2018 intercomparison	
Institute	**Fluid**	**M1**	**M2**	**M1**	**M2**
VSL	Natural gas		8, 20, 50		
PTB	Natural gas	8, 20, 50	8, 20, 50	20, 50	20, 50
FORCE	Natural gas	8, 20, 50	8, 20, 50	8, 20, 50	8, 20, 50
LNE-LADG	Air			8, 20, 50	8, 20, 50
PTB	Air			atmospheric	atmospheric

Table 2. Overview of the current and previous intercomparisons. The figures in the cell indicate the calibration pressure in bar.

Meter	b_0 [kg m³/s²]	b_1 [kg/s]	$c_{p,air}$	$c_{p,NG}$
M1	-7.64·E-05	-2.45·E-02	-9.65·E+05	-2.34·E+05
M2	-8.17·E-05	-3.65·E-02	1.80·E+05	1.00E+06

Table 3. Values of the coefficients of the turbine gasmeter model for meter packages M1 and M2.

where e_{Re} is the meter deviation that is dependent of the Reynolds number. The coefficients a_j (j=0..n) are obtained by curve fitting. The value of n is chosen from 1 to 4, depending of the best curve fit result. The factor 10^6 is introduced to obtain arguments of the logarithm that are around 1, which supports the numerical stability of the least-square approximation. The *Re* number is defined as

$$Re = \frac{\rho v D}{\eta} = \frac{4\rho Q}{\pi D \eta} \quad (2)$$

where ρ is the density, D the nominal internal diameter of the meter, η the dynamic viscosity and Q the volume flowrate.

Equation (1) works well as long as the meter behaviour is dominated by flow forces. At low flowrates the bearing friction causes the turbine gasmeter to deviate from the Reynolds behaviour. An interaction between the turbine wheel and the pressure measurement point will become significant at high flow speeds at the turbine wheel (Mach number effect) and is small for modern, balanced turbines (in order of 0.1 to 0.2%). Now the deviation of the meter under test (MuT) e_{MuT} can be composed of a contribution of the flow force e_{Re} in equation (1), a contribution due to the bearing friction e_b and a contribution due to the Mach effect at high flowrates e_p.

$$e_{MuT} = e_b + e_{Re} + e_p \quad (3)$$

where $e_b = \frac{b_0}{\rho Q^2} + \frac{b_1}{\rho Q}$ (4) and $e_p = c_p Q^2 \frac{\rho}{p}$ (5)

Equations (1, 3, 4, 5) form the PTB turbine gasmeter model [9]. In the period 2007–2019 the experiments to have an independent measurement of the coefficients for bearing friction and the Mach effect dependencies were determined [10]. The coefficients b_1, b_2 and c_p are to be established for each individual meter. In addition, c_p is depending on the type of gas, air or natural gas. The coefficients were determined when both meter packages were for calibration at PTB in Braunschweig using atmospheric air. After the normal calibration, a so-called spin-down test was performed under low-density, no-flow conditions. In addition, so-called jump tests were performed, in which during steady conditions the flow is suddenly increased or decreased with 10% Q_{max}. The characteristic times obtained from both experiments result in the coefficients [10].

5. Calibration Data and Least-Squares Approximation

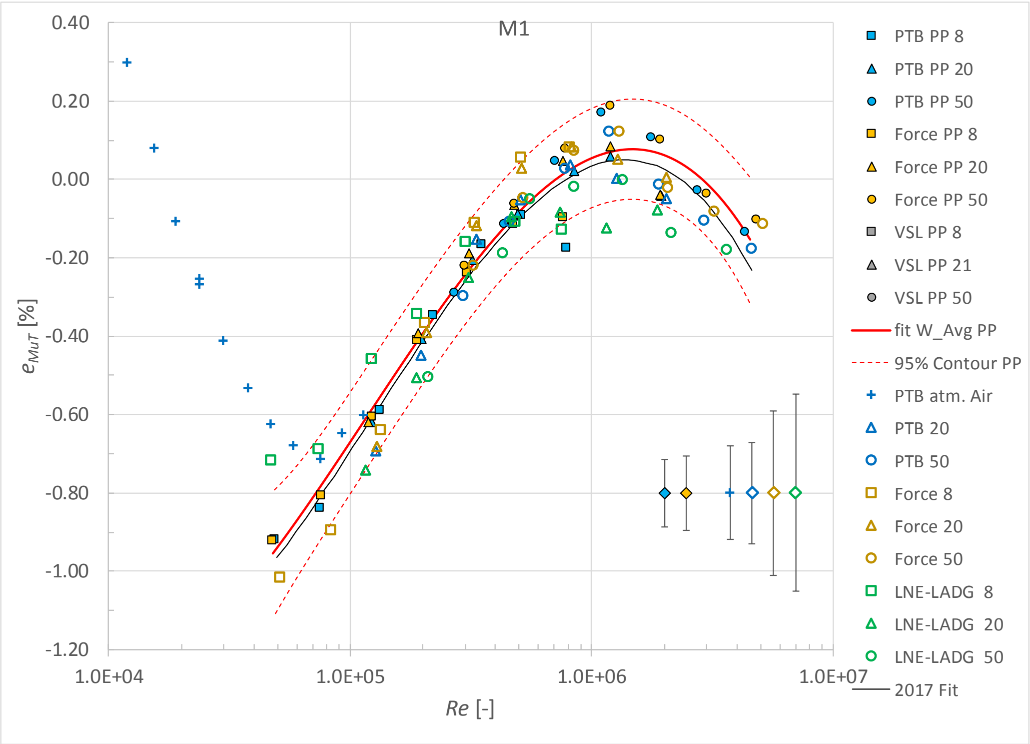
Figure 1 depicts all calibration data as the observed deviation e_{MuT} versus the Reynolds number *Re*, which is plotted on a logarithmic scale. In this way the results obtained at different pressures can be compared. For meter package M1 the results are shown in the upper part of Figure 1. The results of meter package M2 are shown in the bottom part of Figure 1. The scale divisions of both figures are equal, as is the legend. The first impression is that both meters have different characteristics, which is understandable as the meters are different brands.

The solid markers represent the calibration results obtained when using the piston provers. The red solid line is the least-squares fit of the weighted average of the laboratories' results and the dashed lines represent the 95% uncertainty contours. The open markers represent the calibration results from the previous intercomparison [3]. The black solid line is the least-square approximation of the weighted averages of the intercomparison data. For reference, the associated expanded uncertainties are indicated in the bottom-right corner of each figure. It clearly shows that the results obtained with the piston provers have a much lower uncertainty than the results of the previous intercomparison.

The shape of the black line has a similar shape as the red fit, running between its 95% contours and not deviating more than 0.05% from the red fit. Most data agree within their uncertainty with the fit. This clearly demonstrates the consistence of the previous intercomparison results with the present calibration results obtained by the piston provers.

As the data points of the calibrations with atmospheric air are in a much lower Reynolds range than the pistop prover intercomparison, they are excluded from the fits. For meter package M1 the air flow results are within the 95% contours. At lower flowrates the curve bends away from the fit. Here the influence of the bearing friction becomes visible. For M2 the upper air flow data points are parallel to the fit at approximately 0.25% distance which is greater than the uncertainty.

The next step is the application of the turbine meter model. Each individual data point is corrected for the influence of the bearing friction and the high-speed Mach effect, using equations (4) and (5) and the constants of Table 3. For each data point e_b and e_p are calculated and subtracted from e_{MuT}, which results in e_{Re}. This is done for



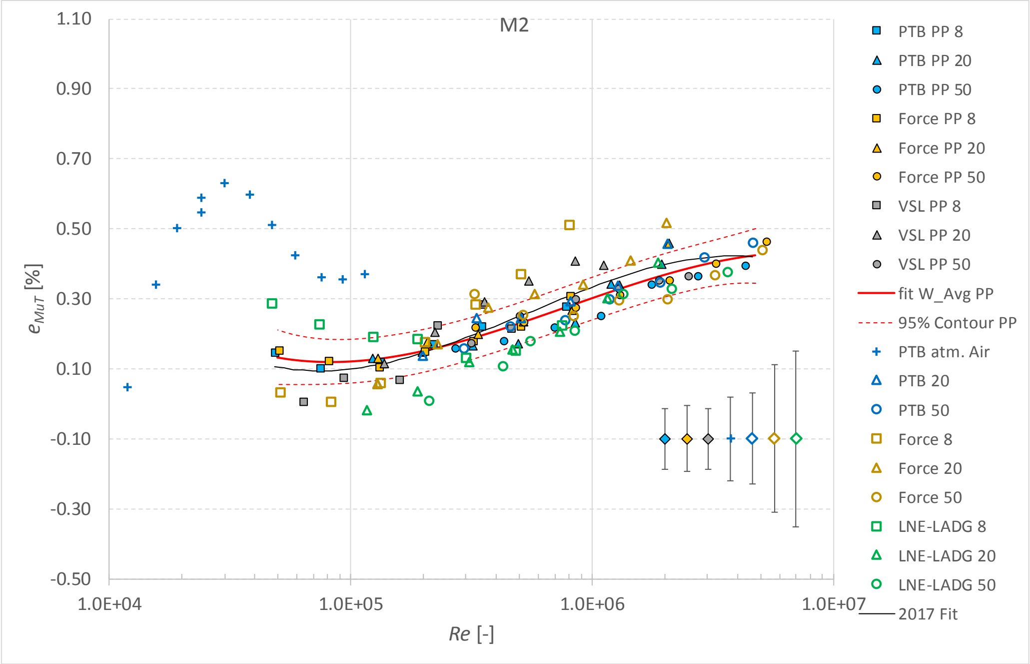


Figure 1. Calibration results of the DN100 turbine gasmeters M1 upper and M2 bottom. The meter deviation e_{MuT} [%] is plotted versus the Reynolds number *Re* [-] on a logarithmic scale. The solid markers represent the results obtained with the piston provers. The red solid line is the least-squares fit of these results and the dashed lines represent the 95% uncertainty contours. The open markers are the result from the previous intercomparison [3]. The black solid line is the fit of these intercomparison data. The crosses (+) are the calibrations with atmospheric air, which are excluded from the fits. For reference the associated expanded uncertainties are indicated in the bottom-right corner.

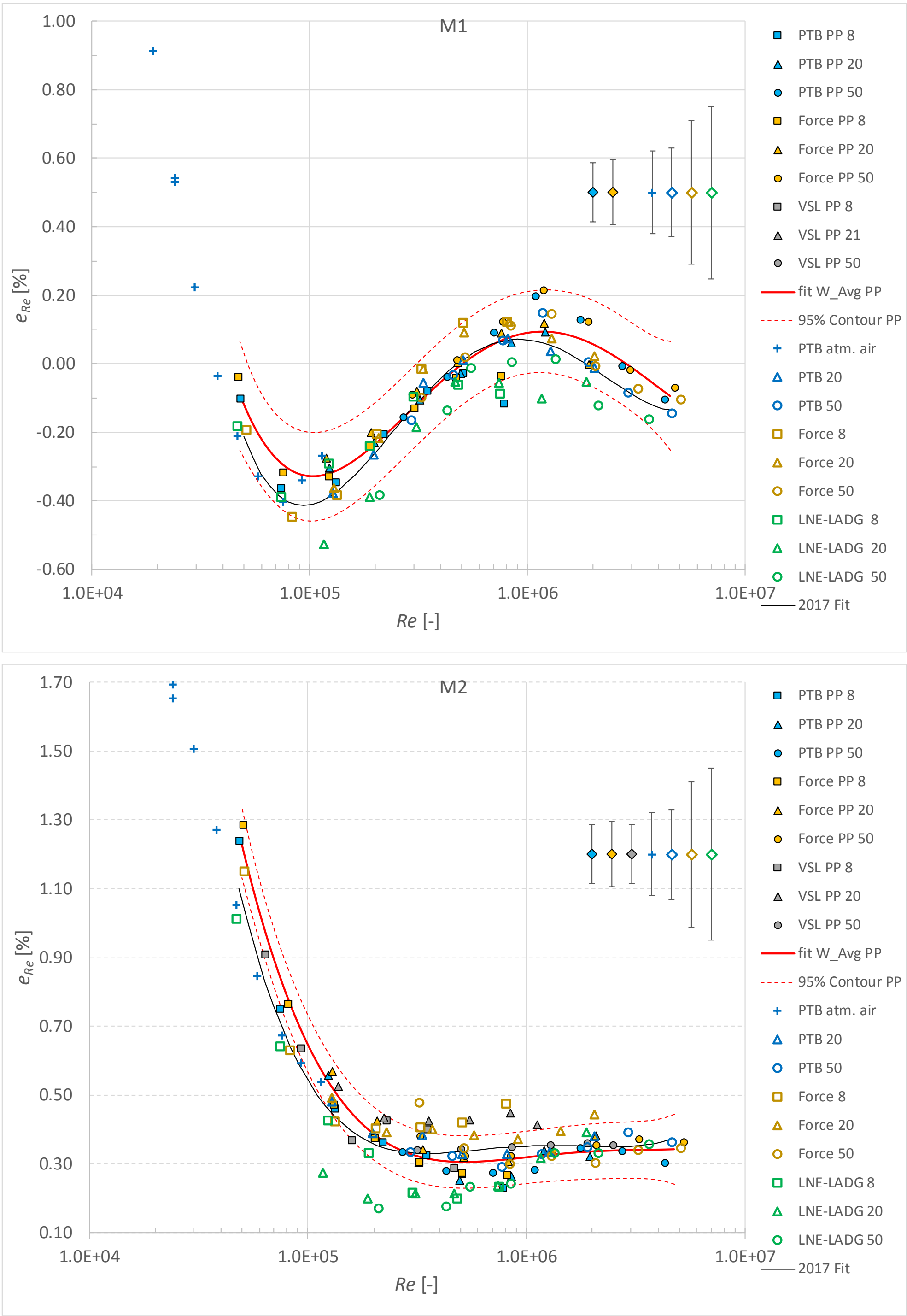


Figure 2. Calibration results of the DN100 turbine gasmeters M1 upper and M2 bottom. The meter deviation e_{Re} [%] is plotted versus the Reynolds number *Re* [-] on a logarithmic scale. The solid markers represent the results obtained with the piston provers. The red solid line is the least-squares fit of these results and the dashed lines represent the 95% uncertainty contours. The open markers are the result from the previous intercomparison [3]. The black solid line is the fit of these intercomparison data. The crosses (+) are the calibrations with atmospheric air, which are excluded from the fits. For reference the associated expanded uncertainties are indicated in the upper-right corner.

both the calibrations with the piston provers, the earlier obtained intercomparison results and the calibration results obtained with atmospheric air. Like Figure 1, Figure 2 depicts the results of e_{Re}. Again, the characteristics of both meter packages are different.

Most data points agree within their uncertainty with the fit (red line) of the weighted averages of the piston prover calibrations. The black line, i.e. the fit of the previous intercomparisons, has the same shape as the red line fit and lies for meter package M1 within the 95% contours. For meter package M2 the black line is in the upper Reynolds range within the red 95% contours. For the lower Reynolds range it is running parallel to the red fit. The data of the atmospheric air calibrations connect to the visual extrapolation of both the red-line and black-line fits of e_{Re}. The atmospheric-air data are within the 95% contours of the M1 package. For the M2 package, the atmospheric-air data are in the lower range quite close to the contours of the fit.

In conclusion, the turbine meter model is an adequate method to connect the calibration data obtained with natural gas at different pressures on one side and the calibration data with atmospheric air at the other. After applying the turbine meter model, the consistency of the piston prover results with results from previous intercomparisons remains.

6. Normalized Deviations

The processing of the measurement data is done according to [8], [6]. Instead of using the laboratory observations e_{MuT}, the values corrected for bearing friction and Mach effect e_{Re} are used now. The data analysis is performed in the Reynolds domain. In this way the results obtained at different pressures can be compared. For each combination of pressure and flowrate $\bar{e}_{Re}$ is the weighted average of the deviations e_{Re} observed by the labs, which makes $\bar{e}_{Re}$ the reference level, also referred to as common reference value (CRV). The small differences between the corresponding Reynolds numbers of the laboratories' observations are ignored.

The next step is to calculate the deviations $d = e_{Re} - \bar{e}_{Re}$ with respect to the CRV ($e_{Re} = \bar{e}_{Re}$ or d = 0) and the corresponding uncertainties, calculated from $U^2(d) = U^2(e_{Re}) - U^2(\bar{e}_{Re})$.

The normalized deviations $E_n = d/U(d)$ are shown in Figure 3. Here E_n values are plotted versus the Reynolds number *Re*. The CRV ($E_n = 0$) is only based on the calibration results obtained with the piston provers. The results of the previous intercomparisons are also included. The data were processed for meter packages M1 and M2 separately. The results are combined in one graph. The markers for M1 obtained by piston prover have a red border, for M2 this is a black border. The open markers corresponding with

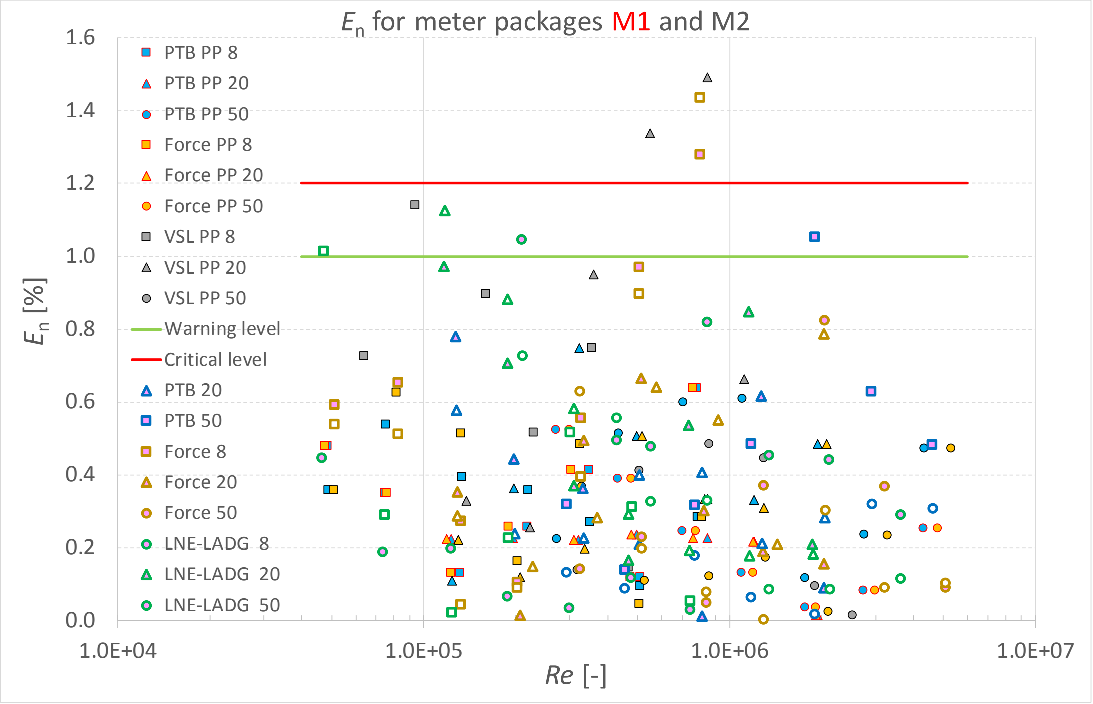


Figure 3. E_n [-] values versus *Re* number [-]. The green horizontal line is the warning level corresponding to E_n = 1. The horizontal red line is the critical level corresponding to E_n = 1.2.

	2019 Piston Prover		2017-2018 Intercomparison	
Histogram Bin	Number	Percentage	Number	Percentage
$0 \leq E_n \leq 0.5$	80	78.4%	79	70.5%
$0.5 < E_n \leq 1$	19	18.6%	27	24.1%
$1 < E_n \leq 1.2$	1	1.0%	4	3.6%
$E_n > 1.2$	2	2.0%	2	1.8%
Total	102	100.0%	112	100.0%

Table 4. Frequency distribution of observed E_n values.

the previous intercomparison, have a blank filling for M2 and a pink filling for M1. There are no E_n results for the atmospheric-air calibrations because there is no second lab in the *Re* range covered. Figure 3 shows that most of the normalized deviations are below $E_n = 1$. From the piston prover results two data points exceed the critical level and one exceeds the warning level. From the previous intercomparison four data points exceed the warning level and two data points exceed the critical level.

Table 4 shows the complete frequency distribution of the observed E_n values. This table confirms that 95% of the results matches $E_n \leq 1$. Approximately 74% of the results matches $E_n \leq 0.5$. Only 2% of the results exceeds the warning level $E_n = 1.2$.

7. Summary

A recently performed intercomparison between three laboratories using the piston provers as a primary reference, was re-evaluated using PTB's turbine meter model. The two DN100 transfer packages that were calibrated, were also utilized in a previous intercomparison and were calibrated at PTB using atmospheric air.

The unprocessed data show that most of the piston prover data lie within the 95% contours of the fit. Most of the data from the previous intercomparison also lie within the 95% contours of the fit of the piston prover results, which proves the consistency of the two intercomparisons. Only the air calibration results, which were measured at much lower Reynolds numbers show a different course.

In the PTB turbine meter model the meter deviation is split up into three contributions: the bearing friction, a high-speed Mach effect and the remaining flow forces. When the first two contributions are corrected for, a much better connection with the air calibration data is achieved. The consistency between the piston prover data and the data from the previous intercomparison remains. This makes the turbine meter model promising for future intercomparisons that are performed in a wider Reynolds number range.

For all calibration data except the atmospheric-air data, the normalized deviation E_n was calculated using the weighted average of the piston prover calibration as common reference value. At least 95% of the data matches the $E_n \leq 1$ criterion. Only 2% of the results exceeds the warning level $E_n = 1.2$.

8. Notation

Symbols

a	coefficient	
b	coefficient	
c_p	coefficient	
D	Nominal internal diameter of the turbine gasmeter	[mm]
d	deviation between measured deviation and CRV: $d = e - \bar{e}$	
E_n	Normalized deviation	[-]
e	deviation or error	[-]
$\bar{e}$	average deviation, CRV	[-]
k	coverage factor	[-]
n	maximum grade of the interpolation of e_{Re}	[-]
Q	volume flowrate	[m³/h]
Re	Reynolds number	[-]
U	expanded uncertainty	
u	standard uncertainty	

Index

b	bearing friction
j	coefficient index
max	maximum condition
MuT	meter under test
p	pressure dependent
Re	flow force

Abbreviations

CMC	Calibration and Measurement Capability, i.e. the expanded uncertainty ($k = 2$) that can be achieved for a near ideal instrument under test
CRV	Common Reference Value
DoE	Degree of Equivalence, = normalized deviation
MuT	Meter under Test
TRM	Transfer Reference meter

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Enhancing the Accuracy of a Power and Energy Standard

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Changing requirements in the world's energy market are pushing the measurement performance of existing equipment to their limits. As the accuracy requirements increase, existing precision sources become marginal. Yet, replacing the existing three phase calibrated energy source with improved performance instrumentation is expensive. Many companies are looking for more cost-effective solutions and have started using less accurate three phase sources paired with a more accurate energy reference standard to achieve the accuracies required. However, using this method is more time consuming because the source has to be set and then adjusted until the reference standard meter reads the correct value before it can be compared to the UUT's reading. We believe a similar level of accuracy can be achieved by characterizing the source with a reference standard meter and using that characterized value for a period of time. This allows the test system to run almost as fast and efficiently as it would using a more accurate source, saving labs time and money.

This paper explains how software can be used to monitor and chart the energy output of the Meatest M133C Power and Energy Standard (or similarly offered as a Fluke 6003A/E) using a Radian Research RX-33 Reference Standard tracking Frequency, Voltage, Current, Power, and Power Factor over a period of two weeks. This paper also shows that measurement uncertainties were greatly reduced, allowing for a wider range of equipment the system would now be able to test. Test labs investing in a high accuracy energy meter now have the option to use that energy meter to calibrate their energy source in place. They save on shipping cost and calibration costs because one meter can be used to calibrate, monitor, and chart multiple energy meters.

Background

The front line, point of use, energy meters used in residential, commercial, and industrial areas have measurement accuracies across a wide range of performance. It ranges through accuracies from several percent to a tenth of one percent. In turn, the power/energy standards and systems supporting the testing and calibration of these must have accuracies significantly better than what they are testing.

Industry quality standards, such as those managed by the American National Standards Institute (ANSI), the International Electrotechnical Commission (IEC), or other national organizations around the world govern the requirements of this performance verification and testing relationship. In particular this paper will focus on the metrology quality processes found in the appropriate IEC standards, in particular several within the IEC 62052 and IEC 62053 series of documents. These standards address the wide range of aspects that can influence this process. Just the electrical signal characteristics alone include voltage, current, and power measurement performance; additional parameters such as time, harmonics, and so on are also covered.

Beyond these basic parameters, these standards give additional requirements for other test conditions as they affect the measurement performance as well, from temperature and environmental conditions, to testing methodology, to loading, and the list goes on.

In this study, we will focus on the general key areas of electrical measurement accuracy of the unit under test, the accuracy of the testing system energy source, the requirements of the ratio of these two accuracies, and the uncertainty of the measurement/testing process. As our intention, we will focus on techniques used to improve these parameters for the quality benefit of the test being done.

Energy Market Test Requirements

It is specified in IEC 62052-11 section 7.3[1] that the total measurement uncertainty (that is the combination of the error of the testing device and the other contributing errors influencing the measurement) should be no more than one fifth of the maximum error limits for the unit being tested. So in a simple application, a Class 1 billing meter has 1% accuracy, so the overall uncertainty of the test must be no more than 0.2% of the parameter being tested.

Considering that the required accuracies apply to the range of differing energy meter classes from class 1 or class 2 (from one or two percent error) to class 0.1 or 0.2 (0.1 to 0.2 percent error), the requirements of a test system must adequately cover these ranges.

In the overall consideration of these functions and the associated required accuracies define the capabilities of the equipment needed to support front line energy measurement instrumentation.

But expanding and looking beyond the front line power utilities organization's needs, the support system of testing accuracy steps up significantly when considering the improving accuracies needed for full support of the power/energy industry and its infrastructure. For example, both the manufacturers of power/energy meters, and the regional governmental agencies used to oversee the energy meter test systems have even tighter accuracy requirements to properly support their responsibilities. This expands further when considering accuracies needed for the national government agencies charged with maintaining a country's measurement requirements are properly functioning.

To address this accuracy performance profile, the uncertainties needed range from frontline requirements with test system accuracies of energy measurements 0.02% to higher performance energy measurements at 0.005% for more advanced requirements.

In order to get these levels of accuracy, often a precision power/energy source alone is not accurate enough. For example, such sources have a specification of 0.04% to 0.16% (as shown in the example of the M133's performance specifications, shown in Table 1) are not accurate for the required test accuracy. As a result, such a source is often used in conjunction with a precision energy measurement standard. This precision measurement standard is often integrated in a power/energy system so the accuracy of the system is a combination of the stable precision source being simultaneously measured by a more precise measurement standard. This can be considered a characterization measurement where the generated signal is characterized and has an overall accuracy that is sufficient for the task.

Using a combination precision source and precision measurement device has definite advantages. Also, there are various methods to use a combination of these devices to get the desired/required performance. We will present some alternative ways to combine these devices and compare the different results.

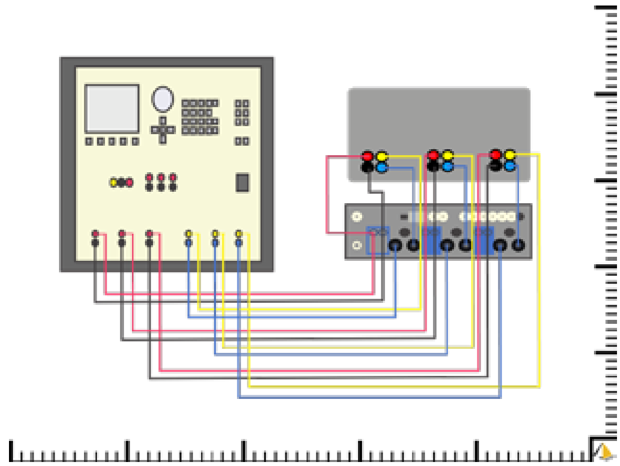

Figure 1. This connection is used with the Radian Research RX-33 and the UUT is connected in parallel to the Meatest M133C.

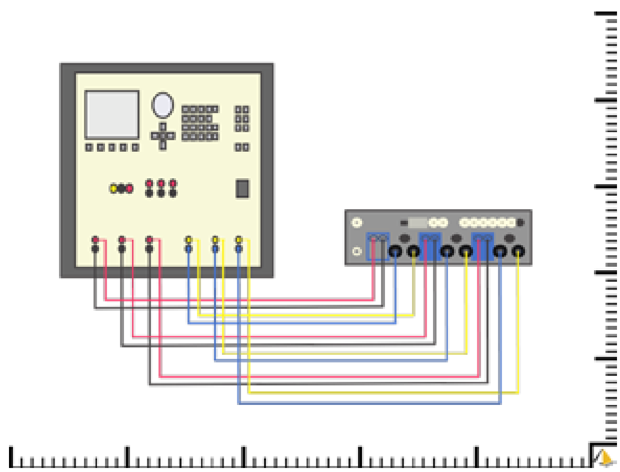

Figure 2. Meatest M133C directly connected to the Radian Research RX-33 for characterization.

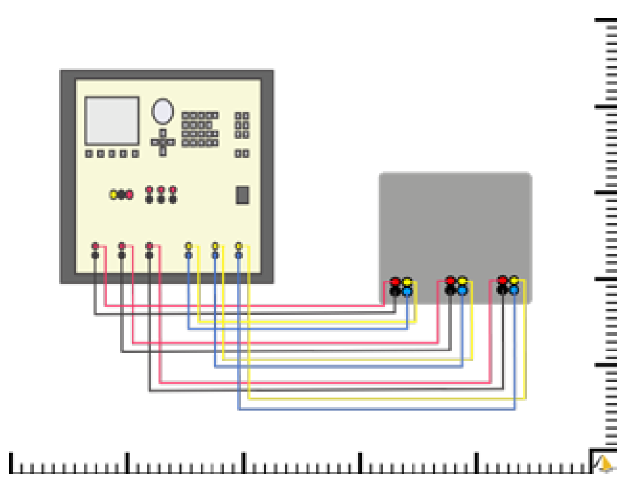

Figure 3. Direct connection from the Meatest to the UUT.

AC Electric Power*		Total Range:	3x (0.005 VA to 18 kVA (900 kVA with current coil option 140-50))			
		Frequency Range:	15 Hz to 1000 Hz			
		Quantity:	W. VA. VAr			
PF = 1.0 f = 40-70 Hz	Voltage Range					
Current Range	1 V - 10 V	10 V - 30 V	30 V - 70 V	70 V - 140 V	140 V - 280 V	280 V - 600 V
5 mA - 100 mA	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %
100 mA - 5 A	0.04 %	0.04 %	0.04 %	0.04 %	0.04 %	0.05 %
5 A - 10 A	0.05 %	0.05 %	0.05 %	0.05 %	0.05 %	0.06 %
10 A - 30 A	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %
PF = 0.5 f = 40-70 Hz	Voltage Range					
Current Range	1 V - 10 V	10 V - 30 V	30 V - 70 V	70 V - 140 V	140 V - 280 V	280 V - 600 V
5 mA - 100 mA	0.16 %	0.16 %	0.16 %	0.16 %	0.16 %	0.16 %
100 mA - 5 A	0.08 %	0.08 %	0.08 %	0.08%	0.08%	0.08 %
5 A - 10 A	0.08 %	0.08 %	0.08 %	0.08 %	0.08 %	0.08 %
10 A - 30 A	0.16 %	0.16 %	0.16 %	0.16 %	0.16 %	0.16 %
*Best accuracy for active power.	Electric power accuracy is calculated according to formula: $dP = \sqrt{(dU^2 + dI^2 + dPF^2 = 0.012)}$ (%)					

Table 1. Meatest M133C Electrical Power Source Specifications [2]

Function	Reading	**% Accuracy** (ppm) TCAL ±5°C	**% Accuracy** (ppm) at Power Factor=1	**Stability** (ppm√ Month)	**17025 Cal Uncertainty** (ppm)	**Temperature Coefficient** (ppm/°C)
		RX-33	RX-32	RX-33		
Potential (U)	30 v to 600 V	0.005 % (50)		2	30	1.5
Direct AC Current (I)	1 mA to 200 A	0.007 % (70)		3	50*	3
Power		0.01 % (100)	0.005 % (50 ppm)	4	50*	5
Energy		0.01 % (100)	0.005 % (50 ppm)	4	50*	5
Phase Angle	0° to 360°	0.003°				
Frequency	45 Hz to 65 Hz	0.0001 % (1)		0.3		0.05
*For Power Factor = 1 Cal Uncertainty = 30 ppm						

Table 2. Radian Research RX-33 Energy Reference Standard Specifications [3]

Test System Setup

This test system can be configured in two ways. The first is the traditional way where you connect the reference meter and the UUT meter to the 3-phase energy source at the same time in series/parallel (Figure 1).

However, this paper will focus on the second method of characterizing the Meatest M133C with the Radian Research RX-33, a high-accuracy energy meter with accuracy in the 100 ppm range. The M133C will be first connected to the RX-33 directly (Figure 2) for the characterization process. The software can then characterize several specific test points that will be used to test the UUTs directly.

Once the M133C has been characterized, it can then be connected to the UUT directly (Figure 3). Now the enhanced accuracy can be applied based on the RSS (Root Sum Squared) uncertainties of the RX-33 and the short-term reproducibility of the M133C. Because the M133C's short-term stability is unknown, we have to collect this data and perform an uncertainty analysis on the data to assign a specification. This method allows the system to be characterized once a day or once a month. It all depends on the stability of the M133C being used and the accuracy requirements of the UUTs being calibrated.

Software Used

We chose the Metrology.NET software package because it is a rapid application development tool that allowed us to focus on the measurement process. The requirements of this project were to evaluate the short-term stability of the Meatest M133C and if its accuracy could be enhanced with a Radian RX-33. Metrology.NET was the perfect tool for this task because all the test point management, IEEE-488, and LAN I/O drives, as well as reporting tools, were already built-in. This allowed us to focus strictly on the measurement operations and evaluation of the M133C.

Features

Already built into Metrology.NET were tools that allowed us to trend standards and their drift over time. The software is able to store, track, and trend measurement values as well as estimate measurement uncertainties and predicted value. In this evaluation project, we needed to track the drift and stability of 135 different set points and manage that data organized by channel, amperage, voltage, frequency, and power factor setting. To evaluate the short-term stability, we need daily and weekly measurements of the M133C in order to prove its short-term stability was better than the 1-year specification, allowing us to use an improved measurement uncertainty based on the RX-33 & the stability of the M133C.

Process Overview

We started by creating a set of test points based on a device we wanted to calibrate with the Meatest M133C. Then we used these test points as the template for the characterization process using a Radian Research RX-33 to measure the output of the M133C at each test point building a database of measurements. For each test point, we tracked the Channel, Voltage, Current, Frequency, and Power Factor creating a dataset of 135 individual test points.

Then for the next two weeks, we repeated the process every day collecting another set of measurements. After the characterization process was complete we imported that data into Microsoft Excel so we could validate the numbers from Metrology.NET. Over the course of 8 days, we collected seven runs of data, which was more than enough data to prove daily or even weekly characterization of the M133C would produce a substantial increase in measurement uncertainties. This data could also be used for short-term drift analysis.

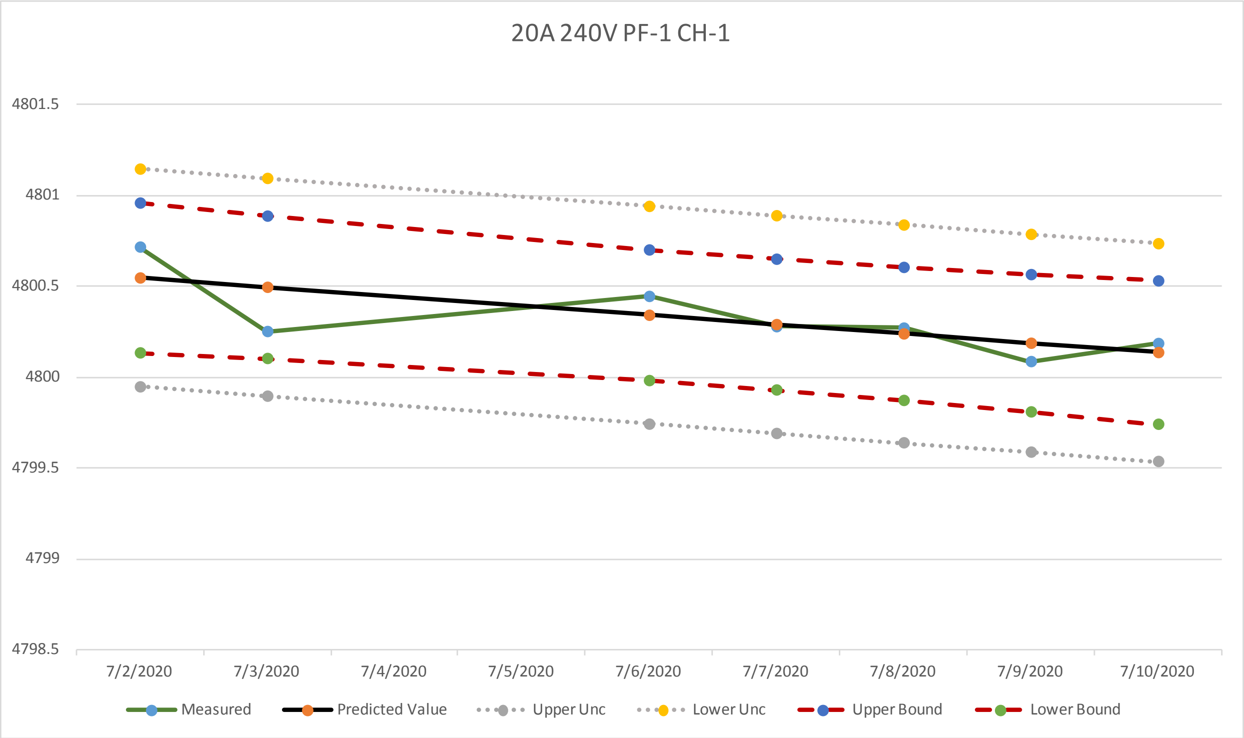

Figure 4. Two week control chart for the Meatest M133C channel 1 @ 20 A, 240 V, 53 Hz.

Description	Watts	Unc	2-Jul	3-Jul	6-Jul	7-Jan	8-Jan	9-Jan	10-Jan	STD ppm	RX-33	Better
Chan=1 Amps=20 Volt=240 Freq=53 Powe=1	4800	2.8E+0	-121.15	-52.29	-92.52	-57.83	-56.22	-17.83	-38.56	34.34	6.0E-1	4.61
Chan=1 Amps=20 Volt=240 Freq=53 Powe=0.5	2400	2.0E+0	447.02	401.54	500.99	403.62	446.29	440.16	440.00	33.20	3.0E-1	6.70
Chan=1 Amps=20 Volt=240 Freq=53 Powe=-0.5	2400	2.0E+0	-671.31	-693.43	-688.56	-586.79	-642.03	-613.52	-637.61	39.44	3.0E-1	6.61
Chan=1 Amps=10 Volt=240 Freq=53 Powe=1	2400	9.9E-1	8.02	64.87	60.13	62.68	76.30	39.79	88.31	26.30	2.9E-1	3.37
Chan=1 Amps=10 Volt=240 Freq=53 Powe=0.5	1200	8.8E-1	739.11	848.59	863.71	751.61	798.65	786.47	844.80	49.17	1.6E-1	5.65
Chan=1 Amps=10 Volt=240 Freq=53 Powe=-0.5	1200	8.8E-1	-704.00	-738.95	-662.74	-721.41	-684.26	-718.52	-616.41	41.92	1.5E-1	5.76
Chan=1 Amps=5 Volt=480 Freq=53 Powe=1	2400	1.3E+0	54.60	88.88	101.14	118.58	125.11	94.97	117.06	24.08	2.9E-1	4.29
Chan=1 Amps=5 Volt=480 Freq=53 Powe=0.5	1200	9.6E-1	947.30	1120.05	1152.59	1042.25	1090.10	1057.46	1074.55	65.48	1.6E-1	5.86
Chan=1 Amps=5 Volt=480 Freq=53 Powe=-0.5	1200	9.6E-1	-906.96	-881.42	-912.29	-813.56	-837.56	-861.16	-818.15	40.40	1.5E-1	6.32
Chan=1 Amps=5 Volt=240 Freq=53 Powe=1	1200	5.9E-1	66.62	104.21	112.66	103.94	138.76	97.93	125.00	22.71	1.5E-1	4.02
Chan=1 Amps=5 Volt=240 Freq=53 Powe=0.5	600	4.7E-1	782.33	825.02	876.89	890.54	924.56	916.08	891.23	51.14	7.8E-2	5.97
Chan=1 Amps=5 Volt=240 Freq=53 Powe=-0.5	600	4.7E-1	-722.34	-701.04	-727.93	-672.97	-629.53	-696.80	-648.05	37.01	7.5E-2	6.20
Chan=1 Amps=5 Volt=120 Freq=53 Powe=1	600	2.9E-1	33.64	54.65	78.01	85.82	110.59	86.95	106.08	27.36	7.4E-2	3.99
Chan=1 Amps=5 Volt=120 Freq=53 Powe=0.5	300	2.3E-1	800.22	794.00	843.15	835.13	825.06	807.30	832.04	18.99	3.6E-2	6.41
Chan=1 Amps=5 Volt=120 Freq=53 Powe=-0.5	300	2.3E-1	-734.19	-717.63	-684.48	-678.04	-591.27	-686.91	-673.55	45.34	3.8E-2	6.07
Chan=1 Amps=5 Volt=60 Freq=53 Powe=1	300	1.5E-1	12.86	36.16	67.55	68.25	89.41	70.46	92.29	28.55	3.7E-2	3.98
Chan=1 Amps=5 Volt=60 Freq=53 Powe=0.5	150	1.2E-1	-48.05	-10.05	72.62	23.30	136.98	45.32	97.19	63.39	2.0E-2	5.74
Chan=1 Amps=5 Volt=60 Freq=53 Powe=-0.5	150	1.2E-1	76.02	155.15	86.73	75.21	131.89	65.25	138.51	36.51	1.9E-2	6.21
Chan=1 Amps=2 Volt=240 Freq=53 Powe=1	480	2.8E-1	-83.69	-69.68	-42.97	-36.36	-19.74	-31.44	-31.90	23.01	5.9E-2	4.71
Chan=1 Amps=2 Volt=240 Freq=53 Powe=0.5	240	2.0E-1	685.83	687.81	793.76	708.49	685.28	746.23	702.43	40.52	3.0E-2	6.59
Chan=1 Amps=2 Volt=240 Freq=53 Powe=-0.5	240	2.0E-1	-814.08	-819.08	-906.44	-731.56	-863.13	-809.72	-802.19	54.17	3.2E-2	6.34
Chan=1 Amps=1 Volt=240 Freq=53 Powe=1	240	1.3E-1	-82.93	-54.68	-18.85	-15.52	-33.29	-11.41	-10.56	27.19	3.0E-2	4.33
Chan=1 Amps=1 Volt=240 Freq=53 Powe=0.5	120	9.7E-2	706.47	746.05	815.98	755.99	730.53	686.09	786.27	44.73	1.5E-2	6.29
Chan=1 Amps=1 Volt=240 Freq=53 Powe=-0.5	120	9.7E-2	-803.62	-868.67	-840.04	-762.90	-761.31	-810.88	-841.29	40.63	1.5E-2	6.36
Chan=1 Amps=0.5 Volt=240 Freq=53 Powe=1	120	6.4E-2	-126.34	-104.20	-88.73	-81.10	-90.33	-81.38	-60.32	20.65	1.5E-2	4.37
Chan=1 Amps=0.5 Volt=240 Freq=53 Powe=0.5	60	4.8E-2	659.15	697.33	788.19	666.57	705.75	759.34	766.49	51.04	7.8E-3	6.18
Chan=1 Amps=0.5 Volt=240 Freq=53 Powe=-0.5	60	4.8E-2	-988.43	-894.05	-937.46	-927.20	-864.77	-864.16	-969.31	48.83	7.8E-3	6.22
Chan=1 Amps=0.25 Volt=240 Freq=53 Powe=1	60	2.8E-2	-152.19	-168.94	-133.73	-121.82	-143.91	-121.03	-107.07	21.12	7.3E-3	3.83
Chan=1 Amps=0.25 Volt=240 Freq=53 Powe=0.5	30	2.3E-2	724.62	504.32	659.50	658.97	622.23	614.25	617.95	66.96	4.1E-3	5.56
Chan=1 Amps=0.25 Volt=240 Freq=53 Powe=-0.5	30	2.3E-2	-1041.09	-959.88	-764.84	-959.11	-995.84	-926.47	-909.43	87.39	4.5E-3	5.15
Chan=1 Amps=0.2 Volt=240 Freq=53 Powe=1	48	2.4E-2	-180.74	-184.01	-159.45	-150.47	-177.32	-150.30	-141.12	17.18	5.8E-3	4.05
Chan=1 Amps=0.2 Volt=240 Freq=53 Powe=0.5	24	1.9E-2	660.88	647.45	726.63	649.40	737.25	656.17	641.61	40.04	3.0E-3	6.16
Chan=1 Amps=0.2 Volt=240 Freq=53 Powe=-0.5	24	1.9E-2	-877.87	-973.48	-981.48	-981.21	-1026.60	-918.65	-865.47	60.03	3.2E-3	5.81
Chan=1 Amps=0.1 Volt=240 Freq=53 Powe=1	24	1.5E-2	-248.97	-241.62	-225.02	-216.88	-244.76	-210.35	-203.94	17.92	2.9E-3	5.10
Chan=1 Amps=0.1 Volt=240 Freq=53 Powe=0.5	12	1.0E-2	511.28	500.86	643.97	599.93	486.98	584.82	695.52	78.85	1.7E-3	6.03
Chan=1 Amps=0.1 Volt=240 Freq=53 Powe=-0.5	12	1.0E-2	-961.74	-1152.90	-1076.65	-1045.93	-1070.72	-991.28	-1011.97	63.53	1.6E-3	6.37
Chan=1 Amps=0.05 Volt=240 Freq=53 Powe=1	12	1.1E-2	-323.24	-287.41	-273.38	-271.37	-289.23	-262.49	-251.10	23.34	1.5E-3	7.33
Chan=1 Amps=0.05 Volt=240 Freq=53 Powe=0.5	6	6.5E-3	613.06	657.14	661.49	648.69	673.78	522.74	707.17	59.10	8.0E-4	8.08
Chan=1 Amps=0.05 Volt=240 Freq=53 Powe=-0.5	6	6.5E-3	-1336.55	-1372.21	-1206.61	-1363.10	-1388.15	-1346.78	-1202.10	78.41	8.6E-4	7.54
Chan=1 Amps=0.02 Volt=240 Freq=53 Powe=1	4.8	8.5E-3	-663.43	-615.01	-593.40	-592.34	-615.70	-579.79	-575.48	30.09	5.9E-4	14.33
Chan=1 Amps=0.02 Volt=240 Freq=53 Powe=0.5	2.4	4.5E-3	399.17	309.88	474.24	225.62	447.37	363.28	206.01	104.27	3.8E-4	11.78
Chan=1 Amps=0.02 Volt=240 Freq=53 Powe=-0.5	2.4	4.5E-3	-1620.77	-1913.41	-1606.30	-2367.63	-1629.16	-1593.57	-1314.84	333.66	8.5E-4	5.28
Chan=1 Amps=0.01 Volt=240 Freq=53 Powe=1	2.4	7.8E-3	-1047.86	-996.58	-946.61	-948.64	-951.44	-906.60	-913.73	49.03	3.1E-4	25.17
Chan=1 Amps=0.01 Volt=240 Freq=53 Powe=0.5	1.2	4.0E-3	-87.63	14.35	7.81	459.83	139.27	85.92	455.77	219.36	3.0E-4	13.27
Chan=1 Amps=0.01 Volt=240 Freq=53 Powe=-0.5	1.2	4.0E-3	-2322.86	-2378.06	-2181.41	-2563.07	-2579.59	-2241.46	-2820.46	224.80	3.1E-4	13.02

Table 3. This is a sub set of just channel 1.

Data Collected

From the data, we had 945 points (135 test points in seven runs) we could then evaluate the stability of the M133C. At each test point, we calculate the error in ppm from the nominal value set on the M133C compared to the measured value by the RX-33. The daily ppm error was then copied to the summary sheet in Excel where the "STEV.S()" was calculated for all 135 setpoints. The standard deviation from the day to day indicates the M133C's repeatability. The lower the standard deviation, the more stable the M133C is at that setpoint. If the ppm error is high for specific test points, but the deviation error is low, that means we can characterize and assign a value to that set point and be reasonably assured it will remain within its standard deviation for a short period of time.

The results from analyzing the data show that we could adjust the uncertainties of our metrology process by as much as 26.98 times better than just using the M133C's 1-year specifications, with an average of 6.44. Characterizing the M133C with the RX-33 showed improved uncertainties at every test point with the smallest improvement being 2.84 times better. You can see the results in Table 3.

Evaluating the Results

From the data collected, we created a control chart which allowed us to look at the predicted values vs. measured values and evaluate how they drifted/varied over time. The goal of this project was to evaluate if the Meatest M133C could be characterized once a day and used with a short-term higher accuracy specification. The chart shown as Figure 4, shows the performance of the M133C over a two week period, indicating first that the 24 hour stability is predictable and second the predictability for greater time periods is possible.

Conclusion

As the measurement and accuracy requirements change in the energy market, calibration and testing labs do not have to purchase more accurate energy sources. As long as their existing equipment meets a short term stability requirement, hardware like the Meatest M133C and Fluke 6003A/E can be periodically characterized with the Radian Research RX-33 Reference Standard. By applying proven metrological techniques for tracking the stability and drift, it's easy to prove and validate that the hardware can perform better than specified by the manufacturer's specifications.

Other Good Information

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[1] IEC 62052-11, Ed. 2, Electricity metering equipment - General requirements, tests and test conditions - Part 11: Metering equipment. 2020-06.

[2] M133C Series Electrical Power/Energy Calibrators Datasheet, MEATEST, spol.s r.o, www.meatest.com, 12/31/2020.

[3] RX-33 Xytronic Three-Phase Reference Standard Datasheet, Radian Research, Inc., www.radianresearch.com, 05-20-19.

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NEW PRODUCTS AND SERVICES

New Rohde & Schwarz System Amplifier SAM100

As the market for mobile radio, IoT, satellite and radar applications grows, Rohde & Schwarz has introduced a new approach to the system amplifier challenge. With unprecedented output power, bandwidth and market-leading noise performance, the compact R&S® SAM100 offers users a unique proposition.

Rohde & Schwarz, a global leader in microwave test & measurement systems, has announced the introduction of a new system amplifier. Designated R&S® SAM100, the microwave amplifier sets new standards in ease of operation, robust design and super-compact footprint within the 2 – 20 GHz range with up to 20W output power.

SAM100 targets manufacturers of passive and active microwave components and microwave devices for mobile radio (UMTS, LTE, 4G & 5 G), IoT (WLAN, Bluetooth), satellite and radar applications. Rohde & Schwarz has focused on the professional requirements of R&D engineers using system amplifiers for design validation testing (DVT), system integrators and test engineers using system amplifiers for setting up automatic test systems for product validation tests (PVT) as well as for production validation of RF products. Another target group is EMC test lab engineers with a need to test up to 18 GHz.

"SAM100 represents a new approach to the system amplifier challenge," said Wolfram Titze, Director of Product Management and Sales Support, Amplifier Systems at Rohde & Schwarz. "It offers a unique approach with its combination of output power, high bandwidth and low noise. Especially when used as compact desktop version with external power supply, SAM100 allows users to bring the RF-power where it is needed."

The product of extensive research & development within Rohde & Schwarz, SAM100 represents an ultra-broadband amplifier for a variety of test setups and system configurations in the 2 – 20 GHz range. Featuring high gain with low noise at superior linearity makes the unit highly suited to AM, FM, PM, and OFDM applications.

"We have seeded beta test units with several of our key customers and the SAM100 is earning rave reviews – with increased demand for mobile radio and IoT devices, this new amplifier is proving to be a big asset in bringing new products to market faster," added Wolfram Titze.

IAS to Accredit Testing Laboratories to Test Medical Devices

Brea, California, November 25, 2020: The U.S. Food and Drug Administration (FDA) has recognized the International Accreditation Service (IAS) under the Accreditation Scheme for Conformity Assessment (ASCA) pilot program to accredit testing laboratories that perform premarket testing for medical device companies.

"IAS is pleased to be a part of this FDA ASCA pilot program that may lead to improvements in medical devices," said Raj Nathan, IAS President. In this program, IAS will accredit testing laboratories using the standard ISO/IEC 17025 and the ASCA program specifications.

Relying upon international conformity assessment standards and a set of FDA-identified ASCA program specifications, the pilot is intended to increase consistency and predictability in the FDA's approach to assessing conformance with FDA-recognized consensus standards and test methods eligible for inclusion in the ASCA Pilot in medical device premarket reviews. Ultimately, the ASCA Pilot is intended to help the FDA ensure patients have timely and continued access to safe, effective, and high-quality medical devices.

Testing laboratories interested in getting more information or applying for accreditation may contact IAS at iasinfo@iasonline.org. For more information about IAS, visit www.iasonline.org.

About IAS

The International Accreditation Service (IAS) is a nonprofit accreditation body based in Brea, California USA. Providing accreditation services since 1975, IAS is one of the leading accreditation bodies in the United States and a signatory to several international mutual recognition arrangements (MRAs). For more information, visit iasonline.org.

Sartorius Introduces Table-Top Mass Comparator

- *Large capacity rack allows longer walk-way measurement time*
- *Dual robotic arm saves time by collecting up to four test weights and a reference weight for simultaneous measurement*
- *Modular, compact design provides three systems to suit different applications and budgets*

Germany, October 23, 2020 - Sartorius, a leading international partner of the life science industry today introduced three new Table-Top CCR-C Automated Mass Comparators to expand its premium weight calibration range. These compact systems combine user-driven features to support efficiency and accuracy, enabling metrology and calibration laboratories to achieve high-throughput, reliable, mass dissemination and calibration.

Designed to save laboratory space, the new automated CCR-C Table-Top Mass Comparators, consist of dual robotic arms that pick and place the reference and test weights simultaneously from a 120-magazine position rack and transfer them to a weighing cell.

These robust mass comparators are integrated with easy to use software which guides users to set-up their process workflows for accurate measurements. This premium weighing technology comes in three different models that are suited to the requirements of National Metrology Institutes and Legal Metrology Laboratories accredited up to Class E1, or calibration laboratories accredited up to Class E2 or F1.

For maximum productivity and user comfort, the CCR-10 automated mass comparator's unique 120-magazine position rack allows loading of a large number of weights. The rack has a hand rest for users to utilize while loading the magazine positions and can hold any weight shapes and sizes from 1 mg to 10 g without needing additional weight carriers or holders. These clever features mean that the CCR-C Table-top Mass Comparators can provide continuous walk-away measurements overnight, or at weekends and is ideal for laboratories that demand high throughput.

Built for optimum efficiency, the CCR-10 Table-top Mass Comparator's dual robotic arm with its patented multi and single weight handlers can collect of up to four weights, as well as a reference weight for simultaneous measurement in a minimum number of movements. Using fewer movements ensures fast weighing with less risk to weighing repeatability, thus generating results that meet the high levels of precision that the International Organization of Legal Metrology (OIML) and American Society for Testing and Materials (ASTM) demand.

The CCR-C table-top mass comparators come with built-in climate sensor in the weighing cells, which makes corrections according to changes in temperature, humidity and air pressure to ensure optimum weighing accuracy. When in use, the mass comparators' Windows-based software automatically acquires data for secure processing and storage in a range of user-friendly formats, eliminating time-consuming, error prone manual data handling, to assure accuracy and reproducibility.

Dirk Ahlbrecht, Head of Product Management Lab Weighing at Sartorius comments: "Due to limitation on space and budget automated mass comparator systems need to be small enough to fit on a table-top and be more affordable than large systems. However, as many metrology facilities are in cities where there are vibrations from traffic, they also have to be designed to be robust and stabilize quickly to ensure accurate mass comparison measurements at high throughput."

"We're delighted to introduce our CCR-C Automated Table-top Mass Comparator range as it offers an excellent, cost-effective solution to many of these challenges. The well-designed, compact equipment generates results with low error rates, saving users the time and cost of repeating measurements," adds Ahlbrecht.

To find out which Sartorius CCR-C Table-Top Mass Comparator would best suit your applications, please visit this link: https://www.sartorius.com/en/products/weighing/mass-comparators-metrology/tabletop-comparators

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Additel's New 850 Laboratory Thermocouple Furnace

Brea, Calif., November 18, 2020 – Additel Corporation introduces their new ADT850 Laboratory Thermocouple Furnace which covers a temperature range from 300°C to 1200°C. Commonly used in a multitude of industries such as energy, calibration laboratories, aerospace and metallurgy to accurately calibrate noble and base metal temperature probes, the ADT850 provides the best available stability and performance on the market in this newest temperature calibration product from Additel.

With two primary ordering options to choose from, calibration professionals can select the ADT850 Thermocouple furnace that meets their needs. The ADT850-1200-CUPL includes the ADT850 mainframe and a cup-style insert to accommodate base metal thermocouple calibration work while the ADT850-1200-ALUM is configured to support noble metal thermocouple calibration work. Additional optional interchangeable insert types are available to help users accommodate a vast array of additional device types.

Product Availability

The Additel 850 is available for order now. For more information, please visit www.additel.com. For information on Additel products and applications, or to find the location of your nearest distributor, contact Additel corporation, 2900 Saturn Drive, #B, Brea, CA 92821, call 1-714-998-6899, Fax 714-998-6999, email sales@additel.com or visit the Additel website at www.additel.com

About Additel

Additel Corporation is one of the leading worldwide providers of laboratory and process calibration tools. Additel Corporation is dedicated to the design and manufacture of high-quality handheld test tools, portable calibrators and laboratory equipment for process and calibration professionals. With more than 20 years in the industry, Additel has successfully developed Dry Well Calibrators, Thermometer Readouts, Thermocouple Calibrators, Pressure Controllers, Portable Automated Pressure Calibrators, handheld Digital Pressure Calibrators, Documenting Process Calibrators, Multifunction Process Calibrators, Digital Pressure Gauges, and various Calibration Test Pumps.

Low-Code to No-Code Software Development

Michael L. Schwartz
Cal Lab Solutions, Inc.

I am sure most calibration technicians and lab managers have never heard of Low-Code and No-Code software development. To be honest, before a year ago neither had I, but now I think this is going to be a game changer—even bigger than Object Oriented Programming (OOP) was in the 80s and 90s. If you have read anything from me, it's easy to conclude I am a huge OOP advocate.

So let me first explain the concept of Low-Code/No-Code by explaining what it is not. The overarching idea is to create working software without the overhead of thousands upon thousands of lines of code a developer has to write and support. Software is expensive to write and maintain. And those of use in the business know, poorly written code is extremely expensive to support and maintain. That is the idea behind this software movement: do more with less.

The concept of Low-Code/No-Code comes in several flavors. The first is the idea of domain-specific languages that allow users to build their own software, usually with a graphical development environment. Generally, these tools will allow a user to define items and flow of the software in a flow-chart like format. Then the software will write the actual code from the flow-chart. One example we all know that fits this pattern is LabView. And for those who have used LabView, it really makes complex instrumentation control easy.

Another idea behind Low-Code to No-Code is the idea of skipping the visual development environment. Here, the idea is to take the data items and convert them directly to computer instructions based on standard processes. The best example of this is database access code. Create, Read, Update and Delete (CRUD) access to a database is pretty much standard across all databases.

But wait, there's more! CRUD access, because it is standardized, can be implemented across any database and the software can auto-generate the SQL scripts on the fly. So now the developer doesn't need to write SQL access scripts, since they are done automatically. And small changes from one database to another are also managed in the auto-generated scripts.

This type of database/application programming has become the standard. Programmers today will write applications based on an Object-Relational Model where all the SQL code will be written for them automatically. And if they want to support a no-SQL database, all they have to do is change the database connector. Everything is handled for them, with No-Code!

This brings us back to a year ago when I first learned about Low-Code/No-Code from Mahdi, a friend of mine working on his Ph.D. developing a Low-Code solution in the Netherlands. As he was explaining to me the concepts behind the Low-Code he was working on I started thinking that's what Metrology.NET® does. Then he said "Exactly! That is what I am trying to tell you." Mahdi was one of the developers on the team that developed version 1.0 of Metrology.NET and neither of us realized it was a Low-Code solution.

Now, looking back on the goals of the project, it is easy to see just how much Low-Code technologies and concepts we managed to build into the software. Our goal was to approach metrology from a purely Object-Oriented perspective, defining all of the instrument settings and measurement process variables into name-value pairs. These name-value pairs could then be used to set up and configure the hardware during the measurement process.

When I designed the architecture of Metrology.NET, I wanted to get more use out of the code that I wrote. I wanted to put my data into a single silo that was reusable. I also wanted to create data points and automation in Metrology.NET. But if a customer wanted a MET/CAL® procedure I could press a button and get 80% of the code automatically generated from the Metrology.NET Test Package.

I know as I explain this to other programmers, it takes a little bit of time to wrap your head around Low-Code to No-Code software development. But if you think about it like this, the name-value pairs are timeless. They will always be the same for a given UUT and metrology taxon. The actual test script is just a way of expressing the name-value pairs in greater detail. And if software can write software with a press of a button, we can output name-value pairs into any language you can imagine. That is the end goal of No-Code software development. ❧

"Celebrating 50 Years of Education"

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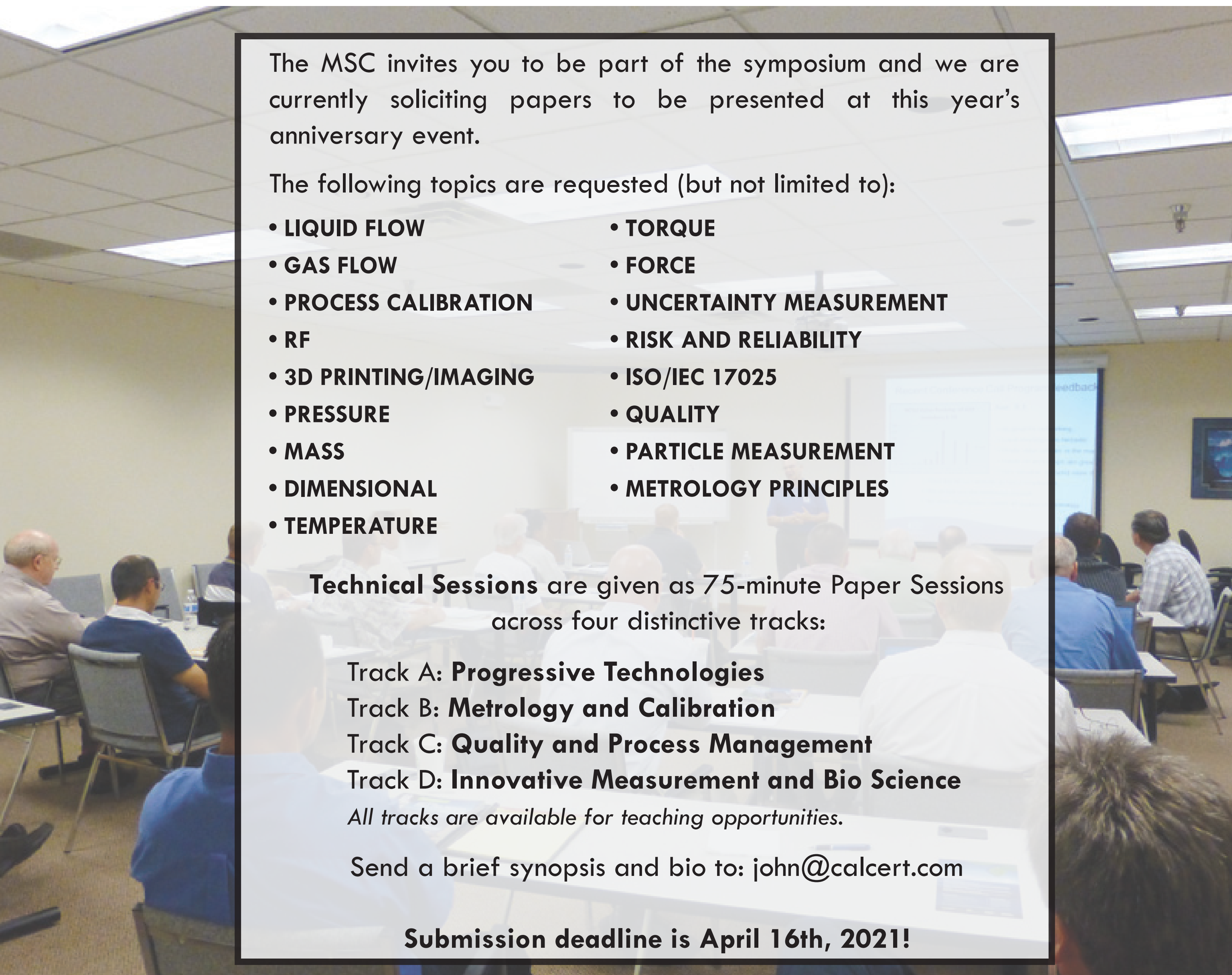
The MSC Training Symposium takes place annually in Orange County, California, and is celebrating 50 years of educational training. The symposium provides measurement professionals the opportunity to provide a training session of related subjects within the measurement industry and share the knowledge that you have gained through education or on-the-job training.



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