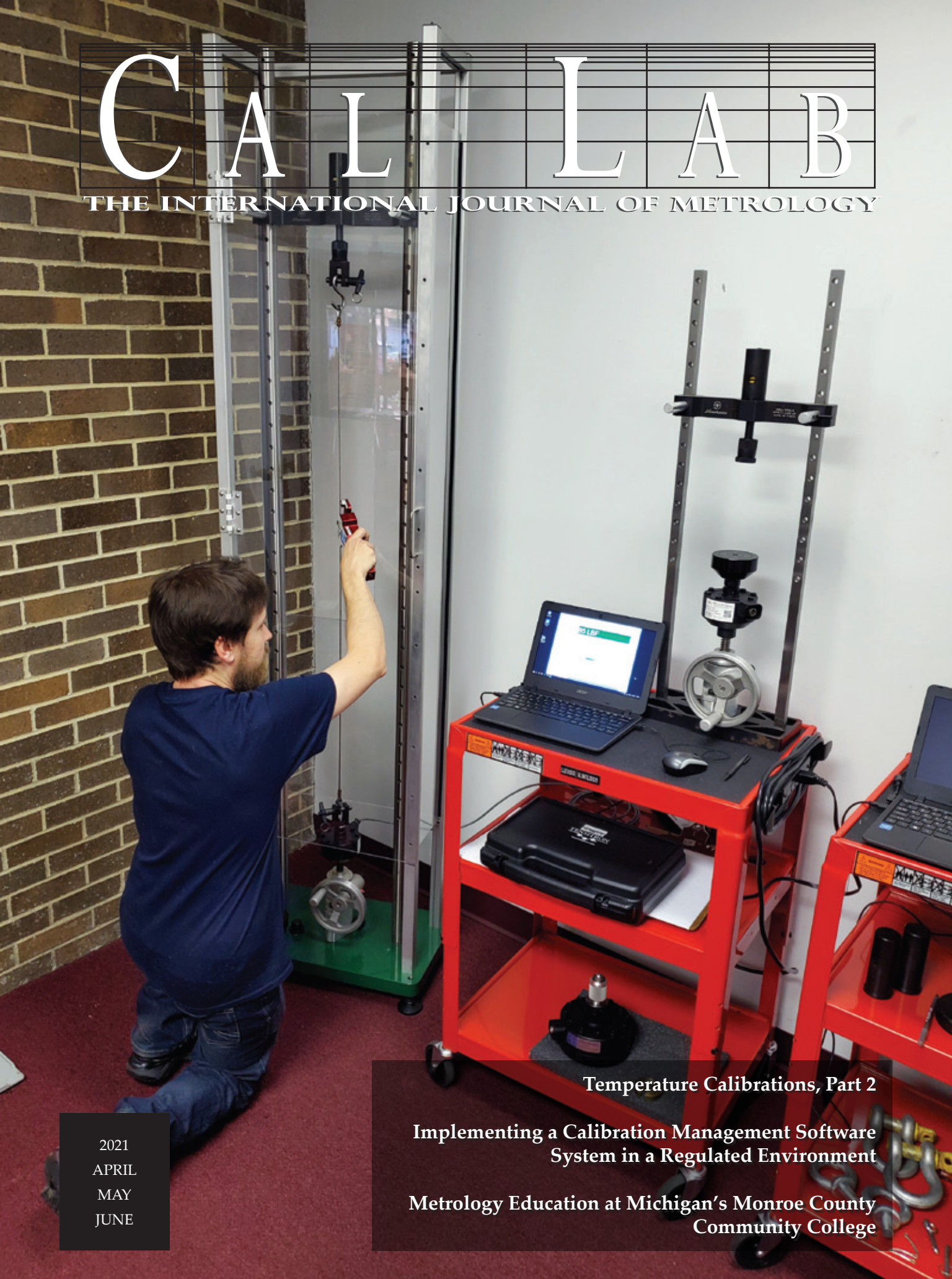

CAL LAB

THE INTERNATIONAL JOURNAL OF METROLOGY

2021
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Temperature Calibrations, Part 2

Implementing a Calibration Management Software System in a Regulated Environment

Metrology Education at Michigan's Monroe County Community College

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VOLUME 28, NUMBER 2

FEATURES

DEPARTMENTS

ON THE COVER: Engineer Justin Reschke calibrating a Digital Tensiometer on a Morehouse Mechanical Tensiometer Calibrator at Benchmark Calibration Laboratory in Sanford, Florida.

CALENDAR

UPCOMING CONFERENCES & MEETINGS

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

Jun 21-24, 2021 NEWRAD. Virtual Event. 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. Virtual Event. 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/

Aug 1-4, 2021 A2LA Tech Forum. Hybrid Event - 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-2021

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 3, 2021 The XXIII IMEKO World Congress. Virtual Event. 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/

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EDITOR'S DESK

Education

I enrolled at a local community college just out of high school. Tuition was just $50/term my first year, but jumped to $300/term the next year. By the time I graduated with an undergraduate degree, one term cost me $2000 at a public university. For the past 30 years, formal education in the US has become increasingly unaffordable.

And while our industry needs people, they don't need to have expensive degrees. They just need to have opportunities put in front of them—it might be just what they need, at just the right time in their lives. Community colleges, vocational schools, and apprenticeships can provide the mentorship and training a young person needs to start on a path to a fulfilling career.

Unfortunately, the fragmented state of metrology education and training doesn't help attract new people to our industry. The formal metrology programs out there often rely on local industry to help bolster their programs and attract new students. In some cases, a metrology program exists to reinforce related curriculum such as machine tooling or coordinate measuring machine (CMM) operation. Though far and few between, these opportunities do exist. But our industry needs more engagement with education.

For this issue, Michael Taylor contributed an article about Monroe County Community College's metrology program, its challenges, and activities. Besides working with local industry, MCCC hosts a summer metrology camp. It was interrupted by COVID-19, but I'm encouraged that such programs will continue to introduce measurement science to young people, so when they think about STEM careers, they naturally make the connection with metrology.

There are also a lot of quality training programs specifically for those wanting continuing education in their field—whether it's dimensional, electrical, uncertainties, etc. Our calendar is full of seminars and webinars in each issue and online. Speaking of continuing education, this issue's Metrology 101 is the second in a four-part series on temperature calibration by Ryan Egbert and Joseph Rindone of Sine Calibration School.

And included in this issue, Walter Nowocin of IndySoft continues his documentation of "Implementing a Calibration Management Software System in a Regulated Environment." If you missed the last issue, Walter meticulously documented "Selecting a Calibration Management Software System in a Regulated Environment." This and other previous articles/issues are freely available online by visiting **https://www.callabmag.com**.

Happy Measuring,

Sita Schwartz

CALENDAR

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

Oct 4-6, 2021 International Workshop on Metrology for the Sea; Learning to Measure Sea Health Parameters. Reggio Calabria, Italy. METROSEA will serve as a forum for presenting recent advances in the field of measurement and instrumentation to be applied for the increasing of our knowledge for protecting and preserving the Sea. http://www.metrosea.org/

Oct 26-27, 2021. FORUMESURE. Casablanca, Morocco. An event to meet exhibitors on Measurement, Quality and Instrumentation. FORUMESURE 2021 offers you a lot of activities in free access : Tutorials, Conferences, Round Tables, Collaborative Projects. FORUMESURE 2021 is organized during the International Conference of Metrology - CAFMET 2021. https://www.forumesure.com/

Oct 26-28, 2021 CAFMET. Casablanca, Morocco. Le CAFMET, en partenariat avec l'EHTP de Casablanca, organise la 8ème Conférence Internationale de Métrologie en Afrique. CAFMET 2021 constitue un carrefour d'échanges d'information, d'idées et d'expériences en Métrologie et en Management de la Qualité, autour de conférences, de tables rondes, d'ateliers techniques et de stands d'exposition. https://www.cafmet-conference.com/en/

Nov 15-18, 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/

Visit **https://www.callabmag.com/calendar/**
for metrology events & webinars!

CALENDAR

SEMINARS & WEBINARS: Dimensional

Jun 30, 2021 Introduction to Dimensional Gage Calibration. Novi, MI. Mitutoyo Institute of Metrology. This 1-day classroom course is part of our dimensional metrology curriculum and is a blended learning opportunity to maximize the student's time in the classroom. https://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/

Jul 12-13, 2021 Gage Calibration & Repair. Hartford, CT. 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

Aug 12-13, 2021 Gage Calibration & Repair. Bloomington, MN. 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

Aug 17-19, 2021 Dimensional Gage Calibration. Aurora (Chicago), IL. Mitutoyo Institute of Metrology. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/

Aug 20, 2021 Geometric Dimensioning & Tolerancing Workshop. Auckland, New Zealand. Measurement Standards Laboratory. This course explores the fundamentals of geometric dimensioning and tolerancing and explains the symbols, modifiers, rules, and concepts of GD&T based on the ASME Y14.5-2018 Standard. https://www.measurement.govt.nz/training/

Sep 1, 2021 Introduction to Dimensional Gage Calibration. Mason, OH. Mitutoyo Institute of Metrology. This 1-day classroom course is part of our dimensional metrology curriculum and is a blended learning opportunity to maximize the student's time in the classroom. https://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/

Sep 8-9, 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

Sep 21-23, 2021 Dimensional Gage Calibration. Aurora (Chicago), IL. Mitutoyo Institute of Metrology. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/

Oct 5-6, 2021 Dimensional Gage Calibration (2-day Version). Novi (Detroit), MI. Mitutoyo Institute of Metrology. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/

Oct 13-14, 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

Oct 19-21, 2021 Dimensional Gage Calibration. Aurora (Chicago), IL. Mitutoyo Institute of Metrology. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/

Oct 29, 2021 Dimensional Metrology Quality. Aurora (Chicago), IL. Mitutoyo Institute of Metrology. This 1-day course focuses on measurement quality – including how to understand and assess the errors in dimensional measuring systems. The primary topic of this course is Gage Repeatability and Reproducibility (Gage R&R), a common tool to study variation in measuring systems. https://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/

Nov 2-3, 2021 Dimensional Gage Calibration (2-day Version). Mason (Cincinnati), OH. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/

Nov 16-18, 2021 Dimensional Gage Calibration. Aurora (Chicago), IL. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/

SEMINARS & WEBINARS: Electrical

Sep 20-23, 2021 MET-301 Advanced Hands-On Metrology. Everett, WA. Fluke Calibration. A four-day course on advanced measurement concepts and math used in upper echelon calibration labs and primary standard labs. https://us.flukecal.com/training

Oct 18-21, 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

Nov 24-25, 2021 Electrical Measurement. Lindfield NSW, Australia. NMI. This two day (9am-5pm) course covers essential knowledge of the theory and practice of electrical measurement using digital multimeters and calibrators; special attention is given to important practical issues such as grounding, interference and thermal effects. https://shop.measurement.gov.au/collections/physical-metrology-training

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RTC-158
- Combination Liquid Bath and Dry Block Calibration

CTC-652
- 190 mm Immersion Depth for Long Sensors

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CALENDAR

SEMINARS & WEBINARS: Flow

Sep 23-24, 2021 Flow Measurement and Calibration Seminar. Neufahrn, Germany. TrigasFI. This Training Seminar is intended for individuals with responsibility to select, calibrate and use liquid and gas flowmeters. It is designed to be an objective, independent review and evaluation of the current state of flow metering and calibration theory and technology for flowmeter users and metrologists. Featuring networking event with lunch hosted at the Munich Oktoberfest. https://www.trigasfi.de/en/training-and-seminars/

Oct 4-7, 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

Aug 9-13, 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

Aug 10, 2021 Calibration and Measurement Fundamentals. Online. NMI, Australia. This course covers general metrological terms, definitions and explains practical concept applications involved in calibration and measurements. The course is recommended for technical officers and laboratory technicians working in all industry sectors who are involved in making measurements and calibration process. https://shop.measurement.gov.au/collections/physical-metrology-training

Aug 16-20, 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

Sep 13-17, 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

CALENDAR

SEMINARS & WEBINARS: Industry Standards

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

Jul 12-13, 2021 Understanding ISO/IEC 17025:2017 for Testing & Calibration Laboratories. 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

Jul 15-16, 2021 Auditing Your Laboratory to ISO/IEC 17025:2017. Virtual. A2LA WPT. 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

Aug 9-10, 2021 Introduction to ISO/IEC 17025:2017. Live Online. ANAB. The Introduction to ISO/IEC 17025 training course will provide attendees an overview of the requirements of ISO/IEC 17025:2017. Those involved with the standard and potentially seeking accreditation should attend this course. For full description visit https://anab.ansi.org/training/17025/intro

Aug 9-10, 2021 Understanding ISO/IEC 17025:2017 for Testing & Calibration Laboratories. Frederick, MD. A2LA WPT. 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

August 9-11, 2021 Internal Auditing to ISO/IEC 17025:2017. Live Online. ANAB. This training is designed for laboratory managers, technical staff, and others who want or need to learn better audit practices. For full description visit https://anab.ansi.org/training/17025/internal-auditing

Aug 12-13, 2021 Auditing Your Laboratory to ISO/IEC 17025:2017. Frederick, MD. A2LA WPT. This ISO/IEC 17025 auditor training 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

Aug 24-25, 2021 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Webinar (Timed for the Americas). IAS. To learn about ISO/IEC 17025 from one of its original authors. To learn its Principles and what it requires of laboratory staff. This Training Course applies to testing and calibration laboratories and regulatory agencies seeking to specify 17025 within their policies and regulations. https://www.iasonline.org/training/testing-cal-labs/

Aug 24-25, 2021 Internal Audit Course for All Standards. Webinar (Timed for the Americas). IAS. Training for internal auditors in all organizations with quality systems (labs, inspection bodies, certification bodies, proficiency testing providers). https://www.iasonline.org/training/internal_audit_for_accredited_organizations/

Sep 7-8, 2021 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Webinar (Timed for ME and South Asia). IAS. To learn about ISO/IEC 17025 from one of its original authors. To learn its Principles and what it requires of laboratory staff. This Training Course applies to testing and calibration laboratories and regulatory agencies seeking to specify 17025 within their policies and regulations. https://www.iasonline.org/training/testing-cal-labs/

Sep 13-16, 2021 Understanding ISO/IEC 17025:2017 for Testing & Calibration Laboratories. 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

Sep 20-23, 2021 Auditing Your Laboratory to ISO/IEC 17025:2017. Virtual. A2LA WPT. 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

Oct 12-13, 2021 Understanding ISO/IEC 17025:2017 for Testing & Calibration Laboratories. Frederick, MD. A2LA WPT. 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

Oct 13-14, 2021 Auditing Your Laboratory to ISO/IEC 17025:2017. Frederick, MD. A2LA WPT. This ISO/IEC 17025 auditor training 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

Oct 19-21, 2021 Introduction to ISO/IEC 17025:2017. Cary, NC. ANAB. The Introduction to ISO/IEC 17025 training course will provide attendees an overview of the requirements of ISO/IEC 17025:2017. Those involved with the standard and potentially seeking accreditation should attend this course. For full description visit https://anab.ansi.org/training/17025/intro

Oct 19-21, 2021 Internal Auditing to ISO/IEC 17025:2017. Cary, NC. ANAB. This training is designed for laboratory managers, technical staff, and others who want or need to learn better audit practices. For full description visit https://anab.ansi.org/training/17025/internal-auditing

SEMINARS & WEBINARS: Management & Quality

Jul 7-8, 2021 Quality Fundamentals. Virtual. A2LAWPT. During this course, the participant will gain an understanding of the basic concepts of quality fundamentals terms and quality principles. https://www.a2lawpt.org/events

Sep 8-9, 2021 Quality Fundamentals. Virtual. A2LAWPT. During this course, the participant will gain an understanding of the basic concepts of quality fundamentals terms and quality principles. https://www.a2lawpt.org/events

Oct 4-5, 2021 Quality Fundamentals. Virtual. A2LAWPT. During this course, the participant will gain an understanding of the basic concepts of quality fundamentals terms and quality principles. https://www.a2lawpt.org/events

SEMINARS & WEBINARS: Mass

Sep 20-30 Advanced Mass Seminar. NIST Gaithersburg Campus, MD. This 9-day, hands-on mass calibration seminar focuses on the comprehension and application of the advanced mass dissemination procedures, the equations, and associated calculations. https://www.nist.gov/pml/weights-and-measures/about-owm/calendar-events

Oct 18-29 Mass Metrology Seminar. NIST Gaithersburg Campus, MD. The Mass Metrology Seminar is a two-week, "hands-on" seminar. It incorporates approximately 30 percent lectures and 70 percent demonstrations and laboratory work in which the participant performs measurements by applying procedures and equations discussed in the classroom. The seminar focuses on the comprehension and application of the procedures, the equations, and calculations involved. https://www.nist.gov/pml/weights-and-measures/about-owm/calendar-events

SEMINARS & WEBINARS: Measurement Uncertainty

Jul 12-13, 2021 Introduction to Measurement Uncertainty. Virtual. A2LA WPT. 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

Jul 14-16, 2021 Introduction to Estimating Measurement Uncertainty. Online & Face-to-Face. NMI, Australia. This course will give you a clear step-by-step approach to uncertainty estimation with practical examples; you will learn techniques covering the whole process from identifying the sources of uncertainty in your measurements right through to completing the uncertainty budget. https://shop.measurement.gov.au/collections/physical-metrology-training

Jul 20-22, 2021 Measurement Uncertainty: Practical Applications. Live Online. ANAB. This course is designed for individual interested to further their understanding of measurement

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uncertainty to identifying uncertainty components, specifying the measurement process and calculating and combining standard uncertainties, as well as expanding uncertainties For full description visit https://anab.ansi.org/training/forensic/practicalapplicationsmc150

Aug 10, 2021 Introduction to Measurement Uncertainty. Frederick, MD. A2LA WPT. 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

Aug 11, 2021 Measurement Uncertainty and Calibration Workshop. Lower Hutt, New Zealand. Measurement Standards Laboratory. This course gives a broad high-level overview of measurement and calibration principles, and calculation of uncertainty. https://www.measurement.govt.nz/training/

Aug 11-12, 2021 Applied Measurement Uncertainty for Testing Laboratories. Frederick, MD. A2LA WPT. During this workshop, the participant will be introduced to several tools and techniques that can be applied in the testing laboratory environment to efficiently and effectively create measurement uncertainty budgets which comply with ISO/IEC 17025 requirements. https://www.a2lawpt.org/events

Aug 11-13, 2021 MET-302 Introduction to Measurement Uncertainty. Everett, WA. Fluke Calibration. A three-day "how to" course that introduces and demonstrates measurement uncertainty concepts and techniques. https://us.flukecal.com/training

Aug 12-13, 2021 Measurement Confidence: Fundamentals. Live Online. ANAB. This training course is designed for laboratory management and technical staff responsible for review of uncertainties, and for consultants working with organizations seeking or maintaining accreditation to ISO/IEC 17025. For full description visit: https://anab.ansi.org/training/17025/understanding-measurement-uncertainty

Aug 18, 2021 Measurement Uncertainty and Calibration Workshop. Auckland, New Zealand. Measurement Standards Laboratory. This course gives a broad high-level overview of measurement and calibration principles, and calculation of uncertainty. https://www.measurement.govt.nz/training/

Aug 18-19, 2021 Uncertainty of Measurement for Labs. Webinar (Timed for the Americas). Evaluation and Estimation of Uncertainties of Measurement. Introduction to metrology principles, examples and practical exercises. https://www.iasonline.org/training/uncertainty-of-measurement/

Sep 13-14, 2021 Introduction to Measurement Uncertainty. Virtual. A2LA WPT. 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

Sept 20-23, 2021 Applied Measurement Uncertainty for Calibration Laboratories. Virtual. A2LA WPT. 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

Oct 12, 2021 Introduction to Measurement Uncertainty. Frederick, MD. A2LA WPT. 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

Oct 12-14, 2021 Measurement Uncertainty: Practical Applications. Live Online. ANAB. This course is designed for individual interested to further their understanding of measurement uncertainty to identifying uncertainty components, specifying the measurement process and calculating and combining standard uncertainties, as well as expanding uncertainties. For full description visit https://anab.ansi.org/training/forensic/practicalapplicationsmc150

Oct 13-14, 2021 Applied Measurement Uncertainty for Testing Laboratories. Frederick, MD. A2LA WPT. During this workshop, the participant will be introduced to several tools and techniques that can be applied in the testing laboratory environment to efficiently and effectively create measurement uncertainty budgets which comply with ISO/IEC 17025 requirements. https://www.a2lawpt.org/events

SEMINARS & WEBINARS: Photometry & Radiometry

Aug 9, 2021 Spectrophotometer Calibration Workshop. Gracefield, Lower Hutt, New Zealand. Measurement Standards Laboratory. This course covers the calibration of bench-top spectrophotometers, including wavelength accuracy, photometric accuracy and stray light characterization. It is highly interactive and includes hands-on sessions to develop practical skills. https://www.measurement.govt.nz/training/

Nov 17-18, 2021 Photometry and Radiometry. Lindfield NSW, Australia. NMI. This two-day course (9 am to 5 pm) covers the broad range of equipment and techniques used to measure colour and light output, the basic operating principles involved in radiometry, working techniques, potential problems and their solutions. https://www.industry.gov.au/client-services/training-and-assessment

SEMINARS & WEBINARS: Pressure

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

Aug 10, 2021 Pressure Calibration Workshop. Lower Hutt, New Zealand. Measurement Standards Laboratory. This workshop is a practical one-day session dealing with all aspects of pressure gauge and transducer calibration. https://www.measurement.govt.nz/training/

CALENDAR

Aug 17, 2021 Pressure Calibration Workshop. Auckland, New Zealand. Measurement Standards Laboratory. This workshop is a practical one-day session dealing with all aspects of pressure gauge and transducer calibration. https://www.measurement.govt.nz/training/

Sep 20-24, 2021 Principles of Pressure Calibration. Phoenix, AZ. Fluke Calibration. A five-day training course on the principles and practices of pressure calibration using digital pressure calibrators and piston gauges (pressure balances).The class is designed to focus on the practical considerations of pressure calibrations. https://us.flukecal.com/training

Oct 18-22, 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

SEMINARS & WEBINARS: RF & Microwave

Jun 29-Jul 1, 2021 VNA Tools Training Course. Bern-Wabern, Switzerland. Federal Institute of Metrology METAS. VNA Tools is 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. www.metas.ch/vnatools

Sep 7-9, 2021 VNA Tools Training Course. Bern-Wabern, Switzerland. Federal Institute of Metrology METAS. VNA Tools is 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. www.metas.ch/vnatools

Sep 21-23, 2021 VNA Tools Training Course. Beaverton, OR. Federal Institute of Metrology METAS. VNA Tools is 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. www.metas.ch/vnatools

CALENDAR

SEMINARS & WEBINARS: Software

Jul 12-16, 2021 Basic MET/CAL Procedure Writing. Everett, WA. Fluke Calibration. In this five-day Basic MET/CAL® Procedure Writing course, you will learn to configure MET/CAL® software to create, edit, and maintain calibration solutions, projects and procedures. http://us.flukecal.com/training

Jul 19-23, 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

Aug 30-Sep 2, 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

Sep 20-24, 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

Oct 25-29, 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

Nov 8-12, 2021 MC-206 Basic MET/CAL Procedure Writing. Everett, WA. Fluke Calibration. In this five-day Basic MET/CAL®Procedure Writing course, you will learn to configure MET/CAL® software to create, edit, and maintain calibration solutions, projects and procedures. http://us.flukecal.com/training

SEMINARS & WEBINARS: Temperature & Humidity

Aug 9, 2021 Infrared Radiation Thermometry Workshop. Gracefield, Lower Hutt, New Zealand. Measurement Standards Laboratory. This is a practical course covering problems with the use and calibration of infrared radiation thermometers, including reflections, absorption, emissivity, and instrumental effects. The course builds confidence in non-contact temperature measurements in the range −50 °C to 2000 °C. https://www.measurement.govt.nz/training/

Aug 12, 2021 Temperature Measurement and Calibration Workshop. Lower Hutt, New Zealand. Measurement Standards Laboratory. This course covers the use, care, and calibration of

liquid-in-glass, platinum resistance, thermocouple, and radiation thermometers. https://www.measurement.govt.nz/training/

Aug 13, 2021 Humidity and Moisture Calibration Workshop. Lower Hutt, New Zealand. Measurement Standards Laboratory. This practical one-day course will introduce you to humidity generation, calibration and measurement, along with the conceptual framework for understanding the various limitations in humidity measurements. https://www.measurement.govt.nz/training/

Aug 19, 2021 Temperature Measurement and Calibration Workshop. Auckland, New Zealand. Measurement Standards Laboratory. This course covers the use, care, and calibration of liquid-in-glass, platinum resistance, thermocouple, and radiation thermometers. https://www.measurement.govt.nz/training/

Aug 20, 2021 Humidity and Moisture Calibration Workshop. Auckland, New Zealand. Measurement Standards Laboratory. This practical one-day course will introduce you to humidity generation, calibration and measurement, along with the conceptual framework for understanding the various limitations in humidity measurements. https://www.measurement.govt.nz/training/

Sep 13-17, 2021 Advanced Topics in Temperature Metrology. American Fork, UT. A three-day course for those who need to get into the details of temperature metrology. This course is for experienced calibration technicians, metrologists, engineers, and technical experts working in primary and secondary-level temperature calibration laboratories who would like to validate, refresh, or expand their understanding of advanced topics in temperature metrology. https://us.flukecal.com/training

Oct 4-6, 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

Oct 5-7, 2021 Temperature Measurement. Lindfield NSW, 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://shop.measurement.gov.au/collections/physical-metrology-training

SEMINARS & WEBINARS: Time & Frequency

Oct 20-21, 2021 Time and Frequency Measurement. Lindfield, NSW. Australia NMI. This two-day course (9 am to 5 pm) covers the broad range of equipment and techniques used to measure time and frequency and to calibrate time and frequency instruments. https://shop.measurement.gov.au/collections/physical-metrology-training

SEMINARS & WEBINARS: Vibration

Nov 9-11, 2021 Fundamentals of Random Vibration and Shock Testing. San Diego, CA. Equipment Reliability in collaboration with WESTPAK. Review basic vibrations, sources and causes, then explore vibration measurements, analysis and calibration. Our discussion is supported by projected visuals and video clips. We'll compare sinusoidal vs. random vibration with emphasis on testing systems, specifications, standards and procedures. https://equipment-reliability.com/open-courses/

SEMINARS & WEBINARS: Weight

Aug 10, 2021 Balances and Weighing. Gracefield, Lower Hutt, New Zealand. Measurement Standards Laboratory. There are increasing demands on laboratories to demonstrate quality assurance in their measurements. This course provides training to assist laboratory personnel to meet these demands. https://www.measurement.govt.nz/training/

Aug 17, 2021 Balances and Weighing. Auckland, New Zealand. Measurement Standards Laboratory. There are increasing demands on laboratories to demonstrate quality assurance in their measurements. This course provides training to assist laboratory personnel to meet these demands. https://www.measurement.govt.nz/training/

Sep 9, 2021 Calibration of Weights and Balances. Lindfield NSW, Australia. NMI. This course covers the theory and practice of the calibration of weights and balances. It incorporates hands-on practical exercises to demonstrate adjustment features and the effects of static, magnetism, vibration and draughts on balance performance. https://shop.measurement.gov.au/collections/physical-metrology-training

Visit **https://www.callabmag.com/calendar/** for upcoming metrology events & webinars!

NIST Team Compares 3 Top Atomic Clocks With Record Accuracy Over Both Fiber and Air

March 24, 2021, NIST News -- In a significant advance toward the future redefinition of the international unit of time, the second, a research team led by the National Institute of Standards and Technology (NIST) has compared three of the world's leading atomic clocks with record accuracy over both air and optical fiber links.

Described in the March 25 issue of Nature

, the NIST-led work is the first to compare three clocks based on different atoms, and the first to link the most advanced atomic clocks in different locations over the air. These atomic clock comparisons place the scientific community one step closer to meeting the guidelines for redefinition of the second.

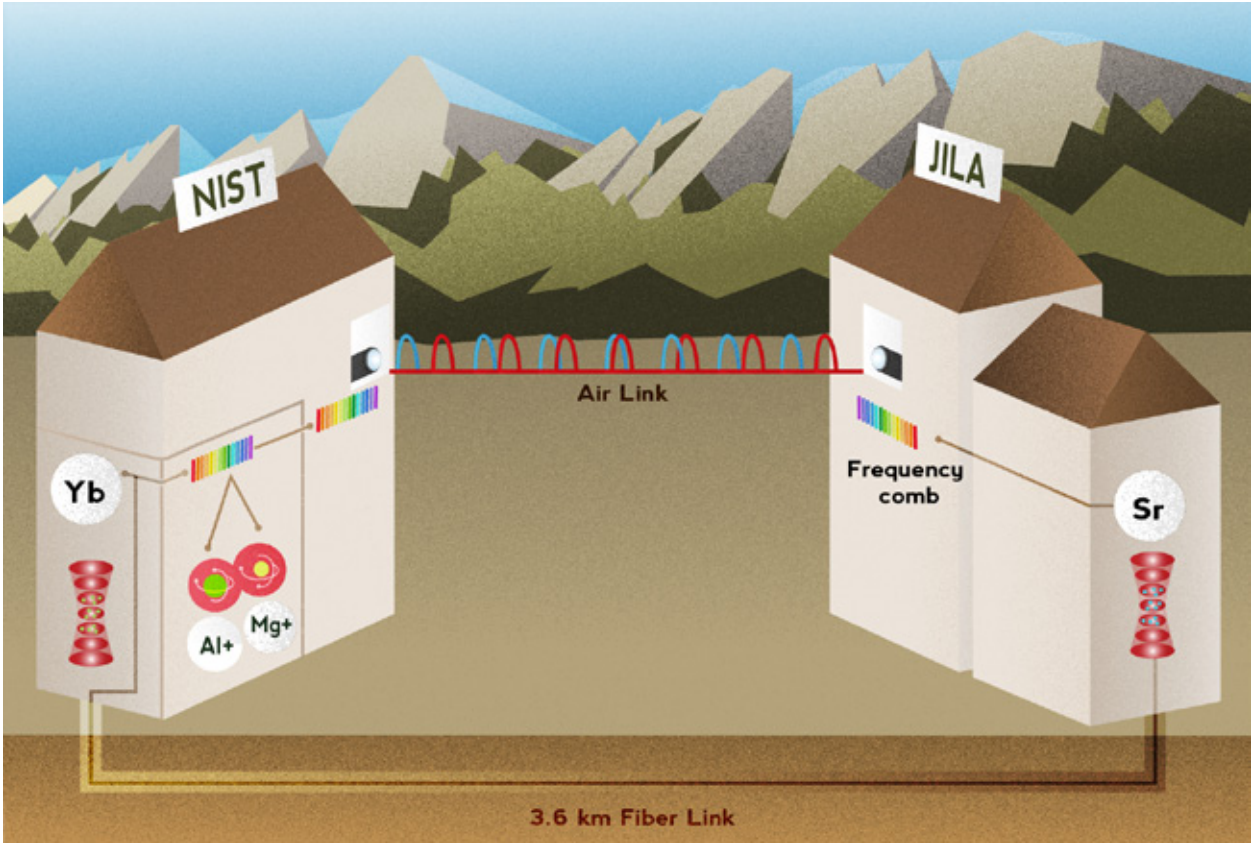
"These comparisons are really defining the state of the art for both fiber-based and free-space measurements — they are all close to 10 times more accurate than any clock comparisons using different atoms performed so far," NIST physicist David Hume said.

The new measurements were challenging because the three types of atoms involved "tick" at vastly different frequencies, because all the many network components had to operate with extreme accuracy, and because the wireless link required cutting-edge laser technology and design.

The study compared the aluminum-ion clock and ytterbium lattice clock, located in different laboratories at NIST Boulder, with the strontium lattice clock located 1.5 kilometers away at JILA, a joint institute of NIST and the University of Colorado Boulder. The team's measurements were so accurate that uncertainties were only 6 to 8 parts in 1018 — that is, errors never exceeded 0.000000000000000008 — for both fiber and wireless links.

NIST researchers previously described in detail how they transferred time signals over the air link between two of the clocks, the NIST ytterbium and JILA strontium clocks, and found the process worked as well as the fiber-based method and 1,000 times more precisely than conventional wireless transfer schemes. This work shows how the best atomic clocks might be synchronized across remote sites on Earth and, as time signals are transferred over longer distances, even between spacecraft.

The key to the air link was the use of optical frequency



NIST researchers precisely compared the signals from three optical atomic clocks over air and optical fiber, with two of the clocks (indicated by Yb and Al+/Mg+) located in different NIST-Boulder laboratories, and a third (Sr) located 1.5 kilometers away at JILA. Credit: N. Hanacek/NIST

combs, which enable accurate comparisons of widely different frequencies. NIST researchers developed two-way transfer methods to precisely compare optical clocks over the air, even in conditions of atmospheric turbulence and laboratory vibrations. The comb-based signal transfer technique had been demonstrated previously, but the latest work was the first to compare state-of-the-art atomic clocks.

Since 1967, the second has been defined based on the cesium atom, which ticks at a microwave frequency. The atomic clocks used in the new comparisons tick at much higher optical frequencies, which divide time into smaller units and thus offer greater precision. Comparisons are crucial to the international community's selection of one or more atoms as the next time standard.

The new NIST results reported in Nature also set other important records. Frequency is the most accurately measured single quantity in science. The NIST team measured frequency ratios, the quantitative relationships between the frequencies of the atoms as measured in three pairs (ytterbium-strontium, ytterbium-aluminum, aluminum-strontium). The results are the three most accurate measurements ever made of natural constants. Frequency ratios are considered constants and are used in some international standards and tests of fundamental physics theories.

Frequency ratios offer an important advantage as a metric for evaluating optical atomic clocks. A direct measurement of an optical clock frequency in the usual units of hertz (one cycle per second) is limited by the accuracy of the current international standard, the cesium microwave clock. Frequency ratios overcome this limitation because they are not expressed in any units.

Frequency ratios are usually measured over long distances by use of fiber networks, which are few and far between, or in some cases with microwave data transferred over satellite links, which tend to be unstable.

Guidelines for redefinition of the second recommend the demonstration and verification of multiple frequency ratio measurements with uncertainties approaching the best optical clock performance. All three types of clocks in the new study offer superlative performance now and promise further improvements. NIST's ytterbium clocks, for example, represent the natural frequency of the atoms (a value known as systematic uncertainty) to within a possible error of just 1.4 parts in 1018 — about one billionth of a billionth.

NIST's new frequency ratio measurements, while record-setting, are not quite that good yet. But the research team is working on improving measurement stability and clock performance, Hume said.

Beyond their role in the next generation of international standards, optical atomic clocks can be used as sensitive probes for new physics, such as the "dark matter" believed to constitute most of the stuff in the universe. Technological applications for optical clocks include improved timing and navigation systems and measuring Earth's gravitational shape (geodesy).

This work was supported in part by the Defense Advanced Research Projects Agency, the Air Force Office for Scientific Research, the National Science Foundation, the Office of Naval Research, NASA Fundamental Physics, and the Department of Energy.

Paper: Boulder Area Clock Optical Network (BACON) Collaboration: K. Beloy, M.I. Bodine, T. Bothwell, S.M. Brewer, S.L. Bromley, J.-S. Chen, J.-D. Deschenes, S.A. Diddams, R.J. Fasano, T.M. Fortier, Y.S. Hassan, D.B. Hume, D. Kedar, C.J. Kennedy, I. Khader, A. Koepke, D.R. Leibrandt, H. Leopardi, A.D. Ludlow, W.F. McGrew, W.R. Milner, N.R. Newbury, D. Nicolodi, E. Oelker, T.E. Parker, J.M. Robinson, S. Romisch, S.A. Schaeffer, J.A. Sherman, L.C. Sinclair, L. Sonderhouse, W.C. Swann, J. Yao, J. Ye and X. Zhang. Frequency Ratio Measurements with 18-Digit Accuracy Using an Optical Clock Network. Nature. Published March 25, 2021. DOI: 10.1038/s41586-021-03253-4

Source: https://www.nist.gov/news-events/news/2021/03/nist-team-compares-3-top-atomic-clocks-record-accuracy-over-both-fiber-and

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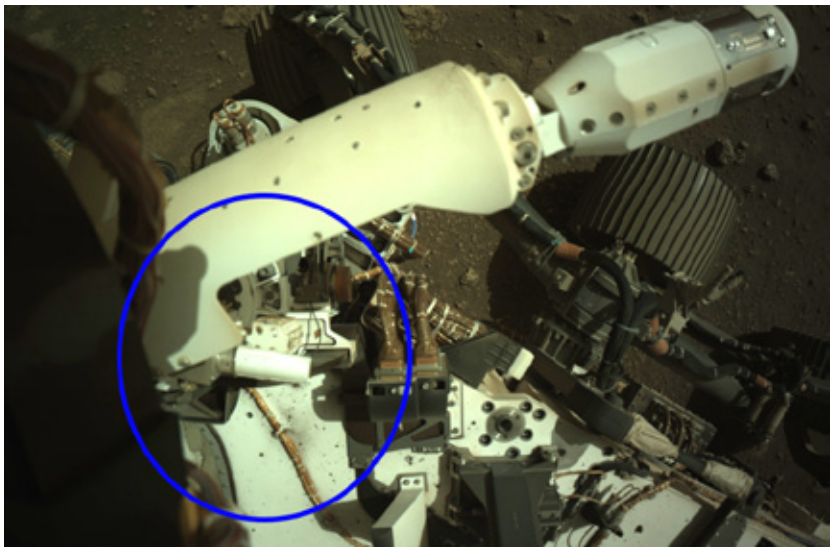
NASA's Perseverance Rover Commences Scientific Measurements on Mars with Finnish Equipment

April 15, 2021, Vaisala and Finnish Meteorological Institute Press Release — NASA's Perseverance rover has now spent its first months on the surface of Mars. The testing and deployment phase is proceeding well, and after the first technology demonstration with the Ingenuity helicopter, the rover is commencing the continuous scientific measurements. With the arrival of the humidity and pressure measurement instruments onboard Perseverance, the first meteorological network on another planet is being created.

The Perseverance rover landed successfully on Mars in February 2021 and will now explore an ancient river delta in the Jezero Crater for at least the next Martian year, which is approximately two Earth years. After the landing, the rover stretched its robotic arms and has already delivered a good number of high-quality photos, videos, and audio samples back to Earth.

The rover's Mars Environmental Dynamics Analyzer (MEDA) instrumentation suite, developed by a Spanish-led research consortium, has also been deployed. MEDA is a weather station that has been developed specifically for the conditions on Mars. Instruments by the Finnish Meteorological Institute (FMI) and Vaisala are included in the MEDA suite to measure pressure and humidity conditions on Mars. The measurements and local wind data provided by the MEDA suite is also used by the Ingenuity Helicopter.

The measurement instruments need to be able to deliver reliable high-quality measurements even after the long space journey.



Courtesy: Vaisala (GlobeNewswire)

"Accurate and reliable science-based measurements are at the core of Mars research. That's why it is great to receive verification that our sensors are working in the extreme conditions on Mars, even after the demanding space journey. Vaisala's measurement technology is at its best in challenging measurement conditions," says Liisa Åström, Vice President of Products and Systems at Vaisala.

"The equipment on Mars needs to work in all conditions and is tested accordingly. Manufacturing, testing, and finalizing the measurement instruments has been a major project lasting many years, so it feels great to see the instruments finally at work on Mars," summarizes Maria Hieta, Research Engineer at FMI.

Hieta continues: "For instance, the humidity measurement instruments on Perseverance have gone through a tough selection process. FMI built 13 different instrument models around the humidity sensor, and these models were tested several times in harsh conditions such as very low temperatures. Additionally, the tests exposed them to vibration and shocks. The most reliable model was chosen as part of the MEDA equipment."

First measurements reflect expectations

The MEDA equipment has now delivered the first round-the-clock measurement series on pressure and relative humidity to Earth. The measured values correspond to what was expected.

"The pressure levels and variation according to the time of day in the Jezero Crater reflect our models well. Relative humidity is practically zero (0% RH) during the day and rises during the night as the local temperature falls to nearly -80 °C. For comparison, 20 percent relative humidity is considered very low on Earth, and relative humidity near zero is hardly ever measured. The pressure data has also let us observe dust devils passing Perseverance, showing them as fast and sharp declines in the pressure signal," explains Maria Genzer, Group Leader of Planetary Research and Space Technology at FMI.

Martian weather conditions and atmosphere interest Finnish researchers

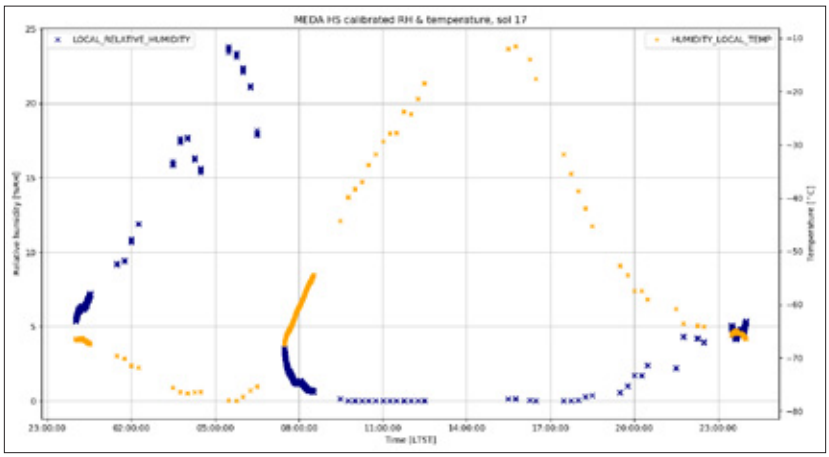
The Perseverance rover has been designed to explore Mars' conditions and geology as well as to search for signs of ancient life. Even though signs of life are fascinating, Finnish researchers are especially interested in the Martian atmosphere.

"Earth and Mars share a lot of similarities, which is why we find the study of Mars' atmosphere so fascinating: it helps us to understand the behavior of Earth's atmosphere. Additionally, dust storms on Mars can be harsh, so it is crucial to be able to predict the storms if we are to send manned space missions to Mars in the future. For this reason, Mars needs a weather station network," states Maria Genzer.

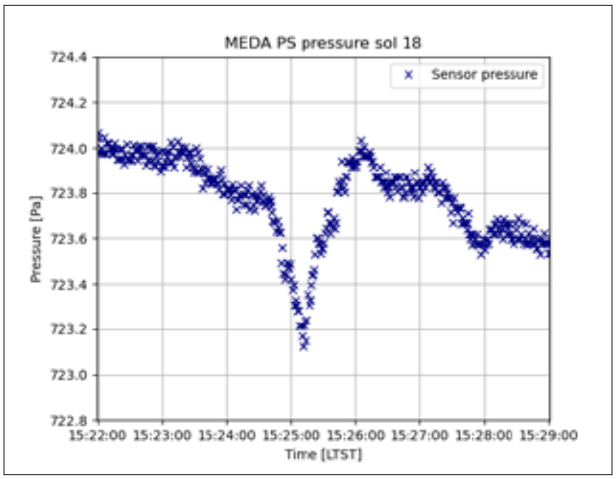
Meteorological observation network based on Finnish expertise

Perseverance and the Curiosity rover, which landed on Mars in 2012, provide measurements approximately 3,700 kilometers apart from each other. Both rovers carry similar Finnish pressure and humidity measurement instruments, which deliver data that is sent to Earth for analysis.

The data from the rovers, combined with observations from NASA's InSight Lander on Mars, form the first three-



Courtesy: Vaisala (GlobeNewswire)



Courtesy: Vaisala (GlobeNewswire)

point meteorological observation network on another planet. The network will enable even more accurate modeling of Mars' atmosphere and its phenomena.

"In the future, we hope to get more measurement points on Mars. This is the ultimate goal for example in our MetNet program, in which we are developing small probes that will impact and penetrate Mars' surface. These probes would then form a comprehensive meteorological observation network on the planet," Maria Hieta explains.

The Mars 2020 mission is a part of NASA's Mars exploration program. One of the main tasks of the Perseverance rover is to gather and store a series of rock and soil samples that can be brought back to Earth for analysis in the future. Finnish technology is scheduled to be launched to Mars again in 2022 aboard the ExoMars mission by the European Space Agency (ESA) and the Russian space agency Roscosmos.

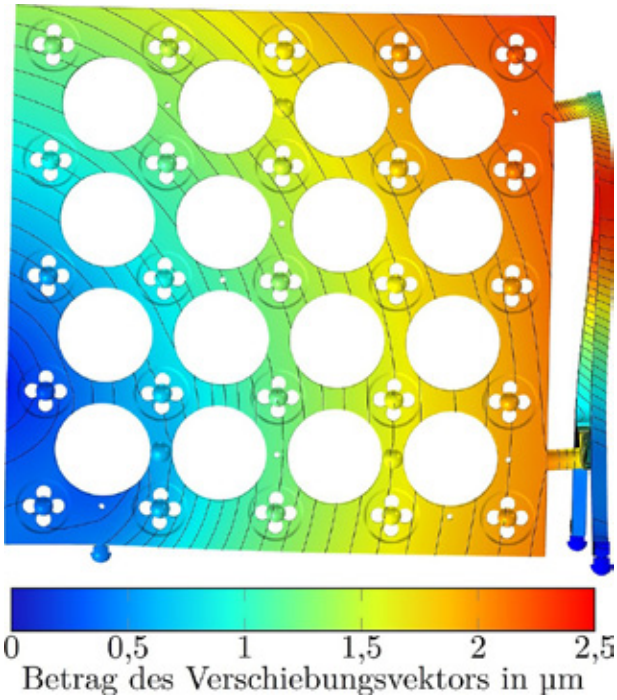
Ilmatieteen laitos is a research and service agency under the Ministry of Transport and Communications in Finland. Its mission is to produce high-quality observation and research data on the atmosphere and seas. The Institute combines this expertise into the weather, climate and oceanographic services it provides to promote public safety as well as increase well-being in the society and the environment, taking into account the needs to maintain preparedness. More information about FMI in space: https://space.fmi.fi

Vaisala is a global leader in weather, environmental, and industrial measurements. Building on over 80 years of experience, Vaisala provides observations for a better world, with space-proof technology even exploring Mars and beyond. We are a reliable partner for customers around the world, offering a comprehensive range of innovative observation and measurement products and services. Headquartered in Finland, Vaisala employs over 1,900 professionals worldwide and is listed on the Nasdaq Helsinki stock exchange. vaisala.com/space

Setting Up Ball Plates and Hole Plates

PTBnews 1.2021 — Ball plates and hole plates are measurement standards typically used to ensure the traceability of coordinate measuring machines. To arrange the plates vertically, one single supporting stand is often used that is placed laterally to the standard. Numerical simulations based on the finite-element method that were performed at PTB have shown that such an arrangement no longer fulfills the ever stricter requirements for the calibration of modern, high-precision coordinate measuring machines.

In the past few years, high-precision coordinate measuring machines have been developed to ensure the quality of ever more accurate manufacturing processes in production. These coordinate measuring machines achieve uncertainties of 0.3 µm + 1 µm/m for length measurement errors. The traceability, correct adjustment and checking of such coordinate measuring machines require standards that have been calibrated with a much lower measurement uncertainty. This is the reason why influences that could previously be neglected, now have to be taken into account when calibrating ball and hole plates typically used as standards as their considerable dead weight leads to a deformation of the standards, depending on how they were set up on the coordinate measuring machine. A simulation study using the finite-element method (FEM) was carried out in order to describe these influences quantitatively and to allow the measurement and calibration procedures used



Deformation of a ball plate made of tool steel with a mass of approx. 30 kg and an edge length of 620 mm. Credit: PTB

to be improved. Here, the central question was to determine the relation between the deformations undergone by the plates and typical measurement uncertainties and whether these deformations are negligible.

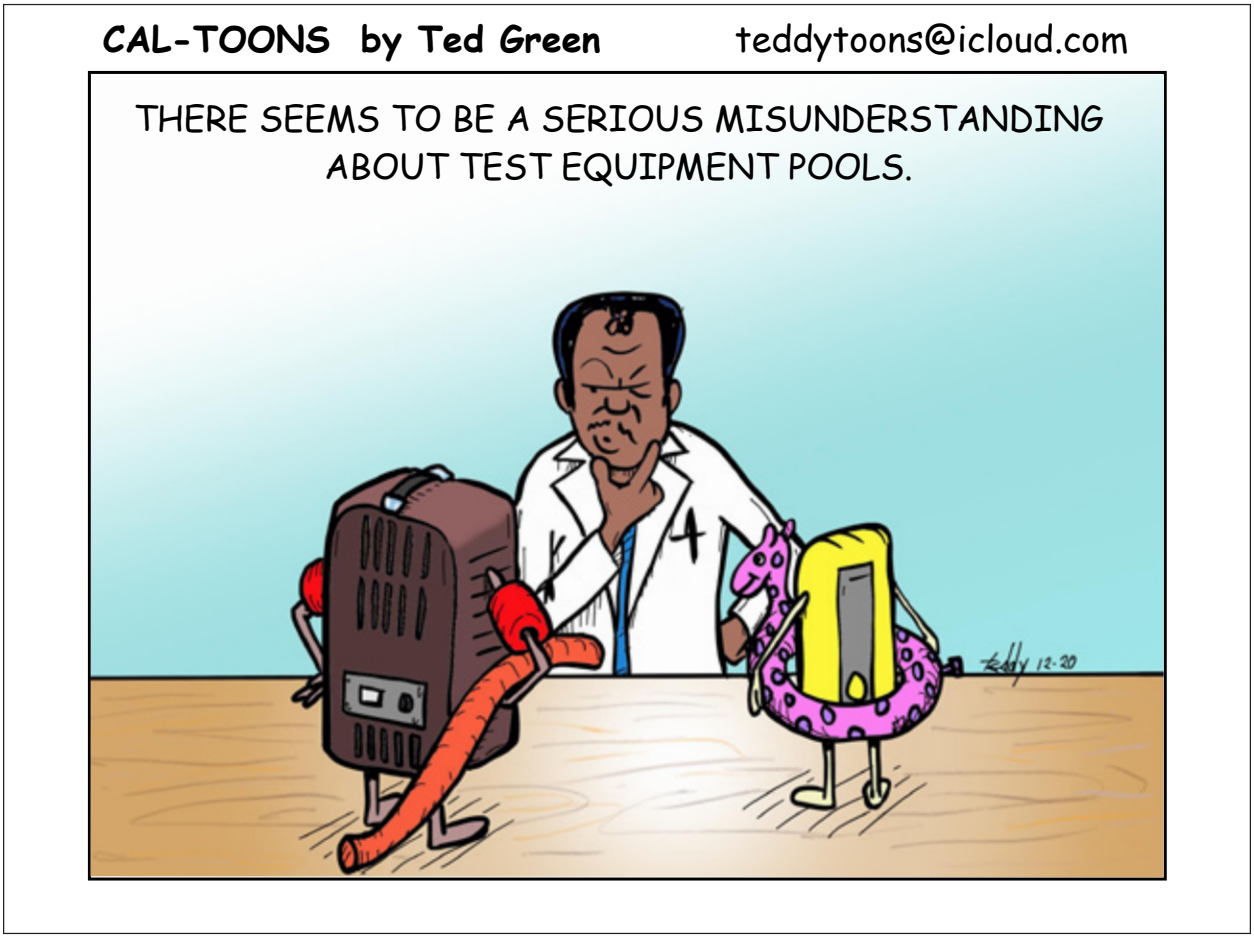
The results of the FEM investigations have shown that the vertical supporting stands currently used in industry for ball plates (consisting of a single supporting stand applied laterally to the standard) are particularly prone to plying under the influence of the dead weight of the ball plates. This causes an asymmetric deformation of up to 0.37 μm, which is not negligible. In this scenario, the deviations from the calibration values of the standards are particularly large in the horizontal plane, since spherical calotte plates are usually calibrated horizontally but also used in various positions.

The obvious alternative involving two supporting lateral stands was also investigated. It showed that this arrangement reduces deformation to such an extent that the influence becomes acceptable, even to ensure the traceability of high-precision coordinate measuring machines.

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

TÜV SÜD National Engineering Laboratory Launches the UK's First Domestic Hydrogen Meter Calibration Facility

The new facility will help meter manufacturers determine if existing meter stock, and new technologies under development, are correctly measuring hydrogen flow rates. This is a crucial step to ensure that hydrogen gas meters deployed onto the market in the future will deliver accurate measurements for customer billing and taxation purposes.Marc MacDonald, Head of Clean Fuels at TÜV SÜD National Engineering Laboratory, said: "Accurate measurement is an essential element to enable the decarbonisation of heat via the replacement of natural gas with hydrogen in the grid. From our involvement in EU hydrogen metrology projects, and our extensive experience as the UK institute responsible for National Flow Measurement Standards, it is clear that the change from natural gas to hydrogen can result in increased meter measurement errors. Our new hydrogen calibration facility will give manufacturers the independent assurance they need to prove that metering systems are suitable for their intended service."



Funded by the Department for Business, Energy & Industrial Strategy (BEIS), through the National Measurement System mechanism, the new facility will initially support ongoing hydrogen feasibility and metrology research, including HyDeploy (a pioneering hydrogen energy project), the European Metrology Programme for Innovation and Research (EMPIR), and the UK Flow Programme. The research will be shared publicly so that industry can make more informed choices about meter selection.

Dr Lisa Cameron, MP for East Kilbride, Strathaven and Lesmahagow, opened the facility and said: "It is wonderful to be opening our UK-based world-leading facility that represents a vital step in ensuring hydrogen is a key pillar within a sustainable future. TÜV SÜD is signalling to the world that East Kilbride will be at the forefront of global efforts to explore hydrogen's potential and the role it will undoubtedly play in combatting climate change at the forefront of our global goals for COP26 and beyond."

Although the new facility was originally developed for testing domestic gas meters, other meter types including Coriolis, turbine and differential pressure can also be calibrated. Hydrogen flow meter manufacturers will also be able to use the facility for their own R&D purposes.

Source: https://www.tuvsud.com/en-gb/press-and-media/2021/march/uk-first-domestic-hydrogen-meter-calibration-facility-launched

Temperature Calibrations, Part 2

Ryan Egbert and Joseph Rindone
Sine Calibration School

The following article is part two of a four-part Metrology 101 series focusing on temperature. The written content provided here is also intended to be combined with demonstration videos that we will provide through our school, Sine Calibration School. If you follow this series and complete the training online, you will be awarded our temperature badge credential for free! But, for this to happen, you must complete all of the content provided this year and complete the final quiz in our school in December 2021. Register today at www.sinecalibration.com, you will see a link at the top of the screen. More information will be provided along the way, but let us not waste any more space here in this article.

Introduction

From the first article of this series, you should now understand our temperature scales, why temperature is important, and some of the "points" that we use in calibration of temperature devices. Now, it is time to start focusing on the specific types of sensors we will cover in this training. If you are following along in our online portion you will already know that the first type of temperature sensing device we are going to cover is the ***thermocouple***.

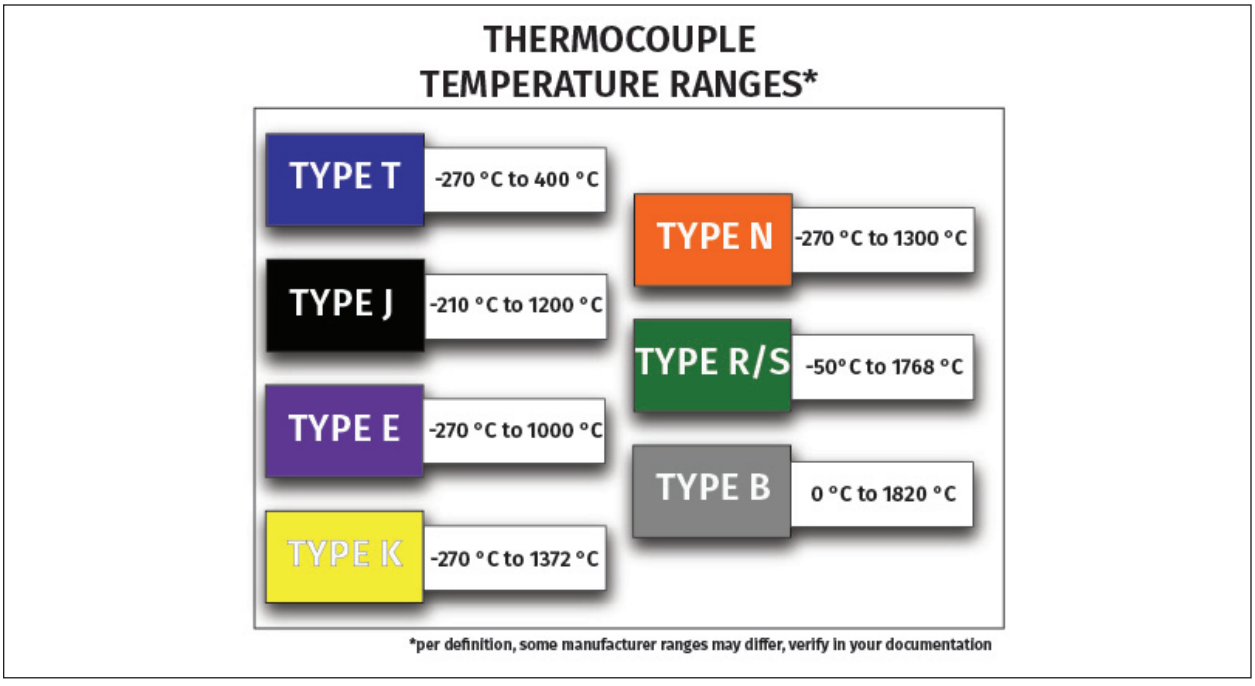
Thermocouples

Thermocouples, even though they are simple devices, are by far the most common you will see as a calibration professional. This is especially true if you are going on-site to perform calibrations at customer facilities. The bottom line behind their popularity is that they are accurate enough for most applications in manufacturing, but also relatively low cost. When you combine those two important factors with being robust enough to handle most manufacturing environments and wide temperature ranges, you have a winner for most companies. So, what exactly ARE thermocouples?

Thermocouples, at their most basic level are simply two wires, that are different alloys from one another, joined at a point that we call a thermocouple ***junction***. The key here is that each wire is different alloys from one another. Combining two copper wires together, for instance, would not create a thermocouple. However, if you use one copper wire and one of constantan (which is a copper-nickel alloy), you will have a standard Type T thermocouple, which is a very stable known type of thermocouple [1]. We say known type because, in theory, you could make a thermocouple out of almost any combination of dissimilar metals. However, the purpose of having known combinations is that it allows predictable responses that can be reproduced easily. This is why there are published standards, like ASTM in the United States, that publish the established types of thermocouples that can be manufactured for commercial use and the requisite accuracy to fit the standard. The chart shown on the next page is the current thermocouples per the definition, their assigned color, and temperature ranges. These are the thermocouples most commonly seen in the United States, but even U.S. based metrologist must understand that there are many thermocouple standards world-wide.

Notice that each type has a temperature range, but also is identifiable by color with each type of thermocouple having an assigned hue. The purpose for this becomes apparent when you look at the connectors for a thermocouple probe or extension wire, the distinct color allows for quick identification of what kind of thermocouple you have in your hand. The color of the individual wire insulation is important as well, allowing the polarity of the wires to be easily identifiable. Those familiar with electronics will be aware that the standard color code for most wires we deal with is the red wire is positive, and the black wire is negative. With thermocouples, throw that mindset out of the window. ***In the U.S. standards, all thermocouple types have a RED negative wire***. It is for this reason that after short experience going onsite to customer facilities, you will get used to seeing thermocouples wired backwards.

In this instruction we discuss the American standards, but everyone must be conscious of different coloring standards out there. Even though most thermocouple manufacturing standards will share the same temperature ranges for each type, the color conventions could be different. This is noteworthy because you may be onsite working on a machine that was built in a country that uses green instead of yellow for type K thermocouples, for example. Another scenario is that they use a type L thermocouple that will look identical to the U.S. J type thermocouple. To make matters worse, type L and J have similar mV measurements up until 600 °C or so causing an untrained individual to think that the "J type" thermocouple is simply failing at the higher temperatures. The lesson here is knowing



your country's specific types, but also be keenly aware that there are different thermocouple standards out there. Lastly, always pay close attention to the manuals for the equipment, if available. Sometimes they will give you a good clue to figuring out what type of sensor you have, if it is difficult to deduce.

For our course you do not need to memorize the colors or temperature ranges, but it is extremely important to be aware of them and where to find the references. Even though thermocouples are fairly rugged, going over the maximum temperature can change the composition of the metals used and completely ruin the sensor.

Making a Thermocouple Junction

Before we can discuss thermocouples and how they accomplish the things that they do you need to realize the term, Electromotive Force or EMF. What is EMF in relationship to temperature? EMF is generated in most cases by some sort of source, i.e., the Sun. It radiates EMF throughout a complete spectrum of frequencies. Visible light being an example of a portion of that broad spectrum. With thermocouples there is no source, so to speak, instead the relationship is called the "Seebeck Effect."

This idea was introduced by a physicist named Thomas Johann Seebeck in 1821. Basically, he discovered that when two metal wires of dissimilar metal contact each other at a junction there is an EMF generated between 0-40 mA [2]. This happens because the two dissimilar metal alloy wires react differently at any specific temperature and this creates a small voltage differential between those wires and a small current to flow. For the scope of our discussion here, in a beginner calibration lesson, we are not going to discuss what is going on at a molecular level, but instead we are going to identify what the ***variable*** for each temperature device is. Variable, meaning what quantity of our temperature device changes if the temperature changes?

If we apply what we have just learned about the Seebeck effect it will be found that thermocouples are in fact a ***voltage-variable*** temperature sensing device. As the temperature changes so does the millivolt offset voltage created by the junction of the two dissimilar wires. This offset is predictable, as we mentioned in the case of known thermocouple types, and that is why we can use them to read temperature. We know (with uncertainty) from a century of experimentation and through complex polynomial math what temperature it is when a type K, or any other type of thermocouple, produces a millivolt offset. Luckily for us modern day metrology practitioners we have standards that convert the voltages for us and consequently the math is outside the scope of this level of instruction.

In the first video of the online portion of this training we will show you the interaction between the thermocouple wires and the readings we get from the standard when we make the wires touch, but we need to discuss the term "junction" a little further here. Up to this point, we have been loosely using the word junction in this article, allowing the reader to use the definition they are most familiar with, that is until now. In learning thermocouples, it is important to know about three different junctions: the measurement junction, the reference junction, and unintentional junctions.

First, the ***measurement junction*** is often called the ***hot junction***. This is the point that goes into whatever you are trying to make a measurement of and can be in the form of two thermocouple wires connected at the end, or often they will be housed in a probe. Even though the name suggest that we are measuring something "hot," it is where the measurement is happening, even if it is a "cold" temperature.

Second is the ***reference junction***, this is sometimes known as the ***cold junction***. Remember when we said that a thermocouple junction is anytime there is a connection between two dissimilar metals? This is also the case when you are plugging your thermocouple into your standard. This is because your standard has a circuit board printed in copper, and thus, will create another millivolt offset at the junction of your thermocouple wires and the input to your standard. If not compensated for, this will cause significant errors in the measurement, but thankfully, science found our solution… ***Cold Junction Compensation, or CJC***. Most modern standards that you will use, as well as most modern readouts that you calibrate, will have built in CJC. We will talk about CJC in further detail in the video portion of the lesson when we are showing some examples of temperature calibration standards.

The third and last junction we are going to cover here are ***unintentional junctions***. This can be viewed as the opposite of cold junction compensation, where there is a junction at some point in your thermocouple signal wire that is not supposed to be there and is not compensated for. This type of junction will cause faulty, and at times, confusing readings. We feel that this is left best demonstrated and we have recorded some examples of this that you will see in the online videos. Just always keep in mind… if you are getting strange readings, look for a short somewhere in your wiring.

International Temperature Scale of 1990 (ITS-90)

To conclude the written portion of this module we wanted to also introduce you to one of the many written references for temperature measurements. This resource is the International Temperature Scale of 1990, or the ITS-90 [3], and it is one we must mention when we start talking about temperature calculations and realizing any of the temperature scales.

The ITS-90 is a reference guide in Thermometry. Temperature scales strive to be linear and precise but even with exacting precision the way electrons move evade reproducibility. Only through repeated measurements and applying statistics is how the ITS-90 happened. Countless days were spent by numerous people interpolating data. Compiled together with other temperature related data the ITS-90 provides personnel with highly accurate information used to chart thermocouples. As stated on the NIST website [4] "ITS-90 contains 17 reference points based on naturally occurring, highly reproducible states: phase transitions (freezing or melting) or the triple points in many familiar, naturally occurring substances." A couple quick examples of these fixed points, just to give you an idea:

- Triple point of oxygen at 54.3584 K
- Triple point of mercury at 234.3156 K
- Freezing point of aluminum at 933.473 K
- Freezing point of gold at 1337.33 K

These reference points can be used to calibrate temperature at relatively low uncertainties and the complex polynomial math we discussed is used to interpolate in between those fixed points. You may see this in some of your lab standards, with some displaying an indication that the temperature reading you are seeing is calculated using the ITS-90 calculations. We will show a visual example of this in the video demonstration.

This will conclude the written portion of the thermocouple lesson; at this time you can now proceed to the online curriculum inside of the school. As always, please do not hesitate to reach out to us if you have any questions, or if you need help accessing the online training.

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Implementing a Calibration Management Software System in a Regulated Environment

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Implementing a Calibration Management Software System is a critical process for a calibration laboratory, especially in a bio-medical regulated environment. However, there are few examples or documents that explain this process from a user's perspective. The objective of this paper is to explain the implementation process, provide examples of the documentation used, and to pass along lessons that were learned. The following topics will be discussed: Implementation Process Overview, System Development and Validation Life Cycle, Data Conversion, Test Scripts, Training, and Project Planning.

Background

In a preceding paper, "Selecting a Calibration Management Software System in a Regulated Environment," we discussed how as Microsoft kept updating their Windows Operating System with less compatibility with DOS, it became increasingly clear that we were at risk in continuing to use a custom-designed Calibration Management Software System written in Paradox DOS [1].

In the earlier paper, we also highlighted that the most important aspect of selecting a calibration management software system was in identifying your business requirements as it pertains to your software system needs. We ended up using the business requirements list throughout the selection process and it was the key to our project success [2].

In regulated industries, software system implementation is considered a critical process. Therefore, it will require careful planning, detailed documentation, and considerable testing activity to successfully release and use the software system in an operational work environment.

This implementation process was successful in implementing an off-the-shelf software solution that best met our requirements. Because of the rigorous implementation process, we were able to implement the software solution to operate with minimum quality or operational issues for six years before the first major upgrade. Additionally, the software system was effectively implemented into three of our high-volume medical device manufacturing facilities with similar excellent results.

This paper is intended to explain the implementation process, provide examples of the documentation that was used, and to pass along lessons that were learned.

Assumptions

As with any demonstrated process, future success is dependent upon understanding the process limitations and the project constraints. We have identified several assumptions for you to consider when using this process:

- This paper is not a software validation presentation. A validation discussion would take several articles to adequately describe the process. We will identify some of the excellent resources that are available.
- We performed a site-by-site standardized approach. This maximized flexibility while minimizing project management and scheduling issues.
- Understand your system requirements—completely; never substitute good research with a quick, easy fix. You will be disappointed in the results.
- This process was not fixed, but dynamic. We made changes along the way. Your process also needs to have that flexibility.
- The implementation process tried to involve as many people as possible. Stakeholders are in many areas of the business: customers, employees, supporting departments (IT, Finance, etc.) peers, upper management, etc. Your success will be proportional to how many stakeholders you involve.
- The process is time dependent. If we performed this implementation process today, the process would incorporate the lessons learned and any ideas gleaned from new research.

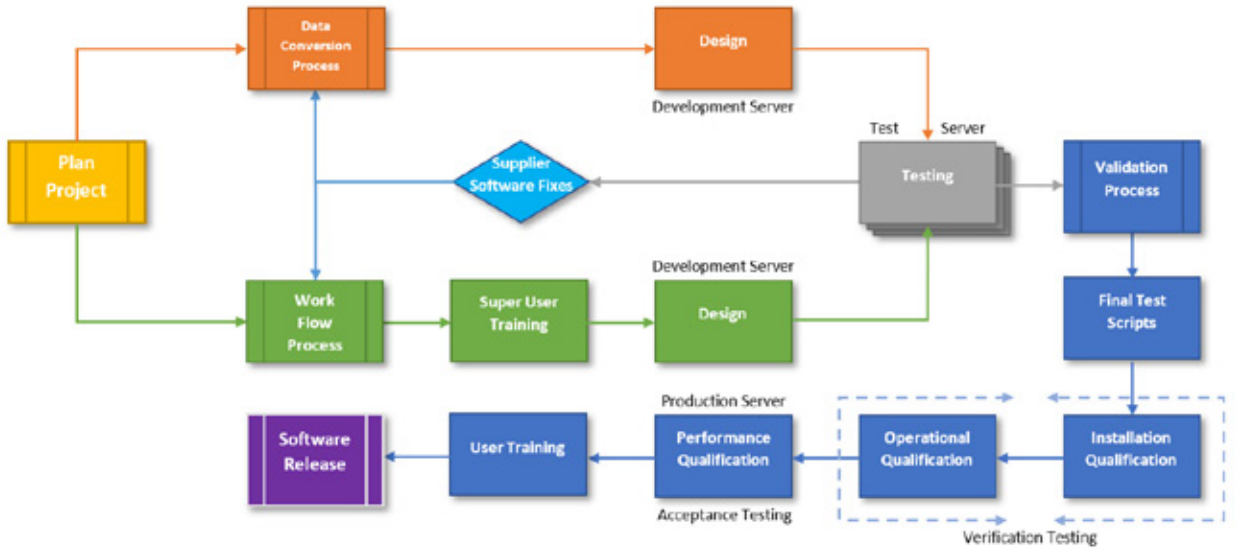

Figure 1. Implementation Process.

The Implementation Process

The implementation process we used is illustrated in Figure 1. There were two main processes started together: (1) Data Conversion, and (2) Work Flows. The third main implementation process, Validation, was started last for obvious reasons.

Project Planning

Initially, we thought that the entire project would be performed within our metrology department as it had been done in the past. We worked to get company project training and to learn more from project planning references such as Project Management for Dummies [3]. It then became apparent that the project would be one of the first company projects to fall under the newly developed System Development and Validation Life Cycle requirement [4]. This was both good news and bad news. Good news, in that there was a standardized validation process; bad news, in that we would have to work under more scrutiny and work through the growing pains of using a new process. The company IT project group turned out to be a great resource and they were a tremendous help. We would not have completed the implementation project successfully without their active engagement.

Additionally, any large successful project is a result of working with talented, dedicated people. The project Key Business Representatives were instrumental in our success [5].

Lessons Learned: The more knowledgeable you are about project planning, the more successful the project. We had fortunate timing to be one of the first projects to fall under the new company standardized SDVLC IT process. It is a great comfort knowing that you have adequate validation paperwork ready for any audit.

Data Conversion Process

The first question to ask is "Should we convert our data into the new database, or should we archive the data and start from scratch?" This is a very good question and very important. There are advantages and disadvantages from both points of view, see Figure 2.

We decided to convert our data. We had a relatively clean database, we had a large amount of equipment history, and we had successfully passed regulated audits so we felt comfortable that we had a solid database foundation.

Convert Data	Start New
Complex Validation	Simpler Validation
Work Flows are more fully tested	Work Flows are less fully tested
Critical Project Milestone	Not a Project Critical Path
More Data for Trending	Less Data for Trending
More historical data to support audit responses	Less historical data to support audit responses
Tests Software Functions more completely	More difficulty in fully testing software functions
Higher Project Costs	Lower Project Costs
Previous Database needs to be normalized (clean)	Previous Database does not require clean data

Figure 2. Advantages and Disadvantages for Converting Data.

Though it was a very painful process, we are glad that we decided to convert our data into the new software system.

In the purchase contract, we had a quote from the supplier for converting our data from our custom-built database to their off-the-shelf database. Data conversion can be very complex and expensive, and not every supplier offers this service. Our database held over 500,000 historical equipment records over nine years of calibration activity at the time of the data conversion.

We started off by supplying a copy of our database to the supplier with a data conversion script sheet defining the data fields and where we wanted them to go in the new database. We then tested the returned data structure by printing out a full equipment field listing on a random sample of ten instruments from the previous database. We verified each field. This comparison identified numerous errors in the conversion process. We continued to work with the supplier to address each conversion issue and continued the process. Once a random sample of ten instruments passed with 100% accuracy, we then increased the random sample to 100 instruments. This identified new issues to resolve. Finally, after passing 100 instruments we went to the final statistical random sample of 360 instruments that would achieve a 99% confidence level of the accuracy of the database migrated data. This took another round of iterations to resolve the new conversion issues. Think of this process like an iceberg, the first iterations identify the more visible functional issues. As you progress deeper, you begin to find the hidden issues that revolve around seldom used applications or functions. Eleven data conversion iterations later and we finally had a successful data migration.

Lessons Learned: This was the most critical part of the implementation process and though very painful, we would definitely do the process again. Because of this level of scrutiny, we were able to successfully operate the software at a high-level of data integrity from the very beginning with minimum modifications over a six-year period. The data conversion process resulted in software improvements that the work flow testing would not have identified. Be careful in your data conversion estimates; build in plenty of slack time.

Work Flow Process

The important question to ask is "Do we use the existing work flows for a simpler conversion or do we create new work flows to take advantage of new software functions?" Once again, there are advantages and disadvantages to consider, see Figure 3.

We decided to use existing work flows to minimize the need to re-write existing operating procedures and to minimize training so we could quickly get up and running after the database switchover. Because we already had a mature work flow process, we were not impacting operational effectiveness by delaying use of new work flow features.

Use Existing Work Flows	Use New Work Flows
Less SOPs to re-write	New SOPs to develop
Quicker Implementation	Longer Implementation
Less initial use of new functions	Take advantage of new functions immediately
Less software training time	More software training time
Can identify software flaws	May hide software flaws
Requires mature work flows	Does not require mature work flows

Figure 3. Advantages and Disadvantages for Using Existing Work Flows.

We initially planned on using the supplier's distributor to provide work flow design conversion from the existing work flow structure. This is a benefit that may not be provided by all software suppliers. The first work flows from the distributor showed a large gap from what we needed to see to meet the project schedule, as we were already delayed because of the multiple data conversion iterations. There was just too much re-work to do to make these work flows perform to the business requirements. So, we re-planned the project and asked the supplier to provide the project team with "Super User" software configuration training. This training would allow the team to design the work flows more quickly as we were

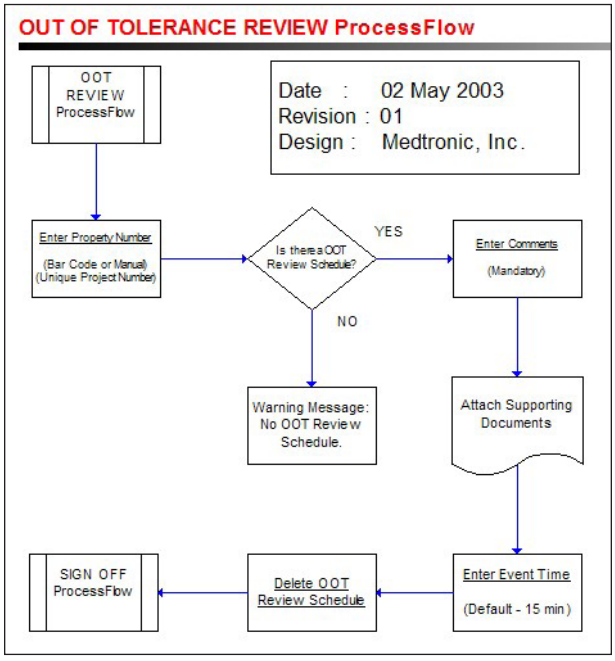

Figure 4. Work Flow Chart Example.

the most familiar with our processes. This turned out to be an excellent decision for the short-term and long-term success of the project. We used the supplier to assist us with the more complex work flow designs. This proved to be a good balance in using the supplier's design expertise for the most complex work flows and to leverage the super user training on the less complicated work flows. As a side benefit, we were able to take advantage of the Super User training after the software release to design new work flows and take quick advantage of the new features in the software.

Because of the complexity of the work flows, we decided to outline them in a Visio work flow chart. See Figure 4. We then used those charts to help with developing test scripts and also as part of the training material for users.

Lessons Learned: Having sufficient knowledge to work on your own work flows is very beneficial to long-term success. This allows you to take future advantage of software functions. Of course, this cannot happen if the software of choice is not flexible in work flow design or configuration. Successful work flow design can also identify additional software improvements.

Validation Process

There are many good sources for information that describe software validation processes. One excellent resource for the bio-medical industry is GAMP 5: A Risk-based Approach to Compliant GxP Computerized Systems [6]. GAMP 5 has these elements: key concepts, life cycle approach, life cycle phases, quality risk management, regulated company activities, supplier activities, and efficiency improvements. Two important concepts within GAMP 5 are (1) Use of Risk-based Decisions, and (2) Leveraging Existing Documentation. Both of these concepts are regulatory accepted methods to efficiently scale life cycle activities. GAMP 5 comes with excellent additional documentation that can be used as templates for your software validation process; e.g., forms, checklists, questionnaires, etc.

Another excellent resource for the bio-medical industry is ASTM E2500 Standard Guide for Specification, Design, and Verification Pharmaceutical and Biopharmaceutical Manufacturing Systems and Equipment [7]. ASTM E2500 focuses in these areas: specification, design, verification, and lifecycle. ASTM E2500 also highlights the concept of "leveraging vendor documentation" to more efficiently verify the software system.

The supplier had a comprehensive validation package that we purchased; however, we did not end up using it because the project became one of the first software projects to use our company's System Development and Validation Life Cycle methodology [4]. The SDVLC process was very comprehensive and involved these main areas: detail project definition, analysis, architecture, detail design, construction, system implementation, and system management. Each of these areas had many sub-set requirements, so you can imagine the paperwork involved and the project planning necessary to execute this process. Another variation of SDVLC is the "System Development Life Cycle" that has seven phases: planning, analysis and requirements, design, development, testing, implementation, and maintenance [8]. This paper will concentrate in these validation areas: test scripts, installation qualification, operational qualification, performance qualification, and software release.

Test Scripts & Test Environments

We developed data conversion and work flow test scripts using a development server environment. At this point, many of the test scripts discovered software configuration issues that the supplier had to help us resolve. Once the test scripts were successfully developed, we then tested them in a test server environment and ensured that there were no remaining data conversion and work flow issues with the new software installation. Final test scripts were written and used in the IQ, OQ, and PQ validation processes. The Work Flow Visio Charts were very helpful in writing these test scripts. In fact, the IT group helped write many of these test scripts and they were able to do this using the detailed work flow charts. See Figure 5 for an example of a simple test script.

Some important considerations for a test script are:

- Document the actual results and provide objective evidence in a manner that demonstrates that the specified expected results were met. Software screen shots are very useful to meet this objective evidence expectation.
- Indicate a "Pass" or "Fail" status for every test step that confirms a requirement.
- Document and manage defects that are encountered during testing.
- Provide documented rationale/mitigation for every failed test step.

We used three different test environments: (1) Development Server, (2) Test Server, and (3) Production Server. The Development test environment is where we performed prototyping, programming, and workflow development. Included was developing data conversion scripts. The Test environment is where we performed formal/verification testing which included configuration testing and final data conversion tests. In the Production environment we performed acceptance testing in the working environment. We used physically different servers for each environment. Your IT team may define virtual server environments to meet these isolated testing needs.

Test Case	Test Instructions	Results Expected	Actual Results (Pass/Fail/Description of deviation)
6.17 Print Label Event			
	Test Set-up: Perform Print Label tests with the Standard User profile login ID. Select any active equipment. A label printer is configured as printer 2 in Workstation Setup		
	1. Execute the Print Label event.	The Print Label *Event Information* screen is displayed.	
	2. Verify data in the following fields: Event Ver, Barcode Label, Part of Label, Choose Equipment grid	• Event Ver = Current event version date • Barcode Label = Checked (Default) • Part of Label = Unchecked (Default) • Choose Equipment grid = The equipment selected for the test.	
	3. Click on Part Of Label to check the field.	The *Part Of Label* field displays as checked.	
	4. Click the Finish button to complete the event	A dialog box is displayed requesting the number of PART-OF labels to print.	
	5. Select 2 from the Copies field and press the OK button.	The dialog box closes and the event completes.	
	6. Verify the results of the event.	• The event is not entered into the history grid. • A barcode label and a 2 part-of labels are produced on the label printer.	

Figure 5. Test Script Example.

Software validation terms will differ between organizations, but the underlying details are very much the same. We used the traditional validation qualification terms (IQ, OQ, and PQ); however, all testing elements fall within the general SDLC concepts of design and performance verification testing.

Installation Qualification

The purpose of Installation Qualification verification is to ensure the correct installation and configuration of the software and hardware. Three areas of focus are the data migration, the hardware interfaces and architecture, and the environmental conditions. The IT group led the way in this validation area and performed many of the testing tasks. Some of the areas we covered in the IQ: data conversion verification, database server architecture and design, database hardware component selection and implementation, printing and e-mail interface functions, and web-based interface functions.

Operational Qualification

The purpose of Operational Qualification verification is to test the system against specifications to demonstrate correct operation of the software system functions. The OQ is the centerpiece of software validation and will take up the most resources and time. This was a joint effort between the IT group and the metrology project team. The OQ process is intended to test the software functions and therefore is a very detailed testing process and the largest component of the validation process. The OQ report ended up being over 140 pages long and was mainly comprised of the work flow test scripts. The OQ took three people a week to execute after all of the documentation and test scripts were written and approved.

Performance Qualification

The purpose for Performance Qualification verification is to test the system to demonstrate fitness for intended use and to accept the system to documented specified requirements. The PQ plan covered these areas: functional testing, user limit testing, data conversion testing, stress testing, performance and load testing, volume testing, failover and recovery testing, and configuration testing. These tests were performed on a production server environment.

Because of the thorough design testing prior to IQ, OQ, and PQ verification testing, we did not encounter any major software or hardware issues.

As a precaution, we worked with the supplier to have a software technical expert on hand during the final testing and software release. This technical software expert was valuable in the switchover in fine-tuning configurations and custom reports, and assisting with technicians during the first day of production use. This worked so well that we recommended this person by name to be on-site for the other three high-volume manufacturing site implementations.

Lessons Learned: As you can see, software validation is not an easy process and it comes with high resource needs as well as requiring very large amounts of documentation; e.g., plans, reports, approvals, etc. We were fortunate that we were able to leverage the expertise of the IT group to help in this documentation process. Another great help was having a company standardized software validation process.

Software Release

We made the determination to perform a switchover from the previous database system to the new database system. We would continue to use the existing system

and then switchover to the new database in a two-day period. This required careful planning, especially in the aspect of providing user training and coordinating data conversion, final testing, and documentation efforts. Additionally, we initiated a hard-copy documentation process in case the switchover was delayed or if a high priority work request was needed to be completed and documented during the switchover.

We provided user training during the switchover time in a classroom setting where we provided handouts that comprised the software user manual, copy of work flow charts, and the training document itself.

Lessons Learned: The switchover process went very well. It was valuable having a supplier software technical expert on-site, both from a trouble-shooting aspect and in providing on-hand training for users. Formal class room user training close to implementation works best for better retention of software operational information.

Summary

The initial implementation project was planned for four months which in hind-sight was a very aggressive schedule. Instead, the project lasted eight months mainly due to additional unplanned data conversion iterations to resolve software workflow corrections and improvements. With this experience, we would recommend that any data conversion effort be carefully planned using conservative schedule estimates. The good news is that because we decided on a site-by-site implementation approach, the other high-volume manufacturing facility site implementations went much smoother and came in closer to project schedule forecasts.

Due to the robust testing and validation process, the software was able to operate for six years without any significant issues. This is a major quality achievement considering we were replacing a custom-built software system operating in DOS with a commercial off-the-shelf software solution operating in a Windows-based, Oracle environment. This included the data conversion of over 500,000 equipment records.

Successful software implementation also requires a close working partnership with the software supplier. The supplier's software design expertise will be critical to the success of your implementation and future operational use and software system performance.

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Walter Nowocin was a Calibration Department Manager for Medtronic PLC, the world's largest medical device manufacturer, when this project was implemented.

Metrology Education at Michigan's Monroe County Community College

Michael L. Taylor
Monroe County Community College
Career Technology Center

Monroe County Community College's Career Technology Center

Introduction

Monroe County Community College (MCCC) was created in Monroe County Michigan in 1964. Since that time, it has undergone a good variety of change and growth. The original metrology program began about 20 years ago. It was originally incorporated with the quality technology program, as it remains today. Metrology and Quality Program students have since then shared some similar courses. Opportunities also exist where a dual degree is possible. This can be accomplished with the addition of only a few classes in either program. Classes for both programs originally were taught in one of the older buildings of the college, the East Technology Building, until in the Fall of 2013, when there was a significant new construction development. This occurred to satisfy the educational needs of local businesses and to greatly improve the college's technology programs. Generous donations provided by industry made it possible to build the new and impressive high tech Career Technology

Center (CTC). This new building greatly enhanced many of the technology programs at the college, and it has very much improved the quality of the teaching environment and the equipment used for education in several technology fields. Some examples of fields that are represented are electronics technology, robotics, 3D printing, mechanical engineering, auto mechanics, welding, and various others. A metrology lab and a metrology/quality classroom were part of the original design and plan for this building. Today, among the originally proposed areas, the allocated metrology education facilities remain an important part of this plan.

The Metrology Program

Regarding the actual Metrology Program class offerings, these are mostly geared towards a general focus on dimensional metrology. The reason is that manufacturing in Michigan is largely centered around the automotive industry, and the demand for Metrologists therefore is mostly regarding the making of dimensional measurements. The initial portion of the MCCC Metrology Associates Degree Program curriculum involves core required courses as a necessary basis for program completion. These classes provide many background skills and abilities that prepare students, so they can accomplish many of the advanced metrology activities included in the later courses. Among these basic required courses are those that are needed for most majors, such as: English; math; a science course requirement that can be fulfilled either by a physics or chemistry course; and others, including electives. Afterwards, several specific required technical courses for the program must be completed. They include Mechanical Drafting, Manufacturing Processes, Basic Electronics, Geometric Dimensioning & Tolerancing, and Blueprint Reading. Thereafter, come the essential metrology and quality courses. These are major portions of all courses remaining and they are required to complete the program. These final courses include: a basic dimensional metrology course; use of coordinate measuring machines (CMMs) and articulating arms; an auditing course; a Gauge R&R course; and a course in statistical math, including a focus course on statistical process controls (SPC). Students who have limited time or budgets may instead pursue Certificate Programs in both Metrology and Quality Technology. The Certificate Programs usually may be completed in one year.

Undeniably, courses of most interest to students are those involving actual acts of measurement and use of test equipment. The one course that is at the heart of everything in the MCCC Metrology Program is "Introduction to Metrology" (QSTC 150). It involves basic measurement studies with hands on lab-work including use and study of a good variety of dimensional measurement devices. These range from basic dimensional measurement items, such as rules, scales, various types of micrometers, vernier, dial and digital calipers, bevel protractors, gage blocks, plug gages, ring gages, snap gages, dial indicators, height gages, cylindrical squares. Later in the course, students get to use and study somewhat more sophisticated dimensional measurement items, such as optical flats, optical comparators, measuring microscopes, air (back-pressure) gages, and a variety of electronic and mechanical comparators. Also included in the course, is an elaborate study of surface plates and the idea of flatness. The final sections of this course involve introduction to the 3D cartesian coordinate system and use and study of probably the most sophisticated dimensional measuring devices today, which are CMMs and articulating arms. This includes use of both PolyWorks and PCDMIS software. This Intro class is general, but it provides good descriptions and creates a familiarity for students of many conventional dimensional measurement concepts, and the main ideas behind basic dimensional measurement technologies and equipment. Included in all of this, is a surreptitious goal to inspire a deeper interest in metrology that hopefully will motivate students towards looking further into taking additional metrology or quality classes. The Introduction to Metrology course includes a generous number of labs and hands-on measurement opportunities for students. It

Basic Dimensional Measurement Equipment

Romer Articulating Arm

also is the most popular MCCC metrology/quality course for students with no intention to work towards either a metrology/quality program degree or certificate, but need or want a general understanding of the science of measurement. Today, some other MCCC technology programs, such as mechanical engineering, require this course and the experience gained from it regarding use and understanding of the large variety of measuring and test equipment that the course provides.

A full blown CMM & Articulating Arm course (Advanced Metrology, QSTC-210) also is available at MCCC. This course is the only one that currently involves 100% classroom activities in the metrology program at MCCC. It involves significantly more complex programming activities than the QSTC 150 introductory course, including extensive performance involving a development of an understanding of the theory behind these two popular 3D measurement technologies. The use of both PCDMIS with a CMM, and a Romer Articulating Arm with PolyWorks software are included. This course prepares students for entry level jobs operating CMMs and Articulating Arms using these two different software packages.

A few additional courses focusing on Metrology and Quality also are required and available for the MCCC Metrology Associate degree program. Likely, the next most significant of these is the Gauge Repeatability and Reproducibility (QSTC 220) course (Gage R&R). This includes actual gauge repeatability and reproducibility studies, where students perform calibrations of equipment, and then in depth encounter with the theory of and how to perform Gage R&R studies. This course also provides experience and understanding about currently available software and technologies for the purpose of gathering data and utilizing gauge and test equipment automation for this purpose. Fluke MET/CAL® software is used to generate the automation and to perform calibrations. Some examples of the types of instruments that are calibrated in this class and that are used to perform Gage R&R studies are pressure gauges, digital multimeters, torque wrenches, temperature gauges, mass balances, and a few other items.

Even though, as mentioned before, the MCCC Metrology Program focuses mainly on dimensional measurements, this class includes additional instruments that measure various other parameters. This provides students with an opportunity to become familiar with and to experience some other important aspects of metrology. MCCC is prepared to expand on this capability to teach additional measurement parameters in more detail, should industry and/or students' express an interest in this. Furthermore, this Gage R&R course also includes subjects that provide the student with a grand overview of the whys and benefits of Gage R&R studies, and it explains reasons for and values resulting from industry's decisions to conduct such studies. Student insights and understanding of the value of Gage R&R tests are the intended results.

The following sub-topics also are a part of this course: what makes a Quality System tick, what essential elements must be in place so everything will work and work well, what documentary standards should be or might be followed in given situations, what is involved in auditing of a metrology lab, what is metrology laboratory accreditation and when is this preferred or needed, when should a lab perform proficiency studies, what is and when should a lab make uncertainty studies of their measurements, understanding of equipment specifications, calculation of calibration tolerances, use of statistical math in calculations regarding measurement results, and Gage R&R studies.

This Gage R&R course also includes the student's gaining of a general familiarity with various important metrology terms and concepts. The text used in this course, is *The Metrology Handbook*, by Jay L. Bucher.

Challenges

For the past 1.5 years, as is the case with probably all schools, COVID-19 has had a definite impact on how things are done by faculty and students in schools everywhere, and this is certainly not different at the MCCC. However, life does go on, and actual numbers of students taking

courses in metrology, perhaps surprisingly, has not changed much. In 2020 only one student took a metrology course at MCCC, and three students took quality courses. The Winter semester of 2020 was cut short due to COVID-19, the result was that it took two semesters to complete one course. Social distancing and the wearing of face masks and face shields now is the norm across the school. For the Winter semester of 2021, one student is taking a Quality course, and three students are enrolled in the Introduction to Metrology class. None of the current students are working towards Metrology Degrees; however, they are either taking these courses as electives or as a required part of another program. Some students are involved in the apprenticeship programs of various local industries.

Michigan's MCCC is one of very few community, or any other type of college in the USA that currently offers any type of degree in metrology. Even though this is the case, maintaining an interest and attracting students to this program has sadly been a continuous challenge. Good paying jobs in metrology certainly exist in the local areas of Michigan and Ohio, and the demand for graduates of the Monroe County Community College Metrology Program from local industry, has always been considerably greater than the supply. Obstacles identical to this also exist at most other colleges in the US and Canada with metrology study programs. This unfortunate fact has remained to be the case throughout the various economic seasons occurring in our country for the past several years.

There have been many ambitious plans and initiatives used and attempted with the sole purpose of resolving this difficult metrology education issue; these have been organized by colleges, industry, and even NIST with varying levels of success, but the ongoing issue of a limited amount of trained metrology personnel available continues to challenge us. During the first decade after the year 2000, at MCCC, metrology classes had an average of 12-15 students per semester. However, even then very few (one to two per year) students became graduates of the program who now hold a metrology degree. Currently, only about 7 students have graduated with either a Metrology Certificate or an Associate Degree in Metrology in this schools' history. Today, an average year has 4-10 students attending all Metrology and Quality classes combined.

Metrology Summer Camp

Prior to COVID-19, one good method that was used to get out the word about the Metrology Program at MCCC was the offering of an annual Metrology Summer Camp. This initiative was designed mostly for local high school students to generate awareness and interest in metrology among younger students. Average participation in this annual event has been 8-10 students. The costs to attend has usually been generously covered by local industry, and some other interested parties, in hopes that this might successfully elevate the interest of students, so they might take future metrology classes at MCCC. This summer camp is a one-week long event, and it includes 5 days of 4-hour classes/day, usually offering a different and very distinguished instructor for each day.

The Summer Camp has involved an interesting array of events especially geared to the interests of the young students. It provided training in basic metrology and quality theory and it involved various hands-on experiments and practice in the use of a variety of measuring and test equipment items. This occurred by performance of various labs and activities designed and taught by an exceptional assortment of elite veteran metrologists who provided their services as volunteers. Students who participated in this Summer Camp were presented with the unique opportunity to associate and discuss metrology, physics, and quality theory with many renowned metrologists, quality professionals and engineers from across the USA. Most of the volunteer teachers in this event came from distinguished organizations such as NIST, local electric utilities, Parker Fittings, General Motors, NSF International, E=mc3 Solutions and several other organizations. Certificates of Attendance and photos, published by the college newspaper, were provided to students who participated. This program and future similar summer camps will very likely be continued after the COVID-19 pandemic has subsided.

Raising Awareness

One strong and continuous incentive to further metrology education exists at MCCC. This is to encourage a large variety of students, representing many different professional fields, to consider taking at least one course in metrology, so that they might become a part of the now very small, unique, (and we feel) elite sector of society that is truly aware of the many very important metrology concepts. As most metrologists and quality professionals know, the science of measurement is certainly and absolutely a very important contributing factor to the level of quality of nearly any item or service produced by our manufacturing organizations. Perhaps the deepest hope of those of us who are promoting metrology education, is that there will be many new metrology students and that these students will, at some point in time, be working in most of our major industries.

Having a good awareness of metrology can be generated by simply taking one metrology course. This can provide a basis and potential for substantial quality improvements in virtually all industry. Metrology has for years worked to distribute and promote deeper understanding and appreciation for the value of improving measurement and quality. Metrology will improve quality overall, and likely ultimately reduce manufacturing costs. Concerns about the cost of this quality has always been one of the primary concerns and one of the major reasons given to reject the idea of making measurement quality improvements in

Metrology Summer Camp

our industries. Therefore, one of metrology education's primary objectives has continually been to provide proof, including data to back it up, that clearly shows measurement improvement's positive effect on quality. Even though costs do exist up front, the significant positive results in cost savings, via lower defects in items produced, do in most cases eventually eliminate and even reverse any financial losses that may apparently occur up front.

We, in US Industry, have learned this lesson at least once before; when we initially rejected our own W. Edwards Deming, and when he, because of our rejection of him, went to Japan and provided the Japanese with his momentous quality philosophies. This resulted in Japanese goods' quality phenomenally exceeding that of our own. The resultant effect on the US economy was huge losses of countless dollars for many years. This economic tragedy continued in our country until we replicated the Japanese quality systems and reached quality levels approximately equal to those of Japan. By the same logic, skimping on quality by continually rejecting metrology and measurement technology—even if we do once again reach the top of the quality ladder, and becoming lazy and complacent is not at all a good thing—can serve no good purpose and it will surely result in less than the best possible quality. Furthermore, this is true even more since current surges in high technology are greater than at any other time in history. Measurement is becoming more and more essential and is an absolutely required part of making things work efficiently and work right. Metrology could very well be the most important key idea that keeps us in the game of international competition, which daily grows more and more keen.

Michael L. Taylor is an Adjunct Metrology/Quality Instructor at Monroe County Community College in Monroe, Michigan, US. For more information about MCCC and the Metrology and Quality programs, visit: Main College website at **https://www.monroeccc.edu/**, Metrology/Quality Technology Program at **https://www.monroeccc.edu/programs/metrology-and-quality-technology**

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NEW PRODUCTS AND SERVICES

Yokogawa IS8000 Integrated Measurement Platform

Houston, TX – February 18, 2021 – Yokogawa Test&Measurement Corporation has released the IS8000 Integrated Measurement Platform to accelerate engineering workflows with a platform-based approach that synchronizes data collection, unifies instrument displays, and optimizes programming. The IS8000 provides simplified configuration and control of multiple test points, across multiple test instruments, from a single, common interface. This not only streamlines the development process but also allows engineers to expedite test system development and focus on collecting and analyzing valuable data, quickly and efficiently.

Successful product development requires data to be shared effortlessly across multi-disciplined program teams. Engineers, today, typically rely on multiple instruments to meet the broad variety of technical challenges in their design, testing, and validation processes. Collecting, analyzing, and maintaining large volumes of test data from multiple instruments, each with different formats and storage media, presents risks to successful project completion. Each instrument uses unique device drivers, communication interfaces, and synchronization protocols. Lack of correlation significantly impacts time-to-market, presents quality risks, and increases expenses.

As a pioneer in the test and measurement industry, Yokogawa recognizes that a standardized and robust testing strategy that is based on a unified hardware and software platform is essential for successful product development. The IS8000 software platform enables unified testing by tightly integrating the timing, control, and data collection from several instruments using the IEEE1588 PTP protocol via USB or Ethernet to create a comprehensive measurement suite.

According to Tom Quinlan, Vice President for Yokogawa Corporation of America, "Engineers who are using a variety of instruments such as mixed-signal digital oscilloscopes, power analyzers, and high-speed recorders can now depend on the IS8000 software platform to view, analyze, and debug all measurements in a single, unified environment. Correlating the timing of waveform displays from several sources provides a far more accurate assessment of complex systems and will make the development of new products much quicker and easier."

For further information on the IS8000 Integrated Measurement Platform, please visit https://tmi.yokogawa.com/us/solutions/products/oscilloscopes/oscilloscopes-application-software/is8000-integrated-software-platform/

New R&S NGA100 Basic Power Supplies

Munich, April 22, 2021 — Rohde & Schwarz continues to expand its range of basic power supplies with the new R&S NGA100 series. The R&S NGA100 is available in four models, providing a choice of single and dual outputs with up to 35 V/6 A per output, or 100 V/2 A per output. Single output models supply up to 40 W, dual output models up to 80 W power. The dual model outputs can be combined to provide up to 200 V or 12 A.

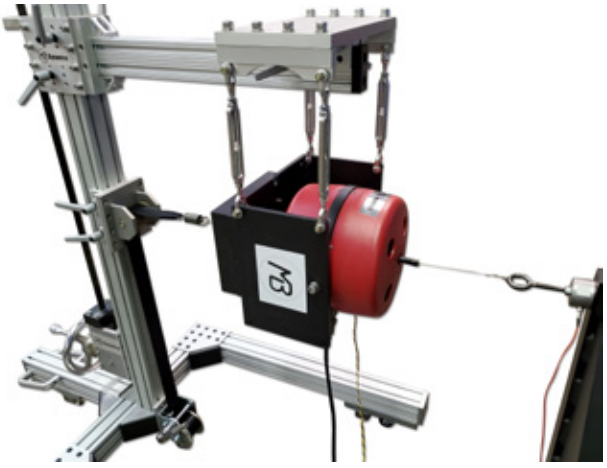
Rohde & Schwarz has implemented a linear design throughout the output circuits of the R&S NGA100 which significantly improves performance compared to the switched-mode circuits frequently found in basic power supplies. The resulting higher accuracy means engineers can be confident of supplying exactly the right power level without any need for an additional multimeter. The standard level of readback resolution, 1 mV/100 µA, is enhanced for currents under 200 mA to a resolution of 1 µA, ideal to test low current levels typical for IoT applications in standby and sleep mode. The R&S NGA100 also has the necessary dynamic range for power and current spikes when switched to active mode.

While many basic power supplies only output maximum power within a very limited voltage/amperage range, the FlexPower technology from Rohde & Schwarz provides maximum power for a wide range of combinations, so that a single instrument can support many different applications. No matter which application, users benefit from the clear screen, intuitive user interface, and features like instantaneous statistical functions for maximum and minimum values for power, voltage and current, displayed directly on the screen.

Other features of the R&S NGA100 not commonly found in a basic power supply include logging voltage and current values for analysis, with up to 10 samples per second. For data export and remote control, Ethernet and USB are supported as standard, with optional WLAN and an external trigger with digital I/Os. Users can generate sequences of voltage/current settings at intervals down to 10 ms. The supplied power is low distortion and low noise, and cable losses can be compensated thanks to the R&S NGA100 remote sensing function. The correct level is at the input to the device under test, not at the output of the power supply.

The new R&S NGA100 power supply series is part of the R&S Essentials portfolio, and is available now from Rohde & Schwarz and selected distribution partners. For more information, visit: www.rohde-schwarz.com/product/nga100

NEW PRODUCTS AND SERVICES



New Lateral Excitation Stand from MB Dynamics

April 21, 2021 – Cleveland, Ohio, USA – MB Dynamics, Inc. (www.mbdynamics.com), field-proven industry experts in the design, manufacture and supply of vibration test systems and equipment, including buzz, squeak and rattle (BSR), steering, and suspension component test systems; modal exciters and amplifiers; single- and multi-DUT automated accelerometer calibration systems; dynamic controllers; transducer calibration systems; and engineering services, today announced the global market introduction of its Lateral Excitation Stand.

The MB Dynamics Lateral Excitation Stand can be used to help reduce measurement errors which can arise during experimental modal surveys. It does so, by offering versatile modal exciter suspension and support, as well as by applying force to a test structure in one of two unique ways: either horizontally, into the side of a test structure; or, obliquely, beneath a test structure. The stand further allows exact modal exciter positioning, in either horizontal or vertical direction, while still accommodating a maximum suspended load of up to 60 kg.

Designed by 40-year global industry experts in experimental modal analysis, the stand offers seamless compatibility with MB Dynamics' own industry best-selling MODAL 50A and MODAL 110 exciter systems, of which more than 1,300 remain successfully installed in the field. The main structural parts of the Lateral Excitation Stand are constructed of a lightweight, durable, and rugged aluminum, while its rubber-footed adjustable steel legs offer added stability.

The Lateral Excitation Stand may also be used in combination with tensioned piano wire or compression stingers to help reduce measurement errors arising from unmeasured transverse forces. This, given that tension-only stingers can be used to apply axial forces without the typical sideloads which can otherwise contaminate measured data.

Typical applications for the MB Dynamics Lateral Excitation Stand include virtually any experimental modal survey application incorporating the company's own MODAL 50A and MODAL 110 exciter systems. These include, though may not be limited to, aircraft and automotive testing, civil engineering, power generation, and test & measurement applications. For more information about the new Lateral Excitation Stand, or MODAL 50A and MODAL 110 exciter systems, please contact MB Dynamics at +1-216-292-5850, sales@mbdynamics.com, or visit www.mbdynamics.com

Vitrek Portable, Battery-Operated DC Calibrator

Poway, CA—May 6, 2021— Vitrek, the leader in high-voltage test and measurement equipment, offers the XiTRON 2000 series for metrologists who need superior accuracy and portability when calibrating thermocouple, pressure, flow and DC instrumentation. Delivering laboratory-level accuracy in a battery-powered DC calibrator, the 2000 Series is a cost-effective calibration/simulation tool for applications spanning the consumer, medical, automotive, process control and many other industries.

The high-performance 2000 Series computes current or voltage output using an equation derived from two data points to simulate the sensor output. Automatic cold junction compensation is included, allowing both measurement and simulation of values in °C or °F for B, E, J, K, N, R, S and T thermocouples. Additionally, current loop (4-20mA) indicators, controllers and recorders can be precisely calibrated with accuracy measured in parts-per-million (ppm) rather than percentages.

Key features of the XiTRON 2000 Series DC calibrator include:

- DC voltage and current capability, +/- 22 volt, 10ppm accuracy, +/-22mA, 40ppm accuracy Temperature simulation with 01o resolution, 0.015o– 0.12o accuracy (90 day)
- DC resolution down to 10nV or 10pA
- Temperature measurement with 0.1o-0.2o accuracy (90-day)
- Auto cold junction compensation NiMH battery operation (8 hours typ.)
- Standard RS232 interface allows laptop PC control in the field, while the optional IEEE-488 interface supports ATE applications
- Additional memory can be added to either interface for 10 user-defined test steps
- Temperature control loops
- Thermocouple measurement and simulation

"In the past, metrologists who wanted to check systems around the factory floor had to either buy an expensive calibrator for lab use only or use a portable calibrator that didn't provide the accuracy they needed," said Chad Clark, Vitrek's VP, Sales & Marketing. "Vitrek now offers the ideal solution. The XiTRON 2000 Series is portable and battery-powered – and yet it has the performance of a bench calibrator."

Learn more about the XiTRON 2000 by visiting https://vitrek.com/2000-series-portable-calibration-instrument/.

Multiple Levels to Metrology Software

Michael L. Schwartz
Cal Lab Solutions, Inc.

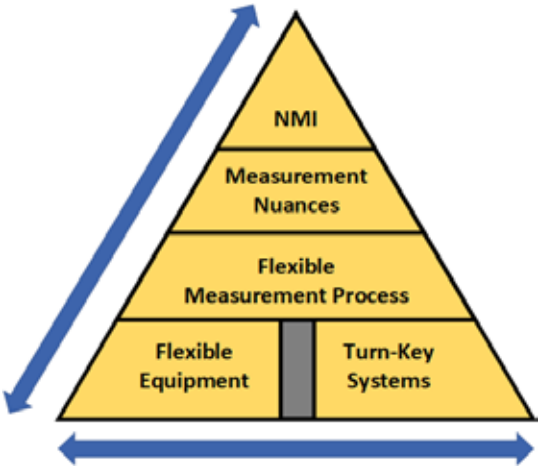
I have been developing automated calibration procedures for more than 20 years now, and if there is one thing I have learned is no two projects are the same! Metrology Software and its complexity can be compared to the traceability pyramid. The closer you are to the peak, the more facets and nuances there are to the test process.

This can be easily explained when looking at a Fluke 87 calibration versus a Keysight 3458A verification procedure. The Fluke 87 and most handheld DMMs are 3½ digit volt meters with accuracies in the .1% range, whereas, the Keysight 3458A is an 8 ½ digit volt meter with accuracy in the parts per million range. The 3458A is something like 1000 times more accurate than a handheld DMM; the complexity of the automation is almost the same.

Most multifunction calibrators are able to calibrate 3½ to 5½ digit multimeters straight up, meaning the calibrator is accurate enough to allow you to simply output the voltage and measure it with the voltmeter. This makes writing the automation easy—setup commands to the calibrator and the DMM, output on, measure, output off, and on to the next test point.

But to calibrate an 8½ digit meter, the problem there is that most of those meters are more accurate than the multifunction calibrator. So, you can't simply output a value and measure it; no, this is primary level metrology. This is the top two sections of the pyramid, and for many countries, NMI level calibration work.

For this level of metrology, you are often comparing a measurement to a measurement using a stable transfer standard, accounting for all the things that can affect your measurement. Things like projected drift of a 10 V cell has to be calculated. Thermal stability of the environment plays a role—3458As have an internal thermometer so the user can check the stability.



When you are calibrating a meter 1000 times more accurate than the everyday meter, every source of error has an effect on the measurement! This is why the software is more complex. Often there are corrections, calculations, and even drift charts for everything used in the calibration. And the software has to keep track of the data, perform the calculations, and produce corrected measurement with the corresponding uncertainty.

This is part of what makes the software more difficult to write, support, and maintain. And now you have the added complexity that most of the top tier labs in the world don't use the exact same hardware. At that level, a 30 year old standard with drift data is more valued than the newest standards. The problem is 30 years of data is known, but with newer standards, how that standard will perform 30 years from now, well that's unknown!

It's not just the difference in hardware that complicates the software. It's also the technician and the lab environment. Something as simple as using a different type of test lead can drastically affect the measurement result. I once tracked a problem down to the number of twists in the cabling that was causing the numbers to be off. Software can only do so much.

Most managers think primary level automation is the same as the simple 3½ digit stuff. They want to buy automation and have it pumping out 3458A option 002 calibration at 90 day specs with 4 to 1 TUR the next morning!

It's not impossible. It just takes a little time to work through all the non-software errors that can blow up a measurement, evaluate what can be updated or handled in the software and measurement process, collect and evaluate the data, updates made, and then the cycle repeats until it's right.

In the end, there is no substitute for good metrology when writing primary/NMI level automation. Software at this level is like an atomic clock—you just can't pick up and move primary level automation to another lab and expect to get the same results!

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