CAL LAB

THE INTERNATIONAL JOURNAL OF METROLOGY

Surface Roughness and Roundness Measurement: How to Know What Your Gage Can (and Can't) Measure

The Quality System at INRiM: A Research and National Metrology Institute

Automating Calibration with LabVIEW: A Practical Guide for Calibration Laboratories - 3rd Continuum

2026
JANUARY
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FEATURES

DEPARTMENTS

ON THE COVER: Precision in action! Technician Carlos Velasco completed the calibration by ensuring ultra-low temperature accuracy by stabilizing the SPRT probe at −195.795 °C within a controlled cryogenic environment at the Northrop Grumman Space Park Calibration Lab in Redondo Beach, California. This process is essential for traceable, high-accuracy temperature measurements in scientific and industrial calibration laboratories.

CALENDAR

UPCOMING CONFERENCES & MEETINGS

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

Mar 23-27, 2026 IMEKO TC3, TC5, TC16, TC20, TC22 Joint Conference & the 3rd International Conference on Dynamic Measurement. Hangzhou, China. This international conference aims to convene experts from both the industrial and academic domains, addressing a diverse range of topics from the fields of "Measurement of Force, Mass, Torque, and Gravity" (IMEKO TC3), "Hardness Measurement" (IMEKO TC5), "Pressure and Vacuum Measurement" (IMEKO TC16), "Measurements of Energy and Related Quantities" (IMEKO TC20) and "Vibration Measurement" (IMEKO TC22). https://conferences.imeko.org/event/14/

Apr 12-15, 2026 ANNCON. Nashville, TN. The A2LA Annual Conference is the ultimate opportunity for accreditation professionals to meet face-to-face, learn new skills, and collaborate on topics associated with the accreditation industry. https://a2la.org/annual_conference/

Apr 21-23, 2026 ASMEA Flow Measurement Workshop. Abu Dhabi, UAE. Over three days, this technical conference will cover common measurement topics such as the importance of measurement, measurement uncertainty and real-world application with ample opportunities for networking and learning. https://www.tuvsud.com/en-gb/events/asmea-flow-measurement-workshop

May 17-20, 2026 IMEKO TC9 20th International Flow Measurement Conference. Nara, Japan. The International Flow Measurement Conference (FLOMEKO) is recognized as one of the most important international conferences in the field of flow measurement by researchers worldwidehttps://flomeko2026.sice.jp/

May 25-28, 2026 I2MTC. Nancy, France. The IEEE International Instrumentation and Measurement Technology Conference (I2MTC) focuses on all aspects of

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EDITOR'S DESK

Tooting Our Own Horn

The release of this issue marks **15 years** since we purchased Cal Lab Magazine from Carol Singer. She published for 16 years before passing the torch. Before that, Charles Masi produced the first three issues in 1994. It was Carol who brought in advertisers to help keep funding the publication. Since then, it has become harder to source articles, as organizations have reined in their resources to leverage in-house produced media.

For over 30 years, Cal Lab Magazine has remained a cottage-industry publication. Both myself and the Publisher have volunteered our time and contributed software development to the measurement community. The publication has always been an extension of sharing knowledge and being an advocate for the industry. Our hope is to continue to deliver curated content from inside the measurement community; to circulate targeted information that isn't algorithmically or AI generated.

If you are a senior tech, engineer, or other seasoned metrology professional, consider contributing an article to Cal Lab Magazine this year. Your contribution is valued in an industry that is made up of **lots of fresh, new faces**—attending a training conference like MSC or NCSLI is proof of that!

For this first issue of the year, we bring you three feature articles, beginning with a Metrology 101 article, "Surface Roughness and Roundness Measurement: How to Know What Your Gage Can (and Can't) Measure," by Mike Zecchio, Jeff Dax, and Mark Cobb. Mike Zecchio is a repeat contributor on this subject… Thank you Mike!

Next, we have another repeat contributor, Flavio Galliana, with an insightful paper on "The Quality System at INRiM: A Research and National Metrology Institute." Co-written with authors Adelina Leka and Luigi Iacomini, the paper presents an ongoing arrangment between multiple laboratories examining the efficacy of a quality management process, with a focus on Italy's NMI (INRiM).

Lastly, we have a follow-up to a series of articles about LabVIEW, "Automating Calibration with LabVIEW: A Practical Guide for Calibration Laboratories - 3rd Continuum," by Ajay M.V. He has been a repeat contributor as well, sharing his expert knowledge on a long-time popular automation tool.

Again, a big "Thank You" to all our repeat author contributors; they certainly have their own horns to toot!

Happy Measuring,

Sita Schwartz

instrumentation and measurement science and technology research development and applications. https://i2mtc2026.ieee-ims.org/

Jun 7-12, 2026 IMS. Boston, MA. The IEEE International Microwave Symposium (IMS) is the world's foremost conference covering the UHF, RF, wireless, microwave, millimeter-wave, terahertz, and optical frequencies; encompassing everything from basic technologies to components to systems including the latest RFIC, MIC, MEMS and filter technologies, advances in CAD, modeling, EM simulation and more. https://ims-ieee.org/

Jun 8-11, 2026 European Test and Telemetry Conference. Nürnberg, Germany. As a premier event in the test and telemetry field, ETTC brings together leading experts from the aeronautics, space, automotive, and defense industries. https://telemetry-europe.org/

Jun 9-10, 2026 CEESI Ultrasonic Meter User's Conference. San Antonio, TX. The CEESI USM Conference provides an opportunity for ultrasonic meter manufacturers and end users to discuss challenges in the hydrocarbon measurement industry. https://www.ceesi.com/Ultrasonic2026

Jun 9-10, 2026 ITG/GMA Conference: Sensors and Measuring Systems. Nürnberg, Germany. The "Sensors and Measurement Systems" conference, first held in 1982, is now the most important German-language scientific event in the field of sensor technology. The conference focuses on sensors and sensor systems for industrial use. https://sensoren2026.de/

Jun 9-11, 2026 SENSOR+TEST. Nürnberg, Germany. SENSOR+TEST is the world's leading forum for sensor, measurement and testing technology. https://www.sensor-test.de/

Jul 7-8, 2026 Accreditation Matters. Melbourne, Australia. Accreditation Matters 2026 is for Everyday Heroes, the people in Standards, Measurement, Testing, Accreditation and Conformity Assessment and those working in the fields of quality, trust and public safety. This conference will provide two days of practical learning, shared expertise, and strategic insight. https://www.accreditationmatters.com.au/

Jul 20-24, 2026 CMSC. Dallas, TX. The Coordinate Metrology Society Conference (CMSC) is the world's premier event for Measurement Technology Professionals sponsored by the Coordinate Metrology Society. https://www.cmsc.org/

Jul 25-29, 2026 NCSLI Workshop & Symposium. Kansas City, MO. https://ncsli.org/

SEMINARS & WEBINARS: Dimensional

Mar 10-11, 2026 Virtual ISO Gage Calibration & Repair Training. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/calibration-metrology-training-events/

Mar 13, 2026 1-Day Virtual ISO Gage Calibration & Repair Training. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/calibration-metrology-training-events/

Mar 18-19, 2026 ISO Hands-On Calibration & Repair Training. Denton, TX. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/calibration-metrology-training-events/

Mar 24-26, 2026 EDU-105: Introduction to Dimensional Metrology Hand Tools V. Aurora, IL. Mitutoyo. EDU-105 is a three-day class for entry-level team members who need to learn the fundamentals of the steel rule, caliper, micrometer, pin gage, gage block, surface plate, height gage, indicator and stands, angle block, v-block, sine bar, depth gages, telescoping gages, holtest gages, bore gages, and thread gages. https://www.mitutoyo.com/training-education/

Mar 25-26, 2026 Gage Calibration & Repair Training. Bloomington, MN. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

Mar 30-31, 2026 Dimensional Measurement Tools Basics Class. Chicago, IL. QC Training. This program provides a fundamental and practical review of Basic Dimensional Measurement Tools and Methods, including variable gages such as steel rules, depth and dial gages, micrometers, and calipers. In addition, attribute gages such as plug, ring and screw thread gages are covered. https://qctraininginc.com/course/course-basic-dimensional-measurement-tools/

Apr 14-15, 2026 Gage Calibration & Repair Training. Cleveland, OH. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people

interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

Apr 16-17, 2026 Gage Calibration & Repair Training. Indianapolis, IN. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

Apr 21, 2026 1-Day Virtual ISO Gage Calibration & Repair Training. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

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Apr 27-28, 2026 Virtual ISO Gage Calibration & Repair Training. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

May 4-5, 2026 Gage Calibration & Repair Training. Bloomington, MN. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

May 13-14, 2026 Dimensional Measurement. Melbourne VIC, Australia. NMI. This two-day course (9 am to 5 pm) presents a comprehensive overview of the fundamental principles in dimensional metrology and geometric dimensioning and tolerancing. https://shop.measurement.gov.au/

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May 13-14, 2026 Surface Roughness, Texture, and Tribology. Livonia, MI. Michigan Metrology. Looking to expand your knowledge of surface texture? The annual, 2-day class is a great opportunity to learn both fundamental and advanced surface texture analysis and tribology. https://michmet.com/classes/#liveclasses

May 14-15, 2026 Gage Calibration & Repair Training. Las Vegas, NV. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

May 18-19, 2026 Gage Calibration & Repair Training. Omaha, NE. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

Jun 9-10, 2026 Gage Calibration & Repair Training. Chicago, IL. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

Jun 11-12, 2026 Gage Calibration & Repair Training. Madison, WI. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

Jun 16, 2026 1-Day Virtual ISO Gage Calibration & Repair Training. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

Jun 18, 2026 1-Day Virtual ISO Gage Calibration & Repair Training. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/calibration-metrology-training-events/

Jun 24-25, 2026 Gage Calibration & Repair Training. Atlanta, GA. IICT Enterprises. Enhance your career knowledge in Metrology with this in-depth Gage use, Calibration, and Repair course. Recommended for people interested in pursuing the ASQ CCT Exam. https://calibrationtraining.com/

SEMINARS & WEBINARS: Electrical

May 6-7, 2026 Electrical Measurement. Lindfield, NSW. Australian NMI. This course provides in-depth 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. The course is most suitable for those already familiar with electrical measurements using digital multimeters and calibrators, as well as with the estimation of measurement uncertainty, wishing to further advance their knowledge and skills. https://shop.measurement.gov.au/collections/physical-metrology-training

May 8, 2026 High-Voltage Test and Measurement. Lindfield, NSW. Australian NMI. This one-day workshop provides hands-on experience and practical techniques involved in performing high-voltage tests and measurements, and explains how to make such tests and measurements in accordance to relevant international and Australian standards. https://shop.measurement.gov.au/collections/physical-metrology-training

Apr 13-16, 2026 MET-301 Advanced Hands-On Metrology. Everett, WA. Fluke Calibration. This course introduces the student to advanced measurement concepts and math used in standards laboratories. https://www.fluke.com/en-us/product/calibration-tools/electrical-calibration/training-met-301

May 6-7, 2026 Electrical Measurement. Lindfield NSW, Australia. NMI. This course provides in-depth 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/

May 8, 2026 High-Voltage Test and Measurement. Lindfield NSW, Australia. NMI. This one-day workshop provides hands-on experience and practical techniques involved in performing high-voltage tests and measurements, and explains how to make such tests and measurements in accordance to relevant international and Australian standards. https://shop.measurement.gov.au/

Jun 8-11, 2026 MET-101 Basic Hands-On Metrology Course. Everett, WA. This Metrology 101 basic metrology training course introduces the student to basic measurement concepts, basic electronics related to measurement instruments and math used in calibration. https://www.fluke.com/en-us/product/calibration-tools/electrical-calibration/training-met-101

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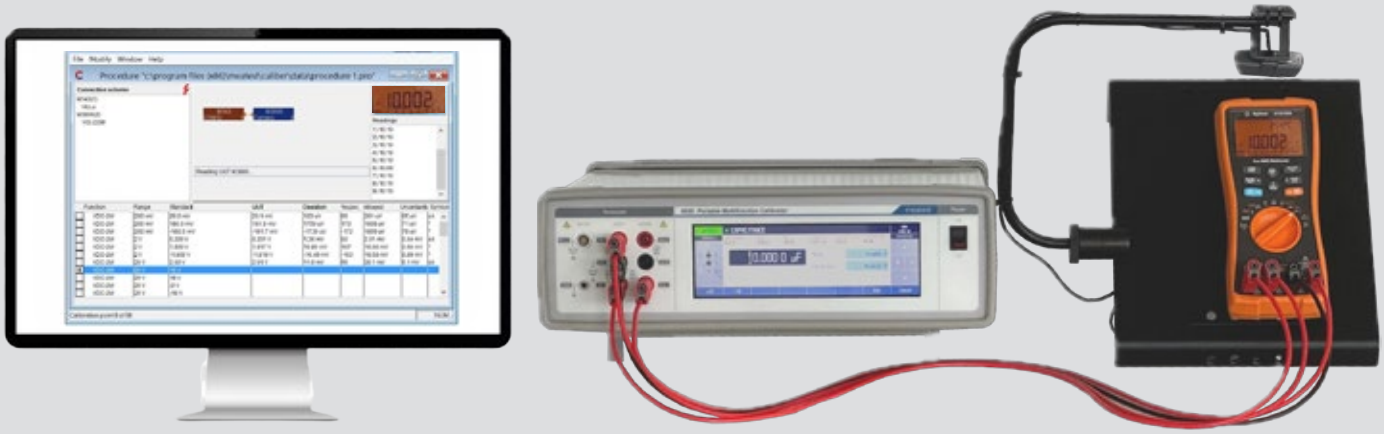

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SEMINARS & WEBINARS: Flow

Mar 23-26, 2026 Gas Flow Calibration Using molbloc/molbox. Phoenix, AZ. Fluke Calibration. Gas Flow Calibration Using molbloc/molbox is a four day training course in the operation and maintenance of a Fluke Calibration molbloc/molbox system. https://www.fluke.com/en-us/product/calibration-tools/flow-calibration/training-trnflwbas

SEMINARS & WEBINARS: General

Apr 20-24, 2026 Fundamentals of Metrology. Gaithersburg, MD. NIST. The 5-day Fundamentals of Metrology seminar is an intensive course that introduces participants to the concepts of measurement systems, units, good laboratory practices, data integrity, measurement uncertainty, measurement assurance, traceability, basic statistics and how they fit into a laboratory Quality Management System. https://www.nist.gov/pml/owm/owm-training-and-events

Apr 20-22, 2026 C-101 Calibration. Memphis, TN. TriNova Technical Education. This instructor led calibration course is delivered by our experienced technical education specialists who deliver a high-quality course covering calibration fundamentals, detailed documentation procedures, temperature, and pressure basics, and basics of DP flow calibration. In-depth demonstrations and hands-on exercises will follow each lecture. https://trinova.arlo.co/w/

May 12-14, 2026 C-101 Calibration. Mobile, AL. TriNova Technical Education. This instructor led calibration course is delivered by our experienced technical education specialists who deliver a high-quality course covering calibration fundamentals, detailed documentation procedures, temperature, and pressure basics, and basics of DP flow calibration. In-depth demonstrations and hands-on exercises will follow each lecture. https://trinova.arlo.co/w/

Jun 18, 2026 2062 Documenting Traceability and Calibration Intervals. Online or Virtual Training. NIST. This 2-hour webinar covers the essential elements of metrological traceability and the documentary evidence required to support traceability and calibration intervals. https://www.nist.gov/pml/owm/owm-products-and-services/training-classes-and-events

Jun 22-24, 2026 C-101 Calibration. Mobile, AL. TriNova Technical Education. This instructor led calibration course is delivered by our experienced technical education specialists who deliver a high-quality course covering calibration fundamentals, detailed documentation procedures, temperature, and pressure basics, and basics of DP flow calibration. In-depth demonstrations and hands-on exercises will follow each lecture. https://trinova.arlo.co/w/

Jul 27-31, 2026 2066 Fundamentals of Metrology. Gaithersburg, MD. NIST. The 5-day Fundamentals of Metrology seminar is an intensive course that introduces participants to the concepts of measurement systems, units, good laboratory practices, data integrity, measurement uncertainty, measurement assurance, traceability, basic statistics and how they fit into a laboratory Quality Management System. https://www.nist.gov/news-events/events/2026/07/2066-fundamentals-metrology

SEMINARS & WEBINARS: Industry Standards

Mar 10-11, 2026 Understanding ISO/IEC 17025:2017 for Testing & Calibration Labs. Virtual or Online Training. A2LA WorkPlace Training. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. https://a2lawpt.org/courses

Mar 12-13, 2026 3004 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Virtual or Online Training. IAS. Online schedule for the Middle East, India, and South Asia. This 2-day 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/ias-training-schedule/

Mar 17-18, 2026 Auditing Your Laboratory to ISO/IEC 17025:2017. Virtual or Online Training. A2LA WorkPlace Training. This ISO/IEC 17025 auditor training course will introduce participants to ISO 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. The course includes hands-on exercises for planning, establishing, implementing, and maintaining an audit program, and also focuses on developing auditing methods, questioning techniques, and record sampling. https://a2lawpt.org/courses

Apr 14-15, 2026 3004 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Virtual or Online Training. IAS. Online schedule for the Americas. This 2-day 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/ias-training-schedule/

Apr 21-22, 2026 Understanding the Requirements and Concepts of ISO/IEC 17025:2017. Virtual or Online Training. ANAB. Understand requirements of ISO/IEC 17025:2017, including general, structural, resource,

process, and management system requirements. Learn practical concepts, such as impartiality, documents control, ensuring validity of results and risk management. Gain an understanding of an ISO/IEC 17025:2017 laboratory management system. https://anab.ansi.org/training/

Apr 21-23, 2026 Internal Auditing to ISO/IEC 17025:2017 (Non-Forensic). Virtual or Online Training. ANAB. This training is designed for laboratory managers, technical staff, and others who want or need to learn better audit practices. Attendees of Auditing to ISO/IEC 17025 training course will learn how to coordinate a quality management system audit to ISO/IEC 17025:2017 and collect audit evidence and document observations, including techniques for effective questioning and listening. https://anab.ansi.org/training/

Apr 21-23, 2026 Understanding ISO/IEC 17025:2017 for Testing & Calibration Labs. Virtual or Online Training. A2LA WorkPlace Training. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. https://a2lawpt.org/courses

Apr 28-30, 2026 Auditing Your Laboratory to ISO/IEC 17025:2017. Virtual or Online Training. A2LA WorkPlace Training. This ISO/IEC 17025 auditor training course will introduce participants to ISO 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://a2lawpt.org/courses/

May 5-6, 2026 3004 Understanding ISO/IEC 17025 for Testing and Calibration Labs. Virtual or Online Training. IAS. Online schedule for the Middle-East, India, and South Asia. This 2-day 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/ias-training-schedule/

May 11-12, 2026 Understanding ISO/IEC 17025:2017 for Testing & Calibration Labs. Frederick, MD. A2LA WorkPlace Training. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. https://a2lawpt.org/courses

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May 13-14, 2026 Auditing Your Laboratory to ISO/IEC 17025:2017. Frederick, MD. A2LA WorkPlace Training. This ISO/IEC 17025 auditor training course will introduce participants to ISO 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. The course includes hands-on exercises for planning, establishing, implementing, and maintaining an audit program, and also focuses on developing auditing methods, questioning techniques, and record sampling. https://a2lawpt.org/courses/

Jun 9-10, 2026 Understanding the Requirements and Concepts of ISO/IEC 17025:2017. Virtual or Online Training. ANAB. Understand requirements of ISO/IEC 17025:2017, including general, structural, resource, process, and management system requirements. Learn practical concepts, such as impartiality, documents control, ensuring validity of results and risk management. Gain an understanding of an ISO/IEC 17025:2017 laboratory management system. https://anab.ansi.org/training/

Jun 9-11, 2026 Internal Auditing to ISO/IEC 17025:2017 (Non-Forensic). Virtual or Online Training. ANAB. This training is designed for laboratory managers, technical staff, and others who want or need to learn better audit practices. Attendees of Auditing to ISO/IEC 17025 training course will learn how to coordinate a quality management system audit to ISO/IEC 17025:2017 and collect audit evidence and document observations, including techniques for effective questioning and listening. https://anab.ansi.org/training/

Jun 9-12, 2026 Understanding ISO/IEC 17025:2017 for Testing & Calibration Labs. Virtual or Online Training. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. https://a2lawpt.org/courses/

Jun 23-26, 2026 Auditing Your Laboratory to ISO/IEC 17025:2017. Online or Virtual Event. A2LA WorkPlace Training. This ISO/IEC 17025 auditor training course will introduce participants to ISO 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. The course includes hands-on exercises for planning, establishing, implementing, and maintaining an audit program, and also focuses on developing auditing methods, questioning techniques, and record sampling. https://a2lawpt.org/event/auditing-your-laboratory-to-iso-iec-170252017-8/

SEMINARS & WEBINARS:
Measurement Uncertainty

Mar 18-19, 2026 Introduction to Measurement Uncertainty. Virtual or Online Training. A2LA WorkPlace Training. This course is a suitable introduction for both calibration and testing laboratory participants, focusing on the mathematics, basic statistics, key concepts, and approaches of the measurement uncertainty evaluation process. The participant will gain an understanding of the statistical techniques required to estimate measurement uncertainty and will practice those skills to create basic uncertainty budgets (calculator). This course is designed for personnel working in calibration, metrology, testing, or other measurement fields. https://a2lawpt.org/courses

Apr 1-2, 2026 3006 Uncertainty of Measurement for Labs. Virtual or Online Training. IAS. Scheduled online for Middle-East, India, and South Asia. Evaluation and Estimation of Uncertainties of Measurement. Introduction to metrology principles, examples and practical exercises. https://www.iasonline.org/training/ias-training-schedule/

Apr 14-15, 2026 Measurement Confidence: Fundamentals. Virtual or Online Training. ANAB. This Measurement Confidence course introduces the foundational concepts of measurement traceability, measurement assurance, and measurement uncertainty and details ISO/IEC 17025 and ISO/IEC 17020 requirements. https://anab.ansi.org/training/

Apr 16-17, 2026 Measurement Uncertainty: Practical Applications. Virtual or Online Training. ANAB. This course reviews the basic concepts and accreditation requirements associated with measurement traceability, measurement assurance, and measurement uncertainty as well as their interrelationships. https://anab.ansi.org/training/

May 12, 2026 Introduction to Measurement Uncertainty. Frederick, MD. A2LA WorkPlace Training. This course is a suitable introduction for both calibration and testing laboratory participants, focusing on the mathematics, basic statistics, key concepts, and approaches of the measurement uncertainty evaluation process. The participant will gain an understanding of the statistical techniques required to estimate measurement uncertainty and will practice those skills to create basic uncertainty budgets (calculator). This course is designed for personnel working in calibration, metrology, testing, or other measurement fields. https://a2lawpt.org/courses

May 13-14, 2026 Applied Measurement Uncertainty for Calibration Laboratories. Virtual or Online Training. A2LA WorkPlace Training. During this course, the participant will be introduced to several tools and techniques that

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can be applied in the calibration laboratory environment to efficiently and effectively create measurement uncertainty budgets that comply with ISO/IEC 17025 requirements. https://a2lawpt.org/courses/

May 28, 2026 2059 Basic Uncertainty Concepts. Virtual or Online Event. NIST. This 2-hour webinar provides a very basic introduction to uncertainty calculations and reporting using the 8-step process published in NIST SOP 29 (NISTIR 6969), beginning with some definitions and concepts from the Guide to the Expression of Uncertainty in Measurement (GUM) and includes some simple calculations. https://www.nist.gov/news-events/events/2026/05/2059-basic-uncertainty-concepts

Jun 2-3, 2026 Introduction to Measurement Uncertainty. Virtual or Online Training. A2LA WorkPlace Training. This course is a suitable introduction for both calibration and testing laboratory participants, focusing on the mathematics, basic statistics, key concepts, and approaches of the measurement uncertainty evaluation process. The participant will gain an understanding of the statistical techniques required to estimate measurement uncertainty and will practice those skills to create basic uncertainty budgets. This course is designed for personnel working in calibration, metrology, testing, or other measurement fields. https://a2lawpt.org/courses/

Jun 2-3, 2026 Measurement Confidence: Fundamentals. Virtual or Online Training. This Measurement Confidence course introduces the foundational concepts of measurement traceability, measurement assurance, and measurement uncertainty and details ISO/IEC 17025 and ISO/IEC 17020 requirements. https://anab.ansi.org/training/measurement-confidence-fundamentals/

Jun 4-5, 2026 Measurement Uncertainty: Practical Applications. Online or Virtual Training. ANAB. This course reviews the basic concepts and accreditation requirements associated with measurement traceability, measurement assurance, and measurement uncertainty as well as their interrelationships. https://anab.ansi.org/training/measurement-uncertainty-practical-applications/

Jun 23-25, 2026 Applied Measurement Uncertainty for Testing Laboratories. Online or Virtual Training. A2LA WorkPlace Training. 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 that comply with ISO/IEC 17025 requirements. https://a2lawpt.org/event/applied-measurement-uncertainty-for-testing-laboratories-5/

SEMINARS & WEBINARS: Pressure

Apr 13-17, 2026 TWB 1061 Principles of Pressure Calibration Web-Based Training. Fluke Calibration. This is a short form of the regular five-day in-person Principles of Pressure Calibration class. This online class is held for 2-hour sessions each day. https://www.fluke.com/en-us/product/calibration-tools/pressure-calibration/training-twb-1061

Apr 20-24, 2026 Advanced Piston Gauge Metrology. Phoenix, AZ. Fluke Calibration. Focus is on the theory, use and calibration of piston gauges and dead weight testers. https://www.fluke.com/en-us/product/calibration-tools/pressure-calibration/training-trnprsadv

Jun 17-18, 2026 Pressure Measurement. Port Melbourne 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/

SEMINARS & WEBINARS: Quality

Mar 10-13, 2026 Quality 101 Foundational Concepts Class. Virtual. QC Training. This program provides a fundamental and practical overview of quality, the evolution of quality systems, and their applications. Problem solving tools and root cause analysis, along with statistics are discussed. https://qctraininginc.com/course/quality-101-foundational-concepts/

Mar 24-25, 2026 Quality 101 Foundational Concepts Class. Mason, OH. QC Training. This program provides a fundamental and practical overview of quality, the evolution of quality systems, and their applications. Problem solving tools and root cause analysis, along with statistics are discussed. https://qctraininginc.com/course/quality-101-foundational-concepts/

Mar 24-25, 2026 Quality 101 Foundational Concepts Class. Milwaukee, WI. QC Training. This program provides a fundamental and practical overview of quality, the evolution of quality systems, and their applications. Problem solving tools and root cause analysis, along with statistics are discussed. https://qctraininginc.com/course/quality-101-foundational-concepts/

Mar 24-25, 2026 Quality 101 Foundational Concepts Class. Minneapolis, MN. QC Training. This program provides a fundamental and practical overview of quality, the evolution of quality systems, and their applications. Problem solving tools and root cause analysis, along with

statistics are discussed. https://qctraininginc.com/course/quality-101-foundational-concepts/

SEMINARS & WEBINARS: Software

Mar 16-20, 2026 TWB 1071 Crystal Reports Web-Based Training. Online or Virtual Training. Fluke Calibration. This course is designed for those who are involved with modifying or writing custom reports for use with MET/TEAM. The duration of this online class is 5 days, 2-hour sessions each day. https://www.fluke.com/en-us/product/fluke-software/fluke-calibration-software/training-twb-1071

Mar 23-27, 2026 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. https://www.fluke.com/en-us/product/fluke-software/fluke-calibration-software/training-mc-206

Mar 30-Apr 3, 2026 MC-205 MET/TEAM® Asset Management. Everett, WA. Fluke Calibration. This five-day course presents a comprehensive overview of how to use MET/TEAM® Test Equipment and Asset Management Software in an Internet browser to develop your asset management system. https://www.fluke.com/en-us/product/fluke-software/fluke-calibration-software/training-mc-205

Apr 21-23, 2026 VNA Tools Training Course. Beaverton, OR. METAS. VNA Tools is a free software developed by METAS for measurements with the Vector Network Analyzer (VNA). The software facilitates the tasks of evaluating measurement uncertainty in compliance with the ISO-GUM and justifying metrological traceability. The software is available for download at www.metas.ch/vnatools. The three day course provides a practical and hands-on lesson with this superior and versatile software. https://www.metas.ch/metas/en/home/dl/kurs_uebersicht/vna_training_usa_26.html

May 4-8, 2026 MC-206 Basic MET/CAL® Procedure

CALENDAR

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. https://www.fluke.com/en-us/product/fluke-software/fluke-calibration-software/training-mc-206

May 5-8, 2026 VNA Tools Training Course + VNA Expert Day. Bern-Waburn, Switzerland. METAS. VNA Tools is a free software developed by METAS for measurements with the Vector Network Analyzer (VNA). The software facilitates the tasks of evaluating measurement uncertainty in compliance with the ISO-GUM and justifying metrological traceability. The software is available for download at www.metas.ch/vnatools. The three day course provides a practical and hands-on lesson with this superior and versatile software. https://www.metas.ch/metas/en/home/dl/kurs_uebersicht/vna_training_spring_26.html

May 11-15, 2026 TWB 1051 MET/TEAM® Basic Web-Based Training. Virtual or Online 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. This course is typically held from 10:00 am to 12:00 pm (Noon) Pacific Standard Time. https://www.fluke.com/en-us/product/fluke-software/fluke-calibration-software/training-twb-1051

Jun 22-26, 2026 TWB 1031 MET/CAL® Procedure Development Web-Based Training. Fluke Calibration. Learn to create procedures with the latest version of MET/CAL, without leaving your office. The workshop is presented as a five-part, ten-hour course with each two-hour session scheduled on consecutive days, typically from 10:00 am to 12:00 pm (Noon) Pacific Standard Time (Everett, WA USA). https://www.fluke.com/en-us/product/fluke-software/fluke-calibration-software/training-twb-1031

Jul 14-16, 2026 MC-203 Crystal Report Writing. Everett, WA. Fluke Calibration. This course is designed for those who are involved with modifying or writing custom reports for use with MET/TEAM. https://www.fluke.com/en-us/product/fluke-software/fluke-calibration-software/training-mc-203

Jul 27-31, 2026 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. https://www.fluke.com/en-us/product/fluke-software/fluke-calibration-software/training-mc-206

SEMINARS & WEBINARS: Validation & Verification

May 27, 2026 Validation and Verification of Analytical Methods. Virtual or Online Training. This course provides an introduction to validation and verification of analytical methods and ISO/IEC 17025 & ISO/IEC 17020 requirements. https://anab.ansi.org/training/validation-verification-analytical-methods/

Aug 13, 2026 Calibration Method Validation. Webinar. NIST. This 2-hour webinar on Calibration Method Validation will examine the ISO/IEC 17025:2017 requirements for selection of calibration methods and for method validation and provide guidance on developing a process for validating a new or modified calibration process. https://www.nist.gov/pml/owm/owm-products-and-services/training-classes-and-events

SEMINARS & WEBINARS: Vibration

Jun 23-25, 2026 Fundamentals of Random Vibration and Shock Testing Training. Plano, TX. ERI. This three-day Training in Fundamentals of Random Vibration and Shock Testing covers all the information required to plan, perform, and interpret the results of all types of dynamic testing. Some of the additional areas covered are fixture design, field data measurement and interpretation, evolution of test standards and HALT/HASS processes. https://equipment-reliability.com/open-courses/

SEMINARS & WEBINARS: Volume

Jul 6-10, 2026 2065 Volume Metrology Seminar. Gaithersburg, MD. NIST. The 5-day OWM Volume Metrology Seminar is designed to enable metrologists to apply fundamental measurement concepts to volume calibrations. Registration Deadline: May 4, 2026. https://www.nist.gov/news-events/events/2026/07/2065-volume-metrology-seminar

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Performance testing of the standard reference thermoelectrical module developed by the research team. Credit: KOREA INSTITUTE OF ENERGY RESEARCH

KIER Successfully Develops Korea-Made "Calibration Thermoelectric Module"

Daejeon, Korea, Jan 5, 2026 – A "standard reference thermoelectric module (SRTEM)[1]" for objectively measuring thermoelectric module performance has been developed in Korea for the first time. A research team led by Dr. Sang Hyun Park at the Korea Institute of Energy Research (KIER; President Yi, Chang-Keun) developed the world's second standard reference thermoelectric module, following Japan, and improved its performance by more than 20% compared with existing modules, demonstrating the excellence of Korea's homegrown technology.

A thermoelectric module is a device that generates electricity by creating a flow of electrons driven by a temperature difference, with one side becoming cold and the other becoming hot. Conversely, when an electric current is applied to a thermoelectric module, one side cools down while the other side heats up. Thanks to these characteristics, thermoelectric modules are widely used in applications such as compact camping refrigerators and electronic equipment including computers. In addition, because they are environmentally friendly and well suited to miniaturization, they can be broadly applied to emerging fields such as carbon-free power generation and the space industry, which have recently drawn significant attention.

However, technological progress was slow due to the lack of methods to objectively and accurately measure the performance of thermoelectrical modules. In particular, the only standard reference thermoelectrical module for correcting measurement-equipment errors was the one developed in Japan.

To address this issue, researchers at KIER improved upon the limitations of the existing standard reference thermoelectrical module and developed a thermoelectrical module that is more suitable for calibration. The standard reference thermoelectrical module developed by the team achieved more than a 20% improvement in key performance indicators such as output voltage compared to the existing module, and it demonstrated excellent reproducibility by maintaining its output without degradation even after more than 300 operating cycles.

The research team used a metallic material instead of the commonly used semiconductor powder–based material. Semiconductor powder can produce a large output voltage even with a small temperature difference, resulting in high thermoelectric performance (Seebeck coefficient)[2]. However, during powder-based fabrication, the particle size and performance vary from batch to batch, making it unsuitable as a standard for calibration. In contrast, metallic materials offer relatively uniform and stable performance, making them well suited for a standard thermoelectrical module. The challenge, however, is that their thermoelectric performance is much lower about one-tenth that of semiconductor powder–based materials (BiTe based materials).

To enhance the performance of the metallic thermoelectric material, the research team developed a new thermoelectric leg[3] structure in a "hollow hourglass" shape. The narrowed waist and the hollow region increase thermal resistance, thereby enlarging the temperature difference between top and bottom sides of the leg and boosting the output voltage. When the newly developed thermoelectric legs were applied, the output voltage was found to be more than about three times higher than that of conventional rectangular-prism–shaped thermoelectric legs.

1 SRTEM (Standard Reference Thermoelectric Module): A reference standard used to check the status of output-measurement instruments and calibrate their measurement errors prior to thermoelectric module measurements.

2 Thermoelectric performance (Seebeck): An indicator of a thermoelectrical module's performance, defined as the amount of voltage generated when a temperature difference of 1°C is applied.

3 Thermoelectric leg: A single small pillar that makes up a thermoelectrical module. It is located between the hot side and the cold side of the module and is responsible for converting heat to electricity (and vice versa).

In addition, the team investigated optimal combinations of metallic materials and fabricated two types of thermoelectric legs: Chromel–Constantan and Chromel–Alumel. Among them, the Chromel–Constantan thermoelectric leg achieved an output voltage 23.6% higher than that of previous standard calibration thermoelectrical module, and it maintained the same output even after more than 300 operating cycles.

Dr. Sang Hyun Park, who led the study, stated, "This work establishes an important technical foundation that could enable Korea to secure an advantage when international standardization of the standard calibration thermoelectrical module moves forward." He added, "In 2026, we plan to expand the scope of the research and further enhance its completeness by conducting cross-performance evaluations with leading research teams in Germany and Japan."

Meanwhile, this study was conducted with support from Korea's Ministry of Trade, Industry and Energy (MOTIE), and it was selected as the cover article for the September issue of the internationally renowned journal ACS Applied Materials & Interfaces (IF 8.2).

Source: https://www.kier.re.kr/board?menuId=MENU00642&siteId=null

First Successful Key Comparison of Josephson Voltage Standards for AC Voltage Completed

BIPM News, Jan 15, 2026 – A major milestone has been reached in electrical metrology with the successful completion of the first key comparison of Josephson voltage standards for AC voltage, carried out between the Bureau International des Poids et Mesures (BIPM) and the Physikalisch-Technische Bundesanstalt (PTB).

The comparison, completed in 2025, covered AC voltage amplitudes of 0.75 V and 7 V across a frequency range from 62.5 Hz to 1.25 kHz, demonstrating agreement between the two systems at the level of a few tens of nanovolts per volt.

This comparison represents an important step in extending the international measurement infrastructure for electrical quantities, supporting traceability and equivalence for AC voltage at the highest level. It strengthens confidence that AC voltage measurements realized in different countries are consistent, comparable and anchored to the same quantum-defined reference.

How the comparison was carried out

The comparison was carried out using a stable AC voltage source as a transfer standard, which was alternatively measured by the PTB and BIPM AC quantum

Stéphane Solve and Régis Chayramy (BIPM) preparing and operating the measurement setup used for the key comparison of Josephson standards for AC voltage. Credit: BIPM

voltage standards. The AC quantum voltage standards generated a stepwise-approximated sinewave of the same frequency and the same nominal root-mean-square value as the transfer standard. The small voltage differences between the transfer standard and the AC quantum voltmeters were measured with a synchronized sampler. The measured voltage differences together with the predictable quantized voltages allowed us to determine the root-mean-square value of the signal from the transfer standard.

The results: Across both voltage amplitudes and nearly all frequencies, the two systems showed excellent agreement, with relative differences at the level of a few tens of nanovolts per volt, confirming the robustness and maturity of quantum-based AC voltage measurements.

This confirms that Josephson-based techniques can deliver highly reliable and reproducible AC voltage measurements, suitable for key comparison purposes.

The full comparison results have been published in Metrologia and can be accessed here.[1]

Background

Since the early 1990s, the BIPM has coordinated an on-site, on-going key comparisons programme of Josephson voltage standards for DC voltage, supporting global equivalence in electrical measurements through comparisons such as BIPM.EM-K10. As the international use of quantum measurement technology has expanded into AC applications, the need for equivalent comparison capabilities has grown.

In response, the Consultative Committee for Electricity and Magnetism (CCEM) tasked the BIPM with extending the key comparison BIPM.EM-K10 to AC voltage. Over the past seven years, the BIPM — with significant technical collaboration from PTB, NIST and KRISS — has carried out pilot studies to develop suitable measurement methods, assessed AC signal generators, and established a robust comparison protocol. This protocol was formally approved by the CCEM in 2023.

1 https://doi.org/10.1088/0026-1394/62/1A/01012

Source: https://www.bipm.org/en/-/2026-01-15-first-successful-key-comparison-of-josephson-voltage-standards-for-ac-voltage-1 (https://creativecommons.org/licenses/by/3.0/igo/)

Trescal Expands Global Footprint with 14 Acquisitions and Entry into India

Paris, France – January 13, 2026 – Trescal, the global leader in metrology services, announces 14 acquisitions throughout Europe, Asia, Oceania, and the Americas. This represents €50M+ additional sales and 800 employees.

In Portugal, the company acquired a legal metrology specialist. In France, Trescal added a provider of 3D measurement services. In Spain, the acquisition expanded qualification offerings for the life science sector and calibration services for the aeronautics industry. In the United Kingdom, four laboratories propelled Trescal to the market leader in the region.

Trescal entered India, its 34th country, through the purchase of a leading domestic calibration laboratory with locations in Bengaluru and Hyderabad. This move provides Trescal's multinational clients with immediate, NABL-accredited services in one of the world's largest and fastest-growing manufacturing hubs.

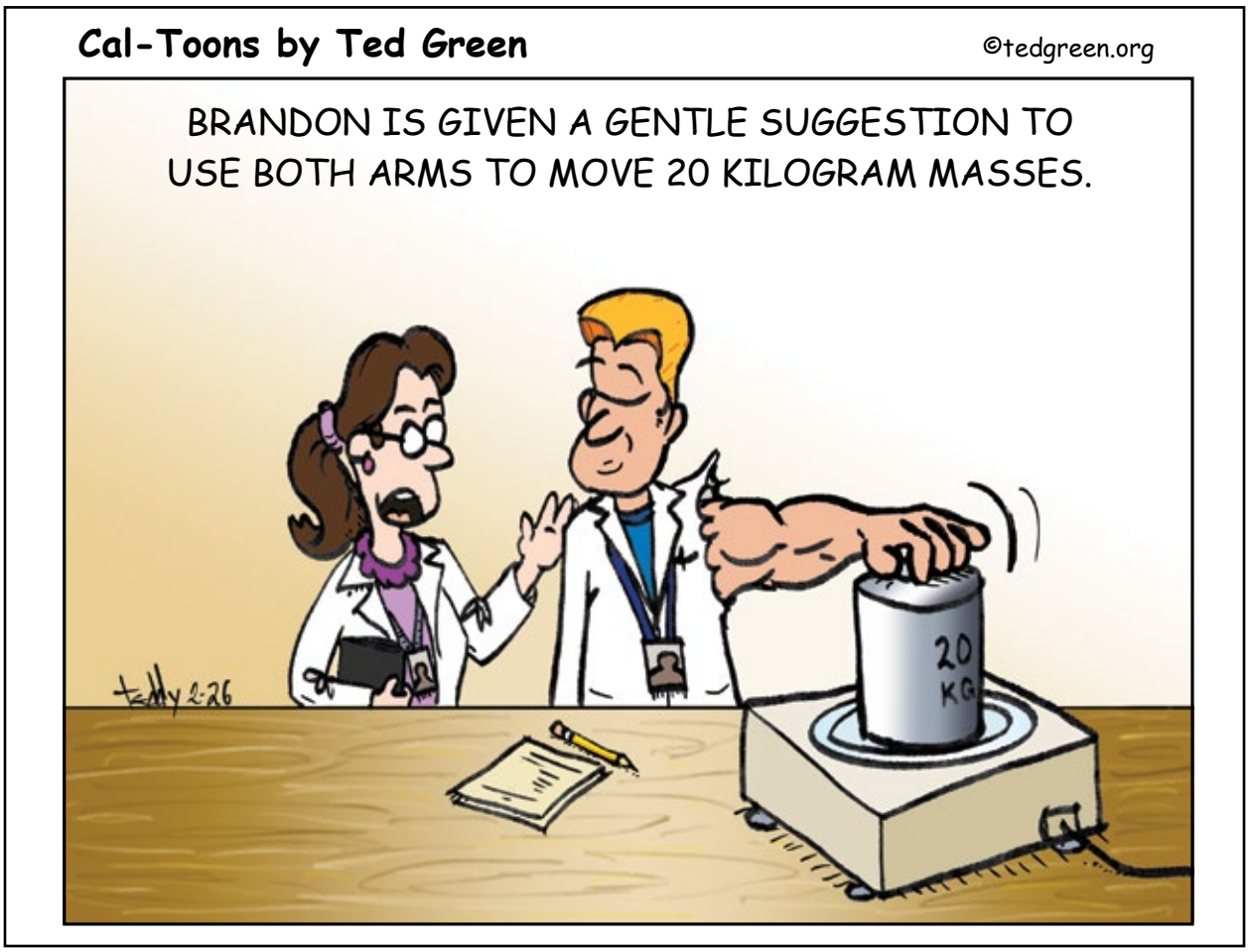
To fortify its coverage in the Asia-Pacific region, Trescal acquired a state-of-the-art temperature laboratory in South Korea, an Australian company specializing in scales and balances for life sciences, and a calibration provider in China operating five laboratories focused on the aeronautics industry.

Two acquisitions in the Americas reinforced Trescal's leading flow capabilities, particularly for the energy sector in Brazil.

Guillaume Caroit, Trescal CEO: "With the new market entry, we can now provide our clients with the same calibration service in India that they receive in Europe, the Americas, and the rest of Asia Pacific. We will continue this pace of global expansion, with two market entries planned for 2026. We have the technical expertise and the infrastructure needed to meet clients' needs worldwide."

About Trescal

Trescal is the global leader in calibration services, offering a single-source solution for calibration, measurement, repair, qualification, validation, and asset management across diverse industries. With over 7,000 employees worldwide, Trescal delivers accredited and non-accredited services for all measured variables and instruments in every technical domain. The company performs 3.3 million operations annually, including 27,000 repairs on 150,000 types of instruments from 20,000 brands.



Surface Roughness and Roundness Measurement: How to Know What Your Gage Can (and Can't) Measure

Mike Zecchino, Jeff Dax, and Mark Cobb

Introduction

Many instruments can be used to measure surface roughness and texture—from handheld gages to ultra-precise interferometers and 3D optical profilers. But not all instruments are intended for all applications: a measurement may produce a number, but whether that number is accurate and valid depends on some basic factors. Knowing the strengths and limitations of your gage(s) can help avoid measurement errors and misinterpretations of process variables that can lead to expensive mistakes on the shop floor.

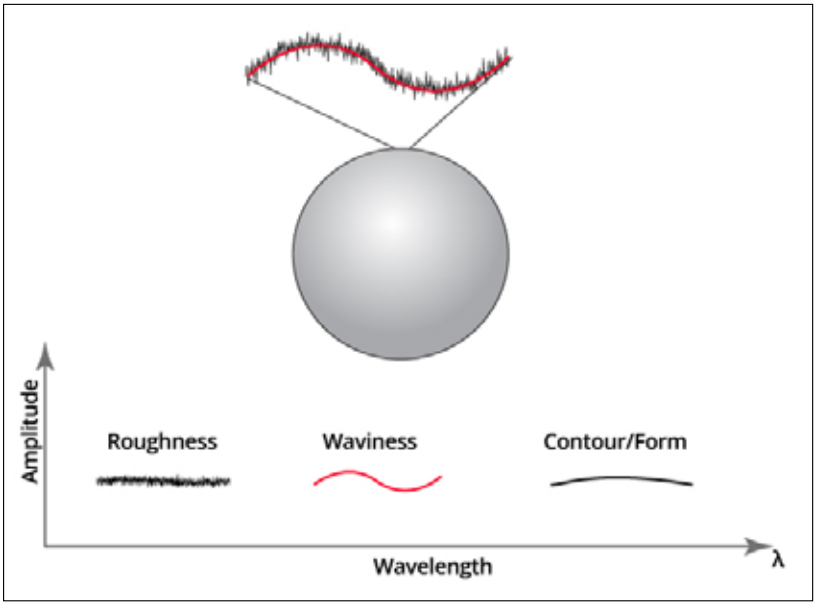


Figure 1. Texture consists of a spectrum of feature sizes (wavelengths), from finer roughness through waviness and contour/form.

Measuring What Matters

Before we look at instruments for measuring surfaces it's important to remember that texture is *not* defined by a single number (for example, Ra, which is the roughness average or average roughness). Texture consists of a spectrum of feature sizes, or wavelengths, ranging from atomic scales through short-wavelength roughness and longer-wavelength waviness and form/contour.

By separating texture into roughness, waviness, and form we can track the ranges of wavelengths that matter for a particular application. In a shaft, for example, it may be important to measure roughness to control friction and wear characteristics. We may also need to evaluate longer-wavelength waviness and straightness (form) which may also impact function.

It's important to note that the feature sizes that we call "roughness" or "waviness" depend entirely on the application. What we call roughness on a casting, say, would be orders of magnitude larger than the roughness on a precision optical surface.

It's also important to note that the longer-wavelength waviness may matter as much as, or more than, roughness, in a given application. Simply measuring roughness and calculating roughness parameters ignores these critical wavelengths completely.

Comparing System Capabilities

Measurement systems offer many different options at many price points. For this article we will focus on general categories of instruments. For this general comparison, we will look at:

- Measurable Geometry: whether the instrument is capable of measuring roughness, waviness, and/or form/contour
- Measurable Features: whether the instrument is limited to roughness on a flat surface, or whether it can measure texture on curves, on edges, inside bores, around and along shafts, etc.
- Part Envelope: the size of the component that can be measured given the physical limitations of the instrument
- Vertical Range: the largest vertical departure that the instrument can measure
- Vertical Resolution: the finest measurable vertical step
- Cost

Types of Measurement Instruments

The following section introduces several common categories of surface texture gages and their strengths and limitations.

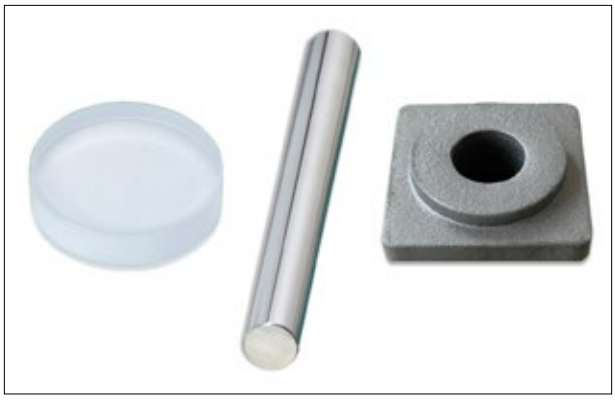


Figure 2. What we call "roughness" depends on the application. The roughness of this lens, shaft, and casting are orders of magnitude apart in scale but may still measured as "roughness" in each application.

Most handheld gages include a "skid" which rides along the surface, providing a reference point (datum) for the stylus to measure against. The skid reduces the gage's sensitivity to vibration by providing a measurement "loop" (i.e., mechanically coupling the test piece, and instrument). The skid also offers protection for the delicate stylus—all important aspects for shop floor measurement. However, because the skid rides along the larger features of the surface, it effectively filters out those longer wavelengths, so the gage can only "see" and measure roughness.

Surface Roughness Testers

A surface roughness tester (roughness gage) is a small, handheld, stylus-based instrument that can be placed directly on a part to measure roughness on relatively flat surfaces. Because they are small and portable, these gages can be used to measure large components, assemblies, or stock. Handheld roughness gages are inexpensive, easy to use, and provide fast shop floor measurements with little setup. Standard , 5 µm or 10 µm stylus tips enable measurement of the feature heights considered roughness for many machined surfaces.

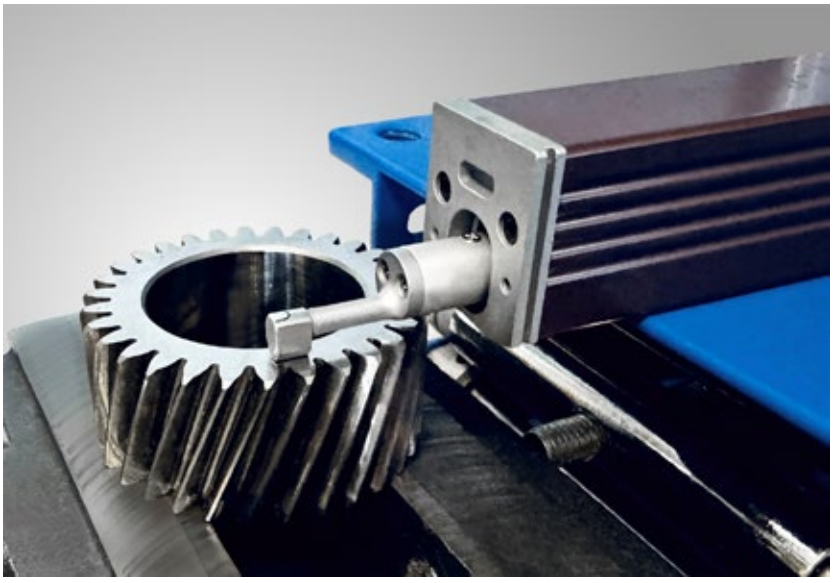


Figure 3. A "skidded" roughness gage. Courtesy Digital Metrology Solutions.

Skidless Profilometer

The stylus in a "skidless" instrument can measure over a larger range of feature heights than a skidded system. These relatively inexpensive, portable, and easy-to-use instruments can measure larger vertical departures than skidded gages, enabling roughness measurement on angled surfaces, and in some cases partial arc measurements on curved surfaces. An internal datum provides a reference that supports long traces —up to many millimeters in length—to capture waviness wavelengths and provide a larger sampling for roughness assessment.

The ability to measure roughness, waviness, and partial arcs makes skidless gages ideal for applications such as measuring bearing races, where both shape and texture are critical. These gages, however, are typically not capable of measuring geometric dimensions such as a bearing race radius, slopes, or complex forms such as aspheric optical lenses.

Because skidless gages are more susceptible to vibration (a 2 µm radius stylus only exerts 70 mg to 100 mg of force against the surface) they require more isolation than skidded instruments. The exposed stylus is also more prone to damage from encounters with steep steps or sharp edges, so care must be taken to protect the delicate stylus.

Contour Gage

The gages we've mentioned so far are designed primarily for roughness measurement. Contour gages, on the other hand, are designed for measuring larger scale shape and features such as blends, arcs, corners, thread root radii, etc. Contour tips typically have a 20µm or 25µm radius, making them robust for measuring larger features but incapable of measuring roughness scale features.

Some instruments include interchangeable measurement heads and software for measuring either roughness or contour. This arrangement can be a cost-effective solution for labs that measure a wide range of parts and features; however, the setup required to switch frequently between measurement types can limit lab throughput.

To limit the impact of vibration, these instruments are typically mounted on a rigid post attached to a vibration-isolated heavy base, with staging for positioning the test part. The size of the component that can be measured is limited laterally by the stage size (e.g., 600 x 600 mm) and vertically by the height of the column (e.g., 450 mm, 700 mm, or 1 m). The system cost typically increases with the size of the column, type of stage and the accompanying precision datum.

Inductive Pickups

An inductive measurement pickup (LVDT) measures changes in inductance caused by the proximity of the test surface. This technology is more precise than the piezo-electric transducers often found in entry-level instruments and enables better vertical resolution (e.g., 15 nm – 30 nm). Some high-performance instruments claim sub-nanometer resolution; however, these higher resolutions may not produce meaningful data in all cases (a small step height, for example, may appear as a fuzzy

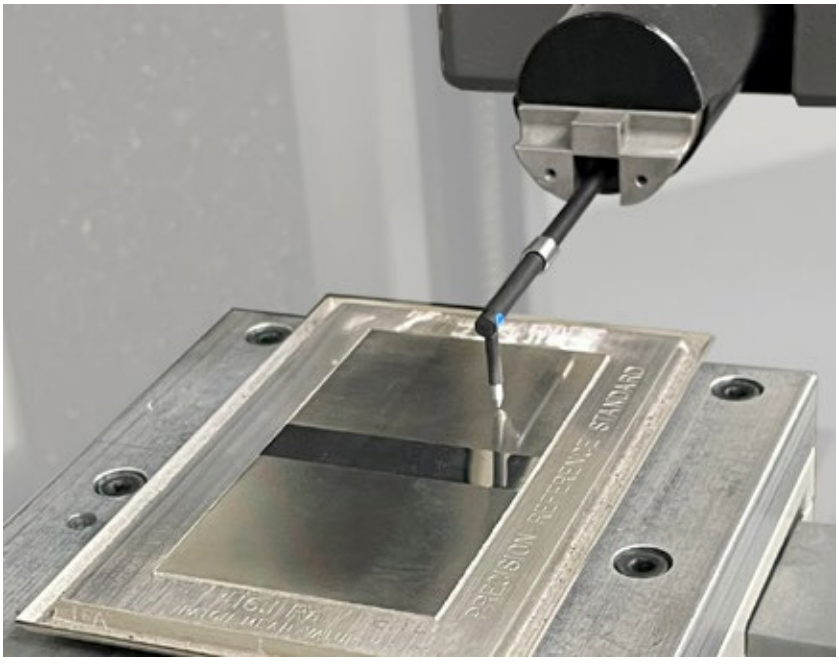


Figure 4. A skidless stylus measuring surface roughness.

Figure 5. A metrology engineer measuring roughness with a laser-based gage.

square wave). The onus is on the buyer to verify/evaluate that the system is capable of a particular measurement before purchase.

An inductive measurement system can be used for measuring texture, small arc, slopes, straightness and even larger scale form. The vertical range may be limited (typically 1 mm for a standard length stylus, 2 mm for a 2X length stylus). Applications include small optics and roller bearings where both the texture and the small curvature are critical for function.

Some instruments rely on capacitance rather than inductance, with similar range and resolution as inductive transducers. Capacitive systems are much more infrequently used, however.

Laser Pickups

Laser-based pickups use an internal interferometer to precisely measure the stylus position. Laser-based systems can have a resolution as low as 10 nm over a larger range than an inductive system (up to 6 mm for a standard 1X length stylus tip).

Laser instruments can measure dimensions and form (including aspheric form) as well as texture. Some systems even enable multiple, side-by-side traces to be assembled into a 3D surface map Applications include bearings and raceways, optics, and semiconductors.

Some laser systems employ "phase grating interferometry" or "PGI" transducers capable of 12 mm (1X length stylus) vertical range or more, with resolution as low as 0.2 nm.

Of course, the price of these systems is commensurate with the flexibility, range, and resolution. Most systems offer a range of software options geared toward particular applications that can increase the cost further. But, when the application requires this level of performance, the cost may not only be warranted but necessary.

Optical

Optical measurement technologies take advantage of the properties of light for non-contact measurement of surface roughness and shape. The 3D nature of optical measurements provides excellent accuracy for roughness measurements and helps highlight aspects of texture that cannot easily be described by a 2D trace. For example, hills and dales can be completely characterized in 3D (whereas they are reduced to peaks and valleys in 2D, and the actual highest/lowest point of any feature are rarely captured). This ability makes it possible, for example, to determine the volume of fluid that can be retained on a surface for lubrication or printing.

Optical instruments are capable of capturing roughness with sub-nanometer resolution, making them exceptionally useful for applications such as optics and semiconductors. However, they have several limitations for production measurement:

1. The measurement size is typically quite small vs. a stylus trace.
2. The instruments typically require more setup and require a longer learning curve to grasp the many options that impact the results.
3. Most optical systems are susceptible to vibration and require significant isolation from machinery and air handlers.
4. Most optical instruments are based on rigid stands which limit the size of the component to be measured.
5. Many features, including spheres, bores, grooves, and low-reflecting or scattering surfaces, are challenging to measure because insufficient light is returned to the object.

Despite these limitations, a 3D optical measurement system is the tool of choice for many precision applications where 3D data and high resolution are required.

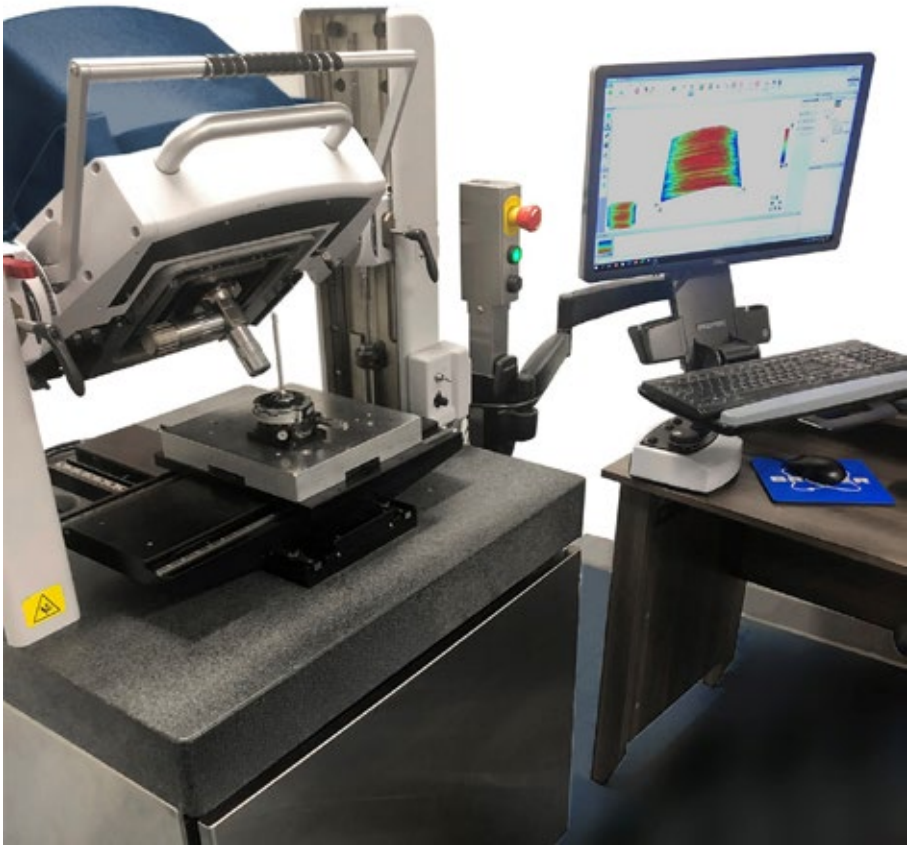


Figure 6. A white light optical profiler. Courtesy Michigan Metrology, LLC.

CMM

Coordinate Measurement Machines (CMMs) provide accurate geometric measurements. Some systems include an optional roughness measurement probe, (a skidded or skidless stylus or non-contact optical sensor) that can provide texture data as well as form and waviness. This arrangement proves sufficient for surfaces with Ra greater than a few microns; however, most CMMs are incapable of measuring finer roughness scales.

The following chart summarizes the relative strengths of these various measurement technologies.

Ultimately, which instrument is appropriate for a measurement will depend on many factors in addition to those listed above. The component material, the volume of parts to be measured, and budgetary concerns may all impact the decision. What matters most, however, is choosing an instrument that is not just able to produce a scan of the surface but that is also capable of measuring the wavelengths that matter for the part's function, with sufficient resolution and accuracy.

About the Authors

Mike Zecchino (mike@mikezecchino.com) has created technical content related to metrology for over 25 years. His articles have appeared in dozens of publications, and his training materials and videos support numerous measurement instruments and technologies.

Jeff Dax (j.dax@emigage.com) founded EMI Gage in 1994 as an independent supplier of calibration, support, repair, and accessories for measuring instruments. Following his service in the US Army and earning his B.S. in Electronics Engineering, he has supported a wide range of measurement instruments, from dial indicators to CMMs.

Mark Cobb (m.cobb@emigage.com) has spent nearly 30 years in quality positions, from floor inspector to quality manager and holds an ASQ Certification. He has calibrated and repaired surface texture, form, and roundness measurement instruments for the past 18 years.

Instrument Type	Measurable Geometry	Measurable Features	Part Envelope	Vertical Range	Vertical Resolution	Cost
Handheld Skidded Stylus	Primarily flat	Roughness	Unlimited	< 500 µm typical	0.001 µm – 0.025 µm typical, range dependent	Least expensive
Skidless Stylus	Flat, arc	Roughness, waviness, partial arc	Unlimited	1 mm for 1X stylus; 2 mm for 2X stylus	< 1 nm to tens of nanometers typical, range dependent	Inexpensive
Inductive/ Capacitive Pickup	Flat, arc, complex geometry	Roughness, waviness, partial arc, geometric dimensions	Limited by stage size and column height	1 mm for 1X stylus, 2 mm for 2X stylus typical	15 nm –30 nm typical; as low as sub-nanometer for some applications	Moderate; Price varies with hardware/software options, including column height
Laser Pickup	Flat, arc	Roughness, waviness, partial arc, form, geometric dimensions	Limited by stage size and column height	6 mm	Down to 10 nm; sub-nanometer with PGI	Relatively high; hardware/software options can increase cost
Optical	Flat, arc, complex geometry	Roughness, waviness, radius, form	Limited by stage size and rigid stand supporting the optics	10 mm or more	Sub-nanometer	Typically higher; some handheld instruments are more affordable
CMM	Flat, arc, complex geometry	Geometric dimensions and form; roughness to an extent with precision measurement head	Large (limited by extent of staging and reach of measurement	1 mm for 1X stylus; 2 mm for 2X stylus	20–100 nm with precision head; Often insufficient for roughness parameters when Ra < 1 µm	Moderate

The Quality System at INRiM: A Research and National Metrology Institute

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National Institute of Metrological Research (INRiM)

The Quality Management System (QMS) of the Istituto Nazionale di Ricerca Metrologica (INRiM), Italy, deals with calibration and measurement activities in accordance with the Mutual Recognition Arrangement (MRA), established to ensure the mutual acceptance of national standards and calibration certificates among signatory countries. The INRiM system also covers other scopes such as testing for the Association for the Certification of Electrical Equipment (ACAE) and the Low Voltage Agreement Group (LOVAG), production of certified reference materials, interlaboratory comparisons (ILCs), and provision of technical documentation and contract-based services using. The QMS complies with ISO/IEC 17025:2017, Option A, for calibration and testing, with ISO 17034:2016 for production of certified reference material and with ISO/IEC 17043:2023 for interlaboratory comparison provider. The INRiM QMS does not cover research activities. In 2024, INRiM maintained 448 Calibration and Measurement Capabilities (CMCs) and, between 2022 and 2024, issued 5336 certificates, 173 test reports, and 337 ILC reports. The INRiM organization, where a QMS coexists within a research environment and where scientific and technical personnel are involved in the three INRiM tasks, has a positive impact on all INRiM activities.

1. Introduction

The Comité International des Poids et Mesures (CIPM) Mutual Recognition Arrangement (MRA) [1] is an international agreement allowing national metrology institutes (NMIs) to demonstrate the international equivalence of their measurement standards and the mutual recognition of their calibration certificates. The CIPM MRA imposes that NMIs participate in key comparisons (KCs) and supplementary comparisons (SCs) of measurement standards to demonstrate the equivalence of their capabilities. NMIs publish their calibration and measurement capabilities (CMCs) in the key comparison database (KCDB), maintained by the International Bureau of Poids et Meaures (BIPM). These CMCs signify that the participating NMIs' measurement standards and calibration certificates are mutually recognized. A further requirement to support MRA is that the NMIs must implement a Quality Management System (QMS) in accordance with ISO/IEC 17025 [2]. CMCs are submitted to Regional Metrology Organizations (RMOs) for review. Several NMIs extended the scope of their QMS to cover additional activities in accordance with other standards. For example, QMSs of the following NMIs cover:

- Federal Institute of Metrology (METAS Switzerland): General Quality System (QS) [3], Calibration and Testing (C&T), Reference Materials (RMs) production [4], Conformity Assessment for Inspection bodies [5], Risk Management [6], Information security system [7];
- Physikalisch-Technische Bundesanstalt ((PTB Germany): QS, C&T, RMs production;
- National Physical Laboratory (NPL Great Britain): QS, C&T, RMs production, information security system and Proficiency Testing (PT) or Interlaboratory comparisons (ILCs) provider [8] all accredited by UKAS[2];
- Laboratoire national de métrologie et d'essais (LNE France): QS, C&T, RMs production,

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2 UKAS is the National Accreditation Body of United Kingdom for accreditation of organizations that providing certification, testing, inspection, calibration, validation and verification.

conformity assessment for bodies providing audit and certification of management systems [9];

- VSL National Metrology Institute, Netherland: C&T, RMs production and PT provider, all accredited by RvA[3];
- National Institute of Standards and Technology (NIST USA): C&T, RMs, PT provider and standard Reference data.

The conformity of INRiM's QMS with [2, 4, 8] is self-declared. Without a formal accreditation, INRiM is periodically subject to re-evaluation through peer reviews carried out by personnel and experts from other NMIs. For RMs production and ILCs provider activities, the INRiM QMS includes additional requirements, which are applied in addition to the requirements of [2]. INRiM is also a qualified laboratory within the Association for Certification of Electrical Equipment (ACAE), a network of qualified testing laboratories. ACAE is a certification body active in the fields of electrical low-voltage and high-voltage equipment. An ACAE-qualified laboratory is authorized by ACAE to carry out tests consistent with its technical capabilities and equipment. ACAE qualification implies the compliance by the laboratory to the requirements of [2], and ACAE specific requirements. The qualification process consists in the verification by ACAE assessors, documental and onsite, of the compliance to [2] and to the specific ACAE requirements. The maintenance of the qualification requires annual surveillance. In [10], it is demonstrated that stronger national Quality Infrastructures (NQIs), including NMIs, are generally associated with more robust economies. NMIs play a central role in NQIs through their connections with scientific and legal metrology, as well as with conformity assessment and accreditation bodies. These include the BIPM, CIPM, the International Organization for Standardization (ISO), the World Trade Organization (WTO), the International Laboratory Accreditation Cooperation (ILAC), and the International Accreditation Forum (IAF). NMIs often participate in committees with such organizations sharing and transferring advances in technology allowing these organizations to update their rules and accreditation/certification criteria.

3 Dutch Accreditation Council RvA.

2. INRiM: A Research and Metrology Institute

INRiM is a national public scientific research organization (Figure 1) supervised by the Ministry of University and Research. It serves as Italy's NMI. INRiM was established in 2006 merging the Istituto Elettrotecnico Nazionale "Galileo Ferraris" (IEN) with the Istituto di Metrologia "Gustavo Colonnetti" (IMGC). INRiM performs scientific research in metrology and develops advanced measurement standards and methods. As a signatory participant of the CIPM-MRA, INRiM maintains the national standards to ensure the metrological traceability and legal validity of the measurements across industry, commerce, scientific research, healthcare, and environmental protection. The INRiM NMI Role encompasses metrology activities for both internal and external clients, including C&T, ILCs provider and RMs production. INRiM also is active in the knowledge transfer (KT) and advancements in measurement and materials science, aiming to enhance national technology, quality of life, and public services. The INRiM scientific structure is led by a Scientific Director, and it is organized into three Departments:

- Applied metrology and engineering (AE);
- Metrology of innovative materials and life sciences (ML);
- Quantum metrology and nanotechnology (QN).

The QMS board and system operate at the highest level, reporting directly to the INRiM President.

Each department encompasses research and metrology activities relevant to their respective fields. AE covers the quantities of Mass and related ones, length, Electrical and electronic, and thermodynamics. QN covers the Time and Frequency quantities, as well as Photometry. ML is responsible for Acoustics, Ultrasound, and Magnetism. A structural change at INRiM mandated that all Departments participate in the institute's three tasks: Research, NMI and KT Roles. In the INRiM's previous organization, scientific departments were primarily involved in research activity. Within this framework, research outcomes were not readily accessible to the Department exclusively in charge of the NMI and KT roles. This change has enhanced the internal KT, as researchers and technicians now participate in all the three tasks, facilitating the application of research findings to

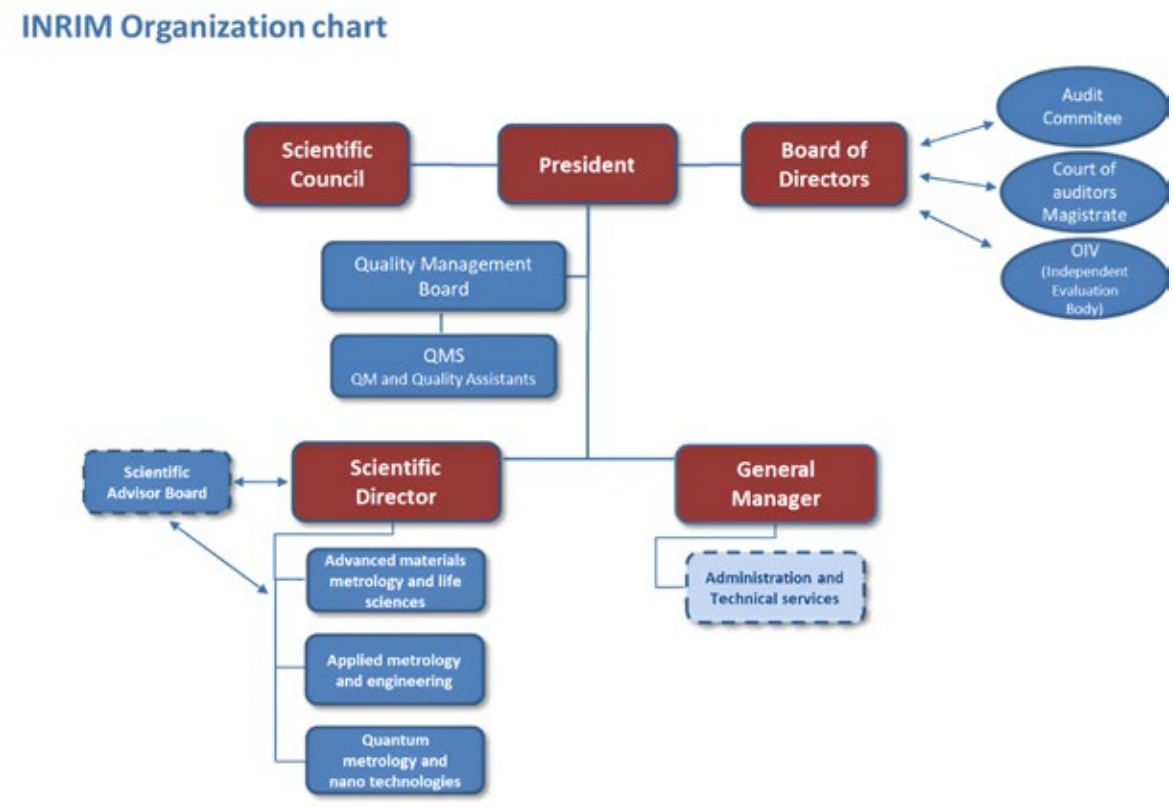

Figure 1. INRiM Organization chart.

metrology activities (C&T) especially for external customers. INRiM provides also technical support to the Italian accreditation body for calibration laboratories, ACCREDIA-DT, providing expertise and technical assessors for the accreditation processes. The INRiM QMS does not encompass research activities, as no formal standards for research currently exist. Nevertheless, in [11] it is stated that some organizations published schemes and guidelines for quality in research, but these were not generally accepted. The INRiM QMS was generally accepted by researchers, as its implementation was required for participation in the CIPM MRA and because it does not directly govern research activities, but only those related to the NMI role (calibration & testing, reference materials, ILCs provider). The current INRiM organization, in which a QMS coexists with research activities and where scientific, appears to be successful both for scientific productivity, dissemination of measurement units, and technology transfer, while preserving the scientific autonomy of researchers. This is demonstrated in Table 1 reporting the figures for INRiM's three core tasks from 2019 to 2024. The table shows that, starting from 2021, when the organizational change was implemented, the outcomes of research (no. of scientific publications, 1st column), of documents (certificates and reports for NMI role, 2nd column), and no of patents (for KT role, 3rd column).

2.1 Documents for the INRiM QMS

The INRiM QMS is made of 24 general procedures and of 236 technical procedures that support 63 laboratories. The QMS is primarily focused on the requirements outlined in [2] concerning the C&T activities, which represent the core service for both internal and external customers. Additional requirements concern the RMs production and ILCs provider activities. Therefore, specific additional requirements are detailed in dedicated management procedures. In [8, 12] specific rules to evaluate the ILCs results are given.

Year	Publications in Indexed Journals	Documents for External Customers	Patents
2019	167	1802	0
2020	176	1749	3
2021	175	2116	4
2022	194	1980	4
2023	205	2042	5
2024	208	1824	10

Table 1. Number of the three INRiM tasks from 2019 to 2024.

2.2 The LATFC Laboratory

Among the INRiM's laboratories, the Laboratorio Alte Tensioni e Forti Correnti (LATFC)-High Voltage and High Power Laboratory https://www.inrim.it/sites/default/files/2022-05/LATFC.pdf - stands out for its specialization and capabilities. LATFC is active on research and calibration of measurement systems testing of electrical equipment, including switchgear and controlgear assemblies, busbar systems, insulators, circuit breakers, fuses, contactors, instrument transformers, and similar devices. LATFC performs high-current tests such as short-circuit, withstand and prospective current tests, endurance tests, and temperature rise tests. It also performs high-voltage tests, including power-frequency tests (at 50 Hz) in both dry and wet conditions, as well as lightning and switching impulse tests. Under the ACAE qualification, carries out verifications of short-circuit conditions, dielectric withstand verification, temperature rise, overload releases, under-voltage and shunt releases, auxiliary circuits, mechanical operation, operational performance capability, lifting tests, and degrees of protection. By means of ACAE qualification, INRiM plays an important role in electrical safety and regulatory compliance by actively participating in European and international networks, such as LOVAG, the Low Voltage Agreement Group. The collaboration between INRiM - the only NMI laboratory recognized by LOVAG and certification networks such as LOVAG represents an effective model of integration between scientific metrology and technical conformity assessment. This synergy contributes to a safer, efficient, and competitive European electrical market. It enhances the product quality, fosters trust in the EU market, reduces business costs through mutual recognition, and supports innovation by ensuring that emerging technologies are both measurable and certifiable. LATFC is subjected to regular surveillance by ACAE in accordance with [2], as well as the applicable IEC and EN standards relevant to the qualified tests. ACAE imposes additional requirements for laboratories performing tests on its behalf such as the guidelines of the procedure "Current Technical Decisions" which provides authoritative interpretations of the applicable rules. The uncertainty associated with the tests must comply with the ACAE document: Instrument Accuracy Limits for low-voltage tests and with the Short-Circuit Testing Liaison procedure: "Handling of Measurement Uncertainties in Testing and Test Documents for high-voltage." ACAE signed an agreement with INRiM, outlining the criteria for operating as an ACAE-accredited laboratory.

2.3 INRiM Results Reports for C&T, RMs and ILCS Provider Activities

The technical documents issued by INRiM in the framework of its QMS are related to the CMCs in the Appendix C of the CIPM MRA https://www.bipm.org/kcdb/and/or to other activities made by INRiM as NMI according to the Italian law 273/91 instituting the Italian calibration system (SNT). Specifically, the issued documents are:

- Calibration certificates: concerning the calibration of a measurement standard, instrument or system;
- Measurement certificates: concerning a measurement activity;
- Test reports: concerning test activities on products or devices according to procedures and specifications defined by technical standards and/or agreed with customers;

- ACAE test reports concerning test activities issued in the framework of the ACAE qualification;
- Certificates of CRM: concerning Reference Material Certification activities;
- Information sheets of RM: concerning the produced Reference Material;

On the first page and inside of the calibration and measurement certificates covered by CMCs, the CIPM MRA logo and the CIPM MRA note[4] are respectively reported. Calibration and measurement certificates not covered by CMCs but issued in the capacity of the NMI designated under Italian Law No. 273 include the annex "ILAC Annex P10" /9/. This annex provides customers with the information required to ensure traceability in compliance with the same document. These certificates are issued for internal instruments.

2.4 Surveillance of the C&T, RMs and ILCS Provider Activities by the INRiM QMS

The C&T, RMs, and ILCs provider activities are monitored by the INRiM QMS through:

- Application of quality assurance to results, requiring laboratories performing these activities to monitor the validity of their results at planned intervals;
- Participation in national and international comparisons;
- INRiM has participated in 229 key comparisons (29 as pilot laboratory) and 86 supplementary comparisons (7 as pilot).
- Internal audits. INRiM carries out approximately 50 internal audits each year across all laboratories covered by the QMS. These audits include the assessments of technical procedures, their implementation, and the adequacy and effectiveness of the laboratories.
- Assessments under international agreements as the European Association of National Metrology Institutes (EURAMET), Technical Committee (TC) Quality: EURAMET TC-Quality has established a process for the continuous monitoring of the QMSs of its NMIs. Once a QMS is approved by EURAMET TC-Quality, all signatory NMIs and Designated Institutes (DIs) under the CIPM MRA are required to submit an annual report to the TC-Quality on the current status of their QMSs. The review of these annual reports ensures that institutes are maintaining their QMS, reviewing their services, and addressing any issues that could impact on their CMCs. Additionally, a periodic review of the QMS must be conducted at intervals not exceeding five years. To this end, INRiM, besides the QMS annual reports, presents a comprehensive five-year QMS activity report every five years to EURAMET TC-Q. This planned monitoring ensures that the QMS continues to cover the declared CMCs and that peer reviews remain valid.
- Peer visits performed by experts of other NMIs to INRiM facilities, activities and laboratories: INRiM is involved in the EURAMET Project 1123, "On-site Peer Review CEM, INRiM and IPQ." This joint audit project aims to support the development and improvement processes of NMIs, providing a tool for better international recognition and strengthening confidence in the fulfilment of the CIPM MRA requirements. The peer review program is scheduled on annual basis. Started in 2009, the project involves a program of cross-audits conducted each year. In general, each technical subfield is assessed every five years, while the overall QMS is reviewed every two years.
- Surveillance visits by the ACAE to the LATFC: Surveillance is conducted annually to determine whether the LATFC laboratory still meets the requirements of [2] and of ACAE specific requirements. Since INRiM is a non-accredited institution, the annual monitoring is carried out through inspections, planned in such a way that, within a three-year period, all the requirements of [2] are checked at least once.

4 This certificate is consistent with the capabilities (CMCs) that are included in Appendix C of the CIPM MRA drawn up by the CIPM. Under the CIPM MRA, all participating institutes recognize the validity of each other's calibration and measurement certificates for the quantities, ranges and measurement uncertainties specified in the KCDB. For details see https://www.bipm.org/kcdb/.

- Analysis of risks and opportunities according to the relevant procedure "Risks and opportunities." This analysis is reviewed every year during the management review.
- Continuous improvement of the QMS applying the relevant managing procedure "Improvement," in which Key Performance Indicators (KPIs) are established and annually evaluate. They mainly concern: Performance adequacy, system compliance, product compliance and customer's satisfaction. For example, one of these KPIs is defined as the ratio between the no. of work orders completed during the year and the no. of quotes issued during the year.
- Management review outputs, which report on the effectiveness of the QMS and its processes, the improvement of the activities of the laboratories, the adequacy of resource provision, and any identified need for changes.

2.5 INRiM Numbers in the Years 2022-2024 for C&T, RMs and ILCS Provider Activities

The metrological areas covered by the MRA include: EM (Electricity and Magnetism), T (Temperature) TF (Time and Frequency), L (Length), M (Mass and related quantities), AUV (Acoustics, Ultrasound and Vibration), QM (Amount of Substance), PR (Photometry and Radiometry).

Metrology Area	No. of INRiM CMCs
EM	135
M	71
T	111
L	51
AUV	41
PR	17
QM	12
TF	10

Table 2. Number of the INRiM CMCs per metrological area in 2024.

As of the end of 2024, INRiM maintains 448 CMCs published in the KCDB, distributed across these metrological areas, as shown in Table 2. In the following, data on activities conducted under the INRiM QMS between 2022 and 2024, divided by metrological area, are provided.

Figure 2 shows the percentage distribution of the INRiM's issued C&M certificates per metrological area over the three-year period 2022–2024, when 5336 certificates were issued.

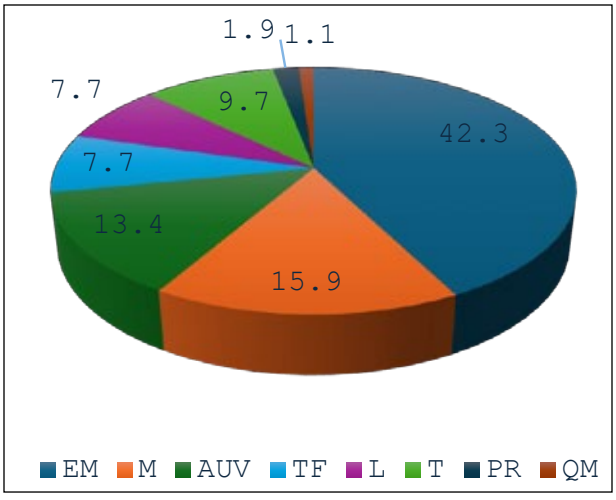

Figure 2. Percentage distribution of C&M certificates issued by INRiM per metrological area in the period 2022-2024.

Figure 3 shows the number of ILCs provided by INRiM per metrological area from 2022 to 2024. During this period, INRiM provided 113 ILCs with an average of 54 participants per year and issued a total of 337 ILC reports.

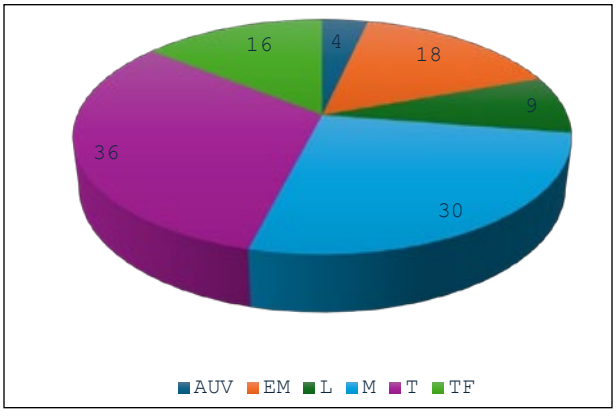

Figure 3. Number of ILCs provided by INRiM in the period 2022-2024 per metrological area.

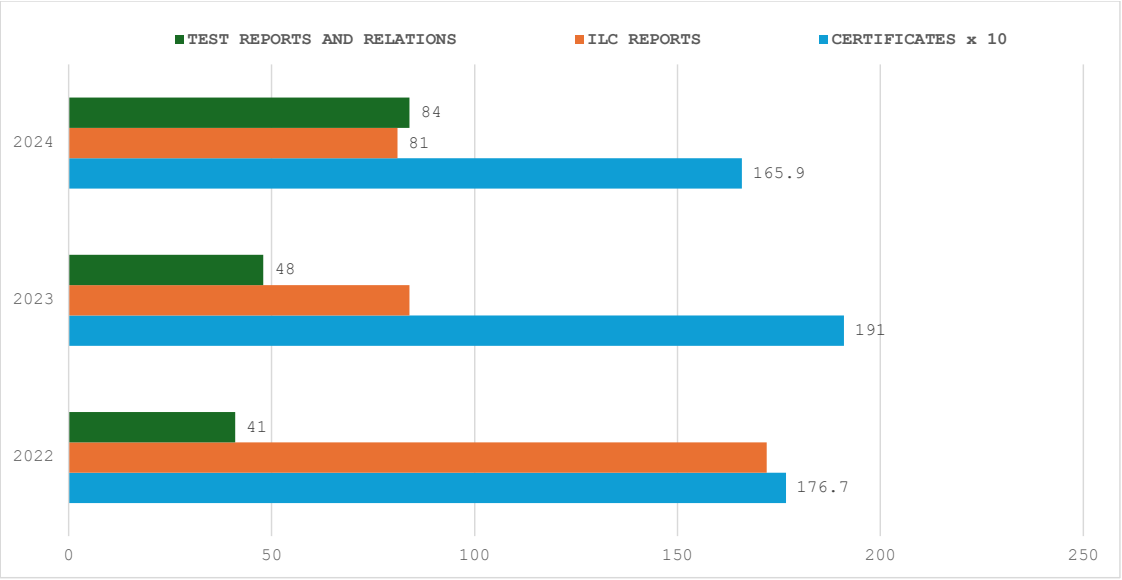

Figure 4. Number of documents issued by INRiM in the years 2022-2024 according to their typology.

During the three-year period, INRiM issued 173 technical reports, most of which were provided by the EM area. In 2024, INRiM issued the first certificate for a RM. Finally, Figure 4 shows the number of the documents issued by INRiM according to their typology in the same three-year period.

3. Discussion

The INRiM experience suggests that QMS and research activities can successfully coexist within a research environment, preserving scientific autonomy of the researchers whit potential mutual benefits. The collaboration between INRiM and LOVAG is an effective example of integration between scientific metrology and the conformity framework to improve the reliability of the electrical market. Furthermore, the peer review process under the CIPM MRA assessessing the conformity of the INRiM's QMS and of the laboratories represents a collaborative framework that facilitates the exchange of best practices, promotes mutual trust and reinforces international partnerships. This peer review process offers greater flexibility than a formal accreditation, being well-suited to meet the evolving needs of emerging and technologically advanced sectors, an essential characteristics for any research institution.

On the basis of this integrated QMS, INRiM is strategically positioned to address the challenges of an increasingly interconnected context and to fully harness the opportunities arising from digital transformation; since July 2025, as a direct outcome of the QMS implementation, INRiM issues documents as certificates and reports in electronic format.

Acknowledgements

The authors wish to thank P. Roccato of LATFC for his advice on the activity of LATFC concerning ACAE and relevant documentation.

References

[1] Comité international des poids et mesures, Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes October 1999.

[2] ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories.

[3] ISO 9001:2015 Quality management systems — Requirements.

[4] ISO 17034:2016 "General requirements for the competence of reference material producers.

[5] ISO/IEC 17020:2012 Conformity assessment—Requirements for the operation of various types of bodies performing inspection.
[6] ISO 31000:2018 Risk management — Guidelines.
[7] ISO/IEC 27001:2022 Information security, cybersecurity and privacy protection-Information security management systems Requirements
[8] ISO/IEC 17043:2023 Conformity assessment — General equirements for the competence of proficiency testing providers, Edition 2.
[9] ISO/IEC 17021-1Conformity assessment- Requirements for bodies providing audit and certification of management systems. Part 1:Requirements.
[10] S.Rab et al. Quality Infrastructure of National Metrology Institutes: A Comparative Study. Indian Journal of Pure & Applied Physics 59 (2021)pp. 285-303.
[11] V.Biasini (2012). Implementation of a quality management system in a public research centre. Accred Qual Assur. 7:621–626 https://doi.org/10.1007/s00769-012-0936-9
[12] F.Galliana et al. Methodology and Analysis of the ILCs provided by INRIM from 2016 to 2018 Mapan 35 (3) (2020):435–445. https://doi.org/10.1007/s12647-020-00374-5

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Automating Calibration with LabVIEW: A Practical Guide for Calibration Laboratories - 3rd Continuum

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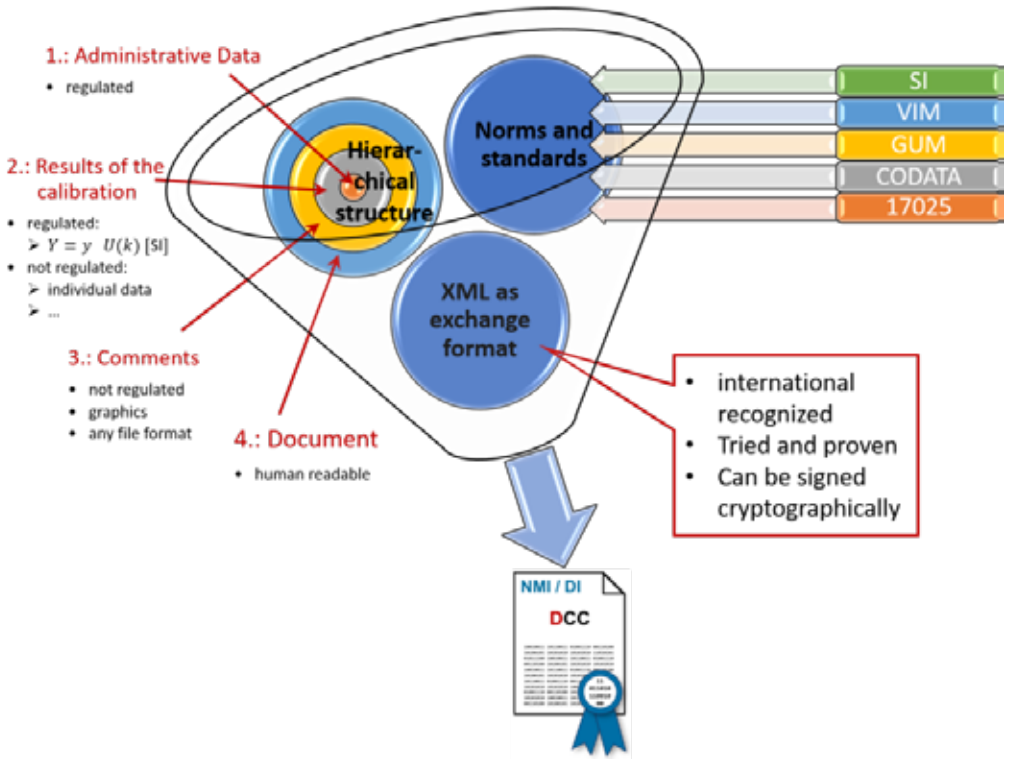
Introduction

Digital Calibration Certificates (DCCs) are reshaping calibration documentation by turning certificates into structured, machine-readable data that can be searched, analyzed, and trusted digitally—rather than stored as static PDFs or paper records. This article explains what DCCs are, why they matter, and how LabVIEW-based automation is a practical way for calibration laboratories to adopt DCC-ready workflows while improving efficiency, traceability, and data integrity.

From Paper Certificates to Digital Data

Traditional calibration certificates are primarily designed for human reading: a technician performs the calibration, the lab generates a PDF, and the record is filed for audits or customer compliance.

That model works, but it limits the value of calibration results because key information (as-found/as-left data, uncertainties, environmental conditions, limits, and standards used) is effectively trapped in a document that is difficult for software to interpret at scale.



DCCs address this by expressing certificate content in a structured format intended for interoperability, allowing calibration results to flow into quality systems, asset management tools, and analytics pipelines without manual transcription.

What a Digital Calibration Certificate (DCC) Is

A Digital Calibration Certificate is a calibration certificate represented in a structured, machine-readable form—commonly based on standardized data models—so its contents can be processed automatically by software systems.

Because DCC content is structured, it becomes easier to analyze calibration data across fleets of instruments, compare performance over time, and support initiatives such as digital twins in process industries.

A core expectation of the DCC concept is trust in the digital artifact, which is supported through mechanisms like cryptographic signatures that protect authenticity and integrity.

Why DCCs Matter to Calibration Laboratories

For calibration labs, DCCs are not "just a new file type"; they change how calibration results can be reused operationally.

Instead of spending effort searching folders, manually re-entering results into separate systems, or reconstructing evidence during audits, labs can treat each calibration as a standardized data package that can be indexed, queried, and validated automatically.

This shift also supports scale: as labs grow in volume, customers, and device variety, digital workflows reduce administrative overhead while improving consistency.

Where LabVIEW Fits in the DCC Journey

Many laboratories already use LabVIEW to automate calibration benches, control instruments, acquire readings, perform limits checks, log data, and generate reports. Our previous article emphasized that robust LabVIEW applications rely on proven architectures—state machines for clear sequencing, event-driven programming for responsiveness, and producer–consumer designs for smooth operation under load.

Those same architectures create a natural "landing zone" for DCCs: once the calibration workflow is already structured in code, producing structured certificate data is an extension of the system, not an additional manual reporting step.

Building a DCC-Ready Calibration Workflow in LabVIEW

A practical way to align LabVIEW automation with DCC goals is to treat the calibration process as a controlled pipeline: capture data consistently, validate it, package it, and secure it at issuance.

LabVIEW state machines are especially effective here because each stage of the calibration—initialize, source/set stimulus, measure, compute, evaluate limits, finalize—maps cleanly to a state where the required data can be collected and standardized.

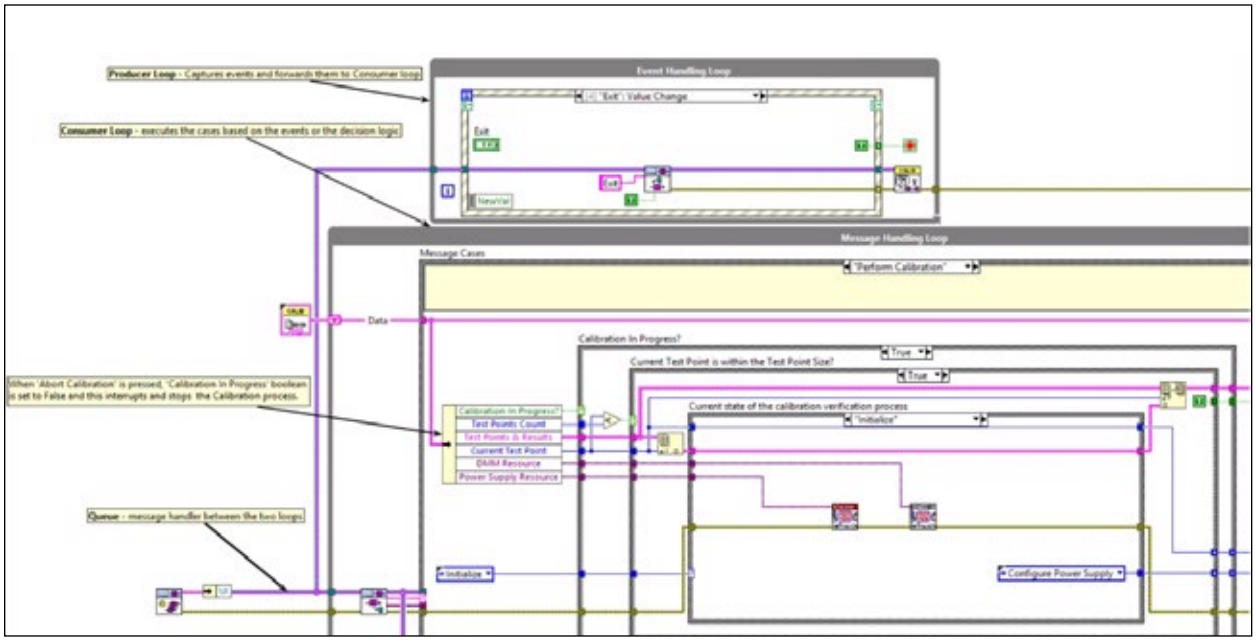
By the time the workflow reaches a "Finalize/Report" state, the program can generate both a human-readable report (PDF) and a DCC payload (structured data) from the same validated dataset, ensuring the two remain consistent.

Recommended Functional Blocks

- Instrument & environment acquisition: Capture UUT readings, reference readings, and relevant environmental data in a consistent schema.
- Computation & limits evaluation: Compute errors, uncertainties (where applicable), and pass/fail decisions in deterministic, testable steps.
- Data packaging: Serialize results into a structured certificate object aligned with DCC expectations (fields, units, traceability references).
- Issuance & protection: Apply cryptographic signing at the moment of certificate issuance to protect authenticity and integrity.

Benefits for calibrators (and why they show up quickly)

Implementing DCCs through LabVIEW-based systems offers tangible lab-level wins, not just "future readiness."



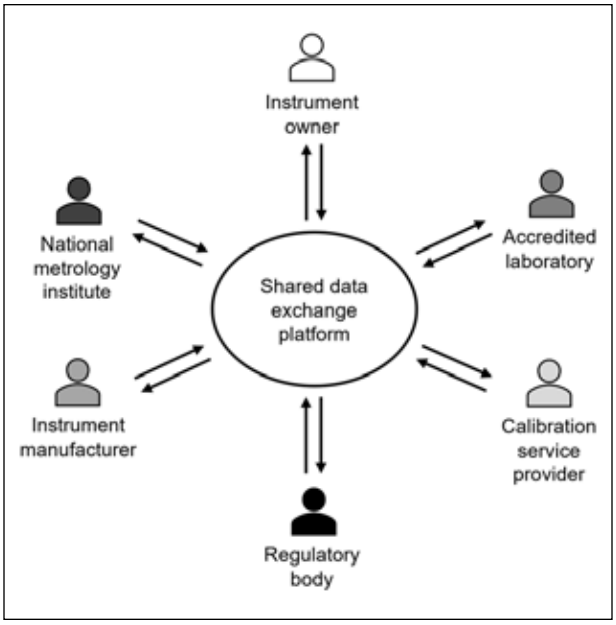
- Manage and search calibration data at scale: Structured records allow rapid retrieval by serial number, asset ID, date range, procedure version, measurement function, or uncertainty band—capabilities that are painful with paper and inconsistent PDF naming.
- Increased traceability: Digitally structured fields make it easier to demonstrate traceability links (standards used, methods, conditions, results) during audits and customer reviews.
- Preventive maintenance enablement: When results are captured as data (not just documents), drift patterns and approaching-tolerance trends can be detected to trigger earlier checks instead of relying only on fixed intervals.
- Cryptographic protection: Digital signatures help show that a certificate is authentic and unchanged since issuance, strengthening trust for remote reviews and system-to-system exchange.

Common Adoption Path (Practical, Not Disruptive)

DCC adoption does not need to be a "big bang" replacement of everything at once; it can be layered onto existing LabVIEW automation incrementally.

A common transition approach is: keep generating PDFs for human consumption while adding DCC outputs for machine use, then gradually integrate DCC data into search, analytics, and quality workflows as systems mature.

This mirrors how labs typically modernize—first stabilize automation and architecture (state machine, event-driven UI, producer–consumer), then expand interoperability and governance.



Implementation Considerations to Get Right Early

Two areas tend to determine whether DCC initiatives succeed in real labs: data consistency and governance.

Even the best certificate format won't help if identifiers, units, tolerances, or procedure metadata are inconsistently captured—so a lab should define a clear internal schema and enforce it in the LabVIEW code paths that write results.

Similarly, certificate trust depends on issuance controls (who can issue, how revisions are handled, how signing keys are managed), so cryptographic protection should be designed as part of the workflow, not bolted on later.

References

[1] PTB (Physikalisch-Technische Bundesanstalt) – "Digital Calibration Certificate (DCC)" overview page. https://www.ptb.de/cms/en/research-development/ptbs-innovation-clusters/innovation-cluster-for-digitalization/kernziel1einheitlichkeitim/digital-calibration-certificate-dcc.html

[2] Mustapää, T. et al. (2024) – "Enabling the use of digital calibration certificates in industrial calibration management systems" Journal of Sensors and Sensor Systems. https://jsss.copernicus.org/articles/13/71/2024/jsss-13-71-2024.pdf

[3] Nummiluikkia, J. et al. (2022) – "Developing and testing Digital Calibration Certificate in an industrial application" (IMEKO TC6 Proceedings). https://www.imeko.org/publications/tc6-2022/IMEKO-TC6-2022-026.pdf

[4] Beamex blog (2025) – "Digital Calibration Certificate (DCC) – What is it and why should you care?" (good industry explanation + benefits). https://blog.beamex.com/digital-calibration-certificate-dcc-what-is-it-and-why-should-you-care

[5] Kan, K. et al. (2024) – "Design and Implementation of Digital Calibration" (open-access article discussing limits of paper/PDF and value of machine-readable DCCs). https://pmc.ncbi.nlm.nih.gov/articles/PMC11511384/

About Author

Ajayvignesh Manonmani Velumani (Ajay MV) is a Certified LabVIEW Architect and Certified TestStand Architect from National Instruments with over 15 years of experience. He leads a dedicated team specializing in calibration management systems, with a focus on DCC (Digital Calibration Certificates) through their SaaS product, Gagemakkal, and LabVIEW automation services (Makkal). He can be reached at ajay@makkal.co. Further information about Gagemakkal and Makkal can be found at https://gagemakkal.com and https://makkal.co respectively.

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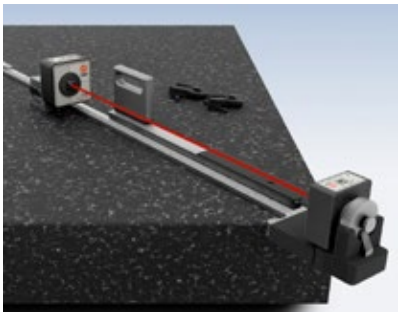

Hamar Laser Surface Plate Calibration System

DANBURY, CONN., December 9, 2025 – Hamar Laser Instruments, Inc., a world leader in laser alignment and calibration systems, announces that the U.S. Air Force Metrology & Calibration Office (AFMETCAL) in Heath, Ohio awarded the company a multi-year contract for its L-703SP Surface Plate Calibration System on August 22.

Under the U.S. Air Force contract, valued at more than $2.6 million, AFMETCAL anticipates acquiring up to 84 Hamar Laser L-703SP Surface Plate Calibration Systems over a four-year period for various Air Force bases and Air National Guard bases throughout the U.S., including Alaska and Hawaii.

"As a veteran-owned manufacturer, we are very proud to be supplying the L-703SP Surface Plate Calibration System to the Air Force's metrology labs throughout the United States," said Rod Hamar, president of Hamar Laser Instruments. "We have worked very hard to make this the best surface plate calibration system available in the marketplace and winning this contract speaks volumes to the success of our efforts."

"Our competition under AFMETCAL's solicitation was electronic levels," continued Hamar. "Electronic levels are the most widely used tool for surface plate calibration, but are slower, not as repeatable as our L-703SP and do not offer features like customized software, straightedges, measuring increments down to .38 in., and the corner locating tools that make our calibration process so easy. The U.S. Air Force staff rigorously evaluated and tested the L-703SP and, as this award demonstrates, they believe our geometry laser system is the superior choice."

Hamar Laser's L-703SP Surface Plate Calibration System is a geometry, laser-based calibration system designed from the ground up to quickly check surface plate calibration. It is highly repeatable, with flexible measuring increments, extremely high resolution and accuracy, easy setup and training, and fast data collection. R&D and field testing have shown that the L-703SP significantly reduces the time for calibrating surface plates with conventional methods like electronic levels, autocollimators and laser interferometers.

For further information or to request a free demonstration, visit www.hamarlaser.com or contact the company at +1-203-730-4600 or sales@hamarlaser.com.

Rohde & Schwarz Power Sensor with 0.80 mm RF Connector

Munich, 10-Dec-2025 – Equipped with a next generation high-performance coaxial 0.80 mm RF connector supporting frequencies up to 150 GHz, the new R&S NRP150T thermal power sensor provides the world's widest non-banded frequency range of any commercially available RF power sensor. It unlocks new applications in high-frequency power measurement, including upcoming automotive radar bands. In addition, the new wideband power sensor also streamlines the validation and calibration of RF instruments.

With the new R&S NRP150T thermal power sensor, Rohde & Schwarz expands the frequency range of its R&S NRPxT series to 150 GHz. The R&S NRP150T is the first RF power sensor to cover all of the automotive radar frequency bands, including a new higher frequency band. Here, the ADAS/AD community is working with standardization authorities to define new frequencies up to 148.5 GHz for advanced radar sensors. Beyond automotive applications, the sensor supports power measurements in diverse fields such as satellite communication, inter-satellite links, and radio astronomy, facilitating exploration of higher frequency ranges.

The R&S NRP150T thermal power sensor achieves up to 500 measurements per second. Combined with its wide frequency range, this allows for single-sweep measurements across the entire spectrum, accelerating the validation and calibration of vector network analyzers and other RF instruments. The sensor is compatible with any application using the next generation 0.80 mm RF connectors for frequencies up to 150 GHz, supporting device development and component manufacturing.

The R&S NRP150T thermal power sensor offers a broad dynamic range of -35 to +20 dBm and provides long-term stability. It compensates for environmental temperature fluctuations within its 0°C to +50°C operating range and exhibits excellent drift performance, remaining resilient to external temperature changes and out-of-band signals. With a maximum voltage standing wave ratio (VSWR) of 1.7, the sensor ensures great matching and efficient power transmission. It is easy to use thanks to USB connectivity, compatible with standard PCs and Android mobile devices using a free remote control app, or through the R&S NRX base unit from Rohde & Schwarz.

Like all power sensors of the R&S NRPxT series, the new R&S NRP150T sensor also offers traceability to national metrology institutes (NMI), which is a prerequisite for commercial and industrial utilization of a frequency band. The Physikalisch-Technische-Bundesanstalt (PTB) and other European NMIs collaborated with Rohde & Schwarz were first to establish NMI traceability for D-Band ranging from 110 to 170 GHz, using R&S technology. This includes the frequencies up to 150 GHz utilized by R&S NRP150T power sensors.

The new R&S NRP150T thermal power sensors are now available from Rohde & Schwarz. For further information visit: R&S®NRPxxT/TN/TWG/TWGN (rohde-schwarz.com).

Mahr Inc. Introduces New Precimar SM Setting Instrument

PROVIDENCE, RI, November 18, 2025 – Mahr Inc., a leading provider of dimensional metrology solutions, today introduced the new Precimar SM setting instrument, designed to simplify and accelerate the adjustment of measuring equipment. By automating the process, the Precimar SM eliminates the complexity of manual calibration with gage block combinations and expensive setting rings, resulting in significant time and cost savings.

Enter the desired reference value, and the Precimar SM automatically positions itself as a setting standard with the relevant dimensions.

With an exceptional accuracy of 0.7 µm + L / 1000, the device sets a new benchmark in the metrology industry, making it an ideal solution for calibrating measuring equipment such as indicating snap gages, universal measuring instruments, and 2-point inside measuring devices. Designed for production environments and available in measuring ranges of 350 mm, 650 mm, and 1150 mm, the Precimar SM is compatible with a variety of accessories for mounting different types of measuring devices. Its intuitive touch display provides straightforward operation, featuring a wide range of functions, including favorite settings for quick adjustments and barcode scanning for effortless dimension selection.

Key Advantages:

- Save time and costs by eliminating the need for setting rings and gage blocks
- User-friendly touch display with intuitive controls
- No loss of accuracy compared to setting rings or gage block combinations
- Flexible applications with an extensive range of accessories

"With the Precimar SM, we are providing a solution that not only streamlines calibration procedures but also ensures the highest levels of accuracy and ease of use in a production environment," said Dr. Farzad Azimi, Precision Gages Product Manager at Mahr Inc. "By automating the process, the Precimar SM significantly reduces calibration time while maintaining exceptional precision standards."

For more information, visit www.mahr.com

Vitrek 4700 Makes Compliance Simpler & Less Costly

Lockport, IL, December 4, 2025 – Vitrek's 4700 Precision High Voltage Meter is gaining recognition as the simplest deployment-ready solution for laboratories looking to achieve ISO/IEC 17025—a compliance requirement needed for a growing number of medical device, aerospace, and energy devices worldwide.

This comes as the global test and measurement market, valued at $38.9 billion in 2024, is experiencing accelerated growth driven by compliance requirements.

With thousands of units already deployed worldwide, the 4700 is not new technology—but its relevance has never been greater. Vitrek's simple, compliance-ready approach has made the 4700 the preferred meter for laboratories that cannot afford measurement uncertainty.

The 4700 can handle the full array of needed ISO/IEC 17025 tests that would otherwise require multiple devices. Also, unlike traditional high voltage meters requiring expensive external calibration, the 4700 includes ISO 17025-accredited certification out-of-the-box, eliminating $800-$1,500 in initial compliance costs and significantly reducing audit prep time.

"Standard equipment voltage ranges have increased in many industries and ISO 17025 compliance has shifted from 'nice to have' to 'business critical' in just 18 months," said Bryan Withers, Vitrek's VP of Engineering. "The 4700 transforms compliance from a $2,000 initial cost into a competitive advantage while delivering the unmatched 0.03% accuracy that precision-critical applications demand."

Vitrek's trusted 4700 Precision High Voltage Meter fits a growing sweet spot as calibration laboratories and compliance-focused manufacturers respond to the need to address supply voltages that typical voltage meters are unable to measure. Traditional approaches to achieving ISO 17025 compliance for high voltage measurement typically require:

- Initial Integration with Companion Devices: 8-16 hrs by specialized engineers
- System uncertainty analysis: Requiring dedicated expertise
- External calibration: $800-$1,500 per device(s)

– Adoption delay: 2-4 weeks – calibration and transit

"Recent adopters have reported a 60-80% reduction in initial compliance prep time," added Withers.

The Vitrek 4700 is widely deployed in labs and manufacturing test environments where high-voltage measurement precision is mission critical. Industry analysts note that ISO 17025 requirements will become universal across all safety-critical sectors within 3-5 years, making early adoption a strategic advantage for forward-thinking organizations.

For more information, visit: vitrek.com.

Working with Difficult Equipment

Michael L. Schwartz
Cal Lab Solutions, Inc.

I'm currently writing some automation for a piece of equipment I would classify as difficult to communicate with! And like you should never end a sentence with a preposition, this particular piece of equipment, every command must end with a LineFeed (i.e., char 10). If you send it two commands but don't end each command with a LineFeed, then it will ignore both commands and beep at you, "BAD COMMAND!" When you look at each command in the Manufacturer's Programmer's Reference, the commands are 100% correct.

Like I said, "Difficult!"

This article is mostly me ranting, because over the years, I have seen just about everything and know what to try next. I have a very large bag of tricks, all from trial and error.

Each trick was hours of head-scratching. Why didn't that work? Walking away, sometimes for days, then the answer appears. Or worse, it just works, and I changed nothing. So I thought I would write a short article on some of the tricks of the trade.

First, check the connection. I once spent hours on the phone with someone whose equipment wasn't connected. And I have done it too. Hours of troubleshooting, then called technical support only to find out the unit has two GPIB connectors.

Next, test the connection with something simple. Most equipment will respond to an *IDN? This is not only good for testing the connection initially, but also handy for periodically checking that the equipment is not locked up. When the equipment is not behaving, send it a quick *IDN? The instrument should return the Manufacturer, Model Number, Serial Number, and Firmware in a comma-separated string. Quick Sidenote: If you get something different back, that could mean the read buffer is full. I have worked with some instruments that will return "Done" after every write command. Before I could get the return value, I needed to clear the Read Buffer.

When working with TCP/IP instruments, it is a good idea to open a command prompt and run "ping <address>" of the instrument before attempting to communicate with the device. The ping will test the route between the PC and the instrument; it will tell you whether the instrument can be reached and how far away the instrument is in milliseconds.

Next is the TCP/IP Port number. TCP/IP supports 65,535 ports. Most people know port 80 for http:// webpages or 443 for https:// webbages. But an instrument can use any port – some instruments can use multiple ports simultaneously.

If the instrument is an LXI/VISA compliant device, it will most likely use port 111 or port 5025. National Instruments' NI Max has a great tool for setting up TCP/IP instruments. While you are working on the configuration, you can test the connection by pressing the "Verify Button." It can save a lot of time.

Another thing to keep in mind when communicating with TCP/IP and some USB devices is that the connection is a session. If the PC and the UUT lose their connection, the session is terminated. The session, and most likely the user interface, is dead. You will need to close the application and reestablish the connection.

Speaking of sessions, RS-232 and RS-485 COM port connections support only a single connection. GPIB-488, TCP/IP, and some USB devices support multiple connections from the PC to the instrument, whereas serial connections are limited to a single connection.

While I'm on the topic of COM Ports, I can't stress this enough: READ THE MANUAL! You have to get the wired connection from the PC's pinout to the UUT's pinout correct! If the UUT wants the connection on pin 2 and the connection is on pin 9, it will not work!

Next is the configuration. Baud Rate, Data Bits, Parity, Stop Bits, and Flow Control all need to be set on the PC and the UUT. One wrong setting and nothing works.

Finally, I will end on USB. USB for Test Equipment will come with three types of communication:

First, USB-488/USBTMC-compliant devices are the easiest to work with; the drivers are standardized and are included with most I/O packages that include VISA Drivers. When these devices are connected, they will show up with the *IDN? response for the instrument.

Second, many manufacturers will use a USB-to-serial device in their equipment. When you connect the USB cable to the PC, it detects a COM port and can install a standard driver. When the device is connected, they will appear as COM# (e.g., COM5).

Finally, some manufacturers have specific communication drivers for their equipment. You will need to install the manufacturer's specific software. Without their specific software, the device will appear as an unknown device.

Happy Troubleshooting, I hope this helps.

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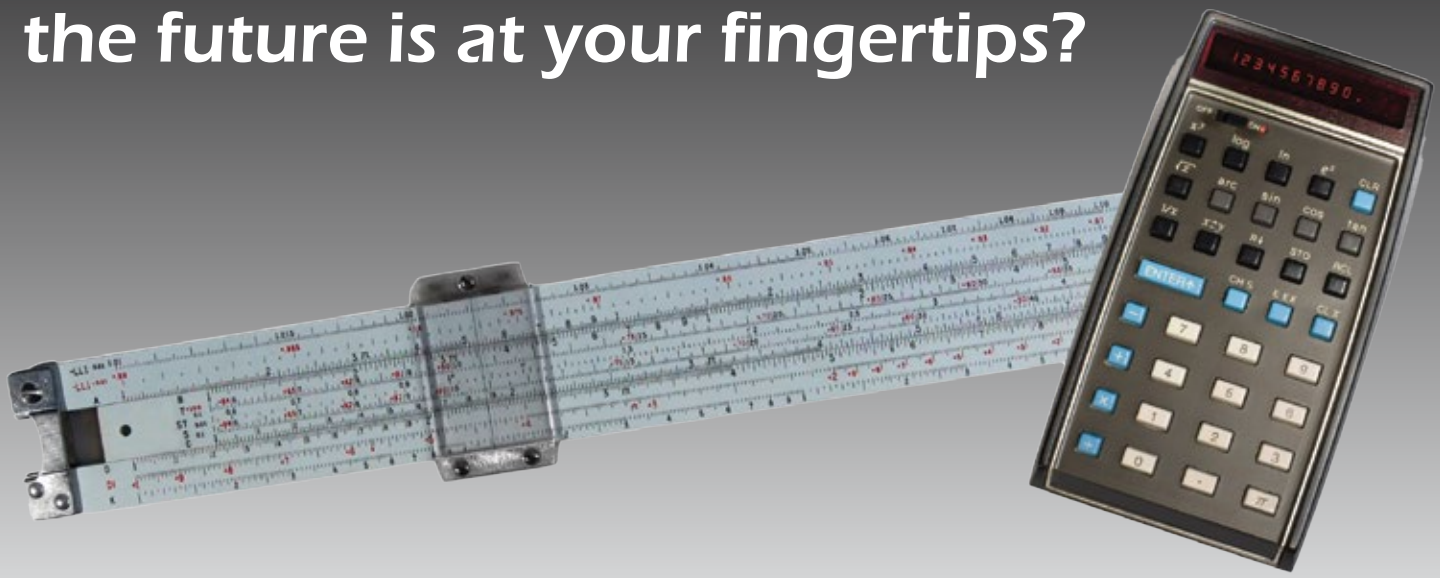

DISRUPTIVE INNOVATION

The **1972 introduction of the HP-35 scientific calculator** by Hewlett-Packard was a **classic example of disruptive innovation** that also triggered a **paradigm shift** in engineering and scientific calculations. The HP-35 effectively rendered the **slide rule**, the dominant tool for engineers and scientists for decades, **obsolete almost overnight**.

Similarly, **Metrology.NET** is positioned to revolutionize the calibration industry by replacing outdated legacy software with a modern, integrated, and automated solution.

Aspect	Slide Rule (Legacy Software)	HP-35 Calculator (Metrology.NET)
Ease of Use	Complex, requires expertise and training	Simple, intuitive, minimal learning curve
Speed & Efficiency	Slow, manual calculations	Fast, automated processing
Accuracy	Prone to human error	Highly precise with minimal error
Portability/Scalability	Bulky, single-user	Compact, multi-user, and scalable
Technological Advancement	Mechanical, limited in functions	Digital, continuously evolving
Market Disruption	Decades of dominance ended overnight	Established software is now outdated
Cost & ROI	Initially cheaper, but labor-intensive	Higher upfront, but massive long-term savings

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