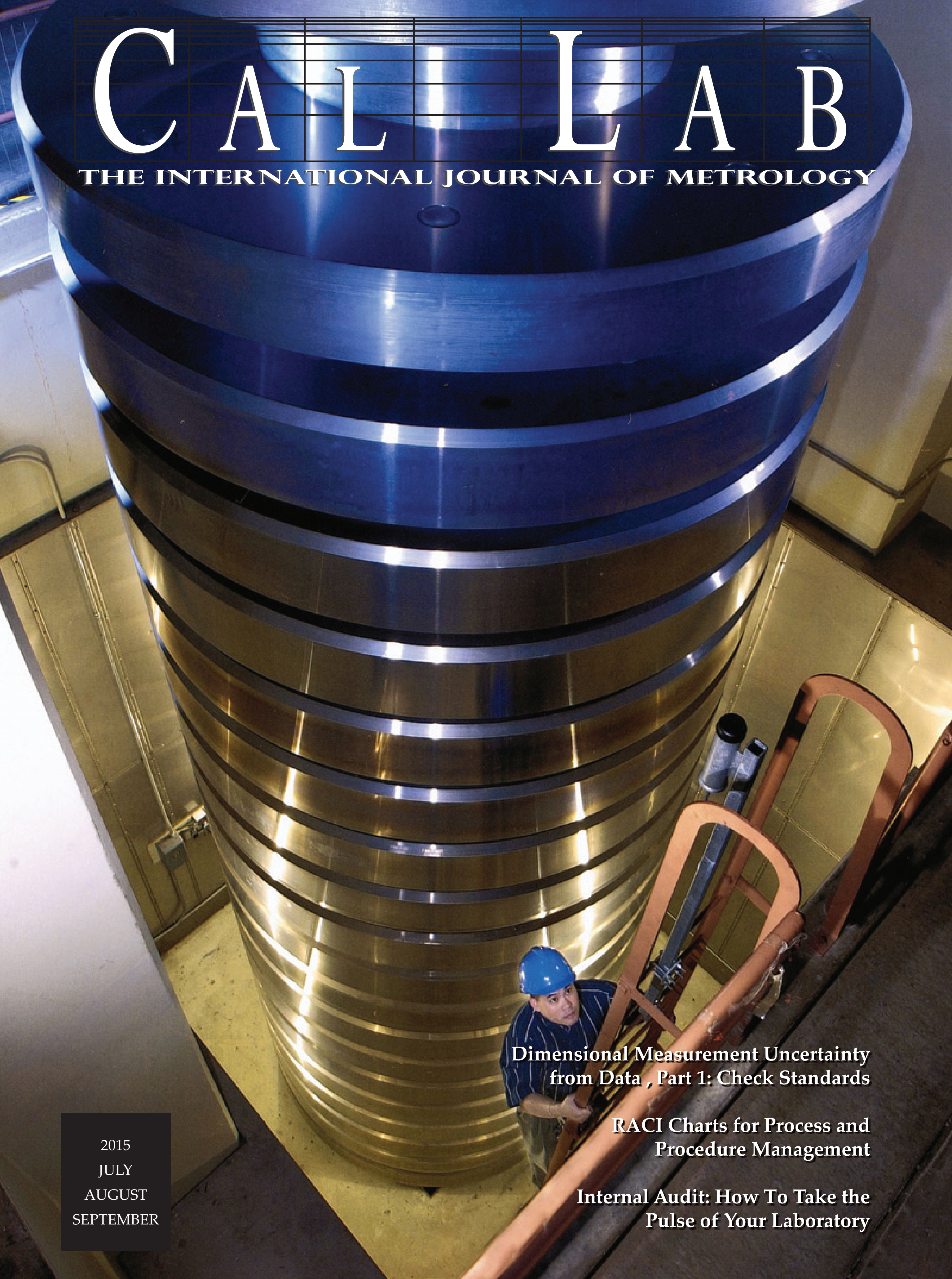
CAL LAB

THE INTERNATIONAL JOURNAL OF METROLOGY



Dimensional Measurement Uncertainty from Data , Part 1: Check Standards

RACI Charts for Process and Procedure Management

Internal Audit: How To Take the Pulse of Your Laboratory

2015
JULY
AUGUST
SEPTEMBER

Electric Current Measurement

DS Series Current Transducers

DANISENSE

±300A to ±8000A, high accuracy for Power Analyzers and improved performance for Power Amplifiers

- Very high absolute amplitude and phase accuracy from dc to over 1kHz
- Low signal output noise
- Low fluxgate switching noise on the pimary
- Enhanced electrostatic shielding to increase rejection of primary dV/dt coupling
- Increased operating temperature range
- Reduced mechanical dimensions
- Options: Voltage Output Signal; Calibration Winding
- Amplitude and Phase measurement to 300kHz included with each head

DS200

DS2000

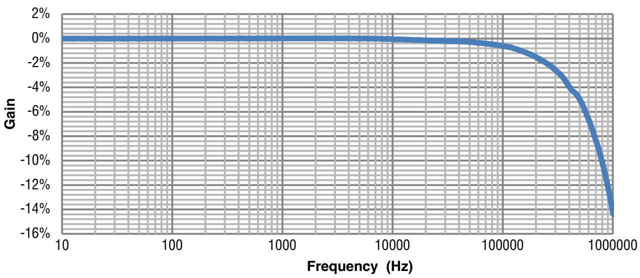
	DS200	DS600	DS2000	DS5000
Primary Current, rms	200A	600A	2000A	5000A
Primary Current, Peak	±300A	±900A	±3000A	±7000A
Turns Ratio	500:1	1500:1	1500:1	2500:1
Output Signal (rms/Peak)	0.4A/±0.6A†	0.4A/±0.6A†	1.33A/±2A†	2A/±3.2A†
Overall Accuracy	0.01%	0.01%	0.01%	
Offset	<20ppm	<10ppm	<10ppm	<5ppm
Linearity	<1ppm	<1ppm	<1ppm	<1ppm
Operating Temperature	-40 to 85˚C	-40 to 85˚C	-40 to 85˚C	0 to 55˚C
Aperature Diameter	27.6mm	27.6mm	68mm	150mm

Bandwidth Bands for Gain and Phase Error	DS200			DS600			DS2000			DS5000	
	<5kHz	<100kHz	<1MHz	<2kHz	<10kHz	<100kHz	<500Hz	<1kHz	<10kHz	<5kHz	<20kHz
Gain (sensitivity) Error	0.01%	0.5%	20%	0.01%	0.5%	3%	0.01%	0.05%	3%	0.01%	1%
Phase Error	0.2˚	4˚	30˚	0.1˚	0.5˚	3˚	0.01˚	0.1˚	1˚	0.01˚	1˚

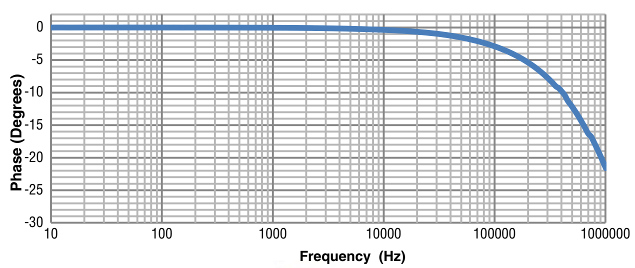
† Voltage Output options available in ±1V and ±10V

Gain / Phase

Gain (DS200, typical)



Phase (DS200, typical)



DSSIU-4 for Multi Channel Systems

4-channel Transducer Interface Unit and Power Supply improved performance for Power Amplifiers

- Power and Signal connections for up to four Current Transducer heads
- Heads may be mixed (e.g.: One DS2000 Head and three DS200 Heads)

DSSIU-4

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VOLUME 22, NUMBER 3

FEATURES

DEPARTMENTS

ON THE COVER: NIST's 4.45-million newton (one million pound) deadweight machine when fully assembled. Photo Credit: NIST.

UPCOMING CONFERENCES & MEETINGS

Sep 24, 2015 Less Risk, More Performance: Best Calibration Practices. Research Triangle Park, NC. The 2015 conference will provide the very latest insights, trends and best practices—direct from leading industry experts—for process plants seeking to improve calibration quality, safety, accuracy, profitability, lower costs and optimize production. http://www.isa.org/calibrationconference2015.

Sep 21-24, 2015 The International Congress of Metrology (CIM). Paris, France. The conference allows everyone to explore the developments in measurement techniques and their application for industry, and to realize the added value of measurement for improvement of industrial processes and risk management. http://www.metrologie2015.com.

Oct 12-14, 2015 Test & Measurement International Conference and Workshop. Cape Town, South Africa. Hosted by the National Laboratory Association (NLA) of South Africa. The Conference will have various streamed presentations, interactive discussion sessions and tutorials. The first two days will have combined plenary sessions which will be of a general nature. On the last day we will be conducting a series of workshops and tutorials and will focus on either special interest groups such as Water Testing, Materials Testing for Civil Engineering, Stack Emission Testing or technical subjects including Uncertainty of Measurement, Method Validation etc. http://www.nla.org.za.

Oct 22-23, 2015 1st International Conference on Metrology for Archaeology. Benevento, Italy. The Conference will involve researchers and operators interested in the valorisation, characterisation and preservation of archaeological heritage with the main objective of focusing the discussion on the production, interpretation and reliability of the measured data. http://www.metroarcheo.com.

Nov 1-6, 2015 30th Annual Meeting of the American Society for Precision Engineering. Austin, TX. As the premier precision engineering conference in the U.S., each Annual Meeting offers the latest in precision engineering research through presentations from national and international speakers. Participants in the Annual Meeting have the opportunity to exchange ideas with internationally renowned experts in the field. http://aspe.net/technical-meetings/.

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EDITOR'S DESK

Irony

If you read last issue's Editor's Desk, you will find the Correction below ironic... just saying. I will be on the lookout for any more metrology and calibration programs getting axed or added! My email box is always open for any corrections or additions you might have: office@callabmag.com.

It's been a cruel summer all over the globe. My little world of spiders run amok and in-laws in the basement is a sanctuary compared to what has been covered in the news recently. The world feels like it is flexing and turning wildly instead of in its usual, imperceptible kind of way. The world of metrology is a bit more quiet and predictable—we always need more measuring.

We also need more quality. And though this is not a quality magazine, we can always use some reinforcing of practical and necessary skills in the lab. This is why this issue includes Ken Parson's article on Internal Audits and Russ Keenan's article on RACI charts. I saw Russ's RACI presentation at the Measurement Science Conference (MSC) last March and found it addressed the very problem another attendee had been complaining about to me: the failure of employees to understand their own job function. Such an understanding is imperative in a technical environment that depends heavily on routine to maintain quality standards.

On the technical side, we have a dimensional article by Ted Doiron of the Dimensional Metrology Group at NIST, discussing the role of check standards and how to use them. His article,"Dimensional Measurement Uncertainty from Data, Part 1: Check Standards," will be followed up later with Part 2, discussing Uncertainty Repeatability and Reproducibility Studies. I certainly look forward to reading it and hope you do too! In the meantime, enjoy the great selection of articles in this issue and, as usual...

Happy Measuring,

Sita Schwartz
Editor

CORRECTION

A reader brought to our attention that one of the schools mentioned in the Apr-Jun 2015 issue Editor's Desk has discontinued their calibration program: Ridgewater College in Hutchinson, MN.

CALENDAR

Nov 2-5, 2015 AUTOTESTCON 2015. National Harbor, MD. IEEE AUTOTESTCON is the world's premier conference that brings together the military/aerospace automatic test industry and government/military acquirers and users to share new technologies, discuss innovative applications, and demonstrate their products and services. It is sponsored annually by the Institute of Electrical and Electronic Engineers (IEEE). http://ieee-autotest.com/

Dec 1-4, 2015 – 86th ARFTG Microwave Measurement Symposium. Atlanta, GA. An important part of all ARFTG conferences is the opportunity to interact with colleagues, experts and vendors in the RF and microwave test and measurement community. This event's theme is "Microwave Measurements with Applications to Bioengineering and Biomedicine."
http://www.arftg.org.

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SEMINARS: Analytical

Oct 5-8, 2015 Analytical Metrology Training. York, PA. J.M. Ingram & Associates. The first workshop of a series on Analytical Metrology, for those with some knowledge of measurement uncertainty, will include Risk Analysis and Guard Banding in addition to Measurement Uncertainty Analysis. Tuition is $1295. Contact J.M. Ingram & Associates at 315-323-8642 or by e-mail at jingram@twcny.rr.com.

SEMINARS: Dimensional

Sep 29-30, 2015 Hands-On Gage Calibration and Repair. Cleveland, OH. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Sep 29-Oct 1, 2015 Dimensional Metrology: Measurement, Inspection and Calibration. Aurora, IL. Mitutoyo Institute of Metrology. This expanded and updated 3-day course presents an overview of dimensional metrology – the practical science of dimensional measurement, inspection and calibration. http://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/.

Oct 1-2, 2015 Hands-On Gage Calibration and Repair. Detroit, MI. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Oct 6-8 , 2015 Hands-On Gage Calibration. Aurora, IL. Mitutoyo Institute of Metrology. The Hands-On Gage Calibration course is active, hands-on and focused on the application of calibration procedures in the laboratory environment. http://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/.

CALENDAR

Oct 13-14, 2015 Hands-On Gage Calibration and Repair. Houston, TX. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Oct 15-16, 2015 Hands-On Gage Calibration and Repair. Dallas, TX. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Oct 20-22, 2015 Dimensional Metrology: Measurement, Inspection and Calibration. Mason, OH. Mitutoyo Institute of Metrology. This expanded and updated 3-day course presents an overview of dimensional metrology – the practical science of dimensional measurement, inspection and calibration. http://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/.

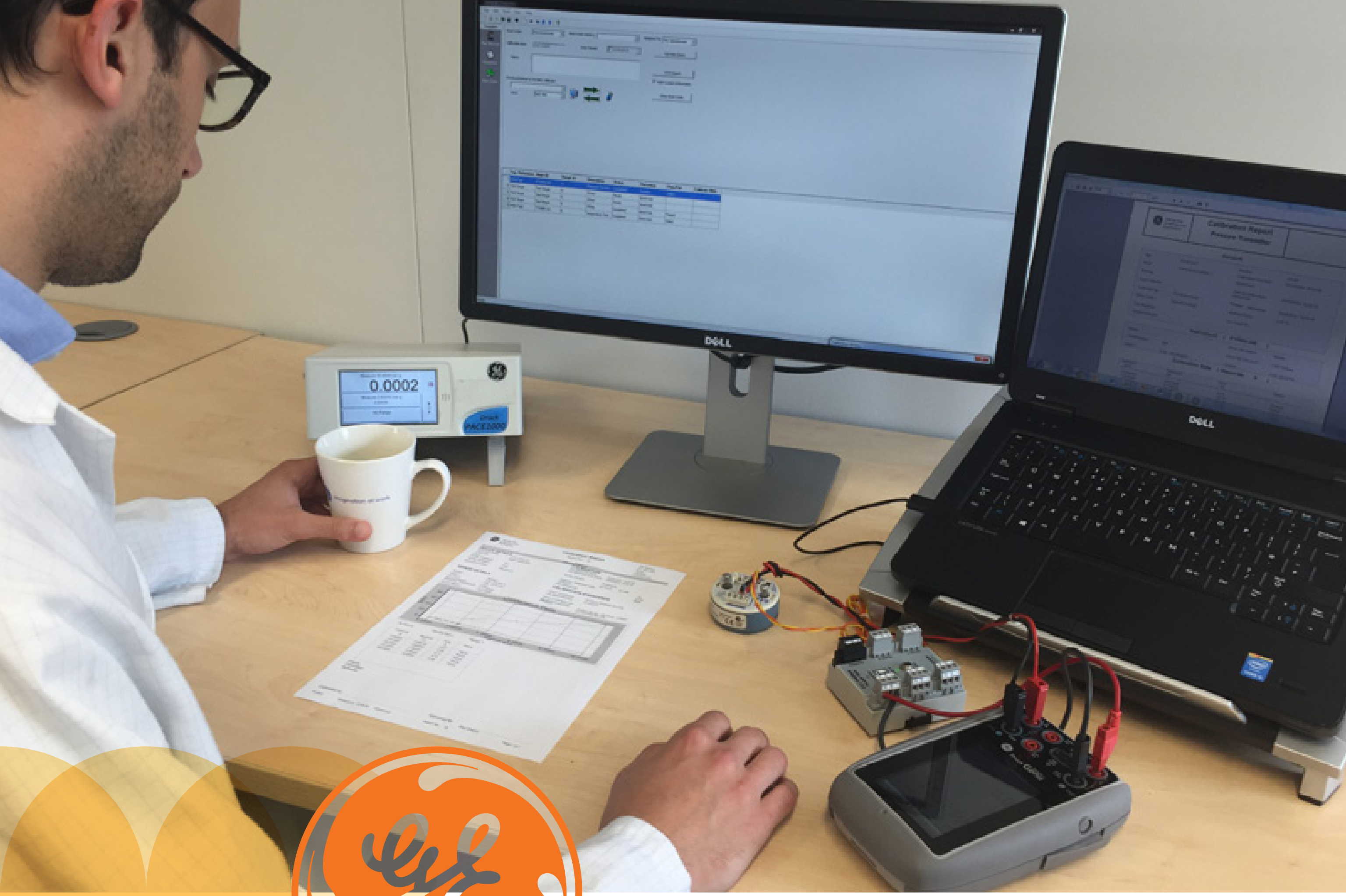
Oct 27-28, 2015 Hands-On Gage Calibration and Repair. Chippewa Falls, WI. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Nov 3-5, 2015 Dimensional Metrology: Measurement, Inspection and Calibration. Marlborough, MA. Mitutoyo Institute of Metrology. This expanded and updated 3-day course presents an overview of dimensional metrology – the practical science of dimensional measurement, inspection and calibration. http://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/.

Nov 5-6, 2015 Hands-On Gage Calibration and Repair. Clearwater Beach, FL. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Nov 10-11, 2015 Hands-On Gage Calibration and Repair. Nashville, TN. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Nov 17-19 , 2015 Hands-On Gage Calibration. Aurora, IL. Mitutoyo Institute of Metrology. The Hands-On Gage Calibration course is active, hands-on and focused on the application of calibration procedures in the laboratory environment. http://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/.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Dec 8-9, 2015 Hands-On Gage Calibration and Repair. Detroit, MI. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Dec 10-11, 2015 Hands-On Gage Calibration and Repair. Schaumburg, IL. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Dec 14-15, 2015 Hands-On Gage Calibration and Repair. Bloomington, MN. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

SEMINARS: Electrical

Nov 9-12, 2015 MET-101 Basic Hands-on Metrology. Everett, WA. Fluke Calibration. This course introduces the student to basic measurement concepts, basic electronics related to measurement instruments and math used in calibration.http://us.flukecal.com/training/courses/MET-101.

Nov 16-19, 2015 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. http://us.flukecal.com/training/courses/MET-301.

SEMINARS: Flow & Pressure

Sep 23-25, 2015 TrigasFI Flow Seminar (English). Neufahrn, Germany. The material presented is based on more than 30 years experience in operation of gas and liquid flow calibration facilities and related research. http://www.trigasfi.de/.

Sep 28-30, 2015 TrigasFI Flow Seminar (Deutscher Sprache). Neufahrn, Germany. http://www.trigasfi.de/.

Oct 5-9, 2015 Principles of Pressure Calibration. Phoenix, AZ. Fluke Calibration. A five day training course on the principles and practices of pressure calibration using digital pressure calibrators and piston gauges (pressure balances). http://us.flukecal.com/Principles-of-Pressure.

Oct 19-23, 2015. Advanced Piston Gauge Metrology. Phoenix, AZ. Fluke Calibration. Focus is on the theory, use and calibration of piston gauges and dead weight testers. http://us.flukecal.com/training.

SEMINARS: Force & Torque

Sep 15-16, 2015 Applied Fundamentals of Force Calibration. York, PA. A2LA. Instructors Henry Zumbrun (Morehouse) and Dilip Shah (E=mc3). This 2-day course will cover applied force calibration techniques and will include live demonstrations using secondary standards to exhibit potential errors made in everyday force measurements. The course will cover the basics of measurement uncertainty and provide the tools for anyone to put together a CMC or uncertainty budget. To register, contact jcollins@a2la.org or visit: http://www.a2la.org/training/index.cfm.

SEMINARS: General & Management

Sep 29-30, 2015 Internal Auditing. Columbus, OH. A2LA. This 2-day training course practices the internationally-recognized approaches of ISO 19011:2011 to conducting effective internal audits. http://www.a2la.org/training/intaudit.cfm?private=no.

Oct 26-27, 2015 Internal Auditing. Frederick, MD. A2LA. This 2-day training course practices the internationally-recognized approaches of ISO 19011:2011 to conducting effective internal audits. http://www.a2la.org/training/intaudit.cfm?private=no.

Nov 2-5, 2015 Effective Cal Lab Management. Everett, WA. Ideal for anyone in a lead or supervisory position in a cal lab looking for ways to better communicate and manage personnel, and to bring about efficiency and customer satisfaction improvement. http://us.flukecal.com/training.

Nov 3-5, 2015 Cal Lab Manager Training; Beyond 17025. Boca Raton FL - WPT/QSL Training Academy. WorkPlace Training. This course is designed for new lab managers, and for experienced managers who would like to learn how modern labs meet the challenge of satisfying greater customer demand with ever-diminishing lab resources. http:// www.wptraining.com .

Nov 20, 2015 Root Cause Analysis and Corrective Action (RCA/CA). Savannah, GA. A2LA. Presentations, discussions and exercises that provide an in-depth understanding of how to analyze a system in order to identify the root causes of problems and to prevent them from recurring. http://www.a2la.org/training/rootcause.cfm?private=no.

Dec 7-11, 2015 Fundamentals of Metrology. Gaithersburg, MD. NIST. The Fundamentals of Metrology seminar will introduce the participant to the concepts of measurement systems, units, measurement uncertainty, measurement assurance, traceability, basic statistics and how they fit into the laboratory Quality Management System. http://www.nist.gov/pml/wmd/5392.cfm.

Dec 8-10, 2015 Cal Lab Manager Training; Beyond 17025. Los Angeles CA - Transcat (Fullerton). WorkPlace Training. This course is designed for new lab managers, and for experienced managers who would like to learn how modern labs meet the challenge of satisfying greater customer demand with ever-diminishing lab resources. http:// www.wptraining.com .

SEMINARS: Industry Standards

Sep 23-25, 2015 ISO/IEC 17025:2005 and Laboratory Accreditation. Dallas, TX. A2LA. This course is an introductory look at ISO/IEC 17025 and its requirements for demonstrating the technical competence of testing and calibration laboratories. http://www.a2la.org/training/iso17025.cfm?private=no.

Sep 28, 2015 ISO/IEC 17025:2005 Advanced: Beyond the Basics. Columbus, OH. A2LA. The course will provide a brief overview of the requirements of this laboratory standard, as well as provide an understanding of how to apply specific sections of the Standard in your laboratory. http://www.a2la.org/training/ISO17025forAccredCABs.cfm?private=no.

Oct 5-7, 2015 ISO/IEC 17025:2005 and Laboratory Accreditation. Frederick, MD. A2LA. This course is an introductory look at ISO/IEC 17025 and its requirements for demonstrating the technical competence of testing and calibration laboratories. http://www.a2la.org/training/iso17025.cfm?private=no.

Oct 12-16, 2015 ISO/IEC 17025 Lead Assessor Training. Covington, KY. ANAB. This 4.5 day course will enable attendees to develop a solid understanding of the ISO/IEC 17025 standard and be able to plan and lead an ISO/IEC 17025 assessment. http://anab.org/training/.

Oct 19-23, 2015 Assessment of Laboratory Competence. Albuquerque, NM. A2LA. This course is a comprehensive look at the ISO/IEC 17025:2005 requirements and a detailed approach to the assessment of a laboratory's competence. http://www.a2la.org/training/aolc.cfm?private=no.

Nov 2-6, 2015 Assessment of Laboratory Competence. Frederick, MD. A2LA. This course is a comprehensive look at the ISO/IEC 17025:2005 requirements and a detailed approach to the assessment of a laboratory's competence. http://www.a2la.org/training/aolc.cfm?private=no.

Nov 18-19, 2015 ISO/IEC 17025:2005 and Laboratory Accreditation. Savannah, GA. A2LA. This course is an introductory look at ISO/IEC 17025 and its requirements for demonstrating the technical competence of testing and calibration laboratories. http://www.a2la.org/training/iso17025.cfm?private=no.

Dec 2-3, 2015 ISO/IEC 17025:2005 and Laboratory Accreditation. Frederick, MD. A2LA. This course is an introductory look at ISO/IEC 17025 and its requirements for demonstrating the technical competence of testing and calibration laboratories. http://www.a2la.org/training/iso17025.cfm?private=no.

Dec 7-11, 2015 ISO/IEC 17025 Lead Assessor Training. St. Petersburg, FL. ANAB. This 4.5 day course will enable attendees to develop a solid understanding of the ISO/IEC 17025 standard and be able to plan and lead an ISO/IEC 17025 assessment. http://anab.org/training/.

SEMINARS: Mass & Weight

Oct 26-Nov 6, 2015 Mass Metrology Seminar. Gaithersburg, MD. NIST Office of Weights and Measures. The Mass Metrology Seminar is a two-week, "hands-on" seminar. It incorporates approximately 30 percent lectures and 70 percent demonstrations and laboratory work in which the trainee performs measurements by applying procedures and equations discussed in the classroom. Successful completion of the Fundamentals of Metrology Seminar is a prerequisite for the Mass Metrology Seminar. http://www.nist.gov/pml/wmd/5340.cfm.

SEMINARS: Measurement Uncertainty

Sep 16-18, 2015 Practical Measurement Uncertainty - Testing. Atlanta, GA. ANAB. Attendees of this 2.5- day course will learn a practical approach to measurement uncertainty applications and understand the steps required, accepted practices, and the two practical types of uncertainties needed by competent accredited laboratories. Examples are relevant to testing laboratories. http://anab.org/training/.

CALENDAR

Sep 21-22, 2015 Introduction to Measurement Uncertainty. Dallas, TX. American Association for Laboratory Accreditation, http://www.a2la.org/training/course_schedule.cfm.

Sep 21-23, 2015 Measurement Uncertainty. Loveland, CO. Colorado Engineering Experiment Station, Inc. http://www.ceesi.com/training.

Oct 7-8, 2015 Measurement Uncertainty (per ILAC P14 Guidelines). Portland, OR. WorkPlace Training. This workshop introduces basic measurement uncertainty and traceability concepts. The concepts taught are then put in practice by developing sample measurement uncertainty budgets. http://www.wptraining.com.

Oct 8-9, 2015 Measurement Uncertainty Advanced Topics. Frederick, MD. A2LA. The use of industry-proven tools covered in this workshop helps establish a laboratory's reputation in providing the correct solutions to its customers and maintaining its accreditation. http://www.a2la.org/training/muadvanced.cfm?private=no.

Oct 20-21, 2015 Measurement Uncertainty (per ILAC P14 Guidelines). Boca Raton, FL – WPT/QSL Training Academy. WorkPlace Training. This workshop introduces basic measurement uncertainty and traceability concepts. The concepts taught are then put in practice by developing sample measurement uncertainty budgets. http://www.wptraining.com.

Oct 20-22, 2015 Introduction to Measurement Uncertainty. Everett, WA. Fluke Calibration. MET-302 Hands-On Metrology Statistics is a three-day course that will teach you how to develop uncertainty budgets and to understand the necessary calibration processes and techniques to obtain repeatable results. http://us.flukecal.com/training.

Nov 2-3, 2015 Measurement Uncertainty (per ILAC P14 Guidelines). Puerto Rico. WorkPlace Training. This workshop introduces basic measurement uncertainty and traceability concepts. The concepts taught are then put in practice by developing sample measurement uncertainty budgets. http://www.wptraining.com.

Nov 16-17, 2015 Introduction to Measurement Uncertainty. Savannah, GA. American Association for Laboratory Accreditation, http://www.a2la.org/training/course_schedule.cfm.

SEMINARS: RF & Microwave

Oct 27-29, 2015 VNA Metrology and Uncertainty Workshop. Bern-Wabern, Switzerland. Federal Institute of Metrology METAS. The course covers installation of the software, interaction with the VNA and data taking, VNA calibration and error correction, data visualization and export, evaluation of uncertainty contributions and uncertainty budget. http:// www.metas.ch/vnatools.

SEMINARS: Software

Sep 28-Oct 2, 2015 Basic MET/CAL® Procedure Writing. Everett, WA. Fluke Calibration. In this five-day basic MET/CAL procedure writing course, you will learn to configure MET/CAL software to create, edit, and maintain calibration solutions, projects and procedures. http://us.flukecal.com/software-training.

Dec 14-18, 2015 Basic MET/CAL® Procedure Writing. Everett, WA. Fluke Calibration. In this five-day basic MET/CAL procedure writing course, you will learn to configure MET/CAL software to create, edit, and maintain calibration solutions, projects and procedures. http://us.flukecal.com/software-training.

SEMINARS: Temperature

Sep 15-17, 2015 Advanced Topics in Temperature Metrology. American Fork, UT. Fluke Calibration. A three-day course for those who really need to get into the details covering: ITS-90 calibration, process design, curve fitting, uncertainty analysis, and advanced procedures for reducing uncertainties. http://us.flukecal.com/training/courses/Principles-Temperature-Metrology.

Oct 13-15, 2015 Principles of Temperature Metrology. American Fork, UT. Fluke Calibration. A three-day introduction to temperature metrology covering: ITS-90 principles, traceability, thermometry, calibration systems, measurement techniques, uncertainty budgets, quality assurance and more. http://us.flukecal.com/training/courses/Principles-Temperature-Metrology.

SEMINARS: Vibration

Oct 6-8, 2015 Random Vibration and Shock Testing. Santa Barbara, CA. A review of basic vibrations, sources and causes, followed by an exploration of vibration measurements, analysis and calibration. http://www.equipment-reliability.com.

Visit **www.callabmag.com** for upcoming and future events!

New Picoamperemeter: Handy, Simple, Extremely Accurate

Measuring currents in the range of 100 pA accurately is increasingly gaining in importance – not only for the calibration of picoamperemeters for applications in medical engineering or in the semiconductor industry, but also for fundamental research in the field of current generation based on single electrons. The accuracy of conventional commercially available measuring instruments is limited to relative uncertainties of approx. 10 parts in a million (i.e. 10–5). Better accuracy could previously only be achieved by using extremely complex metrological procedures and apparatuses.

A new development, which is currently being expedited at Physikalisch-Technische Bundesanstalt (PTB), opens up new measurement capabilities with unprecedented accuracy. The ULCA is based on a new picoamperemeter concept with a two-stage set-up whose patent is pending. The first stage amplifies the input current by a factor of 1000 while the second stage converts current to voltage. Besides being relatively easy to use, this handy device is characterized by excellent amplifier properties. The second ULCA prototype generation already showed a very low input current noise of 2.4 fA/√Hz with a white spectrum down to very low frequencies of about 1 mHz. The optimized circuit design allows the realization of an amplification factor with maximum stability and linearity (the effective transimpedance is 1 GΩ). In addition, the amplification factor can be calibrated with a relative uncertainty of better than 10–7 at averaging times below one hour, hereby ensuring traceability to the quantum resistance standard (quantum Hall effect) by means of a cryogenic current comparator (as used for electric resistance metrology at PTB).

The combination of these excellent properties thus allows the absolute measurement of a 100 pA current within a measuring time of only 10 hours with a relative uncertainty of one part in ten million. The ULCA hereby exceeds the accuracy of previously available picoamperemeters by about two orders of magnitude.

Contact: Dietmar Drung, Physikalisch-Technische Bundesanstalt, Department 7.2 Cryophysics and Spectrometry. Phone: +49 (0)30 3481-7342 | E-mail: dietmar.drung@ptb.de

Scientific publications:

D. Drung, C. Krause, U. Becker, H. Scherer, F. J. Ahlers: "Ultrastable lownoise current amplifier: a novel device for measuring small electric currents with high accuracy." *Rev. Sci. Instrum.* 86, 024703 (2015).

D. Drung, M. Götz, E. Pesel, and H. Scherer, "Improving the traceable measurement and generation of small direct currents," *IEEE Trans. Instrum. Meas.* 64 (2015).

Source: PTB News, *Issue 1 (2015) April 8, 2015, http://www.ptb.de/cms/en/presseaktuelles/journals-magazines/ptb-news.html.*

Two-channel ULCA prototype (front view with SMA connectors). Credit: PTB.

Metrology Center and Coordinate Metrology Society Win NIST Grant

The Coordinate Metrology Society and UNC Charlotte announced they have won an Advanced Manufacturing Technology Consortia (AMTech) Grant from the National Institute of Standards and Technology (NIST), an agency of the U.S. Commerce Department.

The AMTech Grant is one of 16 awards totaling $7.8 million, which are dedicated to accelerating growth of advanced manufacturing in the United States. These industry-driven coalitions will focus on developing and executing strategic plans to solve common technology challenges. The CMS-UNC Charlotte team will form a consortium for Large-Scale, Precision Manufacturing Innovation (CLPMI). This group will identify and prioritize the technology needs of the aerospace, defense, energy, and other industries that manufacture large-scale, high accuracy parts and products.

"The Coordinate Metrology Society is a natural partner in the field of large-scale metrology," says Dr. Ed Morse, a professor in the department of mechanical engineering and engineering science at UNC Charlotte, and deputy director of UNC Charlotte's Center for Precision Metrology. "Using the society's large membership base, we can gather input from the full array of stakeholders in large-scale manufacturing and metrology processes and use our expertise in technology selection and management to guide the development of the initial roadmap for advancement in this area."

The area that Morse is talking about—large-scale, close-tolerance measurement achieved through the use of portable 3D equipment—requires the special focus and attention of industry experts due to the nature of the work and the challenges that metrologists encounter.

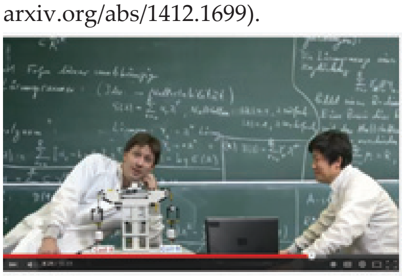
"The CMS-UNC Charlotte alliance is a natural progression of our charter to foster the advancement of three-dimensional measurement throughout industry. The Coordinate Metrology Society is the one association that connects all of the industry players ¾ end users, OEMs, software developers and service providers ¾ involved in large-scale manufacturing endeavors," states Ron Hicks, CMS Past Chair and AMTech Committee Chair. Established in 2013, the NIST AMTech Program reinforces strategic partnerships between U.S. industry, academia and government. The program strives to form new industry-led consortia and strengthen existing ones with the aim of tackling shared technical barriers to the growth of advanced manufacturing. NIST promotes U.S. innovation and industrial competitiveness by advancing measurement science, standards and technology to enhance economic security and improve quality of life. To learn more about NIST, visit www.nist.gov.

Source: UNC Charlotte, William States Lee College of Engineering News *(http://engr.uncc.edu/news/metrology-center-and-coordinate-metrology-society-win-nist-grant).*

NIST LEGO® Watt Balance

A LEGO® model of the watt balance was created by the National Institute of Standards and Technology (NIST) PML group in Gaithersburg, Maryland, as an educational outreach tool for their Electronic Kilogram project (http://www.nist.gov/pml/div684/grp05/kilogram.cfm).

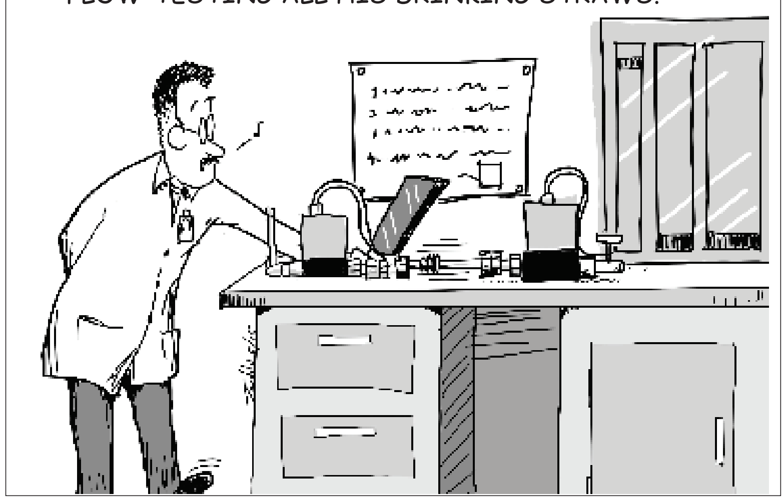
As part of this outreach, the video "How to Build Your NIST D.I.Y. Watt Balance," was posted on www.youtube.com. Besides the presentation of basic concepts behind the redefinition of the kilogram, this video also serves as an intro to the complete project posted on Cornell University's website (http://arxiv.org/abs/1412.1699).



Screenshot of YouTube video, "How to Build Your NIST D.I.Y. Watt Balance."

CAL-TOONS **by Ted Green** teddytoons@verizon.net

JERROD OBTAINS THE PERFECT PINA-COLADA BY FLOW-TESTING ALL HIS DRINKING STRAWS.



Progress Report with Photos: Restoration of NIST's Million-Pound Deadweight Machine

Restoration is well underway for NIST's 4.45-million newton (equivalent to one million pounds-force) deadweight machine, the largest in the world. The three-story-tall deadweight, comprising a stack of stainless steel discs weighing about 50,000 pounds each, was disassembled last winter for the first time in fifty years.*

The surfaces of a half dozen components of the deadweight recently underwent minor machining at NIST and by a company offsite, to permit more free operation at those interfaces. Pieces that were sent offsite returned to NIST in June fully restored.

The final task remaining before reassembly is recalibration of the approximately 50,000-pound discs.

Force measurements require an accurate assessment of mass. Since the international standard for mass is the kilogram (kg), PML staff members begin their calibrations with standard masses of this size (1 kg is slightly more than 2 pounds). They then work their way from 1 kg weights to standard weights that are tens of thousands of pounds, making a continuous chain of mass comparisons using progressively larger standards.

This recalibration process began in late spring and will take several weeks to complete.

Built in 1965, NIST's million pounds-force deadweight system consists of a calibrated lifting frame and a stack of 19 stainless steel discs about three meters in diameter (a little less than ten feet) when assembled. Their average mass is about 22,696 kg (just over 50,000 pounds) each.

Customers who rely on this unique machine include US aerospace manufacturers, US military laboratories, and several top-end commercial force calibration labs, which have performed hundreds or thousands of calibrations, all directly traceable to NIST.

The NIST million-pound deadweight system is expected to be back online this year.

See below source URL for additional photos depicting the recent machining of several components of the weights and their return to NIST.

*See "Restoration Begins on NIST's Million-Pound Deadweight Machine." January 27, 2015.

--Jennifer Lauren Lee

Source: http://www.nist.gov/pml/div684/grp07/million-pound-deadweight-restoration-continues-06262015.cfm.

A restored component of the million-pound deadweight machine being returned to NIST in June. Credit: NIST

NIST 'How-To' Website Documents Procedures for Nano-EHS Research and Testing

As engineered nanomaterials increasingly find their way into commercial products, researchers who study the potential environmental or health impacts of those materials face a growing challenge to accurately measure and characterize them. These challenges affect measurements of basic chemical and physical properties as well as toxicology assessments.

To help nano-EHS (Environment, Health and Safety) researchers navigate the often complex measurement issues, the National Institute of Standards and Technology (NIST) has launched a new website devoted to NIST-developed (or co-developed) and validated laboratory protocols for nano-EHS studies.

In common lab parlance, a "protocol" is a specific step-by-step procedure used to carry out a measurement or related activity, including all the chemicals and equipment required. Any peer-reviewed journal article reporting an experimental result has a "methods" section where the authors document their measurement protocol, but those descriptions are necessarily brief and condensed, and may lack validation of any sort. By comparison, on NIST's new Protocols for Nano-EHS website, the protocols are extraordinarily detailed. For ease of citation, they're published individually—each with its own unique digital object identifier (DOI).

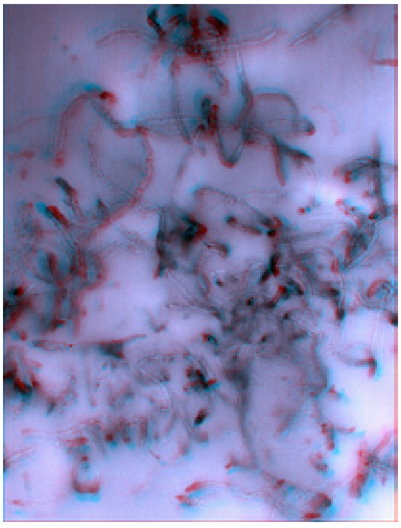
The protocols detail not only what you should do, but why and what could go wrong. The specificity is important, according to program director Debra Kaiser, because of the inherent difficulty of making reliable measurements of such small materials. "Often, if you do something seemingly trivial—use a different size pipette, for example—you get a different result. Our goal is to help people get data they can reproduce, data they can trust."

A typical caution, for example, notes that if you're using an instrument that measures the size of nanoparticles in a solution by how they scatter light, it's important also to measure the transmission spectrum of the particles if they're colored, because if they happen to absorb light strongly at the same frequency as your instrument, the result may be biased.

"These measurements are difficult because of the small size involved," explains Kaiser. "Very few new instruments have been developed for this. People are adapting existing instruments and methods for the job, but often those instruments are being operated close to their limits and the methods were developed for chemicals or bulk materials and not for nanomaterials."

"For example, NIST offers a reference material for measuring the size of gold nanoparticles in solution, and we report six different sizes depending on the instrument you use. We do it that way because different instruments sense different aspects of a nanoparticle's dimensions. An electron microscope is telling you something different than a dynamic light scattering instrument, and the researcher needs to understand that."

The nano-EHS protocols offered by the NIST site, Kaiser says, could form the basis for consensus-based, formal test methods such as those published by ASTM and ISO.



Rigorous measurement protocols are key to unraveling the complex physical structure of carbon nanotubes [CNTs] embedded in a polymer composite, shown here in a three-dimensional scanning electron microscope image. The sizes, shapes and distribution of CNTs in the polymer can be measured from this image. (A larger anaglyph 3D version can be viewed online with the usual red-cyan 3-D glasses—visit the following Source URL.)

NIST's nano-EHS protocol site currently lists 12 different protocols in three categories: sample preparation, physico-chemical measurements and toxicological measurements. More protocols will be added as they are validated and documented. Suggestions for additional protocols are welcome at nanoprotocols@nist.gov.

Source: NIST Tech Beat *for June 30, 2015 (http://www.nist.gov/public_affairs/tech-beat/tb20150630.cfm#protocols).*

Dimensional Measurement Uncertainty from Data, Part 1: Check Standards

Ted Doiron
Dimensional Metrology Group,
National Institute of Standards and Technology

Uncertainty has proven difficult to implement in calibration labs. The subject has advanced mathematics and statistics that are often needed for scientific research, but are seldom needed to develop uncertainty budgets for routine calibrations. There is, however, a second path to uncertainty that does not require such mathematical skills, only patience. This method, using check standards to sample the sources of variability is actually part of the GUM, albeit a small part.

Introduction

In the Guide to the Expression of Uncertainty in Measurement (GUM) [1] there is a small and passing reference to a method for determining uncertainty that does not involve modeling, statistical analysis, and most of the other tools that are part of the GUM:

> 3.4 Practical considerations
>
> 3.4.1 If all of the quantities on which the result of a measurement depends are varied, its uncertainty can be evaluated by statistical means. However, because this is rarely possible in practice due to limited time and resources, the uncertainty of a measurement result is usually evaluated using a mathematical model of the measurement and the law of propagation of uncertainty. [1]

In dimensional metrology, for routine calibrations I don't believe the second statement point of "rarely possible in practice" is true. The NIST Dimensional Metrology Group has used check standards as the basis for our uncertainty estimates for more than 30 years and the practice is conceptually very simple. While we do have check standards in every calibration so that we perform statistical process control, the use of many fewer measurements is quite adequate as a basis of uncertainty. This idea of check standards for uncertainty is not new and it has been gaining support in the standards community under the term "intermediate reproducibility," as in ASTM 2655-08, "Standard Guide for Reporting Uncertainty of Test Results and Use of the Term Measurement Uncertainty in ASTM Test Methods":

> 7. Uncertainty Estimation by the Control Sample Approach
>
> 7.1 A measure of intermediate precision within the laboratory can be used as the basis for routine reporting of uncertainty for measurements when a control sample is run together with routine samples. [2]

In dimensional metrology, the control sample would be a few gage blocks, wires, or spheres that are calibrated on a regular basis.

The question is which check standards to choose and how many measurements are needed over time for the check standard variation to approach the long term reproducibility that can be used for uncertainty. The first question requires a list of influence factors that can be used as criteria for check standard selection. The basic uncertainty budget used for NIST dimensional calibrations is the Generic Uncertainty Budget for Dimensional Calibrations [3].

1. Master Gage Uncertainty
2. Repeatability/Reproducibility
3. Thermal Factors
   a. Thermometer calibration
   b. Temperature variation between master and customer gage
   c. Uncertainty in customer gage coefficient of thermal expansion (CTE)
4. Measuring Machine Scale Uncertainty
5. Elastic Deformation
6. Instrument Geometry
7. Customer Gage Geometry

Uncertainty Sources and Check Standards

1. Master Gage Uncertainty

Master Gage Variation is difficult to sample with check standards because the master gages have long recalibration intervals. If their calibration is yearly it will take 10 years to fully realize the uncertainty from master gage calibration. In practice the best policy is to take the uncertainty from the calibration lab that calibrated the gages as the uncertainty. Check standards seldom are adequate.

2. Repeatability

Repeatability is obviously sampled each time a check standard is measured so we don't need a separate line in our budget.

3. Thermal Influences

For most laboratories, the temperature varies by about 1 ^{0}C during any one time period. With check standard measurements made across the yearly weather cycle and the daily variation from the controller, the variation in temperature is part of the check standard data. There is one caveat to this in that when calibrating gages by comparison, if the master gage and check standard gages are all the same material then the check standard history does not sample the actual variation in temperature for materials that are not alike. Measurement of steel gage blocks against steel gage blocks only show variations in the temperature difference between the blocks, uncertainty component 3b. If the lab does measure other materials, some check standards should be steel and others typical of their customer requirements.

At NIST our master/check standard gages are steel and chrome carbide, which covers 90% or more of our customer gages. We add a separate uncertainty to other materials based on separate experiments on the variation of gages on the measuring machine. If all of your master gages are steel you should have at least a few check standards of different, yet common materials such as tungsten carbide and ceramic. With these additions, the check standard can sample all of the thermal influence factors.

4. Comparator Scale

For the check standard data to include the variation in comparator scale, it must be checked and adjusted on a regular basis. If the scale is never adjusted, you will have no information on the scale accuracy. Most labs do check their scales on a regular basis, and if the master gages used to check the scale are changed, the check standards will sample the variations in scale.

As an example, many labs use two gage blocks that vary by 1 or 2 micrometers (50 μin to 100 μin). Setting the scale using their 2 mm and 2.002 mm one week and then the 2.001 mm and 2.003 mm the next, followed by different pairs in the 2 mm – 2.010 mm series, will sample the scale variation as well as the consistency of the gage block calibrations.

5. Elastic Deformation

Whenever there is a point contact between the gage and instrument contact there is deformation, often considerably larger than the uncertainty from other sources. In some cases the deformation is easy to calculate, for example spheres between plane contacts or crossed cylinders in thread wire calibrations. It is easy to calculate because you know the actual contact geometry and elastic properties of the materials. For gage blocks there are numerous problems because the actual geometry is not known. Contacts start off spherical, but after calibration of a few sets of blocks the diamond wears and the deformation will change. There is no really good method to make this correction and the best that you can do is to have blocks of different materials and monitor their apparent lengths, which will show the change. The use of diamond is also a problem. While diamond is very hard the elastic modulus varies by about 30% depending on which way the crystal axis is aligned. Thus, even if you know the geometry you will not be able to calculate the correction to better than 30%. For high accuracy calibrations this is huge and can't be tolerated. Thus it is imperative that check standards of different materials be used.

The second effect is the contact force can change. If the force is checked on a regular basis and adjusted, the check standards variation in length will include this source of variation.

6. Instrument Geometry

The simplest case to image is the plane parallel contacts of a universal measuring machine (ULM). These instruments usually have 5 mm to 10 mm circular contacts. If the check standard is measured in exactly the same place each time, the results will not have sampled the flatness or parallelism of the contacts. Generally, however, the operator positions the gage by hand and each measurement is in a slightly different place. Even in the case of one operator, where you might expect better consistency, over a few years it is very probable that there is enough variation to be useful as a sample. Large variation might suggest the geometry be looked at carefully and improved, but if it is improved the check standards will reflect this change and the measured variation will be measured.

7. **Customer Gage Geometry**

If the customer sends a sphere that is out of round by 10 μm, the measurement uncertainty from the other sources is probably negligible. You cannot make good measurements on poor gages. On the other hand, if the check standards have perfect geometry, the data will only describe the uncertainty when the customer gage is perfect. Thus, some of your check standards should have geometry typical of the customer gages you calibrate. With some very good geometry check standards you will have information on how well you could do, and with typical geometry check standards, you will have information on how well you typically do.

Summary of Check Standard Selection Criteria

1. Use check standards that span your typical range (on say your scope of accreditation).
2. Check standards of different materials is important if you typically measure gages of different materials. This is important for both thermal influences and elastic deformation.
3. Check standards should have geometry typical of your calibration load, plus one or two of excellent geometry.
4. Treat your check standards the same way you treat customer blocks. Thermal preparation, in particular, should be identical.
5. Check standards should be calibrated on random days and random times of day. Don't measure check standards every Monday morning or Friday afternoon. You know that won't show your best effort.

Example – Gage Blocks

For gage blocks, there are a very large number of sizes, perhaps 500 counting metric and inch sets, so how many check standards do we need? The primary difference between measuring a 2 mm gage block and 500 mm gage block is the effects of temperature. Gages that are close to the same size will all have similar variability. The main sequence of check standards would be

Base: 2 mm, 20 mm, 50mm, 100 mm, 250 mm and 500 mm.

Ceramic gage blocks have roughly ½ the thermal diffusivity of steel which means they are slow to change temperature and thus "remember." Short blocks will not show this effect because they are small, so we choose 75 mm.

Chrome carbide blocks have higher elastic moduli than steel, so their elastic deformations are different. This effect is about the same size for all blocks, so we can sample it with a smaller block, say 5 mm.

How Much Data Do I Need?

The accuracy of our estimated standard deviation depends on the number of data taken [4]. Suppose we take 10 data points and find the estimated standard deviation (σ). We than take 10 more data and find a new estimated σ. In fact we spend all day long making sets of 10 data points and getting a very large number of estimates of σ and then look at the histogram of values. The curve will look like a normal distribution where the center is the most probable value of σ. We will also find that the standard deviation of this distribution is about 25% of the center value. This means that if we take 10 data points and estimate σ we will be within 25% of the correct value only two thirds of the time and outside 25% one third of the time. To get an estimate of the standard deviation good to 10% we need to take 50 data points. Most people use 2. Thus the only part of your estimated uncertainty budget that depends

Block Length	Material
2 mm	Steel
5 mm	Chrome Carbide
20 mm	Steel
50 mm	Steel
75 mm	Ceramic
100 mm	Steel
250 mm	Steel
500 mm	Steel

Table 1.

Sample	Percent Variation of s
2	61
3	47
4	39
6	30
8	26
10	24
20	16
30	13
50	10

Table 2.

on actual data is between poor and horrible.

Recognizing this limitation the ASME committee on Dimensional Metrology (ASME B89) have written a standard, ASME B89.7.3.3, "Guidelines for Assessing the Reliability of Dimensional Measurement Uncertainty Statements" that recommends that if two parties differ in their uncertainties by less than 25% they should be averaged because of the wide variation in estimating uncertainty. Thus, an estimate of your calibration uncertainty that is good to 25% is actually a success.

Some Examples

Since the NIST calibrations have check standards in every calibration, we have lots of check standard data. What is presented below is a thought experiment in which I take a certain size gage and then sample the data as if it were check standard data taken once each month. The nice thing about this is that I really have a few hundred check standard values and thus the actual standard deviation is well known.

The first example is from wire calibrations shown in Figure 1. The Wire Micrometer was put into service in 1997. It is the first system we went from master wires for each nominal size to only about 20 master wires. The data represents a number of different operators. John Stoup, who built the instrument, did the initial measurements to validate the system. The next three operators took over where the breaks in the data occur, and each shows a learning curve. Generally, the check standard variation reaches a good approximation of the long term variation in 20 to 30 measurements.

Since the uncertainty is updated each year or so, the check standard data used for our uncertainty did change and rise slightly over the years. Check standards do not lie, so all you can do is report what the check standards tell you.

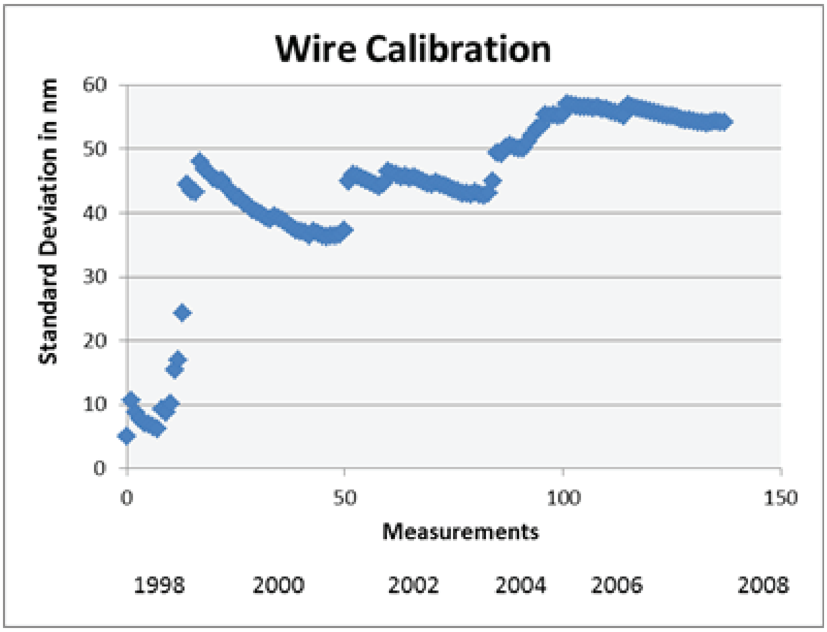


Figure 1. Check Standard history shows variation of uncertainty from operator affects as well as the general sources of uncertainty.

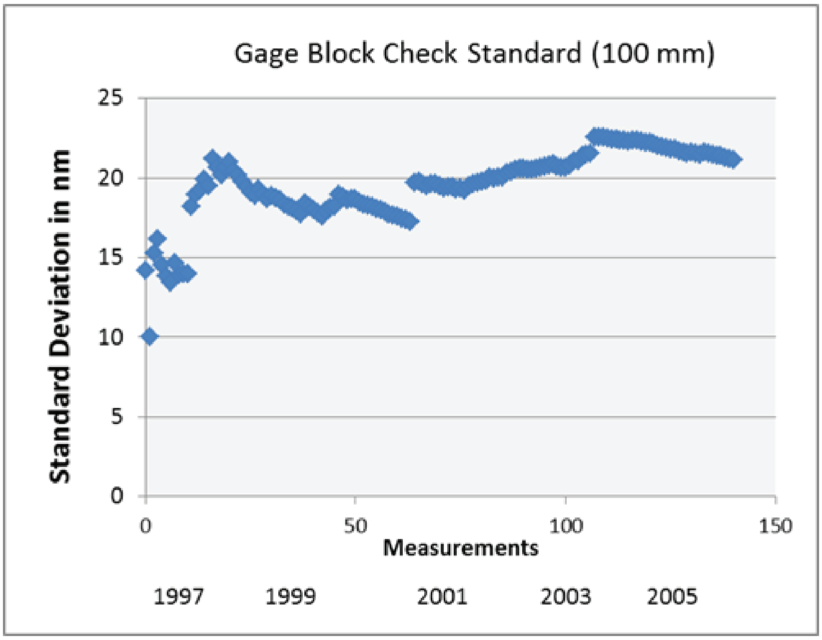


Figure 2. Check Standard history for 100 mm steel gage. Shows typical behavior as the estimate of the standard deviation starts low and rises to the standard deviation.

The second data set in Figure 2 is for the 100 mm gage block check standard. This system is not as physically demanding as wires and thus operator effects are smaller. The data span about 10 different operators using two different comparators in two different buildings. The check standard deviation was reasonably close to the long term behavior in only

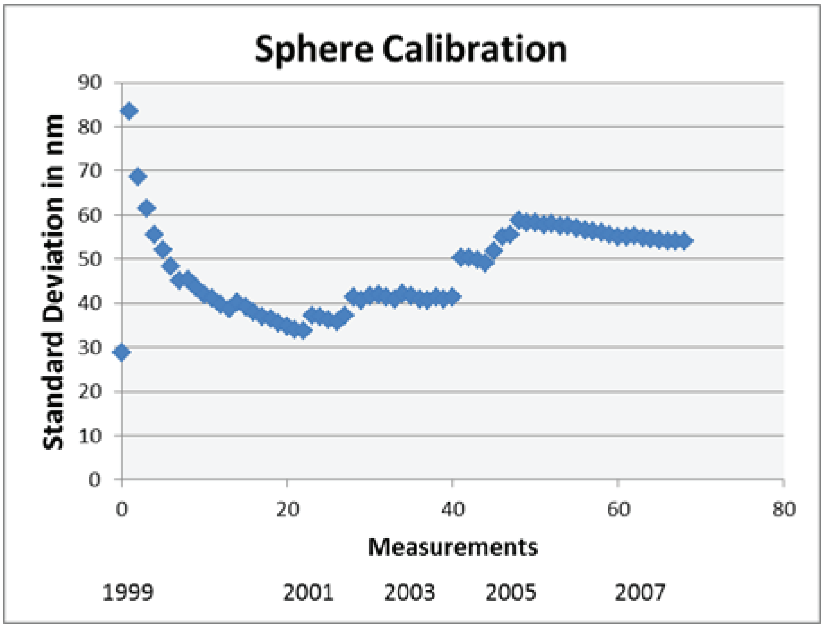


Figure 3. Check Standard history for sphere calibrations. Unusual early behavior, but not statistically significant.

about 20 measurements.

Generally, the standard deviation from the check standards starts low and gradually rises to its actual value. The first 10 measurements, however, do have enough randomness that for some cases the standard deviation of the check standards begins higher than the true standard deviation, as shown in Figure 3. We have over 400 check standards for gage blocks and 20 each for wires and spheres, so at least some of them produce random, but distinctive patterns. The patterns seldom last very long and nearly all check standard plots have the typical behavior after 10 to 15 measurements.

In all of these cases, the estimate of the long term standard deviation is within 25% of its true value after 40 to 50 measurements. If you thoughtfully choose your check standards and measure them monthly, or better semi-monthly, two years' worth of data give you a usable estimate of the uncertainty from instrument repeatability, resolution, thermal effects, elastic deformation, and scale. The two remaining sources, master gages and customer artifacts, must be handled outside of the check standard system. This gives you an uncertainty budget with 3 basic components:

1. Master Gage Uncertainty
2. Long Term Reproducibility
3. Customer Artifact

Conclusion

Check standards work if you know how to choose them and they represent the results of the various influence factors effects on the calibration in a natural way, relieving you of the complications of determining uncertainty from the methods described in the ISO Guides.

References

[1] International Organization for Standardization, *Guide to the Expression of Uncertainty in Measurement*, Geneva, Switzerland (1993). (corrected and reprinted 1995).

[2] ASTM E2655 – 08, *Standard Guide for Reporting Uncertainty of Test Results and Use of the Term Measurement Uncertainty in ASTM Test Methods*.

[3] Doiron, T and J. Stoup, "Uncertainty and Dimensional Calibrations," *J. Res. Natl. Inst. Stand. Technol*. 102, 647 (1997).

[4] Greenwood, Joseph A. and Marion M. Sandomire, "Sample Size Required for Estimating the Standard Deviation as a Per Cent of its True Value," *Journal of the American Statistical Association*, Vol. 45, No. 250, pp. 257-260 (1950).

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RACI Charts for Process and Procedure Management

Russell Keenan, PMP

RACI charts are a type of Responsibility Assignment Matrix (RAM), which can be used to clarify and more effectively define, resource, and implement processes and procedures. RACI charts are especially well-suited for metrology applications where accuracy, precision, and meeting meticulous standards is a routine requirement. RACI charts are developed through cross-functional collaboration between management and personnel to define functional areas, roles, and responsibilities; identify process ambiguities and/or inefficiencies; highlight best practices and support continuous improvement; and facilitate frequent, effective, and meaningful communication between teams and departments. RACI charting techniques take a systems approach to operational processes and procedures; recognizing and enabling the inter-relationships between stakeholders that are necessarily involved with successfully executing every process and procedure. RACI charts unambiguously define the relationships between the four fundamental functional roles associated with processes and procedures; specifically, who is (1) Responsible; (2) Accountable; (3) Consulted; and (4) Informed (RACI). Clearly defining and documenting these four roles eliminates the majority of confusion found in performing job functions, as well as a significant portion of the cost of poor quality (COPQ) related to errors, non-conformances, and omissions associated with poorly defined and implemented processes and procedures.

What is RACI?

RACI charts are a type of Responsibility Assignment Matrix (RAM) (Lewis, 1998, 2001; Lock, 2013; PMI, 2013), which are management tools and techniques used to identify functional areas, key activities, and decision points in project, department, and/or organizational processes and procedures (Table 1).

RACI charts are different from traditional RAMs in that RACI processes are grounded in collaboration between natural working groups (i.e., the combination of management and workers who complete tasks) to identify and clarify how four key operational assignments will be addressed to effectively complete processes and procedures (Table 2).

RACI charts (Table 3) are useful management and operational tools that allow an organization to:

- Evaluate and plan what functions on a process or procedure are necessary, who does what, and when on a given process or procedure.
- Improve employee, project team, and inter-departmental communication and engagement.
- Facilitate quality and change management processes (e.g., continuous improvement, 6-Sigma, Lean, etc.).
- Validate that accountabilities and responsibilities for each activity or process within their operating system(s) are assigned and performed at the appropriate level.

Why do we need RACI?

To prosper, organizations must continually evolve in response to changing requirements, market conditions, and the need for continuous improvement to create greater efficiencies and economies of scale. For highly regulated industries, such as those reliant on measuring and testing equipment and services, the need to demonstrate compliance with industry and/or regulatory standards is

Role	Personnel Assigned	Workscope (Inputs)	Primary Responsibilities	Deliverables (Outputs)
Project Review Team				
Project Sponsor				
Project Manager				
Engineering Design				
Marketing				
Public Relations				

Table 1. Example Responsibility Assignment Matrix

"R" = Responsible	Individuals charged with getting work done: *The Doer's*.
"A" = Accountable	Individuals ultimately responsible: *The buck stops here*.
"C" = Consult	Individuals who must be consulted before an action is taken.
"I" = Inform	Individuals told after an action is taken.

Table 2. RACI is an Acronym

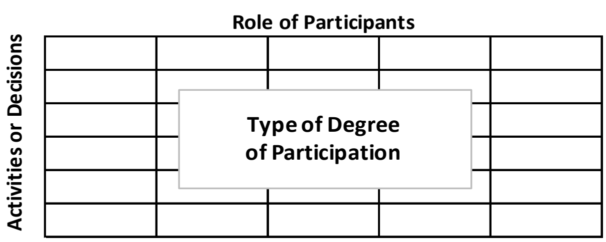

Table 3. RACI Chart Format

critical and includes two components: (1) Demonstrating knowledge concerning which standards are applicable and they are being followed; and (2) Documentation (internal processes, procedures, calibration certifications, work records, etc.) is maintained to substantiate appropriate accreditation requirements are met, internal procedures are implemented, and external standards are achieved.

Even with all the work put into developing processes and procedures, most organizations have a significant portion of workers with some degree of confusion concerning what they should do, why they should do it, and who they "*really*" work for. Much of this confusion is an unintentional result of a lack of or poor communication, a lack of collaboration or understanding of the relationships within and between work teams and departments, a lack of a shared sense of urgency and purpose, and a lack of a shared understanding of how success is defined (Ackoff, 1994; Bellows 2013, 2014).

The use of RACI processes alleviates this confusion and resulting inefficiencies by providing a bridge between roles, responsibilities, processes and procedures, by linking standards and procedures with job responsibilities, and by clarifying the relationships between functional roles as presented on organizational charts with actual work required to perform job procedures and processes. RACI processes are effective at dealing with fundamental operational considerations that affect all organizations (Table 4).

RACI processes are also useful to address common areas of unintentional ambiguity found in many organizations (Roth, 2001; Goetsch 2010; Prosser, 2015):

- Executives and managers that are over-committed and scheduled; they cannot be accountable for everything in their organization and are pressed to maintain overall accountability.
- Responsibility and accountability for each process and procedure are job-function dependent and often poorly defined and/or are not assigned to the most appropriate personnel.
- Supervisor/subordinate relationships are defined with a minimum of detail or only presented on organizational charts that do not provide specificity.

Further exacerbating the confusion are Human Resources job/position descriptions that, out of necessity, are broadly defined, but may also be out of date or otherwise do not define specific job responsibilities at a level that is fully meaningful to those performing the work. A lack of clear position definitions and standardization within an organization frequently leads to differing perceptions that may cause one person's view or understanding of a job or position "role" to be quite different from another's. Commonly, there are three categories of role confusion that generate job-role perception/misconception issues (Smith, 2010):

1. Role Conception: What you think your job is and what you're supposed to do.
2. Role Expectation: What others at work think your job is and what you're supposed to do.
3. Role Behavior: What you actually do to perform you job.

RACI techniques provide tools to reconcile role conceptions, expectations, and behaviors to be effective, efficient, productive, and eliminate the majority of these misconceptions (Smith, 2010, PMI, 2013; Lock, 2013).

Management Issue	RACI Opportunity
Roles and Responsibilities	To Better Understand To Improve Communications
Accountability	To Clarify
Responsibilities	To Identify Authority
Job Responsibilities	To Empower Employees with Power to Perform
Role of Middle Manager	To Bring up to Speed with Organization Structure
Approval	To Reduce Uncertainty of Multiple Reporting

Table 4. Issues and Opportunities

Achieving the "Standard"

Regardless of which standard an organization is aligned with (e.g., ISO 9001, ISO 17025, NQA-1, etc.), organizations are required to maintain documentation specifying how they addresses the following core quality processes (Burcher, 2007, 2008; Payne 2007):

- Training and verification of personnel
- Specification of how to perform key processes
- Distribution of technical and quality documents
- Control of measuring and testing equipment (M&TE)
- Procurement of services and items
- Corrective action
- Records management

While there are an abundance of standards that address industry-specific needs and requirements, there are commonalities in both standards/requirements and industry responses to applicable requirements:

- Most standards present requirements that dictate work processes, procedures, and documentation needed to achieve minimum standards/results.
- Most organizations have processes and procedures that provide direction on how to accomplish minimum standards.
- Most organizations have initial and ongoing job- and process-specific training aligned to accomplish minimum requirements of applicable standards.
- Most organizations have "HR job/position descriptions" that present minimum requirements and qualifications necessary to perform each job/position.
- Most organizations have organizational ("org") charts identifying how their organization is structured to meet the minimum requirements of applicable standards.

RACI techniques provide organizations with the ability and opportunity to clearly and concisely link internal processes and procedures with the applicable standard(s) in a manner that generates greater engagement and ownership at all levels of an organization.

RACI Chart Fundamentals - Process

The purpose of RACI charts is to provide clarity, increase understanding, and facilitate more effective work processes and procedures. The objectives of RACI charts are to (PMI, 2013; Lock, 2013):

- Assist natural work teams in charting roles and responsibilities in a consistent manner.
- Assist natural work teams with development of implementation tool kits.
- Clarify individual/departmental roles and responsibilities.
- Identify accountabilities.
- Eliminate misunderstandings, encourage teamwork.
- Reduce duplication of effort.
- Initiate/increase meaningful communication between management and workers.

Developing RACI charts is a six-step process, starting with initiation meetings with organizational and/or department leadership and culminating a continuous improvement evaluation, as summarized below:

1. Conduct introductory meetings with key management and/or department leaders to inform them on the purpose and requirements of RACI techniques.
    - Don't assume management/department leaders know or have used RACI.
    - Bring examples; be prepared to discuss and educate.
    - Develop management/department leader "buy-in" for successful RACI process.
    - Secure management/department leader's active support.
2. Decision and function lists are developed, analyzed, and collated into a master function list.
    - Who is/should be responsible to carry out each decision/step?
    - Who is best qualified to carry out each decision/step?
    - Is each decision/step appropriately resourced?
    - Who else will be affected by each decision/step and are they appropriately notified?
3. Conduct responsibility workshops and prepare RACI Charts.
    - RACI development is a team exercise and not done in a vacuum.
    - Agree to and develop consensus on function definitions.
    - Agree to and assign RACI functional responsibilities.
    - Evaluate for duplication and/or redundancies.
    - Confirm understanding by all for all functions and goals.
4. RACI Charts are documented and distributed to all participants and interfacing organizations.
    - RACI is an inclusive, iterative, evergreen process.
    - Don't expect to get it "right" the first time.
    - Value feedback and opportunities for improvement.
    - It's not "who's" right; rather what's pragmatic and effective.

5. Communication and reinforcement of RACI roles are done through feedback meetings with all individuals and departments involved.
   - RACI is not a "fire and forget" process.
   - Visible, proactive reinforcement from leadership is required.
   - Visible, proactive support by department leaders is necessary.
   - Smaller meetings with natural teams are most effective for delivering feedback.
   - Peer pressure and reinforcement is very effective.
6. Follow-up is conducted with team members and management to reinforce RACI relationships and/or initiate continuous improvement and/or change management processes.
   - RACI charts are fundamental to continuous improvement.
   - Has/have underlying processes changed?
   - Is the underlying process applicable, effective, or needed?
   - Have job responsibilities changed or evolved?

RACI Chart Fundamentals – Guidelines

The essence of a well-prepared RACI chart is simplicity of content, form, and format. The following guidelines are presented to assist in developing RACI charts that are rich in content, effective to use, and readily understandable by all potential users.

1. Avoid obvious or generic activities; for example "attend meetings."
2. Each activity or actions should begin with a good action verb (Smith, 2010) (Table 5):
3. When the action verb implies a judgment or a decision (for example, evaluate, monitor, inspect, or review), add a phrase to indicate the primary outcome.
   Examples:
   - "Monitor phone service [*handling of customer requests*] to identify training needs"
   - "Analyze data to locate source of delay"
4. Additional, general guidelines for developing and refining RACI charts:
   - Understand the potential for systems thinking and cultural changes when defining roles and responsibilities:
     - Eliminate "checkers checking checkers" (i.e., no micromanagement).
     - Encourage collaboration and teamwork.
     - "Perfectionism" is counter-productive and unnecessary.
   - Place accountability (A) and responsibility (R) at the level closest to the action or knowledge.
   - There can only be one accountability (A) per activity.
   - Authority must accompany accountability.
   - Minimize the number of consults (C) and informs (I).
   - All roles and responsibilities must be documented and communicated.
   - "Rule of thumb" - restrict RACI Charts to one (1) page for ease of use.

Evaluate	Schedule	Write	Record	Determine
Operate	Monitor	Prepare	Update	Collect
Approve	Conduct	Develop	Inspect	Train
Publish	Report	Review	Authorize	Decide

Table 5. Examples of Activity Action Verbs

	Functional Roles						
Activities	**Chief Training Officer**	**Trainer**	**Dept. Leaders**	**Admin. Support**	**Selected Employees**	**Employee Supervisors**	**Other Depts.**
Develop Training Curriculum	A	R	C			I	I
Select Personnel for Training		I	A		I	R	C
Select Training Date / Venue	I	R	A		I	C	I
Confirm Logistics with Venue	I	A		R			
Deliver Training	A	R		I		C	
Document Training Completion		A		R	I		

Table 6. Example RACI Chart for Employee Training

Table 6 presents an example of a RACI chart that was developed by a firm to document one portion of the process of training employees. The activities, in order of occurrence, begin with developing training curriculum and close with documenting training completion. The functional roles presented include only those actively participating in the process, from the Chief Training Officer as management sponsor of the process, through the supervisors and department heads involved and/or affected, the employees to be trained, as well as the administrative support personnel involved in logistics and records management. Note this RACI chart summarizes a process and associated functional roles; it is not an "all inclusive" document that covers all aspects of training employees – it is focused the higher level activities and functions related to developing and delivering training to employees. The organization that developed this RACI chart also has training-specific RACI charts that address task-specific activities and functional roles associated with each skill and type of training.

RACI Chart Fundamentals – Analysis and Debugging

Analysis and debugging of RACI charts is an evergreen process that starts during the development of a specific RACI chart and continues through the life cycle of the chart to make sure it remains effective, relevant, and useful for its intended purpose. Analysis and debugging is a two-stage process: (1) Vertical analysis of functional roles; and (2) Horizontal analysis of decisions, functions, and activities. The debugging process focuses on maintaining simplicity and reducing duplication, redundancy, and unnecessary or gratuitous participation by individuals not adding value to the process or procedure. Table 7 presents a summary of key vertical analyses of functional roles; Table 8 presents a summary of key horizontal analyses considerations.

Table 9 presents an example of a poorly constructed RACI chart that illustrates many of the analysis and debugging issues shown in Tables 7 and 8; including over-

Issue	Response Considerations
Lots of R's	Can the individual stay on top of so much work? Can the activity be separated into smaller, more manageable functions?
No Empty Spaces	Does the individual need to be involved in so many activities? Are they a "gatekeeper" or could management be exception principles be used?
No R's or A's	Should this function be eliminated? Have processes changed or evolved to the point that resources can be transferred or utilized on other activities?
Too many A's	Does a proper "segregation of duties" exist? Should other groups be accountable for some of these activities to ensure that appropriate checks and balances and accurate decision making processes are in place? Is this a "bottleneck" in the process – is everyone waiting for decisions or direction?
Qualifications	Does the type or degree of participation fit the qualifications required for this role?

Table 7. Vertical Analysis and Debugging of Functional Roles

Issue	Response Considerations
No R's	Is the job getting done? Some roles may be waiting to approve, be consulted, or informed. No one sees their role to take the initiative.
Too many R's	Is this a sign of "over the wall" activities (i.e., check the list and move one)
No A's	Why? There must always be an "A" for an activity or function. Accountability should be pushed down to the most appropriate level.
Too many A's	Having more than one "A" on an activity creates confusion, through real or perceived differences in mission, vision, and/or approach.
Too few A's and R's	The process must slow down while an activity is performed on a *ad hoc* basis. Or, the procedure may be outdated and can be streamlined or eliminated.
Lots of C's	Do all the functional roles need to be consulted? Are there justifiable benefits from consulting all the roles?
Lots of I's	Do all these roles need to be routinely informed, or only in exceptional circumstances?
Every cell filled	They shouldn't be! If they are, too many people are involved – typically too many C's and I's.

Table 8. Horizontal Analysis and Debugging of Activities and Functions

allocating all functional roles and filling in every cell of the RACI chart. Table 10 represents the same laboratory analysis RACI chart after more carefully evaluating process and resource allocation needs and applying the debugging guidelines outlined in Tables 7 and 8.

Example Uses of RACI Techniques

There is no "one" type of RACI chart that is useful for any or all circumstances. Rather, the real power of RACI charts lies in their simplicity and flexibility of use – they can literally be adapted to bring clarity to almost any process or procedure. Some of the more common uses of RACI charts are presented below:

Workload analysis: RACI charts can be used for "as-is analyses" to help identify redundancies that may exist or to improve the quantity and/or quality of the work being performed.

Reorganization: RACI charts can be used for "what if" scenarios to assure that key functions and continuous improvement processes are not overlooked as a new structure is being developed or evaluated.

Employee turnover: RACI charts can be used as aids in redistributing workloads, in retraining affected employees to fill the void, or shifting responsibilities with minimal disruption of work flow.

Teamwork: RACI enhances the understanding of individual contributions to an overall work process or procedure as well as providing a "road map" for understanding other's roles and responsibilities.

Control of work processes: RACI charts can be used to make sure that necessary and applicable work activities are identified, appropriately resourced, completed, and documented. RACI charts facilitate accreditation and certification processes as well as process and facility audits.

Minimize risk and variance: RACI charts can be used as a process evaluation and analysis tool to identify, develop potential mitigation, and/or eliminate task activities that can cause or exacerbate risk and variance in work processes and procedures. RACI charts facilitate root cause analysis and can provide a forum for presenting lessons learned.

	Functional Roles					
Activities	**Materials Lab Director**	**Materials Lab Manager**	**Engineer of Record**	**Materials Lab Technician**	**Materials Lab Analyst**	**Admin. Support**
Receive / Log-in Samples	C	A	C	I	I	R
Prepare Samples for Analysis	C	I	C	C	I	I
Confirm M&TE in Calibration	A	A	A	A	A	A
Analyze Samples	I	R	C	R	A	I
Check / Validate Analytical Results	A	A	C	I	R	I
Enter Analytical Results into LIMS	C	A	C	I	C	R
Laboratory Validation / Sign-off	A	R	C	I	I	I
EOR Acceptance / Sign-off	A	I	A/R	I	C	I

Table 9. Laboratory Analysis RACI Chart - Pre-Analysis and Debugging

	Functional Roles					
Activities	**Materials Lab Director**	**Materials Lab Manager**	**Engineer of Record**	**Materials Lab Technician**	**Materials Lab Analyst**	**Admin. Support**
Receive / Log-in Samples		A	C		I	R
Prepare Samples for Analysis		I	C	R	A	
Confirm M&TE in Calibration		C	I	R	A	
Analyze Samples		I	C	R	A	
Check / Validate Analytical Results	I	A	C		R	
Enter Analytical Results into LIMS		A				R
Laboratory Validation / Sign-off	A	R	C		I	I
EOR Acceptance / Sign-off	I	I	A/R			I

Table 10. Laboratory Analysis RACI Chart - Post Analysis and Debugging

Conclusions

The RACI process delivers clarity and greater effectiveness of business processes and procedures on multiple levels in response to a shared, systematic understanding of goals, objectives, relationships, and how success is defined. Specifically:

- **RACI delivers alignment, clarity, and structure:** The collaborative development of RACI charts creates a shared understanding of goals, objectives, internal and external relationships, and how success is defined.
- **RACI generates discussion and engagement:** The development and continuous improvement of RACI charts creates a highly effective forum for focused activity-specific discussions that would otherwise not typically take place.
- **RACI increases capacity and productivity:** The clarity of purpose and common understanding of goals and objectives developed through the RACI processes results in more effective use of time and resources at all levels of an organization.
- **RACI reduces scrap, rework, and redundancies:** The greater alignment, clarity of purpose, and organizational engagement developed through RACI charts reduces worker/management confusion, errors, and wasteful overlap of responsibilities and/or duplication of effort.
- **RACI supports process certification and QA/QC documentation:** RACI charts are quality documents that facilitate certification and auditing by providing documentation that bridges the gap between an organization's organizational charts, processes, training, and execution of processes and procedures.
- **RACI facilitates personnel training:** Personnel capabilities skills are increased by involving them in workshops where fellow workers discuss all roles and functions.
- **RACI supports better, more effective planning:** This process of developing and continuously improving RACI charts creates better, more effective planning processes through greater organizational participation, as a result of building and strengthening internal and external relationships.
- **RACI facilitates continuous improvement and change management:** The RACI process develops a more complete understanding of processes, procedures, facilitates continuous improvement in response to evolving circumstances, and aligns and defines roles and responsibilities during change management.

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Internal Audit: How to Take the Pulse of Your Laboratory

Kenneth Parson
Parson Consulting – International

I. Introduction

The objective of Internal Audit is to examine all documented elements of the Quality/Management system including Technical operations. It is important to understand that the focus of Internal Audit is to determine by in-house laboratory personnel that all laboratory operational processes are functioning within documented limits. This is much like an autopilot where operating limits are set and continuously monitored to be sure the craft is staying on course. It is also a form of housekeeping and keeping things "shipshape."

If internal, in-house laboratory operating requirements (SOP'S – SAP'S and Work Instructions) for these processes are well organized, documented and implemented, it will give management the ability to ensure all in-house laboratory processes remain under control and to identify and measure areas for improvement within the management system. The results of an active, low level, continuous internal audit program will enable the organization to remain in control and be more competitive and provide better products and services to its customers. Like the autopilot, Internal Audit will help laboratory operational processes stay on course and under control. It should take much less time and effort to do continuous audit than say a once a year effort which has allowed the laboratory to possibly go out of control with major corrective action required—not a good practice.

II. Policy & Procedure

There are many ways to carry out an internal audit. The important thing is to understand whether the laboratory is an independent organization or part of a larger parent organization. If part of a parent organization, the laboratory quality manual will need to comply with the quality system policy and operational procedures of the parent organization along with internal laboratory operations. Laboratory management will need to work with the quality system and quality manager of the parent organization to determine how internal auditing will be accomplished. Whatever arrangements are made, they then must be documented and included in the quality manual to ensure all members of the staff understand how the system works. It is important to understand that laboratory management should have an internal laboratory audit system in place.

When writing the quality manual, be sure to adequately address all applicable Standards, Regulations and Contractual requirements that may apply to laboratory operations. You will need to ensure that "how to" procedures are then developed, documented, implemented, made available and understood by all personnel concerned. Set up your internal audit to determine if the in-house laboratory procedures you have invoked by your quality system are being complied with. Use a Standard checklist format tailored to each activity; this means audits of technical processes as well as all other elements of the laboratory's operations. In all cases, be sure those who perform internal audit are identified, trained and qualified. This will help to make certain personnel have the knowledge and skills for the subject matter being audited.

> Like the autopilot, Internal Audit will help laboratory operational processes stay on course and under control.

Many laboratories simply do not do any internal auditing. They rely on external audits performed by other organizations. They also may think inter-laboratory comparisons and proficiency testing satisfying the requirement for internal audit, but that is not true. Internal auditing should be done by in-house laboratory staff on a routine basis.

Checklists should be designed and used that will enable an individual to observe a process or set of conditions that will determine if in fact the process is being accomplished as specified in the quality manual and related "how to" documents. Housekeeping, safety and industrial hygiene requirements should also be check-listed, even though they are not required by the International Standard, and then verified periodically. Process monitoring of measurement processes can also be check-listed and compliance verified.

Continuous, low-level auditing should be performed. If audits are only performed "periodically," there is a very good chance management will find that laboratory operations are unknowingly going off-course and have gradually departed from documented methods and procedures.

III. Frequency

The cycle for internal auditing should be completed within a year. It should be planned and carried out throughout the year. Laboratory management should avoid making this a single, once a year event. It should be setup as a continuous, systematic, low-level activity accomplished by in-house personnel.

Internal audit is a major undertaking and requires a sound understanding of all elements involved in this type of auditing. A SOP will need to be developed and forms designed and used to systematically and consistently carryout internal audits. Procedures for compiling and reporting results will also need to be documented. Here are some things to consider:

- All elements of the quality/management system need to be included in the internal audit process. Depending on how the Quality Manual is arranged. There should be about 15 elements within Management and about 10 within Technical that need to be planned for and set up within the annual plan. In addition, a few weeks will need to be set aside to enable the quality manager to recheck areas where chronic problems have been found during previous audits. Audits should be done on a weekly basis except for holidays.
- The quality manager should be assigned to plan, coordinate and organize annual audits as required by management. This responsibility needs to be reflected in the Functions & Responsibilities (F&R) and job description for the quality manager. All F&R's should also include the requirement for laboratory personnel to participate in the internal audit program. Each year, in preparation for the management review, the quality manager should prepare and coordinate a proposed audit plan for the coming year and have it coordinated with and ready for approval by top management before the Annual Management Review. Once signed, the quality manager will cause the audits to be done in accordance to the approved schedule and will be expected to report on results and provide a periodic progress report during management reviews.

IV. The Internal Element

All laboratory personnel including management should be trained and qualified to perform these audits. Internal Audit is an in-house affair and should not be contracted out or accomplished by individuals outside the laboratory. Internal Audit is an internal self assessment. For the laboratory quality manager there should be evidence of training received and experience gained in the audit process. This level of qualification should be documented in the quality managers qualified auditor file. These credentials are important because they allow the quality manager to train and qualify others to perform internal audits within specified areas of the laboratory operations.

Internal Audit should be accomplished by personnel within the laboratory. Management should consider the merits of conducting a continuous, low-level audit. As stated earlier, this is much like the role of an autopilot in an aircraft. Once limits are set the autopilot continually monitors performance and when limits are exceeded immediate corrective action is taken. This results in helping to ensure the aircraft remains on course and under control.

There are major benefits to be derived when in-house personnel participate in Internal Audit. It is a good use of resources and a form of on-the-job training. Personnel become much more familiar with and aware of how the overall quality/management system operates because they are active participants in examining the process. Everyone in the laboratory organization should participate. Yes, even executives should subordinate and be willing to actively participate in the internal audit process. Executive participation will bring much more value to the process.

V. Sample Audit Cover Sheet & Checklist

Audit follow up activity should be included in the SOP. It should verify compliance to in-house requirements. Checklists should be designed and developed by the Quality Manager and used by in-house auditing personnel to perform internal audits to standardized checklists.

Don't use the accrediting body checklist for Internal Audit. Those checklists are used by external assessors to verify compliance to the International Standard ISO/IEC 17025. If you are planning to achieve Accreditation or just improve on laboratory operations, then the external accrediting body checklists should be used to ensure compliance to the external body checklist requirements which should be based on the requirements of ISO/IEC 17025.

The following is a sample of a laboratory developed Audit Cover Sheet and Audit Checklist. In this case, an example of requirements for Laboratory Facilities is used to show how the data would be documented.

Note: Each identified nonconformance should be documented on a Nonconformance Report (NCR) form and submitted to the Quality Manager along with the attached, completed checklist.

SAMPLE
AUDIT CHECKLIST

COVER SHEET

Audit Element – Laboratory Facilities

Form No.	Revision	Date	Checklist Number
			10.3.1

Assigned Auditor ________________

Period of Performance - Week of ____________

Requirement Documents:

QM-001 - Quality Manual
SOP 003- Standard Operating Procedure - Facility Requirements
SOP 004 – Safety Regulations

Instructions to Auditor:

Provide special instructions that may be unique to this audit, such as:

1. Contact the supervisor and arrange for entry into the area of audit.
2. Do not enter any posted operating areas without first contacting the area supervisor.
3. Eye, foot or other protection, as required, must be worn in the areas where auditing is to be accomplished.

Classification of Findings: (Keep it simple)

S – Satisfactory, for compliance to requirement
X – Nonconformance, not in compliance with requirement
C – Comment, any concern or suggestion offered by the auditor

VI. Conclusion

In conclusion, I highly recommend that laboratory managers consider the merits of Low-Level Internal Audit and take action to implement the process. I will say it again; Internal Audit means "Internal" so don't use external personnel or organizations to do this work. If you do not use in-house personnel you lose all the benefits of the process. It enables management to know if laboratory operations are beginning to go out of control and able to institute immediate corrective action where necessary. It is also an excellent training and awareness program that helps all laboratory members to become more knowledgeable and better understand how laboratory systems and processes work. It also helps to improve morale because everyone is able to participate and contribute to better management of laboratory operations. And finally, it encourages a "Team Effort" philosophy which is so important for everyone within the laboratory. A team effort is a must if your laboratory is accredited or if you wish to pursue accreditation.

SAMPLE
AUDIT CHECKLIST

CK Number – 10.3 Laboratory Facilities

Form No.	Revision	Date	Checklist Number
			10.3.1

Audited by (Name) ____________ Audit Date ____________ Time to Audit (including prep & exit brief) ____________

No.	Ref. Doc. Pg/Par	Audit Element	Finding S/X/C
1	QM-001 6/4.3.2	Temperature: Verify temperature-monitoring instruments are in current calibration.	
		Auditor Comments:	
2	SOP 10.3 3/7.6	Verify temperature-monitoring instruments are within current calibration periods.	
		Auditor comments:	
3	SOP 10.3 4/2.1	Check laboratory temperature recordings and verify areas within temperature limits: Electrical – 21 to 25 °C Dimensional – 22 to 24 °C Chemical Storage area – 19 to 27 °C	
		Auditor Comments:	
4 Thru 10		Note: Limit number of check list items to 10. Check list questions can and should be changed over time to keep the audit activity relevant.	

For the Quality Manager - Auditor Feedback, Comments and/or Recommendations:

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The preceding are excerpts from the author's book titled, Laboratory Quality/Management: A Workbook with an Eye on Accreditation *(ISBN13: 978-1-4797-5395-6). This book provides far more details about Records Management, Measurement Traceability and Final Reports. Copies may be obtained through xlibris.com, amazon.com, bn.com, or from your local bookstore.*

Yokogawa Corporation WT3000E Precision Power Analyzer

Yokogawa Corporation of America announces its latest Precision Power Analyzer, the Model WT3000E, offering the world's highest power measurement accuracy of 0.01% of reading +0.03% of range. This new addition to Yokogawa's highly recognized digital power analyzer product line offers innovative measurement functions which benefit the engineer with electrical power measurements. It is the ideal measurement solution for testing product efficiency and the design of inverters, motor drives, lighting systems, uninterruptible power supplies, transformer testing, aircraft power systems, and other power conversion devices.

The WT3000E Precision Power Analyzer is the enhanced model of the existing WT3000. Its power measurement accuracy has been improved and is now considered as the top level in the world. Power electronics technology is being challenged for better energy conservation and improvement in the level of product efficiency. In order to evaluate the energy loss of the latest product designs more precisely, higher accuracy is required for the power measurement instruments. With its cutting-edge performance, the WT3000E satisfies such market needs.

The WT3000E offers two types of input elements. The low current element provides selectable input ranges of 5, 10, 20, 50, 100, 200 and 500 mA and 1 and 2 amps. The high current element provides selectable ranges of 0.5, 1, 2, 5, 10, 20 and 30 amps. Both offer eight selectable voltage ranges from 15 to 1000 volts. One to four input elements can be installed with any combination of low and high current versions. Measurements of Crest Factors of up to 300 are possible. This is very important in dealing with power electronic circuits. The measurement frequency range is from DC and 0.1Hz to 1MHz.

Many of today's power conversion circuits use energy saving switching techniques. These can cause highly distorted voltage or current waveforms with high harmonic content. To measure these waveforms accurately, the WT3000E uses high resolution sixteen bit analog to digital converters. This will benefit the design and test engineer in product performance evaluation and for power quality conformance testing. The normal power parameters and harmonic data are measured simultaneously, providing for faster and more accurate power analysis.

Two new measurement functions are provided as standard with the WT3000E. The Delta Calculation function allows users to calculate the individual phase voltages, line-to-neutral, from the line-to-line voltages measured in a three-phase three-wire system. This function can be very beneficial to the engineer in applications such as motor testing and others where there are no neutral lines. The Cycle by Cycle measurement function enables users to list the measurement parameters of voltage, current and active power for each cycle in a time series. This is a unique method to capture the fluctuating transient power with high precision.

For electric motor testing applications, the WT3000E offers a unique and powerful motor evaluation function. In one unit, you can measure all the electrical power parameters along with rotation speed, torque, mechanical power, synchronous speed, slip, motor efficiency and total system efficiency.

Fo IEC Standards Compliance testing, the WT3000E provides harmonic measurement in accordance with the latest IEC61000-3-2 and IEC61000-4-7 standards. Voltage fluctuation and flicker measurements can be made in accordance with the latest IEC61000-3-3 and IEC61000-4-15 standards. The Yokogawa harmonic and flicker software, 761922, used with the WT3000E, provides a complete compliance measurement test system per the IEC standards.

With its large high resolution 8.4 inch TFT LCD display, it is simple to set up and display up to nine different pages of measurement items in formats such as numeric, waveforms, harmonic spectrum bar graphs and trends. In addition, a vector display is available for voltage and current phase analysis.

All the latest communication interface ports such as Ethernet, USB and GPIB, as well as RS232 are available in the WT3000E. Support for USB removable storage media is also available.

For more information about the WT3000E, please visit http://tmi.yokogawa.com/products/digital-power-analyzers/digital-power-analyzers/precision-power-analyzer-wt3000e/.

Pasternack VNA Calibration Kits

Pasternack, a leading manufacturer and supplier of RF, microwave and millimeter wave products, has expanded their portfolio of general purpose VNA calibration kits with new 50 and 75 Ohm versions. These new cal kits offer excellent performance characteristics that are specially designed for the fine-tuning and calibration of sensitive test equipment in engineering labs, production environments and quality testing facilities. All of Pasternack's calibration kits are built to withstand years of rigorous use and provide accurate RF equipment calibration for the life of the product.

Pasternack's new line of general purpose VNA calibration kits come in three economical versions including a 50 ohm 3.5mm calibration kit up to 26.5 GHz, a 3.5mm kit up to 8.5 GHz , and a 75 Ohm Type-F calibration kit operating to 3 GHz. These new VNA calibration kits complement the company's existing models which include a 3.5mm kit operating to 26.5 GHz (PE5500-KIT) and a Type-N kit operating to 18 GHz (PE5501-KIT).

Each of the new VNA calibration kits from Pasternack includes all of the necessary Short Circuits, Open Circuits, Loads and Thru (SOLT) components required for proper testing. The kits are suitable for many 50 Ohm and 75 Ohm network analyzers from the industry's leading providers such as Agilent, Rohde & Schwarz, Anritsu and Copper Mountain. These RF test and measurement kits all come packaged inside protective wooden boxes.

Pasternack's new general purpose VNA calibration kits are in-stock and available to ship today. You can view the company's new calibration kits by visiting http://www.pasternack.com/pages/RF-Microwave-and-Millimeter-Wave-Products/vna-general-purpose-calibration-kits.html. Pasternack can be contacted at +1-949-261-1920.

NEW PRODUCTS AND SERVICES

Mahr Federal Introduces the Millimar C1200 Digital IC Amplifier

PROVIDENCE, RI – Mahr Federal has introduced the Millimar C1200, a new low-cost easy-to-view and easy-to-use Digital IC Amplifier. Incorporated in the C1200 is a new high resolution, high color contrast display that provides clear and very responsive analog readings with selectable scales. Users can view the analog scale, numeric digital readings, or both. Display range is ±5000 µm and reading resolution 0.1 µm. The display may be adjusted to the ideal viewing angle (0º to 90º) and the C1200 unit can also be wall-mounted.

"A major design goal of the new C1200 was to produce a digital display that would produce the smooth motion of an analog meter," said George Schuetz, Director Precision Gages for Mahr Federal. "This fast response is ideal for exploring part deviations, common with surface plate measurement applications."

The C1200 is powered by five standard AA cell rechargeable batteries, or by external power supply. When battery operated, the compact lightweight unit (<1.4 lbs) is fully portable for use anywhere. Single probe input using Mahr probe specification accommodates standard or long-range inductive probes. Data output is available using MarConnect cables for Digimatic, Opto-RS 232, or USB interface. Output type is auto-sensed by the cable connected to it. External wireless may also be used.

Operating features are set up using an integrated 5-button keypad. Features such as unit selection (in/mm/µm), normal/reverse polarity, measuring range, preset, factor, and tolerance entry are easily set up by visual menu options. When tolerances are used the display shows pass/fail status using green/red color on the backlit display. The Millimar C1200 model replaces the 1200IC amplifier.

For more information visit http://www.mahr.com

New Booklet on Good Operating Procedures for pH Sensors

Urdorf, Switzerland – pH is the most common liquid process analytical parameter. Its measurement and control are important across the process industries including pharmaceuticals and chemicals production. Typically, pH is measured using glass pH sensors, an instrument that has been available for almost 100 years. Over this time, many developments have been introduced to improve sensor measurement accuracy, durability and ease of use. Today, pH sensors for industrial use are high performance devices, tailored for specific applications.

This good operating procedures guide explains how to correctly use and maintain pH sensors. The guide also describes how greater measurement accuracy and performance are possible from METTLER TOLEDO's Intelligent Sensor Management (ISM®) digital sensor platform.

METTLER TOLEDO's new booklet "Good Operating Procedures for pH Sensors" explains step by step how to correctly use and maintain pH probes to give you greater performance and measurement accuracy.

The writer of the guide, Kurt Hiltbrunner, Pharma Industry Specialist at METTLER TOLEDO said, "Modern pH sensor are extremely reliable and robust tools provided they're well looked after. In some applications proper care can easily double the lifetime of a sensor and our ISM technology tells you what maintenance is required and when to do it."

Further topics covered in the guide include:

- pH sensor structure
- Calibration (1-point and multi-point)
- pH sensor maintenance
- selecting the best pH sensor for your processes

The guide is available to download from www.mt.com/pro-pH-GOP.

Zygo Verifire™ XL Interferometer for Large Aperture Form Metrology

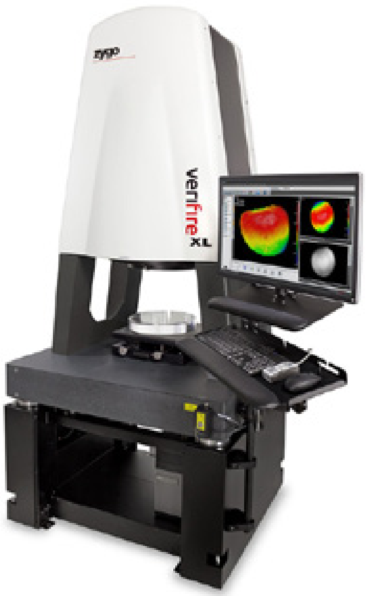
Zygo Corporation announces the release of the Verifire™ XL high-precision Fizeau interferometer for the simple and accurate characterization of flat surfaces up to 12 inches (300 mm) in diameter. Designed for measuring large plano surfaces, such as mirrors, semiconductor wafers, or optical windows, the Verifire XL is a turn-key solution incorporating staging, accessories and production-oriented technology.

The Verifire XL system comes with an integrated TMC vibration isolation platform and ZYGO's patented QPSI™ vibration-robust acquisition technology. Those features permit precise, reliable metrology, even in production environments where vibration can degrade measurement data using other acquisition techniques.

Measurement and analysis of surface topography on the Verifire XL interferometer is handled by ZYGO's Mx™ metrology software, the industry's most powerful data analysis and visualization platform. In addition to QPSI acquisition, the Mx software also includes ZYGO's new Smart Averaging feature, which automatically provides the best possible measurement in the shortest time.

Verifire XL interferometer is an application-centric model of ZYGO's industry-leading Verifire line of phase-shifting laser Fizeau interferometers. The system shares their robust and stable design, a long-life high-powered laser source and high-speed, high-resolution camera for unmatched data and instrument reliability in the most demanding applications. The Verifire XL interferometer is now available worldwide for purchase.

Zygo Corporation, a unit of AMETEK Ultra Precision Technologies Division, is a leading provider of optical metrology solutions, high-precision optics, and optical assemblies used in a wide range of scientific, industrial, and medical applications.



Fluke Calibration 5790B Automated AC Measurement Standard

The 5790B AC Measurement Standard is an ac voltage and current measurement or transfer standard designed for the most demanding calibration applications. It combines the accuracy one would expect from a thermal transfer standard with the ease of use of a digital multimeter. Absolute ac voltage measurement uncertainties are as low as plus-or-minus 24 ppm (one year, 23 degrees C plus-or-minus 5 degrees C).

The 5790B is designed to meet the complete ac voltage, current, and wideband verification requirements of the Fluke Calibration 5730A, 5720A, and 5700A Multifunction Calibrators; 5522A, 5502A, and 5500A Multi-Product Calibrators; plus other calibrators, amplifiers like the 5725A and 5205A/5215A, transfer standards, and ac voltmeters.

Built on the legacy of the 5790A and the patented Fluke solid-state Thermal RMS sensor, the versatile Fluke Calibration 5790B offers all of the performance and features of the 5790A and also many new capabilities, including:

- New user interface and touch screen display — the new 5.5-inch touchscreen display allows users to see more information on the screen, reducing the need to switch between menus.
- Calculation free, absolute current measurements with Fluke A40B current shunts— 5790B's can now make direct, absolute or relative current measurements with current shunts without needing to make any calculations. The interface now allows users to input and save characteristics and coefficients such as shunt serial numbers, calibration constant values (24 ac/dc, 5 loading error points) to automate the ACI-to-ACV conversion calculations.
- Expanded wideband range (50 MHz) — a new "/5" wideband option expands the bandwidth to 10 Hz to 50 MHz, allowing users to calibrate more devices with a single standard.
- Improved statistics - Statistics allow users to easily gather measurement samples over a set period of time – providing min, max, average, Standard deviation, and peak to peak data while still viewing the main measurement.
- Waveform Calculator - ability to view waveform calculations on the main display for four common waveforms: peak-to-peak sine, square, triangle, and truncated waveforms.

To learn more about the Fluke Calibration 5790B Automated AC Measurement Standard, visit www.flukecal.com/5790B.

Rohde & Schwarz FSW85

The new R&S FSW85 high-end signal and spectrum analyzer is the only instrument on the market to cover the frequency range from 2 Hz to 85 GHz in a single sweep. This makes it possible for users to test baseband and RF with a single analyzer. Since no external harmonic mixers are required, the R&S FSW85 makes the test setup much simpler. An internal preselection suppresses the image frequency and other spurious emissions that commonly occur during harmonic mixing.

The R&S FSW85 can be optionally equipped with an internal analysis bandwidth of 500 MHz, giving developers of radar components a variety of analysis options – particularly for automotive and aerospace and defense applications. When combined with the R&S FSW-B2000 option and an R&S RTO oscilloscope, it is even possible to achieve an analysis bandwidth of 2 GHz, allowing developers to analyze broadband signals for 5G next-generation mobile communications signals or complex pulse parameters and chirp signals for radar systems.

The R&S FSW85 offers easy touchscreen operation with clear diagrams and a flat menu structure. Various measurements can be displayed simultaneously in separate windows on the large 31 cm screen to simplify interpretation of results.

The new high-end R&S FSW85 signal and spectrum analyzer is now available from Rohde & Schwarz. Website: https://www.rohde-schwarz.com/.

Vibration Isolator from Minus K Technology

Minus K Technology, a leading manufacturer of passive vibration isolation products, has just released a compact, high-capacity, low-frequency negative-stiffness isolator designed to support heavy payloads while reducing low-frequency vibrations. The new LC-4 isolator comes in several capacity ranges to match vibration-sensitive instruments such as SPMs, AFMs, STMs, micro-hardness testers, profilers, interferometers, electron microscopes and other imaging systems, for weight loads from 1 to 130 lbs.

The LC-4 comes in two versions (Low Freqency Horizontal, and Ultra-Low frequency Horizontal). Both versions can deliver a vertical natural frequency of 0.5 Hz or less, which can be achieved over the entire load range. Horizontal natural frequency is load dependent. The Low Frequency version has a 1.5 Hz natural frequency, while the Ultra-Low Frequency version can achieve 0.5 Hz or less near the nominal loads.

As with all Minus K isolators, the LC-4 is completely passive, using no air or electricity. The new isolators can be combined into multi-isolator systems to support heavier payloads while taking up very little room themselves (4.75" wide x 4.75" deep x 7" high). The LC-4 isolators can be placed inside OEM equipment as needed enabling the systems to achieve much better isolation.

The LC-4 isolators can be customized to achieve user-specific needs, and can also be made cleanroom or vacuum compatible.

About Minus K Technology, Inc.

Minus K® Technology, Inc. was founded in 1993 to design, manufacture and market state-of-the-art vibration isolation products based on the company's patented negative-stiffness-mechanism technology. Minus K products are used in a broad spectrum of applications including nanotechnology, biological sciences, semiconductors, materials research, zero-g simulation of spacecraft, and high-end audio. The company is an OEM supplier to leading manufacturers of scanning probe microscopes, micro-hardness testers and other vibration-sensitive instruments and equipment. For more information, contact Steve Varma, Minus K Technology, Inc.; 460 Hindry Ave., Unit C, Inglewood, CA 90301; Phone 310-348-9656; Fax 310-348-9638; email stevev@minusk.com; www.minusk.com.

Mensor CPC4000 Industrial Pressure Controller

The CPC4000 Industrial Pressure Controller represents the most recent advancement in an affordable, entry-level pressure controller for the calibration and instrumentation industry.

Key features include:

- Custom pressure ranges from 1 to 3045 psi
- Up to two transducers with auto-ranging
- Barometric reference for emulation
- 0.02% accuracy
- Fast and stable control
- Optional contamination filter

This product features a modern intuitive user interface and a price that will fit your budget. The CPC4000 stands out for its ease of use, versatility and affordability. In addition, custom transducer ranges make it configurable to your specific requirements. Remote communication to a computer is achieved via IEEE-488, RS232, USB, Ethernet or optional WiFi.

The Mensor CPC4000 Industrial Pressure Controller gives the user ultimate control and versatility at an affordable price. It provides an automated way to maintain pressure for calibrating and testing pressure gauges, transducers, transmitters or other pressure sensing instruments.

Motorized Large Spheres

Gooch & Housego Orlando now offers motorized large integrating spheres. Coupled to our high performance OL 770 multi-channel spectroradiometer, they are ideal for IES LM-79 compliant testing of large sources and luminaires. All sphere designs feature innovative baffling and port design for optimal uniform spatial response, are coated with our proprietary Optolon2 coating for broad spectral response, and are built to the highest quality standards for tough production environments. Contact us to learn more about how we can improve your critical product measurement and testing. Optronic Laboratories LLC, DBA Gooch & Housego, 4632 36th Street, Orlando, FL 32811. T: 407-422-3171 E: orlandosales@goochandhousego.com W: www.GHinstruments.com.

Mitutoyo America CNC Coordinate Measuring Machine

Mitutoyo America Corporation announces the release of the latest LEGEX ultra-high accuracy CNC coordinate measuring machine (CMM). The ultra-accurate LEGEX 4 surpasses conventional CMM performance to deliver world-leading accuracy in length measurement of E0,MPE = (0.28+L/1000) µm.

With the unceasing advancement of scientific and industrial technologies and driving demand for significant improvements in high-accuracy manufacturing, Mitutoyo LEGEX meets the needs of a growing number of manufacturers with applications such as ultra-precise molds, components and aspherical lenses in the automotive, aviation and medical instrument industries, and calibration of master gages for research institutes. To meet these increasing needs, Mitutoyo took a fresh approach when it came to accuracy, starting from the elemental technology level and working upward, with the aim of eliminating all possible sources of measurement error.

Key features:

- Sources of static and dynamic error minimized to realize world-leading measurement accuracy of 0.28 µm
- Fixed-bridge structure with moving table
- Base is made from spheroidal graphite (ductile) cast iron in a sealed-structure design to provide high rigidity and vibration-attenuating characteristics
- High-rigidity structure and feed mechanisms increase accuracy and improve cycle times
- Thermally symmetric structure features full covers around the main body to reduce possible impact in ambient temperature changes
- Vibration-dampening unit is standard
- An air server stabilizes the air temperature to 20°C±0.1°C

Mitutoyo Corporation is the world's largest provider of measurement and inspection solutions offering the most complete selection of machines, sensors, systems and services with a line encompassing CMM (Coordinate Measuring Machines), vision, form and finish measuring machines, as well as precision tools & instruments, and metrology data management software. Mitutoyo's nationwide network of Metrology Centers and support operations provides application, calibration, service, repair and educational programs to ensure that our 6,500+ metrology products will deliver measurement solutions for our customers throughout their lifetime.

Website: www.mitutoyo.com.

It's All About Test Points

Michael Schwartz
Cal Lab Solutions, Inc.

Recently, I had a conversation with a lab manager about their lab and how they measure productivity. This really got me to thinking about how we measure productivity in this industry. As in any industry, there are several factors that contribute to overall efficiencies of a calibration lab. But metrology is unique, in that all too often, our inefficiencies decrease our uncertainties—that is a good thing in a world where the lab with the lowest uncertainties is the winner.

But there has to be a tipping point. As we all know from the GUM (Guide to the Expression of Uncertainty in Measurements), it's not feasible to take an infinite number of measurements, so we make a determination related to the time it takes to test the units compared to the uncertainties required. But how do we find that same tipping point when we have to balance out how to measure productivity?

The problem is further complicated when it comes to measuring the productivity and value of our technicians. As in many labs when it's time for the annual review of your technicians, how can you gage their productivity in an unbiased format? Most labs/accounting systems are based on a piece count metric. But this values a physical dimensional technician with a much higher piece count than a comparable RF & Microwave technician.

Now let's add in some automation, where the electrical lab's productivity can be increased as much at 400%. In this environment, a lower skilled technician can simply connect the DUT (Device Under Test) per the instructions and walk away. He can also efficiently run multiple stations at the same time, so depending on the DUTs being tested, the lowest skilled technician in the lab could have the highest piece count.

I remember my team chief, back when I was still in the Army, wanting to do the same thing. I remember having to spend a day or two every couple of weeks calibrating high volume instruments like torque wrenches and micrometers just to get my piece count up. It seemed like a waste of time because we were always behind on the complicated calibrations. So much so, that many times the assistant team chief would set up the cal station, line up all the equipment, then do all the paper work. This minimized the time lost on the longer more complex time consuming calibrations, while at the same time, keep the piece rate up for the technician assigned to that area.

In the Army, we were masters at the paperwork shuffle, but in business we run on metrics. Maximizing efficiencies is a must. Having your best technician spend a day calibrating torque wrenches, just to get his piece count up, would be considered a waste of time. Not that an RF & Microwave technician is above the work; that's not my reasoning here. Unlike in the Army, commercial calibration technicians are paid based on their skill set, not based on their time in service or rank.

How do we balance the scales? (No pun intended!) We need a way to gauge technical skills and productivity. We need a better metric! Something that can highlight a technician's skill level matched to their work performance and how they are doing it (automated or manually). Managers, especially upper managers and Human Resource managers, need a better metric when corporate bureaucracy and pay structures make it impossible to justify getting a valuable technician the raise they deserve.

I think the better metric lies in measurement of test points. They are the great equalizer! At the very least, they can provide us with more details in the metric for gauging a technician's work performance, where simple items tend to have less test points while more complex items tend to have more. By simply counting test points, we can see which technicians perform more tests over the same period of time.

Additionally, each of the test points can be tagged with a complexity metric: values that are designed to show the difficulty of collecting the data for the test point. We can also tag each of the test points with automated vs. manual calibration. We can then weigh human work vs. automation doing the work for the technician. These metrics can be rolled up into an overall report on work performed and the technician performing the work.

To my knowledge, neither this type of metric nor its level of detail has ever been build. Right now, it is only a vision of the future measurement information infrastructure systems, geared towards making metrology more usable. ❧

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