MEASUREMENTS OF TOMORROW

Closing Keynote by Dr. James Kakalios
Author of “The Physics of Superhero.”
Girls Technology Day

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Dear readers, it has been my great pleasure and honor to serve as your President during this amazing year for metrology. Years like this one truly only come once in a lifetime. The experience of being in Versailles for the meeting that redefined the International System of Units (SI) was life changing. And it was made all the more special since I could experience it not only as one of the representatives from the United States, but also as the President of NCSLI International. In the picture you can see that NCSLI was also represented by Georgette Macdonald who is the NCSLI Treasurer.

This was also a big year for our annual conference. It was a pleasure to see so many of you in Portland, Oregon. If you are like me, you found the conference to be a great opportunity to catch up with colleagues, meet with exhibitors and to come away with increased knowledge and strengthened relationships that allow you to improve and succeed in your career. The successes we took from this year’s event in Portland were the expansion of our tutorial program from Sunday to Monday, exceptional keynote speakers, an energetic exhibit hall, and focusing sessions on important issues such as new procedures and practices compliant to ISO/IEC 17025:2017.

On deck, the 2019 NCSLI Technical Exchange is right around the corner from February 25 – 27, 2019 at the Florida Hotel & Conference Center in Orlando, Florida. The Tech Exchange program includes a wide range of engaging tutorials related to many areas of metrology. Register for the Technical Exchange to learn from subject-matter experts in the field of metrology on innovative and cutting-edge content. Through attending these superlative training opportunities, measurement science professionals make their field stronger, better educated, and more updated.

Every year we strive to plan as efficiently and far ahead as possible. As such, our Call for Papers for NCSLI International’s 2019 Cleveland, Ohio conference is already open and awaits your exceptional submissions. Submissions are coming in fast, so make sure to reach the March 31, 2019 deadline in order to receive a discount on your conference registration.

My time with NCSLI International has been full of discovery and excitement. Closing out my presidency with the organization, I would like to thank all the metrological minds one last time who contributed to our mission of providing the best opportunities for the world’s measurement science professionals to network and exchange information, to promote measurement education and skill development and to develop a means to resolve measurement challenges.

Passing the torch to Executive Vice President Dana Leaman, I am confident in the future of NCSLI International and thankful for my experience with the organization.
Welcome New Members

ACCURA CALIBRATION
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Garland TX 75041
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mmartin@accuracal.com
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Accura Calibration is Service-Disabled-Veteran-Owned owned company in the Dallas/Ft. Worth area. We are currently certified by ANAB to ISO/IEC 17025:2005, ANSI/NCSL Z540-1 and ISO/IEC 9001:2008. The owner, Dwight Martin, has over 47 years of experience in the calibration industry, including seven years in the U.S. Army. Accura Calibration currently services prime military contractors, government agencies and various manufacturers. Our metrics on customer satisfaction rates 4.92 out of 5.00. These metrics have been consistent, which is why out motto is “Setting the Standard”. Our custom, calibration-management software is responsive to our customer’s special requirements.

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Cummins Inc., a global power leader, is a corporation of complementary business units that design, manufacture, distribute and service engines and related technologies, including fuel systems, controls, air handling, filtration, emission solutions and electrical power generation systems. Headquartered in Columbus, Indiana, (USA) Cummins employs approximately 46,000 people world-wide and serves customers in 190 countries. Our network extends to more than 600 company-owned and independent distributor locations and approximately 6,500 dealer locations. Cummins earned $1.66 billion on sales of $17.3 billion in 2012.

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Techmaster Electronics is an accredited calibration company that repairs/calibrates all Test, Measurement and Diagnostic test equipment from physical/dimensional to GPTE along with RF test equipment up to and including 50 GHz. We also preform calibrations on antenna’s us to 40 GHz. We are a distributor of Kikusui, Mountz, Megaphase, Xitron, Com Power, Mitutoyo test equipment.

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The first name in materials testing, Tinius Olsen is the leading specialist manufacturer and supplier of static tension and/or compression materials testing machines. Our machines are designed for measuring material’s strength and performance. Using Tinius Olsen equipment it is possible to perform tests on raw materials such as metals, polymers, textiles, rubbers, adhesives, food and other finished components. Our machines are capable of executing a wide variety of tests including tension, shear, compression, flex/bend, puncture/burst, tear, peel and melt flow. Other applications can be found in Charpy and Izod impact, friction, stiffness, heat distortion temperature, Vicat penetration, and torsion. All such tests are designed and implemented by Tinius Olsen in accordance with key international testing standards including ISO, ASTM, EN and other industrial standards.
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Contact: Christine Michels
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www.wuxiapptec.com

WuXi AppTec Group is a leading global pharmaceutical, medical device, open-access capability and technology platform company with global operations. As an innovation-driven and customer-focused company, WuXi AppTec Group provides a broad and integrated portfolio of services to help our worldwide customers and partners shorten the discovery and development time and lower the cost of drug and medical device R&D through cost-effective and efficient solutions. With its industry-leading capabilities in small molecule R&D and manufacturing, cell therapy and gene therapy R&D and manufacturing, and medical device testing, WuXi platform is enabling more than 3,000 innovative collaborators from more than 30 countries to bring innovative healthcare products to patients, and to fulfill WuXi AppTec Group’s dream that “every drug can be made, and every disease can be treated.”

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Production Sites: Five state-of-the-art manufacturing facilities located in: Denmark, Hungary, China and in the U.S. Xellia's Finished Dosage Form facilities are in Denmark and the U.S. Expertise: Xellia has over 100 years' experience in the development, manufacture and supply of generic fermented and semi-synthetic Active Pharmaceutical Ingredients (APIs) and Finished Dosage Forms (FDFs). Xellia is the leading supplier of important anti-infectives Vancomycin and Colistimethate Sodium (CMS). Customers: Xellia’s generic anti-infective business is built to meet the immediate and long-term requirements of our customers comprising branded, specialty and generic pharmaceutical companies in more than 70 countries around the world. Innovation: Xellia is developing novel antibiotics effective against resistant species in partnership with SINTEF Materials and Chemistry and the Statens Serum Institut of Denmark, supported by a grant from the Research Council of Norway. Compliance: We operate according to current Good Manufacturing Practice (cGMP) and our facilities have received regulatory approval from all relevant authorities, including the U.S. Food and Drug Administration (FDA).

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Join Us for Three Days of Measurement Training Conducted by Experts in the Field of Metrology!

The NCSLI Technical Exchange will build and enhance specific hands-on skills in the calibration of measurement and test equipment. This three-day training will also teach best practices along with introducing new and innovative calibration hardware, software and calibration services. Each training session is taught by measurement science experts from throughout the industry.

### PRICING AND REGISTRATION

<table>
<thead>
<tr>
<th>Training</th>
<th>Member</th>
<th>Non-Member</th>
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<tr>
<td>1/2-Day Course (4 hours)</td>
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<td>1-Day Course (8 hours)</td>
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<tr>
<td>2-Day Course (16 hours)</td>
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**Registration Includes:**
- Monday Evening Reception, Materials Bag, Continental Breakfast, Lunch and Expert Measurement Training for that day!

**Discounts:**
- 10% discount when registering 3 or more attendees from your company. Must call the NCSLI Business office at 303-440-3339 to register and receive discount.
- Non-Members: Join NCSL International and receive member pricing on your Technical Exchange registration.

Visit NCSLI.ORG for more information.

NCSL INTERNATIONAL  | 303-440-3339  | NCSLI.ORG
5766 CENTRAL AVENUE, SUITE 150  | BOULDER, COLORADO 80301
2019 TECHNICAL EXCHANGE HOTEL INFORMATION
The Florida Hotel & Conference Center
1500 Sand Lake Road, Orlando, FL 32809

NCSL International
Room Rate: $149
Room Rate Ends January 31
Call for Reservations:
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THANK YOU 2019 SPONSORS & EXHIBITORS

TABLETOP EXHIBITS AND SPONSORSHIPS AVAILABLE

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The American Association for Laboratory Accreditation (A2LA) provides methods for evaluating the traceability of GPS disciplined oscillators (GPSDOs) or GPS disciplined clocks (GPSDCs). It explains why GPS time is traceable to the Universal Time (UTC) time scale maintained by the United States Naval Observatory (USNO). Despite their excellent performance, it can be difficult to evaluate their uncertainty, and even more difficult for skeptical laboratory assessors. This tutorial is for metrologists to prove their claims of uncertainty and traceability for bench or floor weighing instruments. We will cover overcoming potential errors and optimize a balance metrology regime.

**TE-2 | February 25**
8:00 AM - 5:00 PM | 1-Day (8 hours)
**Time and Frequency Measurements Using GPS**
Instructor: Michael Lombardi, National Institute of Standards and Technology (NIST)
Global Positioning System (GPS) disciplined oscillators and clocks serve as standards of frequency and time in numerous calibration and metrology laboratories. These devices are inherently accurate sources of both frequency and time because they are adjusted via the GPS satellites to agree with the Coordinated Universal Time (UTC) time scale maintained by the United States Naval Observatory (USNO). Despite their excellent performance, it can be difficult to evaluate their uncertainty, and even more difficult for metrologists to prove their claims of uncertainty and traceability to skeptical laboratory assessors. This tutorial is for metrologists and laboratory assessors who work with GPS disciplined oscillators (GPSDOs) or GPS disciplined clocks (GPSDCs). It describes the relationship between GPS time and Coordinated Universal Time (UTC), explains why GPS time is traceable to the International System (SI), and provides methods for evaluating the frequency and time uncertainty of signals produced by a GPSDO or GPSDC.

**TE-4 | February 25**
8:00 AM - 5:00 PM | 1-Day (8 hours)
**Measurement Uncertainty: Best Practices**
Instructor: Dilip Shah, E = mc3 Solutions
Besides a requirement for ISO/IEC 17025, measurement uncertainty evaluation is a requirement to support metrological traceability claims. There are many ways to evaluate and estimate measurement uncertainty. This workshop takes the attendee through the measurement uncertainty evaluation process that is described in the ISO Guide to the Uncertainty of Measurement (GUM) in a step by step, best practices approach. This way, the measurement uncertainty budget that is developed is easy to explain and defend to the accrediting body and the customer.

**TE-5 | February 25**
8:00 AM - 5:00 PM | 1-Day (8 hours)
**Internal Auditing of your ISO/IEC 17025 Accredited Laboratory**
Instructor: Helga Alexander, International Accreditation Service (IAS)
This tutorial examines auditing principles and techniques and facilitates the practice of required internal audit skills. It is based on internationally recognized approaches to conducting conformance internal audits. The techniques learned by participants promote the involvement of all types of staff as auditors and auditees. The course includes easy-to-implement methods for risk based thinking, continual improvement, and closing out findings through the analysis of root causes aimed at their elimination.
TECHNICAL EXCHANGE MEASUREMENT TRAINING PROGRAM

TE-6 | February 25
8:00 AM - 5:00 PM | 1-Day (8 hours)
AC Measurements and Measurement Parasites Particular to AC
Instructor: Mark Evans, Guildline Instruments
This eight-hour hands-on course covering AC current measurements including sources, shunts, Current Transformers (CTs) and associated measurement setups. The focus will be on measuring AC current in various applications including power, precision, and high-frequency measurements. The course will cover the theoretical background and practical aspects of AC measurement setups.

TE-7 | February 25 & 26
8:00 AM - 5:00 PM | 2-Day (16 hours)
Flow Measurement and Uncertainties
Instructor: Dr. John Wright, National Institute of Standards and Technology (NIST)
We will cover background metrology and fluid mechanics subjects that are important for flow measurement including:
- The transition from laminar to turbulent flow
- Pipe flow profiles and boundary layer concepts
- The continuity equation and conservation of mass
- Fluid and gas properties and their calculation
- Pressure and temperature measurement
The operating principles and equation of flow for the commonly used flow measurement techniques will be derived and explained including:
- Differential pressure devices (laminar flow meters, orifice plates, venturi tubes)
- Critical flow venturis and nozzles
- Ultrasonic flow meters
- Turbine and positive displacement meters
- Electromagnetic flow meters
- Coriolis flow meters
- Thermal meters
- Rotameters
Methods of flow meter calibration used in laboratory, including NIST standards, will be covered. Field conditions will be discussed as well as installation effects and how distorted velocity profiles affect flowmeter accuracy. Flow calculations and uncertainty analyses for certain flow meter types will be taught. Our goal is to cover topics with a range of physics and mathematical difficulty so that the course will be of interest to students with a wide range of mathematical backgrounds and flowmeter experience. Distributed throughout the course, there will be optional, advanced sections of interest to only extreme flow geeks.

TE-8 | February 25 & 26
8:00 AM - 5:00 PM | 2-Day (16 hours)
Selection, Calibration, and Use of Contact Thermometers
Instructors: Dawn Cross and Karen Garrity, National Institute of Standards and Technology (NIST)
In this course, we will discuss contact thermometers commonly used in industry for applications that use platinum resistance thermometers, thermistors, thermocouples and digital thermometers. You will learn how to make and use an ice melting point, calibrate a digital thermometer using a dry well block, and wiring thermocouples for measurements.

TE-9 | February 26
8:00 AM - 5:00 PM | 1-Day (8 hours)
ISO/IEC 17025:2017 Gap in Spanish
Instructor: Marcella Shkolnik, American Association for Laboratory Accreditation (A2LA)
Este curso consiste en un resumen de un día de los cambios realizados a el ISO/IEC 17025 en su última revisión. En este curso, el estudiante se dará cuenta de los cambios significativos y sutiles a los sistemas de laboratorio existentes ISO/IEC 17025, así como los pasos necesarios para garantizar la conformidad con la nueva versión de la norma.

TE-10 | February 26
8:00 AM - 5:00 PM | 1-Day (8 hours)
Introduction to Calibrating RF Power Meters
Instructors: Andrew Brush and Greg Tolentino, Tegam Inc.
Measurement of RF and microwave power, from milliwatts to kilowatts, at frequencies from a few kHz to over 100 GHz, is critical to industries as diverse as communication and semiconductor manufacturing. This class will explore the traceable calibration of all types of wattmeters. The characteristics and uncertainty of the various primary standards will be covered, and the process and measurements involved in transferring from primary standards to industrial wattmeters will be covered. After reviewing basic power transfer, examples in both low power (below 100 mW) and high power (up to several kW) will be presented.

VISIT NCSLI.ORG FOR UPDATES AND CURRENT INFORMATION
TECHNICAL EXCHANGE MEASUREMENT TRAINING PROGRAM

TE-11 | February 26
8:00 AM - 12:00 PM | 1/2-Day (4 hours)
Industrial Pressure Calibration and Measurements
Instructor: Dallen Baugh, Additel Corporation
This course will provide an introduction to basic pressure calibration and measurement. We will cover considerations when making pressure measurements and calibrations. Some of these considerations include a discussion on different pressure types such as gauge, absolute, compound, differential, negative gauge, and vacuum. We will also cover requirements for field calibration, uncertainties associated with field calibration, errors relating to temperature effects and different methods of calibration. In addition to pressure calibration and measurement theory, this course will also include a hands-on work shop where various methods of pressure calibration are tried and experienced.

TE-12 | February 26
1:00 PM - 5:00 PM | 1/2-Day (4 hours)
Dynamic Sensors and Calibration
Instructor: Patrick Timmons, The Modal Shop
Vibration calibration class will dive into calibration theory, standards, and methodology for dynamic sensors as well as explanations of different sensor types and the operational theories behind them. Target audience is beginner to intermediate level.

TE-13 | February 26
1:00 PM - 5:00 PM | 1/2-Day (4 hours)
Theory and Operation of Dry-Block Temperature Calibrators
Instructor: Scott Crone, Ametek
This course will describe the construction, evolution, and practical use of dry-block temperature calibrators. This will include the basic design, the added features that are bringing later generations closer to the precision of calibration baths, and how they should be used as well as common misuses.

TE-14 | February 26 & 27
8:00 AM - 5:00 PM | 2-Day (16 hours)
Dimensional Metrology Hands-On Workshop
Instructors: Dr. Ted Doiron and Eric Stanfield, National Institute of Standards and Technology (NIST)
The basic principles of dimensional metrology are the same for nearly every calibration made in typical labs. This workshop teaches these principles through guided hands-on characterization of the most typical dimensional measurement instrument, the Universal Length Measuring Machine.

TE-15 | February 26 & 27
8:00 AM - 5:00 PM | 2-Day (16 hours)
Decision Rules: Reducing Risk in Conformance Decisions
Instructor: Scott Mimbs, Sponsored by American Association for Laboratory Accreditation (A2LA)
This two-day course provides the information needed to evaluate the decision risk for measurements used in conformity assessments and to develop decision-rules that mitigate the risks. The technical and mathematical details are based on International standards and internationally accepted practices. There is a focus on metrology’s influence throughout a product’s lifecycle, and where key elements reside within the Quality Management System (QMS), specifically ISO 9001:2015, AS9100D, and ISO 13485:2016. This course provides the information to meet the decision rule requirements found in ISO/IEC 17025:2017 and the 2% risk requirements of ANSI/NCSL 2540.3-2006.

TE-16 | February 26 & 27
8:00 AM - 5:00 PM | 2-Day (16 hours)
The NIST Uncertainty Machine and the NIST Consensus Builder
Instructor: Antonio Possolo PhD, National Institute of Standards and Technology (NIST)
The NIST Uncertainty Machine (NUM) and the NIST Consensus Builder (NICOB) are web-based applications accessible worldwide via any internet browser. The NUM provides a user-friendly interface to uncertainty analysis for measurement models of the type described in the GUM (“Guide to the Expression of Uncertainty in Measurement”), using the GUM approach and the Monte Carlo method of the GUM Supplement 1. The NICOB provides a user-friendly interface for the analysis and reduction of measurement results obtained in interlaboratory studies, including key comparisons: computation of consensus values, characterization of associated uncertainty, evaluations of reproducibility, and degrees of equivalence. This course will provide a hands-on familiarization with the NUM and with the NICOB, using concrete examples and real data from a wide range of fields of measurement science, and will also give the participants sufficient background and guidelines to empower them to make the particular choices needed to apply these tools thoughtfully and appropriately. The participants will have the opportunity to apply these tools also to their own data during the course, and to share their experiences while doing so. The participants are expected to have general familiarity with the basic notions and methods of uncertainty analysis as are explained in the GUM (or in NIST Technical Notes 1297 and 1900), but do not need to possess specialized knowledge of probabilistic or statistical methods.
We do hands-on calibration of torque wrenches and discuss other types of torque instruments: pressure and temperature on relative humidity will be explored including key terms, formulas and parameters. The effect of pressure and temperature on relative humidity will be covered. The science behind humidity measurement will be covered including key terms, formulas and parameters. The effect of pressure and temperature on relative humidity will be explored using the psychrometric chart as a tool as well as available calculators. Selecting the appropriate measurement technology for various applications will be covered, looking at the key advantages, disadvantages and principles of operation of some of the more common measuring technologies. A closer look at instrument specifications will highlight the different components of the instrument specification and how they relate to the overall instrument performance which is can be significantly different than the accuracy specification.

TE-17 | February 27
8:00 AM - 5:00 PM | 1-Day (8 hours)
Geometric Dimensioning and Tolerancing (GD&T):
Application to Gage Calibration Requirements
Instructor: E.A. "Tony" Bryce, Sandia National Laboratories
The course will cover, related to gage design, symbol interpretation, feature control frames, datums and datum reference frames (DRF), material conditions (MMC & LMC), positional tolerancing, profile tolerancing, orientation (parallelism, angularity and perpendicularity), profile tolerancing. Determination of feature virtual condition boundaries will also be covered. This course is based on ASME Y14.43 Dimensioning and Tolerancing Principles for Gages and Fixtures and the ASME Y14.5 Dimensioning and Tolerancing Principles. Gaging principles will be applied to both functional hard gages as well as CAD based soft gaging applications. This course is suitable for those individuals needing a basic understanding of the concepts related to drawing and CAD model definition. Please note that course participants should be very familiar with 2D engineering drawings.

TE-19 | February 27
8:00 AM - 5:00 PM | 1-Day (8 hours)
Fundamentals of Humidity Measurement
Instructor: Mike Boetzkes, Sponsored by Rotronic
The science behind humidity measurement will be covered including key terms, formulas and parameters. The effect of pressure and temperature on relative humidity will be explored using the psychrometric chart as a tool as well as available calculators. Selecting the appropriate measurement technology for various applications will be covered, looking at the key advantages, disadvantages and principles of operation of some of the more common measuring technologies. A closer look at instrument specifications will highlight the different components of the instrument specification and how they relate to the overall instrument performance which is can be significantly different than the accuracy specification.

TE-20 | February 27
8:00 AM - 5:00 PM | 1-Day (8 hours) | Forum East 2
Active Asset Management
Instructor: James Smith, The Boeing Company
Are you getting bang for the buck? Are your assets making you money, lowering your cost of business, utilized efficiently or are they idle, underused, are you emotionally attached to them, are they costing you in non-recuperated expenses? This course will focus on the increased value a company can realize by taking proactive life cycle management approaches in the ownership and utilization of laboratory assets and facilities. By striving to focus on value orientated uses of capital and expense items, related utilization and visibility of equipment life-cycles, your business will see significant increases on "Return on Investment" (ROI). New lab, new management, merged or acquired? Do you want to avoid creating the culture that has driven so many others to poor performance, failure, bankruptcy and loss of business? Stop managing your assets at arm's length using decades old mental models. Instill forward thinking processes based on proven methods and results, stop sub-optimizing your operational budgets, attend and gather lessons learned from others who battled these challenges and came out better for it.

TE-21 | February 27
8:00 AM - 5:00 PM | 1-Day (8 hours)
Applying Risk Management Tools to Make Business Decisions
Instructor: Tim Osborne, American Association for Laboratory Accreditation (A2LA)
This course introduces the participants to risk-based thinking from a business perspective using principles from ISO 9001:2015, ISO 31000:2018 and the risk management tools from industry as they apply to an ISO/IEC 17025:2017 laboratory. The participants will briefly review how ISO/IEC 17025:2017 manages risk for the laboratory and where the Standard gives the laboratory liberties to manage its own risk. Using provided scenarios experienced in an ISO/IEC 17025 laboratory and self-determined risk appetites of the team, participants will learn how to apply the fundamentals of risk management when evaluating new opportunities as well as improving established processes using a 1D, 2D and 3D approach. Students will then consider levels of mitigation vs. cost implications when evaluating opportunities and process improvements.

TE-22 | February 27
8:00 AM - 12:00 PM | 1/2-Day (4 hours)
Understanding Pass/Fail Measurement Decision Risk and How to Comply with ISO/IEC 17025:2017
Instructor: Jonathan Harben, Keysight Technologies
This tutorial will cover: What is measurement decision risk? Specific vs. global (average) risk, when to use each type, techniques for estimating approximate percent risk, inputs needed, tables and figures to interpolate, importance of considering both false accept and false reject risk, level of risk associated with several common decision rules in use today, guidance flowchart for general selection of appropriate decision rules, class examples, and class exercises.
Welcome everyone, we hosted our Annual Conference in Portland, Oregon, from August 25-29, 2018, at the Portland Convention Center. NCSLI would like to thank all 705 measurement science professionals that joined together as attendees, sponsors, exhibitors, tutorial instructors, speakers, staff, guests and volunteers for a wonderful week of edification, collaboration and interactions supporting our goal in promoting metrology education.

Conference sponsorships play a big role and are vital to the success of our Annual Conference. We would like to extend a heart-felt “thank you” to our 2018 sponsors for their continued support and commitment to making our conference the best ever. This year’s Platinum Sponsors: Keysight Technologies and Transcat. Gold Sponsors: Additel Corporation; American Association for Laboratory Accreditation, A2LA; Fluke Calibration and Simco Electronics. Silver Sponsors: The Boeing Company,
Mensor Corporation and Precision Environments. Media Sponsor: Quality Magazine. We are currently working on new sponsorship concepts and ideas in 2019. If your organization would like to sponsor an event in Cleveland, Ohio, reach out and share your ideas with us.

At the beginning of our conference is our annual Tutorial Program which ran from Saturday, August 25 through Monday, August 27. In Portland NCSLI offered 33 focused and intensive tutorial courses, supporting 350 course registrations! We had an excellent program and turnout this year. Attendees gave their full attention to the expert training and opportunities to level up their skills, share ideas and find the talent with people who speak their language and understand their challenges. Attendees and instructors alike, took the time to reunite with old friends and colleagues, cultivate new leads, and to reinforce their dedication to helping one another.

On Monday we had 87 exhibiting companies move-in and prepare for our three-day tradeshow and the Monday evening Exhibitor Welcome Reception. The exhibitors always provide our conference with such exceptional value and worth. When asked, our exhibitors often state that they continue to participate in our tradeshow and tradeshows in general, to raise awareness of their company and its brand. When dealing with a niche audience (like ours) attending events show customers the human side of your business forming an emotional connection which builds brand loyalty. The power of face to face will never be matched when it comes to; interactions with existing customers, key customers and prospective customers. Above all else, exhibitors provide value to the attendees as attendees provide value to the exhibitors. As they both educate us on the tried-and-true, and state of-the-art products, services, and industry standards being offered today.

The highlights of the Monday Awards Reception featured our Education and Training Award winner, Jesse Morse! The Best Paper Awards were presented to Michael Rusnack, AmericanPharma; Nicholas Vlajic PhD, NIST and James Salsbury PhD, Mitutoyo Corporation. Tom Hutteman was awarded for his outstanding contributions to NCSLI and our region and section coordinators were recognized for their outstanding meetings and training events throughout the year.
Tuesday’s general session welcomed keynote speaker Dr. Barry Wood, National Research Council Canada (NRC). Dr. Wood presented a brilliant talk on “The Revised SI – A Change That’s Worth the Weight.” The NCSLI Wildhack Award was also announced on Tuesday and this year was awarded to Dr. Richard Davis, BIPM!

Our technical program offered attendees 78 excellent oral presentations from Tuesday, August 28 - Thursday, August 30. In addition, 30 very informative posters were presented in the exhibit hall on Tuesday and Wednesday. Thank you speakers for your amazing contributions!

On Wednesday Dr. Gregory Strouse, National Institute of Standards and Technology, NIST started our day delivering a robust presentation on the "Democratization of the SI through Quantum SI Technologies." Thursday closing keynote speaker; Dr. James Kakalios, Professor in the University of Minnesota’s School of Physics and Astronomy, and author of "The Physics of Superheros," and other books you should check out, gave us a very interesting and enjoyable presentation.

In addition to the technical sessions and poster presentations, more than 18 NCSLI committees and working groups met in the early mornings, late afternoon and evenings to review, update, improve and discuss NCSLI Technical Publications — making for very busy days.
Lastly, we would like to thank Tektronix for a very interesting and enjoyable Lab Tour offered to our conference attendees on Friday.

NCSL International will head to the Huntington Convention Center in Cleveland, Ohio from August 24-29, 2019. Call for Papers is open, and we encourage everyone to submit a tutorial, oral presentation or poster presentation! We look forward to seeing you in Cleveland as we define “Metrology in Motion.”
The Revised SI—A Change That’s Worth the Weight

We were very pleased to have Dr. Barry Wood, National Research Council, Canada, as our opening keynote speaker on Tuesday morning. Dr. Wood detailed how we will all embark on the most fundamental change to our SI measurement system in living memory. And that the international initiative is the result of decades of negotiations and associated metrological advancements and finally, implements the century old advice of such scientific giants as Gauss, Maxwell and Planck. He then delineated the origins and evolution of our measurement system, the SI, and described the revised SI, its ties to fundamental constants, and the impact of these changes.
Democratization of the SI through Quantum SI Technologies

On Wednesday Dr. Gregory Strouse, NIST, delivered our morning keynote on the “Democratization of the SI through Quantum SI Technologies.” Dr. Strouse spoke about how the SI redefinition, on May 20, 2019 will create the opportunity for NIST to disrupt the dissemination of the SI and how they are working to eliminate the reliance on artifact-based traceability to the SI through a National Measurement Institute (NMI) such as NIST. He spoke about how NIST is creating new Quantum SI technologies, by leveraging the SI redefinition to that of quantum phenomena and fundamental constants of nature. And how through this effort, the Quantum SI will redefine what traceability means to mainstream measurement capabilities in industry. Deployment of multifunction Quantum SI devices on a NIST-on-a-Chip (NoaC) platform creates an innovative and visionary approach to solving measurement needs in metrology and technology applications, essentially giving stakeholders the chance to have direct and automatic traceability in their labs. Additionally, he said the business model of relying on an NMI to calibrate artifacts to initiate SI traceability will be phased out. By creating a ubiquitous quantum SI environment, which will enable NIST to focus on new metrology frontiers and solve challenging science problems, while maintaining measurement expertise to support the metrology community.
We ended our week of measurement education with Dr. James Kakalios, Professor in the University of Minnesota’s School of Physics and Astronomy. He is the author of “The Physics of Super Heroes,” “The Amazing Story of Quantum Mechanics” and “The Physics of Everyday Things.” Dr. Kakalios provided an extremely exciting, fun and entertaining presentation!

“As a kid, comic books helped fuel my curiosity,” says James Kakalios. More importantly, his childhood interest in science was cultivated by comic books and superheroes, especially the scientist superheroes. In comic books,
James found enjoyment in seeing superheroes use science and creative problem-solving to defeat villains and save the day.

When James was just starting high school, he had started to lose interest in science because he didn’t know if his abilities were strong enough. Initially, his high school math teacher inspired him to consider a career in patent law. While looking through the classes that he would need in college, James realized that he was more interested in the engineering classes than the pre-law classes and so he majored in engineering. But, after working in a physics lab, he came to like physics more and so he changed his major to physics.

James teaches and does research when he’s not consulting for movies. At the University of Minnesota, he has developed a research program in experimental condensed matter physics with projects ranging from nanocrystals to applications in neuroscience to solar cells. More importantly, much of his research is interdisciplinary as he works with mechanical engineers, biomedical engineers, and neuroscientists.

As Hollywood comes out with more science fiction movies and superhero movies, many directors have opted for more accurate movies featuring real science knowledge which requires consulting actual scientists. James is one of those scientists and he has consulted for Watchmen and Amazing Spider-Man.

The real science knowledge that he provides has made these movies much more scientifically correct and may help attract more of the younger generations into the field of physics. In addition to giving accurate science language and details, James also gives some science insight to the design teams when it comes to the visual effects.

Some of his scientific contributions to science fiction movies may seem like small details, but these small details keep the audience engaged and may even get them interested in some real science. The most important thing is getting the students to ask the right kinds of questions. “If a character has wings on her back, what important physical forces and issues do we need to consider if she’s going to use them to fly? What kind of wingspan and muscle structure would that require? Hopefully, pointing out issues like these will help students think critically in other situations,” says James.

He uses comic books to explore the basic laws of physics and brings science to a younger audience. All of James’s books are written in an accessible language that allows anyone and everyone to get a little bit of physics knowledge and learn some interesting things in physics.

Not only does James believe that he can spark an interest in science within students, but he also believes that the general public also has a genuine interest. With about 1.8 million views for his YouTube video that talks about the science in Watchmen, James is sure that the public is interested in learning about science phenomena.

He supports developing the public’s interest through science outreach that doesn’t talk down to the audience, but rather in an intriguing way and allows the audience to connect.

James’s search for science in comic books and consultations for sci-fi movies shows that it can be found in art, movies, and things we encounter every day. With science having applications in many different things, there’s bound to be something that will interest you and will have a scientific explanation behind it.
CONFERENCE REVIEW

NMI TALKS

Dr. James Olthoff, NIST.

Dr. Alan Steele, NRC Canada.

Jennifer Romero Parrado, INM Colombia.

Dr. Walter Copan, Director, NIST.

Dr. Takashi Usuda, NMIJ/AIST.

NMI Presentations

- BPM
- Colombia
- Mexico
- Hong Kong
- Japan
- United Kingdom
- Canada
- USA
- INM de Colombia
- CENAM
- SCL
- NMI
- NPL
- NRC
- NIST

2018 NCSL INTERNATIONAL WORKSHOP & SYMPOSIUM
CONFERENCE REVIEW

NMI TALKS

Dr. Theodoor “JT” Janssen, NPL.

Dr. Terry Hau Wah Lai.

Dr. Salvador Echeverria-Villagomez, CENAM.

Andy Henson, BIPM.

NCSLI.ORG | OCTOBER 2018
AWARDS RECEPTION

Tom Hutteman PhD, Retired Kodak and NCSLI Meeting Planner.

Mike Duncan and Mark Lapinskes.

Bill Miller and Mike Schwartz.

Wesley Thompson and Tony Reed.

Sharon and Tom Hutteman.

2018 NCSL INTERNATIONAL WORKSHOP & SYMPOSIUM
**BEST PAPER AWARDS**

Michael R. Rusnack  
(Overall Best Paper)  
AmericanPharma Technologies  
“Accurate Temperature Representation of Stored Goods using an Algorithm as a Replacement to a Physical Buffer”

Dr. Nicholas Vlajic  
National Institute of Standards and Technology (NIST)  
“Fundamentals of Dynamic Force Metrology”

James G. Salsbury PhD  
Mitutoyo America Corporation  

Award presented by Jorge Martins, NCSLI Technical Program chair.
Dana Leaman, NCSLI Executive VP had the pleasure to announce the 2018 William A. Wildhack Award winner at the conference open general session on Tuesday. This award is the highest honor awarded by NCSL International to an individual in recognition for outstanding contributions to the field of metrology and measurement science. The award consists of a commemorative medallion and an honorarium. This year eight nominee submissions were reviewed in accordance with the NCSLI administrative procedure for this award and it was awarded to Dr. Richard Davis. Dr. Davis was not able to attend but that didn’t affect the overall excitement and appreciation this man holds to many.

About Dr. Richard Davis

Dr. Davis has been, to many metrologists worldwide known as “Mr Mass” in his role as leader of the Mass standard group at the BIPM (International Bureau of Weights and Measures). Richard took this post at the BIPM after an extensive research career at the National Institute of Standards and Technology, NIST.

Dr. Davis’s research was not limited to only mass measurement. His research in electrochemistry and the density of air enabled insights into a more precise formulation of the air density formula (the modified Edlen equation) and so to improved precision and accuracy in mass measurements. He also developed a unique magnetic susceptibility measuring instrument which enables more accurate values for the magnetic characteristics of the stainless-steel weights used as the work-horse of mass measurements worldwide.

Dr. Davis has also been central to the development of our current understanding of mass standards and balances. As “Keeper of the Kilogram,” his custodianship of the International Prototype Kilogram and his extensive and influential work on its proposed redefinition, have led to world-wide confidence in the realization of the new definition and its future dissemination. He played a key role in the building of the BIPM’s Kibble (Watt) balance and he has been instrumental in the construction of other Kibble balances used in NMIs which have contributed to the crucial measurements of the Planck Constant, which are soon to be at the heart of the new definition. Congratulation Dr. Davis!
Another exciting award is our Education and Training Award, which was presented to Jesse Morse.

Jesse has brought a wealth of experience and knowledge to focus in calibration-related metrology courses and training tutorials across North America. Jesse was instrumental in the formation of NCSLI publications, NCSLI Measure and Metrologist. Jesse authored many other articles for NCSLI and co-authored the ANSI/NCSL Z540.1 Handbook. He was also a strong contributor to the Calibration: Philosophy in Practice book, by Fluke Corporation which has provided training to thousands of metrologists and is a part of nearly every calibration laboratory’s library.

Jesse started working at Fluke Corporation in 1969 after completion of duties in the U.S. Air Force, as a service center manager in the southeastern United States. In 1979, Jesse relocated to Everett, Washington and started performing training activities for Fluke.

Jesse’s career at Fluke spanned over 40 years where he has developed and continues to teach Fluke’s Calibration Lab Management course and the Advanced Hands-on Metrology course with excellent reviews. He has conducted many tutorials at NCSLI over the years, training hundreds of metrologists in electrical metrology theory and laboratory management. He also provides various other training courses under his company name, Morse Metrology. Congratulations Jesse!
TUTORIAL PROGRAM

Henry Zumbrun, Morehouse Instruments.  
Tony Kowalski, Sartorius.

Mark Evans, Guideline Instruments.  
James Salsbury PhD, Mitutoyo.

Karen Garrity, NIST.  
Antonio Possolo PhD, NIST.

James Smith, The Boeing Company.
TUTORIAL PROGRAM

Jonathan Harben, Keysight.

Michael Lombardi, NIST.

Jim Pronge, Ametek.

Michael Boetzkes, Consultant, Sponsored by Rotronic.

Walter Nowocin, Medtronic Inc.

Ken Futomick, Tektronix, Inc.

Dr. Malcolm Smith, WesCan Calibration Services.

Jeff Gust, Fluke.

Trevor Thompson, UKAS.
CONFERENCE REVIEW

TECHNICAL PROGRAM

Guy Robinson, Tektronix.

Steven Dwyer, Naval Surface Warfare Center.

Michael Lombardi, NIST.

James Salsbury PhD, Mitutoyo.

Mike Imholte, Boston Scientific.

Kevin Abercrombie, Naval Air Warfare Center.

Dr. Dennis Dubro, Metrology Consultant.

Dr. Nobu-Hisa Kaneko, NMIJ/AIST.

Patrick Abbott, NIST.
TECHNICAL PROGRAM

Edward Mulhern, NIST.
Jay Hendricks, NIST.
Dr. Terry Hau Wah Lai, Innovation and Technology Commission.

Dr. Samuel P. Benz, NIST.
Jennifer Fleenor, Tektronix.
Branislav Djokic PhD, NRC.
Dr. Zhaoyu Wang, DWFritz.

Mark Kuster, Pantex.
Paul Reese, Abbvie.
Tim Vonderhaar, Precision Environments.
Collin Delker PhD, Sandia National Laboratories.

Al Tartaglino, Pratt & Whitney.
Dawn Cross, NIST.

Michael Dobbert, Keysight Technologies.
Steve Sidney, NLA.
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TECHNICAL PROGRAM

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NCSLI COMMITTEES

2018 NCSL INTERNATIONAL WORKSHOP & SYMPOSIUM
NCSLI COMMITTEES

MEASUREMENTS OF TOMORROW
Measurement Science Professionals
Please submit your abstracts! We have a wonderful opportunity for you to present at the 2019 NCSL International Workshop & Symposium. The NCSL International Technical Program Committee welcomes papers from practitioners and researchers in the field of measurement science including: engineers, metrologists, scientists, technicians, young professionals, old professionals, laboratory managers, quality managers, statisticians, lab assessors, technical writers and all measurement science professionals!

Abstract deadline March 31, 2019
Abstracts are required for all proposed presentation types; oral presentations, poster presentations, panels etc.

Manuscript deadline May 20, 2019
All papers received by the manuscript deadline will be included in the NCSL International Conference Proceedings.

Speaker Discounts
• All speakers who upload their abstract by the March 31, 2019 deadline (and are accepted) will receive a $150 discount off registration.
• All speakers who upload their manuscript by the May 20, 2019 deadline will receive a $400 discount off registration.
• All deadlines must be met to receive the maximum speaker registration discount of $550.

Best Paper Awards
The “Best Paper” awards will be presented to the top highest scored papers. The overall Best Paper will be awarded to the paper with the highest point total. All deadlines must be met to qualify for the Best Paper Award.

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2018 GIRLS TECHNOLOGY DAY
THE STEM EXPERIENCE

William Hinton
Hinton Technical Services, LLC
New Hampshire Metrology Ambassador

The New Hampshire Department of Education (DOE) in conjunction with the Community College System of New Hampshire (CCSNH), local industry and high technology partners again assembled to reach out to New Hampshire girls in the 9th and 10th grades. We learned through experience that many of the schools do not limit the grades that attend, resulting in girls from grades nine through twelve participating in these events. Attendance is limited only by the allowed quota for the attending school.

This year included four venues across the state for the annual Girls Technology Day events. Locations included Manchester Community College (MCC), New Hampshire Technical Institute (NHTI), the University of New Hampshire (UNH) and a new location on the campus of Hypertherm in Lebanon, New Hampshire.
More than 900 students were registered for the four events. However, mother nature was the biggest barrier this year with a two-day snow storm resulting in the cancellation of the events at NHTI and UNH. NHTI and UNH host the event locations that our NCSL International metrology team supports every year. However, two members of our team were able to attend the events at Manchester Community College in Manchester, New Hampshire and the final event at Hypertherm in Lebanon, New Hampshire as sponsors and observers. The team was able to arrange an ad hoc event at the RW Creteau Technology Center on the campus of the Spaulding High School, in Rochester, NH in late May.
KEYNOTES
The event at Manchester Community College began with an attendee welcome and introduction by Dr. Susan Huard, the president of the school followed by a keynote address presented by Allison Labore. Allison is a Systems Analyst at Fidelity Investments, a multinational financial corporation based in Boston, MA. Allison is a graduate of the University of New Hampshire, with a BS in Applied Mathematics with the Economics option and a minor in Information Technology. Enjoy her talk on Vimeo (https://vimeo.com/260840266).

“All it’s never too early to get girls exposed to and excited about STEM fields. The more they learn, the likelier they are to find something that sparks their passion.”
- Allison Labore

The event at Hypertherm began with an attendee welcome and presentation of the schedule for the day’s activities by Stacey Chiocchio, Hypertherm’s Community Citizenship Manager. The Hypertherm keynote speaker was Jenny Levy, Vice President of Corporate Social Responsibility at Hypertherm. Jenny is a graduate of Dartmouth College – The Tuck School of Business at Dartmouth. Listen to Jenny’s student engagement on Vimeo (https://vimeo.com/276623370).

“The more diverse a team is, the more successful that team becomes.”
- Jenny Levy
OUR 2018 TEAM

Our team changed this year due to normal growth of people’s careers and the growth of the Girl’s Technology Day events. The team included William Hinton (NCSLI/NextEra Energy Retiree); Gary Confalone and Michael Divito (ECM Global Solutions); Dana Wilson (Turbocam Level III NDT); Reed Brockman (AECOM Civil Engineer and Massachusetts state bridge inspector); Kurt Douglas (Great Bay Community College, Professor of Advanced Composite Manufacturing) and Jim Prato (Retired 42-year career high school physics teacher). One of our original members, Tim Osmer, the former New Hampshire State Metrologist, now works for NIST and was not available.

Students learn theory and application of additive manufacturing (3D Printing).
WORKSHOPS AND FOCUS
The NCSL International team interaction with the students this year migrated from being a metrology presenter to being true metrology ambassadors as we spoke with the students and the presenters at the MCC and Hypertherm events. Students were surprised to learn how measurements, either in the physical characterization of a component or the measurement of equipment performance, impact many industries, sciences and even the trades.

The students spent their day interacting with the NCSLI metrology team, school staff at each of the venues as well as volunteer technology leaders from the local community. Individual schools and industry partners establish the workshops that support STEM related industry, skills and education.

Hypertherm is an engineering/manufacturing firm that specializes in the design, engineering and production of plasma cutters for metal fabrication. Their facility operates much like the schools who support this
event. Several guest presenters were also part of the Hypertherm team that engaged students with opportunities to learn about the design process, manufacturing of components and assemblies as well as additive manufacturing (3D printer). A highlight of this venue for the students was the opportunity to perform metal cutting using a Hypertherm plasma cutter.

We focused on metrology for the Spaulding event ranging from high-end laser metrology to simple visual testing and measurement with calipers and plug gages in the Nondestructive Testing (NDT) quality inspection component of our student engagement. Lessons learned from the 2017 event and implemented with the help of this year’s students at Spaulding improved the data collection with the Vernier Technology ultrasonic position sensor for the ball drop and determination of acceleration.
due to gravity. A smooth ball versus a fuzzy tennis ball improved data with students getting data ranging from 9.65 m/s² to 10.45 m/s².

This was another successful event with metrology being introduced to a large group of students and many technical people in local industry. Lessons learned include being prepared for and ready to respond to schedule changes and cancellations, reach out to partners and schools for potential internships for students and always be curating metrology professionals to support outreach efforts. The NCSLI team is already preparing for Girls Technology Day 2019. Additional information on the 2018 event as well as other information is available at www.gtd-nh.org.

William Hinton is a NextEra Energy Retiree and owner of Hinton Technical Services, LLC in Rochester, NH. An NCSLI member since 1996, he is currently engaged in education outreach, NCSLI document development and is a New Hampshire statewide Metrology Ambassador.

REFERENCES

Every event had a repeating comment from the participants, “I never knew about this” and “I did not know that this could be a career for me.”
Magnets Attract Young Minds
First Grade STEM with Magnets on World Metrology Day

The first-grade class of Davita Fortier, a career teacher at McClelland Elementary School here in Rochester, New Hampshire, was once again the center of attention for World Metrology Day. We have been doing this education outreach event long before these future STEM practitioners were in school.

The first discussion regarding what makes a magnet a magnet is the most difficult part of the event. Not because the concept is hard, but the tables are covered with lots of magnets and demonstration materials. It was like trying to keep the kids away from the Christmas tree on Christmas morning. We had comparison measurements of the pull-off force required to remove different magnets from a steel block to the field strength of magnets using a gauss gage from a magnetic particle kit (NDT). The collection of magnets collected from the home and the garage grows every time we have the event.

One significant difference this year was the intentional passing of the baton from the NCSLI presenter and event coordinator to the class teacher. The students were led by first-grade teacher Davita Fortier using the presentation materials and hardware provided by William Hinton, following Georgia Harris's 'Train the Trainer' approach. Students were introduced to the theory of pole interactions with magnets as well as the pole development of the earth and why the earth has a magnetic field. This was followed by short periods of self-discovery with the group of magnets and things that are attracted by magnets. The sorting activity included questions as to why some items were attracted to the magnet and others were not. There is deep understanding and discussion as to why a metal washer (stainless steel) is not attracted to the magnet. Additional periods of discussion with the group included diagrams and simple theory followed by more discussion and questions.

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hands-on experiences. The transition from an image of a magnetic, scrap yard crane to a similar electromagnet made from a copper wire coil, a steel bolt and a battery box was intuitive. Students easily made the connection between completing the circuit and the resulting magnetic attraction.

There were several demonstrations with minimal explanation. The experience and the mystery is the hook. This included a magnetic chemistry stirrer with a bar magnet in a beaker of water. The spinning magnet results in a vortex, tornado in young student speak, and was something they could start and stop during self-discovery. The eddy current demonstration again captivated students with the effect in addition to the opportunity to learn how to use a stopwatch.
Students were allowed plenty of time to interact with the various magnets and other items provided for this event and were only redirected to instruction when the group activity level increased to a point of distraction. The object of the activities was to blend simple magnet interactions that the student may have experienced with more advanced magnet functions and a simple theory of both. The expanded interaction included visual aides such as flat panels with iron filings that indicate the flux field of a magnet placed below the panel up to a thin-film ferro fluid sheet that indicates the magnet flux in an alternate way.

Every student was encouraged to interact with the materials and occasional one-on-one time was required to reduce the anxiety often found in some students when confronted with new experiences. Some of the items also required adult supervision to ensure safety but otherwise, each breakout session was open to the students to explore. It is interesting to see the development of these students who ranged from six to seven years of age. There were students who were enthralled to be allowed to touch the items and there were others who progressed way beyond basic demonstrations and began experimenting on their own. One student tried to couple two magnets through a tabletop after seeing this performed on a student’s hand by one of the presenters.

We do not focus on teaching the students the specifics and science behind magnetic theory but rather to

“I learned the earth is a magnet and I learned about a cow magnet.”

−McClelland Student
Peer coaching to achieve the goal of removing the magnet.

Ferro-fluid flux indicator sheet.

Iron filings on panel align with magnet below.
introduce them to the world of science through magnets. We have demonstrated that these students retain a lot of their experiences based on follow-up after previous events. This year we were pleased to have one of the students from the 2017 event, a more “senior” second grader, who agreed to participate in our demonstrations for the younger students. The student was the instructor on the magnetic stirrer experiment where the students could create a “tornado”. This young scientist also demonstrated the eddy current effect produced when a magnet is dropped through a copper tube.

We have learned that students are never too young or too old to engage with STEM and to learn or relearn principals of the world around us. The most important lesson for the adults is that students learn best when they can touch the materials and experience the mystery of science.

The students were given a challenge at the very beginning of the event regarding the removal of a magnet from introduce them to the world of science through magnets. We have demonstrated that these students retain a lot of their experiences based on follow-up after previous events. This year we were pleased to have one of the students from the 2017 event, a more “senior” second grader, who agreed to participate in our demonstrations for the younger students. The student was the instructor on the magnetic stirrer experiment where the students could create a “tornado”. This young scientist also demonstrated the eddy current effect produced when a magnet is dropped through a copper tube.

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The students were given a challenge at the very beginning of the event regarding the removal of a magnet from

“Now I know how magnets attract and repel.”
−McClelland Student
a steel block. Those who could accomplish this task ‘may’ get a prize. Unlike previous magnet events, the students did not need to be coached to be successful. One student discovered how to remove the magnet and eventually shared with the others...teamwork.

Every student was successful in removing the magnet from the steel block and received a prize. Those of you born in the last century may remember the "Wooly Willy" magnet game. Appropriate for a magnet event.

William Hinton
NextEra Energy Retiree, NCSLI former board member, and a New Hampshire statewide Metrology Ambassador. Request an equipment list and PowerPoint to do your own event at wdhinton@gmail.com.

Davita Fortier
First grade teacher for more than 25 years, and a current New Hampshire Science Teachers Association board member

REFERENCES
Caution: Are You Ready for an FDA 21 CFR Part 820.72 Calibration Program Audit?

Gregg Schaeppi
Director, PK Calibration & Validation
(formerly) Palen Kimball
Medical device manufacturers tend to use two Quality systems: QSR and ISO 13485. The systems are complimentary.

The FDA has a code of regulations for medical device calibration requirements, it’s called: Part 820 of the FDA’s QSR, section 72.

21 CFR Part 820.72 details the calibration requirements for: Inspection, Measuring and Test Equipment (IM&TE). Section 72 states: “All inspection, measurement and test equipment, including: mechanical, automated or electronic inspection and test equipment must be suitable for its intended purposes and be capable of producing valid results.”

21 CFR Part 820.72 also requires medical device manufacturers to have procedures in place for: calibrating, inspecting, checking and maintaining, handling, preserving and storing equipment.
The FDA’s medical device calibration code requires medical device manufacturers to have procedures in place, including directions and precision and accuracy limits. When a medical device fails to meet manufacturer stated standards for precision and accuracy, the FDA will evaluate the potential to harm a patient. Once discovered, the manufacturer must re-calibrate to improve quality until the standards are met. All procedures must be documented.

After completing an FDA audit/inspection, auditors may send an FDA Warning letter if FDA Investigators find specific calibration deficiencies at the manufacturing site.

The following are FDA calibration deficiencies that you don’t want to see at your facility:

**FDA audit findings discovered manufacturer A’s:**

1) “Failure to document calibration dates, Individual performing each calibration, and next calibration date for inspection, measurement and test equipment, as required by 21 C.F.R. § 820.72(b) (2).”

2) “No recorded documentation of Calibration dates, individuals performing Calibration, or next calibration date for the Multi-meter used in repair of the device for testing: battery voltage, conductivity of printed Circuit board circuits or assessing shorted circuits.”

**FDA audit findings discovered manufacturer B:**

1) “Failed to ensure calibration of the inspection, measuring, and test equipment’s traceability to national or international standards, as required by 21 CFR 820.72(b) (1).”

2) “Specifically, manufacturer failed to insure test lens was manufactured and calibrated to NIST standards.”

**FDA audit findings discovered manufacturer C:**

1) “Failed to ensure that calibration procedures include specific directions and limits for accuracy and precision, as required by 21CFR 820.72(b).”

2) “(IE), temperature gauges used for monitoring package sealing equipment are not calibrated using limits for accuracy. Specifically, during calibration, temperatures exhibited on sealing apparatuses range from less than X to greater than X, however, there is no indication as to which temperature ranges are acceptable to ensure monitoring gauges are operating within calibration standards.”

3) “The FDA has reviewed your response and has concluded that it is inadequate because it only states that validation of the heat sealer used on sterilized packaging is conducted and provides a correction completion date. Your Organization must submit documentation as evidence of the implementation of the correction and the corrective action that demonstrates that the temperature gauges used for monitoring package sealing equipment were calibrated using limits for the accuracy.”
To prepare for an FDA calibration audit (820.72) you should ensure:
1. maintenance of an adequate calibration schedule
2. maintaining records of calibration
3. written calibration procedures
4. records of calibration
5. trained calibration personnel
6. Standards traceable to NIST or other independent reproducible standards.

The same points apply to internal (1st party) and supplier (2nd party) audits.
For internal audits ensure:
7. The calibration supplier was selected and is monitored following 820.50.
8. Receiving includes certification that the equipment was calibrated under controlled conditions using traceable standards. Be sure to adhere to GMP/FDA Calibration Requirements per FDA 21 CFR §820.72 IM&TE.

GMP calibration requirements are:
1. routine calibration according to written procedures
2. documentation of the calibration of each piece of equipment requiring calibration
3. specification of accuracy and precision limits;
4. training of calibration personnel
5. use of standards traceable to the National Institute of Standards and Technology (NIST), other recognizable standards, or when necessary, in-house standards
6. Provisions for remedial action to evaluate whether there was any adverse effect on the device’s quality.
FDA 21 CFR §820.72 IM&TE Requires Calibration Records include:
1. purpose and scope
2. frequency of calibration
3. equipment and standards required
4. limits for accuracy and precision
5. preliminary examinations and operations
6. calibration process description
7. remedial action for product
8. documentation requirements

Managing an FDA compliant calibration program is a complex undertaking. An FDA compliant calibration system requires many specialized skills such as:
• Certification of traceability,
• Documentation,
• Qualification,
• Validation plans, and
• FDA QSR: 21 CFR Part 820.72 (IM&TE) calibration audit readiness.

Not to mention skilled metrologists and program managers who understand all the foibles of FDA inspectors who can trip up many a technician.

CONCLUSION:
Whether metrology is a core competency of your organization or whether you chose to outsource your calibration program, metrology is critical to product quality and successful patient outcomes. Compliance is your ultimate goal. However, your stellar metrology efforts may even reduce the number of adverse events and increase the percentage of your products that comply with the FDA Quality System and reporting regulations for your organization. These are the two most important and monitored metrics medical device manufacturers watch. Professional Metrologists should be capable of assisting with your FDA audit, creating validation plans and assisting with quality document traceability.
The Case for Metal Capillary Hoses in High Pressure and Hydraulic Test Circuits

Barry Singer
King Nutronics Corporation
www.kingnutronics.com
Introduction

In a pressure test circuit, particular attention is given to the accuracy and precision of the reference device, and of the ability of the pressure source to provide the required test pressure. However there is one other factor that is sometimes overlooked, and can influence the outcome of the test. That factor is stability.

FACTORS AFFECTING STABILITY

There are a few factors which can influence the stability in pressure test circuits. Understanding these variables will help you to identify the difference between them, and to safeguard against them for better calibration results.

LEAKS

Leaks may be very small but can affect the pressure reading immensely. In hydraulic test circuits, the effects of leaks are more pronounced than in pneumatic test circuits. The bottom line, leaks in any test circuit will make pressure readings difficult. Best practices should always be used to prevent leaks in the test circuit, and system integrity should be verified before starting a test.

ADIABATIC EFFECT

When system leaks are ruled out, the most common cause of instability is the result of temperature changes in the test circuit as pressure is increased or decreased. This effect is called Adiabatic. The pressure medium (gas or liquid) will change temperature as it’s compressed or uncompressed. As the temperature equalizes with the surroundings, the pressure of the medium will also change.

MATERIALS

The third most common factor contributing to instability is due to the types of materials used to contain the test pressure, and more specifically, with the types of test hoses used to transfer the test pressure between the calibration pump and the device under test (DUT).
Test Hose Considerations

When selecting a hose for your application consider the following:

**DISTANCE TO CONNECTION**

The ideal is always to use the shortest possible hose for the test being carried out. The longer the run, the greater volume of pressure medium in the test hose, and the higher likelihood of instability. Limitation of the ability to generate sufficient test pressure may also occur—this is particularly true of gas pressure medium that compresses fairly easily.

**TEST SITE CONDITIONS**

Conditions at the site could affect the ability to achieve a safe and practical test. For example if the hose gets kinked, bent, damaged, or is exposed to heat.

**PRESSURE MEDIUM**

The hose must be compatible with the pressure medium. For example, Skydrol is a commonly used hydraulic fluid in the aerospace industry, and is not recommended for use with many synthetic materials.

**PRESSURE SOURCE LIMITATIONS**

Due to the limitation on how much volume of medium the pressure source can output it’s possible that you may not be able to generate a high enough test pressure to calibrate the DUT.

**PRESSURE RANGE**

Select a hose that’s designed to function correctly within the operating range of the pressure to be applied.
Types Of Test Hoses Available

There are many different types of hoses available for calibration and test type applications, the two most common categories to consider are:

SYNTHETIC HOSES

Commonly used for pneumatic and hydraulic pressure testing up to 5,000 PSI (345 bar). Typically they have an internal core construction of nylon reinforced with polyamide fibers. Most have an internal diameter of 0.08” to 0.12” (2mm to 3mm). The hose outer cover may be polyurethane or similar for low cost, or something like Kevlar® for high strength. Outer covers may be pinpricked to prevent bubbles or blisters, very important for use in certain applications. Mechanical attachments to end fittings are made with crimp or compression type connections.

ADVANTAGES
- Low Cost
- Easily Repairable
- Small Bend Radius
- Lightweight and Small

METAL CAPILLARY HOSES

Designed for critical applications, metal capillary hoses may be used up to 10,000 PSI (690 bar) for pneumatic and hydraulic testing. A stainless steel inner core construction is very common. Typical ID of the hose is 0.04” (1mm) or less. The hose is sleeved with a flexible material such as PTFE, and then encased in a stainless steel braid for protection against physical damage. Connections to end fittings are made using braising or welding for suitability in high pressure applications.

ADVANTAGES
- Durable
- Low elasticity/stretching
- Corrosion Resistance
- High Pressure Rating
Performance Comparison

For a real world comparison we chose four commercially available test hoses and ran the same sequence of testing on all four, refer to Table 1. Our goal was to test the high pressure performance of each hose operated hydraulically. For the purpose of these tests high pressure is defined as over 500 PSI (34 Bar).

HOSES TESTED FOR PERFORMANCE

<table>
<thead>
<tr>
<th>Model:</th>
<th>Model Q</th>
<th>Model X</th>
<th>Model S</th>
<th>King Nutronics (KNC) SuperPressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Tubing:</td>
<td>Nylon/Polyamide</td>
<td>Nylon/Polyamide</td>
<td>Nylon/Polyamide</td>
<td>Metal Tubing</td>
</tr>
<tr>
<td>Outer Cover:</td>
<td>Not specified</td>
<td>Kevlar</td>
<td>Polyurethane</td>
<td>Stainless Steel Braid</td>
</tr>
<tr>
<td>Inner Diameter:</td>
<td>0.08” (2mm)</td>
<td>0.08” (2mm)</td>
<td>0.08” (2mm)</td>
<td>0.04” (1mm)</td>
</tr>
<tr>
<td>Rated Pressure:</td>
<td>6,900 PSI (476 bar)</td>
<td>10,000 PSI (690 bar)</td>
<td>9,135 PSI (630 bar)</td>
<td>10,000 PSI (690 Bar)</td>
</tr>
<tr>
<td>Connection:</td>
<td>Proprietary</td>
<td>AN-4</td>
<td>AN-4</td>
<td>AN-4</td>
</tr>
</tbody>
</table>

The hoses were connected from a King Nutronics Model 3750 hand pump to a pressure gauge stand. A precision pressure gauge was mounted on the gauge stand. As shown in the picture, the hand pump was positioned in a holder to prevent it from moving during the test and influencing the results.

The test circuit was evacuated of air and filled with distilled water. A priming pressure of 500 PSI (34 bar) was generated before each test was started.

High pressure is generated using the volume adjuster knob. This acts as a piston in a cylinder to compress the pressure medium.
Each hose was tested 3 times and results were recorded. The test procedure as follows:

1. Increase pressure by rotating volume adjuster 2 turns over a period of 10 seconds.
2. Take initial reading.
3. Take subsequent pressure readings after 1, 2, 3, 4, 5, & 10 mins.
4. After 10 mins. volume adjuster rotated back to original position and priming pressure adjust back to 500 PSI.
5. Repeat steps 1-4 for a total of 3 test cycles.

Data from the testing was analyzed to determine 3 performance characteristics:
- Pressure Buildup: Characterized as the maximum pressure generated with a given pumping stroke.
- Pressure Drop: Characterized as the loss of pressure over time compared to an initial reading.
- Pressure Stabilization: Characterized as the time taken for the system to stabilize without having to add pumping stroke to maintain a given pressure. A stable reading is defined as a rate of pressure change less than 20 PSI/min (1.4 bar/min).

A digital pressure gauge was used to monitor the pressure decay rate ($\Delta P$). The pressure gauge we used has a secondary reading (shown in red circle) which indicates $\Delta P$ in PSI/min.
PRESSURE GENERATION

Test results varied from hose to hose but consistently each hose recorded higher readings on subsequent tests. However, the comparison from hose to hose was consistent. The metal capillary hose generated at least twice the initial pressure compared to the synthetic hoses.

Conclusion:
Not surprisingly a hose with smaller ID and lower overall volume allows for a significantly higher pressure generation using the same pump stroke.

PRESSURE DROP

From the data recorded the percentage of pressure drop was calculated and compared to the initial reading. The greatest pressure drop is seen in the first minute of observation, however from hose to hose the difference is very noticeable. The metal capillary hose pressure dropped typically 2% over a 10 minute period compared to a pressure drop of at least 12% for the synthetic hoses.

Conclusion:
The metal capillary hose pressure loss was noticeably less than the synthetic hoses by at least a factor of 4.
PRESSURE STABILIZATION

The hand pump was adjusted to generate an output pressure of 5,000 PSI (345 bar) and small adjustments were made as necessary to maintain the 5,000 PSI (345 bar). The time was recorded from the initial 5,000 PSI (345 bar) setting until the output pressure was reasonably stabilized (ΔP <20 PSI/min).

Conclusion:
The metal capillary hose stabilized almost immediately, the synthetic hoses took up to 13 minutes to stabilize.

Overall Conclusion

Synthetic hoses are typically much lower in cost and seem to work just fine for lower pressure <500 PSI (34 bar) and/or pneumatic applications. They are also more flexible and easier to work with compared to metal capillary hoses. However, for higher pressures and for hydraulic applications, the performance requirement becomes more critical, and differences in design and construction become more noticeable.

We evaluated these hoses for the ability to build pressure, hold pressure over time, and the time to stabilize. With these objectives in mind, the metal capillary hoses clearly outperform synthetic hoses. Certainly if your requirement is to conduct precise high pressure calibrations efficiently, the metal capillary hose will provide the highest level of performance.
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On Thursday, July 19, 2018 the NCSLI Boulder/Denver Section met at Philips Company in Colorado Springs, CO. Included in this section meeting were highly educational talks on topics like uncertainty measurements, flow meters, thermocouple accuracy, measurement standard changes, and much more. The morning kicked off with an introduction of our speakers and by providing useful information for new or returning members. Following this introduction was a meet-and-greet where our 12 attendees could congregate and get to know one another and exchange information.

Our first presentation was by Dr. Jun Bautista with Micro Quality Calibration, Inc. Dr. Bautista presented “New Concepts & Best Practices in the Calibration of Climatic Chambers.” His focus was on determining levels of unavoidable uncertainty in measurements and calibrations. Highlighting the difference between errors and uncertainty as a matter of the accuracy of the input, formulations involved, and subsequent evaluations. Dr. Bautista cited eight steps to follow correctly in order to determine uncertainty. Also discussed during his presentation were uncertainty elements for 1-P and 2-P dew...
point generators, measuring humidity levels and electrical resistance using impedance RH hygrometers and methods for the measurement and calibration of newly-designed secondary standards by which laboratories can conduct test-specific queries. After Dr. Bautista’s presentation ended, attendees were given a 15-minute question and answer period.

Thomas Kegel with Colorado Engineering Experimentation Station Inc. (CEESI) presented “Coriolis and Ultrasonic Flowmeter Technology.” Tom’s presentation contained a host of information on flow meter operation and multipath designs in the context of measuring molasses production. Important pieces of this
field of measurement include the pipe friction factor composed of surface roughness and the Reynolds number (Re), which are based on flow profile distortion, swirls in the mixture, meter error, and distortion elements. Key diagnostics in the process are gain, signal/noise ratio, speed sound, flow velocity ratios, performance, rejects, turbulence, and standard deviation. Following the briefing on these diagnostics was a demonstration of examples of the Coriolis effect; lessons on meter installation, orientation, flange misalignment, vibration effects, and zero shift. Tom wrapped things up by discussing the final metrological applications of molasses production, which are measuring the variable density and amount of entrained air in each batch.

Next up Dan Jackson with Tegam, Inc. presented “Best Practices of Measuring Temperature with Thermocouples.” Mr. Jackson went over the detriment of thermocouple inaccuracies and the three laws that
govern how they work: the law of homogenous material, intermediate metals, and successive/intermediate temperature. Second, he went over cold junction compensation and its accuracy, thermal coefficient and the time constant used. Imperative to the thermocouple discussion is also the matter of electrical safety. Jackson stressed the importance of never touching anything in an elevated electrical level with thermocouples, running thermocouple cables in single wire trays away from the power conductor, and remaining grounded around noisy electrical equipment. Also covered were proper connection procedures for thermocouples; appropriate gauge wire usage to account for high temperature ratings, surface measurements, immersion measurements and risks to consider when dealing with thermocouples.
After lunch, we sat down to listen to Anna Escarcega with Metrology ERP, Inc. discuss the updated ISO/IEC 17025: 2017 standard in relation to impartiality and risk. Escarcega went more into depth about the goals and risks associated with these changes, as well as the impact of change on things like calibrations and company infrastructure. As a result of these changes, risk and impartiality have become larger components of the standard—initially transparent risks proving quite detrimental to the accuracy and quality of calibrations. Reviewing, identifying, citing, and properly documenting all ID’d risks is an important consideration she highlighted as one of the most important changes to the standard. She also noted that if a laboratory is ISO/IEC 17025:2017 compliant, they are also ISO 9001:2015 complaint. Impartiality is imperative to both of these standards, she said. Regular impartiality and risk assessments are important to the upkeep of impartiality, since lacking such an attitude can cost people their lives in metrology careers. Escarcega finished up by summarizing the standard changes and refreshing our memories on additional definitions and clause names.

This meeting was full of incredible conversation and immersive training material. Participation and questions were encouraged, and in return both were facilitated by attendees. Our objective of spreading valuable knowledge to new laboratories and the professionals they entail was a success. Regular discussion of risk, updates, procedures, and always exercising impartiality are paramount in the advancement and continued quality assurance of the measurement science world. Changes that are geared toward the improvement of our collective industry must be widespread and common knowledge amongst our experts in order to ensure that each laboratory’s discoveries can be distributed across the globe for the betterment of all scientists and engineers.
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<td>1-Day Course (8 hours)</td>
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<td>2-Day Course (16 hours)</td>
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