CAL LAB

THE INTERNATIONAL JOURNAL OF METROLOGY

METROLOGY 101: HOW TO FUNCTION CHECK A SPECTRUM ANALYZER

Development of the New Line Scale Calibration Facility at the Dutch Metrology Institute VSL

The Effect of High Traverse Inputs on Accelerometer Calibration

A Paperless Calibration Department

2011
JANUARY
FEBRUARY
MARCH

CAL LAB
THE INTERNATIONAL JOURNAL OF METROLOGY

Volume 18, Number 1

www.callabmag.com

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ON THE COVER: Morehouse Instrument Company's torque standard accurate to 0.002% of applied torque. This machine on the cover was once the National Torque Standard for the United Kingdom. This primary standard was commissioned by the National Physical Laboratory in England and verified through inter comparisons with National Measurement Institutes to be one of the most accurate torque machines in the world.

CONFERENCES & MEETINGS 2011

Mar 31-Apr 1 METROMEET: 7th International Conference on Industrial Dimensional Metrology. Bilbao, Spain. METROMEET, tel +34 94 480 51 83, info@metromeet.org, www.metromeet.org.

Apr 6-8 Conference on Metrological Traceability in the Globalization Age. Paris, France. Presented by CITAC, College Francais de Metrologie, IMEKO. Info: www.citac.cc.imeko.pdf. Contact: philippe.charlet@lne.fr.

Apr 11-13 Quality Conference. Charlotte, NC. Quality Magazine in collaboration with UNC Charlotte and the Charlotte Research Institute. www.qualitymagconference.com.

Apr 26-28 TUV NEL The Americas Workshop 2011. Houston, TX. Building on the success of the previous three events, the 2011 Workshop will continue to address the changes in flow measurement practice which affect North, South and Central America. The Workshop will examine the relevant issues relating to complex fluids, measurement technologies, allocation and verification. Info: http://www.tuvnel.com/tuvnel/event_detail_template/the_americas_workshop_april_2011.

May 2-5 Fourth Conference on Pressure Measurement together with the **5th CCM International Conference on Pressure and Vacuum Metrology** Berlin, Germany. Info: www.inrim.it/events/docs/CCM%20International%20Conference_Web.pdf. Contact: karl.jousten@ptb.de.

May 12-15 Advances in Applied Physics and Materials Science Congress. Antalya, Turkey. Global forum for researchers and engineers to present and discuss recent innovations and new techniques in Applied Physics and Materials Science. Companies and institutions are also encouraged to showcase their products and equipment in the conference area. Further information at www.apmas2011.org or for questions use info@apmas2011.org.

May 23-24 The 4th International Conference on Metrology: Measurement and Testing in the Service of Society. Jerusalem, Israel. Israeli Metrology Society. Co-sponsored by NCSL International, The Israel Analytical Chemistry Society, Cooperation on International Traceability in Chemistry (CITAC). Further conference info at www.isas.co.il/metrology2011.

May 23-27 The 2011 International Conference on Frontiers of Characterization and Metrology for Nanoelectronics. (Formerly titled Characterization and Metrology for ULSI Technology). Grenoble, France. This conference, the eighth in the series, will focus on the frontiers and innovation in characterization and metrology of nanoelectronics. This is the first time the conference will be held outside of the United States.

CAL LAB
THE INTERNATIONAL JOURNAL OF METROLOGY

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Subscription fees for 1 year (4 issues)
$50 for USA, $55 Mexico/Canada,
$65 all other countries.
Visit www.callabmag.com to subscribe
or call 303-317-6670
Printed in the USA.

EDITOR'S DESK

Continuing On...

A hearty welcome from Colorado! If you haven't heard, Cal Lab Magazine changed hands this past January. Carol Singer has trustingly passed the torch over to our care, so Cal Lab may continue. We want to thank her for all the help she has given us during this transition.

During the most frigid Colorado winter I have yet to experience, I donned the editor's hat to venture into unknown territory. I've only known metrology from the business side, but now I'm getting to know it from other angles. One of the first emails I received was all the way from China, from a devoted reader who wanted to publish an article. Flipping through old issues, I was impressed with the volume of writers who are not publishing in their native language. The international angle of metrology is one I had not known the extent of before. Metrology is not a decommissioned training facility across town, audits and uncertainties, or a decade's old rivalry between businesses. It is much beyond my limited scope. Carol saw that early on when she changed the name of the magazine by adding *The International Journal of Metrology*.

Starting with this issue, you will find a colorful strip down the spine with "Metrology 101" in bold letters. Besides the usual technical articles, each issue will also include a training level, "How To" as part of our Metrology 101 series. Our purpose is to appeal to all levels of metrology, from the calibration technician to scientist.

Certainly, the biggest change you will see this year is online, as we will be expanding Cal Lab's online presence. The web site already has a new look and feel (visit us at www.callabmag.com). Our hope is to increase Cal Lab's exposure across international borders and engage readers further through online discussion.

As a niche publication in a niche industry, Cal Lab plays a vital role as one of the few industry serial publications, and one that is independent and objective. We want to thank Cal Lab readers and advertisers for their continuing support, without which there would cease to be a Cal Lab Mag.

Kindest Regards,

Sita

CALENDAR

May 24-26 Fundamentals of Random Vibration and Shock Testing.: HALT, ESS, HASS Measurements, Analysis and Calibration. Jefferson Hills, Pennsylvania. Info at www.equipment-reliability.com/vibration_course4.html.

May 26-27 20th Symposium on Photonic Measurements. Linz, Austria. Info at www.emt.uni-linz.ac.at.

May 30-31 IEEE 6th International Symposium on Medical Measurement and Applications (MeMeA 2011). Bari, Italy. Conference web site: http://memea2011.ieee-ims.org.

Jun 20-22 Ninth Conference on Advanced Mathematical and Computational Tools in Metrology and Testing. Goteburg, Sweden. Organized by SP Sveriges Tekniska Forskningsinstitut, Euramet, IMEKO, and Chalmer's University of Technology. Deadline for paper abstract submission is February 28, 2011. Visit www.amctm.org for more information.

Aug 21-25 NCSLI Conference. National Harbor, MD. Conference theme: 50 Years: Reflecting On The Past - Looking To The Future. Info at www.ncsli.org.

Sep 12-14 10th Symposium on Laser Metrology for Precision Measurement and Inspection in Industry. Braunschweig, Germany. Info at www.lasermetrology2011.com. Contact r.tutsch@tu-bs.de.

Sep 20-22 AeroCon, Chicago, IL. Conference and exhibition for the aerospace and defense industries. Info: www.canontradeshows.com/expo/aerocon/index.html.

Sep 27-29 LabAsia 2011. Kuala Lumpur, Malaysia. Third in a series of biennial international exhibitions that showcase the latest in laboratory and analytical equipment, instrumentation and services. Info at www.lab-asia.com.

Sep 27-30 Metrologia2011. Natal, Brazil. A global multi-event comprising an international measuring instruments exhibition and four international associated events: XVIII TC04 IMEKO Symposium, IX International Congress on Electrical Metrology, II International Congress on Mechanical Metrology, and the VI Brazilian Congress of Metrology. Info at: www.metrologia.org.br/metrologia2011/

Oct 3-6 Fifteenth International Congress of Metrology. Paris, France. Info at www.metrologie2011.com, info@cfmetrolgie.com, or telephone 33 (0)4 67 06 20 36.

Oct 24-27 Third Metrology Forum. Accra, Ghana. Legal metrology; accreditation; temperature, volume, mass; measurement uncertainties; interlaboratory comparisons. www.ac-metrology.com/METROLOGYFORUM2011.

SEMINARS: ISO17025

May 11-13 Understanding ISO 17025. Technology Training, Inc., toll free 866-884-4338, brian@ttiedu.com, www.ttiedu.com.

SEMINARS: Dimensional

Apr 7-8 Gage Calibration and Repair. Portland OR. IICT Enterprises, tel 952-881-1637, carlis@consultinginstitute.net, www.consultinginstitute.net.

Apr 11-12 Gage Calibration and Repair. San Francisco CA. IICT Enterprises, tel 952-881-1637, carlis@consultinginstitute.net, www.consultinginstitute.net.

April 12-14 Hands-On Gage Calibration. Elk Grove, IL. Mitutoyo Institute of Metrology, tel 888-MITUYOYO, mim@mitutoyo.com, www.mitutoyo.com.

Apr 14-15 Gage Calibration and Repair. Las Vegas NV. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Apr 28-29 Gage Calibration and Repair. Hartford CT. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

May 2-3 Gage Calibration and Repair. Pittsburgh PA. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

May 5-6 Gage Calibration and Repair. Toledo OH. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

May 10-11 Dimensional Metrology. Elk Grove, IL. Mitutoyo Institute of Metrology, tel 888-MITUYOYO, mim@mitutoyo.com, www.mitutoyo.com.

May 12-13 Gage Calibration Systems and Methods. Elk Grove, IL. Mitutoyo Institute of Metrology, tel 888-MITUYOYO, mim@mitutoyo.com, www.mitutoyo.com.

May 18-19 Gage Calibration and Repair. Effingham IL. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

May 23-26 Dimensional and Thermodynamic Calibration Procedures. Technology Training, Inc., toll free 866-884-4338, brian@ttiedu.com, www.ttiedu.com.

Jun 7-8 Gage Calibration and Repair. Dallas TX. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Jun 9-10 Gage Calibration and Repair. Oklahoma City OK. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Jun 14-16 Hands-On Gage Calibration. Elk Grove, IL. Mitutoyo Institute of Metrology, tel 888-MITUYOYO, mim@mitutoyo.com, www.mitutoyo.com.

Jun 29-30 Gage Calibration and Repair. Denver CO. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Jul 7-8 Gage Calibration and Repair. Atlanta GA. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Jul 11-12 Gage Calibration and Repair. Myrtle Beach SC. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Jul 26-27 Gage Calibration and Repair. Omaha NE. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Aug 9-10 Gage Calibration and Repair. Seattle WA. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Aug 11-12 Gage Calibration and Repair. Portland OR. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Aug 18-19 Gage Calibration and Repair. Oakland/San Jose area CA. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Aug 15-16 Gage Calibration and Repair. Yorba Linda CA. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Aug 22-23 Gage Calibration and Repair. Las Vegas NV. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Sep 13-14 Gage Calibration and Repair. Effingham IL. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Sep 27-28 Gage Calibration and Repair. Minneapolis MN (North). IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Sep 29-30 Gage Calibration and Repair. Bloomington MN. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Oct 6-7 Gage Calibration and Repair. Hew Haven/Waterbury CT Area. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Oct 10-11 Gage Calibration and Repair. Albany NY. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Nov 8-9 Gage Calibration and Repair. Louisville KY. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Nov 10-11 Gage Calibration and Repair. Indianapolis IN. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Dec 8-9 Gage Calibration and Repair. Clearwater Beach FL (Tampa Area). IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Dec 12-13 Gage Calibration and Repair. Atlanta GA. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

Dec 15-16 Gage Calibration and Repair. Effingham IL. IICT Enterprises, tel 952-881-1637, fax 952-881-4419, carlis@consultinginstitute.net, www.consultinginstitute.net.

SEMINARS: Flow

Apr 11-12 Wet Gas Measurement Training Course. Houston, TX. Colorado Engineering Experiment Station Inc. www.ceesi.com.

Apr 13-14 Comprehensive Ultrasonic Flowmeter Training Course. Houston, TX. Colorado Engineering Experiment Station Inc. www.ceesi.com

June 21-23 Ultrasonic Meter User's Workshop. Colorado Springs, CO. Colorado Engineering Experiment Station Inc. www.ceesi.com

Sep 13-15 Fundamental Flow Measurement Training Course. Loveland, CO. Colorado Engineering Experiment Station Inc. www.ceesi.com.

Sep 19-22 Comprehensive Flow Measurement Training Course. Loveland, CO. Colorado Engineering Experiment Station Inc. www.ceesi.com.

Sep 21-23, 2011 Flow Measurement and Calibration. Munich, Germany. (during Octoberfest) In English. www.trigasfi.de/html/en_seminars.htm.

SEMINARS: General Metrology and Laboratory Management

Apr 18-21 Met 101 Basic Hands-on Metrology. Seattle, WA. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

Apr. 27-29 Instrumentation for Test & Measurement. Technology Training, Inc., toll free 866-884-4338, brian@ttiedu.com, www.ttiedu.com.

May 2-5 Met 301 Advanced Hands-on Metrology. Seattle, WA. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

Jun 21-24 Metrology Concepts and Calibration Laboratory Operations. Las Vegas, NV. Technology Training, Inc., toll free 866-884-4338, brian@ttiedu.com, www.ttiedu.com.

Jun 25-28 Met 101 Basic Hands-on Metrology. Seattle, WA. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

Aug 1-4 Met 301 Advanced Hands-on Metrology. Seattle, WA. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

Oct 24-27 Met 101 Basic Hands-on Metrology. Seattle, WA. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

Oct 31-Nov 3 Met 301 Advanced Hands-on Metrology. Seattle, WA. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

SEMINARS: Mass

May 2-6 Basic Mass For Industry. Gaitersburg, MD. NIST. http://www.nist.gov/pml/wmd/labmetrology/schedule.cfm.

Oct 24-Nov 4 Mass Seminar. Gaitersburg, MD. NIST. http://www.nist.gov/pml/wmd/labmetrology/schedule.cfm.

Dec 5-9 Intermediate Mass and Gravimetric Volume Metrology Seminar. Gaitersburg, MD. NIST. http://www.nist.gov/pml/wmd/labmetrology/schedule.cfm.

SEMINARS: Measurement Uncertainty

Apr 4-7 CLM 303 Effective Cal Lab Management. Seattle. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

June 27-30 Measurement Uncertainty. Technology Training, Inc., toll free 866-884-4338, brian@ttiedu.com, www.ttiedu.com.

Apr11-12 Natural Gas Measurement Uncertainty Training Course. Houston, TX. Colorado Engineering Experiment Station Inc. www.ceesi.com.

Sep 12-15 CLM 303 Effective Cal Lab Management. Seattle. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

Sep 26-28 Measurement Uncertainty Training Course. Loveland, CO. Colorado Engineering Experiment Station Inc. www.ceesi.com.

Nov 8-10 Met 302 Introduction to Measurement Uncertainty. Seattle. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

SEMINARS: Software

Apr 11-15 Advanced Programming Techniques. Seattle. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

May 16-20 Met/Cal Procedure Writing. Research Triangle, NC. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

Jun 6-10 Met/Cal Database and Reports. Seattle. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

Jun 13-17 Met/Cal Procedure Writing. Seattle. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

Jun 15-16 Gage Management and MSA using GAGEpack. Dayton, OH. www.pqsystems.com/training/PublicSeminars/GageManagementGAGEpack.php

Sep 19-23 Met/Cal Database and Reports. Seattle. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

Sep 26-30 Met/Cal Procedure Writing. Seattle. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

Oct 3-7 Advanced Programming Techniques. Seattle. Fluke. Tel 888-79-FLUKE, caltraining@fluke.com, www.fluke.com.

SEMINARS: Time & Frequency

Jun 7-10 NIST Time and Frequency Metrology Seminar. Boulder, CO. http://www.tf.nist.gov/timefreq/seminars/T&Foverview.html

SEMINARS: Vibration

Apr. 11-15 Fixture Design for Vibration and Shock Testing DTS. Technology Training, Inc., toll free 866-884-4338, brian@ttiedu.com, www.ttiedu.com.

June 1-3 Fundamentals of Vibration for Test Applications. Technology Training, Inc., toll free 866-884-4338, brian@ttiedu.com, www.ttiedu.com.

'Electron Vortices' Have the Potential to Increase Conventional Microscopes' Capabilities

Electron microscopes are among the most widely used scientific and medical tools for studying and understanding a wide range of materials, from biological tissue to miniature magnetic devices, at tiny levels of detail. Now, researchers at the National Institute of Standards and Technology (NIST) have found a novel and potentially widely applicable method to expand the capabilities of conventional transmission electron microscopes (TEMs). Passing electrons through a nanometer-scale grating, the scientists imparted the resulting electron waves with so much orbital momentum that they maintained a corkscrew shape in free space.

Although NIST researchers were not the first to manipulate a beam of electrons in this way, their device was much smaller, separated the fanned out beams 10 times more widely than previous experiments, and spun up the electrons with 100 times the orbital momentum. This increase in orbital momentum enabled them to determine that the electron corkscrew, while remarkably stable, gradually spreads out over time. The group's work will be reported in the Jan. 14, 2011, issue of the journal Science.

A beam of corkscrew-shaped electrons, when interacting with a specimen, can exert torque on the material, by exchanging angular momentum with its atoms. In this way, the corkscrew electrons could obtain more information in the process than beams with ordinary electrons, which do not carry this orbital angular momentum.

By using corkscrew electron beams, researchers hope to provide high-contrast, high-resolution images of biological samples by looking at how the spiral wavefronts get distorted as they pass through such transparent objects. While these imaging applications have not yet been demonstrated, producing corkscrew electrons with nanogratings in a TEM provides a significant step toward expanding the capabilities of existing microscopes.

Trescal Sets Up in the US With the Acquisition of Dynamic Technology Inc.

Trescal, the European market leader for calibration services, is continuing its international expansion with the acquisition of Dynamic Technology Inc. (DTI), a principal service provider in the US. DTI, with locations in Detroit Michigan, Chicago Illinois, Cleveland Ohio, Dallas Texas and Houston Texas provides Metrology services in the Automotive, Communications, Semiconductor, Manufacturing, Pharmaceutical and aerospace and defense markets.

The transaction will allow Trescal to take a major step forward in its development by entering the US market.

With its new shareholders, 3i and TCR Capital, Trescal began in September 2010 to step up its international expansion, particularly outside Europe.

Obama Administration's Budget Request for NIST Includes Critical Science and Technology Investments to Advance U.S. Innovation and Boost Economic Recovery

President Barack Obama's fiscal year (FY) 2012 budget submitted to Congress for the U.S. Commerce Department's National Institute of Standards and Technology (NIST) proposes a funding level of $1.001 billion, an 8.9 percent increase over the President's FY 2011 budget request and a 16.9 percent increase above NIST's FY 2010 appropriations.

The NIST budget request reinforces the Administration's commitment to science and technology by doubling funding for NIST laboratories, one of several strategies for maintaining U.S. technological leadership laid out in the President's Plan for Science and Innovation and reaffirmed in the America COMPETES Reauthorization Act of 2010 (P.L. 111-358).

Cleanroom Professionals Invited to Comment on Changes to ISO 14644 Standards

Users of the current ISO 14644 cleanroom Standards are advised to become familiar with the new Draft International Standard (DIS) versions of ISO 14644-1 and 14644-2, released last December and available from the Institute of Environmental Sciences and Technology (IEST). Cleanroom professionals and others whose business operations are likely to be affected by changes in these documents are invited to submit comments on the new documents through April 15, 2011. IEST is the Secretariat for ISO Technical Committee (ISO/TC 209): Cleanrooms and associated controlled environments.

The key differences between ISO 14644-1:1999 and the new DIS version relate to a new principle for selecting cleanroom sample locations; a statistical sampling method is now required, and as a result, statistical testing of the data is no longer necessary. The contamination control community now finds itself choosing between the two versions of the cornerstone ISO cleanroom Standards, both of which may be used as trade reference per agreement between customers and suppliers. To help users of these Standards understand the changes in the new DIS versions, develop comments on those changes, and choose which version of the Standards to use as a reference, ISO/TC 209 recommends reading a peer-reviewed paper published in January as a special edition of the Journal of the IEST. Authored by members of the Working Group that developed the new Draft International Standards, this paper details the statistics behind the revised methods in ISO/DIS 14644-1 and ISO/DIS 14644-2.

Public comments will be accepted at www.iest.org/ISODIScomments through April 15, 2011. Comments will be submitted to the voting members of the US Technical Advisory Group (TAG) to ISO/TC 209 for consideration. For additional information, contact IEST by e-mail at technicaldept@iest.org or by phone at 847-981-0100.

LEM

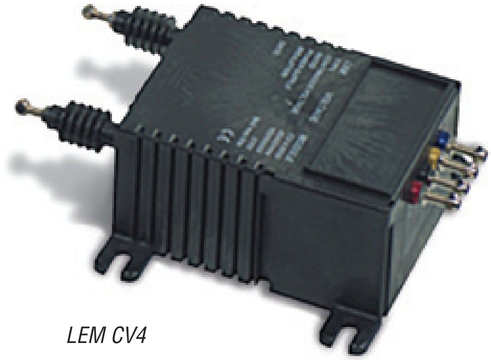
Voltage & Current Measurement

Voltage Transducers

Provide an Analog Output Signal Magnetically Isolated from the Primary Voltage Circuit

- Full-scale Primary Voltages from ±500V to ±8,000V
- Amplitude Accuracy to ±0.2% at dc
- Amplitude Frequency Response dc to 500kHz (-3dB)

Convert High Voltage Levels in Power Converters to Low Level, Low Impedance Signals that can be Used for Accurate and Safe Test Measurements



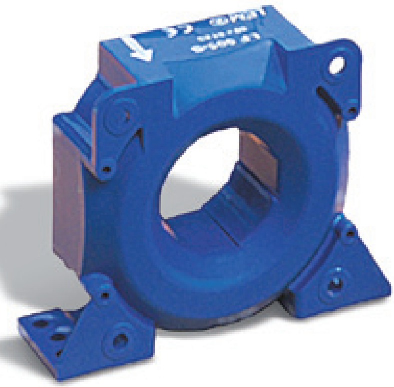
LEM CV4

Closed-Loop Hall Current Transducers

Provide an Analog Output Signal Isolated from the Primary Current Circuit

- Full-scale Primary Currents from ±100A to ±15,000A
- Amplitude Accuracy to ±0.3% at dc
- Amplitude Frequency Response dc to 300kHz (-3dB)
- Common Mode Primary Voltage Isolation
- Split Core Versions Available (±2% at dc)

Suitable for Production Line Testing where Long-term Stability and Reliability are Critical



LEM LF

Closed-Loop Fluxgate Current Transducers

Generate a Very High-Accuracy Output Signal with Electrical Isolation from the Primary Circuit

- Full-scale Primary Currents from ±60A to ±1,000A
- Amplitude Linearity to ±0.3ppm at dc
- Amplitude Frequency Response dc to 300kHz (-3dB)
- Very Low Noise to <5ppm rms (dc to 50kHz) gives Wide Dynamic Range
- Very Low Sensitivity to External Current Conductors

For High-accuracy Power Measurements over an Extended Frequency Range

LEM IT Ultrastab

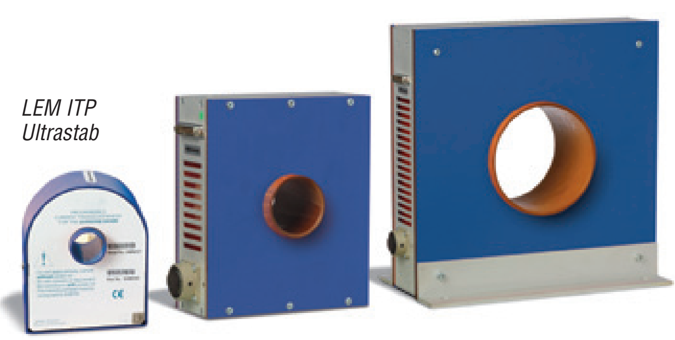
Closed-Loop Fluxgate Current Measurement Systems

Very High-Accuracy Current or Voltage Output Signal with Electrical Isolation from the Primary Circuit

Optional Heads	600A	2,000A	5,000A
Lowest fs Current	40A	125A	2,500A
fs Current Range Increment	20A	125A	125A

Very High-accuracy Calibration and Power Measurements

LEM ITP Ultrastab



Semilab Acquires Tordivel Solar

Semilab, metrology manufacturer of automated and stand alone measurement tools for PV applications, announced that it has acquired the assets of Tordivel Solar for an undisclosed amount of cash. As part of the deal the majority of Tordivel Solar employees have now been engaged by Semilab.

The current acquisition combined with the acquisition last year by Semilab of the Basler micro-crack inspections systems now means sorter manufacturers and PV cell/wafer producers have a single supplier solution for all their metrology, inspection and analysis needs. Tordivel Solar's recipe and yield management software already supported the Semilab series of in line thickness, sheet resistivity and lifetime measurement systems as well as the Semilab (formerly Basler) micro crack inspection systems.

The systems are built on Scorpion Vision Software® for user friendliness, configurability, reliability, flexibility and ease of maintenance. The Scorpion Vision Software is supplied by Tordivel Solar's sister company Tordivel AS, and Semilab and Tordivel AS has entered into a Software License Agreement, where Tordivel will serve Semilab on an exclusive basis within the Wafer Inspection Business. www.semilab.com

ILAC Publishes Policy for Uncertainty in Calibration

In order to better harmonize the expression of measurement uncertainty in calibration certificates and scopes of accreditation, the International Laboratory Accreditation Cooperation (ILAC) published P14, ILAC Policy for Uncertainty in Calibration, which sets parameters for the estimation and statement of uncertainty in calibration and measurement, effective November 2011. The document can be found online at http://ilac.org/news.html

Mercury Thermometers Face Final Phase Out

The mercury thermometer, long a fixture in household medicine cabinets and industrial settings, is going the way of the horse and buggy. The reason: Mercury released into the environment from a broken thermometer is highly poisonous.

Federal and state authorities have lobbied since 2002 for bans on medical mercury thermometers. Now, the Environmental Protection Agency, the National Institute of Standards and Technology, and environmental and industry groups are targeting industrial users of mercury thermometers.

NIST will close down its calibration service for mercury thermometers at the end of this month. The 110 year service has ensured the accuracy of instruments used to monitor temperatures in chemical, pharmaceutical, and petroleum facilities.

Mercury from thermometers reaches the environment in two main ways: improper disposal of broken thermometers and coal-fueled power plants.

Mercury can have significant effects on human health. Its vapor can cause mood swings, insomnia, and memory loss, and high vapor levels can damage organs.

Hat makers in the 19th century had a reputation for strange behavior. It stemmed from their exposure to the mercury solution used to cure animal pelts. The Mad Hatter in "Alice in Wonderland" illustrated the danger.

More dangerous today are the concentrated mercury levels in the fish we consume.

NIST recently sent the mercury from more than 8,000 industrial thermometers to facilities that use it to produce compact fluorescent lights. The one-sixtieth of an ounce of mercury in a typical thermometer is enough to make 125 light bulbs. That form of recycling has two environmental advantages.

"Most of the mercury is bound to the inside of the glass during the life cycle of the bulb, a process that makes it much less environmentally harmful," Strouse said. "And compact fluorescents use less electricity, which reduces the amount of coal burned. That reduces the amount of mercury released by a factor of four."

Meanwhile, NIST is working on alternative options for industrial users in clinical and industrial temperature measurement. And digital electronic thermometers and glass alcohol thermometers measure temperatures just as well as mercury instruments for household use.

Source: Peter Gwynne, ISNS Contributor, Inside Science News Service, http://www.insidescience.org.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Keithley Releases New "How-To" Videos on Operating Electrometers

Keithley Instruments, Inc. has produced a series of four new tutorial videos on topics related to configuring and operating one of its most sensitive measurement instruments. The videos, which range from one to four minutes in length, focus on the Model 6517B Electrometer/High Resistance System and can be downloaded and viewed at http://www.youtube.com/KeithleyInst. The titles of the new videos are:

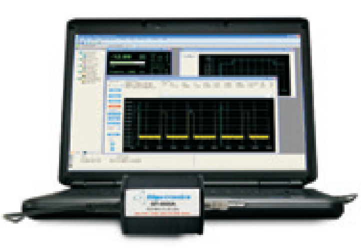
- How to Enable Humidity and Temperature Measurements
- How to Set Up the Model 6517B Electrometer for a Staircase Voltage Sweep
- How to Make a Proper Low Current Measurement
- How to Enable the Meter Connect Feature on the Model 6517B Electrometer

The 5-1/2-digit Model 6517B Electrometer/High Resistance Meter is well-suited for making accurate low current and high impedance voltage, resistance, and charge measurements in areas of research such as physics, optics, nanotechnology, and materials science. A built-in ±1kV voltage source with sweep capability simplifies performing leakage, breakdown, and resistance testing, as well as volume and surface resistivity measurements on insulating materials.

To view Keithley's electormeter/high resistance system how-to videos, please visit http://www.youtube.com/KeithleyInst.

Giga-tronics Introduces New USB Peak Power Sensor

Giga-tronics Incorporated announced the release of the new GT-8555A 100 MHz to 20 GHz USB Peak Power Sensor, which provides fully calibrated peak and average power measurements, with high dynamic range, fast measurement speed and easy-to-use PC-based user interface.



High dynamic range and peak (pulse) capability make this sensor ideal for testing in Wireless communications and Defense electronics systems. The GT-8555A features power versus time, time gating and automatic pulse parameter measurements. It provides high accuracy for R&D laboratory, manufacturing test and field installation and maintenance applications.

The GT-8555A delivers 20 GHz frequency range, 2,000 readings per second typical, wide dynamic range of -40 to +20 dBm and low VSWR of 1.2:1. The GT-8555A includes Giga-tronics MeasurementXpress (MX) software, an easy-to-use interface and a suite of measurement capabilities. The GT-8555A USB Peak Power Sensor includes a trigger input, with software control of the trigger parameters. www. gigatronics.com.

New Leica Map Surface Imaging and Metrology Software for Microscopy

Leica Microsystems and Digital Surf announced the signature of an agreement whereby Leica Map surface imaging and metrology software based upon Digital Surf's Mountains Technology® will be used with the Leica Application Suite (LAS) for Leica industrial microscopes. The new Leica Map software is used to visualize and quantify features of measured surfaces, characterize surface texture and geometry and generate visual surface metrology reports with full traceability. It is available on three levels with optional modules for advanced applications.

Entry level Leica Map Start software is used in conjunction with LAS Montage. LAS Montage acquires a series of image planes at known spacing covering the in-focus region of a specimen with a Leica microscope. Height and functional parameters are calculated in accordance with the latest ISO 25178 standard on areal surface texture.

Leica Map DCM 3D software is dedicated to the Leica dual core 3D microscope Leica DCM 3D, which combines confocal and interferometry technology for non-invasive, high speed, and high-resolution assessment of micro and nano structures. In addition to the standard features of Leica Map Start, Leica Map DCM 3D includes advanced ISO 16610 filtering techniques for separating surface roughness and waviness, basic functional analysis and the ability to extract sub-surfaces and analyze them independently.

The Leica Map product range is completed by Leica Map Premium, a top of the line universal solution that is compatible with single-point tactile and optical profilometers and scanning probe microscopes, as well as with optical microscopes.

More information can be found at Leica Microsystems GmbH, www.leica-microsystems.com and Digital Surf SARL, www.digitalsurf.com.

OHAUS Defender™ 7000 Multifunctional Bench Scales

OHAUS Corporation announces its Defender 7000 Bench Scales provide versatility in various industrial weighing applications.

Among the features that make the OHAUS Defender 7000 scales well suited for industrial applications is a choice of multifunctional indicators, including a dry-use ABS plastic housing, or a NEMA4X/IP66 water resistant stainless steel housing. Easy to set up and use, both housings feature large, bright dual line backlit displays, raised tactile keys and battery-powered use (optional on T71XW). Both the T71P and T71XW indicators feature multiple weighing units, alphanumeric keypad and software modes to meet specific requirements, such as shipping and receiving, production, packaging, and general commercial applications.

OHAUS Defender 7000 Washdown Bench Scales boast a stainless steel NEMA 4X/IP66 indicator and IP67 stainless steel base, so they can be used in washdown environments. Operational features include a totalization mode, library mode with 255 locations, statistics print output and dual-scale operation with remote base input. Hybrid washdown/dry Defender 7000 scales are available in different variations with both square and rectangular bases.

For more information about OHAUS Defender 7000 Bench Scales, and to download product information sheets, visit www.ohaus.com.

Palmer Aero Type Differential Gauges for the HVAC industry

Palmer Instruments Inc. announces the addition of the J-2000 Series of Aero Type Differential Pressure Gauges. Designed with the HVAC industry in mind, this new series of gauges features a frictionless gauge movement. Palmer Aero Type Gauges respond quickly to indicate low pressures, whether positive, negative (vacuum), or differential. Magnetic components of the spiral movement have been replaced with a rubber film, a sensitive component in measuring pressure. This design resists shock, vibration, and over pressures without fluid fill. The result is no difficulty with evaporation, freezing, or leveling that as found in other gauges.

Featuring patented safe-slide pointers in green, yellow, and red, the J-2000 Series of Aero Type Differential Pressure Gauges from Palmer Instruments, Inc. allows the user to set visible reminders of safe, warning, and danger ranges with this unique feature. Combined with the easy-to-read red tipped aluminum pointer, the gauge features excellent readability, even from a distance.

The J-2000 Series of Aero Type Differential Pressure Gauges are available in units of PSI, Pa, kPa, inches of water, millimeters of water, and centimeters of water. Choose from over 100 pressure ranges to meet the needs of your application. With specified accuracies as rigorous as ±2%, measurements are precise and reliable.

The new J-2000 Series of Aero Type Differential Pressure Gauges carries a 2 year warranty, and is available through Palmer Instruments, Inc. and their Authorized Distributors. Visit us at www.palmerwahl.com.

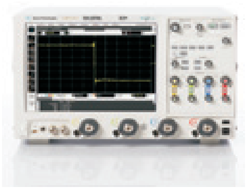
Agilent Technologies Inc. Enhanced the Memory Depth of Its Infiniium Oscilloscope Lineup

Oscilloscopes are the primary tools engineers use to test and debug electronic designs. Scopes with deeper acquisition memory help development and validation teams bring products to market quickly by offering two advantages that yield greater insight: by capturing longer durations of time at a fixed sample rate versus scopes with less memory and maintaining a faster sample rate for a fixed duration of time versus scopes with less memory.

Agilent offers a wide range of Infiniium 9000, 90000 and 90000 X-Series real-time oscilloscopes with bandwidths from 600 MHz to 32 GHz. Mixed signal oscilloscope and digital storage oscilloscope models now ship with 20 Mpts of memory standard – double the industry norm. Digital signal analyzer models now ship with an industry-leading 50 Mpts of memory. Infiniium 9000 and 90000 Series scopes offer a best-in-class 1-Gpt memory option, and Infiniium 90000 X-Series scopes provide memory options up to 2 Gpts.

In scopes with traditional architecture, memory depth increases typically necessitate a reduction in waveform update rate, the amount of time it takes to process and display acquired waveforms.

Additional information on Agilent's complete line of oscilloscopes is available at www.agilent.com/find/scopes.



Rohde & Schwarz Introduces USB-Capable Wideband Power Sensors That Can Measure Up to 40 GHz

Rohde & Schwarz is expanding its portfolio of USB-capable power sensors with the new R&S NRP Z85 and R&S NRP Z86. These are the world's first wideband sensors to measure power from 50 MHz to 40 GHz without requiring a base unit. Instead of a base unit, the sensors are connected to a PC via a USB interface. This cost-efficient solution displays envelope power over a dynamic range of 47 dBm to +20 dBm, which is unprecedented in the industry. High-resolution pulse analysis is another exceptional feature.

Additionally, the R&S NRP Z85 and R&S NRP Z86 provide high-precision continuous-average measurements over the entire dynamic range from 60 dBm to +20 dBm. These performance characteristics make the sensors ideal for a variety of applications in the development and maintenance of microwave and radar systems as well as in the design and production of microwave components.

The wideband power sensors can be operated from a PC via the R&S NRP Z4 USB adapter, or in combination with an R&S NRP/NRP2 power meter. They can also be connected to any signal generator or virtually any signal, spectrum and network analyzer from Rohde & Schwarz. Users can read the power measured from the DUT directly at the generator or analyzer. A complete measurement solution comprising an R&S NRP Z85 or Z86 and an R&S NRP Z4 USB adapter is significantly more cost-effective than a conventional setup involving a power sensor and a power meter.

With a video bandwidth of up to 30 MHz and a sampling rate of 80 MHz, the R&S NRP Z85 and Z86 are the ideal choice for analyzing the time characteristics of modulated signals. The rise time of less than 13 ns enables easy measurement of the most frequently analyzed pulse shapes.

The power sensors can measure both peak power and average power over a defined time interval as well as perform statistical signal analysis (CCDF, PDF).

With a measurement uncertainty of 0.18 dB at 40 GHz, the new sensors offer unparalleled accuracy for continuous-average measurements. This combines with the sensors' other exceptional performance features to make them the market benchmark in peak power applications.

The power sensors' automatic pulse analysis function provides peak power and average power measurements as well as detailed information on other important power and time characteristics of pulsed signals. These include, for example, pulse top level, pulse duration, pulse period, pulse duty cycle and pulse rise and fall times. Using equivalent time sampling, the R&S NRP Z85 and Z86 can display pulsed signals with a very high time resolution. This is done by sampling a series of consecutive waveforms of a pulsed signal. The measurements are time-shifted relative to one another, yielding a compacted sequence of samples, which over time are combined into a complete waveform.

The new R&S NRP-Z85 and R&S NRP-Z86 wideband power sensors are now available from Rohde & Schwarz. The R&S NRP Z85 connects to the DUT via a 2.92 mm connector, the R&S NRP Z86 via a 2.4 mm connector. Web site: www.rohde-schwarz.com.

VD8TC Vacuum Tester for Thermocouples – Check Vacuum Barriers Quickly and Easily

Bulk cryogenic gas storage vessels and vacuum jacketed gas delivery lines are designed with a vacuum barrier that retards costly product loss. The vacuum level must be periodically verified using the thermocouple vacuum sensors that are ordinarily installed on the vessel or delivery line during manufacture.

The new VD8TC vacuum tester of the German instruments manufacturer Thyracont, now enables the bulk gas supplier's field service staff to quickly and easily measure the vacuum level even if the sensors being used are from different manufacturers or have different measuring ranges.

The VD8TC is compatible with the most popular thermocouple vacuum sensors. With the press of one button, it automatically detects which sensor brand and model is connected. Within a few seconds a stable vacuum measurement is displayed. If desired, this measurement can be stored in the instrument's data logger by one more push of the same button.

For monitoring multiple sensors, Thyracont offers their unique ADiscs (pat. pend.). This device attaches to each thermocouple sensor and provides an individual electronic identification. A USB interface enables the user to evaluate and document measurements with Thyracont's VacuGraph™ Windows™ software on a PC. After each measurement, the date, time, sensor ID and pressure value are stored.

The VD8TC completes the successful VD8 product family, which includes five other compact vacuum meters with data logger and USB interface. These are based upon piezo resistive, Pirani or hybrid sensor technologies.

For more information, visit www.thyracont.com.

AEMC® Introduces a New Digital Transformer Ratiometer DTR®

AEMC's Digital Transformer Ratiometer DTR® Model 8510, improves upon on its predecessor, the Model 8500. It offers straight forward operation, high accuracy, data storage and provides automatic test result documentation.

Significant Features Include:

- Ratio Testing: PT/VT from 0.8000:1 to 8000:1 and CT from 0.8000 to 1000.0 (Auto-Ranging)
- Tests performed by exciting the primary and reading the secondary; provides safer conditions for the operator on step-down transformers
- Continuity test indicates open or loose (high resistance) terminal connections
- DC test mode eliminates errors due to magnetic build up
- Stores up to 10 primary/secondary nameplate voltages to use in comparing test results
- Displays ratio, test current, winding polarity, and deviation from nameplate voltage or ratio
- Stores up to 10,000 test results
- DataView software included which allows configuring the instrument, downloading stored measurements and printing of test results in a report format
- Display warns of incorrect lead connection, reverse polarity, open and short circuits
- CE Pending - Consult Factory

AEMC is distributed by techniCAL Systems 2002 Inc.

Contact techniCAL at www.technical-sys.com or call 1-86-MEASURE-1 (1-866-327-8731) for more information.

Mitutoyo USB Input Tool Facilitates Connection of Hand Measurement Instruments to PCs

Mitutoyo America Corporation announces the availability of a new USB input device that streamlines the interfacing of Mitutoyo Digimatic® hand measurement tools with PCs. The new USB Input Tool Direct: USB-ITN® includes seven models – each model is dedicated to a specific type of cable plug/ connector pin configuration. The new design negates the need for two cables, lowering overall costs by as much as 32%.

When connected to a PC's USB port, the USB Input Tool is automatically recognized as an HID (Human Interface Device) keyboard device – a standard Windows® driver. No special software is required. A USB keyboard signal converter translates Digimatic® display values to keyboard signals. This enables the direct inputting of data into the cells of off-the-shelf spreadsheet software, such as Excel®. Data can also be automatically entered into Notepad® or similar programs. Data capture is much faster than manual entry. Additionally, reliability is increased because transcription errors are eliminated.

Optional Mitutoyo USB-ITPAK® Measurement Data Collection Software further enhances the productivity of USB Input Tool Direct: USB-ITN® by facilitating set-up. Excel® input destinations (workbook, sheet, or cell), cell-fill direction (right or down), cell fill intervals, and other settings can be specified. Sequential, batch, or individual measurement methods can be selected. USB-ITPAK® also enables mouse button, function key, and foot-switch functions.

Categories of Mitutoyo Digimatic® hand tools supported by USB Input Tool Direct: USB-ITN® include: calipers, micrometers, indicators, depth gages, height gages, bore gages, surface roughness testers, laser scan micrometers, linear gage/counters, and hardness testing machines.

For more information, visit www.mitutoyo.com

New Fluke 5522A Multi-Product Calibrator

Fluke Calibration has introduced the 5522A Multi-Product Calibrator, designed to improve the capabilities of calibration laboratories industry wide. The 5522A is the next generation of Multi-Product Calibrators, based on the popular Fluke 5520A series calibrator. The new Fluke 5522A will provide daily service both inside and outside of the calibration lab. It is durable enough to be safely transported for on-site or mobile calibration of a wide variety of electronic test tools.

With the Fluke 5522A, metrologists can do more with less by investing in a single calibrator that gives them the flexibility to calibrate a wide range of instruments. For greater productivity, the Fluke 5522A can be fully automated with MET/CAL® Plus Calibration Management Software.

Several reliability-enhancing features protect it against damage and make it easier to transport for on-site or mobile calibration. Internal circuits and fuses protect against damage caused by applying too much voltage or current. A unique carrying case makes transportation easy and safe; front and rear access doors help the user quickly put the unit to work at the job site without fully unpacking it.

The Fluke 5522A covers a wide variety of industrial electronic test tools, including:

- Handheld & bench meters up to 6 ½ digits
- Current clamps and clamp meters
- Thermocouple and RTD thermometers
- Process calibrators
- Data loggers
- Strip and chart recorders
- Watt meters
- Power harmonics analyzers
- Panel meters
- Graphical multimeters
- Power quality analyzers (with option)
- Analog or digital oscilloscopes to 600 MHz or 1.1 GHz (with options)
- …and more, including pressure gauges and transducers and three-phase power meters

An innovative carrying case accessory features built-in handles and wheel, enabling the user to move the calibrator from place to place easily and safely. Front and rear access doors are removable, the 5522A can be used while its top, bottom and side panels remain protected—all without having to completely unpack and re-pack the calibrator. A redesigned front panel and carrying handles make it easy to transport the calibrator short distances within the lab.

Accidently applying too much voltage to a calibrator's input terminals can cause costly damage. The 5522A provides reverse power protection, immediate output disconnection, and/or fuse protection on the output terminals for all functions, making the unit virtually mistake proof.

The Fluke 5522A sources direct voltage and current, alternating voltage and current with multiple waveforms and harmonics, two simultaneous voltage outputs or voltage and current to simulate dc and ac power with phase control, resistance, capacitance, thermocouples and RTDs. It can also measure thermocouple temperature signals, and a wide range of pressures using any of 29 Fluke 700 Series pressure modules. Two options add the capability to calibrate oscilloscopes with bandwidths to either 600 MHz or 1.1 GHz. Another option enables the 5522A to calibrate power quality instrumentation to the standards of the IEC and other regulatory agencies.

For more information on the 5522A Multi-Product Calibrator and other products from Fluke Calibration, visit the Fluke Calibration Solution Center or contact Fluke Corporation, P.O. Box 9090, Everett, WA USA 98206-9090, or call 1-877-355-3225.

How to Function Check a Spectrum Analyzer

By Brien Gauthier

Training Objective: Increase your efficiency and effectiveness by focusing in on any major problems your test unit may have with a quick and simple function check. The analyzer used for the example is an Agilent N9030A PXA Series spectrum analyzer. The instruction given will have to be adapted to your specific analyzer. The function check for your analyzer may include other tests but the tests below are common to all spectrum analyzers and will apply to most signal source analyzers.

Recommended Equipment

Use the compatible equipment listed below for the unit you are testing (i.e. 26.5 GHz or greater signal generator for testing a 26.5 GHz spectrum analyzer):

- Signal Generator
- Power Splitter
- Power Meter
- Power Sensor
- 50 Ohm Termination
- BNC Cable for 10 MHz Connection
- Service Guide or Specification Sheet
- Appropriate Cables and Adapters

Power-On Test & Visual Inspection

On most units watch the display as the unit powers up and listen to the unit. Do you hear noisy fans? Check the results of the self-test. Does the color on the display look correct? Check RF input and all other connectors for damage.

Setup

1. Preset the generator and verify the RF output is turned off.
2. Preset the analyzer and it should show the full span.
3. Connect the BNC cable from the analyzer 10 MHz Ref Out to the generator (10 MHz Ref In). The generator should now show external reference on its display. Again, simple but often overlooked.
4. Connect one output of the power splitter directly to the analyzer's RF input.
5. Use the correct cable to connect from the generator to the input on the power splitter.
6. Zero and calibrate the power sensor then connect the sensor directly to the other output of the power splitter.

Frequency & Power Tests

1. Set the generator frequency to 1 GHz and amplitude to -3 dBm. Turn RF output on. The reading on the power meter should be approximately -10 dBm.
2. Preset the spectrum analyzer and set the reference level to 0 dBm and the frequency span to full.
3. The spectrum analyzer should show a signal about -10 dBm. If there is no signal, move to the attenuator section below.
4. Set the signal generator's step frequency to 1 GHz and quickly step through the frequencies in 1 GHz increments to the max frequency of the spectrum analyzer looking for any holes (Figure 1). The signal won't be exact because the span is set to max, but signal level should be within reason.
5. Now set the signal generator back to 1 GHz. Then set the spectrum analyzer as follows:
   a. Center frequency to 1 GHz
   b. Reference Level to 0 dBm
   c. Frequency Span to 1 MHz

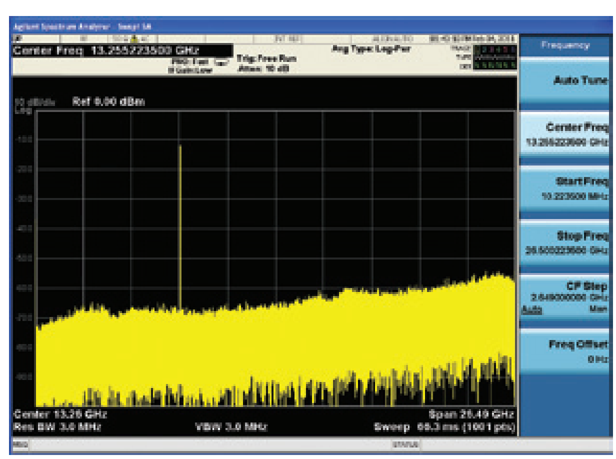


Figure 1

6. Step the signal analyzer and signal generator up in 1 GHz increments. At each frequency, press the marker peak button and verify the power meter and spectrum analyzer read approximately the same (Figure 2).

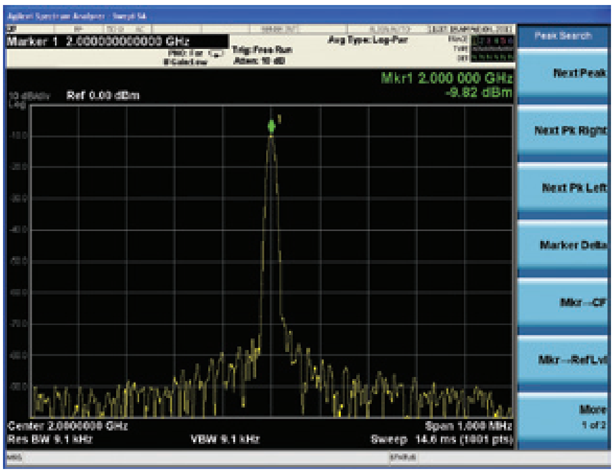


Figure 2

Attenuator Tests

1. Set the signal generator to 1 GHz. Then set the spectrum analyzer as follows:
   a. Center frequency to 1 GHz
   b. Reference Level 0 dBm
   c. Frequency Span 1 MHz
2. Select the manual attenuator control, step the attenuation up by the smallest step allowed (2 dBm, 5 dBm, 10 dBm), and watch the peak reading. Continue stepping up the attenuation until the maximum attenuation is reached. The noise floor should come up but the signal should stay within reason (Figure 3). When checking the attenuators, what you don't want to see is the signal moving (Figure 4).

Noise Tests

1. Turn off the signal generator and remove the splitter/sensor assembly from the RF input and replace it with a 50 Ohm termination.
2. Set the spectrum analyzer as follows:
   a. Center frequency to 1 GHz
   b. Frequency Span to 1 MHz
   c. Reference Level to -40 dBm
   d. Attenuator to default (10 dB typical)
3. Again step through the frequencies in 1 GHz increments, this time verifying the noise flow and looking for any signal spikes.

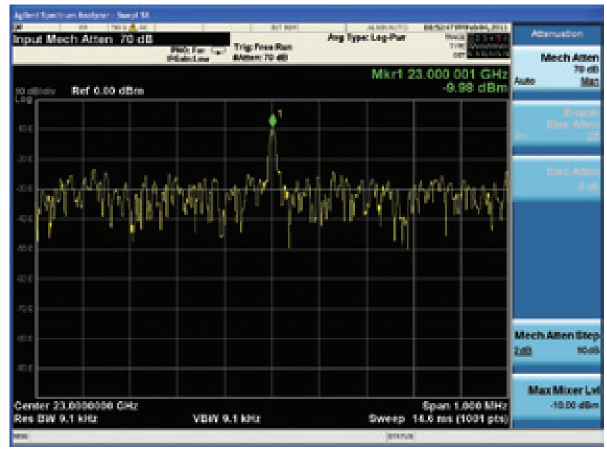


Figure 3

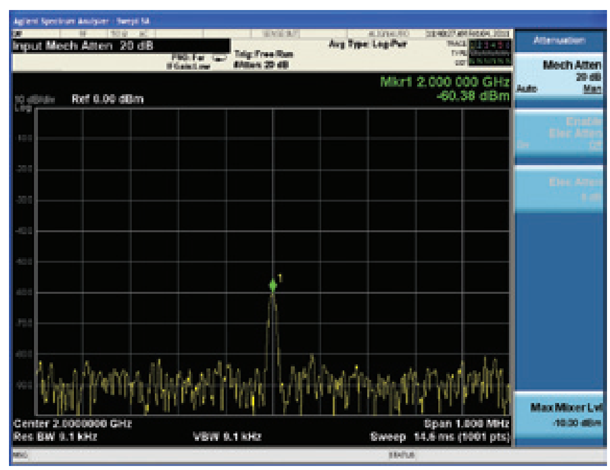


Figure 4

By running the above tests you will save yourself some time and heartache. This is by no means a calibration or performance verification; it is only a tool to point you in the right direction.

Brien Gauthier is an Electronic Technician III specializing in RF metrology. Brien has worked for a leading metrology lab based in Van Nuys, CA since 2001. For any comments, questions, or suggestions for future articles, please contact the publisher at office@callabmag.com.

Development of the New Line Scale Calibration Facility at the Dutch National Metrology Institute VSL

Richard Koops, Ancuta Mares
Research and Development Department, VSL
Jan Nieuwenkamp
Calibration and Reference Materials Department, VSL

Line scales are important physical standards of length used for accurate positioning or measurement in one, two or three dimensions. Depending on the application, line scales can have dimensions from fractions of a millimeter to several tens of meters. For example, small scales are used to calibrate the field of view of optical microscopes. Scales with dimensions in the meter range are used to read out the position of machine tools and measuring machines, while leveling rods find their use in geodetic surveying. Accurate calibration of scales requires dedicated equipment and measurement conditions that are usually only implemented at the national metrology institutes. The Dutch National Metrology Institute VSL (formerly NMi Van Swinden Laboratorium) has several facilities to calibrate scales from small micrometer scales up to leveling rods and tape measures with lengths over tens of meters to high accuracy. In order to ensure that we can continue to provide services for the ever increasing demand for higher accuracies, these facilities are continuously improved. This paper will describe the efforts that have been undertaken recently to improve our capabilities for the calibration of high precision line scales as well as the motivation for the choices that have been made during this process.

Calibration of High Precision Line Scales

Until recently, precision lines scales were calibrated manually at VSL using a 400 mm SIP measuring machine (Figure 1). Although this machine has three axes, only one of them is used during the calibration process.

The measuring machine is equipped with a camera system to visualize the scale markers and a laser interferometer system to measure the position of the camera relative to the scale.

During the calibration procedure, the image from the camera is converted to a single curve that represents the intensity of the image features. Manual alignment of the scale marker to the exact centre of the image is performed by adjusting this curve to its mirror image. After each alignment step, the position of the camera with respect to the scale is stored manually.

The uncertainty that has been realized by this facility and is formally registered in our calibration and measurement capabilities in the CMC database at BIPM [1] is 100 nm + $10^{-6}L$, where L is the length of the scale.

During the past decade, this facility has been upgraded, but due to mechanical, optical, thermal and electronic limitations, further improvements are not feasible without major modifications. Additionally, this facility has the drawback that it requires realignment of the entire optics for the laser interferometer for each scale. Finally, given the fact that a large part of the calibration procedure is performed manually, the amount of scale markers that can be calibrated is limited due to time constraints.

New Calibration Setup

In order to improve the quality for precision line scale calibrations, we therefore decided to design and build a new facility. This facility should enable us to lower the measurement uncertainty to 30 nm + $5 \cdot 10^{-7}L$ for an increased measurement range of 1000 mm. To minimize the manual labor during the calibration process, the measurement sequence should be fully automated, allowing calibration of every marker on the line scale. The basic design concept chosen for the new line scale setup is similar to that realized at the Finnish metrology institute MIKES [2].

A schematic overview of the new setup is shown in Figure 2. The system can be divided into four main parts: a granite guide, an actuation mechanism, a movable vision system and a laser interferometer. The vision system captures images of the scale markers on the fly while moving over the line scale on an air bearing platform that is translated by the actuation mechanism. Along with the image acquisition of the line scale markers, the position of the vision system is captured synchronously by a laser interferometer. In the following sections the individual components will be described in more detail.

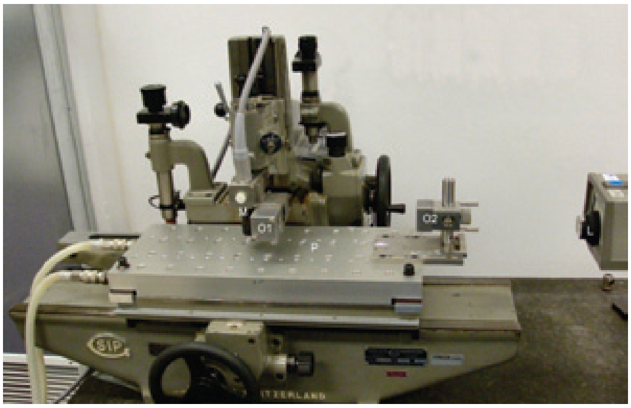


Figure 1. Previous facility to manually calibrate line scales up to 400 mm. The position of the platform P with the scale (not shown) is manually translated with respect to a video microscope M and measured by a laser interferometer consisting of laser L and optical components O1 and O2. For improved temperature stability the temperature of the platform can be controlled separately.

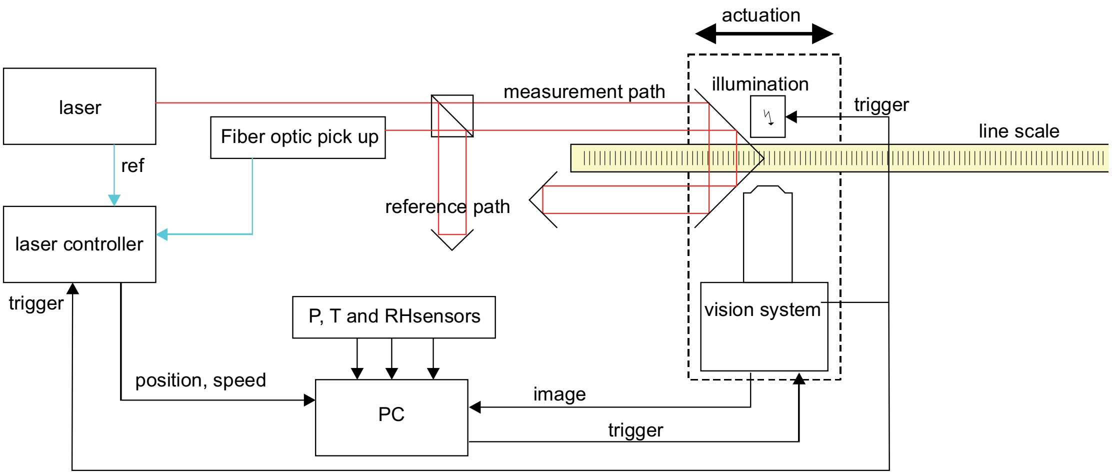


Figure 2. Schematic view of the new setup. The vision system is mounted on an air bearing platform that is connected to a motor by a wire. The position of the platform with respect to the stationary line scale is measured by a laser interferometer.

Granite Straight Guide

The straight guide is part of a granite stone measuring 2000 mm x 1000 mm x 400 mm. The straight guide defines the movement of the air bearing platform that holds the vision system. Shape deviations in the guide result in pitch, yaw and roll motion of the air bearing platform and therefore result in changes in the directions of view of the vision system. Pitch motion will especially rotate the view in the direction of measurement resulting in a measurement error. Given the total measurement uncertainty for the complete setup, our requirements for the maximum angular errors (pitch, yaw and roll) were 0.4 arcseconds (approximately 2 µrad) and were met after the granite guide was post processed by the supplier [3] in our laboratory as one can see in Figure 3.

The thickness of the granite was determined by the boundary condition for the stability of the entire setup. When the granite deforms due to the moving platform, the supporting points of the scale will pivot and translate the scale during the calibration. A constraint of 2 nm for the maximum displacement of the scale restricts the bending of the granite to 30 nm resulting in a thickness of the granite block of 400 mm.

During calibration, the line scale is supported at the Bessel points ensuring minimal change in the length of the scale. Since the remaining bending of the granite will result in opposite pivoting of the supports, the scale might slip on the contact points and change the position of the scale with respect to the measurement system in a non-reversible way. To avoid this, we have selected materials with different friction coefficients for the two supporting points.

The stability of granite reference flats is largely determined by the stability of the vertical temperature gradient along the thickness of the granite [4]. A vertical temperature gradient of 0.1°C will result in a flatness error of about 1 μm that produces 1 μrad angular error over 1000 mm. Therefore besides conditioning the laboratory, the power dissipation in and around the setup should be kept to a minimum. We have realized this by using low power components (high efficiency LED [5, 6] in pulsed mode, low power DC motors [7]) and placing the dissipating equipment outside the measurement area.

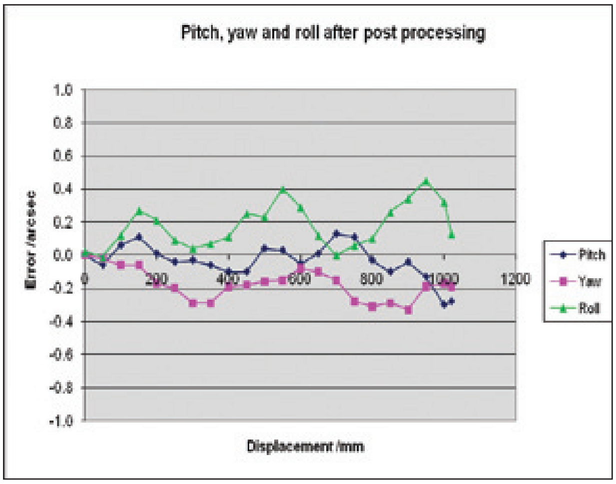


Figure 3. Angular errors of the granite straight guide as measured on the air bearing platform after the final processing step.

Actuation

The air bearing platform is translated over the full range of 1000 mm using a Kevlar® wire that is connected to a low power DC motor [7]. The air supply is connected to the platform by relatively stiff plastic tubing. During the travel over 1000 mm, these tubes change shape and therefore exert changing forces on the platform that could distort the linear translation. In order to avoid this we have realized a second smaller platform on a conventional ball bearing guide that moves synchronously to the main platform to stabilize the shape of the tubing and ensure that the movement of the main platform is not distorted.

The Measurement System

During the calibration sequence, the measurement platform with the vision system is moving continuously. The position of the scale markers is calculated from both the image information and the position information so it is very important that these two are acquired synchronously. The data acquisition timing scheme is shown in Figure 4.

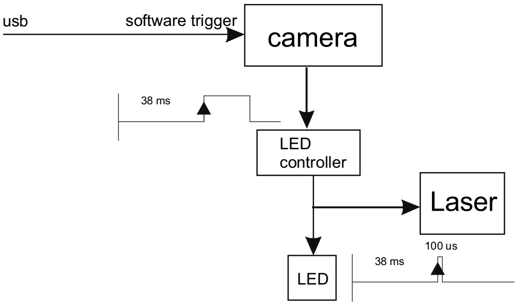


Figure 4. The synchronization of the data acquisition is critical and is initiated by a software trigger of the camera of the vision system. The camera has to prepare for acquisition and after 38 ms releases a trigger that starts the LED flash illumination and latches the momentary position information of the laser interferometer. The trade off between acceptable image blurring and sufficient exposure of the frame has finally resulted in an optimized flash duration of 100 μs.

The vision system consists of a microscope with zooming capability [8] and a camera [9] with a resolution of 1280 pixels x 1024 pixels. The microscope is equipped with a quarter wave plate to maximize the contrast of the relevant features on the line scales. The field of view at the highest magnification setting is about 0.28 mm x 0.35 mm yielding about 270 nm per pixel. Initial image analysis is performed using a basic algorithm on-line during the measurement in order to detect errors of the calibration process itself. A more detailed analysis with higher accuracy is performed off-line because this is computationally too intensive.

Since we are measuring while the vision system is moving, the image will be blurred to some extent. Only when the camera has a very fast shutter or when the illumination time is short enough, the blurring will become acceptable. We have chosen to use pulsed illumination, and for an acceptable image contrast, we have observed that pulse duration of at least 100 μsec is necessary. For our measurement speed of 0.2 mm/sec the blurring therefore becomes 20 nm. Since the blurring should be equal for every scale marker, it does not contribute directly to the measurement uncertainty. It is the fluctuations in the actual measurement speed, determined to be about 10 % of the speed, which will cause different blurring for different markers. The final contribution due to image blurring to the measurement uncertainty is therefore 2 nm.

The image acquisition during the calibration process is adjusted such that the relevant information of the scale marker is close to the center of the image in order to minimize the influence of measurement errors due to the inhomogeneous illumination and aberrations of the imaging system. In order to convert the image information, stated in pixels, to a position in meters, the vision system was calibrated by translating a marker line over the entire field of view. Figure 5 shows the residue of the position for every pixel column of the vision system that was obtained after subtracting the linear response for a scaling factor

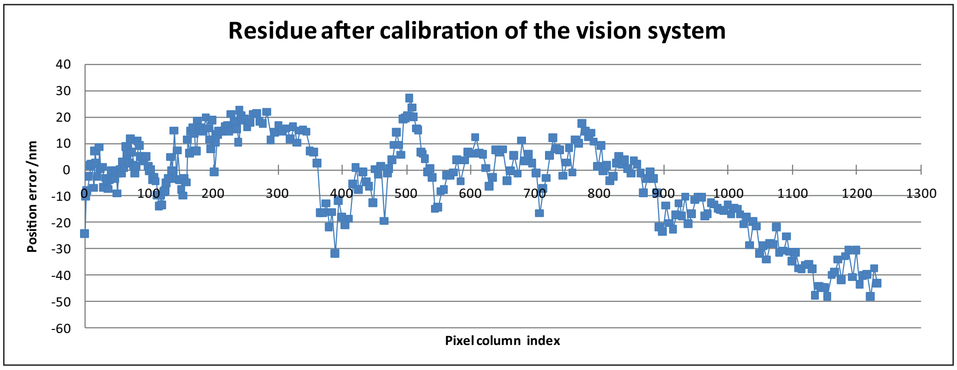


Figure 5. The residual errors of the vision system after calibration with the laser interferometer along all pixel columns. The graph shows slightly less columns than the actual 1280 because, for the first and last few columns, the line scale marker is not completely imaged. The calibration has been optimized for the central region of the vision system between pixel columns 540 and 740 due to the experimental observation that the relevant features of the line scale markers are always imaged within 100 pixels from the center position at column 640.

of 277.34 nm/pixel. The scaling factor was calculated for a minimum residue near the center of the image. The image acquisition is performed between the columns 540 and 740, where the maximum position error is about 15 nm. If the measurement is repeated multiple times, the contribution to the error would average out to less than 1 nm. Since the amount of repeats is limited, the fully average value is not realistic. In order to estimate the uncertainty contribution more realistically, the standard deviation of the errors in the center region is taken. This value is 7 nm.

The position of the air bearing platform with the vision system is measured with a double pass laser interferometer [10], shown in Figure 6, for which most components are commercially available. For the used speed we can only take one image with the scale marker close to the center of the frame. To ensure that we have sufficient signal quality, the image processing will average over all 1024 image lines. The contribution to the measurement uncertainty due to the laser interferometer is given by its resolution of 0.6 nm.

The laser interferometer signal is optimized using high quality mirrors and maximum mechanical and thermal stability of the optical components in the interferometer. Also, the connection between the composite cube corner and the vision system has to be thermally stable. A temperature fluctuation of 0.1 °C would result in an error in the scale calibration of at least 100 nm for a direct mount of the two components. In order to reduce this error, we have constructed a symmetric Invar mount with its thermal center nominally on the symmetry axis of the microscope reducing the contribution to the measurement uncertainty to 10 nm.

During a line scale calibration, the starting position is such that the vision system is closest to the laser interferometer optics, minimizing the amount of air in the measurement path and therefore maximizing the stability of the zero position measurement. Additionally, we have designed the interferometer to have equal lengths of the measurement path and the reference path at the starting position of the calibration such that most local fluctuations will cancel out.

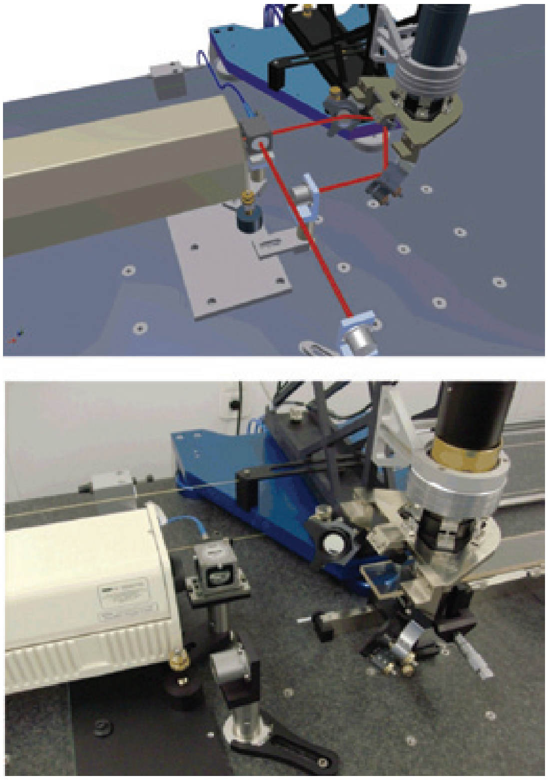


Figure 6. Design and realization of the measurement system. The laser beams along the measurement and reference path have been indicated in the design drawing. The effective measurement position of the laser interferometer is aligned to the field of view of the vision system in order to minimize the Abbe error.

Abbe Errors

Since the accuracy of the straight guide is limited by the residual imperfections that remain after post processing the granite, the translation of the platform is not perfectly straight. The Abbe error that is introduced this way is proportional to the tilt of the vision system and the distance between the vision system and the line scale. We have implemented an Abbe error compensation as shown in Figure 7. The optical system is implemented as a composite cube corner retro reflector with the apex at the effective point of measurement. This way any common movement of this point and the cube corner can be recorded accurately, irrespective of residual rotations during the movements. We have implemented the cube corner as three separate mirrors that are mutually perpendicular and define an apex where their planes intersect. This apex is positioned at the center of the focal plane of the vision system. In practice, the positioning can be done with finite accuracy, typically 1 mm, yielding an Abbe residue of 2 nm.

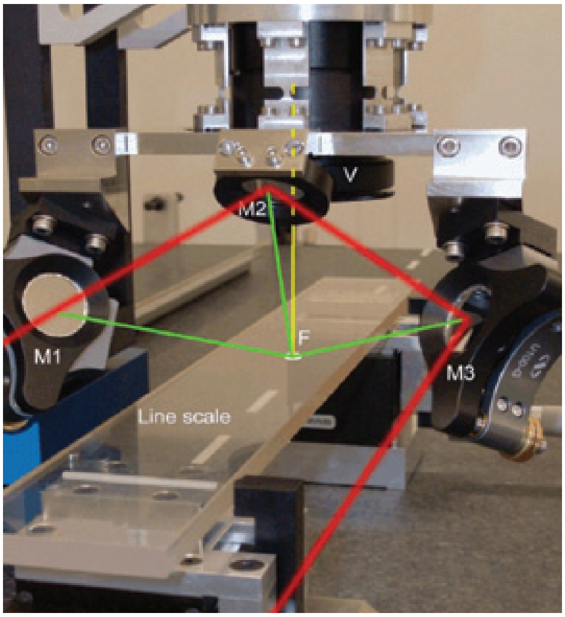


Figure 7. The composite cube corner retro reflector consisting of mirrors M1, M2 and M3 has its virtual apex aligned at the center of the focal plane F of the vision system V. Rotational errors of the vision system during the translation result in tilt of the field of view. The resulting errors are compensated, since the cube corner apex is translated over the same distance.

Cosine Errors

The line scale facility requires several alignment steps to minimize cosine errors.

First the deviation of the three mirrors in the cube corner from mutual perpendicularity causes different directions between the exit beam and the incoming beam. The alignment of the mirrors has been optimized using our angle calibration facility to less than 7 arc seconds. This ultimately results in a length dependent error of approximately $10^{-9}L$, which is nearly insignificant.

The second source of cosine errors is the misalignment of the line scale to the translation direction. The final angular accuracy of alignment is determined by the length of the scale. Given the position accuracy of 1 μm when using the vision system, the cosine error ranges from about $5 \cdot 10^{-7}L$ for small scales to less than $1 \cdot 10^{-12}L$ for scales of 1000 mm.

The third source of cosine errors is the alignment of the laser interferometer to the translation direction of the vision system. This alignment is inspected by tracking the position of the retro reflected laser beam with a position sensitive detector as the platform is moving. The alignment is then optimized by changing the laser position to reduce the position shift of the returning beam to less than 50 μm, resulting in a cosine error of about $10^{-9}L$.

Repeatability

The repeatability has been established by comparing sequential data without changing the alignment and the other measurement parameters like speed and illumination. The dependence of the measured positions of the scale markers on the amount of light and for out-of-focus conditions was studied separately and found to not be significant. This is to be expected, since the conditions are the same for every line scale marker and only the relative positions of the scale markers with respect to the zero markers are finally calculated.

In order to minimize the influence of environmental conditions during the repeatability measurements, we have used the zero marker of the line scale for which the lengths of the interferometer paths are shortest. Also, at a single point, the measurement could be repeated many times in contrast to the situation when the vision system is moving and we can only take one data point with the marker image centered in the frame. The repeatability under these conditions was established to be 8.2 nm and is probably overestimated, since it partly contains the calibration residue of the vision system.

Data Processing

The data analysis is based on combining the position information from the laser interferometer and the image information from the vision system. For a simple line scale marker, the image is a straight vertical line of a certain width, usually imaged as a bright feature on a dark background. First, all horizontal image lines are added obtaining a curve proportional to the average intensity of the line scale marker image. The center position is calculated from the average of the positions of the left and right edge. These positions in turn are defined as the interpolated positions at 50% of the height of the intensity curve. The average of the positions of the left and right edge is finally converted from pixels to meters using the calibration factor of the vision system.

The second part of the position information is generated by the laser interferometer. Also, some processing is required here before this becomes a traceable value. The raw position counts, as generated by the laser interferometer, are converted to meters, based on the calibrated wavelength, the interpolation factor of the laser controller, the correction for the momentary index of refraction and the material temperature of the line scale.

Lasers used by VSL are calibrated in-house using either an Iodine stabilized standard laser or more directly against our frequency comb. These calibrations result in a very accurate knowledge of the frequency of the laser light. The vacuum wavelength is calculated using the definition of the speed of light (c=299 792 458 m/s [11]). When the laser is used under ambient conditions, the wavelength is changed by the refractive index of air. Since direct measurement of the refractive index is difficult, the correction is usually done by calculating the index using the Edlen equation [12] while constantly measuring the required parameters as the air pressure, air temperature, relative humidity and the CO_2 content. The validity of the Edlen model to calculate the index of refraction is limited to about $1{\cdot}10^{-8}$, putting a lower limit on the accuracy. The uncertainty on the distance measurement is also determined by the uncertainty in the values of the ambient parameters adding up to $5{\cdot}10^{-8}L$.

Besides the correction due to ambient air conditions, the length of the line scale also depends on its temperature. The correction is calculated based on the coefficient of thermal expansion and the temperature deviation from 20 °C. When the thermal expansion coefficient is not explicitly calibrated, we assume an uncertainty of $1{\cdot}10^{-6}$ /K in its value. With a temperature gradient over the scale estimated to be 0.1 °C,the relative contribution to the measurement uncertainty is $1{\cdot}10^{-7}L$.

Combining the processed laser interferometer and image information finally results in an accurate position of each line scale marker.

Uncertainty Budget

The most significant uncertainty sources have been identified in the previous sections resulting in the following uncertainty budget in Table 1.

Table 1. Uncertainty Budget

Source	Uncertainty	Distribution	Standard uncertainty
Laser interferometer	0.6 nm	rectangular	0.2 nm
VS	7 nm	normal	7 nm
Data synchronisation	2 nm	rectangular	1.2 nm
Abbe error static	2 nm	rectangular	1.2 nm
Abbe error dynamic	1 nm	rectangular	0.6 nm
Laser alignment	$1.2{\cdot}10^{-9}L$	rectangular	$7{\cdot}10^{-10}L$
Scale alignment	$1.2{\cdot}10^{-9}L$	rectangular	$7{\cdot}10^{-10}L$
Edlen equation	$1{\cdot}10^{-8}L$	normal	$1{\cdot}10^{-8}L$
Refractive index	$5{\cdot}10^{-8}L$	normal	$1{\cdot}10^{-8}L$
Expansion correction	$1{\cdot}10^{-7}L$	rectangular	$6{\cdot}10^{-8}L$
Deformation granite	2 nm	normal	2 nm
Retro reflector aligment	$1{\cdot}10^{-9}L$	normal	$1{\cdot}10^{-9}L$
Retroreflector stability	10 nm	rectangular	5.8 nm
Repeatability	8.2 nm	normal	8.2 nm
	Combined standard uncertainty		12.5 nm + $7.9{\cdot}10^{-8}L$
	Expanded uncertainty (95% coverage)		25 nm + $1.6{\cdot}10^{-7}L$

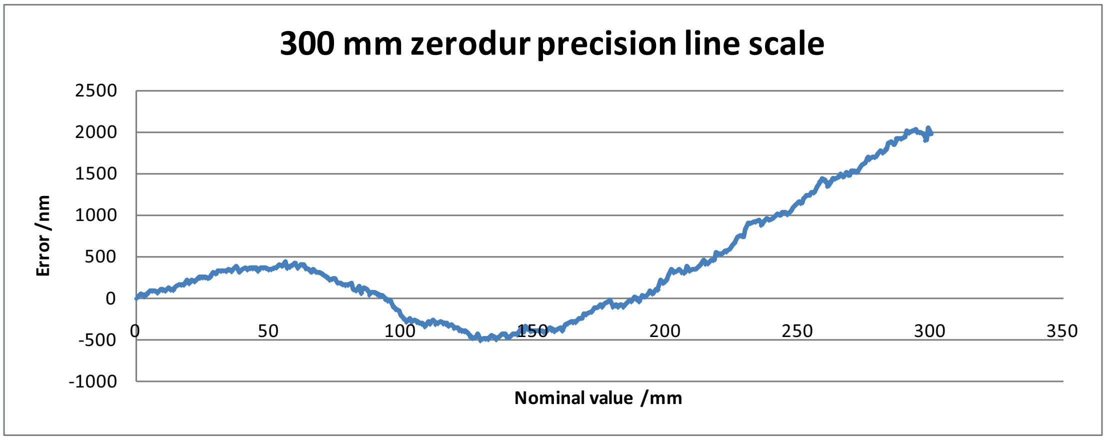


Figure 8. One of the first results obtained with the new setup for our 300 mm Zerodur precision line scale, showing the errors for every single line scale marker along the scale. This scale has a deliberate large deviation from nominal towards the end of the scale, but was previously calibrated only at a few points.

First Results

Fig. 8 shows the result of one of the first fully automated measurements on our 300 mm Zerodur precision line scale. The result is an average over two measurement sequences moving the VS in opposite directions. Although from this result, we had to conclude that the alignment of the laser to the translation direction still had to be improved, the graph shows the errors for all of the 300 individual line scale markers for the first time and reveals a regular sub-structure that was previously unknown and could indicate imperfections in the equipment that was used to manufacture the scale. Because of the low thermal expansion coefficient of Zerodur, the calibration procedure is not suitable to validate the material temperature compensation used in the software to reduce all measurement values to conditions at 20 °C. For this, a material with a larger thermal expansion is needed.

In order to check the compensation in the software and to explore the behavior over the full 1000 mm range, a scale was required of at least this size with a thermal expansion of the order of 10^{-5}/K. As a national metrology institute, VSL still owns one of the Platinum-Iridium x-meter bars that were in use as national standards until the early 1960s. Next to the fact that this artifact had an appropriate length to be used for our purpose, the historical background is worth mentioning briefly. The particular Pt-Ir x-meter from VSL, number 19C, was manufactured in 1884 and originally only had markers at the zero position and 1 m position, until it was refurbished in 1957. At that time, additional millimeter markers were added to the scale, as well as numbers at the centimeter positions. Because in the early days of length metrology it was not yet decided at which temperature the results should be obtained, Pt-Ir meter standards had two markers at the 1 m position; one valid for measurements at 0 °C and one valid for measurements at 20 °C (Figure 9). The adoption of 20 °C as the default temperature for dimensional measurements took place at the CIPM meeting in 1931 and was written down in the first standard (ISO 1) of the International Organization for Standardization in 1951[13] .

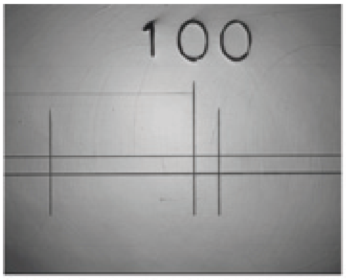


Figure 9. The Dutch x-meter, the former national standard of length, aligned in the new calibration setup. A close-up reveals two markers at the 1 m (100 cm) position since in the early days of length metrology several temperatures values were considered as default. In this case the left marker is valid for calibrating at a temperature of 20 °C and the right one for calibrating at 0 °C.

Just prior to becoming obsolete, our x-meter 19C was calibrated in 1959 and a certificate was issued stating the errors for the 1 meter interval both at 0 °C (actually measured at 0 °C) and at 20 °C, and the errors at the centimeter positions. Since these were the last calibration results and more recent information was not available, we did not use the x-meter results for a formal validation but only to check the performance of our new setup over the full range. Also, the less than ideal quality of the markers and the flatness deviations of the x-meter provided nice challenges for the automated edge detection.

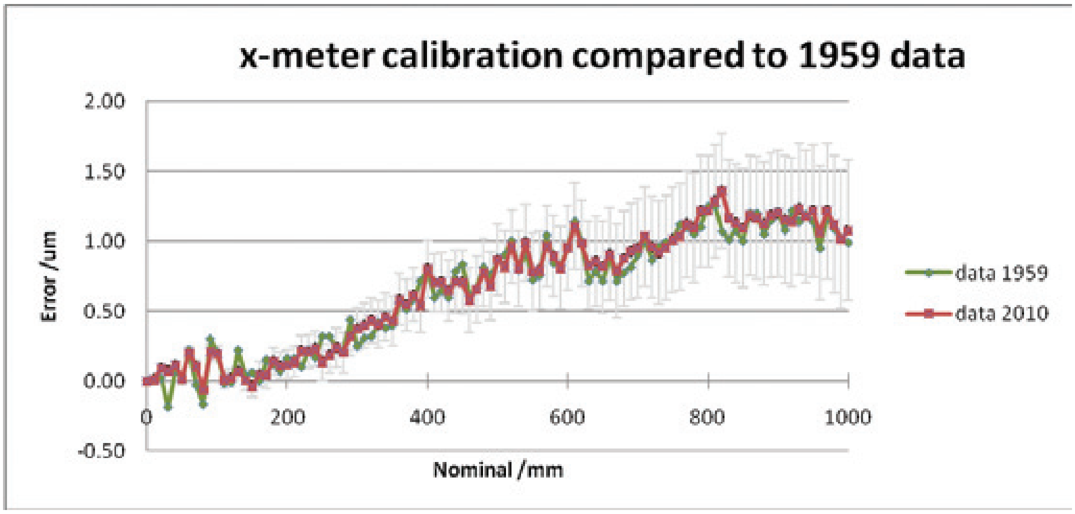


Figure 10. The results obtained with our new setup compared to the calibration performed in 1959 are in good agreement given the measurement error that was evaluated for this calibration. The quality of the surface at the beginning of the scale is responsible for the mismatch in this area.

The results of the calibration and the comparison to the results from 1959 are displayed in Figure 10. Even though the calibration certificate from 1959 does not state a measurement uncertainty, the results are in good agreement except for a few points at the beginning of the scale that could be attributed to the quality of the scale in this region.

Conclusion

The new line scale setup will be validated in the coming months by comparison to results from other national metrology institutes, after which VSL will be able to provide internationally accepted calibration services for line scales at a much reduced uncertainty and covering all individual line markers over a range of 1000 mm.

Acknowledgements
The authors acknowledge the financial support of the Dutch Ministry of Economic Affairs.

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This article was originally published in Mikroniek, the journal of the Dutch Society of Precision Engineering (www.dspe.nl) [Mikroniek 2010, vol. 50(4), pp. 5-12; the results on the x-meter appear in Mikroniek 2011, vol. 51(1)], pp. 48-49.

The Effect of High Transverse Inputs on Accelerometer Calibration

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The Modal Shop, Inc.

ISO 16063 part 21 defines the back-to-back comparison technique for accelerometer calibration. Included in its most recent revision is a recommendation for acceptable limits on shaker transverse motion characteristics. The effect of high transverse inputs can be devastating to accurate accelerometer calibration. This paper discusses the differences between mechanical flexure-based electrodynamic shakers and air bearing shakers and the resulting effects on calibration accuracy and uncertainty.

Introduction

Discussion about accelerometer calibration often refers primarily to the measurement of voltage sensitivity across a frequency range. The most common way to calibrate accelerometer sensitivity is by comparison to a reference transducer, generally another accelerometer designed to have stable low noise sensitivity in the conditions of calibration. Comparison methods are performed by back-to-back measurements, typically as a stepped sinusoid across an appropriate frequency range. The sensor under test (SUT) is mounted in a back-to-back arrangement against a reference accelerometer and both sensors are subject to a common mechanical excitation. Since the motion input is assumed the same for both devices, the ratio of their outputs is also the ratio of their sensitivities, and the SUT sensitivity can be expressed by the following equation:

$$S_{sut} = S_{ref} \bullet (V_{sut}/V_{ref}) \bullet (G_{ref} / G_{sut})$$

where:

S_{sut} is the SUT sensitivity (in mV/G, mV/(m/s^2); pC/G, or pC/(m/s^2))

S_{ref} is the reference transducer sensitivity (in mV/G, mV/(m/s^2); pC/G, or pC/(m/s^2))

V_{sut} is the SUT channel output (in mV)

V_{ref} is the reference channel output (in mV)

G_{sut} is the SUT conditioner gain (in mV/mV or mV/pC)

G_{ref} is the reference conditioner gain (in mV/mV or mV/pC).

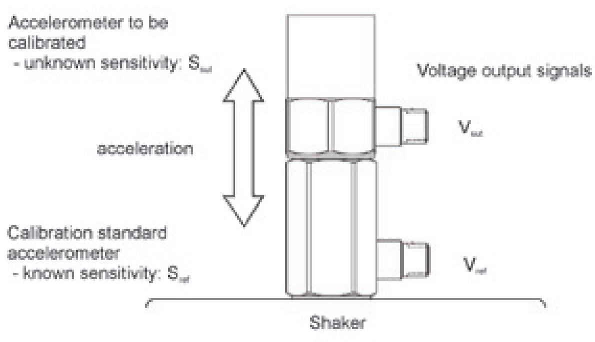

Figure 1. Back-to-back technique.

Accelerometer Vibration Sensitivity Calibration

Vibration calibration uses oscillatory (sinusoidal) excitation normally provided by an electrodynamic exciter or shaker with a back-to-back reference accelerometer (see Figure 1). The procedure for measurement of accelerometer sensitivity is described by ISO 16063-21, "Methods for the calibration of vibration and shock transducers - Part 21: Vibration calibration by comparison to a reference transducer" [1]. The shaker is driven by a sinusoidal vibration signal and the sensitivity of the SUT is measured at that particular frequency. Sweeping through the desired range of frequencies then generates a frequency response curve of the SUT, as shown in Figure 2. Typically the amplitude response showing voltage sensitivity is displayed in units of % deviation from a reference sensitivity (commonly either 100 Hz or 159 Hz).

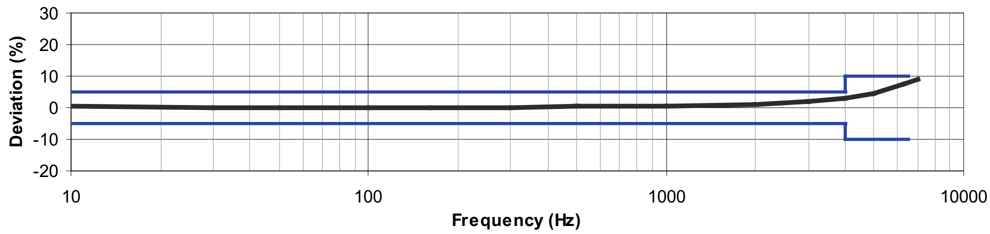

Figure 2. Typical frequency response of an accelerometer. Deviation values refer to calibrated sensitivity at the reference frequency (100 Hz).

Vibration Exciter

Electrodynamic flexure-based exciters (shakers) are commonly used for routine, secondary calibration of accelerometers and often are the "weak link" when calibrating accelerometers. Shakers are structures and have modes of vibration just like any machine. Undesired shaker characteristics, such as excessive transverse motion and waveform distortion will adversely influence the accelerometer's response, resulting in degraded calibration accuracy.

Transverse motion limits are recommended by ISO 16063-21 to be less than 10% for frequencies below 1000 Hz and less than 30% for frequencies greater than 1000 Hz. Undesired transverse motion from bending and rocking modes of traditional flexure-based shakers can be well over 100% of the primary axis motion, particularly at mid-to-high range frequencies corresponding to a flexure or armature resonance. This cross-axis measurement noise can be easily quantified by using a high frequency triaxial accelerometer mounted at the reference accelerometer mounting surface. Using a PCB Model 356B11 ICP® mini-triax and HP 35670A dynamic signal analyzer, swept sine data was acquired to 10 kHz. Applying root-sum-square, the transverse motion vector can be calculated from the accelerometer's X and Y measurement axes. Comparing this value to the measured motion in the Z axis (normally mounted on the back-to-back reference accelerometer) the transverse motion is calculated as a percentage. Experimental results from testing a typical flexure-based "calibration-grade" shaker and the two designs of air bearing shakers presented here, compared to the ISO 16063-21 recommended limits, are shown in Figure 3. Data acquired from the flexure-based design exhibits sizeable cross-axis motion measuring 313%, 103% and 165% at 3560 Hz, 8610 Hz and 9122 Hz resonances, respectively. Both precision air-bearing designs show only a very small amount of cross-axis motion, well less than the ISO recommended limits.

This large cross-axis excitation motion, coupled with inherent transverse sensitivity found in any accelerometer (test methodologies presented by Sill [2]), results in an increased measurement uncertainty at certain calibration frequencies in the frequency response curve. This error can cause a substantial glitch in the frequency response curve, dependent upon how the maximum axis of transverse sensitivity of the reference accelerometer and accelerometer under test happen to line up against the cross-axis excitation motion. Assuming a perfect reference accelerometer and an accelerometer under test with a transverse sensitivity of 5%, a worst-case calibration error at 3560 Hz due to the influence of the measured 313% transverse motion would be 3.13 x 0.05 = 15.65%. It follows that many calibration technicians often scratch their head trying to understand why apparently intermittent glitches cause such trouble in acquiring acceptable calibration data on certain accelerometers (since this measurement error is only present when axes of accelerometer transverse sensitivity align with the exciter cross-axis motion).

As a result, air bearing shakers are the preferred type of electrodynamic shakers for calibration applications. They provide the best approximation of pure single degree of freedom vibration over the widest frequency range, minimizing measurement uncertainty and errors due to the high transverse motion and distortion of traditional flexure-based electrodynamic shakers. As presented previously by Dosch [3], the air-bearing assembly is composed of an armature fitted within a tight-tolerance porous air-bearing. The gap between the armature and air-bearing is extremely small, maintained at about 2 to 4 microns. Since air film stiffness is inversely proportional to gap, this close fitting gap provides the armature with a high lateral stiffness.

The air bearing shaker tested above is shown in Figures 4 and 5. The armature assembly is composed of two parts: the main body, including separate AC and DC coils, and a removable beryllium insert. The reference accelerometer is located within the insert and back-to-back calibration is performed by mounting the SUT on the insert. The armature insert is electrically isolated from the armature body providing means for the armature body to be isolated from the SUT signal ground. This eliminates any electrical noise contribution from the shaker drive signal on the transducer's measurement, unique to this two-part armature design.

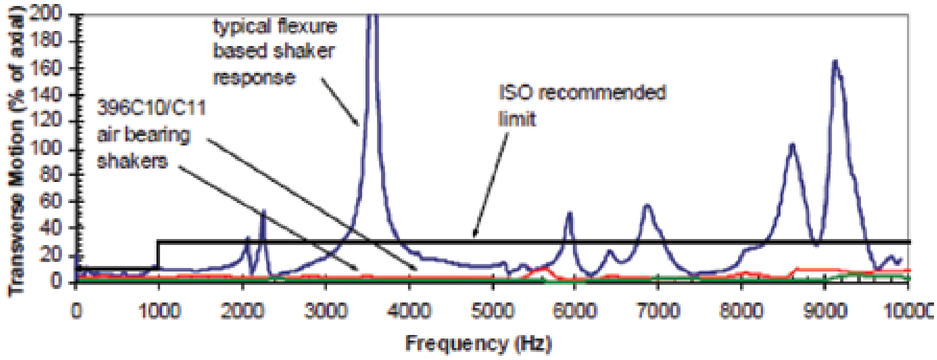

Figure 3. Transverse motion measured on flexure-based and air-bearing calibration shakers, plotted against ISO 16063-21 recommended limits.

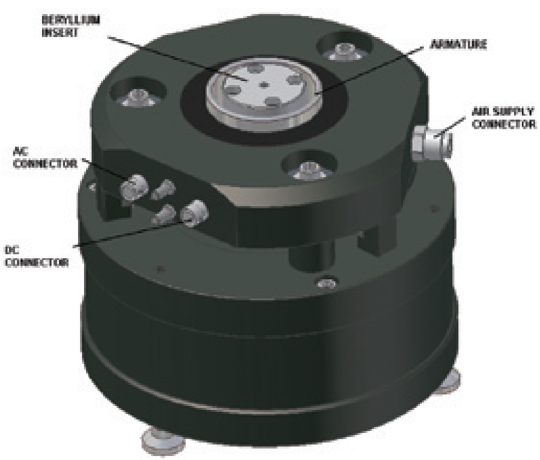

Figure 4. Air bearing shaker [3].

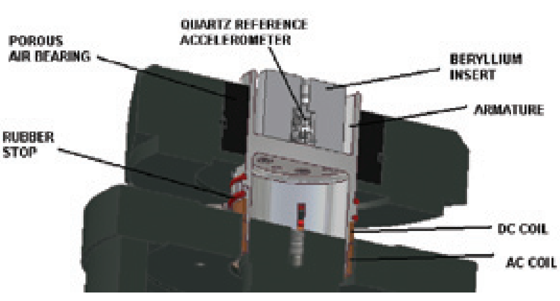

Figure 5. Cross section view of the air bearing shaker [3].

The armature body is fabricated from either aluminum or beryllium. The aluminum design is more common providing excellent calibration signals to 15 kHz while meeting the aforementioned ISO recommended limits. An all-beryllium armature design is also available for extended frequency range calibration. Because beryllium's extremely low density and high stiffness combine to give unusually high speed of sound within the material, structural resonances are therefore very high, so rigid body motion is better approximated, allowing high accuracy calibration up to 20 kHz. The light weight also means higher acceleration levels are possible with the given force. Both the aluminum and beryllium designs also allow for resonance testing up to 50 kHz.

Experimental Calibration Results

A series of calibration data was acquired on a miniature, tear-drop style ICP® accelerometer, PCB Model 352B22. The accelerometer was mounted in six angular positions (rotated every 30 degrees from 0° to 180°) on both flexure-based and air-bearing designs. Data was acquired using The Modal Shop's 9155C accelerometer calibration workstation, which utilizes a National Instruments 24 bit DSA card.

Data acquired while using the flexure-based calibration shaker is shown in Figure 6 (a). The sensor test setup is shown in Figure 6 (b). By overlaying the calibration frequency response data from the six angular positions, the measurement errors due to the large cross-axis transverse motion around 3500 Hz and 8500 Hz are quite obvious. Notice that the size of the measurement glitch (or error) follows the angular position, with a minimum glitch present at 90° and a maximum glitch located perpendicularly at 0°. Calibration data acquired at 3500 Hz, near the 3560 Hz resonance, both the 0° and 30° position yielded approximately an 8% glitch. Also notice that the glitches are not consistent across each of the three areas of high resonance, since the minimum axis of transverse sensitivity and the actual direction of maximum cross-axis exciter motion will not be the same at different frequencies. In other words, optimizing mounting position to minimize the glitch due to the 3560 Hz resonance doesn't necessarily minimize glitches that result near 8610 Hz and 9122 Hz, or vice versa. As a result, a calibration technician may face serious challenges in producing consistent, acceptable calibration certificates, such as the two shown in Figures 7 and 8 for the same accelerometer under test.

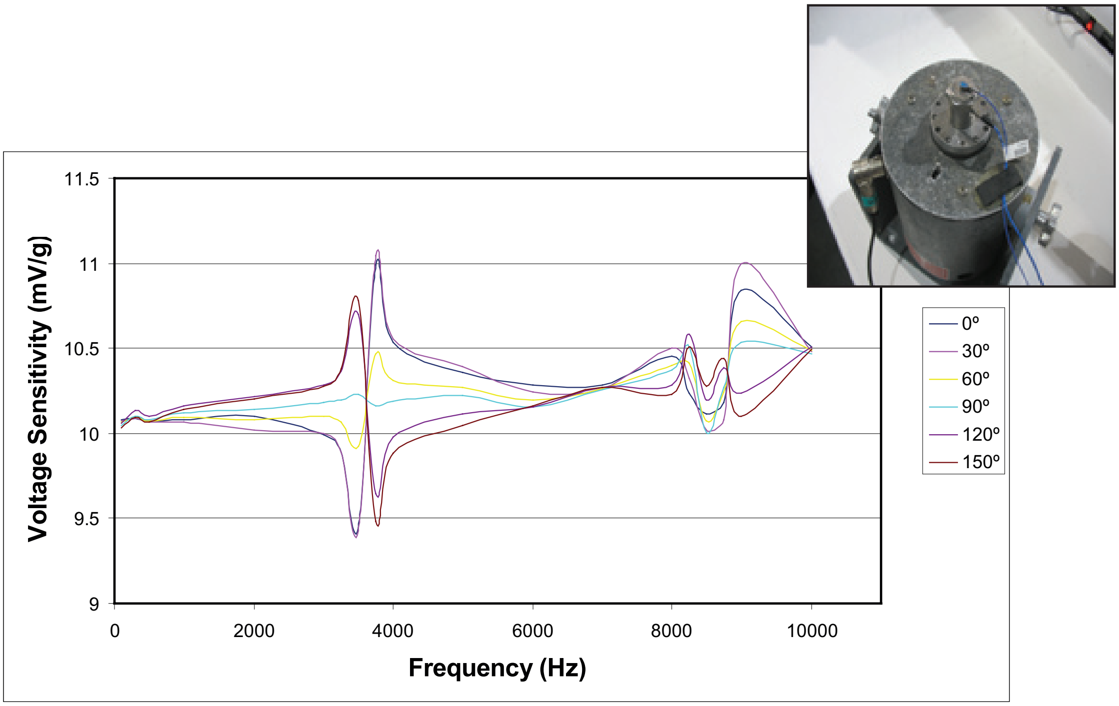

Figure 6. (a) Calibration frequency response data acquired at various rotated positions on flexure-based calibration shaker, (b) Sensor setup mounted on back-to-back reference accelerometer on flexure-based calibration shaker.

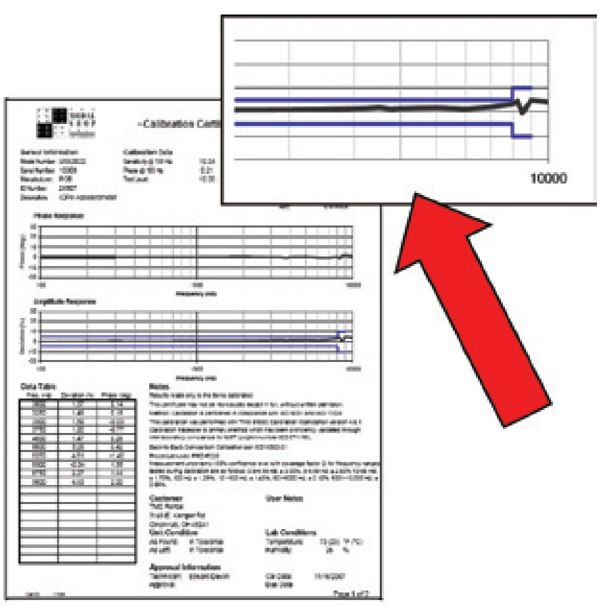

Figure 7. Calibration certificate from the 90° angular position, amplitude response exhibiting small glitch near 3500 Hz exciter resonance.

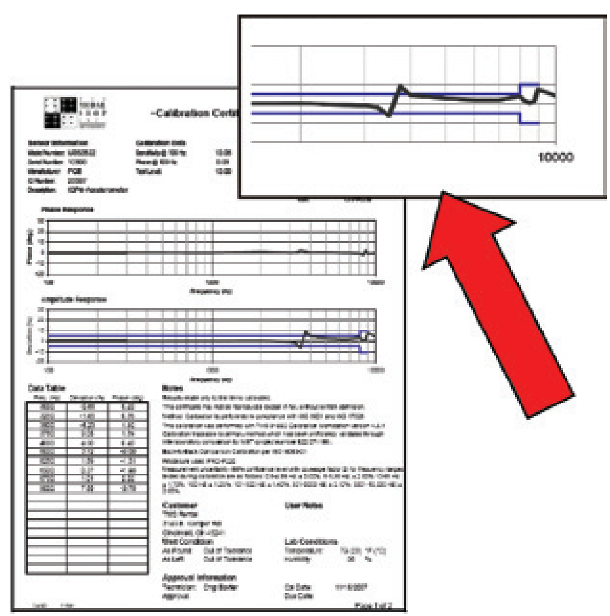

Figure 8. Calibration certificate from the 0° angular position, amplitude response exhibiting large glitch near 3500 Hz exciter resonance.

Data acquired while using a precision air-bearing calibration shaker is shown in Figure 9(a). Its sensor test setup is shown in Figure 9(b). Given the minimal amount of cross-axis exciter motion, significantly better results are seen across the entire frequency range, displayed with the same scale as the flexure-based shaker data in Figure 6. An example calibration certificate generated using the precision air-bearing shaker is shown in Figure 10. The calibration data is much more consistent, with significantly reduced uncertainties and much smaller measurement errors.

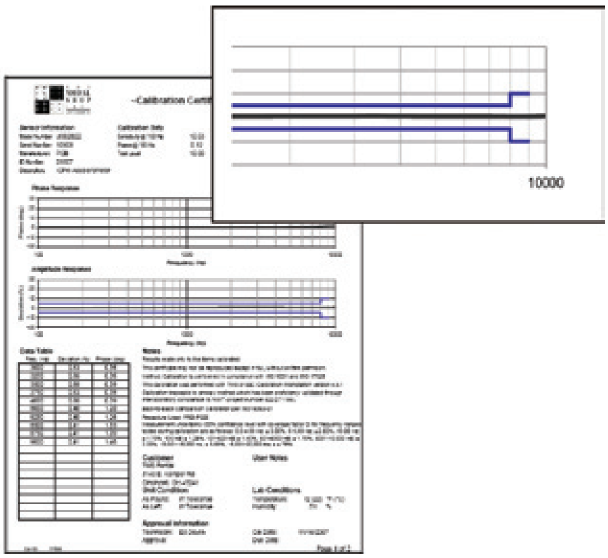

Figure 10. Calibration certificate generated using precision air-bearing calibration shaker. Notice the complete absence of transverse motion induced glitches around 3500 and 9000 Hz.

Effects on Stated System Measurement Uncertainty

ISO 17025 requires that a competent calibration laboratory state measurement uncertainties along with calibration data [4]. In order to adequately define a measurement system's uncertainty, the appropriate sources of uncertainty must be identified. These may include, but are not limited to, mechanical mounting and orientation, signal conditioning gain and frequency response uncertainty, data acquisition resolution, electronics drift, environmental conditions, etc. Cross-axis exciter motion, as shown previously here, can be a substantial source of measurement uncertainty that is often neglected or handled improperly.

A measurement system's combined standard uncertainty is found by taking the root-sum-square of the individual component uncertainties. An expanded uncertainty is determined by multiplying the combined standard uncertainty by a coverage factor, k. Generally, a coverage factor of k=2 is used and corresponds to a coverage probability of 95%. Typical published expanded uncertainties using an air bearing shaker consistent with the design presented here is approximately 1.7% to 2.2% over the 1000 Hz to 10,000 Hz range. Given the measurement errors present in the glitches made using a flexure-based shaker, uncertainties are often understated, and really are substantially larger given the presence of significant cross-axis motion. With just 100% transverse motion, the component uncertainty of transverse motion itself can be approximately 1.7%, compared to an estimate of 0.3% with 15% transverse motion.

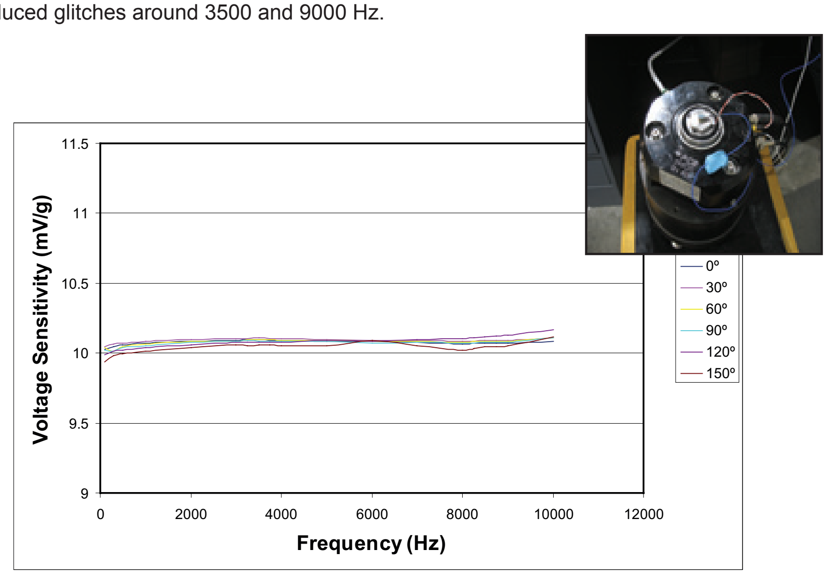

Figure 9. (a) Calibration frequency response data acquired at various rotated positions on precision air-bearing calibration shaker, (b) Sensor setup mounted on insert back-to-back reference accelerometer on air-bearing calibration shaker.

Conclusion

The electrodynamic shaker is the centerpiece of accelerometer frequency response calibration. Undesired shaker characteristics, particularly transverse motion, waveform distortion, electrical cross-talk, etc. result in poor calibration accuracy. Traditional flexure-based calibration shakers introduce significant measurement errors due to these limitations. It follows that when making high accuracy calibration measurements, a reliable, high fidelity air-bearing shaker is one of the most critical components in the entire test setup. A new design of precision air-bearing shakers has made this realizable.

References

[1] ISO 16063-21:2003, Methods for the calibration of vibration and shock transducers — Part 21: Vibration calibration by comparison to a reference transducer.

[2] Sill, Robert D., Seller, Eric J., Accelerometer Transverse Sensitivity Measurement Using Planar Orbital Motion, 77th Shock and Vibration Symposium, November 2006, Monterey, CA, USA.

[3] Dosch, Jeffrey, Air Bearing Shaker for Precision Calibration of Accelerometers, International Modal Analysis Conference, February 2006, St. Louis MO, USA.

[4] ISO 17025, General requirements for the competence of testing and calibration laboratories.

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A Paperless Calibration Department

By Jay L. Bucher
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As metrology/calibration departments need to comply with various requirements, such as 21 CFR Part 11 and ISO 13485, they find their processes increasingly need to be more dependent on electronic systems. The following article is a personal experience in the process of taking his metrology department paperless, including a step by step overview on how to design and create electronic forms to replace hard copy templates. Going paperless not only helps keep metrology departments in compliance, but increases efficiency and security in record keeping.

Introduction

When I was asked to write a short paper on paperless calibration, my first thoughts went back exactly 12 years to January of 1999. That is when I took the metrology department of a large biotech company paperless using Microsoft Word. A few years later, I changed over to using Adobe Acrobat in order to meet 21 CFR Part 11 requirements for electronic records and electronic signatures. From day one, there was no doubt that going paperless was one of the best decisions I have ever made.

Here are a couple of things to keep in mind when reading this article. First, I was not in what most readers assume to be a calibration lab. Not even close. I was managing a metrology department of a biotech company. What that means is this: we performed most calibrations 'on-site' as in taking our standards, calibration SOP, labels and paperwork into a scientific laboratory and calibrating the test instrument on the bench (or floor in the case of large centrifuges) where the unit was used by the customer. We did not perform calibrations for anyone outside the company, so we only had calibration records as opposed to calibration certificates. The only items that were brought to us were pipettes and thermometers to be calibrated in one of our rooms or offices. We did not have a controlled environment other than what the building's normal HVAC system provided; comfortable but not regulated or monitored to the extent any third party calibration lab would be controlled. We were required to meet ISO 9000 and eventually ISO 13485 standards, and then comply with 21 CFR Part 820 requirements. Not a problem since we provided traceable calibration to the SI from day one and maintained a TUR of equal to or greater than four to one (4:1) from the start.

The Push From Paper

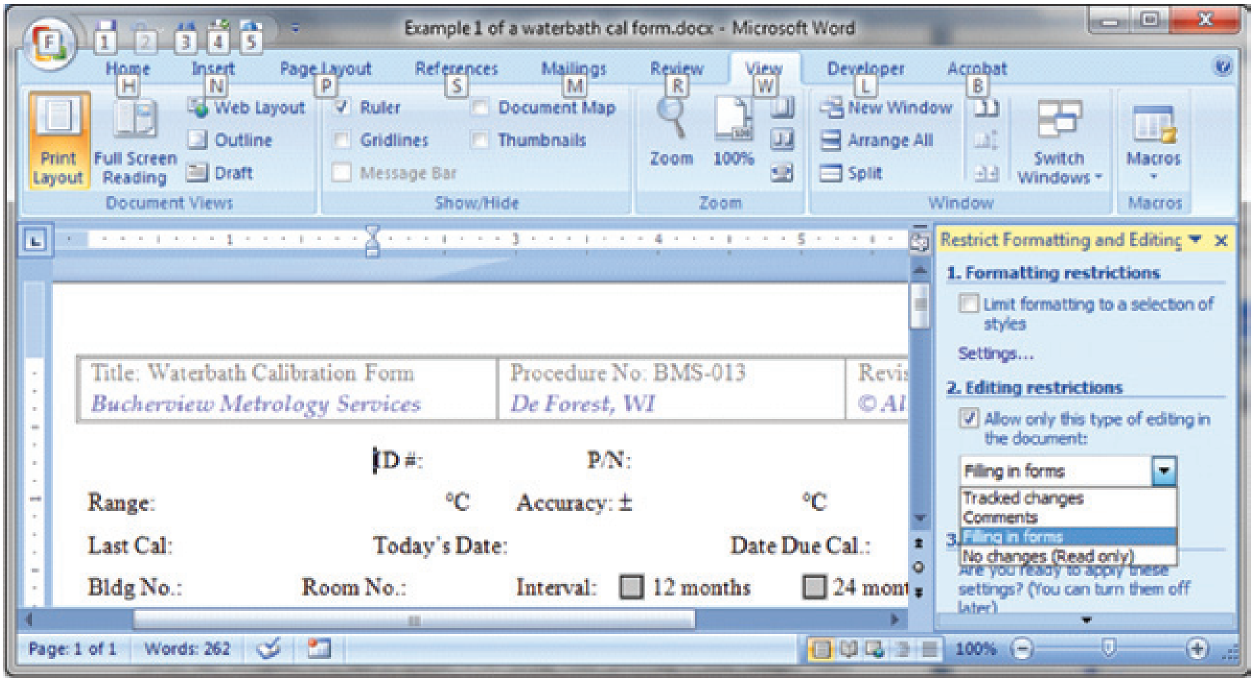
A little history of why we even considered going paperless. In 1998 we had performed 3222 calibrations, which was an increase of twenty percent (20%) over the year before. This had been done by only two full time calibration technicians and part time by me. All indications were that we would continue to grow at a large pace for at least a few years. I started out with four 2 drawer filing cabinets under one of my work benches. That quickly grew to five 4 drawer cabinets that replaced my desk (I was now using a corner bench top for my computer and keyboard). It did not take a crystal ball or statistician to see where this was going. Plus, I was spending at least four hours every Friday morning reviewing the calibration records from that week, co-signing each, and filing in those aforementioned filing cabinets. There had to be a better way. I had an epiphany one morning in the shower, "Why not go paperless with electronic forms to save the data we had to collect, and do away with the filing cabinets?"

The Process

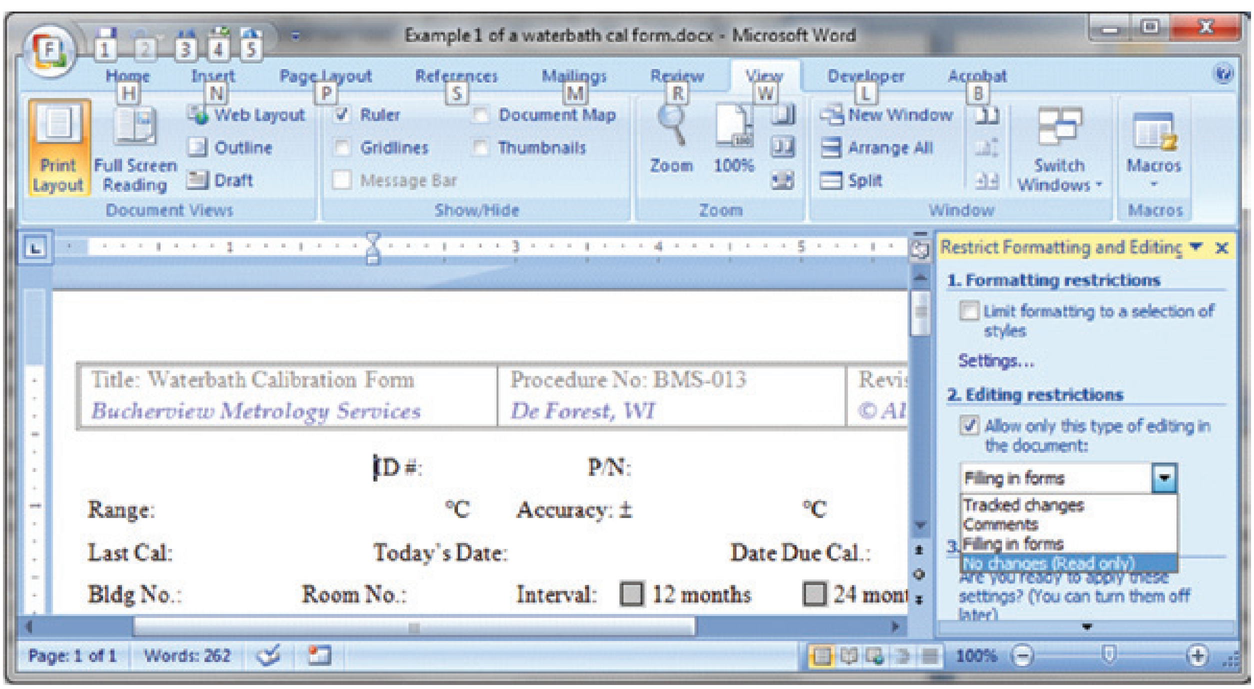
Since my staff would be doing most of the calibrations, I asked them during our weekly staff meeting what they thought. Both were very excited about the idea and could see nothing but positive attributes and no negatives whatsoever. I started putting the system into place right after that morning meeting and, within a week or so, had everything in place to be paperless.

Here is the basic process that you need to accomplish when going paperless:

1. All your hard copy forms used to collect data during the calibration process need to be converted to electronic form templates.
2. You need to set up some sort of system for where to keep the templates, where to keep your completed records (if you co-sign them, you need another folder for that), and a way to have all of these archived and saved on a regular basis.
3. You need to have as many laptop computers available as needed to collect your data while performing your calibrations on-site.
4. If you have the capability, go wireless so that you do not have to transfer your records using thumb drives, network cables, or disk drives (back in 1999 we were using floppy disk drives - 3.5 inch, not 5 1/4 inch for you old timers).



Example 1.



Example 2.

Allow me to expand on each of the previous four steps in the following paragraphs.

Step One: converting your forms into an electronic template isn't as daunting a task as you might originally believe. Using Microsoft Word to design and create electronic forms is easy and can be learned in a matter of minutes. If you do not have to comply with any type of security protocol for tracking changes, ISO compliance or FDA regulations, then Word is an inexpensive and simple way to go. Most businesses already have it at work and once you have designed your forms to meet your requirements, you simply insert the text fields and check boxes; password protect the form for filling in as a form (see Example 1), and you're ready to use it as a template.

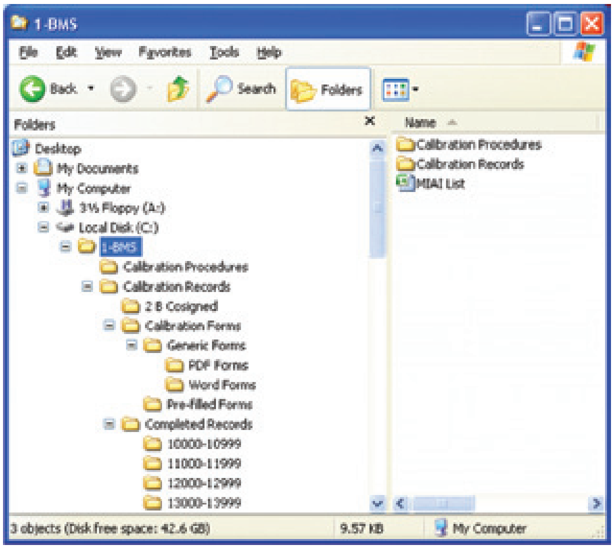
Once you have saved the new form template to a secure location, you're ready to start using them as electronic forms. Once you have completed the form and dated and signed it, you now have an electronic record. Without data and a signature, you only have a form.

As you type data into your text boxes, the fields will expand to accommodate the data. After the form is completed, the calibration technician has saved it to a predetermined folder, and the form has been co-signed (if appropriate), then the supervisor/manager only has to unprotect the form and re-protect as 'read-only' (see Example 2), and save to a secure location.

If you are in a regulated environment, this system will not work. You're required to track changes to your records after completing them. Word does not allow for this type of security. This is why I changed to Adobe Acrobat. You can set up your signature blocks so that after being signed, the selected fields are locked and cannot be accessed (read-only). For those needing a 'second set of eyes' for co-signing, you can also set it up so that the co-signer's date and signature block are the only unprotected fields, so once they date and sign, those are also set to be 'read-only'. This makes your new calibration record secure, safe and in compliance with 21 CFR Part 11. Please keep in mind that you have to build your forms in such a way that you have enough space for comments and data built into the form since the fields do not expand in Adobe Acrobat like they did in Word. This is one of the differences in using the two programs for making electronic templates. Another is that when you convert your Word document into a Portable Document Format (PDF) to use with Adobe Acrobat, any text or check box fields that you have created will not carry over into the PDF. You have to create all new text fields and check boxes. You would have been using a text field to insert a picture of your signature while using Word, but in Adobe Acrobat, you get to create a one of a kind signature block with a special tool within that program to help you do that.

If you decide to use Adobe Acrobat for creating and filling out your electronic calibration forms, here are a few important considerations. There are three versions of Adobe Acrobat: *Reader*, *Standard*, and *Professional*. *Reader* is basically unacceptable for your needs. *Standard* is required for your calibration technicians to fill in your forms and to save them as a complete calibration record. *Professional* is required to make your calibration form templates. It used to create your text fields, check boxes, and signature fields. There are many other options available within Adobe Acrobat Professional that are not in Word, but I will expound on that at the end of this article. Also, you can use *Professional* to complete your forms just like you would when using Standard.

Step Two: setting up a filing system for electronic records. You will need a file folder to keep your templates that all of your calibration technicians can access; a separate file folder for the completed record once the technician has dated, signed, and stored it awaiting the co-signer's signature; and finally, a folder for all the completed records. I set up a folder that was sorted by ID numbers. We used a five digit, sequential ID number system. After completing the calibration, we used the ID number of the item calibrated, along with a hyphen and that day's two digit year and Julian date (e.g. 13169-11018) as the file name for that particular calibration record. The example is for ID number 13169, calibrated on January 18th (018) in 2011 (the 11 before the Julian date). This ensures that we can never have two identical file names for our calibration records, while allowing us to easily find the calibration record we are looking for during audits and inspections. The calibration form templates are filed by their calibration template number/SOP number or can also be filed by their generic calibration name (i.e. gage form, waterbath form, or temperature device form). See Example 3 for a suggestion on how to set up a filing folder system electronically.



Example 3.

As seen in Example 3, there are a few main and sub-folders. The Calibration Procedure folder is self explanatory. The Calibration Records folder is only a place holder, with nothing but the sub-folders under it. Completed and signed calibration records would be stored in the '2 B Cosigned' folder, awaiting co-signing. Once co-signed, they would be moved by the co-signer to the Completed Records folder under the appropriate section with their ID number sequence. The calibration form template would be kept in either the Generic Forms folder, or the Pre-filled Forms folder. The Pre-filled Forms folder would be where you store you calibration form templates that have been pre-filled with data that cannot be changed, such as range and tolerances, part numbers, etc.

An important item to keep in mind when setting up your electronic record keeping system is how often you will archive/backup your forms and records. In my former life, the company backed up the drives where our forms and records were kept nightly, so we did not have to worry about losing data or records. I would recommend having a backup accomplished at least weekly. There are a couple of ways to do this. You can have your IT department do it in conjunction with their normal backups. You can copy your records to another hard drive on a regular basis, or you can copy them to a thumb drive (if you don't have that many records) and store that drive in a safe location. Also, it was found that a separate location for storing your calibration form templates was a very good idea. What would happen on occasion is that the calibration technician would not copy the form to his/her laptop or desktop, but would fill out the unit under the test's data (ID number, part number, calibration dates, location, etc.) and hit the save button, thereby copying over your template with a partially completed record. We all have gotten in the habit of hitting the save icon on our computers as a matter of course, but sometimes this can cause problems. So it is advisable to have your 'master' set of calibration form templates in another location for easy copying when this happens.

Step Three: getting the laptops to use while going paperless. In 1999, we did not have a lot of choice in laptops. Today, we almost have too much variety. In some respects this is good. If you only use the laptop to complete your calibration records and as a wireless unit for transferring files, an inexpensive netbook might fulfill your needs. Your requirements and budget will help make that decision for you. You will have to be able to load a minimum number of programs, including Adobe Acrobat Standard, and possibly any Calibration Management software that your department uses.

Step Four: wireless transfer of your data. As in step three, the electronic market is much better and less expensive than it was 12 years ago. Almost all laptops and netbooks come with some sort of wireless system already installed. Check with your IT department or person to find out what is needed to be wireless in your location.

Books

If the reader wants to be paperless using Microsoft Word as their software package, I wrote a book that explains for the beginner how to use the program to setup, design and create electronic forms. It also shows how to use Adobe Acrobat Pro 8.0 in creating electronic forms. The book can be viewed at: http://www.bucherview-metrology.com/products/products_paperless_book.htm.

If you wish to use the latest updated version, Adobe Acrobat Pro 9.0, I show how to use that version, as well as how to meet biotech, pharmaceutical, and medical device requirements in this book:

http://www.bucherview-metrology.com/products/products_APCDTMBPMDR_Book.htm.

Closing Notes

Keep in mind that this paperless calibration record system could also work in an environment where a calibration technician sits at the same work bench day in and day out performing their calibrations. If this is the case, a desktop computer would work just as easy as a laptop. The only time we had a requirement to access our electronic calibration records was during audits and inspections. Remember, we only calibrated test equipment owned by the company we worked for, not any outside clients, so we did not have to generate calibration certificates or meet ISO/IEC 17025 standards. We did have to meet the ISO standards and FDA requirements of the company we worked for, though. We needed to show our traceability chain back to the SI and we could do that from any location that had a computer for us to use. No more traveling to one location to access filing cabinets, trying to find one particular record and only to discover that it was not where it was supposed to be because it had not been filed for that week yet. Murphy's Law was alive and well where we lived and worked. Mr. Murphy was not so happy after we went electronic in our collection, storage, printing and archiving of our calibration records. We met all ISO standards and FDA requirements, saved time and money immediately upon implementing the system, and did not have to increase our manpower due to increased inventory support. All in all, a very good day in calibration land. I wish all of you the best of luck in your paperless calibration endeavors.

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