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THE INTERNATIONAL JOURNAL OF METROLOGY

Micro-Feature Dimensional and Form Measurements with the NIST Fiber Probe on a CMM

A Programmable Calibration System for Accurate AC Current Measurements at NIS, Egypt

Calibration Management in the ISO/IEC 17025 Accredited Facility

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VOLUME 17, NUMBER 3

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FEATURES

DEPARTMENTS

ON THE COVER: A new system developed at NPL, United Kingdom, enables Morehouse to provide an A2LA accredited calibration of force devices up to 2,250,000 lbf in compression or 1,200.00 lbf in tension. Morehouse also provides calibration service for load cells, proving rings, crane scales, force gauges and other force devices. Visit www.mhforce.com. Photo courtesty of Morehouse Instruments.

CALENDAR

CONFERENCES & MEETINGS 2010

Sep 13-17 AUTOTESTCON. Orlando, FL. www.autotestcon.com.

Oct 12-14 VII International Specialized Exhibition: Controlling, Analyzing and Measuring Equipment 2010. Russia, Moscow. http://www.kipexpo.ru/english/.

Oct 12-14 Microtechnology Expo. Russia, Moscow. www.microtechexpo.ru/eng/.

Oct 25-28 IEST Fall Conference. Arlington Heights, IL. Working Group sessions and tutorials covering issues related to cleanrooms and controlled environments. IEST, www.iest.org

Oct 31 - Nov 5 25th ASPE Annual Meeting. Atlanta, GA. American Society for Precision Engineering (ASPE), www.aspe.net.

Nov 15-18 Eastern Analytical Symposium and Exposition (EAS). Somerset, NJ. www.eas.org.

Dec 10-12 2nd India Lab Expo. New Dehli, India. An exhibition of scientific, biotechnology, analytical & laboratory technology. Expected 280 exhibitors participating. www.indialabexpo.com.

CONFERENCES & MEETINGS 2011

Feb 8-10, 2011 HuLST (Human Life Science Test) Expo. Koelnmesse, Cologne, Germany. Four fairs under the HuLST umbrella are: Medical Device and Technology Test Expo; Food and Beverage Test Expo; Pharma Test Expo, and Biotech Test Expo. Exhibits and technical presentations will cover all types of testing, inspection and quality assurance. www.hulst-expo.com.

Mar 31-Apr 1, 2011 METROMEET: 7th International Conference on Industrial Dimensional Metrology. Bilbao, Spain. Topics: Advances of micro- and nanometrology; measurement issues of large work pieces and their solutions; metrology and economics; new developments in virtual metrology; recent developments in the area of metrological software; state of the art and challenges of multi-sensor coordinate metrology; accreditation and certification; future metrology tendencies; latest developments and solutions in the area of optical non-contact measurement and 3D digitalisation systems; methods, organisation and best practices in industrial metrology; academic education in metrology; new developments in measurement instruments; industrial process quality requirements and metrology-based process improvements; in-line inspection; uncertainty traceability and reliability of measurements with CMMs; sports metrology. METROMEET, tel +34 94 480 51 83, info@metromeet.org, www.metromeet.org.

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THE INTERNATIONAL JOURNAL OF METROLOGY

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The Little Country that Could

American readers may recognize the play on words in my title taken from *The Little Engine that Could*, a children's book about a little train engine chugging along pulling its cars and upon reaching a large hill worries that it won't be able to make it over the hill. There's a dramatic moment as it climbs the hill and looses speed and starts slipping back, but with great determination the engine continues to put everything it has into that climb and finally reaches the top and joyfully rushes down the other side and onto its destination. The point of the story is that even the smallest engine can achieve great things if it believes in itself and tries with all its might.

In November 2008 I visited Israel for the first time to attend their international metrology conference. Like most Americans I had sentimental feelings about Israel and a curiosity to see this tiny land that has so dominated the news since its birth in May 1948. Israel is unlike any country I have ever visited. It is smaller in size than you think — smaller than New Jersey, maybe about the same as Canada's Vancouver Island, less than 1/11th the size of the United Kingdom. It is 20,777 square kilometers (8019 square miles). It has 7.5 million citizens, 74.5% Jewish, 20.3% Arab and 4.3% "others." It is surrounded by hostile neighbors and has endured 4 major wars, hundreds of terrorist attacks, thousands of rocket attacks from terrorists in Lebanon and more recently from Gaza.

Israel is like America in that it is a melting pot of people from all over the world and an open democracy where all citizens are eligible to vote and serve in political office. Israel and America have enjoyed a unique friendship since the beginning, maybe in part because many of its citizens are Americans including past Prime Minister Golda Meir and current Ambassador to the U.S. Michael Oren.

Where Israel becomes relevant to metrology is in the amazing contributions it has made to industry in telecommunications, medicine, biotechnology, agriculture, alternative energy sources, security and the list goes on. Israel recently hosted Biomed 2010, the second largest biotech conference in the world with 7,000 attendees, 1,000 from outside Israel. Intel has a major R&D center and two fabrication plants in Israel. Motorola's plant in Israel is the company's largest facility in the world. The first computer anti-virus software package was developed in Israel back in the 1970s. The mobile phone technologies that allow you to leave voicemail, send text messages and transmit movies or pictures were all developed in Israel. The high quality color images in newspapers are transmitted by graphic technologies developed by Scitex, one of Israel's earliest technology companies. The Pentium processor chip was largely developed in Israel. Many hospital CAT scanners and magnetic resonance imaging (MRI) machines were developed in Israel. The life-saving stent used to keep arteries open was originally developed by Medinol in Israel. The list goes on.

I was so fascinated with the accomplishments of this little dynamo country that I purchased two books that describe their contributions and they are even more amazing than I imagined. Israel is "the little country that could" and does provide technology to the world at a level far beyond their size and despite the immense pressures of surviving in a hostile environment and absorbing thousands of new immigrants each year. Israel deserves our complete support and unwavering commitment to her survival and the well being of her citizens.

Best regards,

Carol Singer

CALENDAR

May 24-27, 2011 AUSPLAS, AUSTECH and National Manufacturing Week. Melbourne, Australia. Ausplas is Australia's national trade show for the plastics processing industry, organized by the Australian Manufacturing Technology Institute, Ltd. National Manufacturing Week is Australia's only fully integrated manufacturing industry exhibition displaying all major aspects across ten specialist product zones. AUSPLAS, info@exhibitionmanagement.com, www.ausplas.com.

Aug 21-25, 2011 NCSLI Conference. National Harbor, MD. Conference theme: 50 Years: Reflecting On The Past - Looking To The Future. www.ncsli.org.

Sep 27-29 LabAsia 2011. Kuala Lumpur, Malaysia. LabAsia 2011 is the third in a series of biennial international exhibitions that showcase the latest in laboratory and analytical equipment, instrumentation and services. Institut Kimia Malaysia (IKM) is a professional scientific organisation to regulate the practice of chemistry, represent the chemistry profession and promote the advancement of chemistry in Malaysia. In conjunction with LabAsia 2011, IKM is organising two major international scientific meetings. The IUPAC International Conference on Chemical Research Applied to World Needs, CHEMRAWN 2011, will focus on Renewable and Sustainable Energy from Biological Sources, and will showcase the latest research, technology and innovation in renewable and sustainable energy. The 13th International Symposium on Advances in Extraction Technologies or ExTech 2011 will feature the latest in extraction technologies, separation science and the ensuring analytical techniques and is especally useful for our scientists working in all areas who are engaging in extraction, separation and analytical sciences. The ExTech series of international symposia has been held all over the world; but this is the first time it is being held in Asia. Institut Kimia Malaysia (IKM), www.lab-asia.com.

SEMINARS Australia

Aug 20 Humidity Workshop. Lower Hutt, New Zealand. Measurement Standards Laboratory of New Zealand, http://msl.irl.cri.nz/training-and-resources/training-courses.

Aug 24 Balances and Weighing Workshop. Auckland, New Zealand. Measurement Standards Laboratory of New Zealand, http://msl.irl.cri.nz/training-and-resources/training-courses.

Aug 24-25 Traceable Electrical Energy Metering. Lower Hutt, New Zealand. Measurement Standards Laboratory of New Zealand, http://msl.irl.cri.nz/training-and-resources/training-courses.

Aug 25 Measurement, Uncertainty and Calibration. Auckland, New Zealand. Measurement Standards Laboratory of New

Zealand, http://msl.irl.cri.nz/training-and-resources/training-courses.

Aug 26 Temperature Measurement and Calibration. Auckland, New Zealand. Measurement Standards Laboratory of New Zealand, http://msl.irl.cri.nz/training-and-resources/training-courses.

SEMINARS Europe & United Kingdom

Sep 24-26 Flow Measurement and Calibration: Liquid and Gas. Munich, Germany. In English. The seminar is being held during the time of the famous Munich Oktoberfest. TrigasFI GmbH, tel: +49-8165-64 72 0, info@trigasfi.com, http://www.trigasfi.de/html/en_seminars.htm.

Sep 27-29 Durchflussmessung und Kalibrierung. Munich, Germany. In Deutscher Sprache. TrigasFI GmbH, tel: +49-8165-64 72 0, info@trigasfi.com, http://www.trigasfi.de/html/en_seminars.htm.

Oct 26-28 28th International North Sea Flow Measurement Workshop. St Andrews, UK. Technical presentations, real work experiences, poster presentations and networking sessions. TUV NEL Ltd., tel +44 (0)1355 272858, events@tuvnel.com, www.tuvnel.com.

SEMINARS USA

SEMINARS: Accreditation & ISO/IEC 17025

Oct 28-29 Auditing to ISO 17205. Bloomington/Burnsville, MN. J&G Technology, tel 952-935-1108, gmeyer@jg-technology.com, www.jg-technology.com/seminars.html.

SEMINARS Analytical Chemistry

Nov 15 Metrology in the Analytical Laboratory. Somerset, NJ. Stranaska LLC, www.stranaska.com. Available through the Eastern Analytical Symposium Short Course Program. www.eas.org.

SEMINARS Certified Calibration Technician Exam

Sep 13-17 CCT-501 Metrology for Cal Lab Personnel. Seattle, WA. Fluke, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

Sep 21 Calculator Refresher for Certification Exams. Bloomington/Burnsville, MN. J&G Technology, tel 952-935-1108, gmeyer@jg-technology.com, www.jg-technology.com/seminars.html.

Nov 2 Calculator Refresher for Certification Exams. Bloomington/Burnsville, MN. J&G Technology, tel 952-935-1108, gmeyer@jg-technology.com, www.jg-technology.com/seminars.html.

Nov 3-5 Certified Calibration Technician Preparation. Bloomington/Burnsville, MN. J&G Technology, tel 952-935-1108, gmeyer@jg-technology.com, www.jg-technology.com/seminars.html.

Nov 3-5 Certified Calibration Technician (CCT) Review. Minneapolis, MN. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

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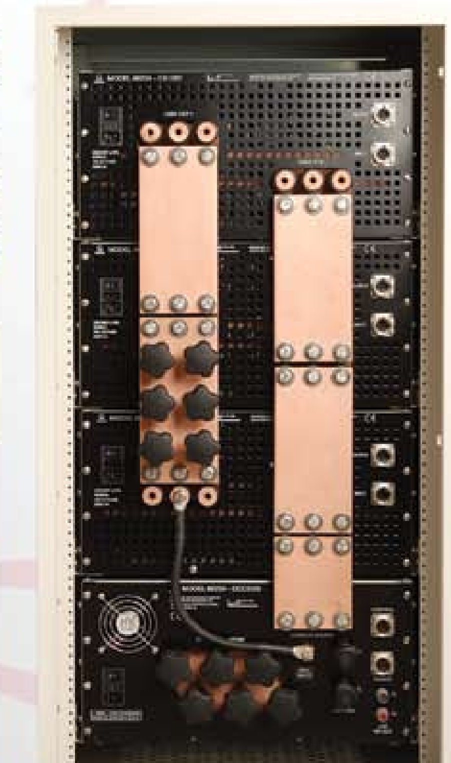

Model 6623A-150 (above) is only slightly larger than 5" in height. The 6623A-300 adds only 2" to total height (7"). Both units are capable of operating off 120VAC line voltage.

GUILDLINE INSTRUMENTS

PRECISION MEASUREMENT SOLUTIONS WWW.GUILDLINE.COM 1-800-310-8104

Nov 10-12 Certified Calibration Technician (CCT) Review. Schaumburg, IL. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

SEMINARS: Dimensional and Gage Calibration

Aug 26-27 Basic Dimensional Measurement Tools and Methods. Jackson, MS. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

Aug 30-31 Calibration Training and Hands-On Gage Repair. Richmond, VA. IICT Training & Productions, info@consultinginstitute.net, http://consultinginstitute.net/.

Aug 31 GD&T Management Overview. Orlando, FL. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

Aug 31 - Sep 1 GD&T Training - Fundamentals. Orlando, FL. Dan Medford, The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

Aug 31 - Sep 2 Coordinate Measuring Machine, CMM Training. Minneapolis, MN. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

Sep 2-3 Calibration Training and Hands-On Gage Repair. Myrtle Beach, SC. IICT Training & Productions, info@consultinginstitute.net, http://consultinginstitute.net/.

Sep 13-14 GD&T Training - Fundamentals. Rolling Meadows, IL. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

Sep 14-15 Basic Dimensional Measurement Tools and Methods. Schaumburg, IL. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

Sep 14-15 Calibration Training and Hands-On Gage Repair. Schaumburg, IL. IICT Training & Productions, info@consultinginstitute.net, http://consultinginstitute.net/.

Sep 15-17 GD&T Training - Advanced Concepts. Rolling Meadows, IL. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

Sep 16-17 Calibration Training and Hands-On Gage Repair. Kenosha, WI. IICT Training & Productions, info@consultinginstitute.net, http://consultinginstitute.net/.

Sep 23 GD&T Management Overview. Jackson, MS. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

Sep 23-24 GD&T Training - Fundamentals. Jackson, MS. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

SEMINARS FDA / ISO 13485 / QSR

Sep 27-28 Calibration in the FDA Regulated Industries. Las Vegas, NV. University of Wisconsin Department of Engineering Professional Development. http://epdweb.engr.wisc.edu/Courses/Course.lasso?myCourseChoice=L625 or Program Director Michael F. Waxman, Ph.D., waxman@epd.engr.wisc.edu, toll free tel 800-462-0876, tel 608-262-2061.

Sep 27-30 Gas Flow Calibration Using molbloc/molbox. Phoenix, AZ. Fluke/DH Instruments, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

Nov 15-18 Gas Flow Calibration Using molbloc/molbox. Phoenix, AZ. Fluke/DH Instruments, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

SEMINARS: General Metrology, Best Practices, Calibration Training & Laboratory Management

Sep 20-24 CLM-301 Cal Lab Management for the 21st Century. Seattle, WA. Fluke, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

Sep 27-30 MET-101 Basic Hands-On Metrology. Seattle, WA. Fluke, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

Nov 1-4 MET-301 Advanced Hands-On Metrology. Seattle, WA. Fluke, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

SEMINARS: Materials Characterization

Aug 25-26 Test Methods for Composite Materials. Tampa, FL. Seminars For Engineers, tel 800-755-2272, info@SeminarsForEngineers.com, www.seminarsforengineers.com/comptest.

SEMINARS: Measurement Uncertainty

Sep 14-16 Measurement Uncertainty Workshop. Fenton, MI. Presented by QUAMETEC Institute, tel 810-225-8588, www.QIMTonline.com.

Nov 9-11 Measurement Uncertainty Workshop. Fenton, MI. Presented by QUAMETEC Institute, tel 810-225-8588, www.QIMTonline.com.

Dec 6 Measurement Uncertainty Overview. Minneapolis, MN. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

Dec 6-7 Measurement Uncertainty Budgets. Minneapolis, MN. The QC Group, tel 800-959-0632, Training@theQCgroup.com, www.theqcgroup.com/courselist/.

Dec 6-7 Understanding Measurement Uncertainty. Bloomington/Burnsville, MN. J&G Technology, tel 952-935-1108, gmeyer@jg-technology.com, www.jg-technology.com/seminars.html.

SEMINARS: Pipette Proficiency & Quality Management

Sep 23-24 Pipette Quality Management Certification. Westbrook, ME. ARTEL, tel 888-406-3463, tel 207-854-0860, info@artel-usa.com, www.artel-usa.com/news/training.aspx.

Nov 15-16 Pipette Quality Management Certification. Westbrook, ME. ARTEL, tel 888-406-3463, tel 207-854-0860, info@artel-usa.com, www.artel-usa.com/news/training.aspx.

SEMINARS: Pressure

Sep 13-17 Precision Pressure Calibration. Phoenix, AZ. Fluke - DH Instruments, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

Oct 12-15 Setting Up and Using COMPASS® for Pressure Software. Phoenix, AZ. Fluke - DH Instruments, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

Dec 6-10 Precision Pressure Calibration. Phoenix, AZ. Fluke/DH Instruments, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

SEMINARS: Software

Oct 4-7 MET/CAL Database and Reports. Seattle, WA. Fluke, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

Oct 11-14 MET/CAL Procedure Writing. Seattle, WA. Fluke, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

Oct 18-21 MET/CAL Advanced Programming Techniques. Seattle, WA. Fluke, tel 888-79-FLUKE, www.fluke.com/2010caltraining.

SEMINARS: Vibration / Shock

Sep 20-23 Fundamentals of Random Vibration and Shock Testing, HALT, ESS, HASS. San Jose, CA. Equipment Reliability Institute, tel 805-564-1260, tustin@equipment-reliability.com, http://equipment-reliability.com/open_courses.html.

Oct 12-14 Pyrotechnic Shock Testing, Measurement, Analysis and Calibration. Santa Clarita, CA. Equipment Reliability Institute, tel 805-564-1260, tustin@equipment-reliability.com, http://equipment-reliability.com/open_courses.html.

Nov 1-4 Fundamentals of Random Vibration and Shock Testing, HALT, ESS, HASS. Orlando, FL. Equipment Reliability Institute, tel 805-564-1260, tustin@equipment-reliability.com, http://equipment-reliability.com/open_courses.html.

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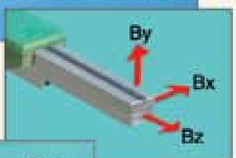
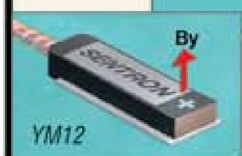
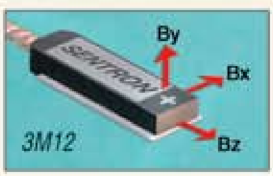


3RTP



YM12



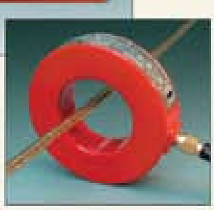
3M12

Application	Product	Range	Resolution	Bandwidth
Linear field sensing. Non-contact measurement of position, angle, vibration, current. Small size, low power.	CSA-1V 1-axis Hall IC, SOIC-8	± 5mT	~ 10µT	dc to 100kHz
	2SA-10 2-axis Hall IC, SOIC-8	± 40mT	~ 50µT	dc to 10kHz
High sensitivity and accuracy for low fields. Survey and monitor sites for magnetically sensitive equipment.	MAG-01 1-axis Fluxgate Teslameter	± 2mT	± 0.1nT	dc to 10Hz
	MAG-03 3-axis Fluxgate Transducer	± 1mT	± 0.1nT	dc to 3kHz
Linear field measurement. Feedback control. Quality control. Magnet mapping. Unique 3-axis at one point.	YM12 1-axis Hall Transducer	± 2T	± 12µT	dc to 5kHz
	3M12 3-axis Hall Transducer	± 2T	± 20µT	dc to 1kHz
	3RTP 3-axis Hall Transducer	± 2T	± 100µT	dc to 10kHz
Hand-held 3-axis for fringe field mapping, quality control, safety monitoring.	7025 3-axis Hall Teslameter	± 2T	± 10µT	dc
Precision field measurement and control. Laboratory and process magnets. Analytical instruments.	DTM-133 1-axis Hall Teslameter	± 3T	± 5µT	dc to 10Hz
	DTM-151 1-axis Hall Teslameter	± 3T	± 0.1µT	dc to 3Hz
Calibration of magnetic standards and sensors. Very high resolution and long-term stability.	2026 total field NMR Teslameter	0.04 to 20T	± 0.1µT	dc
	FW101 total field NMR Teslameter	1.4µT to 2.1T	± 0.5nT	dc
Precision flux change measurement.	PDI 5025 Digital Voltage Integrator	40 V.s	± 2E-8V.s	1ms to 2[illegible]ms

Conversion of magnetic flux density (B) tesla to gauss: 0.1nT = 1µG, 100µT = 1G, 1T = 10kG

Electric Current (isolated measurement)

867-400



CT-36

Application	Product	Range	Resolution	Bandwidth
High sensitivity for low currents, currents at high voltage, differential currents.	IPCT Current Transducer	± 5A	± 10µA	dc to 4kHz
Linear sensor for low-noise, high accuracy, high stability power supplies or amplifiers.	867-400 Current Transducer	± 400A	< 4ppm	dc to 100kHz
	866-600 Current Transducer	± 600A	< 4ppm	dc to 100kHz
Instruments for development, quality control, calibration, precision power measurement.	860R Current Transducer	to ± 2000A	< 5ppm	dc to 300kHz
	862R Current Transducer	to ± 25kA	< 5ppm	dc to 10kHz
	866R 6-channel Current Transducer	to ± 600A	< 10ppm	dc to 100kHz
Passive current transformer for rf and pulse current. Low loss, high frequency.	CT Current Transformer	to ± 10kA	to 5V/A into 50 ohm	to 2GHz
	ICT Charge Transformer	to ± 400nC	± 0.5pC	1µs to < 1ps

Fiber-Optic I/O

FTR

CNA

Application	Product	Range	Resolution	Bandwidth
Input/Output modules that can be placed locally at the transducer or controlled unit.	FTR RS-232-C link			50 to 40 kB
For high voltage, high noise environments. RF signal transmission.	CNA Digital & Analog link	± 100mV to ± 10V	16-bit	dc to 30Hz
	p2p Digital & Analog link	- 20dBm to + 20dBm	< 25dB for 0dBm	dc to 3GHz

US DOE Plans Upgrade to Argonne Photon Source

The US Department of Energy (DOE) has announced a planned upgrade for the Advanced Photon Source (APS) laboratory at Argonne National Laboratory. The upgrade will be more cost-effective than building a new facility and will make revolutionary improvements in performance needed to address the sustainable energy and health research needs of the future. The upgrade will also add new X-ray facilities, make existing X-ray facilities 10 to 100 times more powerful and almost double the number of experiments that can be carried out in a year. In addition, the upgrade is expected to create new high-tech jobs.

Currently, the APS laboratory serves the experimental needs of more than 3,500 researchers each year. The Advanced Photon Source uses high-energy X-ray beams to peer deep into the atomic and molecular structures of materials and living organisms as small as a few nanometers. The APS has been providing the U.S. scientific community with the expertise and research tools that enable breakthroughs such as improved battery technologies, an unprecedented understanding of how engine fuel injectors function, treatment for the human immunodeficiency virus and other diseases, the creation of new nanomaterials, and advances in nanobiology, among other developments.

Upgrades to the accelerator-based x-ray source will include producing record brightness for penetrating x-rays at 25 keV and above using long straight sections, higher beam current and pioneering superconducting undulators; transverse radio-frequency deflection cavities to generate unique high-repetition-rate, 1-picosecond-duration X-ray pulses.

Upgrades planned for unique x-ray capabilities and new beamlines include: long imaging beamlines, nanometer focusing optics for penetrating X-rays, short-pulse X-rays, high magnetic fields, inelastic scattering, phase contrast and nanobeams in realistic environments.

NPL United Kingdom to Establish Branch in Space

The NPL, United Kingdom has submitted a proposal to the European Space Agency (ESA) to establish NPL's first "branch" in space. Leading an international team of Earth observation and climate scientists, together with an industrial consortium, NPL has submitted a proposal for a satellite mission to ESA called "TRUTHS" (Traceable Radiometry Underpinning Terrestrial- and Helio- Studies).

The TRUTHS mission will establish SI traceable benchmark measurements of solar radiation incident upon and reflected from, the Earth at unprecedented accuracies (a factor of ten greater than current missions). The key science objective is to establish an unequivocal reference point of a number of key climate change indicators, with the aim of improving climate modelling. Of particular importance are those which provide radiative energy feedback to the climate system e.g. clouds and surface albedo.

The resultant measurements will significantly reduce uncertainty in climate forecasts giving policy makers more robust information. This will allow them to make key infrastructural decisions on mitigation and adaptation

strategies in decadal, rather than multi-decadal, timescales.

In addition to making its own benchmark measurements, TRUTHS is unique in its ability to transfer its high accuracy to other Earth observation missions, upgrading their performance so that they too can make high quality measurements of other key parameters and processes impacting on climate (for example, ocean colour, aerosols, land cover change). In this way TRUTHS becomes "NPL in space."

Other members of the TRUTHS consortium are: Astrium, the Rutherford Appleton Laboratory, Serco, Physikalish-Meteorologisches Observatorium Davos, OIP Sensor System and Surrey Satellit Technology, Ltd.

The European Space Agency will announce whether the TRUTHS proposal is successful in early December 2010.

Tegam Announces Exclusive License for PPM Instruments Products

Tegam, Inc. has announced a formal agreement with PPM Instruments which grants Tegam an exclusive license to manufacture, market, and service their instrumentation products starting 1 August, 2010. After this date, Tegam will become the sole manufacturer of PPM's resistance measuring equipment, laboratory nano-voltmeters, signal sources, and signal conditioners.

PPM will continue to accept orders and ship products until 31 July 2010. Any orders that cannot be filled before 31 July 2010 by PPM will be filled and invoiced by Tegam. PPM and Tegam will cooperate to ensure a seamless transition of supply for those customers who have open contracts with PPM that extend beyond 31 July 2010.

Customers with warranties issued by PPM will receive warranty service from Tegam for the remainder of their warranty. Where feasible, Tegam will provide repair and calibration service on products that PPM has previously discontinued.

For more information visit www.tegam.com or contact Kim Niznik Goff at kgoff@tegam.com, tel 440-466-6100, fax 440-466-6110, sales@tegam.com.

CAFMET Celebrates 5 Year Anniversary and Cairo Conference Success

The 3rd International Conference of Metrology organized by the African Committee of Metrology (CAFMET) was held recently in Cairo, Egypt. The conference was scheduled to include 117 scientific papers, 90 selected oral presentations, 16 training workshops), a variety of exhibitors, nearly 200 registered attendees from 50 different countries (compared to 25 countries represented in 2008).

Unfortunately eruption of the Icelandic volcano Eyjafjöll just three days before the conference caused air transportation problems for several speakers coming from Europe, but despite the problems, CAFMET organizers were satisfied with the attendance and the hospitality shown by the National Institute of Standards (NIS) Egypt. Germany's PTB and the United Nations Industrial Development Organization provided attendance support for a significant number of African attendees .

CAFMET is celebrating their fifth anniversary in 2010. CAFMET was founded for the purpose of spreading metrology education and culture in Africa. Since it's founding, it has organized three international conferences, held two regional forums and provided several technical workshops in different countries.

CAFMET's 4th International Conference on Metrology will be held in Marrekech, Morocco in 2012.

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Fluke Announces Manual MET/CAL Software

NCSLI Conference Booth #411, 413, 510, 512

Fluke Corporation has introduced Fluke Manual MET/CAL® software — an application for calibration professionals who do not the full calibration automation capabilities of MET/CAL® Plus Calibration Management Software, but who need to collect, store and report calibration data consistently and efficiently. Manual MET/CAL offers a database-driven solution addressing the mechanical and dimensional workload such as torque gages and tools, dimensional and mechanical instruments, and machine tools.

Manual MET/CAL software is also useful for MET/CAL Plus software users who need an easy way to collect and manage calibration data for instruments that cannot be automated via IEEE connection, such as dimensional instruments.

Manual MET/CAL software provides all the tools needed to calibrate such factors as mass, force, density, dimension and hardness, and calibrate multiple instruments at once, increasing cal lab productivity while eliminating the need to record results with paper and pencil.

Manual MET/CAL software allows users to:

- Quickly and easily create, edit, test and run calibration procedures.
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- Capture pre-computed measurement uncertainty and TUR (Test Uncertainty Ratio) values.
- Perform batch calibrations.
- Calibrate instruments which have separate input and output values, such as transducers.
- Put a calibration into hibernation, then come back and finish it later.
- Save calibration results into a database.
- Run all calibration reports and certificates using Crystal Reports.

Manual MET/CAL software is compatible with the Microsoft Open Database Connectivity (ODBC) standard so users can exchange data to and from any ODBC compatible application (such as Microsoft® Excel or Word) for further processing and analysis.

Fluke Manual MET/CAL software uses Crystal Reports, which makes it easy to create custom reports, lists, and labels. Several standard reports are included. Use them right out of the box, or use them as templates to create customized reports.

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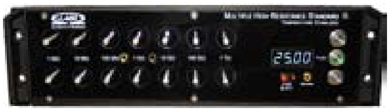

Ohm-Labs Introduces Temperature Stabilized High Resistance Standards

NCSLI Conference Booth #303

Ohm-Labs, Inc. has released the new Multiple High Resistance Standard designed to maintain state-of-the-art resistance at levels above 1 megohm. The MHS incorporates seven fully guarded high resistance standards, identical to those used in Ohm-Labs' 100-H series resistance standards. The 1 and 10 megohm elements are wound from resistance wire for high stability. The rest are custom made to Ohm-Labs' specifications using precious metal oxide as the resistance element.

A custom designed constant temperature chamber provides isolation from variations in ambient temperature. A precision thermometer indicates chamber temperature. A thermistor and two thermometer wells are provided for external monitoring. The integrated air bath may be set from 18 to 30 °C to characterize temperature coefficients. The internal constant temperature air bath stabilizes in less than one hour, allowing high resistance standards to be used in the field or on-site with the highest accuracy.

Connections are made by silver plated slide on BPO plugs. Adaptors to BNC or N type are available. ISO 17025 accredited, NIST traceable calibration is included.

Ohm-Labs tel 412-431-0640, or visit www.ohm-labs.com.

Rotronic Introduces HygroFlex8 Humidity+Temperature Transmitter

Together with the digital HygroClip2 probes, the HygroFlex8 is one of the most versatile and precise humidity and temperature measuring instruments available on the market. With a measurement accuracy of 0.8% RH and 0.1°C, the instruments can measure humidity ranges from 0 to 100% RH and overall temperature ranges of -100 to 200°C depending on the type of probe being used. The latest AirChip3000 technology guarantees an automatic sensor test, drift compensation and every probe is temperature compensated with over 30,000 data points to maintain the highest possible accuracy over the entire measuring range.

The data logging function allows recording of up to 20,000 data points with date and time stamp. Optional digital outputs additionally enable connection to a network via Ethernet and Power over Ethernet (POE).The HF8 can be integrated into an RS485 network and / or make multi-drop connections.

Rotronic, tel 631-427-3898, sales@rotronic-usa.com, www.rotronic-usa.com.

On Time Support Releases Barcode Magician 1.7 Software

On Time Support has released Barcode Magician® 1.7 software for use with Fluke MET/TRACK® 7. Barcode Magician allows busy lab managers to organize the metrology database to meet the needs of different departments.

Metrology Xplorer® 1, from On Time Support, allows customers to view and access data or reports from a web browser. However, there may be times when users need to update a record. Multiply this access by many users and you have the potential to corrupt the database or incur mistakes that later may be discovered by an auditor. Another consideration is systems that have users in different cities, in different departments, accessing a centralized metrology database. Barcode Magician uses an Action Code-based system which functions like macros allowing users to perform functions quickly and easily while maintaining the integrity of the database.

Barcode Magician also allows users to process several instruments at the same time using a scanner or keyboard input. For more information on Barcode Magician contact On Time Support or the Fluke Corporation.

On Time Support, Inc., tel 281-296-6066, fax: 281-465-9478, inquiries@ontimesupport.com, www.ontimesupport.com. Fluke Corporation, tel 800-760-4523, www.fluke.com.

Symmetricom Announces Commercial Time-Scale System

Symmetricom®, Inc. has announced the Time-Scale System, a fully integrated world-class redundant nanosecond level timing solution. Designed for international metrology, aerospace and defense customers, the system combines multiple high-performance atomic clocks in a time scale that drives a local real-time clock (RTC). Comparable to the world's best national laboratories that compute a local time scale steered to agree with Universal Coordinated Time (UTC), the Time-Scale System is ideal for national timing laboratories in countries that need to establish traceable time. It is also designed for government or civilian agencies that require precision timing capabilities independent of a Global Navigation Satellite System (GNSS).

The Time-Scale System's unique set of design features enables

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reliability in a system fully integrated into one or more instrument racks.

A timing quality GNSS receiver provides information used to steer the system

output to UTC and generates common

Micro-Feature Dimensional and Form Measurements with the NIST Fiber Probe on a CMM

B. Muralikrishnan, J. Stone, J. Stoup
Precision Engineering Division, National Institute of Standards and Technology
C. Sahay
Department of Mechanical Engineering, University of Hartford

The NIST fiber probe is a Coordinate Measuring Machine (CMM) probing system intended for diameter and form measurement of micro features and small holes. The Moore M48 CMM at NIST can measure holes down to 500 µm diameter with the Movamatic probe; the NIST fiber probe extends the range to less than 100 µm diameter. Over the last several years, we have performed numerous precision dimensional and form measurements using this probe mounted on the M48 CMM. We have measured size (diameter and thickness) and form (circularity, sphericity, straightness, flatness, conicity) on artifacts such as fiber optic ferrules, fuel injector nozzle holes, knife-edge and cylindrical apertures, ruby spheres, gage blocks, micro gears, and other micro-features on meso-scale components. We briefly describe the probing system and then present a few of the different applications we have studied, highlighting the challenges they represent and the measurement advances our probing system has offered. More importantly, these applications serve to highlight a new calibration service NIST can now offer industry — the dimensional measurement of micro-features at ultra-low forces.

1. Introduction

Micro-parts and micro-features are becoming increasingly important to our economy, but systems for their measurement are still in their infancy. There is tremendous potential for new applications of tiny devices such as MEMS devices (micro-electro-mechanical systems) and their progeny (including micro-opto-electro-mechanical systems [MOEMS] and microfluidic systems such as lab-on-a-chip [LOC]). Beyond micro-parts per se, macroscopic devices may include microfeatures that are critical to performance. A good example is fuel injectors, where spray holes with less than 100 µm diameter show promise of increasing fuel efficiency and reducing pollution.

The increasing prevalence of micro-parts has stimulated the development of micro measurement systems. These include vision systems for two-dimensional measurements and three-dimensional systems such as X-ray tomography or Coordinate Measuring Machines (CMMs) with microprobes. Numerous instrument manufactures, academic researchers and national laboratories have invested in this problem by developing probing systems and micro-CMMs [1, 2]. Of the microprobes, there are a number of varieties, ranging from scaled-down versions of classical macroscopic CMM probes to scaled-up versions of probes originally developed for scanning probe microscopy. A good review of many probing technologies is given in [1, 2].

Here at NIST we have developed a "fiber probe" capable of measuring holes under 100 µm in diameter. There are several varieties of probes that might be described as fiber probes. All of these probes are notable for their ability to measure very high aspect ratio features. The NIST probe, for example, has been used to measure inside small holes at an aspect ratio of 80:1 without noticeable compromise in performance. Among fiber probes, there are at least two varieties that employ a vibrating stylus [3, 4], and at least two varieties where the stylus is static [5-7]. The basic operating principle of a vibrating probe is to detect changes in the amplitude, phase, or frequency of vibration as the probe comes into contact with a surface. A static probe operates in more the manner of a traditional CMM probe, detecting the deflection of the probe tip when it contacts the surface, as described in the next section.

2. The NIST Fiber Probe

Dimensional metrology of micro-scale features in micro- and meso-scale components is a challenging problem not only because of the small sizes involved, but also due to the requirement of low probing forces. At NIST, we have developed a low-force, fiber-based contact probing system [8] that can be mounted on our high accuracy CMM, the Moore M48[1] CMM. This probe enables the measurement of 100 µm scale features such as a micro-hole to a depth of at least 5 mm (sometimes up to about 10 mm) with extremely small contact forces of the order of 5 µN or smaller. The uncertainty in a diameter measurement for a high quality artifact is generally less than 100 nm (k=2).

The probe stylus is made from a glass fiber with a ball formed on the end. The probe functions by optically imaging the fiber stem from two orthogonal directions a few millimeters away from the ball end of the fiber (Figure 1). To be more precise, the optical system does not literally image the fiber, but images a narrow line of light brought to a focus by the stem of the probe, creating a very sharp, high-contrast image for which nanometer-level motions are detectable. Upon contacting a part, the fiber bends by a small amount. The magnitude of the deflection at the tip (which is the part over-travel) is related to the observed displacement of the stem at the point of observation by a previously determined calibration factor. The technique and early results are discussed in [8].

It is of interest to compare our probe to the static fiber probe developed at Physikalisch-Technische Bundesanstalt (PTB) (now available commercially [7]). The PTB probe stylus consists of a small ball on the end of an optical fiber. The ball is illuminated through the fiber and a vision system viewing the ball detects when it is deflected by contact with the wall. The NIST system also employs a camera but does not view the ball directly—rather, it senses a deflection of the stylus stem at a point well away from the ball at the end of a long fiber. This approach has both potential advantages and disadvantages, and it is not clear which approach is preferable.

A clear disadvantage of the NIST system is that it must infer position of the stylus tip based on indirect evidence obtained from the stem, and it must be determined if this indirect information is indeed reliable. An advantage of the indirect approach is that detection of the stem above the hole isolates the measurement from disturbing influences that might be present when imaging inside the hole, such as reflections and diffraction. Also, there may be significant advantages in using the unusual optical detection technique described above (fiber is not directly imaged) with its high-contrast image of a fine line of light. In the final analysis, which system is preferable might well depend on the measurement task and on the environment in which the probe is used.

The deflection mode of operation as described above is the general mode in which the NIST fiber probe is employed. A variation of this deflection mode of operation is the vibration assisted pseudo scanning mode where the probing system operates as a 1D roundness instrument. The part is mounted on a precision spindle and the probe is always in contact with the part. To overcome surface adhesion, the fiber is excited into resonance as the part is rotated from one sampling position to another. We have discussed this enhanced capability in [9].

1. Commercial equipment and materials are identified in order to adequately specify certain procedures. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

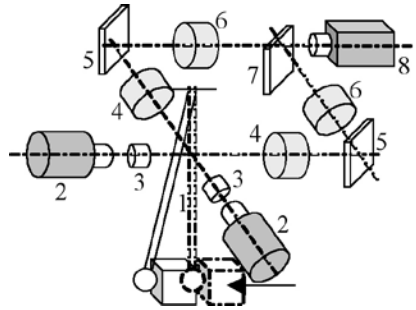

Figure 1 Optical setup for fiber probe when employed in the deflection mode of operation.

Another mode of operation of the fiber probe is "buckling mode" (also discussed in [9]). This mode of operation is needed when measurements directly along Z are required. When the probe is brought in contact with the part along the Z direction, the fiber buckles on contact and the amount of machine over-travel is determined as in the deflection mode by a prior calibration.

3. Applications

Over the last several years, we have performed several high precision dimensional and form measurements using our fiber probe mounted on the M48 CMM. We have measured size and form of numerous artifacts. We describe a few interesting applications where either the small part size and/or contact force limitations in combination with high accuracy requirements have necessitated measurements to be made with our fiber probe.

3.1 Internal Geometry of a 127 µm diameter, 10.5 mm Long Hole in a Fiber Optic Ferrule

Measuring large aspect ratio micro-features at low uncertainties is a major challenge in dimensional metrology. The internal geometry of a fiber optic ferrule is a typical example; in fact the ferrule was a primary driver for development of the NIST fiber probe. With a nominal diameter of 125 µm, a measurement to a depth of 5 mm inside the fiber optic ferrule represents an aspect ratio (depth to diameter) of 40:1. We have performed several measurements inside a ferrule at these depths at expanded uncertainties under 100 nm (k=2). Some early results are shown in [8].

As an interesting test, we recently attempted to increase our working depth to the entire length of the ferrule, which was 10.5 mm long. This represents an aspect ratio of 82:1, which is a significant advance in micro-feature dimensional metrology capability. In order to achieve the increase in working depth with the same fiber probe (its length remains unchanged), we had to move the point of observation on the stem closer to the fixed end of the fiber thus reducing the sensitivity of the fiber. In addition to lower sensitivity,

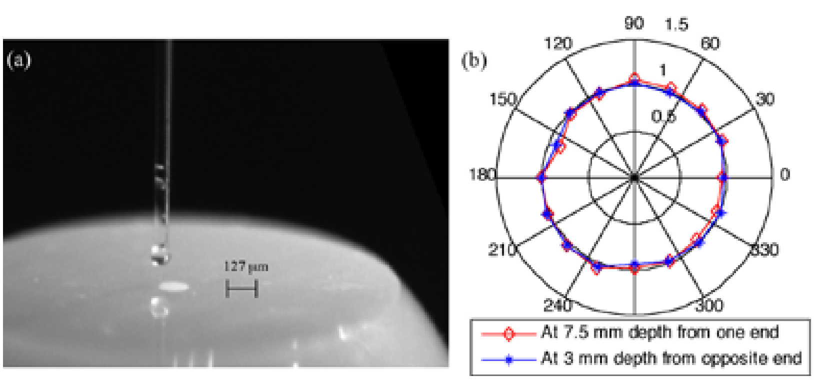

Figure 2 (a) A 127 µm diameter hole in a fiber optic ferrule (b) Radial deviation plot at the 3 mm depth inside a ferrule measured from one end of the ferrule and the corresponding 7.5 mm depth measured from the other end of the ferrule.

there is also the potential problem of non-linear bending due to external forces such as static charge which could lead to measurement errors.

A simple test of the performance of the probe at extended working depth of 10.5 mm is to measure the hole near its mouth, then invert the hole and measure the same region of the hole by inserting the fiber all the way into the hole. Any disagreement in diameter and form is an indication of potential problems associated with stem-wall interactions or other sources of error that vary with depth inside the hole.

We measured the hole at depths of 3 mm and 4 mm from the mouth, then reversed the hole and re-measured it from the other end at depths of 7.5 mm and 6.5 mm. The diameters obtained at the 3 mm and 4 mm depths were 127.39 µm and 127.37 µm, while the diameter (entering the hole from the opposite end) at the 7.5 mm and 6.5 mm depths were 127.37 µm and 127.35 µm. This excellent agreement indicates that there is little degradation in our measurement capability at large depths.

Figure 2 (a) shows a photo of the fiber probe entering a ceramic ferrule. Figure 2 (b) shows the radial deviations at the 3 mm position measured from one end and the corresponding 7.5 mm position measured from the other end. It is clear that the radial deviation plot shows excellent agreement. Similar agreement in radial deviations was observed for the 4 mm and 6.5 mm positions also.

3.2 Internal Geometry of a Reverse Tapered Hole in a Fuel Injector Nozzle

Mapping the geometry of fuel injector nozzle holes is critical in improving fuel efficiency of automobiles and therefore in reducing harmful emissions. Nondestructive technologies such as X-ray computed tomography are sometimes used, but the uncertainty in these methods is large and difficult to assess without an independent measurement technique. Fiber based contact probes offer a unique solution for this challenging measurement problem.

We have measured several micro-holes in a fuel injector nozzle where the diameter of the hole increased with depth (i.e., reverse tapered hole). The nominal diameter at the mouth (fuel exit location) was 130 µm while the diameter at a depth of 0.8 mm (fuel entry location) was 150 µm. In order to measure this taper, we had a special probe fabricated with a ball of larger diameter (100 µm diameter ball) mounted on a thin stem (50 µm diameter stem). This allowed a larger working range so that when the probe is deep inside the hole, there is no contact between the stem and the edge of the hole near the mouth. Figure 3(a) shows a picture of the fiber probe entering the hole, and Figure 3(b) shows a 3D form plot of the internal geometry of the hole.

The uncertainty in these diameter measurements was under 200 nm (k= 2). The largest uncertainty contributors were the poor form/surface finish of the hole. Therefore finite sampling and mechanical filtering introduced errors that were significantly larger than other sources such as uncertainty due to probing system, machine positioning, probe ball calibration etc.

3.3 Area of Knife-Edge Apertures Used in Radiometry/Photometry

A significant advantage of fiber based probes is the extraordinarily low contact forces they exert on the part during a measurement. For instance, our fiber probe exerts a force of less than 5 µN during a typical measurement. This is based on cantilever beam calculations where the nominal geometry and deflections are known.

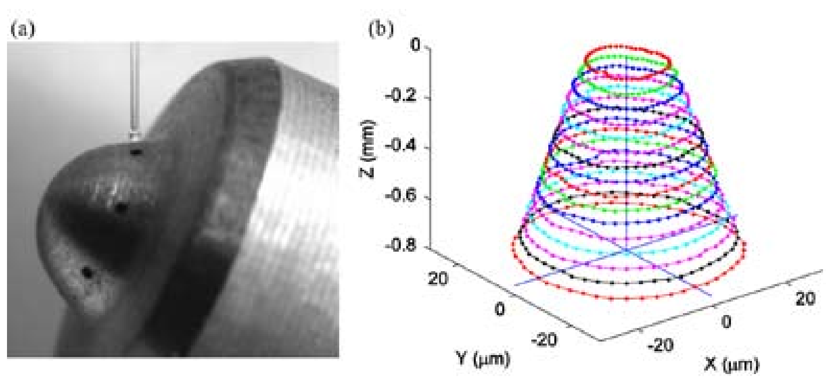

Figure 3 (a) Photo of the fiber probe entering a reverse tapered micro-hole in a fuel injector nozzle, 0.8 mm deep, diameter ranging from 130 µm to 150 µm (b) 3D plot of the data from inside the micro-hole (the data has not yet been compensated for probe radius, hence the x and y axes scales are smaller than expected)

An interesting macro-scale application where such low forces are useful is the determination of the area of knife-edge apertures. Apertures are used as standards in radiometry and photometry where high accuracy area measurement is required. These apertures may have a cylindrical wall, or may have a sharp edge. The diameters range from several millimeters to about a hundred micrometers or smaller. The cylindrical apertures may be measured with a traditional CMM probing system (if the diameter is not too small), but the knife-edge apertures have such delicate edges that they can only be measured optically or using an ultra-low force probing technique.

The uncertainty in optical methods may be small but the agreement between different optical methods is sometimes larger than the uncertainty, as an inter-comparison study showed [10]. We should point out that while the contact forces are very low, the contact pressure on a sharp knife edge aperture may potentially be at or near the yield strength of the material. We have attempted to estimate the contact pressure and any deformation due to hertzian stresses in [11].

We therefore attempted to measure these knife-edge apertures [11] with our fiber probe. Our measurements and analysis suggested that the uncertainties in diameter using the fiber probe are extremely small — of the order of 0.06 μm (k=1) to about 0.17 μm (k=1) depending on the aperture. The largest uncertainty contributors are the part surface roughness and form; the contribution from the probing system is extremely small in comparison. Further, our measurements and uncertainties are validated on cylindrical apertures which could be measured using well established traditional probing systems on CMMs.

An interesting aspect to these knife-edge aperture measurements was that we used the cylindrical portion of the stem as the probing element instead of the sphere at the end of the stem. This is because a sphere is sensitive to any warp or tilt in the aperture leading to potentially large errors if contact occurs above or below the equatorial plane of the sphere. A cylindrical stem, on the other hand, is fairly uniform in diameter over a short portion; its size and shape can be calibrated using a master sphere. Figure 4(a) shows a picture of a knife-edge aperture and Figure 4(b) shows an example profile of a knife-edge aperture measured with our fiber probe.

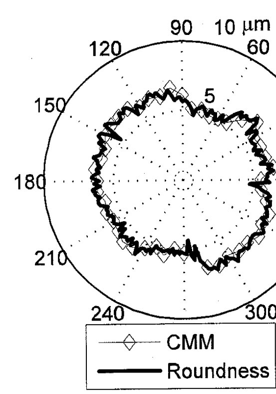

Figure 4((left) Picture of a knife-edge aperture; 4(b) (right) radial form of an aperture. The aperture was measured with our fiber probe operating in 2 modes: The CMM mode is the typical mode of operation where the part is mounted on the machine table and the probe operates in touch-trigger mode. In the roundness mode, the part is mounted on a spindle and the probing system operates as a 1D roundness instrument.

3.4 Three-Dimensional Measurements of Micro-Scale Features Such As Hemisphere and Cone-On-Meso-Scale components

Measuring the 3D geometry of micro-scale features is even more challenging than measuring 2D sections on 3D artifacts for several reasons. The probe diameter and form have to be calibrated over the entire region of the probe that contacts the part, unlike a 2D case where only the equatorial plane of the probe ball is of interest. While probe balls on the styli of traditional probing systems have excellent sphericity, probe balls on micro-scale probes are generally of unknown quality. The probe balls that we utilized on our fiber probe were nearly spheroidal in shape, longer along the Z axis than along X or Y by about 2 μm. The residuals from the best-fit spheroid were within a ±0.25 μm band.

A somewhat related issue that makes the measurement of 3D geometry challenging is that of probe radius compensation. If the probe ball can be assumed to be a perfect sphere and surface normals are along probing direction, probe radius compensation is easy to perform. If the probe ball has arbitrary geometry and when the part feature size is comparable to probe size, probe radius compensation involves detecting surface normals at the point of contact. The surface normals themselves are not necessarily along the direction of machine motion because the flexible probe is free to bend and make contact at any point lateral to the direction of motion. Therefore, the analysis of the data becomes a fairly involved mathematical problem by itself.

A recent application we studied involved a component that comprised a 35 μm nominal radius hemisphere located on a cone whose half-angle was nominally 20°. The region of interest was the top 130 μm portion of the part. After calibrating the probe, we measured more than 500 points on the part. Subsequently, we employed a least-squares best-fit method for probe radius compensation where we recognized the fact that the probe was spheroidal in shape and that in addition, it had some small tilt about the X and Y axes. A photo of the part being measured is shown in Figure 5(a) and the points on the surface after probe radius compensation are shown in Figure 5(b). We have not yet developed uncertainty budgets for this application.

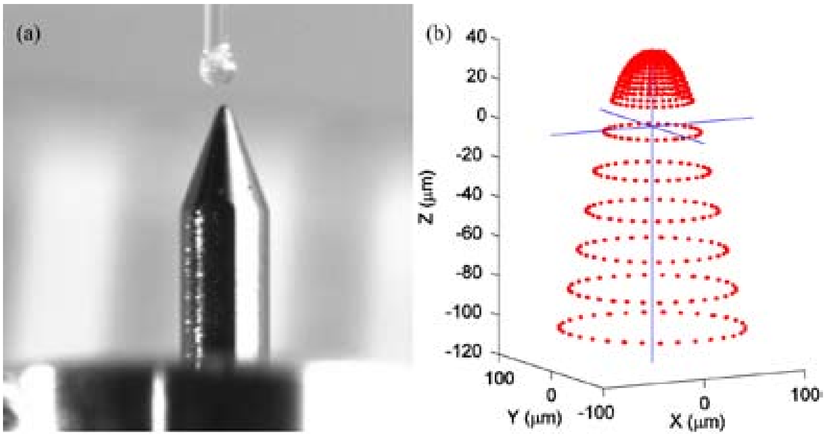

Figure 5 (a) Photo of the probe measuring a hemisphere-cone artifact; (b) Points on the surface of the hemisphere-cone artifact.

3.5 Micro-Holes In Micro Gears

We recently measured micro-holes in several micro-gears produced by a LIGA process. ("LIGA" is a German acronym describing a production process for high-aspect ratio MEMS-like structures.). The gears varied in thickness from 0.15 mm to about 1 mm, while the central holes were about 0.25 mm in diameter. Again, this application required a small probe size and low contact force; our fiber probe was therefore an ideal probing system in this case.

Our measurements indicated that the hole was generally tapered and that not surprisingly, dirt may be a large contributor to the uncertainty in the measurement. Figure 6 (a) shows a picture of the probe entering the micro-gear and Figure 6 (b) shows a form plot of the data from inside the hole. There are several points deep inside the gear that may possibly be dirt. While we have not quantified an uncertainty in diameter at any depth, our experience in making measurements on similar artifacts suggests that the part surface texture and form, and possibly dirt, will be the largest contributors to the overall uncertainty.

4. Error sources

There are numerous error sources associated with a fiber probe measurement. While some error sources are typical in any CMM measurement such as machine positioning accuracy, environmental effects, probe diameter and form calibration errors, etc, there are other sources of error that are unique to the fiber probe. The fiber position is detected by imaging the stem; imaging uncertainty, although extremely small, is therefore a contributor. The non-orthogonality of the two imaging axes and their misalignment with the machine's axes is also critical when measuring small features. We compensate for this error by measuring the magnitude of the misalignment and software-correcting the data.

The flexible fiber stem is susceptible to external forces such as air currents and electrostatics, and the resulting non-linear bending in combination with other error sources such as axis-misalignment may produce errors. We reduce the influence of these effects to some extent by shielding the probing system from air currents and placing Polonium strips near the fiber to dissipate static charge. The fiber itself cannot be coated with metal because the imaging technique we use relies on the glass fiber behaving as a cylindrical lens.

Geometric effects such as probe radius compensation are another unique source of error, particularly when the surface normals are unknown, or when probe imaging axes are misaligned. Mechanical filtering is also a potential error source especially since the probe size is comparable to part feature size. Dirt is a major problem when performing measurements at low forces where contact forces are insufficient to dislocate particles. We have explored these unique error sources in several articles [12-14].

5. Future Directions

Requirements for accurate three-dimensional measurements of microfeatures are increasing in step with improvements in manufacturing techniques. Production techniques

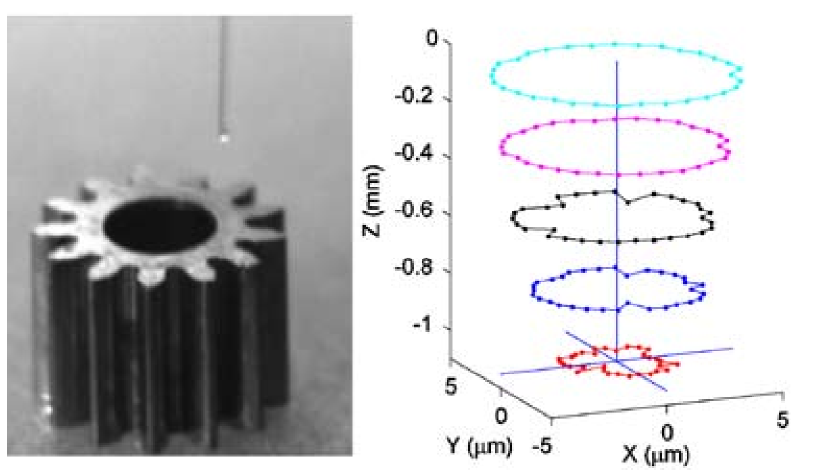

Figure 6 (a) A picture of our fiber probe entering a micro-hole in a micro-gear; (b) Form plot of the central hole in the gear showing both the taper and possible outliers (dirt) in the data.

such as LIGA process and other micro-manufacturing methods (micro-milling, grinding etc) already produce parts with low surface roughness that could benefit from the intrinsic accuracy of our method. Further, unique measurement needs arising from cutting edge applications serve as further drivers of our technique, for example, tiny thin walled targets for high energy physics experiments (such as for the National Ignition Facility targets), soft foams (airogels) for space applications etc.

To meet this emerging need, we must continually improve NIST capabilities; our fiber probe is a step in that direction. We face several problems. As discussed previously, one significant challenge is simply dirt: cleaning dust or debris from a micro-hole with greater than 40:1 aspect ratio is a problem that would benefit from more study. Furthermore, although our M48 CMM provides an excellent platform for the fiber probe, it will not be able to keep up with rapidly-developing micro CMMs unless additional small-scale metrology is retrofit to the machine. Finally, we expect to interface several new probing systems to our CMM and explore performance of these probes for various types of measurements. Through such steps we hope to keep in step with evolving industry needs.

6. Conclusion

The NIST fiber probe was developed in response to a growing need to provide high accuracy dimensional and form measurements on a variety of micro-scale features in micro- and meso-scale components. Even large components such as turbines have tiny holes that are sometimes required to be characterized with low uncertainties. The fiber probe provides a bridge between two extremes of measurement capabilities we currently have at NIST: sub-micrometer level accuracy measurements on meso-scale parts on the Moore M48 CMM and sub-nanometer accuracy of micro-scale parts with atomic force microscope (AFM) and other scanning methods. In providing sub-100 nm level uncertainties on micro-scale components, we have attempted to meet a growing industry need in the area of micro-manufacturing.

The fiber probe is currently in a transition phase from research to application. We have over the last few years measured numerous artifacts that were brought to our notice by customers and colleagues. We have highlighted some of those applications in this paper to illustrate the capability of our probe and more importantly, to highlight a new calibration service that NIST can now offer industry.

Acknowledgements

We are grateful to numerous collaborators who have provided assistance through the years: Dr. Wolfgang Haller, Jeffrey Anderson, Dr. Ted Doiron, Dr. Steve Phillips, Eric Stanfield and Dr. Toni Litorja from NIST, Fedor Timofeev from WTT Inc., S. Vemuri and A. Potluri, former graduates from the University of Hartford, and Dr. Marcin Bauza and Dr. Shane Woody from InsituTec Inc. We also thank Dr. N. George Orji at NIST and Dr. Richard Seugling at Lawrence Livermore National Laboratory for reviewing this paper.

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Establishment of a Programmable Calibration System for Accurate AC Current Measurements at NIS, Egypt

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This paper describes the establishment of a compact programmable system for accurate ac current measurements at National Institute of Standards (NIS), Egypt. The system consists mainly of a fabricated thermal current converter (TCC) associated with a definite hardware and a flexible software. The new system has been harmonized to cover a wideband range from 5 mA to 20 A at frequencies from 10 Hz to 100 kHz. In addition, the system has been used in measuring specific characteristics of the TCC, such as the time response, dc reversal errors, and the transfer errors at different frequencies. The design of the fabricated TCC was re-modified then re-calibrated in PTB, Germany to promote the system reliability.

1. Introduction

Alternating current is commonly measured by comparing an unknown ac current with a known dc current based on the fact that alternating and direct currents have the same effective value when they produce identical amounts of power in a pure resistance. For instance, the root mean square (rms) values of ac voltage are most accurately measured by comparing the heating effect of an unknown ac signal to that of a known, stable and traceable dc signal by using thermal voltage converters (TVC's). These converters normally consist of one or more thermoelements, possibly in series with a range resistor. The thermoelement (Fig. 1) is composed of one or more thermocouples arrayed along a heater structure. These thermocouples are used to detect the temperature along the heater structure while applying a timed sequence of an ac signal and both polarities of a dc signal. By comparing the output of the thermoelement (using a highly sensitive nano-voltmeter) due to the applied ac against the average of both polarities of the dc, the unknown ac quantity may be determined in terms of the known dc quantity. The very small difference between the responses of the ac and dc signals on the thermoelement is normally known as ac-dc difference, δ. This ac-dc difference is determined using [1].

$$\delta = \frac{V_a - V_d}{V_d} \qquad (1)$$

where:
δ is the measured ac-dc difference.
V_a and V_d are the magnitudes of the ac and dc quantities required to produce the same thermocouple output.

For most multi-range thermal transfer devices as in Fig. 2, it is more practical and economical to use a single element in conjunction with an appropriate shunt resistor. The resistance of the shunt is chosen so that the parallel combination of the shunt and heater resistor represent a current divider for the current to be measured. The correction factors for the frequency response of the shunt, of course, must be known and applied if accurate measurements in some technical applications are to be made [2].

On the other hand, the resistance elements of these shunts do not need to be very accurate because the shunt's ac-dc difference at various frequencies is used as a correction factor for the ac current measurement, relative to the accurate dc current source [3]. The ac-dc difference, δ, is given in the test report of the transfer standard in parts per million (ppm) as:

$$\delta = \frac{I_{AC} - I_{DC}}{I_{DC}} * 10^6 \qquad (2)$$

where:
δ = ac-dc difference for the TCC.
I_{AC} = rms value of ac current
I_{DC} = average of the absolute values of dc current applied in positive and negative direction across the transfer standard.

In practice, the national laboratories evaluate the ac-dc differences at various currents and frequencies to cover most scientific and industrial applications.

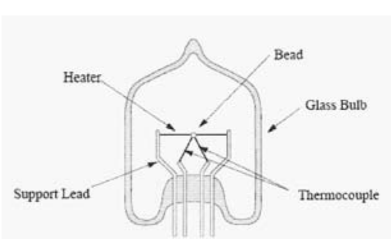

Figure 1. Construction of a typical thermoelement.

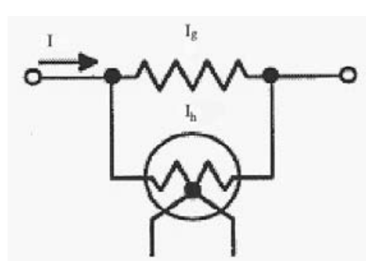

Figure 2. Simplified electrical circuit of the thermal current converter.

The converted value of the ac-dc difference, δ, is applied to the ac-dc transfer standard as a correction factor as:

$$I_{AC} = I_{DC}(1 + \delta) \tag{3}$$

At NIS Egypt, new techniques for performing precision ac-dc difference measurements are subjected for evaluation and investigation regularly. The previous manual system was very time consuming and a reason of significant error due to operator's self-errors and the other sources. As a result, it has been indispensable to promote the calibration services of NIS through establishment of a new programmable system. The system consists of a programmable instrument and a software for controlling the measurements procedures. The system can be also used to calibrate the functions of ac current calibrators and the high sensitive digital ac ammeters. Furthermore, different characteristics of the thermal transfer standards can be evaluated by using the new system. For instance, the standard deviation of the repeatable measurements, the dc reversal difference, time constants and the value of the exponent "n" of the thermoelement's heater are also easily evaluated by the system.

The system is easy to operate. The selection of the applied ranges at definite frequencies is software-controlled to cover a frequency range from 10 Hz to 100 kHz for the current range from 5 mA to 20A. The system has been established as a coherent structure to disseminate the traceability for the calibration services. A new precise thermal current converter (TCC) was fabricated at NIS then re-modified and calibrated at PTB, Germany, to improve the capability of this work. It is also planned to use this TCC in the accurate measurement of the secondary coils parameters of the current transformers. This will enhance the related calculations of the power losses on the transmission lines then the efficiencies calculations of the power stations. The new TCC was also tested and characterized by using the new automated system (as explained in section 4).

2. New Thermal Current Converter

Currently, the highest accuracy of ac current measurement at NIS is based on using the single junction thermal converters (SJTCs) at the current range of 5 mA. The higher current ranges can be provided by using thermal converters (TCs) connected in parallel with current shunts (Fluke A40 & A40A or Holt model 11). Such combinations are called thermal current converters (TCCs) and used for highly accurate ac current measurements up to 20A. A new thermal current converter (Fig. 3) was fabricated at NIS to serve as a working standard for the range of 5A. It mainly consists of a single junction thermal voltage converter connected in parallel with a current shunt Fluke A40 and re-calibrated at frequencies from 10 Hz to 1 MHz at PTB, Germany.

Figure 3. The new thermal current converter.

Table 1. Specifications of the new TCC

STD	Type of TE
95 Ohms	Heater resistance
8 Ohms	Thermocouple resistance
Fluke A40	Current shunt
6 mV nominally at the rated input	Output voltage
Not more than 100 VDC	Insulation
5A	Range
For TVC (104*72*65) mm	Dimensions (length*width*height)
For current shunt (50*35*85) mm	
TVD: 597 gm	Weight
Current shunt: 375 gm	

3. System Setup

The hardware of this automatic system is configured by the operator in relation with the specific calibration needs. Several types of instruments (Fig. 4) can be used in this system to act either as reference instruments or as units under test. The system consists of a programmable source, Wavetek 9100 calibrator, for both alternating and direct currents; two thermal current converters (TCC), (one of them is acting as a reference standard unit while the other represents the unit under test); high sensitive digital multimeter Fluke 8508A to measure the dc current signal, two similar digital multimeters (DMM), HP 3458A, connected across the output of each TCC to record the output emfs of the thermoelements and GP-IB controller.

The controller drives the TCCs and records the readings on the DMMs through the IEEE-488 bus cables. The readings from the DMMs are used for data analysis to compute the ac-dc difference of the TCCs. Mainly; the system performs three tasks according to the state of the three switches S1, S2 and S3.

Task #1: determination of the accurate value of dc current signal.

Task # 2: determination of the ac-dc difference of the TCC (δ)

Task # 3: determination of the accurate value of ac current signal and some important TCC's characteristics such as dc reversal error, time constant, n test,….. etc.

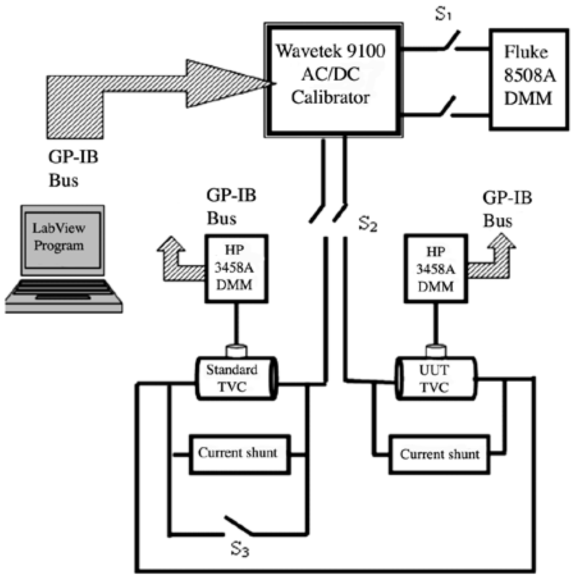

Figure 4. Setup of the compact automatic calibration system of the thermal current converters.

Obviously, we can consider the system as a multifunction automatic program. Each function needs definite positions of the working switches to perform a certain task as follows:

A. Determination of the Accurate Value of the DC Current Signal

According to Eq. 3, it is necessary to determine the actual value of the dc current signal. The system could perform this task when S1 is closed while S2 and S3 are open. In this state, the actual value of the output dc current from the calibrator can be measured accurately by using the high sensitive digital multimeter, Fluke 8508A. The setup of this task is illustrated in Fig. 5.

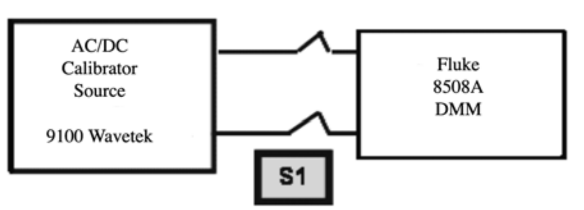

Figure 5. Determination of the accurate value of dc current.

The main advantage of this procedure is the possibility of canceling any effect due to the drift in the value of the dc signal. This means that the value of the dc signal will be instantaneously evaluated before any measurement of the ac signal. In addition, the uncertainty contribution due to the short term stability of the dc signal can be also cancelled from the whole uncertainty budget.

B. Determination of the AC-DC Difference of the TCC (δ)

When S2 is closed while S1 and S3 are open, as illustrated in Fig. 6, the system will be responsible for determination of the ac-dc difference of the tested TCC (as explained in section 4).

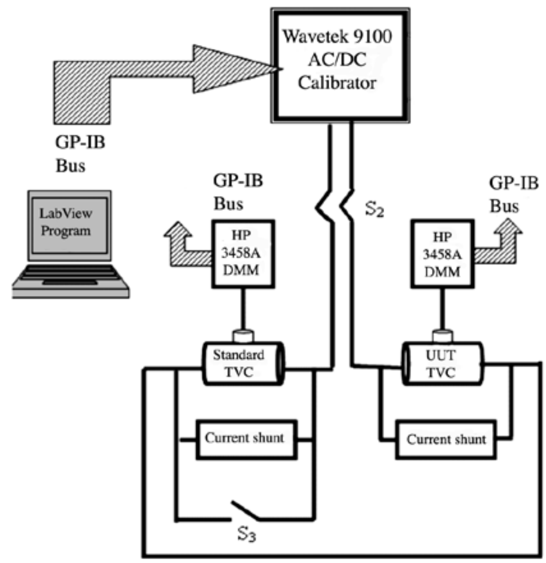

Figure 6. Determination of the ac-dc difference of the TCC.

C. Determination of the Accurate AC Current and Some Important TCC Characteristics

Once the accurate value of the dc current signal is determined successfully (Task #1) and the ac-dc difference of the test TCC is also determined (Task #2), the system could be finally configured as shown in Fig. 7 (S1 is opened while S2 and S3 are closed). This setup aims to calibrate the ac current function of the calibrator at different ranges of currents and frequencies. In addition, some characteristics of the tested TCC could be characterized and evaluated accurately through the same setup (more details in section 5).

4. AC-DC Difference of TCC

The relationship of the output emf, E, as a function in the heater current, I, may be expressed as:

$$E = KI^n \qquad (4)$$

where E is the output emf of the TE, I is the heater current, K varies somewhat with large changes in heater current but is constant over a narrow range where nearly equal ac and dc currents are compared and n is usually 1.6 to 1.9 at rated heater current.

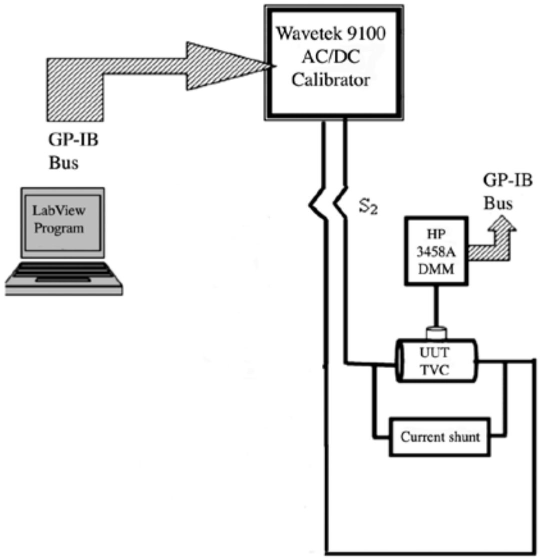

Figure 7. Determination of the accurate ac current value.

The relationship between a small change in the thermoelement heater current (ΔI) and the corresponding change in output (ΔE) is expressed as:

$$\frac{\Delta I}{I} = \frac{\Delta E}{n.E} \tag{5}$$

As stated above, the ac-dc difference, basically, is defined as:

$$\delta = \frac{I_{ac} - I_d}{I_d}, \tag{6}$$

where I_{ac} is the alternating current, and I_{dc} is the average of both forward and reverse dc current; i.e,

$$I_d = \frac{I_+ + I_-}{2} \tag{7}$$

where, I_{ac} , $I+$, $I-$ are current values which give the same output emf of the TE.

After completing the sequence of four steps by applying successively ac, dc+, dc- and ac signals, to minimize the effects of drift in the TCC outputs, the ac-dc difference of the test TCC (δ) is then evaluated from the following relation [4]:

$$\delta = \frac{(E_{as} - E_{ds})}{n_s \cdot E_{ds}} - \frac{(E_{at} - E_{dt})}{n_t \cdot E_{dt}} + \delta_s \tag{8}$$

where δ_S is the ac-dc transfer difference of the standard TCC, E_{as} and E_{at} are output emfs of the standard and the unknown TCCs for ac current, respectively. The mean emf values for forward and reverse dc currents are taken as E_{ds} and E_{dt}, respectively and the factor n is determined at the beginning of the test for both TCCs. The test runs for 20 determinations of ac-dc difference at the same current and frequency, then the average is calculated and printed.

The rated current, the device warming up time, the settling time, the test frequencies and the corresponding ac-dc difference of the reference standard TCC are shown and entered in the main screen of the program. At the beginning of the test, for each device, the program determines the exponent n. The value of the exponent n is level dependent and is measured by measuring the change in the output emf when the dc nominal input current is varied by ± 0.05%. The results are then printed and / or saved on the main screen of the system.

5. Additional System Capabilities

A. Stability Tests

In this type of measurement, it is important to be sure that the current sources are quite stable. Therefore, two programs were built into our software driver entitled "Stability of the DC Source" and "Stability of the AC Source" to investigate the stability of the current sources as a short term stability. At a nominal setting, a number of 120 readings are recorded over a time interval of about 1 hour. The deviation in the measured signal (in ppm) from the nominal value is defined as:

$$\frac{\Delta I}{I} = \frac{I_1 - I_2}{I_2} * 10^6 \tag{9}$$

where, I_1 is the instantaneous measured value, and I_2 is the nominal value. The operator could decide that the AC and DC current sources have acceptable stability if and only if the plot shows that all readings are scattered within the upper and the lower limits of ± 2σ, where σ is the standard deviation of the observations.

B. "n" Test

One of the most important tests that has to be performed is that of determining the factor n of the TCCs. From Eq. (5):

$$n = \frac{\Delta E \,/\, E}{\Delta I \,/\, I} \tag{10}$$

where ΔE is the measured change in output emf for small changes in applied current ΔI, I is the nominal current of the TCC, and E is the measured emf at the nominal current. The value of ΔI was programmed to be ± 5 percent of the nominal current, I. Sufficient time was allowed for the TCC after each current change to reach its rated emf value. The TCC was tested from 45 to 110 percent of the rated current. Each value of n is computed as the average of two determination (+5 % and -5%) at any given current. The computed equation for n variation as a function of the heater current can be also plotted in the final results sheet.

C. DC Reversal Difference (DCRD)

DC reversal difference is generally defined as the percentage difference between the values of the forward and reverse dc current when they both produce the same output emf of the thermoelement. This value is not necessarily constant but increases in some cases as the heater current of the thermoelement is lowered [2]. The value of DCRD was actually measured as:

$$DCRD = \frac{2\,(E_+ - E_-)}{n\,(E_+ + E_-)} \tag{11}$$

where, *E+* and *E-* are the TE output emfs with equal forward and reverse heater current, and n was given as in (10). The program was designed to determine the DCRD as a function of the heater current. In this test, the heater current is changed from 50 % to 105 % of its rated value with 5 % increments and the output emf of the TE is recorded for each heater current value. A plot of the calculated dc reversal difference values against the input heater current is then plotted immediately via the assigned excel worksheet for this function.

D. Frequency and Current Dependence

The TCC, as a transfer standard, is used for accurate AC current measurements in the primary metrological laboratories. But due to the thermoelectric and electromagnetic effects, the TCC is affected by a residual difference of its response to ac and dc, which is a function of both the test current and the applied frequency. The automated program is also used for determination of the ac-dc difference of TCCs at a set of different frequencies from 10 Hz to 100 kHz for different certain currents. Using the relation between the ac-dc differences against the frequencies at constant current, the TCC frequency dependence factor, K_f can be evaluated. K_f is the percentage change in the transfer error for a frequency change of 1 Hz.

Similarly, the TCC is tested by using the same program to determine its ac-dc difference at different current levels from 50% to 105% of its rated current at a constant frequency. This performance helps to evaluate the current dependence factor, K_i, of the TCC at a certain frequency. K_i is the percentage change in the transfer error for a current change of 1A. A summary of these values is shown in Table 2 and 3.

Parameter		Value
"n"		1.76
DCRD (ppm)	Max. value (at 50%)	-357
	Min. value (at 95%)	-8
	Actual value (at 100%)	39.6
K_f		-0.0085 ppm/Hz
K_i at 55 Hz		-0.24 ppm/A
K_i at 1 kHz		2.7 ppm/A

Table 2. Results of some measured parameters of the TCC.

Steady state time S.S.	Time constant τ	Parameter / Frequency
140	2.86	DC
110	3.56	55 Hz
80	2.61	1 kHz

Table 3. Results of the time responses.

The new TCC was first fabricated and tested at NIS using the new programmable automated system at the rated current, 5 A and as listed in Table 4.

Table 4. AC-DC Difference of the new TCC measured in NIS

Frequency (Hz)	AC-DC Difference (ppm)	Standard Deviation (ppm)
10 Hz	24.7	3.6
20 Hz	16.8	2.7
30 Hz	5.0	4.7
40 Hz	12.7	2.4
55 Hz	12.2	3.4
100 Hz	12.4	3.9
400 Hz	-2.3	4.4
1 kHz	10.2	2.8
10 kHz	-72.1	4.3

Fortunately, there was excellent opportunity to send the new TCC to PTB, Germany as a part of scientific mission between NIS and PTB. The design of the TCC was re-modified to be in a cylindrical frame instead of the boxing frame (Fig. 8). New short cables and good soldering material were also used to improve the fabrication of the new TCC. The TCC was then re-calibrated using the very accurate calibration system of PTB (Fig. 9) and results are as listed and plotted in Table 5 and Fig. 10 respectively.

Table 5. AC-DC Difference of the new TCC measured in PTB

Frequency (Hz)	AC-DC Difference (ppm)	Standard Deviation (ppm)
10 Hz	28	0.7
20 Hz	-6.6	0.4
55 Hz	-0.75	0.7
120 Hz	-2.2	0.2
200 Hz	-3.7	1
500 Hz	-6	0.8
1000 Hz	-14.3	0.8
2000 Hz	-21.2	0.6
5000 Hz	-40	0.6
20 kHz	-72	0.9
50 kHz	-165	0.4
100 kHz	-369	1

Figure 8. The re-modified TCC.

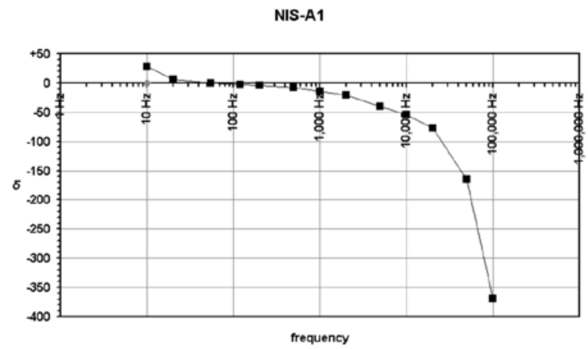

Figure 10. AC-DC difference of TCC as measured at PTB.

Figure 9. Setup of measuring TCC at PTB.

7. Uncertainty Statement

The expanded uncertainty of this type of measurements was reduced by ratio of about 1:3 after using the improved automated calibration system [6]. The uncertainties values of the practical work are calculated in accordance with National Institute of Standards and Technology (NIST) requirements [7].

The uncertainty assigned to the measurements is divided into Type A uncertainties (those evaluated by statistical means for 20 similar times) and Type B uncertainties (those evaluated by other means) and then combine these uncertainties in a form of root-sum of squares (RSS). For AC-DC measurements, the Type B uncertainties are generally dominating [8]. The reported values are usually the average of 20 determinations of the transfer standard's AC-DC difference. For instance, the expanded uncertainty of the SJTVC at 55 Hz (k = 2, for 95% confidence level) is given in Table 6.

Table 6. Uncertainty Budget at 55Hz

Source of Uncertainty	Probability Distribution	Uncertainty Values ± ppm
Calibration certificate	Normal (Type B)	2.5
Tee connector	Rectangular (Type B)	1
Room temp change	Rectangular (Type B)	1
Repeatability (for 20 minutes)	Normal (Type A)	3.4
Expanded uncertainty	Normal (k=2)	8.8

8. Conclusion

A new automated system for highly accurate AC current measurements has been established at NIS, Egypt. The new system can be used for the automatic calibration of the ac-dc current transfer and the ac current calibrators. A new working standard thermal current converter has been fabricated and tested using the new system. The design of the new TCC has been re-modified then re-calibrated at PTB, Germany. The results show that the new TCC exhibits good time constants, reasonable steady state times and small dc reversal difference. The current dependence behavior at 55 Hz and 1 kHz is also evaluated.

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Calibration Management in the ISO/IEC 17025 Accredited Facility

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Prime Technologies, Inc.

Whether your quality practices are guided by the need for compliance with the FDA, ISO 9001 or ISO/IEC 17025, a calibration management software solution can be an important central element of your integrated quality system. Properly implemented, the right software will provide benefits that include stronger compliance controls, daily productivity gains, improved communication and control and the ability to move to a paperless management system. Even if you are fortunate enough to have one of the better computerized maintenance management systems, such as SAP PM, DataStream, JD Edwards or Maximo, they fall short when it comes to understanding or addressing the unique demands of the metrologist.

Calibration is not just another planned maintenance activity. Normal planned maintenance helps to ensure resource availability and reliability but calibration management does more, and is often more technically rigorous. Communication and the management of acceptable process or device specifications are critical. A professional calibration management solution will readily cope with these demands. The instruments, gages, devices and systems that require calibration are as varied as their functionality. Their respective signal types or engineering units of measure are virtually unlimited. Input and output accuracies may vary over the device range. They may be based on percent of range, percent of reading, percent of reading range, plus or minus, or a combination. Remember that while you will want to document the manufacturer's specifications you will also want to define the performance or control specification as the required performance objectives for the item you are planning to manage.

Ideal test point values with allowable variances will aid the technician in the faster accomplishment of the assigned calibration. But remember, the system should automatically recalculate the acceptable performance levels based on the actual test value and immediately inform the technician of an unacceptable result. Subtle performance variations can directly impact product quality.

Regardless of what your company produces: food, beverages, chemicals or pharmaceuticals, the recipes and processes that produce them have been developed to achieve a desired result. Ingredients, their quantities, process temperature, pressure, etc need all be reliably controlled. If the instruments controlling the process are not operating correctly it is easily understandable that the product may fail to deliver the expected result, be it taste or efficacy. The risk of noncompliance, quality excursions and even civil liability is higher than with other maintenance activities.

When you are evaluating your calibration management needs, asset management is a good place to start. The system record should be capable of documenting the complete life cycle of the asset, be it an instrument, device, gage or system. The scope of the information managed is dependent upon the nature of your relationship with the asset. Simply put, if your business is only responsible for providing metrology or calibration services, your records may fail to include the establishment and documentation of instrument specifications for acquisition and validation that the owner of the asset is obligated to maintain.

As a calibration service provider you will often be presented with your client's asset detail and calibration specifications. Although the extent of your responsibility is governed by your service agreement, with a good

Regardless of what a company produces, both product and process quality needs to be reliably controlled.

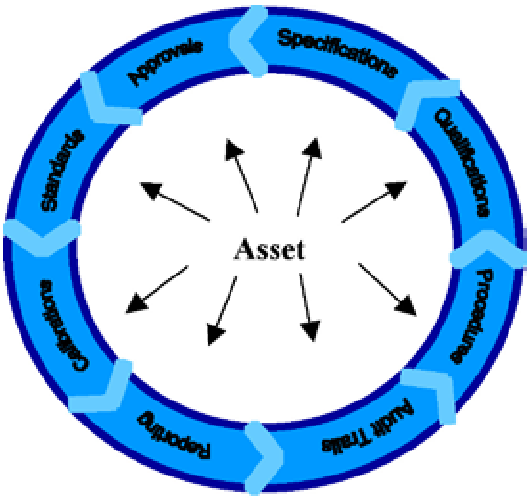

Figure 1. Illustration of the interdependency of the compliant Calibration System.

calibration management system the level of detail and the ease of information retrieval and subsequent evaluation will help enrich the quality of your professional services. The identification of issues less obvious then calibration failure can include trend analysis, potential problem recognition or opportunities for improving calibration practices. All represent opportunities for you to provide better service and to reinforce your relationship with your clients.

Calibration software should support complete details on the asset including the manufacturer's specifications as well as the process or performance specifications. It is the logical center of activity records related to the asset; approvals, validation, maintenance and calibration. Look for software that will allow you to document all the characteristics regardless of complexity. Keep in mind it is not an uncommon necessity to establish a variety of planned activities for a device, and the solution you select should accommodate this.

Calibration, validation and maintenance procedures must be documented, approved and managed. While many of us already have some form of electronic quality procedure management, the ability of the calibration management software to access these documents or, alternatively, allow the user to publish the procedures within the calibration software application is a valuable feature. In order to demonstrate compliance, the system's ability to reflect these documents in the records for all assets and their related activities is imperative. The more complete and accessible your documentation, the easier it will be for those that will use it. Your ability to demonstrate clear asset/procedure relationships and ease of access will go a long way towards instilling a higher degree of confidence in an auditor that your technicians follow your procedures. It doesn't matter if the auditor is from your internal QA staff as required per 21 CFR ¶ 820.22, from your customer, or from a regulatory authority, if you can't readily identify and locate the procedure they are likely going to find it difficult to accept that your busy technicians do so. By using an electronic system to manage your asset/procedure relationships, you will be easily able to locate procedures on-demand, instead of searching through years of records. If you want to avoid receiving an FDA 483 warning letter, be prepared to demonstrate well-documented procedures and practices in compliance with 21 CFR ¶ 211.68 and 21 CFR ¶ 820.72.

Technicians, managers and administrators must be trained, their competency to execute the procedures documented and their periodic retraining proactively managed. Incorporation of this in the system you select can greatly simplify management of this often overlooked quality and compliance element. These requirements are increasingly being carefully audited and are clearly specified for ISO/IEC 17025 accreditation or FDA 21 CFR ¶ 211.25 compliance.

The test standards utilized to perform calibrations, validations and testing must be managed and controlled as strenuously as all other assets. Additional software functionality to automatically communicate suitability for use, the uncertainty contributor of the standard and reverse traceability are all features that will provide additional benefit and efficiency to your integrated quality system. Always a consideration of any calibration activity, easing the burden on the technician and the manager through prequalification and proactive system control will eliminate invalid calibrations and wasted effort while simultaneously enforcing best practices and quality policies.

The greatest gains in productivity and quality control are realized with the implementation of paperless calibration techniques. A calibration management software implementation at a major pharmaceutical manufacturer targeted a paperless calibration environment as a prime objective and reported calibration productivity improvements in excess of 200 percent and nearly 100 percent on-schedule calibration activities without any reduction in performance confidence. Users are immediately and reliably presented with the correct performance specifications and the approved procedure for the item under test. Positive management and quality practices control the schedule as well as the process. The system, not the technician, does the calculations necessary to determine acceptable or unacceptable performance.

When selecting calibration management software, look for a solution that will not only allow you to manage simple input to output (direct) correlation routines but also provide features to execute more complex performance algorithms. Simple devices like gages or thermometers may represent the majority of what we may be called on to calibrate. However, the time and effort necessary to calibrate a complex device or system solutions will typically represent a disproportionate amount of time to complete and represent more opportunities for technician error. Users of professional calibration management systems are offered standard or custom test procedures that prompt the technician what reading is to be taken and then automatically evaluates the recorded result determining performance acceptability regardless of complexity.

No matter what your current practices are, you should look to likely future requirements. One example is the determination of calibration uncertainty. Already a requirement under ISO/IEC 17025 and A2LA, in the world of constant quality improvement and competition, your company may decide on the practice in order to present a qualification or differentiator to your clients. An automated tool to assist managing this more complex practice will greatly simplify things for you and your associates.

The calibration program should be capable of automatically evaluating all the uncertainty contributors, including the coverage factor, and determine the combined budget, consistent with ISO Guide 98: "Guide to the expression of uncertainty in measurement (GUM)." In selecting the right solution you should be able to configure the software to automatically initiate a wide range of functions based upon the results of the calibration.

With a successful calibration result, automatic program functions will satisfy the scheduled calibration and advance to the next date based on the planned interval. If a work order management utility is being utilized as well, the task will be satisfied. Should, on the other hand, the device be found out of calibration or fail, the options get more interesting. They can include electronic notification of the failure to appropriate staff as defined by the classification, criticality or other established business logic, the automatic launching of system generated repair/replace requests, the initiation of quality/compliance incident reports that will become the basis of a corrective and preventive action (CAPA) investigation and more.

In either circumstance, the recording of actual calibration data will simplify evaluation and analysis. The ability to readily retrieve and evaluate historical calibration results can save time for the engineer and quality professional. With manual and paper based systems, the inquiry and review of historical data can easily represent more then 35 percent of the reviewer's time.

Another impediment to quality reporting and improvement is communication. A solution that supports flexible paperless routings for change control, approvals, quality, and compliance incidents can alone justify the investment in a new solution. The better solution will address communication and notification comprehensively. Alerts, reminders, notifications and incident reporting should all include the ability to communicate to defined responsible participants external to the application itself.

Finally no matter how attractive the promised features and benefits may appear, you should be certain to consider the qualifications of the solution provider. I started this dialog with the suggestion that the right system can equal significant benefits to your organization. Whatever solution you select, keep in mind you will be dealing with critical business practices. Take the time to look into the vendor's experience, support services, track record of success and quality practices. Are they prepared to withstand your scrutiny of their design, and testing practices? Inquire regarding the maturity of the product. If you are working in an FDA-regulated environment, ask if the vendor can demonstrate validation qualifications? Ask for references and contact them. It's important to work with a flexible vendor willing to address your special needs but look carefully at what the vendor can actually demonstrate and weigh it carefully against your critical requirements. Remember anyone can promise vaporware and unfortunately many do.

Wrap-Up: Why do you need a Calibration Management System?

- Communication and the management of acceptable process or device specifications are critical. A professional calibration management solution will readily cope with these demands.
- Faster accomplishment of assigned calibrations by technician saving time and money.
- Subtle performance variations can directly impact product quality so it is important to track that all instruments are in calibration.
- A calibration management system will help enrich the quality of your professional services as well as make it easier to pull up required information during audits.
- Your ability to demonstrate clear asset/procedure relationships and ease of access will go a long way towards instilling a higher degree of confidence in an auditor that your technicians follow your procedures.
- Improved productivity and efficiency.
- Automatic Calculations prevent user error.

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