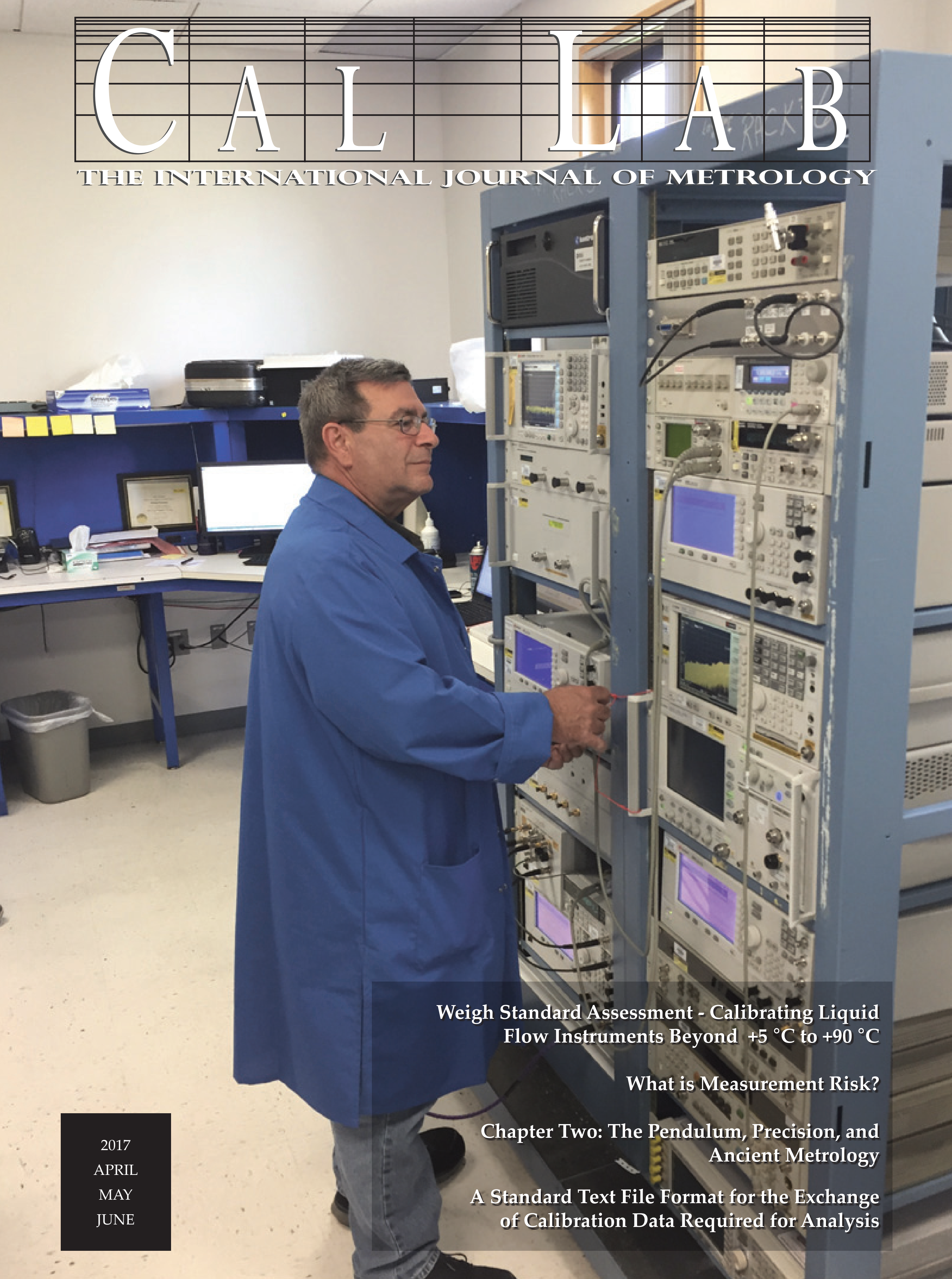


CAL LAB

THE INTERNATIONAL JOURNAL OF METROLOGY

Weigh Standard Assessment - Calibrating Liquid Flow Instruments Beyond +5 °C to +90 °C

What is Measurement Risk?

Chapter Two: The Pendulum, Precision, and Ancient Metrology

A Standard Text File Format for the Exchange of Calibration Data Required for Analysis

2017
APRIL
MAY
JUNE

Electric Current Measurement

DS Series Current Transducers

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

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

DS200

DS2000

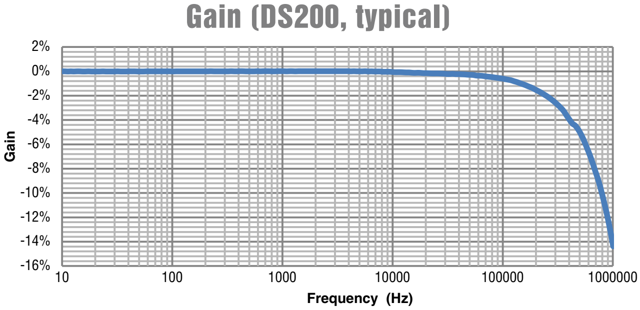
	DS200	DS600	DS2000	DS5000
Primary Current, rms	200A	600A	2000A	5000A
Primary Current, Peak	±300A	±900A	±3000A	±7000A
Turns Ratio	500:1	1500:1	1500:1	2500:1
Output Signal (rms/Peak)	0.4A/±0.6A†	0.4A/±0.6A†	1.33A/±2A†	2A/±3.2A†
Overall Accuracy	0.01%	0.01%	0.01%	
Offset	<20ppm	<10ppm	<10ppm	<5ppm
Linearity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

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

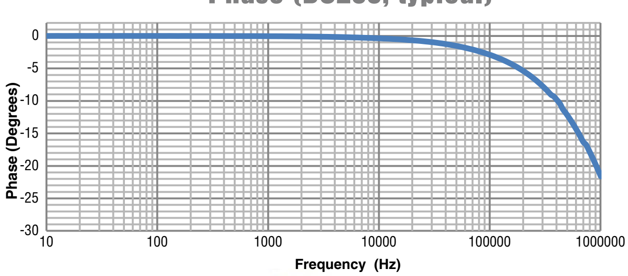
†Voltage Output options available in ±1V and ±10V

Gain / Phase

Gain (DS200, typical)



Phase (DS200, typical)



DSSIU-4 for Multi Channel Systems

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

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

DSSIU-4

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Volume 24, Number 2

FEATURES

DEPARTMENTS

ON THE COVER: Joe Gentile, Senior RF Calibration Technician at Analog Devices Inc. in Wilmington, Massachusetts.

CALENDAR

UPCOMING CONFERENCES & MEETINGS

Jul 16-20, 2017 National Conference on Weights & Measures Annual Meeting. Pittsburgh, PA. The National Conference on Weights and Measures is a professional nonprofit association of state and local weights and measures officials, federal agencies, manufacturers, retailers and consumers. http://ncwm.net

Jul 17-21, 2017 Annual Coordinate Metrology Systems Conference (CMSC). Snowbird, UT. Technical presentations from industry experts, hands-on workshops providing unprecedented training opportunities on the highest quality of metrology hardware and software solutions in the field of metrology. http://cmsc.org

Jun 27-29, 2017 MET&PROPS. Gothenburg, Sweden. 16th International Conference on Metrology and Properties of Engineering Surfaces. http://www.metprops2017.se/

Jul 31-Aug 3, 2017 IMEKO TC1 – Education and Training in Measurement and Instrumentation, TC7 – Measurement Science, and TC13 – Measurements in Biology and Medicine. Rio de Janeiro, Brazil. The 2017 Joint IMEKO TC1-TC7-TC13 Symposium: "Measurement Science Challenges in Natural and Social Sciences" is organized by the Brazilian Society of Metrology (SBM). http://www.imeko-tc7-rio.org.br/

Aug 13-17, 2017 NCSL International. National Harbor, MD. The NCSLI Annual Meeting & Exposition provides you with a three day pre-conference program that includes tutorials and three days dedicated to your professional development and networking. http://ncsli.org

Aug 29-31, 2017 Advanced Mathematical and Computational Tools in Metrology and Testing XI. Glasgow, Scotland. The conference is an IMEKO TC21 event, organized by the National Physical Laboratory (NPL), in conjunction with the University of Strathclyde. http://www.npl.co.uk/events/29-31-aug-2017-amctm-xi

Sep 9-15, 2017 AUTOTESTCON. Schaumburg, IL. AUTOTESTCON is the world's premier conference that brings together the military/aerospace automatic test industry to share new technologies, discuss innovative applications, and exhibit products and services. http://www.autotestcon.com

Sept 19-21, 2017 CIM2017. Paris, France. The 18th International Metrology Congress is a 3 day conference to discover the technologies in measurement and explore industrial challenges and the latest innovations. http://cim2017.com/

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EDITOR'S DESK

Out and About

Spring is a time of anticipation and fresh starts: the house and garden get a good spring cleaning, storms do their destruction, and friends and family move away to begin a new chapter in their lives. After a long, cool and rainy spring, summer is right on time.

This past spring I attended three events, all back-to-back. First, we went to the MSC Training Symposium in Anaheim, California. There we had a booth next to the folks from the National Institute of Standards and Technology (NIST) out of Boulder, Colorado. I was invited to join a group of Air Force Academy Cadets on a NIST tour the following Monday—thanks Matt! To say there was a learning curve is an understatement. That weekend I spent many hours watching science documentaries with my husband—who loves this stuff—and still felt terribly unprepared.

The work and research done at NIST (https://www.nist.gov/) is undervalued in our society. "Working with industry and science to advance innovation and improve quality of life" is what they do in a nutshell. I got to see the labs where researchers are learning about the dynamics of quantum mechanics. Even practical details of laser measurement are fascinating, such as in the design of a graphene heat dump.

The week following my NIST tour, I participated in a NCSLI section meeting for Denver/Boulder. For anyone not familiar… these section meetings happen all over the US and internationally and are open to the public. I encourage anyone at every level in the industry to look up a local section meeting in their neck of the woods >> http://www.ncsli.org/regions. The speakers cover a wide range of topics at different levels, so besides being instructive, the meetings are a great networking opportunity as well!

With all the fantastic craft beer brewers in our area, we thought it fitting to arrange for the section meeting at a craft brewer production facility: North Dock. Starting out as a small home brew supply shop called the Brew Hut, Dry Dock Brewing quickly grew to be a popular and award-winning brewer right here in our hometown of Aurora, Colorado. I thought maybe there was a higher level of precision in the brew process, but it's more about quality control and art. Sour Apricot? Yes, please!

So, in many fits and starts, this issue's articles are finally presented to you here, beginning with a second installment of a series of flow articles by Richard Fertell and others of Proteus Industries. In this installment, a timed dispense methodology, or "Weigh Standard Assessment" is demonstrated at room temperature in order to provide a standard method before addressing it in a future article with higher and lower temperatures.

Henry Zumbrun of Morehouse contributes another article, but instead of focusing on force, this time he defines measurement risk and the role of Test Uncertainty Ratios. This is followed by another second installment from a series of articles: the influence of the pendulum on ancient standards, by Roland Boucher. And finally, Dr. Alex Lepek explains a practical method of collecting and sharing calibration data in a standard text file format.

Happy Measuring,

Sita Schwartz
Editor

SEMINARS: Dimensional

Jul 3-5, 2017 Dimensional Measurement Training: Level 1 – Measurement User. Telford, UK - Hexagon Metrology. A three day training course introducing measurement knowledge focusing upon Dimensional techniques. http://www.npl.co.uk/training.

Jul 10-11, 2017 Hands-On Gage Calibration and Repair. Indianapolis, IN. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Jul 10-13, 2017 Dimensional Measurement Training: Level 2 – Measurement Applier. Telford, UK - Hexagon Metrology. A four day training course for those who have a good basic understanding of measurement principles gained through the Level 1 training course. http://www.npl.co.uk/training.

Jul 10-13, 2017 Dimensional Measurement Training: Level 2 – Measurement Applier. Huddersfield, UK. A four day training course for those who have a good basic understanding of measurement principles gained through the Level 1 training course. http://www.npl.co.uk/training.

Jul 13-14, 2017 Hands-On Gage Calibration and Repair. Milwaukee, WI. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Jul 20-21, 2017 Hands-On Gage Calibration and Repair. Cleveland, OH. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Aug 1-3, 2017 Hands-on Gage Calibration. Aurora (Chicago), IL. Mitutoyo Institute of Metrology. The Hands-On Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. http://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/.

Aug 3-4, 2017 Hands-On Gage Calibration and Repair. Portland, OR. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on

calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Aug 7-8, 2017 Hands-On Gage Calibration and Repair. San Francisco, CA. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Aug 10-11, 2017 Hands-On Gage Calibration and Repair. Las Vegas, NV. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Aug 28-29, 2017 Hands-On Gage Calibration and Repair. Naperville, IL. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Aug 30-31, 2017 Hands-On Gage Calibration and Repair. Madison, WI. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Sep 5-7, 2017 Dimensional Measurement Training: Level 1 – Measurement User. Bristol, UK – INSPHERE Ltd. A three day training course introducing measurement knowledge focusing upon Dimensional techniques. Applicable to all industrial sectors as a stand-alone qualification or as a building block to further NPL Dimensional Measurement Training Levels – 2 & 3. http://www.npl.co.uk/training.

Sep 12-13, 2017 Hands-On Gage Calibration and Repair. Louisville, KY. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Sep 12-4, 2017 Dimensional Metrology. Aurora (Chicago), IL. Mitutoyo Institute of Metrology. Our Dimensional Metrology curriculum is intended for anyone who wishes to learn about dimensional measuring equipment and strategies for implementation. http://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/.

Sep 14-15, 2017 Hands-On Gage Calibration and Repair. St. Louis, MO. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

Sep 19-21, 2017 Hands-on Gage Calibration. Aurora (Chicago), IL. Mitutoyo Institute of Metrology. The Hands-On Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. http://www.mitutoyo.com/support/mitutoyo-institute-of-metrology/.

Sep 26-27, 2017 Hands-On Gage Calibration and Repair. Bloomington, MN. IICT. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Course includes hands on calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. http://www.iictenterprisesllc.com.

SEMINARS: Electrical

Jul 17-20, 2017 MET-101 Basic Hands-on Metrology. Everett, WA. Fluke Calibration. This course introduces the student to basic measurement concepts, basic electronics related to measurement instruments and math used in calibration. We will also teach various techniques used to make good measurements using calibration equipment. http://us.flukecal.com/training.

Aug 9-10, 2017 Electrical Measurement. Linfield, NSW. NMI (Australian Gov. Dept. of Industry, Innovation and Science. This two-day course (9 am to 5 pm) covers essential knowledge of the theory and practice of electrical measurement using digital multimeters and calibrators; special attention is given to important practical issues such as grounding, interference and thermal effects. http://www.measurement.gov.au/Services/Training/Pages/default.aspx

SEMINARS: Flow / Pressure

Sep 11-15, 2017 Principles of Pressure Calibration. Phoenix, AZ. Fluke Calibration. A five day training course on the principles and practices of pressure calibration using digital pressure calibrators and piston gauges (pressure balances). The class is designed to focus on the practical considerations of pressure calibrations. http://us.flukecal.com/training.

Sep 20-22, 2017 Flow Measurement and Calibration. Munich, Germany. TrigasFI GmbH. This Training Seminar is intended for individuals with responsibility to select, calibrate and use liquid and gas flowmeters. It is designed to be an objective, independent review and evaluation of the current state of flow metering and calibration theory and technology for flowmeter users and metrologists. http://trigas.de/.

SEMINARS: General & Management

Sep 12, 2017 Basic Metrology. Delft, Netherlands. VSL Dutch Metrology Institute. http://vsl.nl/en/services/training.

Sep 28, 2017 Root Cause Analysis and Corrective Action. A2LA Headquarters – Frederick, MD. The Root Cause Analysis and Corrective Action (RCA/CA) course consists of presentations, discussions and exercises that provide participants with an in-depth understanding of how to analyze a system in order to identify the root causes of problems and to prevent them from recurring. http://www.a2la.org/.

SEMINARS: Industry Standards

Aug 21-22, 2017 Internal Auditing to ISO/IEC 17025. Memphis, TN. ANAB. The 2.5-day Internal Auditing to ISO/IEC 17025 training course prepares the internal auditor to clearly understand technical issues relating to an audit. Attendees will learn how to coordinate a quality management system audit to ISO/IEC 17025:2005 and collect audit evidence and document observations. http://www.anab.org/training.

Aug 30, 2017 Document Control and Record Keeping Webinar. NIST. This 2 hour webinar will introduce the fundamentals of Laboratory Management System Document Control and Record Keeping that are necessary to successfully implement ISO/IEC 17025. https://www.nist.gov/news-events/events/2018/08/5427-document-control-and-record-keeping.

Sep 14-15, 2017 Introduction to ISO/IEC 17025. Denver, CO. ANAB. Attendees will examine the origins of ISO/IEC 17025:2005 and learn practical concepts such as document control, internal auditing, proficiency testing, traceability, measurement uncertainty, and method witnessing. http://www.anab.org/training.

Sep 18-19, 2017 ISO/IEC 17025 and Laboratory Accreditation. Frederick, MD. A2LA.This course is an introductory look at ISO/IEC 17025 and its requirements for demonstrating the technical competence of testing and calibration laboratories. http://www.a2la.org/.

Additel

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- ***Optional data logging and task documenting***
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- ***4 Channels***

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Salt Lake City Office
1364 West State Rd. Suite 101
Pleasant Grove, UT 84062, USA

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Sep 25-26, 2017 ISO/IEC 17025 and Laboratory Accreditation. Boulder, CO. A2LA. This course is an introductory look at ISO/IEC 17025 and its requirements for demonstrating the technical competence of testing and calibration laboratories. http://www.a2la.org/.

Sep 28, 2017 ISO/IEC 17025 Advanced: Beyond the Basics. Boulder, CO. A2LA. This is an advanced course in the application of ISO/IEC 17025 requirements. The course will provide a brief overview of the requirements of this laboratory standard, as well as provide an understanding of how to apply specific sections of the Standard in your laboratory. http://www.a2la.org/.

SEMINARS: Mass & Weight

Jul 7, 2017 Calibration of Weights and Balances. Linfield, NSW. NMI (Australian Gov. - Dept. of Industry, Innovation and Science). This one-day course (9 am to 5 pm) covers the theory and practice of the calibration of weights and balances. It incorporates hands-on practical exercises to demonstrate adjustment features and the effects of static, magnetism, vibration and draughts on balance performance. http://www.measurement.gov.au/Services/Training/Pages/default.aspx.

Aug 21-31, 2017 Advanced Mass Seminar. Gaithersburg, MD. NIST Office of Weights and Measures. The 9 day, hands-on mass calibration seminar focuses on the comprehension and application of the advanced mass dissemination procedures, the equations, and associated calculations. https://www.nist.gov/news-events/events/2017/08/5437-advanced-mass-seminar.

SEMINARS: Measurement Uncertainty

Jun 27-29, 2017 MET-302 Introduction to Measurement Uncertainty. Everett, WA. Fluke Calibration. This course will teach you how to develop uncertainty budgets and how to understand the necessary calibration processes and techniques to obtain repeatable results. http://us.flukecal.com/training.

Aug 23, 2017 Introduction to Estimating Measurement Uncertainty. Brisbane, QLD. NMI (Australian Gov. - Dept. of Industry, Innovation and Science). This one-day course will give you a clear step-by-step approach to uncertainty estimation with practical examples. http://www.measurement.gov.au/Services/Training/Pages/default.aspx.

Aug 24-25, 2017, Fundamentals of Measurement Uncertainty. Memphis, TN. ANAB. Attendees of this 2-day course will learn a practical approach to measurement uncertainty applications, based on fundamental practices. Measurement uncertainty for both testing and calibration laboratories will be discussed. Attendees will gain an understanding of the steps required, accepted practices, and types of uncertainties that need to be considered by accredited laboratories. http://anab.org/training.

Sep 11, 2017 Introduction to Measurement Uncertainty. Frederick, MD. A2LA. Participants who have never developed uncertainty budgets usually develop the required skill well before the end of the class. Others who seek explanations of GUM complexities obtain clarifications expressed in simple terms. http://www.a2la.org/.

Sep 12-13, 2017 Applied Measurement Uncertainty for Calibration Labs. A2LA Headquarters – Frederick, MD. https://www.a2la.org/training/index.cfm.

SEMINARS: Pressure

Sep 11-15, 2017 Principles of Pressure Calibration. Phoenix, AZ. Fluke Calibration. A five day training course on the principles and practices of pressure calibration using digital pressure calibrators and piston gauges (pressure balances). The class is designed to focus on the practical considerations of pressure calibrations. http://us.flukecal.com/training.

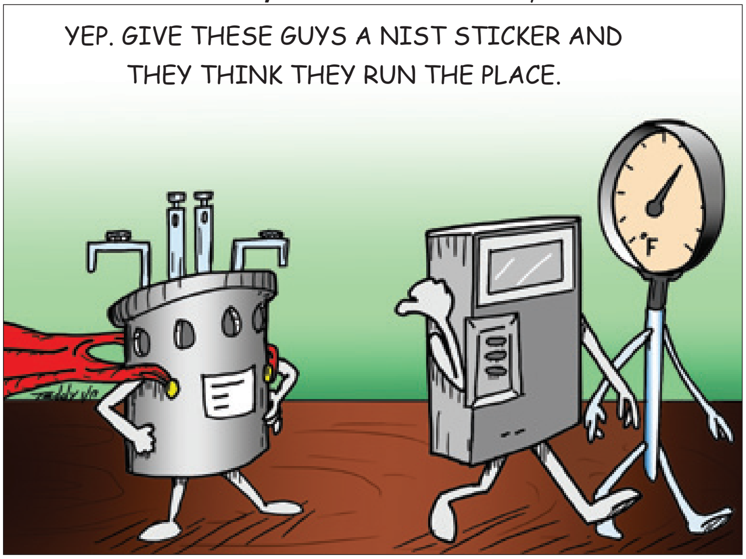
SEMINARS: Temperature

Sep 18-20, 2017 Advanced Topics in Temperature Metrology. American Fork, UT. Fluke Calibration. A three-day course for those who need to get into the details of temperature metrology. This course is for experienced calibration technicians, metrologists, engineers, and technical experts working in primary and secondary-level temperature calibration laboratories who would like to validate, refresh, or expand their understanding of advanced topics in temperature metrology. http://us.flukecal.com/training.

Sep 21-22, 2017 Infrared Calibration Training. American Fork, UT. Fluke Calibration. A three-day course with plenty of hands on experience in infrared temperature metrology. This course is for calibration technicians, engineers, metrologists, and technical experts who are beginning or sustaining an infrared temperature calibration program. http://us.flukecal.com/training.

Visit **www.callabmag.com** for upcoming metrology events & webinars!

CAL-TOONS by Ted Green teddytoons@icloud.com



Isothermal Technology Ltd Earns a Queen's Award for Enterprise

Isothermal Technology Ltd (Isotech) is celebrating winning a Queen's Award for the co-development of an innovative resistance bridge for use in establishing and disseminating the International Temperature Scale (ITS-90).

The product, called microK, is now in use in the world's leading National Metrology Institutes (NMIs) alongside Primary Standards. Outside of NMIs the client base includes oceanography, aerospace, medicine and astrophysics.

John Tavener, founder and Managing Director says, "We are delighted that Her Majesty the Queen has approved the Prime Minister's recommendation that Isotech should receive a Queen's Award for Enterprise in the Innovation category this year."

Sales have risen by 86% over the last five years; outside of the UK and Europe, Isotech has sold to top laboratories as far afield as China, India, New Zealand, Botswana, Uruguay, South Korea, and many other countries. It is even being used as part of a US project searching for exoplanets.

John added that "I recognized that the existing instruments used old technology and relied on obsolete components; cooperating with Metrosol Ltd we developed this new device, with better performance and lower cost than the older designs. Winning a Queen's Award for Enterprise; the highest honour that can be bestowed on a UK company is a real cause for celebration for everyone at Isotech."

The microK operates to a precision of 20 parts per billion - equivalent to 0.00002°C and a unique feature of the microK is that it is drift free in ratio measurement; in contrast the older technology requires periodic adjustment in order to maintain its specification. The National Physical Laboratory and Metron Designs (John Pickering) both contributed to the development of a new type of metrology grade analog-to-digital converter which was necessary to realise this level of performance.

Isotech (www.isotech.co.uk) was founded by John Tavener in 1980, it remains a family business and is located in Southport, North West England. The company developed a range of temperature metrology products and has become a world leader in the field. Additionally Isotech operates an ISO 17025 accredited laboratory which is believed to be the world's most accurate privately owned temperature laboratory. The company has 52 members of staff, many long serving and is recognized for innovation, experience and expertise.

The New Standard for Resistance Standards?

May 22, 2017, NIST News - Contrary to the popular maxim, resistance is not futile. But it is quantized: The ratings of the heat-making resistors in your hair dryer or toaster ultimately trace back to quantum mechanics.

That's because the universal practical standard for electrical resistance is based on a phenomenon called the quantum Hall effect (QHE), in which resistance takes on perfectly exact, discrete (quantized) values under certain conditions. Those values can be measured to an accuracy of about 1 part per billion. Any metrology institute or standards lab that performs authoritative resistance measurements needs a QHE device or instruments that have been calibrated with measurements traceable to one.

QHE devices have conventionally been constructed from adjacent layers of two different, but closely related, semiconductors such as gallium arsenide (GaAs) and aluminum gallium arsenide (AlGaAs). These are, however, difficult and expensive to make. In recent years, many experiments have indicated that graphene – a one-atom-thick sheet of carbon atoms arranged in a hexagonal, chicken-wire lattice – could be used with equivalent accuracy and far fewer operational difficulties.

Now NIST researchers have devised and tested a method (link is external) to produce large, homogenous graphene sheets with uniform strain optimized for QHE measurements. NIST has a long history of leadership in the field. "It's one of the few places in the world that has successfully made standards-quality graphene, developed the technologies to make and test the devices, and done it all in-house – from raw materials to final product," says project scientist Rand Elmquist of NIST's Physical Measurement Laboratory (PML).

The newly reported NIST graphene is produced by placing a wafer of insulating silicon carbide (SiC, best known in abrasives and ceramics) about 2 micrometers above a bed of graphite – a form of carbon (best known as the "lead" in pencils) that is extremely heat-resistant. As the SiC is heated through several stages up to 1900 ˚C, the silicon sublimates, leaving the pure carbon behind to crystallize into graphene.

"With graphene produced by the new technique, we're getting results that are equivalent to the current national standard, in gallium arsenide," Elmquist says. "Recently we made a direct comparison, and got the same values to within 1 part in 10^9. We plan to offer a graphene QHE standard as a Standard Reference Material within a year or two. That would be the first commercial source of quantum Hall devices by themselves, and we're also working with the private sector to make these devices available as a complete instrument package."

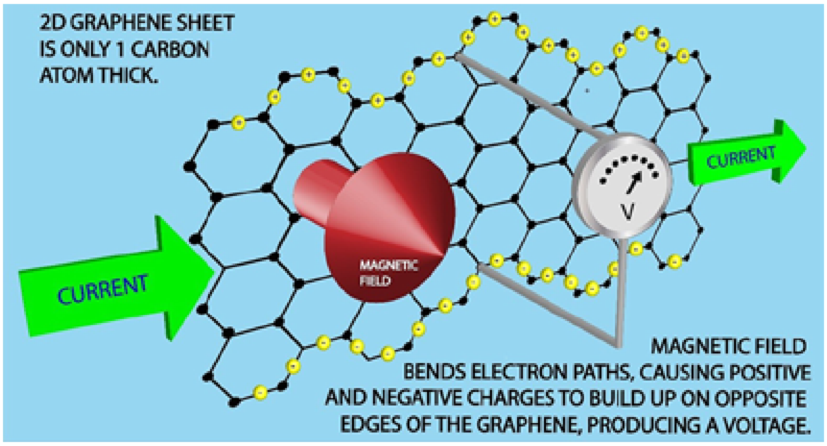
In QHE measurements, electrical current flows in a two-dimensional (2D), low-temperature conductor that has negligible thickness. Ordinarily, the current travels in a straight path and the carriers have a range of energies. But when a strong magnetic field is applied perpendicular to the plane where current flows, the field bends the electrons' paths, forcing the positive and negative charges to detour toward opposite edges of the device. That is, there is a voltage between one edge of the sheet and the other, and the resistance between them is exactly quantized depending on the magnetic field strength due to the quantization of magnetic flux.

In conventional devices, the electrons flow in the ultra-narrow space between a GaAs layer and a ALGaAs layer, and full quantization is achieved only at high magnetic field strength and very low temperature. GaAs-type devices must be kept very cold -- 1.2 K or below, because heat can broaden and mix the energy levels – and thus the instrument requires costly, complicated cooling systems that use liquid helium.

In addition, GaAs has a comparatively small spacing between the quantized magnetic levels, and requires magnetic fields above 5 tesla (T), roughly twice the strength used in the most powerful MRI scanners. Under these conditions, the device measurements are limited to voltage levels of 1 V or below, and to small currents in the range of 20 to 80 microamperes.

"But with graphene, which is an exceptionally good conductor for a 2D material, we've seen full quantization as low as 2 T," Elmquist says, "which allows us to use a much smaller magnetic apparatus that can be placed on a tabletop. Some devices are still perfectly quantized at temperatures as high as 5 K, and we have observed critical currents as high as 720 microamps, which is the highest ever observed for a QHE standard.

"If you can measure using that sort of device with its higher currents, you can accurately calibrate a room-temperature resistor of similar value, like a 1 kΩ or 10 kΩ resistor. With lower field, higher temperatures and higher current you can have a much simpler



Credit: NIST

Crystal pressure

nVision lets you visualize measurements graphically, with or without a pc, in real time as it is being recorded. Separate, easily replaceable modules for pressure, temperature, and voltage and current make nVision tremendously flexible.

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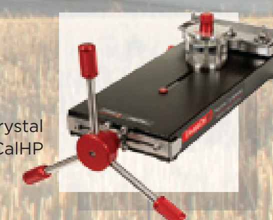
Crystal XP2i



Crystal GaugeCalHP

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M & G PKII

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- Gauge/Absolute Pressure Datalogger to 15 000 psi / 1000 bar / 100 MPa
- Differential Pressure with up to 0.025% of reading accuracy
- Switch, Voltage, Current, and Temperature Measurement
- 500 000 Data Points at 10 Readings per Second from 2 Modules
- Interactive Real-time Graphing of Measurements
- Compensates Accuracy for Temperature Effects from -20 to 50°C
- Connect to a PC to view live readings; or export to tamper-proof digital records

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system: a closed-cycle refrigerator where you won't need liquid helium," he says. "By contrast, we run the NIST gallium arsenide system only twice a year because of the expense and difficulty of running the liquid helium system."

The NIST graphene has several other advantages. Its lattice is uniform and generally lacks topological defects across areas as large as 5.6 mm by 5.6 mm – about the size of the raised electrode tip on a AA battery, and very extensive by ordinary graphene production standards. In addition, it has uniform strain on the lattice, which reduces the likelihood of moving electrons to scatter, increasing their mobility.

"It's an exciting time for the graphene research team, and we are intensely proud of their work," says John Pratt, Chief of PML's Quantum Measurement Division. "They are creating a very practical standard here, one that will drive the cost of ownership and complexity of operation for quantum electrical standards down significantly.

"And this is just the tip of an iceberg for them. They have basic research results with their partners across NIST and around the country that point the way towards networks of these resistors for easy quantum-based scaling of resistance, and they have created novel diode-like junctions with applications in computing and quantum information processing, to say nothing of the optoelectronic aspects they have been considering within the general context of 2D material behaviors. Heady stuff that all spins off from the quest for a better ohm!"

Source: https://www.nist.gov/news-events/news/2017/05/new-standard-resistance-standards

Calibration of Autocollimators

At PTB, a novel calibration system for autocollimators has been set up, the Spatial Angle Autocollimator Calibrator. The calibration capabilities for optical angle measurements have thus been extended from plane to spatial angles for the first time. In addition, the system allows calibrations at distances from 250 mm to 1800 mm.

Autocollimators allow contact-free measurement of the inclination angles of reflecting surfaces via the angular deflection of a reflected measuring beam. To date, PTB has calibrated these by means of the national primary standard for the plane angle, the angle-measuring table 220 (WMT 220). These calibrations are, however, only possible along one measuring axis of the autocollimator and at a distance from 250 mm to 550 mm from the reflector. In order to extend the calibration capabilities to spatial angles and larger distances, a novel calibration system for autocollimators, the Spatial Angle Autocollimator Calibrator (SAAC), has been set up at PTB.

The SAAC is based on a Cartesian arrangement of three autocollimators which are directed towards a reflector cube. Two of them serve as reference measuring systems; the third autocollimator is the object under calibration. It is located on a linear sliding carriage with which the distance from the cube can be adjusted from 300 mm to 1800 mm.

By means of a two-axis tilting system, the cube can be tilted within an angular range of (3000 × 3000) arcsec^2 around two axes that run vertically to each other.

The autocollimator to be calibrated hereby records both tilting angles of the cube.

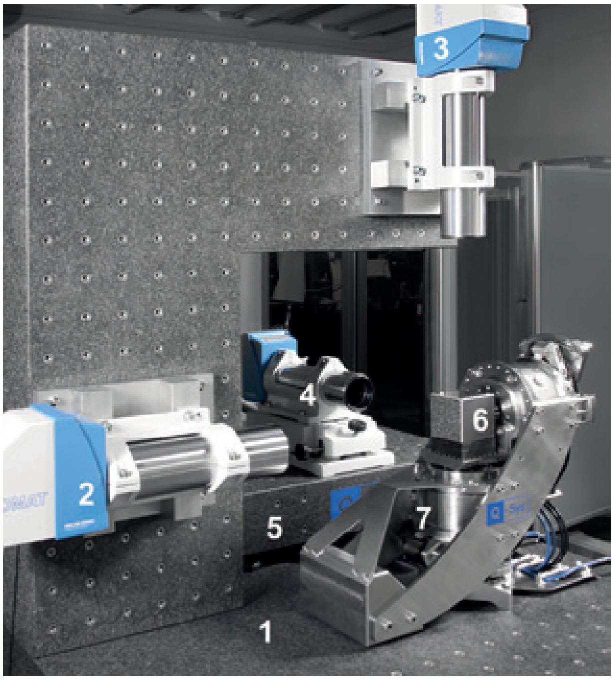
Due to the Cartesian arrangement, each of the reference devices, however, only measures one of the two tilts as a practically plane angular deflection. These reference devices can be calibrated directly using the WMT 220. Measuring two plane angles thus ensures the traceability of the calibration of spatial angles to the national primary standard.

The SAAC makes it possible to calibrate autocollimators with respect to spatial angles and to characterize distance-dependent effects. Manufacturers who would like to improve their instruments and users who apply them to measuring situations other than plane angles and fixed spacing, both benefit similarly from the new calibration facility. An example of this is the high-precision measurement of the shape of optical surfaces that are used to shape synchrotron or free-electron laser radiation beams.

Contact: Ralf D.Geckeler, Department, 5.2 Dimensional Nanometrology, Phone: +49 (0)531 592-5220, ralf.geckeler@ptb.de.

Scientific publication: O. Kranz, R. D. Geckeler, A. Just, M. Krause, W. Osten: "From plane to spatial angles: PTB's Spatial Angle Autocollimator Calibrator." *Adv. Opt. Technol.* 4, 288–294 (2015).

Source: PTB-News 1.2017 (https://www.ptb.de/cms/en/presseaktuelles/journals-magazines/ptb-news.html)



Spatial Angle Autocollimator Calibrator: granite base plate (1), reference autocollimators (2; 3), autocollimator to be calibrated (4), linear sliding carriage (5), reflector cube (6), two-axis tilting system (7)

Weigh Standard Assessment - Calibrating Liquid Flow Instruments Beyond +5 °C to +90 °C

Richard Fertell, Hamed Ershad, York Xu,
Osborne Gumbs, Tammy Tran
Proteus Industries, Inc.

This article is the second of a series describing how to perform liquid flow rate calibrations at fluid temperatures below +5 °C and above +90 °C. We examine the weigh standard method to measure the liquid mass flow rate and the assessment calculations of Measurement Uncertainty for Mass Flow at room temperature. The weigh standard method and assessment techniques need to be understood at room temperature before they are modified and assessed at higher and lower temperatures in future articles. Only then, can the weigh standard method be used to assess a Coriolis meter liquid mass flow measurement so that the Coriolis meter can be used as a master in-line flow reference for calibrating a paddlewheel/turbine meter from -40 °C to +200 °C.

Why Flow Measurement is Important

Errors in flow measurement can have a direct impact on industries such as power, manufacturing, and medical industries. Utilities' operational integrity is put at risk, whenever safety margins are decreased based upon projected lower flow measurement uncertainties for fluid temperatures above +90 °C, in an effort to increase power plant output. Petroleum pumping errors account for upwards of $100 Billion per year because fluid flow measurements are not questioned until exceeding 3% difference at point of transfer (on or off ships, in or out of transfer terminals, out of gas pumps, etc.). Manufacturing process yields may not increase because cooling fluid thermal energy transfers do not happen as predicted for fluid temperatures below +5 °C and above +90 °C. The safety and well-being of patients is put at risk where drug dosage delivery equipment is inaccurate or calibrated improperly. These are just a few examples how flow measurement impacts multiple industries and why it is so important to understand volumetric flow outside the typical range of temperature during calibration.

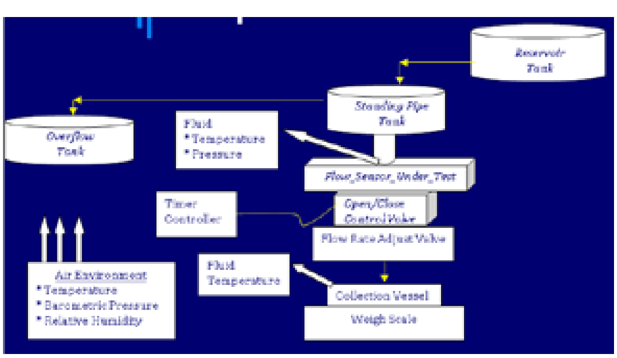


Figure 1. Schematic of a Weigh Standard implemented as a Standing Pipe/Constant Level Head with a Standing Start.

Approach to the Problem

A weigh standard can achieve ISO 17025 Measurement Uncertainty of better than 0.025% of reading for liquid mass flow and water fluid temperatures from +5 °C to +90 °C. To ensure 0.10% of reading for a Coriolis Mass Flow Meter, the Unit-Under-Test (UUT), an ISO 17025 Measurement Uncertainty of 0.025% of reading is required to achieve a Z540.3 Handbook <2% False Acceptance (using a 4:1 Test Uncertainty Ratio) (Harben and Reese).

Calibrating liquid flow instruments with room temperature water or other fluids is a challenge in its own right. Many flow and calibration laboratories work with room temperature fluids in flow ranges from Nano liters per hour to Mega liters per minute. In addition, flow instrument manufacturers work with water temperatures from +5 °C to +90 °C; and thus use mathematical analysis and curve projections to describe instrument performance, behavior and estimated error, below +5 °C & above +90 °C fluid temperature ranges.

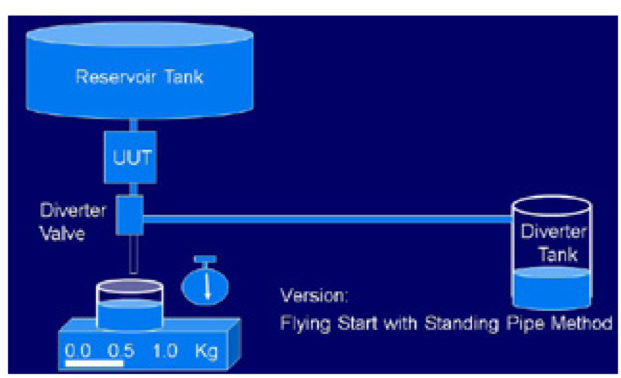


Figure 2. Schematic of a diverter valve in a Standing Pipe/Constant Level Head to a Flying Start.

The weigh standard method is best understood as a bucket and stop-watch approach or timed dispensed methodology. It can be implemented in many ways, such as diverting a flow into a container from either a recirculating system or a Standing Pipe/Constant Level Head. A Standing Pipe/Constant Level Head can either be like: Figure 1) with flow starting from Zero GPM and incrementally increasing when the valve opens; or Figure 2) with stabilized flow in a recirculating loop, then diverted into a capture container. A flying start has the advantage of stabilizing the flow sensor at a flow rate which can reduce the initial flow sensor reading error when the valve opens to the mass flow collection position.

The standing start weigh standard pictured in Figure 3 is constructed in a tight space for mass flow rates <0.13 kg/min, for fluid temperatures between +18 °C to +28 °C. The constant head is maintained by an overflow back into the sump tank on the floor. Flow instability is minimized by using this overflow technique combined with a much larger than standing pipe reservoir raised tank than the inlet flow of the unit-under-calibration as well as adjusting the sump-pump flow into the standing pipe reservoir to maintain an overflow during calibration period. A large standing pipe reservoir relative to the calibration flow also maintains a stable fluid temperature.

The standing start system in Figure 3 is built with a solenoid valve for faster opening/closing and no leakage, instead of with a diverter valve as shown in the schematics of ISO 4185, Figure 4. To prevent UUT flow shock damage, a standing start should be <25% of UUT flow range.

Whichever implemented method is used, the general error sources and the unit of measure directly impacted will be from: the scale, valve operation, timer, fluid evaporation/condensation (see Table 1).

Item	Unit
Scale	Mass
Buoyancy	
Air Temp	Mass
Air Humidity	Mass
Barometric Pressure	Mass
Shape of Sample Container	Mass
Time	Time
Valve Operation	Time
Evaporation Rate	Mass

Table 1. Error sources and unit of measure directly impacted.

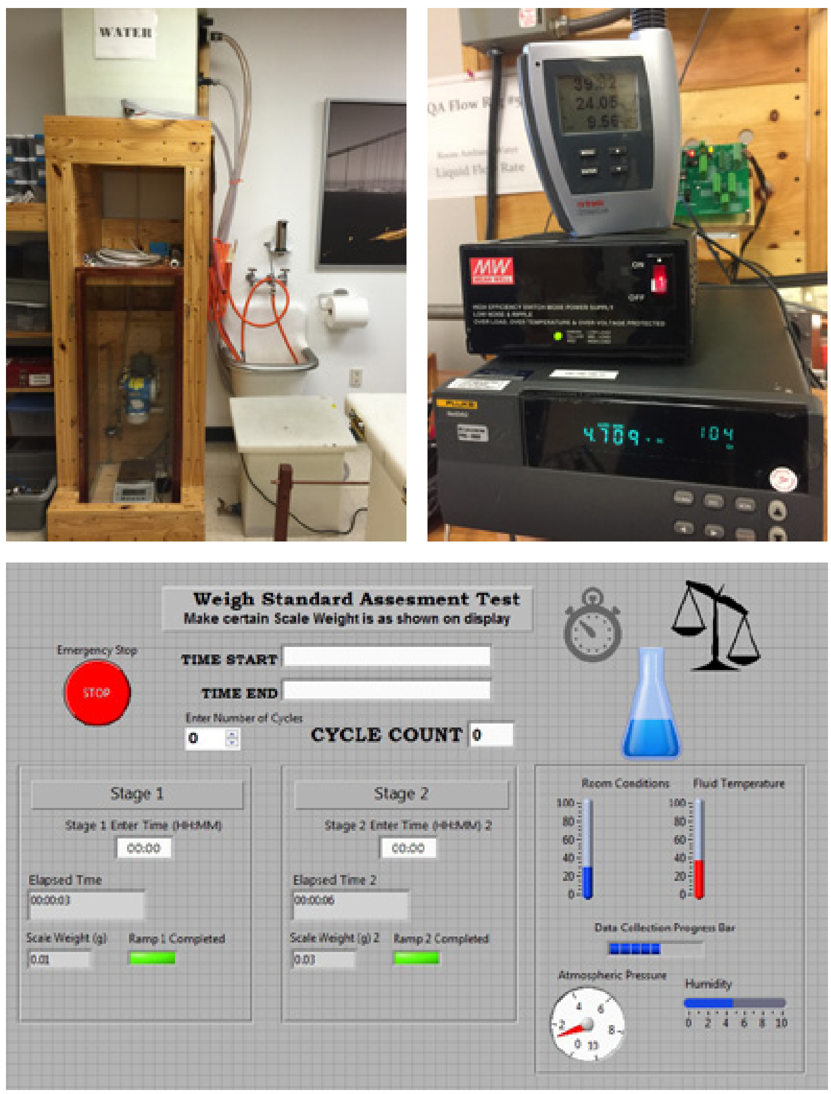


Figure 3. Constant Level Head Weigh Standard calibrating a Coriolis Meter, for fluid temperatures +18 °C to 28 °C. When this standing start system was hand-filled without an over-flow or sump-pump but with the single <20ms open/<30ms close valve without timing switches, it achieved 0.030% U_c, using the broken run analysis of ISO 4185 and a Coriolis meter Inter-laboratory comparison. The system is not built per the ISO 4185 diagrams utilizing diverter valves.

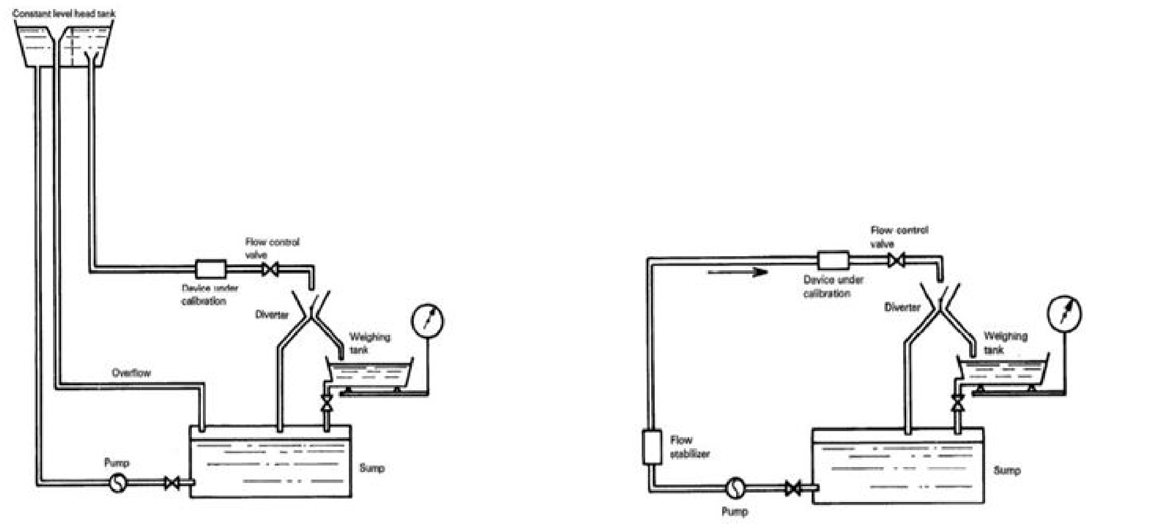


Figure 1A — Diagram of an installation for calibration by weighing (static method, supply by a constant level head tank)

Figure 1C — Diagram of an installation for calibration by weighing (static method, direct pumping supply)

Figure 4. Schematics from ISO 4185 of Static Methods for Constant Level Head or Direct Pumping Supply – flying start.

Measurement of Liquid Flow in Closed Conduits by Weighing Methods

Use the ISO 9368-1:1990, Standardized Procedures for carrying out the measurements and the tests for the liquid flow rate measurement weighing method described in ISO 4185:1980/Cor.1:1993.

It is easy to misunderstand the four ISO Standards covering the liquid flow measurement because they were not originally written as a set but were edited into an intended set. ISO 4185 was written in 1980 as the complete reference document and referenced ISO 5168 (originally released in 1978) as the companion document for Legal Metrology. In 1990, ISO 9368-1 was written to amplify certain aspects of verification and testing of the flow measurement system with example calculations, not just formulas and text descriptions as in ISO 4185. The ISO 9368-1 standard references ISO 4185 for the system diagrams as well as some necessary and some alternative error source method assessments. The referenced ISO 9368-2 for dynamic weighing systems is not released.

ISO 9368-1:1990 & ISO 4185:1980/Cor.1:1993 are the top level ISO Documents that describe error sources and methods for evaluating flow rate error sources for Uncertainty Components E_s (Type B, Systemic) and E_r (Type A, Random) of static weighing systems. Whenever practical, use ISO 9368-1 for static weighing systems because all error sources are identified and evaluated. The diverter valve design will determine practicality of using ISO 9368-1. When the diverter design does not allow timing switches to be inserted into the mechanism, then ISO 4185 Annex A will work well. To determine the other systemic errors required for Legal Metrology, the ISO 5168 Estimation of uncertainty of a flow-rate measurement is used with ISO 9368-1 and ISO 4185.

The methods described in ISO 4185 Annex A use a comparison between a standard and broken run. A broken run is defined as starting and stopping multiple times during the same length of time as the standard run. If a standard run is 10 minutes, then another "broken" standard run will start and stop 10 to 25 times of equal time periods that total 10 minutes. The starts and stops of the broken run will create an average error of the valve opening and closing times that is realized in the sample collected.

Using ISO 4185, uncertainty is calculated using:

E_s = RSS of Type B, which uses $\sqrt{2}$ for expansion of some terms; and

$(E_r)_{95}$ = RSS of Type A, which uses Student's *t* for expansion of some terms.

ISO 9368-1 contains extra error sources not detailed in ISO 4185.

Using ISO 9368-1, uncertainty is calculated using:

$$E_S = (E_{s_1}^2 + E_{s_2}^2 + E_{s_3}^2 + E_{s_4}^2)^{1/2}$$

$$E_R = t * (S_1^2 + S_2^2 + S_3^2 + S_4^2 + S_5^2 + S_6^2)^{1/2}$$

Alternatively as:

$$E = (E_R^2 + E_S^2)^{1/2}$$

The ISO 4185 and ISO 9368-1 were written in a time before the expression of Expanded Combined Measurement Uncertainty came into being and defined in the Guide to Measurement Uncertainty (GUM), NIST Note 1297:1994, and NCSLI RP-12:2013. The expression of Expanded Combined Measurement Uncertainty can render a slightly different understanding and result using the formula:

$$U_e = k * (E_s^2 + E_r^2)^{1/2}$$

where k, the coefficient of expansion, is defined as the confidence interval; typically k = 2 for confidence that 95% of the data is within expanded range. When more knowledge of the data spread is known, then k is calculated using Student's *t* model of distribution with degrees of data freedom[1] reported.

Checking the Weighing System Error Sources[2]

The ISO 9368-1 plan is to determine the magnitude of the errors associated with: the weigh device, the diverter, the timer, density measurement, flow rate stability, flow line characteristics.

Overall Uncertainty with random uncertainty at 95% probability is $E = (E_R^2 + E_S^2)$. Table 2 shows six different E calculations for the two different $(E_R)_{95}$ values in Table 3, with three different Student's *t* values depending upon the way degrees of freedom are calculated.

Student's *t*	***E % of reading***	
2.262	0.002595018	0.004292493
2.0518	0.002502974	0.003985516
<1.980	0.002472868	0.003882406

Table 2. Overall Uncertainty calculated from two different $(E_R)_{95}$ values.

Overall random uncertainty $(E_R)_{95}$ is quoted separately per ISO 5168.

Student's *t*	$(E_R)_{95}$	$(E_R)_{95}$
	S_1,S_2,S_3,S_4	S_1,S_2,S_3,S_4,S_5,S_6
2.262	0.001627209	0.003786712
2.0518	0.001475998	0.003434826
<1.980	0.001424347	0.003314629

Table 3. Random Uncertainty calculated with and without error sources S_5 and S_6.

In Table 3, three Student's *t* values are shown for comparison because the Random Error Source Calculations (Table 4) has two optional error sources, S_5 and S_6, as well as philosophical considerations of *t*. Student's *t* values (2.262, 2.0518, 1.980) come from degrees of freedom (9, 27, 122) for the number of data points (number-1) in the Random Error Source (Table 4). The degrees of freedom possibilities: 9 for 3 data sets all have at least 9 degrees of freedom, 27 for the total of all 3 data sets with 9 degrees of freedom (9 + 9 + 9), and 122 for the total of all possible data sets (including flow instabilities) is possible degrees of freedom (9 + 9 + 9 + 86 + 9).

The Systemic Errors are calculated and summarized in Table 5.

	Random Error Source Description & ISO 9368-1 Section	Value	Squared	Squared	Degrees of Freedom
S_1	Std Dev of Weighing Device, 6.1 & Annex A	0.000712382	5.07488E-07	5.07488E-07	9
S_2	Std Dev of Diverter Operation, 6.2 & Annex B	8.62487E-07	7.43884E-13	7.43884E-13	9
S_3	Std Dev of Diverter Leakage, 6.2 & Annex B	4.30885E-07	1.85661E-13	1.85661E-13	9
S_4	Std Dev of Density Determination, 6.4 (ISO 4185 Section 3.4, $<10^{-4}$, if Water Temp Measurement is +/-0.5 °C)	0.0001	0.00000001	0.00000001	0
S_5	*Flow Rate Instability Within Integration Interval, 6.5 & Annex C*	*0.001157011*	*calculate if instability is liable to affect results*	1.33868E-06	*86*
S_6	*Flow Rate Instability Between Integration Intervals, 6.5 & Annex D*	*0.000972777*	*calculate if instability is liable to affect results*	9.46295E-07	*9*
		sum	5.17489E-07	2.80246E-06	*9, 27, or 122*

Table 4. Random Error Source Calculation Summary.

1 The Degrees of data freedom is defined as the significance factor derived from the number of data points collected that can shift the calculated value.

2 The example calculations use real data and practical possible data to show how to perform the assessment for a system built per the ISO 4185 diagrams which is different in the designs of systems for the real data that achieved 0.030% U_c, using the broken run analysis of ISO 4185 and a Coriolis meter Inter-laboratory comparison.

	Systemic Error Source Description & ISO 9368-1 Section	Value	Value Squared
E_{S1}	Weighing Device, 6.1 & Annex A	0.0005096	2.59664E-07
E_{S2}	Diverter Operation, 6.2 & Annex B	0.0019562	3.82665E-06
E_{S3}	Diverter Leakage, 6.2 & Annex B	0	0
E_{S4}	Density Determination, 6.4; only for volumetric flow		0
		sum	4.08631E-06
		E_S =	0.002021462

Table 5. Systemic Error Source Calculation Summary.

Things to Know Before Actual Data is Collected

Initial runs will determine important values that will prevent overflowing the sample collection container (or tank) or exceeding the scale mass limit. Things to determine are: mass of the empty sample fluid collection container, mass of the filled sample fluid container, approximate mass flow rate, time of the flow collection period, the maximum mass flow rate of the rig, the minimum time to fill at the maximum mass flow rate to fill the sample fluid collection container, the minimum time to fill the sample fluid collection container.

It's easy to get lost in the calculations. Keep in mind that many calculations are simply comparing individual values versus the mean average of the group of values.

For room temperature water, fluid density impact is negligible (< 10^{-4} error on density evaluation) as long as the fluid temperature measurement error does not exceed +/-0.5 °C (ISO 4185-1980).

Evaporation and condensation happen at any temperature. At room temperature water, the evaporation rate is negligible for an open sample collection system, unless the ratio of evaporation rate/(sample collected mass/sample collection time) is >10^{-6} (0.00010%) which occurs for mass collected/collection time of <30 g/min with an evaporation rate of 0.0003 g/min.[3]

Detailed Calculations for Error of Weighing Device

The method in ISO 9368-1 Section 6.1 & Annex A calculates both: E_{S1}, systemic error, and S_1, standard deviation (random error), of the weighing device. In our case, the weighing device will have a tare mass (1.1023 kg) and then be tested with ten equal (0.100 kg) mass standards over five loading and unloading cycles – weighing each addition of mass until all mass standards are added, then weighing as each mass standard is removed (see Table 6 data entry and Table 7 photo series). The data calculations compute the weighing device linearity errors and variation of the masses, including hysteresis effects. The error of the mass standards is e_s. The standard deviation, s, is of the random error in a single fluid mass measurement, M. The mass of the empty collection tank is R_2; the mass of the fluid collected + the empty tank is R_1. The fluid collection mass is $R_2 - R_1$ and will be corrected for differences from the mass points of the weighing device mass measurement study, with corresponding the standard deviations of: $s_{\Delta m1}$ and $s_{\Delta m2}$. Student's t (t^*) is 2.262 based upon number of data points (n = 10) with a two-sided distribution with 95% confidence of a Gaussian distribution having 9 degrees of freedom (n - 1) *or movement interval opportunities*. The equations used are:

$$E_{S_1} = \frac{e_S}{M}$$

$$S_1 = \frac{s}{M}$$

$$e_S = \frac{t^*}{\sqrt{n}} * \left(s_{\Delta m_1}^2 + s_{\Delta m_2}^2\right)^{1/2}$$

$$s = \left(s_{\Delta m_1}^2 + s_{\Delta m_2}^2\right)^{1/2}$$

$$s_{\Delta m} = \left[\frac{\sum_{t=1}^{n} \left(\Delta m_i - \overline{\Delta m}\right)^2}{n-1}\right]^{1/2}$$

The scale errors are determined in Tables 6, 7, 8, and 9 which show the data collection and calculations to achieve E_{s1}, S_1, e_s, M, and S as well as intermediate values: Δm_1, Δm_2, $S_{\Delta m1}$, $S_{\Delta m2}$.

For the weighing method calculations in Table 6, a tare of the empty container is established on the scale; then, the

3 The evaporation or condensation rate impact of the sample collected is not addressed in the ISO Standard Documents.

ISO 9368-1
Annex A Table A.2 working example

R1, fluid collected & tank	3.40945 kg
R2, empty collection tank	1.10023 kg
M, mass of fluid collected	2.30922 kg

A weighing device of tare 1 100 g is tested with ten 100 g mass std over five loading & unloading cycles tare= 1.10023

Table A2

std weight added	Weighing Device Reading, Roi or Rmi										Weighing device error, mi										$\overline{\Delta m}$
	i=1	i=2	i=3	i=4	i=5	i=6	i=7	i=8	i=9	i=10	i=1	i=2	i=3	i=4	i=5	i=6	i=7	i=8	i=9	i=10	Δm$_i$ kg (m
m in kg	load		load		load		load		load												kg
0.000	1.102	1.100		1.100		1.098		1.100			0.0018	-0.0002		-0.0002		-0.0022		-0.0002			-0.0001
0.250	1.352	1.354	1.353	1.351	1.351	1.351	1.351	1.351	1.351	1.351	0.0018	0.0038	0.0028	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0014
0.500	1.602	1.602	1.605	1.601	1.601	1.601	1.601	1.602	1.601	1.603	0.0018	0.0018	0.0048	0.0008	0.0008	0.0008	0.0008	0.0018	0.0008	0.0028	0.0017
0.750	1.852	1.852	1.852	1.851	1.851	1.851	1.851	1.851	1.852	1.851	0.0018	0.0018	0.0018	0.0008	0.0008	0.0008	0.0008	0.0008	0.0018	0.0008	0.0012
1.000	2.102	2.101	2.101	2.101	2.101	2.101	2.101	2.101	2.102	2.101	0.0018	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0018	0.0008	0.0010
1.250	2.352	2.352	2.355	2.351	2.351	2.351	2.351	2.351	2.351	2.349	0.0018	0.0018	0.0048	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	-0.0012	0.0012
1.500	2.602	2.603	2.605	2.601	2.601	2.601	2.601	2.601	2.598	2.601	0.0018	0.0028	0.0048	0.0008	0.0008	0.0008	0.0008	0.0008	-0.0022	0.0008	0.0012
1.750	2.852	2.851	2.851	2.850	2.851	2.851	2.851	2.851	2.851	2.851	0.0018	0.0008	0.0008	-0.0002	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
2.000	3.102	3.103	3.101	3.101	3.101	3.101	3.101	3.101	3.101	3.101	0.0018	0.0028	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0011
2.250	3.352	3.351	3.351	3.350	3.351	3.351	3.351	3.351	3.347	3.348	0.0018	0.0008	0.0008	-0.0002	0.0008	0.0008	0.0008	0.0008	-0.0032	-0.0022	0.0001
2.500	3.602	unload	3.601	unload	3.601	unload	3.601	unload	3.600	unload	0.0018		0.0008		0.0008		0.0008		-0.0002		0.0004
																				mean of Δm kg =	0.00097

Table 6. Mass loading/unloading data entry and weighing device error calculations.

(m+Ro) kg	sum(Δm$_i$ - Δm)^2	sum(Δm$_i$ - Δm)^2/(n-1)	SΔm kg
1.1002	8.13225E-06	0.0000	0.0010
1.3502	1.04E-05	0.0000	0.0011
1.6002	1.49E-05	0.0000	0.0013
1.8502	2.4E-06	0.0000	0.0005
2.1002	1.6E-06	0.0000	0.0004
2.3502	2.04E-05	0.0000	0.0015
2.6002	2.84E-05	0.0000	0.0018
2.8502	2E-06	0.0000	0.0005
3.1002	4.1E-06	0.0000	0.0007
3.3502	2.21E-05	0.0000	0.0016
3.6002	3.48225E-06	0.0000	0.0006

Table 7. Intermediate calculation steps and photo series of mass loading and unloading. Note: The photo series shows masses that are not equal masses as should be used.

INTERPOLATION from working example for R_1 & R_2				Δ	m	SΔm	Calculation	
R1, fluid collected & tank	3.40945	kg	between 3.350 & 3.600	3.350	0.0001	0.0016	0.0001	Δm$_1$
R2, empty collection tank	1.10023	kg	between 1.100 & 1.350	3.600	0.0004	0.0006	-0.0001	Δm$_2$
M, mass of fluid collected	2.30922	kg		1.100	-0.0001	0.0010	0.0013	SΔm$_1$
				1.350	0.0014	0.0011	0.0010	SΔm$_2$
Correction to fluid mass measurement		Δm$_1$	Δm$_2$					
- (Δm$_1$ - Δm$_2$) = -0.0003	kg	0.0001	-0.0001					
Corrected Fluid Mass	original	correction						
2.3090 kg	2.30922	0.000						

$$S_{\Delta m} = \left[\frac{\sum_{t=1}^{n} (\Delta m_i - \overline{\Delta m})^2}{n-1} \right]^{1/2}$$

Table 8. Weigh measured values correction calculations.

mass standards are added one at time, and then removed one at a time. Thus, each cumulative mass is approached from below and above by ten iterations for each cumulative mass. The blue cells indicate data entry. Moving to the right in Table 6, the weighing deviations are calculated for each cumulative mass, m_i. In order to calculate the interpolated error between the measured cumulative mass loads, one calculates Δm and $S_{\Delta m}$. The arithmetic mean of ten errors for each cumulative mass error is Δm. The tare, R_o, is added to each "added" mass standard, m, in the leftmost column.

The rightmost column of Table 6, (m + R_O) is repeated in Table 7, to show the intermediate calculation step results for the standard deviations of average mass loads, $S_{\Delta m}$, in the rightmost column of Table 7.

The measured flow sample collection values will need to be corrected. The correction value is calculated in Table 8, where the weighed value errors need to be interpolated from weighing device errors calculated in Table 6 and Table 7.

Weighing device measurement uncertainties are calculated using the formulas below, from the data in Table 8: E_{S1} = 0.05% and S_1 = 0.07%. The value of t* = 2.262 because n = 10 and n-1 = 9. The error of mass standards is taken as negligible (ISO 9368-1).

$$e_S = \frac{t^*}{\sqrt{n}} * \left(s^2_{\Delta m_1} + s^2_{\Delta m_2}\right)^{1/2} = \frac{2.262}{\sqrt{10}} * (0.0013^2 + 0.0010^2)^{1/2} = 0.0012$$

$$s = \left(s^2_{\Delta m_1} + s^2_{\Delta m_2}\right)^{1/2} = (0.0013^2 + 0.0010^2)^{1/2} = 0.0016$$

$$E_{S_1} = \frac{e_s}{M} = \frac{0.0012}{2.3090} = 0.0005 \qquad S_1 = \frac{s}{M} = \frac{0.0016}{2.3090} = 0.0007$$

Detailed Calculations for Errors Due to the Diverter Valve System

As stated in ISO 9368-1 Section 6.2, before starting testing in an open diverter valve collection system:

1. The diverter is checked at minimum and maximum flow rates to ensure that there is no splashing out of or into the sample fluid collection container.
2. The proximity of the nozzle outlet to the splitter plate is checked for flow rate variations caused by pressure fluctuations.
3. The diverter is checked for effective sealing to ensure that there are no leaks when the closed to the sample fluid collection container.

For the standing start system in Figure 3, no splashing and effective valve sealing was verified.

After the system checks are performed, systemic and random errors produced by the diverter can be determined using either: ISO 4185:1990 sections 6.2.1.3 and 6.2.2.2, and Appendix A for diverter valves without timing switches, or by the alternative method in ISO 9368-1 Annex B for diverter valves with timing switches.

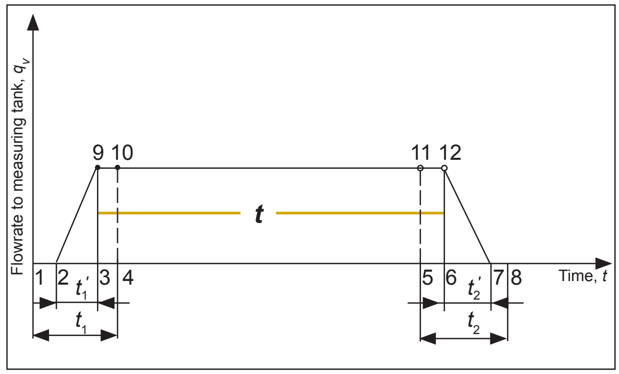


Figure 5. Graph of the filling process from ISO 9368-1 Figure B.1.

For a diverter valve with timing switches, the method in ISO 9368-1 Annex B calculates: E_{S2} - diverter operation, E_{S3} - diverter leakage, S_2 - standard deviation of diverter operation, S_3 - standard deviation of diverter leakage. The flow rig maximum flow rate is $q_{m,max}$ = 0.00213 kg/s = (Annex A collected mass)/t_{min} = (R_1, fluid collected & tank - R_2, empty collection tank)/t_{min} = 2.30922 g/1080 seconds, where the minimum filling time of the sample collection container at maximum flow rate of t_{min}= 1080 seconds[4] and $\frac{1}{t_{min}} = \frac{1}{1080}$ = 0.00092593.

Figure 5 shows the filling time of the sample fluid collection by a diverter valve system.

Steady-state flow rate will occur in the time period t. Flow rate variation occurs, when the diverter is changing flow paths between by-pass and sample collection container during the time periods t'_1 and t'_2; a diverter valve does not move at the same speed in either direction (or time periods).

As in Table 9, the two flow rate variation time periods are evaluated by 9 using ten successive measurements of the timing switches as the diverter valve position changes the fluid flow path from by-pass to sample collection container and then from sample collection container to the by-pass. Collect a series of at least n = 10 measurements of the diverter switching times, t_1 and t_2, between the by-pass and sample fluid collection container paths. A diverter time correction is calculated using the formulas:

$$\Delta t = |\bar{t}_1 - \bar{t}_2| = |0.0320 - 0.0275| = 0.004 \text{ sec} = \Delta t_{max}$$

because only one flow rate is used.

$$\sum_{t=1}^{n} (t_{1i} - \bar{t}_1)^2 = 7.81 * 10^{-6} \qquad \sum_{t=1}^{n} (t_{2i} - \bar{t}_2)^2 = 1.95 * 10^{-6}$$

4 This is real data from a weigh stand design using a standing start with a <30 ms open/close solenoid valve, as shown in Figure 3.

Measure #	By-Pass to Tank	Tank to By-Pass	$t_{1i}-\bar{t}_1$	$(t_{1i}-\bar{t}_1)^2$	$t_{2i}-\bar{t}_2$	$(t_{2i}-\bar{t}_2)^2$
1	0.0312	0.0271	-0.0008	6.24E-07	-0.0004	1.52E-07
2	0.0323	0.0266	0.0003	9.61E-08	-0.0009	7.92E-07
3	0.0319	0.0276	-0.0001	8.10E-09	0.0001	1.21E-08
4	0.0324	0.0279	0.0004	1.68E-07	0.0004	1.68E-07
5	0.0344	0.0282	0.0024	5.81E-06	0.0007	5.04E-07
6	0.0314	0.0280	-0.0006	3.48E-07	0.0005	2.60E-07
7	0.0318	0.0274	-0.0002	3.61E-08	-0.0001	8.10E-09
8	0.0315	0.0274	-0.0005	2.40E-07	-0.0001	8.10E-09
9	0.0315	0.0274	-0.0005	2.40E-07	-0.0001	8.10E-09
10	0.0315	0.0273	-0.0005	2.40E-07	-0.0002	3.61E-08
n = 10 samples $n-1$ = 9	$\bar{t}_1 = 0.0320$	$\bar{t}_2 = 0.0275$	$\sum_{t=1}^{n}(t_{1i}-\bar{t}_1)^2 = 7.81\text{E-}06$		$\sum_{t=1}^{n}(t_{2i}-\bar{t}_2)^2 = 1.95\text{E-}06$	

Table 9. Ten successive measurements of fillings and by-pass with intermediate difference calculations.

Evaluate the diverter valve system at the minimum, middle, and maximum flow rates that will be used because the flow rate will impact the valve open/close response time. Then, $\Delta t \neq \Delta t_{max}$.

The maximum leakage mass, m_{lmax} , is determined from diverter checks described at the beginning of this section, and may differ at the different flow rates checked. The minimum mass of liquid collected in the sample fluid collection container is m_{min}. To minimize impact on total system error, the diverter valve leakage, E_{S3}, should be <10% of the value of the weighing device systemic error, E_{S1} (ISO 9368-1).

The maximum leakage mass is m_{lmax} = 0 kg and the minimum mass collected is $m_{min} = 9.58*10^{-6}$ kg.

The measurement uncertainty is calculated using these formulas:[5]

$$S_2 = \frac{1}{t_{\min}}\left[\frac{\sum_{t=1}^{n}(t_{1i}-\bar{t}_1)^2}{(n-1)}\right]^{1/2} = 0.000092593*\left[\frac{7.81\text{E}-06}{9}\right] = 8.62\text{E}-07 \text{ or } 0.000\%$$

$$S_3 = \frac{1}{t_{\min}}\left[\frac{\sum_{t=1}^{n}(t_{2i}-\bar{t}_2)^2}{(n-1)}\right]^{1/2} = 0.00092593*\left[\frac{1.95\text{E}-06}{9}\right] = 4.31\text{E}-07 \text{ or } 0.000\%$$

$$E_{S_2} = \frac{\Delta t_{\max}}{2t_{\min}} = \frac{0.004}{2*1080} = 2.0833*10^{-6} \qquad E_{S_3} = \frac{m_{l\max}}{m_{\min}} = \frac{0}{9.58*10^{-6}}$$

5 Using the broken run evaluation of ISO 4185 for the solenoid valve system, E_{S2} = 0.00196 and is used in the overall error summary calculation table.

Flow Rate Stability Assessment

All flow systems have some flow instability because of pump pulsations, cavitation, flow tube temperature changes, and such things. Of the various techniques available, successful results are achieved with a low inertia turbine meter (enhanced frequency output for greater discrimination) in the flow line, as in Figure 6. Flow rate stability, during flow diversion to the sample fluid collection container, is assessed within the Integration Interval and between the Integration Intervals.

Figure 6. Low inertia turbine meter installed for flow stability assessments.

sec	x_k	$(x_k)^2$	x_k*x_{k+j}	x_k*x_{k+j}	sec	x_k	$(x_k)^2$	x_k*x_{k+j}	x_k*x_{k+j}	sec	x_k	$(x_k)^2$	x_k*x_{k+j}	x_k*x_{k+j}
0.8353	-0.007250	5.255992E-05	6.548448E-05	8.7887E-05	0.8436	0.002615	6.836603E-06	-7.458112E-06	-1.2119E-05	0.8462	0.005705	3.254449E-05	3.661255E-05	3.7291E-05
0.8338	-0.009033	8.158723E-05	1.094986E-04	-4.5088E-05	0.8390	-0.002852	8.136122E-06	1.322120E-05	1.5255E-05	0.8468	0.006418	4.118912E-05	4.195188E-05	2.2120E-05
0.8312	-0.012123	1.469587E-04	-6.051241E-05	-2.5934E-05	0.8375	-0.004635	2.148445E-05	2.478975E-05	5.0681E-05	0.8469	0.006537	4.272877E-05	2.252971E-05	1.5538E-05
0.8456	0.004992	2.491687E-05	1.067866E-05	-2.0171E-05	0.8369	-0.005348	2.860355E-05	5.847838E-05	-5.0851E-05	0.8443	0.003447	1.187930E-05	8.192623E-06	-4.0963E-06
0.8432	0.002139	4.576569E-06	-8.644630E-06	-1.7035E-05	0.8322	-0.010934	1.195558E-04	-1.039616E-04	-2.3391E-05	0.8434	0.002377	5.650085E-06	-2.825042E-06	-2.8250E-07
0.8380	-0.004041	1.632875E-05	3.217723E-05	-5.4269E-05	0.8494	0.009508	9.040136E-05	2.034031E-05	8.7011E-05	0.8404	-0.001188	1.412521E-06	1.412521E-07	4.9438E-06
0.8347	-0.007963	6.340808E-05	-1.069420E-04	-7.4765E-05	0.8432	0.002139	4.576569E-06	1.957754E-05	1.0170E-06	0.8413	-0.000119	1.412521E-08	4.943824E-07	7.2039E-07
0.8527	0.013430	1.803648E-04	1.260958E-04	5.9058E-05	0.8491	0.009151	8.374838E-05	4.350565E-06	-3.4805E-05	0.8379	-0.004160	1.730339E-05	2.521350E-05	4.2023E-05
0.8493	0.009389	8.815545E-05	4.128800E-05	3.0129E-05	0.8418	0.000475	2.260034E-07	-1.808027E-06	-2.2035E-06	0.8363	-0.006061	3.673968E-05	6.123280E-05	-7.2039E-05
0.8451	0.004397	1.933742E-05	1.411109E-05	3.6584E-06	0.8382	-0.003803	1.446422E-05	1.762826E-05	2.5312E-05	0.8329	-0.010102	1.020547E-04	-1.200643E-04	-6.8437E-05
0.8441	0.003209	1.029728E-05	2.669665E-06	-6.4835E-06	0.8375	-0.004635	2.148445E-05	3.084946E-05	4.6274E-05	0.8514	0.011885	1.412521E-04	8.051371E-05	3.9551E-05
0.8421	0.000832	6.921354E-07	-1.680900E-06	-5.4382E-06	0.8358	-0.006656	4.429667E-05	6.644500E-05	-6.5654E-05	0.8471	0.006774	4.589281E-05	2.254384E-05	-8.8565E-06
0.8397	-0.002020	4.082186E-06	1.320707E-05	2.0891E-05	0.8330	-0.009983	9.966750E-05	-9.848098E-05	-5.1020E-05	0.8442	0.003328	1.107417E-05	-4.350565E-06	-1.0283E-05
0.8359	-0.006537	4.272877E-05	6.758914E-05	-3.0299E-05	0.8497	0.009865	9.730859E-05	5.041288E-05	2.2275E-05	0.8403	-0.001307	1.709151E-06	4.039811E-06	8.5458E-06
0.8327	-0.010340	1.069137E-04	-4.792685E-05	-3.5638E-05	0.8457	0.005111	2.611752E-05	1.154030E-05	-1.3362E-05	0.8388	-0.003090	9.548644E-06	2.019905E-05	2.2770E-05
0.8453	0.004635	2.148445E-05	1.597562E-05	-6.0597E-06	0.8433	0.002258	5.099202E-06	-5.904339E-06	-2.6301E-05	0.8359	-0.006537	4.272877E-05	4.816697E-05	6.3705E-05
0.8443	0.003447	1.187930E-05	-4.505943E-06	-1.8433E-05	0.8392	-0.002615	6.836603E-06	3.045396E-05	-3.1697E-05	0.8352	-0.007369	5.429732E-05	7.181258E-05	-7.0937E-05
0.8403	-0.001307	1.709151E-06	6.991980E-06	1.0410E-05	0.8316	-0.011647	1.356585E-04	-1.411956E-04	-1.1766E-04	0.8332	-0.009746	9.497793E-05	-9.381966E-05	-9.0345E-05
0.8369	-0.005348	2.860355E-05	4.258752E-05	-4.3223E-05	0.8516	0.012123	1.469587E-04	1.224656E-04	6.0512E-05	0.8495	0.009627	9.267552E-05	8.924309E-05	8.6955E-05
0.8347	-0.007963	6.340808E-05	-6.435447E-05	-2.0821E-05	0.8499	0.010102	1.020547E-04	5.042701E-05	4.0822E-05	0.8492	0.009270	8.593779E-05	8.373426E-05	2.7544E-05
0.8482	0.008082	6.531498E-05	2.113132E-05	7.6841E-06	0.8456	0.004992	2.491687E-05	2.017080E-05	-1.2458E-05	0.8490	0.009033	8.158723E-05	2.683790E-05	-2.6838E-05
0.8436	0.002615	6.836603E-06	2.486037E-06	-9.6334E-06	0.8448	0.004041	1.632875E-05	-1.008540E-05	-2.7855E-05	0.8439	0.002971	8.828258E-06	-8.828258E-06	-1.0594E-06
0.8422	0.000951	9.040136E-07	-3.503053E-06	-2.4860E-06	0.8393	-0.002496	6.229219E-06	1.720451E-05	2.7587E-05	0.8389	-0.002971	8.828258E-06	1.059391E-06	7.0626E-06
0.8383	-0.003684	1.357433E-05	9.633395E-06	1.4888E-05	0.8356	-0.006893	4.751721E-05	7.619140E-05	-6.6360E-05	0.8411	-0.000357	1.271269E-07	8.475127E-07	2.5425E-07
0.8392	-0.002615	6.836603E-06	1.056566E-05	1.6470E-05	0.8321	-0.011053	1.221690E-04	-1.064052E-04	-4.7291E-05	0.8394	-0.002377	5.650085E-06	1.695025E-06	3.3901E-06
0.8380	-0.004041	1.632875E-05	2.545363E-05	4.8506E-05	0.8495	0.009627	9.267552E-05	4.118912E-05	5.0342E-05	0.8408	-0.000713	5.085076E-07	1.017015E-06	1.6950E-07
0.8361	-0.006299	3.967772E-05	7.561226E-05	-3.5186E-05	0.8450	0.004279	1.830628E-05	2.237434E-05	2.5425E-05	0.8402	-0.001426	2.034031E-06	3.390051E-07	**-0.0002**
0.8313	-0.012004	1.440913E-04	-6.705238E-05	-3.1386E-05	0.8458	0.005229	2.734641E-05	3.107547E-05	3.2940E-05	0.8412	-0.000238	5.650085E-08	**0.00108850**	sum
0.8461	0.005586	3.120259E-05	1.460547E-05	0.0000E+00	0.8464	0.005942	3.531303E-05	3.743181E-05	0.0000E+00	0.8412	**73.2026**	**0.003768**	sum	
0.8436	0.002615	6.836603E-06	0.000000E+00	0.0000E+00	0.8467	0.006299	3.967772E-05	0.000000E+00	0.0000E+00	0.8441	sum	sum		

Table 10. Turbine meter readings (from ISO 9368-1 Table C.1) in a flow stability run with time for one turbine rotation and x_k and x_{k+j} calculations.

Detailed Calculations of Flow Rate Stability (within the Integration Interval)

Once the flowrate has stabilized, the diverter is actuated to start the timer. When the flowmeter output signal is representative of a flowrate, the signal is recorded at least once per second; at least 60 such recordings are taken over the integration interval. This procedure is repeated at the other selected flowrates, as representative for the full flow rig range or flow rate(s) used (ISO 9368-1). A series of flowrate measurements is carried out. In Table 10, collected data is for a turbine rotor that has 41 pulses per rotation (approximately 0.8 sec for the flow rate). The collected data from Table 10 is calculated in Table 11. The results obtained are analyzed according to the method below.

The relative deviation, x_k, of each measurement in terms of frequency of the output signal from the average value is calculated alongside each measurement in Table 10 from:

$$x_k = \frac{f_k - \bar{f}}{\bar{f}}$$

where f_k is the output signal frequency; f is the average output signal frequency. The following series is obtained: $x_1, \ldots x_k, \ldots x_n$, where n is the number of measurements.

In Table 11, the autocorrelation function R_j is calculated (as a combination of covariance moments R_0, R_1, R_2, etc., calculated for different pairs of the x_k series):

$$R_j = \frac{1}{n-j} \sum_{k=1}^{n-j} x_k \, x_{k+j}$$

where $j = 0,1,\ldots j_{min}$ is the succession step; and k is the running succession number.

In Table 11, the normalized autocorrelation function, the combination of the coefficients of correlation ($r_o = 1$ by definition), $r_1, r_2, \ldots$ is determined from:

Nominal Flow Rate	Diversion (Integration) Time (T)	Number of Measurements During Integration (n)	Sum of Revolution Measurements (time)	Average Time for One Rotor Revolution	$\Delta t = T / n$
0.0628 m³/s	115.7 sec	87	73.2026 sec	0.8414=73.2026/87	1.3299=115.7/87

Covariance Moments	Coefficients of Correlation
$R_0 = 4.3310 \times 10^{-5} = (1/87) * 0.003768$	$r_0 = 1$ by definition
$R_1 = 1.2657 \times 10^{-5} = (1/(87-1)) * 0.00108850$	$r_1 = R_1/R_0 = 1.2657 \times 10^{-5}/4.3310 \times 10^{-5} = 0.2922$
$R_2 = -2.2652 \times 10^{-6} = (1/(87-2)) * -0.0002$	$r_2 = R_2/R_0 = -2.2652 \times 10^{-6}/4.3310 \times 10^{-5} = -0.0523$
	j_{min} is smallest rank from which r_j is =< 0.1 in this case, $j = 2 = j_{min}$

Table 11. Calculations of intermediate values necessary for calculating τ and S_5.

u = (1/ 9) * (1/ 0.00596) * 0.000000105 U = (1/(2* 9)) * (1/ 0.00596) * 0.000000102

u = 1.9477E-06 U = 9.463E-07

Results of a turbine meter between 10 Integration Intervals of a flowrate.

Integration#	Number of pulses	Time (s)	Frequency (Hz)	Equivalent Flowrate (m³/s)			$q_{vi} - q_{v\_avg}$	$(q_{vi} - q_{v\_avg})^2$	$q_{vi+1} - q_{vi}$	$(q_{vi+1} - q_{vi})^2$
1	3702	60.631	61.06	0.07709			-0.00014	0.000000020	2E-05	4E-10
2	3698	60.550	61.07	0.07711			-0.00012	0.000000015	7E-05	4.9E-09
3	3713	60.744	61.13	0.07718			-0.00005	0.000000003	1E-05	1E-10
4	3697	60.472	61.14	0.07719			-0.00004	0.000000002	0.00014	1.96E-08
5	3706	60.504	61.25	0.07733			0.00010	0.000000010	0	0
6	3714	60.641	61.25	0.07733			0.00010	0.000000010	-5E-05	2.5E-09
7	3715	60.692	61.21	0.07728			0.00005	0.000000002	-7E-05	4.9E-09
8	3692	60.375	61.15	0.07721			-0.00002	0.000000000	-4E-05	1.6E-09
9	3692	60.401	61.12	0.07717			-0.00006	0.000000004	0.00026	6.76E-08
10	3684	60.070	61.33	0.07743	n=	10	0.00020	0.000000039		
				0.77232	q_{v_avg} =	0.07723		0.000000105		0.000000102
				sum of q_{vi}	q_v squared =	0.00596		sum		sum

Table 12. Flow Rate Stability (between integration intervals) using a turbine meter for 10 runs of a single flow rate.

$$r_j = \frac{R_j}{R_o}$$

where $j = 0, \ldots . j_{min}$, (j_{min} is the smallest rank from which r_j is less than or equal to 0.l).

Table 11 shows all of the intermediate calculations needed for the calculations of: τ and S_5.

The attenuation ratio, τ, is determined from:

$$\tau = \sum_{j=1}^{j_{\min}} |r_j|\, \Delta t = (|r_0| + |r_1| + |r_2|) * \Delta t$$

$$= (1 + 0.2922 + 0.0523) * 1.3299 = 1.7881$$

where Δt is the interval of time between successive flowrate measurements: Δt = T/ n…T is the integration period. The relative standard deviation of the random error constituent, S_5, caused by flow instability is calculated from:

$$S_5 = \sqrt{2R_0\frac{\tau}{T}} = \sqrt{2 * 4.3310*10^{-5} * \frac{1.7881}{115.7}} = 0.001157 \Rightarrow 0.116\%$$

Detailed Calculations of Flow Rate Stability (Between the Integration Intervals)

Flowrate stability between integration intervals is assessed by measuring the average flowrate during each of n periods (at least ten). This is carried out at five different nominal flowrates which are chosen to be evenly spread over the practical flow range of the installation. A check for the presence of outliers is made and invalid measurements eliminated in accordance with the method described in ISO 5168. The formula by which flowrate stability is assessed depends on whether significant systematic change in flowrate has occurred over the test period (ISO 9368-1). For each selected flowrate the average flowrate and the following values are calculated, as in Table 12, from:

$$u = \frac{1}{n-1} * \frac{1}{\overline{q}_v^2} \sum_{i=1}^{n} \left(q_{v_i} - \overline{q}_v\right)^2$$

$$U = \frac{1}{2(n-1)} * \frac{1}{\overline{q}_v^2} \sum_{i=1}^{n} \left(q_{v_{i+1}} - \overline{q}_v\right)^2 \qquad \overline{q}_v = \sum_{i=1}^{n} \frac{q_{v_i}}{n}$$

The A_1 relation is calculated and compared to the critical value A (Abbe Criterion) in Table 13.

n	**Probability, P, %**		n	**Probability, P, %**		n	**Probability, P, %**	
	1	5		1	5		1	5
4	0,313	0,390	23	0,548	0,671	42	0,655	0,752
5	0,269	0,410	24	0,556	0,678	43	0,659	0,755
6	0,281	0,445	25	0,564	0,684	44	0,662	0,758
7	0,307	0,468	26	0,571	0,689	45	0,666	0,760
8	0,331	0,491	27	0,578	0,695	46	0,669	0,763
9	0,354	0,512	28	0,585	0,700	47	0,673	0,765
10	0,376	0,531	29	0,591	0,705	48	0,676	0,768
11	0,396	0,548	30	0,598	0,709	49	0,679	0,770
12	0,414	0,564	31	0,603	0,714	50	0,681	0,772
13	0,431	0,578	32	0,609	0,718	51	0,684	0,774
14	0,447	0,591	33	0,614	0,722	52	0,687	0,776
15	0,461	0,603	34	0,619	0,726	53	0,690	0,778
16	0,475	0,614	35	0,624	0,729	54	0,692	0,780
17	0,487	0,624	36	0,629	0,733	55	0,695	0,782
18	0,499	0,633	37	0,634	0,736	56	0,697	0,784
19	0,510	0,642	38	0,638	0,740	57	0,700	0,785
20	0,520	0,650	39	0,642	0,743	58	0,702	0,787
21	0,530	0,657	40	0,647	0,746	59	0,705	0,789
22	0,539	0,665	41	0,651	0,749	60	0,707	0,791

Table 13. Abbe Criterion Table from ISO 9368-1.

If $A_1 > A$, then no systemic flowrate variation is considered to exist within the measurement time. The relative standard deviation, S_6, is calculated using these formulas:

$$A_1 = \frac{U}{u}\ ; \quad A_1 > A, S_6 = \sqrt{u}\ ;\ \text{or} \quad A_1 < A, S_6 = \sqrt{U}$$

using the data, $A_1 = \frac{U}{u} = \frac{0.9463*10^{-6}}{1.9477*10^{-6}} = 0.486$.

Look in Table for values of A (Abbe criterion for n = 10), A = 0.531 for a 5% probability.

In this case, A_1 = 0.486 < A = 0.531; therefore, S_6 is calculated as follows:

$$S_6 = \sqrt{U} = \sqrt{0.9463*10^{-6}} = 0.000973 \Rightarrow 0.1\%$$

Conclusion

We have reviewed the ISO 9368-1/4185/5168 standards for measurement uncertainty assessment calculations for a weigh standard with room temperature water. This understanding is necessary to establish a set of weigh standard(s) to assess the Coriolis meter used outside of the +5 °C to +90 °C fluid temperature range. Future articles will address assessing the fluid parameter measurements outside of the +5 °C to +90 °C fluid temperature range so that measurement uncertainty can be accurately stated with a calculated level of confidence.

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What Is Measurement Risk?

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Introduction

Imagine that a satellite is launched into space and communications are intermittent. This happens because the satellite is wobbling, which causes connection problems in the receiver. The cause of the wobbling is identified: it is the result of not using a calibration provider with a low enough uncertainty. The load cells used to measure the amount of fuel stored in the satellite must be highly accurate with very low uncertainties. However, if a calibration provider does not have the right measurement capability, the load cells will not be accurate enough to make the measurement. In this case, the result is a wobbling satellite and significant resources to fix the problem.

If the problem is not using a calibration provider with an uncertainty adequate to perform the calibration, how does one figure out how low is good enough? This article answers this question by defining measurement risk, and the role Test Uncertainty Ratios (T.U.R) play in reducing measurement risk.

Understanding Measurement Risk

AS9100C defines risk as "[a]n undesirable situation or circumstance that has both a likelihood of occurring and a potentially negative consequence." It further states that "The focus of measurement quality assurance is to quantify and/or manage the 'likelihood' of incorrect measurement-based decisions. When doing so, there must be a balance between the level of effort involved in, and the risks resulting from, making an incorrect decision. In balancing the effort versus the risks, the decision (direct risk) and the consequences (indirect risk) of the measurement must be considered."

ANSI/NCSLI Z540.3-2006 defines Measurement decision risk as probability that an incorrect decision will result from a measurement.

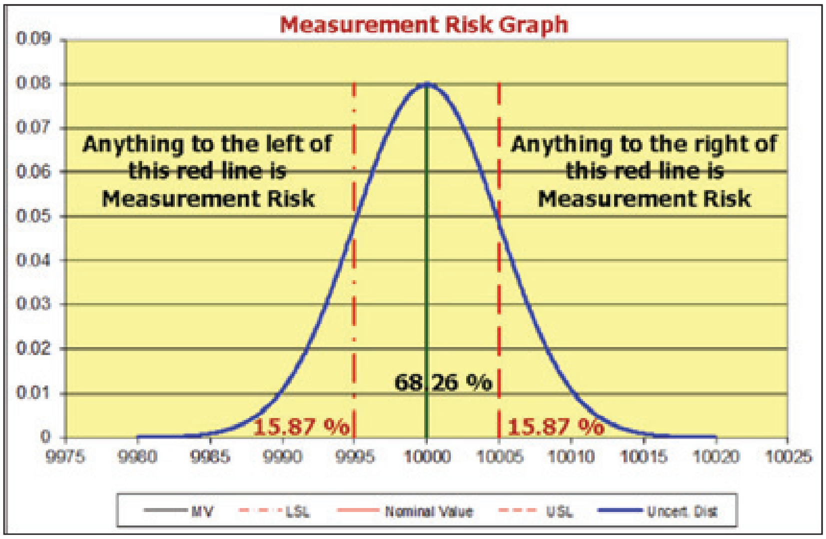

Figure 1. Graph showing the measurement risk which is the Probability of False Accept (PFA).

What Does This Really Mean?

All measurements have a percentage likelihood of calling something good when it is bad, and something bad when it is good. You might be familiar with the terms consumer's risk and producer's risk. Consumer's risk refers to the possibility of a problem occurring in a consumer-oriented product; a product that doesn't meet quality standards passes undetected through a manufacturer's quality control system and enters the consumer market.

An example of this would be the batteries in the Samsung Note 7 phone. The batteries can potentially overheat, causing the phone to catch on fire. In this case, the faulty battery/charging system of the phone device was approved through the quality control process of the manufacturer, which was a 'false accept decision.' If you owned one of these phones, there was a risk of fire and potential damage and injury.

In metrological terms, consumer's risk is like the false accept risk, or Probability of False Accept (PFA). The biggest difference is that in the metrology field, the false accept risk is usually limited to a maximum of 2 percent. In cases where the estimation of this probability is not feasible, there is a requirement for a Test Uncertainty Ratio (TUR) to be 4:1 or greater to ensure lowering the PFA to a low risk level.

So, what does this mean for a metrology laboratory? It means that any lab making a statement of compliance, calling an instrument "in tolerance," must consider measurement uncertainty and properly calculate T.U.R. considering the location of the measurement. In simplistic terms, T.U.R. = Tolerance Required/Uncertainty of the Measurement (at a 95% confidence interval). If the Uncertainty of the Measurement is not less than the tolerance required, there will be a significant risk of false accept. In simplistic terms, a TUR that produces less than +/- 2 % upper and lower risk would be required to ensure the measurement is valid.

Keys to lowering measurement risk include having your calibration provider replicate how the instrument is used in the field, having competent technicians, using the right equipment, and lowering overall uncertainties by the calibration provider. There is quite a bit of difference between force measurement labs with CMCs of 0.1 percent, 0.05 percent, 0.02 percent, 0.01 percent, 0.005 percent and 0.002 percent of applied force. Not using the laboratory with the right capability to meet your requirements is like using a ruler to calibrate a gauge block.

Table 1 shows the Test Uncertainty Ratios (TUR) that force calibration labs with different calibration capabilities can provide for various levels of required tolerances. The far-left column represents the calibration standard required for force measurements. Deadweight primary standards are often required to achieve CMCs of better than 0.01 % of applied force. A high-end load cell calibrated by deadweights would be required to achieve CMCs of better than 0.05 %. This table indicates the best TUR that the labs can provide for the same load cell at similar conditions. Per this table, only calibration labs with CMCs around 0.02 % or better can calibrate devices with a tolerance of 0.1 %. They may still need to adjust the device to read closer to the nominal value. We will discuss guard banding later.

The table was derived from TUR and uncertainty formulas found in JCGM 100:2008 and ANSI/NCSLI Z540.3-2006. The formulas used to determine TUR and Uncertainty are as follows:

$$TUR = \frac{Tolerance}{Expanded\ Uncertainty}$$

$$TUR = \frac{(USL - LSL)}{4 * u}$$

where:
TUR = Test Uncertainty Ratio,
USL = Upper Specification Limit,
LSL = Lower Specification Limit, and
u = standard uncertainty.

Note: We are using 4 assuming k=2, the proper formula would be 2 times the actual k value is for a 95 % confidence interval.

The Calculation of TUR for Tolerances

- ((Upper Specification Limit - Lower Specification Limit))/(4 * Standard Uncertainty)
- Combined Uncertainty (u) – The square root of the sum of the squares of all the input quantity uncertainty components.

$$u = \sqrt{\left(\frac{CMC}{k}\right)^2 + \left(\frac{Res}{3.464}\right)^2 + \left(\frac{Rep}{1}\right)^2}$$

- CMC = Calibration and Measurement Capability. This should be found on the calibration report.
- Res = This is the resolution of the Unit Under Test (UUT) The divisor for resolution will either be 3.464 or 1.732 (depending on how the UUT least significant digit resolves).
- Rep = Repeatability of the Unit Under Test (UUT). Repeatability of UUT must be used if repeatability studies were not previously accounted for in the CMC. If accounted for in the CMC, this would not be required.

How Good Does Your Calibration Provider Have to Be? (T.U.R. Table)

Calibration Standard Required	Calibration Lab capability (CMC)	Tolerance Required 0.010%	0.020%	0.050%	0.100%	0.200%	0.500%
Deadweight	0.002%	4.471	8.941	22.353	44.706	89.413	223.532
Deadweight	0.005%	1.961	3.922	9.805	19.610	39.221	98.052
Deadweight / Lever	0.010%	0.995	1.990	4.975	9.950	19.900	49.751
High End Load Cell	0.020%	0.499	0.999	2.497	4.994	9.987	24.969
High End Load Cell	0.050%	0.200	0.400	1.000	2.000	3.999	9.998
Good Load Cell	0.100%	0.100	0.200	0.500	1.000	2.000	5.000

This table is based on a Calibration Grade Load Cell with 0.01 lbf Resolution; 0.05 lbf Repeatability.

Anything in Red would have too much measurement risk.

Table 1. TUR Table

- Expanded Uncertainty - Typically 2 times the standard uncertainty. However, the appropriate k value should be used to ensure a coverage probability of 95 %, based on the effective degrees of freedom using the Welch Satterthwaite formula.

Is Your Calibration Provider Reporting Pass/Fail Criteria Properly?

If the calibration provider is accredited, it needs to follow the requirements per ISO/IEC 17025. ISO/IEC 17025:2005 Clause 5.10.4.2 states that "When statements of compliance are made, the uncertainty of measurement shall be taken into account."

This translates to minimizing the Probability of False Accept (PFA) by applying a guard banding method. ANSI/NCSLI Z540.3 -2006 Handbook discusses guard banding in section 3.3. Section 3.3 paragraph 2 states "As used in the National Standard, a guard band is used to change the criteria for making a measurement decision, such as pass or fail, from some tolerance or specification limits to achieve a defined objective, such as a 2 % probability of false accept. The offset may either be added to or subtracted from the decision value to achieve this objective."

Examples of Calculating Measurement Risk with Guard Banding

Assume we are testing a load cell at 10,000 lbf force. The accuracy specification is 0.1 % of reading (or +/- 10 lbf at this force), and the measured value was 9990. Is the device in tolerance? After all, the calibration laboratory applied 10,000 lbf and the unit under test (UUT) read 9990. The bias is -10 lbf and the device meets its accuracy specification (accept decision without taking the uncertainty of measurement into account). The report is issued and the end user is happy. However, the problem is that the end user should not be happy. If the calibration and measurement capability (CMC) of the calibration laboratory using a specific reference standard was not considered, the end user will not know whether the device meets the accuracy specification required. Basically, this measurement was passed based on the assumption that the calibration providers reference was perfect and they applied exactly 10,000 lbf to the load cell. However, no measurements are perfect. That is why we estimate the uncertainty of measurement to quantify this "imperfection of the measurement." This is a false assumption which neglected the uncertainty in the calibration provider's measurement.

Let us assume that the standard uncertainty was calculated at 6.5 lbf for k=1. In Figure 2, the item being calibrated would normally be considered "in tolerance" by a large percentage of calibration laboratories since the accuracy specification is 0.1 % of reading or +/- 10 lbf and the measured value was within the accuracy specification at 9990 lbf. <u>However, there is a 50.1 % chance of the calibration being accepted when it is not in tolerance.</u>

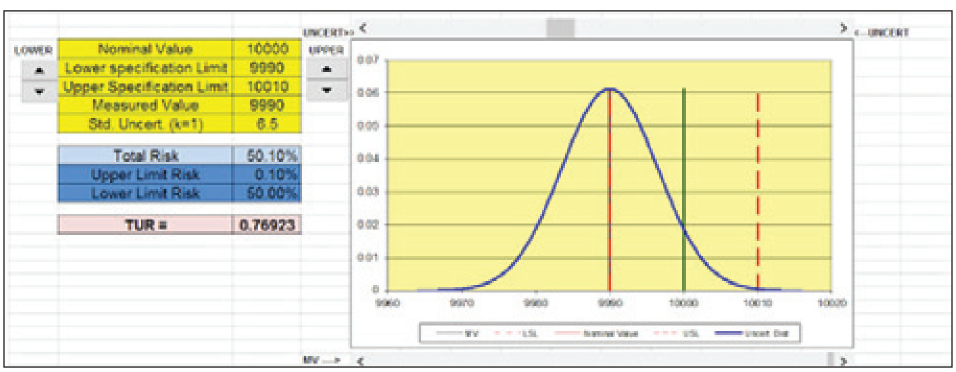

Figure 2.

Figure 3 shows the risk when the measured value of the UUT reads 10,000 lbf. In this scenario, the bias or measurement error is 0. However, there is still a 12.39 % chance that the UUT is not "in tolerance." Simply put, there is too much risk. We need to lower the standard uncertainty to reduce the risk. Note that the TUR remains the same since it is a ratio not dependent on the location of the measurement.

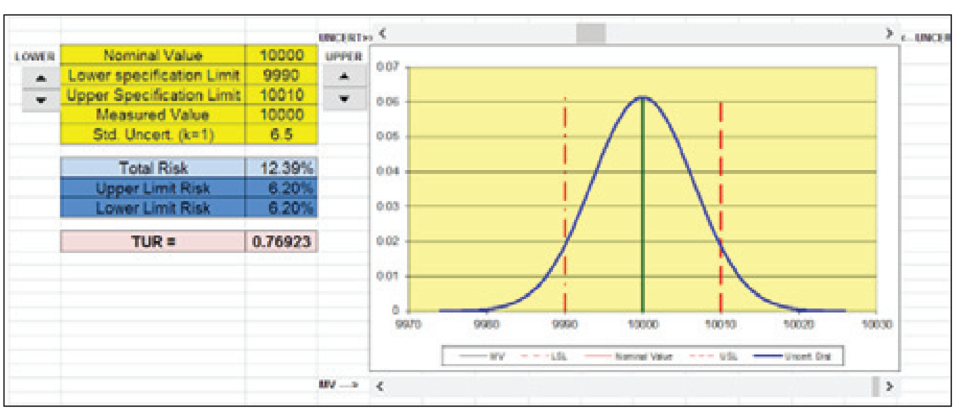

Figure 3.

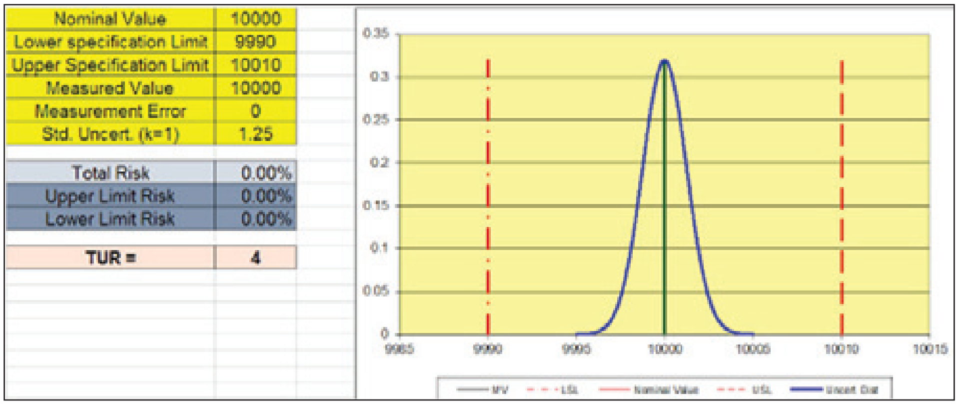

Figure 4.

How to Lower the Risk (PFA) By Lowering the Uncertainty

1. Use better equipment with a lower resolution and/or better repeatability; e.g., higher quality load cell for force measurement.
2. Use a better calibration provider with a Calibration and Measurement Capability (CMC) low enough to reduce the measurement risk.
3. Pay attention to the uncertainty values listed in the calibration report issued by your calibration provider. Make sure to get proper T.U.R. values for every measurement point (but pay attention to the location of the measurement).

The last graph (Figure 4) shows the same test instrument with a lower Standard Uncertainty. This was a real scenario where an instrument was modified from a 10 lbf resolution to a 2 lbf resolution. The total risk is now 0 and the device will be "in tolerance" with less than 2 % total risk from reading of 9,996 through 10,006 lbf. There are several acceptable methods for applying a guard band to obtain what the measured value needs to be in order to maintain less than 2 % total risk.

These graphs comply with Method 5: Guard Bands Based on Expanded Uncertainty in the ANSI/NCSLI Z540.3 Handbook and is described in ISO 14253-1, and included in ILAC G8, and various other guidance documents.

After reading this paper, you may be standing at a crossroads and wondering if any of this extra work is necessary. To the left is the same rough path you've been travelling all along. This is the path that says, "If it's not broken, why fix it?" You might be thinking that measurement risk has not been an issue before, or you'll just wait until an auditor questions you about it (or there is a train wreck). Yet, to the right is the road that fewer people realize will help solve their measurement problems today. This road is not more difficult; it's just different from the current way you may be doing things. Choosing to consider the impact of not doing things right—and making the decision to select the best calibration provider—will make all the difference. The rest is just putting formulas in place to report and know your measurement risk.

References

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[4] ISO/IEC 17025:2005: *General requirements for the competence of testing and calibration laboratories.*

[5] AS9100C *Quality Management Systems - Requirements for Aviation, Space, and Defense Organizations.*

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Chapter Two: The Pendulum and Standards of Measure in the Ancient World

Roland A. Boucher

When the French proposed their first metric system in 1723, they had no idea it had been invented by the ancient Mesopotamians 5000 years earlier. Just as the French proposed to use the length of a one-second pendulum to create standards of length, volume, and weight, the Sumerians created nearly identical meters, liters and kilograms. Our research shows that the Sumerians in ancient Mesopotamia used both the Moon and the Sun as their clock. It appears that the Egyptians improved on this timing accuracy by using the stars. Later the Minoans introduced the use of the planet Venus as a clock.

These concepts spread throughout the ancient world from Britain in the West to Japan in the East. The Minoan standards are immortalized in the Magna Carta of 1215. The old English saying "a pint a pound the world around" had been true for over 3000 years. In the 19th Century, both Stuart and Penrose accurately measured the dimensions of the Parthenon, finding its width to be 0.9997 arc seconds on the polar circumference of the Earth. This accuracy puzzled scholars for 150 years. Our research shows the width of the Parthenon in Athens was designed to be 1/30 of the perimeter of the Great Pyramid of Giza. The same Pendulum Formula, when timed with Venus rather than the Sun, increased the pendulum length just the right amount. This precision was not dumbfounding – it was just dumb luck.

Introduction

Chapter One, in the previous issue (24:1) of *CAL LAB: The International Journal of Metrology*, showed how five pendulums could have established five Sumerian standards of length in Ancient Mesopotamia. Precise matches were found among 32 of Dr. Powell's inscribed weights, among 3 matches of Sir Arthur Evans' Talent weights, and among 7 of Mr. Berriman's lengths, volumes and weights.

Chapter Two will examine additional standards from Egypt and the Minoan civilization on Crete. It will describe a special standard of length, volume, and weight developed in Sumeria, based on the polar circumference of the Earth. A case will be made that this new standard was used to establish the perimeter of the Great Pyramid of Giza at 30 Arc seconds of the polar circumference of the Earth. Two thousand years later, it was used to establish the width of the Parthenon at almost exactly one arc second.

The Standards of Ancient Egypt Circa 3000 B.C.E.

The Egyptians apparently realized that a star, a mere pinpoint of light, could provide a much higher level of precision than the Sun when measuring an interval of time as they developed their own standards. These standards appear to be based on the length of a Foot of approximately 300 mm. This Foot was developed with a pendulum which beat 366 times in the period it took the Earth to rotate through one 366th of a celestial day (one which is measured by the daily motion of a star). This pendulum length was used to create a Cable of 366 times twice the length of this pendulum. The length of the Egyptian Foot became 1/1000 of these Cable lengths.

The stars arrive at the same position in the sky about four modern minutes earlier each day due to the Earth's orbital motion, which may be why the Sumerians divided the day into four-minute intervals they called a Gesh. The star field appears to rotate 366 times in a year, so the number 366 was very important to an astronomer. The length of this new Cable was about 300 meters and their Djser (foot) about 300 mm. The Egyptians based all their measurement standards on their Djeser which was divided into 16 Egyptian Djeba or digits (18.75 mm). This digit was used to develop their Reman, Cubit, and Royal Cubit.

Mr. A.E. Berriman established the length of the Royal Cubit through the volume of Bowls #27 and #8 in the Petri collection at the University College, London [19], as follows:

Bowl #8	Volume = 366.2 cu in = 400 Ro = 1/16 Khar 3/2 Khar = **8789** cu in
Bowl #27	Volume = 546.5 cu in = 600 Ro = 1/16 Royal Cubic Cubit Royal Cubic Cubit = **8744** cu in
Bowl #8	Royal Cubit = $\sqrt{\mathbf{8789}}$ cu in = 20.638 in = 524.21 mm Foot = 299.55 mm
Bowl #27	Royal Cubit = $\sqrt{\mathbf{8744}}$ cu in = 20.602 in = 523.28 mm Foot = 299.02 mm

Note: The volume of the Ro = 1 cubic finger or 1/9600 Khar.

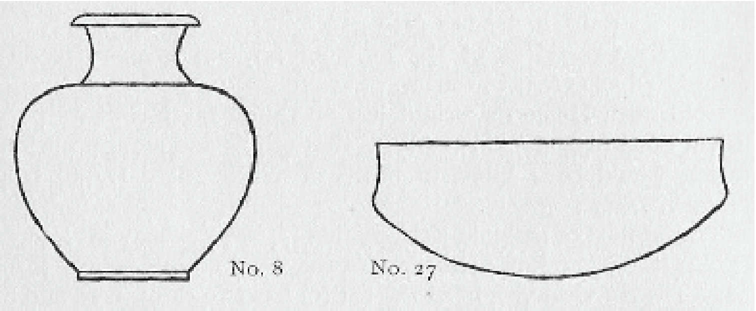

Figure. 8 Egyptian Bowls #8 and #27 in the Petrie collection.

Egyptian Old Kingdom nominal standards of measure:

- Standard of length #1 = Djser (foot) = (366 pendulum lengths)/1000 = (300 mm)
- Standard of length #2 = Reman = 20/16 Djser (375 mm)
- Standard of length #3 = Cubit = 24/16 d=Djser (450 mm)
- Standard of length #4 = Royal Cubit = 28/16 Djser (525 mm)
- Standard of volume = Khar = Volume of 2/3 of the Royal Cubit Cubed (96.5 liters)
- Standard of weight = Deben = 13.6 gm = 3 Sumeria or 2 Minoan Gold Standards

Detail of Calculations for the Egyptian Foot

The Egyptian pendulum beat 366 times in the period of 1/366 celestial day or 235.721 seconds. A Cable of 366 of these pendulum lengths established 1000 Egyptian feet. In Table 7-A we establish the theoretical length of this simple pendulum, then applying modest corrections for the period and length of a real pendulum, we develop the Egyptian Foot and Royal Cubit. In Table 7-B we establish the length of the Finger, Foot, Reman, Cubit, and Royal Cubit along with related volumes. Later in the New Kingdom, the Khar was reduced to 78.6 liters. In Table 7-C, we show standards of weight for both the New and Old Kingdoms.

Pendulum 5	Length mm	Cable m	Matching Values	
P = 0.64405 sec	820.76	300.4	1/360 deg = 307.701m @ Luxor WGS 84	
P - 0.15%	818.3	299.5	5000 Reman = 1.0139 arc minutes @ Luxor	
Foot, mm	299.5	NA	299.5 mm	A. E. Berriman [19]
Royal Cubit	524.10	NA	524.2 mm	A. E. Berriman [19]

Table 7-A. The length of the Egyptian Pendulum, Cable, Foot, and Royal Cubit.

Pendulum 5	R	Length mm	Volume liter	Name	Ratio	Volume liter
Royal Cubit	28	524.1	143.987	Deny	1	144
Cubit	24	449.3	90.674	Khar	2/3	96
Reman	20	374.4	52.473	Heqat	1/30	4.8
Foot	16	299.5	26.865	Hinu	1/300	0.48
Finger	1	18.719	6.559 ml	Ro	1/9600	15 ml

Table 7-B. Egyptian Old Kingdom Lengths and Volumes.

Pendulum 5	R	Old Kingdom	New Kingdom
Sep	10	136 grams	910 grams
Deben	1	13.6 grams	91 grams
Kite	1/10	1.36 grams	9.1 grams
The Old Kingdom Deben = 3 Sumerian or 2 Minoan Gold Standards. In the New Kingdom, the Deben became 1/1000 Khar of water (91 gm).			

Table 7-C. Egyptian Weight Standards for both Old and New Kingdoms.

The Minoan Foot and Its Cousins

Venus was an important goddess to the Minoans (2700-1100 BCE). They timed their pendulum from Venus while in opposition for 366 beats during the time it took Venus to divide the rotation of the Earth by 366. The planet Venus is closer to the Sun than the Earth and orbits the Sun in 244 days. By viewing Venus when it is on the opposite side of the Earth, its motion cancels out some of the apparent motion caused by the spinning Earth, lengthening the period for 1/366 Venus day to 236.504 seconds. This essentially divided the celestial solar day into 365.25 parts. The length of the resulting Cable was 303.6 meters and the Foot 303.6 mm. The elevation of the North Star on its daily circle around the Pole would now change one arc-minute for every 6090 feet the observer moved in a north-south direction. The Minoan Foot [22] was no more accurate in predicting latitude than the Egyptian Foot, but it seems to have traveled widely.

- Minoan standard of length: Foot = 303.6 mm.
- Minoan standard of volume: Amphora = 1 Cubic Foot = 27,984 cm^3.
- Minoan standard of weight: Talent[1] = 27,901 grams = the weight 1 Amphora of rain water at 20 °C.

As we have shown, the Ancient Sumerians divided their volume standard of one Amphora either by 60 or by halves yielding volumes of 1/8 and 1/64 Amphora:

The standard volume for a Pint of 1/64 Amphora = 437.25 cu cm.

The standard weight for a Pound = the weight of one Pint of rain water at 20 °C = 436.0 gm.

The standard weight of a Troy pound became = 1/60 Amphora of wheat at 0.8 kg/liter = 373.2gm.

Traveling from Crete to ancient Britain, we find the length of the Minoan pendulum in the length of Megalithic Yards in Stonehenge [23].

The Minoan Foot was Immortalized in the Magna Carta

The Minoan Foot established the length of an ancient English foot used to develop standards of volume for the Gallon, the Bushel and the London Quarter. These were documented in the Magna Carta in 1215 [24]. The Winchester Bushel was simply the volume of one Minoan Cubic Foot and the Pint 1/64 of this volume. The accuracy of these measurements would suggest that the English Mercantile Pound and Scottish Pound had been established precisely by the weight of one Minoan Pint of rain water. It also would appear that the Troy Pound had been established precisely by the weight of 1/60 of a bushel (Amphora) of wheat at 0.8 kg/liter.

Moving to Japan, we find the Japanese Shaku of 303.0 mm; a very close match to the Minoan Foot when taking into account the difference in latitude. The Japanese, just as the Minoans, were a maritime nation. It is interesting that the largest linear standard of Ancient Japan was the Ri of 12960 Shaku, a length almost exactly that of 1/10,000 the polar circumference of the Earth.

Detail of Calculations for the Minoan Foot

The Minoan pendulum beat 366 times in 236.504 seconds. The length of their Cable of 366 pendulum lengths was equal to 1000 Minoan Feet. In Table 8-A (on the following page), we establish the theoretical length for a simple pendulum and the resulting foot. Applying modest corrections for the period and length of a real pendulum, results in the following Foot, Sila, and Mina along with corresponding measured values from reliable sources.

The Minoan Foot in Early England

In Table 8-B we establish the Minoan Cubic Foot as an English Bushel, and its division into Gallon, Pint, as well as its Cubic Finger which established the Minoan Gold Standard. The English values were guaranteed by the Magna Carta of King John on June 15, 1215.

The Minoan Cubic Foot as a Talent and Its Mina of Grain

In Table 8-C, we establish the Talent as the weight of a Minoan Cubic Foot of water, as well as measured values. We were quite surprised to find that the Troy Pound was of Minoan origin.

The Magnificent Octopus Talent of Bagdad and the Polar Circumference of the Earth

The Octopus Talent was discovered in Knossos, Crete in 1901 by Sir Arthur Evans, who also indicated that it appeared to be of Babylonian origin. This magnificent 29,000 gram Talent Weight from circa 1650 B.C.E. may well have been commissioned to celebrate the 1000th anniversary of the building of the Great Pyramid at Giza. A quick calculation revealed that an Amphora filled with 29,000 gm of water at 20 °C would have a volume of 29,086 ml or the volume of a 307.54 mm cube. This length is within 0.45 mm of the geodetic foot at the latitude of Lagash.

A search for a simple modification of one of the Sumerian pendulums, which would provide a match in length, quickly produced results. Pendulum 3, which beat 360 times in 240 seconds, had produced the 318.56 mm Zhou Market Foot in China and the Fuss in Bern, Austria.

1 A 27,900 gram Bronze Talent was found at Knossos by Professor Halbherr in 1903 [8].

Pendulum 6	Length mm	Sila ml	Mina gram	Measured Values
P = 0.64619 sec	829.160	570.05	284.184	Calculated for a Simple pendulum
Foot	303.473	NA	NA	Calculated for a Simple pendulum
P + 210 ppm	303.60	571.08	284.70	Ratio ball/string, 210 ,swing, 1/20 L
Cubic Foot	303.60	27,984	27,901	303.6 mm A.E.Evans At Knossos [8]
Foot	303.64	NA	NA	Early English Foot [22]
Foot	303.09	NA	NA	303 mm = Japanese Shaku [25]

Table 8-A. Lengths(mm), Sila(milliliter), Mina (grams) and matching values.

Pendulum 6	Ratio	Length mm	Volume ml	Weight g	Measured
Bushel	1	303.60	27,984	27,901	Winchester Bushel [6]
Gallon	1/8	153.61	3,498	3,488	Wine Gallon [6]
Pint	1/64	76.805	437.25	435.96	Wine Pint [6]
Pint	1/64	76.805	437.25	435.96	437.4g Mercantile pound [6]
cu finger	1/4096	1.897	6.831	6.811	6.8 g = Minoan gold standard [7]

Table 8-B. The Minoan Cubic Foot as the Early English Winchester Bushel. The foot (mm), Bushel (cu cm), weight (grams) along with Matching Values (period + 210 ppm).

Pendulum 6	R	Weight, g	Measured
Talent	60	27,901	27900 g Bronze Talent #4 Halbherr, Crete [8]
Sila of water	1	465.02	465.004 g #72 1/2 mina Zeriya [7]
Sila of grain	1	372.02	373.241 g English Troy Pound Zupko [26]

Table 8-C. The Minoan cubic foot as a Talent divided into Mina (period + 210 ppm).

If Pendulum 3 were allowed to beat 366 rather than 360 times in 240 seconds, the length of the resulting Foot would be 307.23 mm. This new Pendulum 7 would be too short to time easily, but one eight feet long would work well. It would beat 150 times in 1/366 solar day (236.065 seconds). The length of an 8 foot version of Pendulum 7, when swung 10 degrees to each side with a Ball/String ratio of 100, would be 246.032 cm.

The resulting Cable of 307.54 meters is almost perfectly equal to 1/360 of a degree at the latitude of Lagash. It is only 0.146 percent short of the true value. The length of 100 of these new Sumerian feet is almost exactly 1 arc second on the Polar Circumference of the Earth.

The Perimeter of the Great Pyramid is within 0.25% of 30 arc seconds of the Polar Circumference of the Earth. This accuracy has puzzled scholars for almost 150 years.

The Great Pyramid of Giza was accurately measured by both Petrie and Cole, establishing the average width at 230.355 meters with a precision of better than one part in 10,000. The four sides are aligned north-south and east west to within 1/15 degree of the true values. The length of the four sides or perimeter is 921.421 meters is within 0.25% of 30 arc seconds (1/120 degree) of the Polar Circumference of the Earth established through satellite measurements.

Figure 9. Octopus Weight

Figure 10. Octopus Amphora

The Perimeter of the Great Pyramid of Giza was Established as 3000 Sumerian Feet

Sometime before 2680 B.C.E., when the construction of the Great Pyramid began, the Egyptian astronomers and engineers would have become aware that a Sumerian geodetic pendulum provided a very accurate measurement of the length of an arc-minute of latitude. Using Pendulum 7, to establish the perimeter of the Great Pyramid, provides a perfect match to the measured values with a modest 67 ppm correction for a physical pendulum when it is operated at Luxor. Past claims for a width of 440 Royal Cubits would require a rather small value for the Egyptian Foot as shown in Table 9.

The Egyptians may not have known just how accurate the Sumerian measurements were, but they were much better than the 1.4 percent error resulting from a 5000 Reman Nautical Mile.

Figure 11. The Great Pyramid at Giza Constructed in 2600 BCE.

The Mysterious Precision in the Construction of the Parthenon

The Parthenon in Athens, Greece, was accurately measured by Stuart in 1750 and later by Penrose in 1888 [17]. The dimension of the width of the Parthenon at 30.861 m appeared to be almost exactly one average arc second on the polar circumference of the Earth, 30.870 m [21]. The small 9 mm error out of 30870 mm was surprising considering that the true measure of the Earth was obtained in 1984 with satellite data. This level of accuracy was just not possible in 600 B.C.E.

The Octopus Talent Yields the Attic Foot in Athens

The accuracy with which the Attic Foot predicts the Polar Circumference of the Earth has perplexed scholars for 150 years. This extreme accuracy was simply the product of luck. Table 10-A (on the following page) shows the evolution of Pendulum 7 into the Octopus Talent found in Knossos. When it was timed using Venus rather than the Sun, Pendulum 7 lengthened about 0.37 percent, eliminating almost all error. Making minor correction for the properties of a real pendulum gave us the famous Attic foot.

The Octopus Talent, Amphora and Foot were Adopted by the Etruscans

It would appear that the Octopus Talent of 29000 grams found by Sir Arthur Evans in 1901 was the basis of the Etruscan measures of volume and weight. The Etruscan Wool Pound of 453.074 grams or 6992 grains is 1/64 of their Talent. It was selected by Queen Elizabeth I as a prototype for the 7000 grain British Imperial Pound.

The Greek Stadion and the Roman Foot

The Greeks created the Stadion of 600 Greek Feet. The length of this Stadion was one-tenth of a British Nautical Mile (600 Stadion = 1 degree on the polar circumference of the Earth [16]). The length of the Stadion was adopted by Rome as the Stadia. However, it contained 625 Roman Feet [28]. This made the length of the Roman Foot 296.296 mm.

The Romans also created a Mile of 8 Stadia or 5000 Roman Feet (1481.424 meters). Thus, there were 75 Roman Miles per degree of latitude and 27,000 Roman Miles in the

Pendulum 7	Foot	3000 Feet	Description
Gravity= 9.7943594	307.234 mm	921.702 m	simple pendulum 7 in Lagash
Gravity= 9.7900450	307.099 mm	921.297 m	simple pendulum 7 in Luxor
period + 67 ppm	307.140mm	921.421 m	921.421 meters Petrie & Cole
440 Royal Cubits	299.162 mm?	921.421 m	3080 Feet @ 299.162 mm

Table 9. The Great Pyramid was designed in conformance with Sumerian Pendulum 7.

Pendulum 7	Foot, mm	Talent, gm	Description
Gravity = 9.7943594	307.234 mm	28,915	simple pendulum 8 in Lagash
Gravity = 9.7975933	307.335 mm	NA	simple pendulum 8 in Knossos
+ 0.1% correction	307.535 mm	29,000 g	Octopus Talent in Knossos*
Gravity = 9.7999303	307.409 mm	NA	Simple pendulum 8 in Athens
Gravity = 9.7999303	308.553 mm	NA	Venus pendulum 8 in Athens
185 ppm correction	308.610 mm	NA	Measured value of Attic Foot **

** Correction for pendulum with 10 degree swing, ball/string ratio = 100*
*** Correction for pendulum with 10 degree swing ,2.4 cm Granite ball & 0.60 gm string*

Table 10-A. Evolution of the Attic Foot and Talent derived from Pendulum 7.

Pendulum 7	R	Volume ml	Weight gm	Measured
Amphora	64	29,086	29,000	307.535 mm cube of water @ room temp.
Gallon	8	3,635.75	3,625.00	no match
Pint	1	454.47	453.13	453.074 = Etruscan Wool Pound [18]
Pint	1	454.47	453.13	453.592 = British Imperial Pound [26]

Table 10-B. The Octopus Talent as Etruscan Amphora, Gallon, Pint, and Pound.

Polar Circumference of the Earth. We may never know if the Romans were aware of the accuracy with which their mile could measure the Earth.

Today, using modern satellite data, we find the circumference was eight Roman Miles short, an error of only 0.02 percent. The Romans used the ratio of (25:24) in developing their new Foot which would lead to cultures throughout Europe adopting it to other standard feet as well. The resulting confusion and profusion of European standards provided a strong impetus for reform.

Conclusion

In Chapter Two we have established three pendulum lengths which produced four Egyptian and two Sumerian standard lengths as well as the Greek Attic Foot, Stadia, Roman Foot and Roman Mile. Precise matches were found among 10 of Dr. Powell's inscribed weights, 4 matches among Sir Arthur Evans' lengths and Talent weights, and 2 among Mr. Berriman's lengths, volumes, and weights. A side trip to early England established Minoan roots in the Winchester Bushel and in both the Mercantile and Troy Pounds. A side trip to Japan established Minoan roots in early Japanese Standards showing that their longest standard of length, the Ri, was 1/10,000 the polar circumference of the Earth. It was quite a surprise to find that the both British Imperial and US Pounds are related to the Polar Circumference of the Earth. If you are in doubt, calculate the length of the edge of a 64 million pound cube of water at room temperature and compare it to one arc second of the Polar Circumference of the Earth.

In conclusion, there can no longer be any doubt that the pendulum was used in the development of ancient metrology.

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Figure 12. Replica of The Parthenon of Ancient Greece.

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A Standard Text File Format for the Exchange of Calibration Data Required for Analysis

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The purpose of this paper is to initiate standardization between calibration labs and users of the file for exchanging calibration data. Experience has it that to agree upon a file that can fully exchange all the data in a calibration report is probably impossible. So I propose a very small step forward that covers only the minimum data required for reference instrument prediction, calibration interval analysis and inter-laboratory and other comparisons. Normally, each calibration lab is using its own proprietary files and sends to the user the calibration report in files (e.g. pdf) or on printed paper that cannot be edited in order to secure the data. This justified practice forces the users that need to make further analysis of the data given in the calibration report to retype it into their computer programs or use other creative ways to do so. In this paper I propose that calibration labs would provide (upon request) an un-protected file, in parallel to the secured file, containing only the minimum required data. Because at least two parties are involved in the process (calibration lab and user) I propose to use a standardized simple text file. I show how this has been done for a long time with the calibration and analysis program MetroVal. I shall go into details of the required programming and target the common calibration lab and its customers.

Introduction

Data from calibration reports of reference instruments is required for the estimation of calibration intervals, prediction of the reference instrument present values (which could drift away since calibration or adjustment), comparisons between labs, proficiency testing, validation of calibration procedures, etc. For such analyses and processing, we do not need all the extra, nice features in a calibration report such as graphs, pictures, traceability information, font and formatting, owner identification and many other facts. Normally, the only required data for the above analyses is presented as numbers (with units) in the calibration report in a tabular form. This numerical data (and units) can be easily stored in text files.

There are several, well-defined simple text file formats for data exchange. They differ by some properties such as robustness, possibility of being read on text editors and understood by humans, inclusion of all the required information, availability of common programs to read and write into them, etc. The most common formats (in order of complexity and capability) are Tab Delimited, CSV [1], JSON [2], XML [3], and HTML [4].

There are many available programs to read and write the above mentioned files. For example, it is easy to handle the majority of these files using Microsoft® Excel. They are all suitable for representing tabular data normally given in the calibration certificates. Here we give a short description of the simplest file format and the reader may check their full definitions and capabilities in the provided references. We ignore in this discussion the fixed width text format for each entry since they are hard to expand when needs dictate to include new entries in the file.

A tab delimited file is a text file where each entry is followed by a tab character which separates the entries. A table is formed by separating the table rows by a newline/carriage return character(s). For example, a two row table with a date, a value with a unit, a parameter, and a report certificate number may look like ([t] represents the tab character):

Year[t] Month[t] Day[t] Value[t] Unit[t] Parameter[t] Certificate[t] [newline]

2007[t] 3[t] 23[t] 115[t] V[t] AC 60 Hz[t] 1234[t] [newline]

2007[t] 3[t] 23[t] 230[t] V[t] AC 50 Hz[t] 1234[t] [newline]

The header row may be required if the order of placing the entries in the table is defined differently by each party.

A CSV (comma separated values) file that holds the same data may look like (note the additional “” encompassing text with spaces and the comma used now as the delimiter not being part of the data):

Year,Month,Day,Value,Unit,Parameter,Certificate [newline]

2007,3,23,115,V ,”AC 60 Hz”,”1234”[newline]

2007,3,23,230,V,“AC 50 Hz” ,”1234”[newline]

Complications may arise in some situations (e.g., when placing a comma within an entry).

A JSON (JavaScript Object Notation) file containing the same information as above might look like the following if we decide that each row in the table is an object:

```
{”Year”:2007,“Month”:3,”Day”:23,”Value”:115,”Unit”:”V”,”Parameter”:”AC 60 Hz”,”ID”=1234}
{”Year”:2007,“Month”:3,”Day”:23,”Value”:230,”Unit”:”V”,”parameter”:”AC 50 Hz” ,”ID”=1234}
```

Here each object is embraced between { } and the Name and Value pairs are separated with “:” and text embraced with “”. Note that there is no need for the header row as all the information is given in each object. Objects do not need to be similar.

A XML file containing the above information might look like this:

```
<?xml version=”1.0” ?>
<calibration id=”1234”
    <record function=”ACV” year=”2007” month=”3” day=”23” value=”115” unit=”V” parameter=”60 Hz”></record>
    <record function=”ACV” year=”2007” month=”3” day=”23” value=”230” unit=”V” parameter=”50 Hz”></record>
</calibration>
```

When standardized, the actual structure must be well defined (usually in another file called DTD) and there are many possibilities for this.

In both of the JSON and XML examples, you can clearly see that the column names are included with every data entry. This allows the data to be organized in any order and the data in the second row doesn’t need to be in the same order as the first row. These formats also allow some flexibility in the number of columns and amount of data stored in the formats.

However, the flexibility in both JSON and XML file formats comes with a high cost in file size. Repeating the column names within every row substantially increased the file size. And sometimes the column name is larger than the data entry, for example, “Month” is 5 characters in length and the data entry of “5” is only 1 character. This makes for a larger file size.

In all the mentioned file formats, the keywords must be agreed upon by the participating parties; a task, which experience shows, becomes more complicated when there are more keywords.

Of the above formats, I think that the simplest to implement, and therefore there will be the least disagreements upon its structure, is the tab delimited format. The actual entries will depend on the application for which such a file may be constructed. The minimum entries that are required for the analysis of calibration intervals, prediction of present value of an instrument, inter-laboratory and other comparisons are:

Date, reference value (and unit), Measurement Error (and unit), Uncertainty (and unit and parameters defining it such as the k coverage factor), tolerances for calibration interval estimation, indication of whether the calibration was after the instrument adjustment (accompanied with calibration data from before adjustment), what was calibrated in each record (row) of the table, and a pointer (e.g., report number) to the original calibration reports.

Therefore, these are the minimum entries to be standardized for the above applications.

Implementation

The calibration and analysis program MetroVal [5] has a Predictor module that can estimate predicted present values of reference instruments, calibration intervals [6] and can do inter-laboratory and other comparisons with respect to the weighted average of all participants. The first two analyses need as much as available data from past calibrations. The other analyses need only data from one calibration for each participating party. It is interesting to mention that the authors of *Guidelines for the Determination of Calibration Intervals of Measuring Instruments* [6] define the applied method (method 5 there) as most complicated of the listed methods probably because one must use a computer program to evaluate the large amounts of data required in such analysis. With MetroVal, when a calibration is ended (or at any other time) the operator has the option to append the relevant recent calibration information to an existing file of similar information or to a new file. The compiled historical information may be then used for the required analyses by the calibration lab as a service to its customers. If only the last calibration is saved in a file and sent to the user, he may append it to his existing file and do the analysis optimized to his needs.

Due to its simplicity, we use the tab delimited text file with a minor addition. The addition is an extra row above the headers row which holds some description of what was calibrated. This was implemented many years ago in MetroVal and has worked successfully since then [7]. Figure 1 shows a screen shot of the file displayed in a grid of the Predictor module. The display ignores the files’ one word headers and provides more explanatory headers that may contain full sentences. The first line in the file goes into the Description line seen in the figure. The file structure is a mapping of the above table into a

Description: This is a 4808 past calibrations file

Row	Day	Month	Year	Unit1	Input	Output Value	Unit2	Deviation	Uncertainty	Paramet	Status	ID String (additiona	Rep	k (co	df	Confid	CM
54	28	10	1996	A	1	1.000070	ppm	70	140	ACI	OK	148,300Hz, 1A,	123	2	99	0.95	
55	4	6	1997	A	1	1.000060	ppm	60	140	ACI	OK	148,300Hz, 1A,	124	1.97	99	0.95	
56	7	1	1998	A	1	1.00010	ppm	102	120	ACI	OK	148,300Hz, 1A,	125	2	99	0.95	
57	15	1	1998	A	1	1.00000	ppm	1	120	ACI	adj.	148,300Hz, 1A,	125	2.02	99	0.95	
58	6	10	1998	A	1	0.999968	ppm	-32	140	ACI	OK	148,300Hz, 1A,	126	2	99	0.95	
59	2	3	1999	A	1	0.999978	ppm	-22	140	ACI	OK	148,300Hz, 1A,	127	2.05	99	0.95	
60	22	9	1999	A	1	0.999993	ppm	-7	140	ACI	OK	148,300Hz, 1A,	128	2	99	0.95	

Figure 1. An excerpt of the content of a past calibration file showing one measurand whose data is sufficient to be used in prediction analysis. The adj. Status means that this record was obtained after the instrument adjustment. The program considers the changes between before and after the adjustments in the regression analyses.

tab delimited file. The last calibration data file is emailed to the user who can further analyze the data. For example, the user could estimate calibration intervals optimized for his needs independent of the calibration lab analysis. Such a user independence is sometimes important as there is always a state of contradiction of interests between the lab and the user concerning the calibration interval. Because at least two parties are involved in the process, it is important to agree upon the file structure and even better, to standardize it. MetroVal files provide a de facto standardization for the two parties that use the program. I propose to extend it to those who use other programs for the benefit of the metrology community.

Figure 2 shows the headers of the file in Figure 1 opened with Microsoft® Word to show the tabs and newline characters. The first line contains a description of what was calibrated and the version of the file format. Each entry in the file header (the next wrapped line) contains only one word describing the field, as close as possible, using only one word to its VIM definition [8].

In Figure 2, **Unit1** is for the **Input** (reference) and **Output** (the result) and **Unit2** for the **Deviation** (measurement Error) and the **Uncertainty**. The **Parameter** defines the calibrated function. The **Status** carries additional information such as if the calibration is before or after an adjustment. **ID** provides identification of the calibration point in a performance test especially in cases where multiple channel UUTs need to be calibrated. **Report** is the report ID number. **k**, **df** and **Confidence** are related to the **Uncertainty** as in GUM. **CMC** is the calibration and measurement capability of the accredited user and may override the given Uncertainty if so required. # is the number of uses for the case where the calibration interval is estimated from the number of uses and not from the calendric interval. **Role** is for future use and indicates whether the instrument was calibrated as a generator or measuring instrument.

-tolerance and +tolerance are tolerances normally used to define the calibration interval (the calibration interval endpoint is defined in MetroVal by the future date where the predicted **Deviation** (measurement Error) plus its **Uncertainty** touch the + or - **tolerance**). The tolerances must sometimes be converted from limits if the calibration lab provides limits in the calibration report. Here, for brevity, we use only +/- **tolerances** in the header. The **Compliance** and **Method** of compliance are for future use. For example, the **Method** of **Compliance** can be based on ILAC G8 [9] clause 2.3 or on Z540.3 requirements etc.

In practice, the calibration lab could provide more or different fields in the text file. For example, one could imagine different units for the measurement error and the Uncertainty as some calibration labs actually do (here they are the same for brevity). However, today (MetroVal version 4.7.4) the provided information is sufficient for all of the analyses mentioned above; the fields given here for future use could be skipped at this time.

```
This·is·a·4808·past·calibrations·file·Version3·¶
Year→Month  →  Day →  Unit1  →  Input  →  Output  →  Unit2
→Deviation→Uncertainty  →  Parameter→Status  →  ID  →  Report  →  k
→df  →  Confidence  →  CMC →  #  →  Role→-tolerance  →  +tolerance
→Compliance  →  Method  →  ¶
```

Figure 2. Shows the two first lines of the text file as displayed on MS Word with the tab and newline characters appearing as an arrow and paragraph character respectively. The second line contains the data headers.

Conclusion

I have described the benefits and importance of sending (upon the user's request) a text data file in addition to the protected calibration report file. The open text file is no treat on the secured data since this is done in parallel by secured files. Such services have been provided successfully for a long time by MetroVal. I am urging other calibration labs to provide similar files for the benefit of the metrology community. Adding the capability of issuing the extra text file by existing calibration programs should not be too complicated a task for the programmers of those programs. Any suggestions are welcome and will help to move towards a standard file for the exchange of calibration data.

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The Food Safety Modernization Act has changed the way the food industry deals with safety. Now food safety management must be preventative rather than reactive. Effected facilities must implement a safety system that includes analysis and preventative measures. The food industry is required to comply by putting new calibration and documentation procedures into place. Failure to comply could have serious consequences. Edgetech instruments can assist by supplying moisture and temperature measurement devices with NIST traceable calibrations performed in an ISO/IEC 17025:2005 accredited laboratory, as well as dew point generators and laboratory setup services.

When customers develop in-house humidity and temperature calibration services they turn to Edgetech Instruments. The Edgetech Instruments DewMaster is known globally as the best value in a high performance, laboratory grade dew/frost point hygrometer. It is used as a calibration standard worldwide and is now available with the high performance X3 chilled mirror sensor featuring low dew/frost point capability without cooling liquids. The DewMaster hygrometer in combination with the DewGen dew point generator are used as the basis of many dew/frost point and humidity calibration laboratories. This high precision combination is a clear choice for accuracy, reliability and economy without compromise.

Edgetech Instruments designs and manufacturers accurate and reliable absolute humidity hygrometers, relative humidity transmitters, humidity probes, moisture and dew point analyzers, relative humidity calibrators, dew point generators and oxygen measurement instrumentation. Edgetech Instruments products are manufactured, calibrated and serviced to the highest industry standards in a modern, ISO 9001:2008 certified, ISO/IEC 17025:2005 accredited facility located in Hudson, Massachusetts, USA. www.edgetechinstruments.com.

Yokogawa Introduces Release 4 of the SMARTDAC+® GX/GP Series Paperless Recorders

Recorders and data acquisition systems (data loggers) are used on production lines and at product development facilities in a variety of industries to acquire, display, and record data on temperature, voltage, current, flow rate, pressure, and other variables. Yokogawa offers a wide range of such products, and is one of the world's top manufacturers of recorders. Since releasing the SMARTDAC+ data acquisition and control system in 2012, Yokogawa has continued to strengthen it by coming out with a variety of recorders and data acquisition devices that meet market needs and comply with industry-specific requirements and standards.

With this release, Yokogawa provides new modules with strengthened functions that meet customer needs for the acquisition and analysis of detailed data from evaluation tests. These modules decrease the cost of introducing a control application by eliminating the need for the purchase of additional equipment.

The functional enhancements available with Release 4 are as follows:

1. High-speed analog input module for high-speed sampling
2. Proportional Integral Derivative (PID) control module for control function
3. Four-wire Resistance Temperature Detector (RTD)/resistance module for precise temperature measurement

Applications for the Release 4 include the acquisition, display, and recording of process data such as temperature, voltage, current, flow rate, and pressure.

SMARTDAC+ stands for Smart Data Acquisition and Control. SMARTDAC+ offers input and output modules for a variety of signal sources and widely supports manufacturing processes and product performance evaluation testing. As a leading company in the recorder market, Yokogawa will continue to respond to a wide variety of needs to help its customers. http://www.yokogawa.com.

Oxford Instruments Asylum Research SurfRider "HQ-Series" AFM Probes

Santa Barbara, CA – Oxford Instruments Asylum Research introduces its new SurfRider "HQ-Series" Atomic Force Microscopy (AFM) probes, offering best-in-class performance at budget pricing. HQ probes are high quality silicon probes exclusively manufactured by Asylum and can be used in all commercially-available AFMs. They offer greater ease-of-use, higher quality and improved consistency for repeatable measurements compared to other probes in their class.

Users can easily engage at the location of interest with controlled tip-to-cantilever registration. The vertical edges make the probes easier to handle with tweezers and reduce chipping. Models are available for all routine image modes such as tapping, force modulation, and contact modes as well as most of the nanomechanical modes. They are an ideal choice for routine AFM measurements, education, or use in multi-user facilities. Purchasing information and specifications can be accessed at www.oxford-instruments.com/afmprobes.

VTI EMX-70XX Series PXIe Precision Programmable Resistor Ladder Modules

IRVINE, CA – AMETEK VTI Instruments (www.vtiinstruments.com) today announced the introduction of its EMX-70XX Series of Precision Programmable Resistor Ladder Modules, the latest addition to its family of PXI Express (PXIe) functional test solutions. As part of the EMX family of products, these modules can be mixed and matched with other EMX series modules to configure high-density measurement and switching systems. The EMX-70XX Series is designed for such applications as precision simulation of RTDs and other resistance-based sensors; process control; ATE calibration; controlled loading of devices under test (DUTs); and potentiometer simulation.

All modules in the EMX-70XX Series can provide four independent channels of programmable resistors, with four decades per channel. Each channel is equipped with its own sense leads for feedback. The EMX-7004 module is designed to deliver exceptional stability and accuracy (up to ±0.02% of programmed value ±0.5 Ω) for any resistance value from 1 Ω to 16,383 Ω. It can be adjusted in 1 Ω increments, either through the software application programming interface (API) or the dynamic soft front panel provided. The EMX-7005, EMX-7006, and EMX-7007 modules are optimized for applications requiring higher resistance values, with programmable settings ranging from 163 kΩ to 16,383 MΩ. All four cards offer a 0.5 W power rating and low thermal offset (≤ ±25 μV). IVI-COM, IVI-C, and LabVIEW™ drivers for the modules are included. The EMX-7014, EMX-7015, and EMX-7016 are available for general purpose applications with less stringent accuracy requirements. "The EMX-70XX Series is designed for easy configurability. Two or four channels can be tied together and programmed to operate as a potentiometer. They also support both parallel and series operation. Two or more channels can be connected in parallel for increased accuracy and to reduce the step size, or, if preferred, two or more channels can be connected in series to increase the range," notes Jon Semancik, Product Line Manager for VTI Instruments.

For More Information, visit http://www.vtiinstruments.com/Products-Services/EMX-7004.aspx. Contact VTI Instruments directly at 949.955.1894 or vti.sales@ametek.com.

Fluke Calibration 6109A and 7109A Portable Calibration Baths

EVERETT, Wash.– Pharmaceutical and biotechnology manufacturers utilize many tri-clamp and sanitary sensors in their clean room production processes. These sensors require periodic calibration which halts production. The new Fluke Calibration 6109A and 7109A Portable Calibration Baths are clean room compatible and calibrate four times more sanitary sensors per batch with twice the accuracy of other baths in their class, speeding the calibration process to get plants back on line quickly.

The 6109A and 7109A feature large tank volumes (112 mm square tank opening by 154 mm deep) allowing technicians to immerse four sanitary sensors at a time — including batches of odd shaped sensors of varying lengths and diameters, which can be accommodated with room left for a reference thermometer. The display panel, keypads, decals, and feet of the 6109A and 7109A baths are made from synthetic materials that don't harbor bacteria. Their stainless steel panels and tank are easy to clean, withstand harsh sterilizing chemicals, and are rust resistant — ideal for clean room use.

- Wide temperature ranges:
  - 6109A: 35 °C to 250 °C.
  - 7109A: –25 °C to 140 °C.
- Excellent display accuracy of ±0.1 °C that provides 4:1 test uncertainty ratio (TUR) for critical applications.
- An adjustable probe fixture accessory that holds up to four tri-clamp sensors securely inside the tank during calibration.
- Fixed bail handle and two bottom recessed handles for easy transport up and down stairs and across catwalks.
- Traceable NVLAP accredited calibration included standard.

To learn more about the Fluke Calibration 6109A and 7109A Portable Calibration Baths, visit http://us.flukecal.com/6109A.

Rohde & Schwarz R&S SMA100B Analog Signal Generator

Munich, June 1, 2017 -- The R&S SMA100B provides purest signals with the lowest possible phase noise at all offset frequencies (1 GHz, -152 dBc/Hz, 20 kHz offset). A 6 GHz instrument generates up to 38 dBm RF output power, and a 20 GHz instrument generates up to 32 dBm in the microwave frequency range. Harmonics are extremely low across the entire frequency range; above 6 GHz they are even significantly lower than 70 dBc at 18 dBm output power. Nonharmonics are below 110 dBc at an output signal of 1 GHz.

"The R&S SMA100B enables our customers to verify the true performance of their DUTs without the signal source affecting the results," says Andreas Pauly, Vice President Signal Generators, Audio Analyzers and Power Meters at Rohde & Schwarz.

State-of-the-art ADCs and DACs require absolutely pure signals with the lowest phase and wideband noise possible. In addition to delivering extremely pure analog RF signals, the R&S SMA100B is the world's only analog signal generator that can simultaneously provide a second, independently configurable, extremely pure and synchronized clock signal up to a frequency of 6 GHz. As a result, users can characterize ADCs with a single analog signal generator. The extremely low wideband phase noise of the clock synthesizer output signal (100 MHz, -175 dBc/Hz, 30 MHz offset) makes it possible to measure the true signal-to-noise ratio of modern ADCs. In conjunction with the excellent wideband noise of the RF signal, this makes the new R&S SMA100B the perfect reference for characterizing high-quality ADCs.

"Rohde & Schwarz's introduction of its low phase noise R&S SMA100A signal generator - the predecessor of the R&S SMA100B - nearly a decade ago has helped us evaluate, test and specify our world-class A/D converters to their maximum capabilities," said Ron Goga, Test Director of High Speed A/D Converters, Analog Devices, Inc.

The R&S SMA100B is also the perfect choice for a clock source when characterizing DACs. The generator's extremely low phase noise produces minimal signal jitter that does not influence the measurement results for the DACs.

The R&S SMA100B has a powerful pulse modulator and generates pulses with extremely short rise and fall times and an on/off ratio below 90 dB. State-of-the-art digital, high-precision automatic level control (ALC) ensures that the absolute top power levels of narrow pulses are output in a highly accurate, reproducible manner. Closed loop level control is available for pulse widths starting at 100 ns. These characteristics make it possible to test advanced radar receivers with unmatched accuracy under demanding pulse scenario conditions.

Extremely pure local oscillator signals are often required to verify system performance before the overall integration of a radar system can take place. The R&S SMA100B is the ideal solution, as it can provide high-level signals with extremely low, close-in phase noise (10 GHz, -83 dBc/Hz, 10 Hz offset).

A base station receiver's selectivity is evaluated by several criteria, including how well it suppresses strong interferers. When simulating in-band or out-of-band interferers with the R&S SMA100B, the instrument's ultra low phase noise option of the instrument ensures that phase noise and wideband noise from the simulated interferer have a minimal impact on the wanted signal. It is through the excellent signal quality of the R&S SMA100B that a base station's true interference suppression performance can be demonstrated (e.g. wideband noise at 10 GHz is below -160 dBc/Hz at 30 MHz offset).

The ultra high output power option enables the R&S SMA100B to provide up to 38 dBm of output power, eliminating the need for external amplifiers in automated test environments. With its integrated, wear-free electronic step attenuators now standard also in the 20 GHz instruments, Rohde & Schwarz is maximizing the operational life of test systems even with millions of level switching cycles, while ensuring zero wear on the instrument. This solution also offers extremely fast level setting times for the first time ever in a microwave signal generator.

The R&S SMA100B is included in the R&S Legacy Pro program and can easily replace obsolete signal generators from Rohde & Schwarz and other manufacturers in automated test environments without the need to modify test software.

For further information, go to: www.rohde-schwarz.com/ad/press/purest-signal.

Testing of Coriolis Meters for Density Measurement Helping Industry to Innovate

May 11, 2017 - During May, calibration will start on an innovative range of Coriolis meters for one of the leading manufacturers in this field. The project highlights NEL's test capabilities and the work the lab is doing to help industry make the transition to the use of Coriolis technology, which provide both direct measurement of mass flow and density in a single device.

"The testing will focus on the density output of the meters," says Principal Consultant, Dr Norman Glen. "Through our Densitometer Calibration Facility we have a very accurate knowledge of our test fluids, so we can check the density performance of a wide range of Coriolis meters, including twin-tubed Coriolis-based devices."

"We are getting an increase in requests of this type," Norman adds. "This highlights the fact that more and more companies are using Coriolis meters to replace flow measurement systems that have separate volumetric flow rate and density measuring elements."

Norman explains that Coriolis meters can give highly accurate measurements of both mass flow and density, if properly calibrated. This enables a single device to provide a determination of mass flows for production reporting and allocation plus flow volumes for applications such as pipe-line tariff calculations.

NEL recently completed a Joint Industry Project (JIP) that investigated the effects of temperature, pressure and viscosity on commercially available Coriolis meters. "This showed us that there are pressure-dependent effects on flow rate measurement," Norman says. "We are now working to get a better understanding of corresponding effects on density measurement at extended temperatures and pressures."

This requirement has been highlighted by ongoing developments to NEL facilities. "To improve the performance of our Wet-Gas Flow Facility, we have been undertaking calibration of the density outputs of our own reference Coriolis meters that we use on the facility," Norman says. "We needed high accuracy density data to enable us to account for cross-contamination from our three-phase separator, as the standard manufacturer-supplied calibrations were not accurate enough for our requirements. In addition to providing such information for internal use, we are now able to offer this as a service to customers."

Source: http://www.tuvnel.com/news/testing_of_coriolis_meters_for_density_measurement_helping_industry_to_inno

Crystal Engineering XP2i Pressure Gauges with Calibration Due Alert

Pressure gauges are used throughout the gas industry for testing and calibrating various instruments. These gauges require periodic calibration to assure their accuracy. Regulatory authorities require routine testing and/or audits of gas systems, which can entail fines for non-compliance. By choosing XP2i digital pressure gauges from Crystal Engineering, costly fines can be prevented with the help of automatic built-in calibration alerts and reminders.

Test gauges are used as the standards for calibrating and testing important equipment used every day. The accuracy of these test gauges can decline over time, and, therefore, they must be regularly calibrated to remain accurate.

Keeping track of the calibration intervals for all test equipment can be a challenging task in which human error can occur. Calibration certificates or stickers can be misplaced or lost, or the technician may not notice that the gauge is beyond its calibration dates. Even if a company has a system to keep track of these dates, it still requires somebody to notify the technician when re-calibrations are due. It also requires the technician to remove the gauge from service once they are notified.

Each of these situations requires human intervention to assure that products are not used outside of their calibration intervals. If mistakes are made, a company could end up using a gauge to test important equipment when they shouldn't be. This could lead to failed audits and costly fines.

Crystal Engineering offers a solution to replace manual record keeping and notifications, with automatic, protected alerts and notifications. The XP2i pressure gauges contains three new features:

1. on-screen customizable calibration reminder alerts prior to the due date,
2. warning alerts on and after the due date, and
3. an optional feature to lock the gauge from use on the calibration due date.

Using free software, users, supervisors, or labs can set a calibration date in the internal memory of the gauge. The due dates, reminder times, and message types can all be customized through the software.

For a start-up reminder, users enter the calibration due date and the notification time prior to that date, which can be set in days or weeks. Once the defined prior to date is reached, the XP2i flashes "Cal Soon" three times during the start-up process and will do that until the calibration due date has been reached, or the alert dates are updated.

Once the calibration due date has been reached, the XP2i has three alert options:

- Gauge Start-up: "Cal Due" flashes three times during the start-up process and the gauge will then operate normally. No additional warnings will occur until the power is recycled on the gauge.
- Always: "Cal Due" is displayed until a button is pressed, and then the gauge operates normally. After that, no additional warnings occur until power is recycled. Password Protection can be added to make the gauge non-operational and always display "Cal Due."
- Alternate with Reading: "Cal Due" flashes three times during the start-up process and then alternates displaying "Cal Due" with live pressure readings.

With increased attention of environmental issues surrounding the oil and gas industry, pressure on businesses and audits have never been higher. A system that relies on human intervention can always be intentionally or unintentionally circumvented. An automatic product based system, which can easily be set-up by managers or supervisors, is much preferred.

Crystal Engineering's XP2i is already the most common gauge used in the oil & gas industry. This new feature now makes the new XP2i even more desirable. If it prevents a company from using it after its calibration date even one time, it has already paid for itself. The new XP2i has been shipping since January of 2017. In fact, Crystal Engineering worked with one of the largest oil & gas companies in the USA when designing the new features. This company has already standardized and implemented the new XP2i throughout.

Crystal Engineering, based in San Luis Obispo, CA, produces highly accurate, field-grade testing and calibration equipment for measurement applications in offshore drilling, oil refineries, gas distribution, power generation, nuclear power, pharmaceutical, waste water, water supply, and aircraft maintenance.

Crystal Engineering is a unit of AMETEK Test & Calibration Instruments, a division of AMETEK, Inc. For more information, contact Crystal Engineering: 1-(800)-444-1850. Or visit ametekcalibration.com/products/digital-pressure-gauges.

SAO/CMC Editor & Search Tools

Michael Schwartz
Cal Lab Solutions, Inc.

Over the past four years, we at Cal Lab Solutions have been heads-down coding and designing new features for Metrology.NET®. Our goal has been to Make Metrology Better! The key members of our team are largely comprised of crusty old calibration techs with strong backgrounds in software and metrology. We, as a collective whole, want to leave a lasting mark on the industry.

About two years ago, Dave Zajac, one of my most gifted programmers, hit me with the idea of creating a XML based SOA (Scope-Of-Accreditation) database that was designed to be machine-readable. His idea addresses a fundamental deficiency plaguing the industry today: most scopes of accreditation leave a large amount of information up to interpretation.

Dave said "There is a better way!" and he explained to me the work he did at the U.S. Army Primary Lab. Listening to his ideas and thoughts, I agreed and said we should wrap all of this up into the Metrology.NET standards. My immediate thought was to use the technology to check every single measurement uncertainty calculation against a lab's SOA. This would be a great tool for use inside the lab, because I have had three customers ask me for a tool similar to what this tool can do.

Additionally, I could see the SOA database used as an aggregation search tool for both *CAL LAB* magazine and Metrology.NET. Many years ago, Carol Singer (*CAL LAB* publisher, 1995-2010) kept a list of all the calibration companies around the world with their capabilities, but she had to stop because it was too time consuming for one person to keep up the list. With this tool, calibration labs can simply upload their information to the website and be instantly added to a Calibration Lab Search page.

In 2016, Dave wrote and presented a technical paper for NCSLI on "Creating a Standardized Schema for Representing ISO/IEC 17025 Scope of Accreditations in XML Data." The paper details his initial ideas on how the schema should be designed and its overall functionality. View the paper at http://www.metrology.net/creating-a-standardized-schema-for-representing-isoiec-17025-scope-of-accreditations-in-xml-data/.

Mark Kuster and other NCSLI Members read Dave's paper and Mark thought its vision seemed to mirror his own of a larger MII (Metrology Information Infrastructure), so an adhock NCSLI group was formed and we held a small group meeting at NCSLI 2016 to show the members our plans for the coming year.

The MII group has been working together for more than a year now, and for an all-volunteer group, we are making amazing progress. It has vetted and improved Dave's original schema, and Dave's presentation at NCSLI later this year will highlight these enhancements and the reasoning behind their implementation.

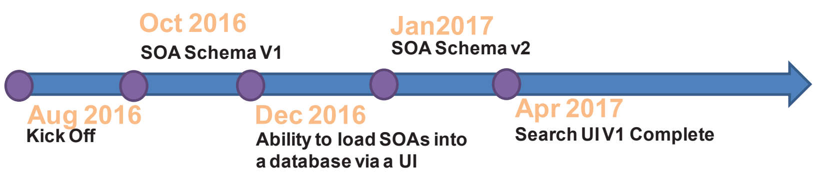
Meanwhile, Kyle Massa with Cal Lab Solutions is working to build out the Units of Measure database. Colin Walker's team at Qualer has entered over 50,000 CMCs from 550+ companies into an intermediate database that could be used to build SOA databases, or at the very least, be used as examples on how to enter data using the editor.

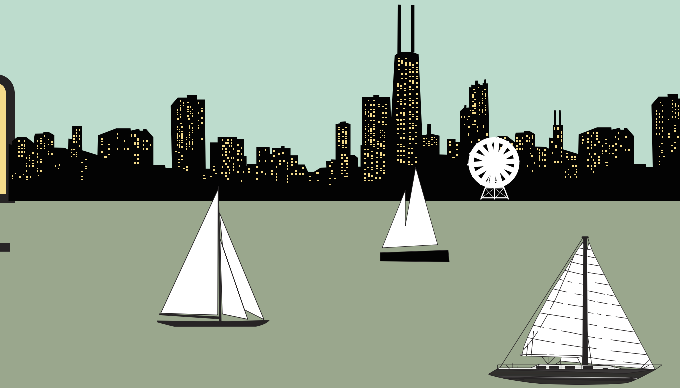
Mark Kuster with Pantex has been working with NCSLI setting up presentations, finding meeting space, and promoting the progress of the MII groups progress in *Metrologist®*, a NCSLI publication. And earlier this year, the group did a presentation at MSC (Measurement Science Conference) Training Symposium, highlighting the progress we have made in terms of search. Colin's presentation showed how the current state of the software allowed a user to perform a basic search on data within several SOAs. See it for yourself at http://beagledev.azurewebsites.net/ .

After the MSC presentations, the MII Group received many questions and input from the show's attendees. We walked away with increased enthusiasm from the acceptance of the technology and realization of its real world needs.

This year at NCSLI, National Harbor, MD, we plan to debut the beta version of our CMC editor to the world. This editor will be freely available to calibration labs and accreditation bodies around the world. Right now we are looking for early adopters—talented individuals who would enjoy using a beta product and providing feedback to the MII Group and development team.

Those interested can email me at mschwartz@callabsolutions.com or join us in August at the next MII Group meeting at NCSLI 2017 Workshop & Symposium, where we will be holding a panel discussion, a paper presentation and a working meeting. Details at http://www.ncsli.org/. ❧





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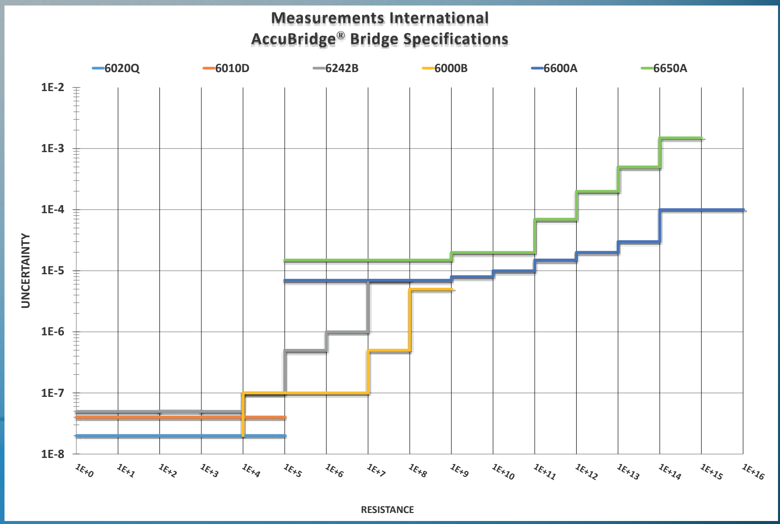

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