CAL LAB

THE INTERNATIONAL JOURNAL OF METROLOGY

2019
JULY
AUGUST
SEPTEMBER

Pass or Fail: With Which Probability?

Aircraft and Truck Scale Calibration

Electric Current Measurement

DS Series Current Transducers

DANISENSE

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

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

DS200

DS2000

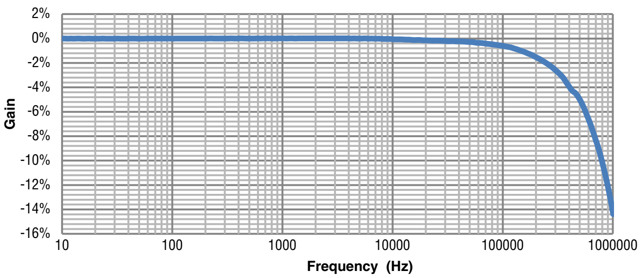
	DS200	DS600	DS2000	DS5000
Primary Current, rms	200A	600A	2000A	5000A
Primary Current, Peak	±300A	±900A	±3000A	±7000A
Turns Ratio	500:1	1500:1	1500:1	2500:1
Output Signal (rms/Peak)	0.4A/±0.6A†	0.4A/±0.6A†	1.33A/±2A†	2A/±3.2A†
Overall Accuracy	0.01%	0.01%	0.01%	
Offset	<20ppm	<10ppm	<10ppm	<5ppm
Linearity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

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

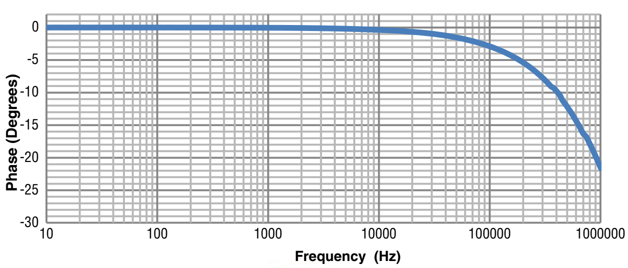
† Voltage Output options available in ±1V and ±10V

Gain / Phase

Gain (DS200, typical)



Phase (DS200, typical)



DSSIU-4 for Multi Channel Systems

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

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

DSSIU-4

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FEATURES

DEPARTMENTS

ON THE COVER: A technician is repairing a PCB at the 1A CAL GmbH facility in Kassel, Germany.

CALENDAR

UPCOMING CONFERENCES & MEETINGS

Oct 22-25, 2019 North Sea Flow Measurement Workshop. Tonsberg, Norway. Running for over 30 years and alternating between the UK and Norway, the North Sea Flow Measurement Workshop combines presentations, discussion sessions and exhibition areas. It is the single most important event in the Flow measurement calendar. https://www.tekna.no/en/events/37th-international-north-sea-flow-measurement-workshop-37344/

Oct 28-Nov 1, 2019 ASPE 34th Annual Meeting. Pittsburgh, PA. The American Society for Precision Engineering holds its Annual Meeting in the fall of each year. http://aspe.net/technical-meetings/

Nov 5-7, 2019. 3DMC. London. The 3D Metrology Conference is dedicated to the application and development of 3D measurement technology for industrial, scientific and cultural purposes. https://www.3dmc.events/

Nov 12-13, 2019 ICEM 2019. Venice, Italy. The International Conference on Electromagnetic Metrology aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Electromagnetic Metrology. It also provides a premier interdisciplinary platform for researchers, practitioners and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of Electromagnetic Metrology. https://waset.org/conference/2019/11/venice/ICEM

Dec 2-3, 2019 ICOMA 2019. Sydney, Australia. The International Conference on Optical Metrology and Applications aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Optical Metrology and Applications. https://waset.org/optical-metrology-and-applications-conference-in-december-2019-in-sydney

Dec 12-13, 2019 ICMI 2019. Rome, Italy. The International Conference on Metrology and Inspection aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Metrology and Inspection. It also provides a premier interdisciplinary platform for researchers, practitioners and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of Metrology and Inspection. https://waset.org/conference/2019/12/rome/ICMI

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EDITOR'S DESK

World Order

It was a busy summer for humans. Politics has been cruel and over the top. Climate change and power grid management is up-ending business as usual. The world is just not the same and expectations are just that—expectations. For my own personal crisis, I am to suffer through two Microsoft Windows 10 updates and Cybersecurity Maturity Model Certification (CMMC). For those readers who must suffer the same… I am so there with you!

Our publisher attended two different measurement shows in Europe this year, Metrology for Industry 4.0 & IoT in Naples and CIM in Paris—though, he wished he could have attended more! There were familiar faces and familiar challenges as well. I've brought this up before, but I want to bring it up again as the world moves into chaos—units of measurement must be standardized for machines and the IoT. "When machines are given common definitions specific to each category of measurement, we can use machines to communicate across industries and disciplines worldwide."* To make this work, parties from different manufacturers and NMIs, around the globe, must create a better and more concise industry standard. Visit http://miiknowledge.wikidot.com/.

For this issue, we have "Pass or Fail: With Which Probability?" kindly contributed by Manuel Rodríguez of the Instituto Nacional de Técnica Aeroespacial (INTA) in Madrid, Spain, in which he aims to express the results of Pass or Fail tests in terms of probability.

And, Henry Zumbrun of Morehouse contributed an article on "Aircraft and Truck Scale Calibration," in which he also addresses Calibration and Measurement Capability uncertainty of measurement. Congratulations to Henry for winning the Best Paper Award at the NCSLI Workshop & Symposium this past August in Cleveland, Ohio!

We are grateful to all our contributors, who make possible our being able to share the knowledge with you.

Happy Measuring,

Sita Schwartz
Editor

*From the Oct-Dec 2018 issue, "Rules & Tools for Creating a Metrology Taxonomy."

CALENDAR

Jan 26-29, 2020 94th ARFTG Microwave Measurement Conference. San Antonio, TX. The topic of this conference is "RF to Millimeter-Wave Measurement Techniques for 5G and Beyond." ARFTG is co-locating with Radio Wireless Week for this conference. https://www.arftg.org/

Feb 14-15, 2020 ICMAMSA 2020. Havana, Cuba. International Conference on Metrology for Aerospace and Monitoring Systems in Aerospace aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Metrology for Aerospace and Monitoring Systems in Aerospace. It also provides a premier interdisciplinary platform for researchers, practitioners and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of Metrology for Aerospace and Monitoring Systems in Aerospace. https://waset.org/conference/2020/02/Havana/ICMAMSA

Feb 24-26, 2020 NCSLI Technical Exchange Measurement Training. Houston, TX. https://www.ncsli.org/te

Feb 26-28, 2020 METROMEET. Bilbao, Spain. During the 16th International Conference on Industrial Dimensional Metrology (METROMEET), we provide information about the latest technological, the progress made in the sector and we constitute a forum for debate on metrology and its development in a fast changing industry. https://metromeet.org/

Mar 3-5, 2020 MSA 2020. Melbourne, VIC, Australia. The Conference of the Metrology Society of Australasia is held biennially. https://www.metrology.asn.au/msaconnected/events-menu/msa2020-melbourne

Mar 24-27, 2020 MSC Training Symposium. Anaheim, CA. Since 1970, MSC has been an international leader in leader in promoting educational training in the measurement and metrology communities. https://msc-conf.com/

May 4-5, 2020 ICMRMA 2020. Rome, Italy. International Conference on Metrology and Relativistic Metrology for Aerospace aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Metrology and Relativistic Metrology for Aerospace. It also provides a premier interdisciplinary platform for researchers, practitioners and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of Metrology and Relativistic Metrology for Aerospace. https://waset.org/conference/2020/05/rome/ICMRMA

SEMINARS: Dimensional

Nov 7-8, 2019 Gage Calibration and Repair. Clearwater Beach, FL. IICT Enterprises. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. This course includes "HANDS-ON" calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. https://www.iictenterprisesllc.com/schedule

Oct 28, 2019 Dimensional Measurement User. Telford, UK. NPL. A three day training course introducing measurement knowledge focusing upon dimensional techniques. This course is delivered by Hexagon Metrology Ltd., NPL Approved Training Provider. https://www.npl.co.uk/training

Oct 29, 2019 Dimensional Measurement User. Huddersfield, UK. NPL Training. A three day training course introducing measurement knowledge focusing upon dimensional techniques. https://www.npl.co.uk/training

Nov 11-12, 2019 Gage Calibration and Repair. Atlanta, GA. IICT Enterprises. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. This course includes "HANDS-ON" calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. https://www.iictenterprisesllc.com/schedule

Nov 12, 2019 Dimensional Measurement User. Bristol, UK. NPL. A three day training course introducing measurement knowledge focusing upon dimensional techniques. This course is delivered by INSPHERE Ltd, NPL Approved Training Provider. https://www.npl.co.uk/training

Nov 12-14, 2019 Gage Calibration Methods. Cincinnati, OH. QC Training. This 3-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Attendees will be equipped with the knowledge to meet current and future calibration needs, be prepared to save the company money on calibrations and grow professionally. https://qctraininginc.com/course/gage-calibration-methods-3-day/

Nov 18, 2019 Dimensional Measurement User. Telford, UK. NPL. A three day training course introducing measurement knowledge focusing upon dimensional techniques. This course is delivered by Hexagon Metrology Ltd., NPL Approved Training Provider. https://www.npl.co.uk/training

CALENDAR

Nov 19-20, 2019 Dimensional Measurement with CMMs, Vision and Form Instruments. Chicago Area, IL. Mitutoyo. This 2-day classroom course is designed for anyone using advanced dimensional measuring systems, such as coordinate measuring machines (CMMs), vision systems, roundness testers, and surface finish measuring instruments. https://www.mitutoyo.com/online-training/

Nov 20-21, 2019 Gage Calibration and Repair. Minneapolis, MN. IICT Enterprises. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. This course includes "HANDS-ON" calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. https://www.iictenterprisesllc.com/schedule

Nov 21, 2019 Dimensional Metrology Quality. Chicago Area, IL. Mitutoyo. This 1-day course focuses on measurement quality – including how to understand and assess the errors in dimensional measuring systems. The primary topic of this course is Gage Repeatability and Reproducibility (Gage R&R), a common tool to study variation in measuring systems. https://www.mitutoyo.com/online-training/

Dec 4-6, 2019 Gage Calibration. Chicago Area, IL. Mitutoyo America's 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. https://www.mitutoyo.com/online-training/

Dec 9-11, 2019 Dimensional Measurement User. Telford, UK. NPL. A three day training course introducing measurement knowledge focusing upon dimensional techniques. This course is delivered by Hexagon Metrology Ltd., NPL Approved Training Provider. https://www.npl.co.uk/training

Dec 10-11, 2019 Gage Calibration and Repair. Altoona, WI. IICT Enterprises. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. This course includes "HANDS-ON" calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. https://www.iictenterprisesllc.com/schedule

Dec 10, 2019 Dimensional Measurement Applier. Bristol, UK. NPL. A four day training course for those who have a good basic understanding of measurement principles gained through the Dimensional Measurement User training course, delivered by INSPHERE Ltd, NPL Approved Training Provider. https://www.npl.co.uk/training

Jan 8-9, 2020 Gage Calibration and Repair. Madison, WI. IICT Enterprises. This 2-day hands-on workshop offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. This course includes "HANDS-ON" calibration and repairs and adjustments of micrometers, calipers, indicators height gages, etc. https://www.iictenterprisesllc.com/schedule

Feb 4, 2020 Dimensional Measurement User. Coventry, UK. NPL. A three day training course introducing measurement knowledge focusing upon dimensional techniques. This course is delivered by Coventry University, NPL Approved Training Provider. https://www.npl.co.uk/training

Mar 9, 2020 Dimensional Measurement Applier. Coventry, UK. NPL. A four day training course for those who have a good basic understanding of measurement principles gained through the Dimensional Measurement User training course, delivered by Coventry University, NPL Approved Training Provider. https://www.npl.co.uk/training

May 27-28, 2020 Dimensional Measurement. Port Melbourne, VIC, Australia. NMI. This two-day course (9 am to 5 pm) presents a comprehensive overview of the fundamental principles in dimensional metrology and geometric dimensioning and tolerancing. https://www.industry.gov.au/client-services/training-and-assessment

SEMINARS: Electrical

Oct 21-24, 2019 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. The student will be competent to make measurements after passing the final exam. https://us.flukecal.com/training/electrical-calibration-training/met-101-basic-hands-metrology

Feb 24-27, 2020 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. The student will be competent to make measurements after passing the final exam. https://us.flukecal.com/training/electrical-calibration-training/met-101-basic-hands-metrology

Mar 17, 2020 Traceable Electrical Energy Metering Workshop. Lower Hutt. Measurement Standards Laboratory of New Zealand. Offered on 17th and 18th March 2020. This course is focused on understanding the steps required to make traceable measurements, and will include training in the calculation of measurement uncertainties. https://measurement.govt.nz/training/

Apr 20-12, 2020 MET-301 Advanced Hands-On Metrology. Everett, WA. This course introduces the student to advanced measurement concepts and math used in standards laboratories. The student will learn how to make various types of measurements using different measurement methods. We will also teach techniques for making good high precision measurements using reference standards. https://us.flukecal.com/training

SEMINAR: Flow

Nov 4-7, 2019 Gas Flow Calibration Using molbloc/molbox. Phoenix, AZ. Fluke Calibration. A four day training course in the operation and maintenance of a Fluke Calibration molbloc/molbox system. The course's central objective is to assure optimum system use. https://us.flukecal.com/training/flow-calibration-training/gas-flow-calibration-using-molblocmolbox

Feb 4-7, 2020 Gas Flow Calibration Using molbloc/molbox. Phoenix, AZ. Fluke Calibration. A four day training course in the operation and maintenance of a Fluke Calibration molbloc/molbox system. The course's central objective is to assure optimum system use. https://us.flukecal.com/training/flow-calibration-training/gas-flow-calibration-using-molblocmolbox

SEMINARS: General

Nov 21, 2019 Calibration and Measurement Fundamentals. Port Melbourne VIC, Australia. NMI. This one-day fully interactive course (9 am to 5 pm) covers general metrological terms, definitions and explains practical concept applications involved in calibration and measurements. The course is recommended for technical officers and laboratory technicians working in all industry sectors who are involved in making measurements and calibration process. https://www.industry.gov.au/client-services/training-and-assessment

Feb 3-7, 2020 5607: Fundamentals of Metrology. Gaithersburg, MD. NIST. The 5 day Fundamentals of Metrology seminar is an intensive course that introduces participants to the concepts of measurement systems, units, good laboratory practices, data integrity, measurement uncertainty, measurement assurance, traceability, basic statistics and how they fit into a laboratory Quality Management System. https://www.nist.gov/news-events/events/2020/02/5607-fundamentals-metrology

Feb 10-14, 2020 5608: Fundamentals of Metrology. Gaithersburg, MD. NIST. The 5 day Fundamentals of Metrology seminar is an intensive course that introduces participants to the concepts of measurement systems, units, good laboratory practices, data integrity, measurement uncertainty, measurement assurance, traceability, basic statistics and how they fit into a laboratory Quality Management System. https://www.nist.gov/news-events/events/2020/02/5608-fundamentals-metrology

Mar 5, 2020 Calibration and Measurement Fundamentals. Lindfield, NSW, Australia. NMI. This one-day fully interactive course (9 am to 5 pm) covers general metrological terms, definitions and explains practical concept applications involved in calibration and measurements. The course is recommended for technical officers and laboratory technicians working in all industry sectors who are involved in making measurements and calibration process. https://www.industry.gov.au/client-services/training-and-assessment

Apr 23, 2020 Calibration and Measurement Fundamentals. Edwardstown, SA, Australia. NMI. This one-day fully interactive course (9 am to 5 pm) covers general metrological terms, definitions and explains practical concept applications involved in calibration and measurements. The course is recommended for technical officers and laboratory technicians working in all industry sectors who are involved in making measurements and calibration process. https://www.industry.gov.au/client-services/training-and-assessment

SEMINARS: Industry Standards

Oct 23, 2019 ISO/IEC 17025:2017 Bridging the Gap from 2005. Minneapolis, MN. QC Training. ISO/IEC 17025:2017 Bridging the Gap from 2005 is a one-day course that gives an overview of the changes made to ISO/IEC 17025 in its latest revision. In this course, the participant will become aware of the significant and subtle changes to existing ISO/IEC 17025 laboratory system, as well as the necessary steps to ensure conformity to the new Standard. https://qctraininginc.com/course/iso-iec-170252017-bridging-gap-2005/

Oct 24, 2019 ISO/IEC 17025:2017 Bridging the Gap from 2005. Frederick, MD. QC Training. ISO/IEC 17025:2017 Bridging the Gap from 2005 is a one-day course that gives an overview of the changes made to ISO/IEC 17025 in its latest revision. In this course, the participant will become aware of the significant and subtle changes to existing ISO/IEC 17025 laboratory system, as well as the necessary steps to ensure conformity to the new Standard. https://qctraininginc.com/course/iso-iec-170252017-bridging-gap-2005/

Oct 28-29, 2019 ISO/IEC 17025:2017 The New Standard for Laboratory Competence (MS 111). Portland, OR. A2LA. This course is a comprehensive review of the philosophies and requirements of this international Standard. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2la.org/events

Nov 5-6, 2019 ISO/IEC 17025:2017 The New Standard for Laboratory Competence (MS 111). Las Vegas, NV. A2LA. This course is a comprehensive review of the philosophies and requirements of this international Standard. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2la.org/events

Nov 12-13, 2019 ISO/IEC 17025:2017 The New Standard for Laboratory Competence (MS 111). Miami, FL. A2LA. This course is a comprehensive review of the philosophies and requirements of this international Standard. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2la.org/events

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Nov 11-13, 2019 Internal Auditing to ISO/IEC 17025:2017. New York, NY. 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 of this course will learn how to coordinate a quality management system audit to ISO/IEC 17025:2017 and collect audit evidence and document observations, including techniques for effective questioning and listening. https://www.anab.org/training

Nov 13-14, 2019 ISO/IEC 17025:2017 The New Standard for Laboratory Competence (MS 111). Atlanta, GA. A2LA. This course is a comprehensive review of the philosophies and requirements of this international Standard. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2la.org/events

Nov 20, 2019 ISO/IEC 17025:2017 Bridging the Gap from 2005. Phoenix, AZ. QC Training. ISO/IEC 17025:2017 Bridging the Gap from 2005 is a one-day course that gives an overview of the changes made to ISO/IEC 17025 in its latest revision. In this course, the participant will become aware of the significant and subtle changes to existing ISO/IEC 17025 laboratory system, as well as the necessary steps to ensure conformity to the new Standard. https://qctraininginc.com/course/iso-iec-170252017-bridging-gap-2005/

Nov 18-20, 2019 Internal Auditing to ISO/IEC 17025:2017. Cincinnati, OH. 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 of this course will learn how to coordinate a quality management system audit to ISO/IEC 17025:2017 and collect audit evidence and document observations, including techniques for effective questioning and listening. https://www.anab.org/training

Dec 3-4, 2019 ISO/IEC 17025:2017 The New Standard for Laboratory Competence (MS 111). Waltham, MA. A2LA. This course is a comprehensive review of the philosophies and requirements of this international Standard. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2la.org/events

Dec 9-10, 2019 ISO/IEC 17025:2017 for Testing and Calibration Labs. Brea, CA. IAS. This 2-day Training Course examines structural components of the standard. Quality system and technical requirements are grouped in a manner that makes them clear and understandable. Technical considerations include traceability of measurement and estimations of uncertainty. Quality system discussions include easy-to-understand approaches (with sample forms provided) for continual improvement (risk based thinking) and handling of customer feedback. https://www.iasonline.org/training/testing-cal-labs/

Dec 9-10, 2019 ISO/IEC 17025:2017 The New Standard for Laboratory Competence (MS 111). Las Vegas, NV. A2LA. This course is a comprehensive review of the philosophies and requirements of this international Standard. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2la.org/events

Dec 11, 2019 ISO/IEC 17025:2017 Bridging the Gap from 2005. Frederick, MD. QC Training. ISO/IEC 17025:2017 Bridging the Gap from 2005 is a one-day course that gives an overview of the changes made to ISO/IEC 17025 in its latest revision. In this course, the participant will become aware of the significant and subtle changes to existing ISO/IEC 17025 laboratory system, as well as the necessary steps to ensure conformity to the new Standard. https://qctraininginc.com/course/iso-iec-170252017-bridging-gap-2005/

Dec 16-17, 2019 ISO/IEC 17025:2017 The New Standard for Laboratory Competence (MS 111). Frederick, MD. A2LA. This course is a comprehensive review of the philosophies and requirements of this international Standard. The participant will gain an understanding of conformity assessment using the risks and opportunities-based approach. https://www.a2la.org/events

SEMINARS: Mass

Mar 9-20, 2020 5609: Mass Metrology Seminar. Gaithersburg, MD. NIST. The Mass Metrology Seminar is a 2 week, "hands-on" seminar. It incorporates approximately 30 percent lectures and 70 percent demonstrations and laboratory work in which the trainee performs measurements by applying procedures and equations discussed in the classroom. https://www.nist.gov/news-events/events/2020/03/5609-mass-metrology-seminar

SEMINARS: Measurement Uncertainty

Oct 22-25, 2019 ISO GUM Measurement Uncertainty Analyst Class. Fenton, MI. Quametec. This course is ideal for the training of anyone needing to meet the measurement uncertainty analysis and measurement quality management requirements associated with ISO/IEC17025 and Z540.3. This course is presented in a manner which is suitable for entry level to senior calibration, testing and inspection technicians; metrologists, engineers, and scientists from any discipline. https://www.qimtonline.com/

Nov 6, 2019 Introduction to Measurement Uncertainty. Frederick, MD. A2LA. This course is a suitable introduction for both calibration and testing laboratory participants, focusing on the concepts and mathematics of the measurement uncertainty evaluation process. https://www.a2la.org/events

Nov 14-15, 2019 Fundamentals Measurement Uncertainty. New York, NY. ANAB. Attendees of this two-day training course will learn a practical approach to measurement uncertainty applications, based on fundamental practices. https://www.anab.org/training

Nov 20, 2019 Introduction to Estimating Measurement Uncertainty. Port Melbourne, Australia. NMI. This one-day course (9 am to 5 pm) will give you a clear step-by-step approach to uncertainty estimation with practical examples; you will learn techniques covering the whole process from identifying the sources of uncertainty in your measurements right through to completing the uncertainty budget. https://www.industry.gov.au/client-services/training-and-assessment

Nov 21-22, 2019 Fundamentals Measurement Uncertainty. Cincinnati, OH. ANAB. Attendees of this two-day training course will learn a practical approach to measurement uncertainty applications, based on fundamental practices. https://www.anab.org/training

CALENDAR

Nov 28, 2019 Introduction to Estimating Measurement Uncertainty. Malaga WA, Australia. NMI. This one-day course (9 am to 5 pm) will give you a clear step-by-step approach to uncertainty estimation with practical examples; you will learn techniques covering the whole process from identifying the sources of uncertainty in your measurements right through to completing the uncertainty budget. https://www.industry.gov.au/client-services/training-and-assessment

Dec 3, 2019 Introduction to Estimating Measurement Uncertainty. Lindfield, NSW, Australia. NMI. This one-day course (9 am to 5 pm) will give you a clear step-by-step approach to uncertainty estimation with practical examples; you will learn techniques covering the whole process from identifying the sources of uncertainty in your measurements right through to completing the uncertainty budget. https://www.industry.gov.au/client-services/training-and-assessment

Dec 11, 2019 Introduction to Measurement Uncertainty. Frederick, MD. A2LA. This course is a suitable introduction for both calibration and testing laboratory participants, focusing on the concepts and mathematics of the measurement uncertainty evaluation process. https://www.a2la.org/events

Dec 11-12, 2019 Uncertainty of Measurement for Labs. Brea, CA. IAS. Introduction to metrology principles, examples and practical exercises. The training includes case studies and discussions, with application of statistical components in practical examples that are frequently encountered by testing laboratories. https://www.iasonline.org/training/uncertainty-of-measurement/

Feb 27, 2020 Introduction to Estimating Measurement Uncertainty. Brisbane, QLD, Australia. NMI. This one-day course (9 am to 5 pm) will give you a clear step-by-step approach to uncertainty estimation with practical examples; you will learn techniques covering the whole process from identifying the sources of uncertainty in your measurements right through to completing the uncertainty budget. https://www.industry.gov.au/client-services/training-and-assessment

SEMINARS: Photometry & Radiometry

Nov 27-28, 2019 Photometry and Radiometry Measurement. Lindfield NSW, Australia. NMI. This two-day course (9 am to 5 pm) covers the broad range of equipment and techniques used to measure color and light output, the basic operating principles involved in radiometry, working techniques, potential problems and their solutions. https://www.industry.gov.au/client-services/training-and-assessment

SEMINARS: Pressure

Jan 13-17, 2020 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. https://us.flukecal.com/training/

Mar 9-13, 2020 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. https://us.flukecal.com/training/

Apr 20-24, 2020 Advanced Piston Gauge Metrology. Phoenix, AZ. Fluke Calibration. Focus is on the theory, use and calibration of piston gauges and dead weight testers. https://us.flukecal.com/training/

SEMINARS: Software

Nov 5-7, 2019 VNA Tools training course. Bern-Wabern, Switzerland. Federal Institute of Metrology METAS. VNA Tools is free software developed by METAS for measurements with the Vector Network Analyzer (VNA). The software facilitates the tasks of evaluating measurement uncertainty in compliance with the ISO-GUM and vindicating metrological traceability. The software is available for download at www.metas.ch/vnatools. The three day course provides a practical and hands-on lesson with this superior and versatile software. https://www.metas.ch/metas/en/home/fabe/hochfrequenz/vna-tools.html

Nov 11-15, 2019 MC-206 Basic MET/CAL® Procedure Writing. Everett, WA. Fluke Calibration. In this five-day basic MET/CAL procedure writing course, you will learn to configure MET/CAL software to create, edit, and maintain calibration solutions, projects and procedures. http://us.flukecal.com/training

Nov 18-22, 2019 TWB 1051 MET/TEAM® Basic Web-Based Training. Fluke Calibration. This web-based course presents an overview of how to use MET/TEAM Test Equipment and Asset Management Software in an Internet browser to develop your asset management system. You will learn a systematic approach to recording the information you need to manage your lab assets routinely, consistently and completely. http://us.flukecal.com/training

Feb 10-14, 2020 TWB 1051 MET/TEAM® Basic Web-Based Training. Fluke Calibration. This web-based course presents an overview of how to use MET/TEAM Test Equipment and Asset Management Software in an Internet browser to develop your asset management system. You will learn a systematic approach to recording the information you need to manage your lab assets routinely, consistently and completely. http://us.flukecal.com/training

Mar 9-13, 2020 MC-206 Basic MET/CAL® Procedure Writing. Everett, WA. Fluke Calibration. In this five-day basic MET/CAL procedure writing course, you will learn to configure MET/CAL software to create, edit, and maintain calibration solutions, projects and procedures. http://us.flukecal.com/training

Apr 27-May 1, 2020 TWB 1051 MET/TEAM® Basic Web-Based Training. Fluke Calibration. This web-based course presents an overview of how to use MET/TEAM Test Equipment and Asset Management Software in an Internet browser to develop your asset management system. You will learn a systematic approach to recording the information you need to manage your lab assets routinely, consistently and completely. http://us.flukecal.com/training

May 4-8, 2020 TWB 1031 MET/CAL® Procedure Development Web-Based Training. Fluke Calibration. Learn to create procedures with the latest version of MET/CAL, without leaving your office. This web seminar is offered to MET/CAL users who need assistance writing procedures but have a limited travel budget. https://us.flukecal.com/training

May 11-15, 2020 MC-207 Advanced MET/CAL® Procedure Writing. Everett, WA. Fluke Calibration. A five-day procedure writing course for advanced users of MET/CAL® calibrations software. https://us.flukecal.com/training/

SEMINARS: Temperature & Humidity

Nov 18, 2019 Temperature Measurement and Calibration (with optional practical day). Teddington, UK. NPL. This is a 2-3 day course, covering the range –200 °C to 3000 °C, the course will concentrate on those methods of measurement which are of greatest technological and industrial importance. https://training.npl.co.uk/

Nov 21, 2019 Humidity Measurement and Calibration. Teddington, UK. NPL. This is a 2 day course covering dew point, relative humidity and other humidity quantities, the course will concentrate on methods of measurement which are of greatest technological relevance to attendees. https://training.npl.co.uk/

SEMINARS: Weight

Jan 27-30, 2020 5606: Balance and Scale Calibration and Uncertainties. Gaithersburg, MD. NIST. This 4-day seminar will cover the calibration and use of analytical weighing instruments (balances and laboratory/bench-top scales), including sources of weighing errors in analytical environments, methodologies for quantifying the errors, and computation of balance calibration uncertainty and global (user) uncertainty. https://www.nist.gov/news-events/events/2020/01/5606-balance-and-scale-calibration-and-uncertainties

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The new H Wing addition to NIST's Radiation Physics Building will add 38 new labs with dramatically better controls for temperature, humidity and air filtration. Credit: J. Stoughton/NIST

NIST Unveils New Laboratory Building for Improved National Radiation Measurements

September 24, 2019, GAITHERSBURG, Md. — The U.S. Department of Commerce's National Institute of Standards and Technology (NIST) held a ribbon-cutting ceremony yesterday to unveil a new laboratory building that substantially enhances NIST's capabilities for radiation measurements critical to the health care, food processing, national security and other industries.

"Every type of health care in the U.S. that depends on radiation relies on the measurements done at the NIST Radiation Physics Building," said Deputy Secretary of Commerce Karen Dunn Kelley. "Which is why it is so important that this addition is now complete and ready for use."

"With completion of the H Wing, we are witnessing the beginning of a new era at NIST for radiation measurements," said Under Secretary of Commerce for Standards and Technology and NIST Director Walter G. Copan. "This is the kind of facility that America deserves. I know it will serve us well for the next 60 years and beyond."

An extension to NIST's current Radiation Physics Building, the new H Wing will add 38 laboratory modules and approximately 7,900 square meters (85,000 square feet) of state-of-the-art space to the building. The new facility will allow:

- improved accuracy of calibrations needed for X-ray, gamma ray and other radiation detectors;
- the creation of standards to verify doses absorbed by tissues from radionuclide medical treatments;
- enhanced national security through better detection of nuclear and radiological materials; and
- an expanded range of radioactive gas standards needed for environmental, medical, national security and other applications, among other benefits.

NIST's measurements enable 17 million nuclear medicine procedures, 40 million mammograms and 80 million CT scans in the U.S. each year. They also help to ensure the safety of milk and vegetables by supporting the irradiation (for pasteurization and canning) of 120,000 tons of foodstuffs each year.

Built at a cost of $82.4 million, the H Wing is part of a multiphase modernization effort expected to cost a total of $327 million. All told, the effort will add nearly 10,000 square meters (107,000 square feet) of space to the original building and bring the older sections up to modern codes and performance standards. The new addition will dramatically improve control of temperature, humidity and air filtration to levels needed for precision measurements.

NIST promotes U.S. innovation and industrial competitiveness by advancing measurement science, standards and technology in ways that enhance economic security and improve our quality of life. NIST is a nonregulatory agency of the U.S. Department of Commerce. To learn more about NIST, visit www.nist.gov.

Source: https://www.nist.gov/news-events/news/2019/09/nist-unveils-new-laboratory-building-improved-national-radiation

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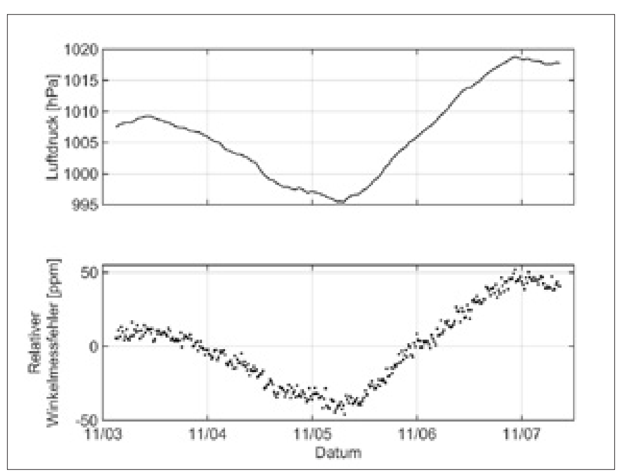
Angle Measurement Under Pressure

PTB News 2.2019 (15.05.2019) - High-precision angle measurements carried out by means of autocollimators are significantly influenced by the refractive index of air—and thus in particular by the ambient pressure. When comparing measurements that have been carried out at different locations, it is therefore necessary to take changes in pressure into account. PTB has developed suitable strategies both to correct the measurement results and to assess the measurement uncertainty.

Autocollimators allow the contact-free measurement of the inclination angle of reflecting surfaces. These devices are used for various applications in industry and research, in particular to measure the straightness and levelness of mechanical and optical components, for example for ultra-precise form measurements on Xray mirrors for synchrotron radiation and free-electron laser radiation.

The measurement principle of autocollimators is as follows:



Simultaneous changes in the air pressure (top) and in the relative angle measurement error of the autocollimator (bottom; ppm: parts per million) as a function of time. Credit: PTB the objective of the autocollimator converts the angle of the measuring beam which is reflected by the surface into the spatial displacement of a measuring mark that is imaged onto the detector. The objective thus acts as a kind of optical lever that transforms small angles into measurable displacements. The leverage effect depends on the focal length of the objective, which, in turn, is influenced by the refractive index of air.

As recent investigations have shown, the influence which changes in the refractive index of air have on angle measurements that are carried out by means of autocollimators must not be neglected. These changes are due to changes in the environmental conditions (air pressure and humidity, temperature). Here, it is particularly important to emphasize the importance of air pressure, which is not only subject to variations due to the weather, but which also depends on altitude. In contrast to this, temperature and humidity are precisely controlled in air-conditioned laboratories, so that they remain practically constant. The error in the angle measurement of the autocollimator increases proportionally to the angle and to the ambient pressure. In addition, it is also scaled along with the distance (i.e. the air clearance) between the autocollimator and the reflecting surface in relation to the focal length of the objective.

Environmental data, which were collected over a decade in PTB's Clean Room Center, have exhibited an ambient pressure range of 84 hPa, and thus a relative change in pressure of more than 8 % compared to the standard pressure. An international comparison was carried out with laboratories located at heights ranging from 2 m to 712 m above sea level. This comparison revealed pressure differences of up to 89 hPa. The resulting relative angle measurement errors were each on the order of up to 10^{-4}.

As shown by the figures, both quantities that have an influence on the ambient pressure (the meteorological conditions and the geographical elevation) must be taken into account when comparing angle measurements carried out by means of autocollimators at different locations and at different times in order to avoid substantial angle measurement errors.

Contact: Ralf D. Geckeler, Department 5.2, Dimensional Nanometrology, ralf.geckeler(at)ptb.de

Scientific publication: R. D. Geckeler, P. Křen, A. Just, M. Schumann, M. Krause: "Influence of the air's refractive index on precision angle metrology with autocollimators." *Meas. Sci. Technol.* 29, 075002 (2018)

Source: https://www.ptb.de/cms/en/presseaktuelles/journals-magazines/ptb-news.html

Navy Receives Three Patents on Laser-Based Technologies for Detection Screening of Biochemicals

September 19, 2019, NORCO, CA—The Navy was recently awarded three U.S. patents, developed by Naval Surface Warfare Center, Corona Division, for laser-based air biosensors for remote detection, real-time monitoring and control of biological chemicals including biohazards.

The Air Biosensors for Remote Detection of Biohazards will allow the Navy to sample, analyze and send real-time data regarding biological hazards. By analyzing active and passive threats in real time, the devices – including one that enables detection from a remote location – will provide warfighters and first responders significantly more time to seek cover or change into protective gear to avoid dangerous biological hazards.

"These laser-based Air Biosensors for Detection of Biohazards will be important new tools for the warfighter and the Navy," said Capt. Rick Braunbeck, Commanding Officer of NSWC Corona. "Equipping our warfighters with these innovative technologies will provide them significant advantage in the face of a threat. This is yet another achievement that strengthens the Navy's intellectual property holdings and adds long-term value to the Navy's mission."

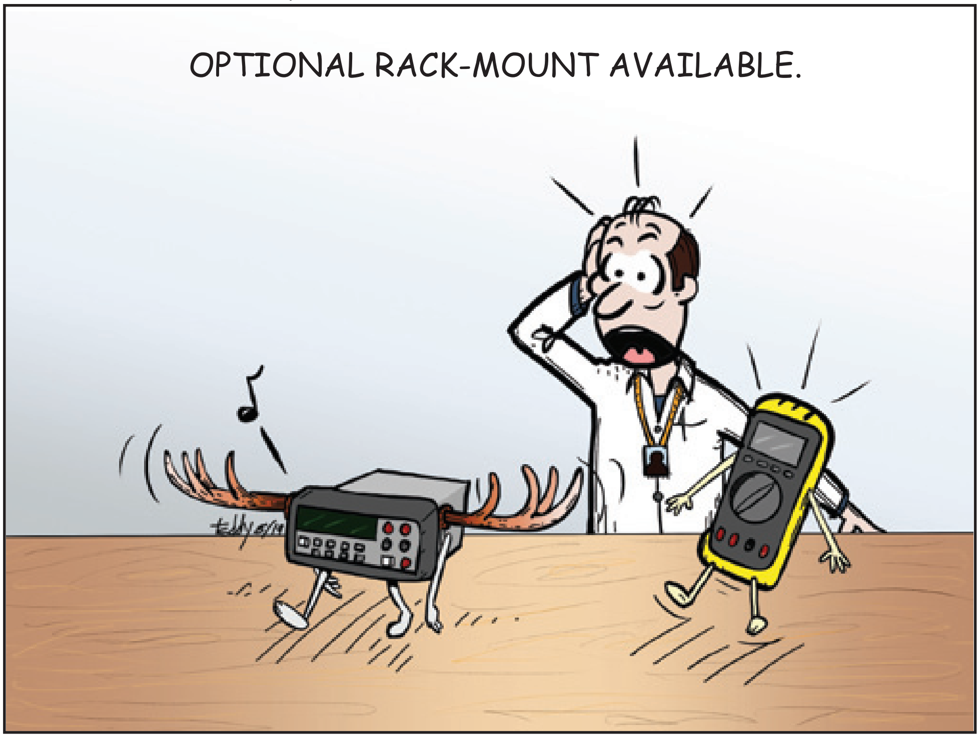
By employing two common types of laser-based technologies used for chemical detection—molecular absorption spectrophotometry (MAS) and molecular fluorescence spectrophotometry (MFS)—these three devices promise to generate more reliable results than if either technology were used separately.

Two of the three inventions combine the two technologies. The detection capability is based on "label-free" spectrometric signals from native biomolecules. The compact, novel designs are portable; use application-specific scalability of size, weight and power consumption (SWaP); and allow for a long laser path in the air sample for increased sensitivity and selectivity of detection.

The third and latest patent in the series (US 10,209,188 B2) was awarded Feb. 19, 2019 for a novel, compact air biosensor that uses a suction baffle to selectively screen ambient air, including particles and spores, for hazardous biomolecules and bio-agents using the laser-based dual detection technologies (MAS and MFA). This Air Biosensor is designed to mount on and interface with an unmanned aerial vehicle (UAV) or drone that is equipped with GPS, video or still cameras, sensors, and a remote controller for remote operation. It could also attach to a wearable or stationary device.

The second patent (US 10,132,752 B2) was issued Nov.

CAL-TOONS by Ted Green teddytoons@icloud.com



20, 2018 for a hand-held, laser-based biosensor using molecular fluorescence spectrophotometry for detecting and identifying native biomolecules via direct sampling in solids, fluid, atmospheric air, and on surfaces.

The first patent in this series (US 10,036,703 B1) was awarded July 31, 2018 for a portable, pocket-wearable, laser-based biosensor including interchangeable modular components for the efficient and quick field testing of substances within fluid samples. No such portable biosensor currently exists in the market. Applications include use by first responders, the military, and the food and drug industries.

NSWC Corona is currently pursuing government and industry partnerships to transition these laser-based biosensor concepts into widely available warfighter tools.

"These inventions are win-win outcomes from the summer faculty research program work at NSWC Corona funded by the Office of Naval Research (ONR)," said Dr. Subrata Sanyal, co-inventor and chief scientist in the Measurement Science and Engineering (MS) Department at NSWC Corona. "For the past four summers, the opportunity to work with our ONR summer faculty researcher and co-inventor, Dr. Kin Chiu Ng, an eminent analytical chemistry professor from California State University Fresno, culminated in these inventions for the Navy and a long-term collaboration of mutual benefits. These inventions have great technical potential for warfighters and mankind, when deployed. On a side note, we are very happy and excited that Dr. Ng has recently joined us in the MS Department as a Navy civilian employee."

The latest Patent Power Scorecard (2017) published by the Institute of Electrical Engineers ranks the Navy's patent portfolio second in the world amongst all other government agencies, a distinction fueled by employees and contractors across the Navy's science and engineering enterprise.

About Naval Surface Warfare Center Corona

Naval Surface Warfare Center Corona, headquartered in Norco, California, is the Navy's premier independent analysis and assessment agent using measurement, analysis and assessment to enable our warfighters to train, fight and win. The center analyzes warfare and missile defense systems, provides systems engineering for Live Virtual Constructive training ranges, and advises and administratively manages measurement and calibration standards for the Navy and Marine Corps. Capt. Khary W. Hembree-Bey commands the Naval Sea Systems Command (NAVSEA) field activity with a workforce of more than 3,500 scientists, engineers, contractors and support staff.

Pass or Fail: With Which Probability?

Manuel Rodríguez
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In this paper, the Probability of Pass (*PoP*) and the Probability of Fail (*PoF*) are derived following a metrological approach, in which concepts such as repeatability, number of effective degrees of freedom, level of confidence, coverage factors and expanded uncertainty will play a role.

1. Introduction

Pass-or-Fail tests are often defined in order to assess whether a given piece of equipment meets specifications or not. They are not in principle intended for use within a metrological environment, and normally rely on one single measurement. There are normally two types of tests: Single (in which a unique threshold or limiting value is defined, either maximum or minimum) and Double (in which two limiting values are specified, maximum and minimum).

In a Single-Limit Test, it is normally agreed that the result of the test is "Pass" when the measured value lies well below the maximum value or well above the minimum value. In a Double-Limit Test, "Pass" is defined as the measured value lying below the maximum value and above the minimum value.

The question sometimes arises as whether measured values which lie close to the limiting values are to be "accepted" (Pass) or "rejected" (Fail). The question becomes more difficult to answer if the measured value is the result of one single experiment. One would normally repeat the measurement in order to decide whether to accept or to reject the test result, but on occasion the same result is obtained repeatedly, which does not help in making a decision.

The problem still remains whenever the margin between the measured result and the specification limit is less than the measurement uncertainty [1], [2]. Our aim is to express the results of Pass-or-Fail Tests in terms of probability.

2. Statistical Background

In a general case, a coverage factor k_p should be derived for the expression of the uncertainty related to a measured quantity, where p is the probability or level of confidence in percent [3], [4], [5]. This coverage factor is based on a Student´s t Distribution in case of unreliable input quantities. The expanded uncertainty is then given by:

$$u_{\exp} = k_p \cdot u_c(y)$$

where $u_c(y)$ is the combined uncertainty. For determination of k_p, the number of effective degrees of freedom, υ_{eff}, of the combined standard uncertainty, has to be estimated. This is made using the Welch-Satterwaite equation, based on the degrees of freedom υ_i of the individual uncertainty contributions $u_i(y)$:

$$\upsilon_{eff} = \frac{u_c^4(y)}{\sum_{i=1}^{N} \frac{u_i^4(y)}{\upsilon_i}}$$

The degrees of freedom υ_i of Type A contributions is n-1, n being the number of measurements. The degrees of freedom υ_i of Type B contributions can be assumed to be infinite. The coverage factor as a function of the confidence level and the number of effective degrees of freedom is then given by the inverse t Distribution:

$$k(p, \upsilon_{eff}) = Inverse\ tDistribution\left(100 - p\ (\%);\ \upsilon_{eff}\right)$$

3. The Expression of Uncertainty in a Measurement Result

Having obtained the expanded uncertainty related to the measurement of a given quantity, the result is reported:

$$y \pm U$$

This result could be expressed in words as follows: "The measurand is estimated to lie within the interval $[y–U, y+U]$ with a level of confidence of p(%). The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor of k."

Note that the information about the number of effective degrees of freedom is redundant, since the customer can deduce it from k and p (alternatively, a simpler although perhaps less intuitive solution could be to provide υ_{eff} and let the customer obtain k for <u>any</u> probability p he or she might wish!).

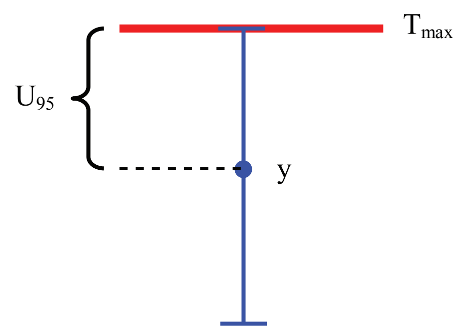
Note also, assuming a symmetrical probability density function around the measured value, the following statements:

- The measurand is estimated to lie <u>outside</u> the interval [$y–U$, $y+U$] with a level of confidence of $100–p$.
- The measurand is estimated to be <u>greater than</u> $y+U$ with a level of confidence of $(100–p)/2$.
- The measurand is estimated to be <u>less than</u> $y–U$ with a level of confidence of $(100–p)/2$.

...are also true!

4. The Expression of Uncertainty in a Single Pass-or-Fail Test

Let us define a Pass-or-Fail Test in which a maximum threshold T_{max} is defined. We measure the quantity y (the measurand) below the threshold, with an expanded uncertainty U, and for a confidence level of p = 95%. Let us assume that the difference between T_{max} and y is exactly the measurement uncertainty, U.

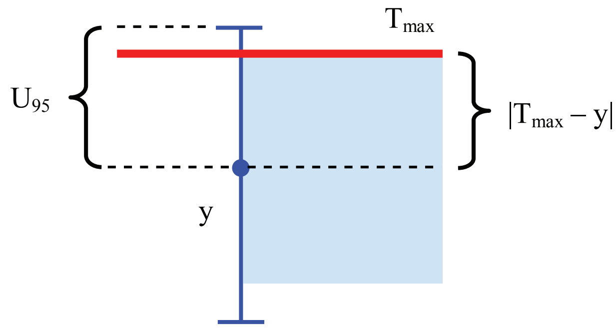


Let us recall one of the above statements: "The measurand is estimated to be <u>greater than</u> $y + U$ with a level of confidence of (100–95)/2=2.5%," which is equivalent to any of the following:

- The measurand is estimated to <u>Fail the Test</u> with a probability or level of confidence of 2.5%
- The measurand is estimated to <u>Pass the Test</u> with a probability or level of confidence of 97.5%

4.1 Probability of "Just-in-Margin"

Let us now define a new coverage factor which we can call the "just-in-margin" factor. It can be defined as the coverage factor which exactly includes the threshold limit. As it can be seen in the following figure, this "just-in-margin" factor is related to the absolute difference $|T_{max} – y|$. We have denoted it with the subindex p, because our next step will be to obtain the probability or level of confidence associated to this coverage factor.



The so-defined "just-in-margin" factor is given by:

$$k_p = \frac{|T_{max} - y| \cdot k_{95}}{U_{95}}$$

And the probability p related to this coverage factor is:

$$p(\%) = 100 - tDistribution\left(k_p; \upsilon_{eff}\right)$$

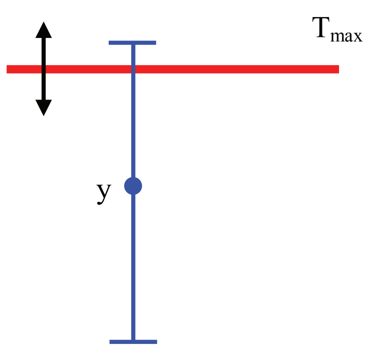
4.2 Probability of Pass and Probability of Fail

This "just-in-margin" coverage factor serves us to state things as follows: "The measurand is estimated to lie within the interval [y–|Tmax – y|, Tmax] with a level of confidence of p".

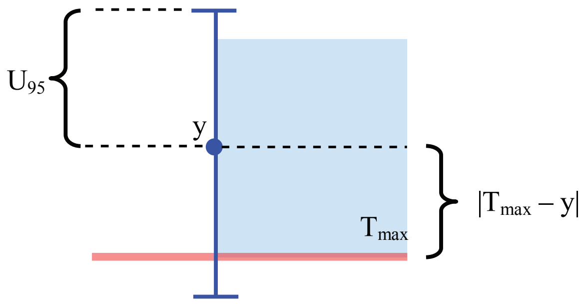
Of course this is a mere intermediate step in order to compute the following probabilities, expressed as any of our usual statements:

- The measurand is estimated to Fail the Test with a probability of (100–p)/2
- The measurand is estimated to Pass the Test with a probability of (100+p)/2

In the above example, if p=70%, the Probability of Fail would be PoF=(100–70)/2 and the Probability of Pass PoP=(100+70)/2:



In the following example, we assume that the measured value exceeds the maximum limit.



In this case, the measurand is estimated to lie within the "just-in-margin" interval $[T_{max}, y + |T_{max} - y|\,]$ with a level of confidence of p. The expressions of the Probability of Pass and the Probability of Fail are reversed:

- The measurand is estimated to Fail the Test with a level of confidence of (100+p)/2
- The measurand is estimated to Pass the Test with a level of confidence of (100–p)/2

If the probability of "just-in-margin" is the same as in the previous example p=70%, in this case *PoF*=85% and *PoP*=15%.

5. Some Examples of Single Pass-or-Fail Tests

5.1 Example I

In Figure 1, several cases of test results are shown, together with their associated Probability of Pass. Hereinafter, the probability level considered is p=95.45%. The threshold value T_{max} is 1 and the measurement uncertainty U is 0.1. As it can be seen, as the measured value approaches the limit, the probability of pass decreases.

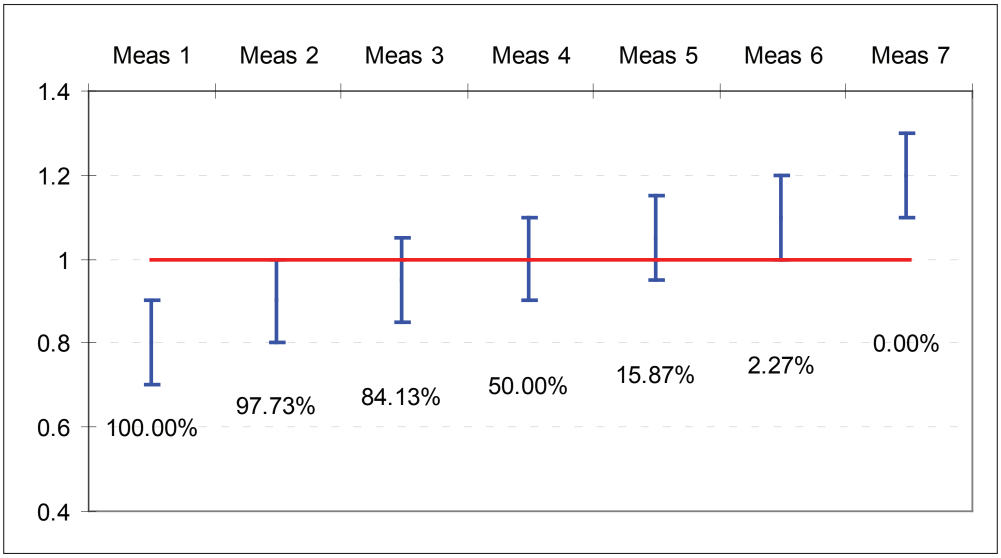


Figure 1. T_{max} =1, U=0.1, Number of effective degrees of freedom υ_{eff} =10^6

	Value	Uncertainty	k_{95}	k_p	p(%) "In-margin"	p(%) of Pass	p(%) of Fail
Meas 1	0.8	0.1	2.00	4.00	99.99	100.00	0.00
Meas 2	0.9	0.1	2.00	2.00	95.45	97.73	2.27
Meas 3	0.95	0.1	2.00	1.00	68.27	84.13	15.87
Meas 4	1	0.1	2.00	0.00	0.00	50.00	50.00
Meas 5	1.05	0.1	2.00	1.00	68.27	15.87	84.13
Meas 6	1.1	0.1	2.00	2.00	95.45	2.27	97.73
Meas 7	1.2	0.1	2.00	4.00	99.99	0.00	100.00

Table 1. Probability of "just-in-margin," Probability of Pass and Probability of Fail

From the comparison between these particular cases, it can be seen that Meas #1 and Meas #7 are paired, i.e. their position with respect to the threshold value is reversed. This is also the case for Meas #2 and #6 and for Meas #3 and #5. The Probability of Pass and Fail are reversed within each pair, just as probably our common sense would tell us.

Meas #2 and Meas #6 are particular cases, since the "just-in-margin" factor is exactly k_{95}. This makes *PoP* and *PoF* independent on the number of effective degrees of freedom, which can be verified as compared with Meas #2 and Meas #6 in Examples II and III.

Meas #4 is also a particular case. Our common sense is also happy to know that when the measured value exactly coincides with the threshold value, there is no means to assign a greater probability to the event "Pass" or to the event "Fail."

5.2 Example II

In Figure 2, the same cases as in Example I are shown below. The threshold value and the measurement uncertainty remain the same. The only difference is the number of effective degrees of freedom.

If we take a look at the different measurements and compare them with those in Example I, we notice that Meas #2 and #6 show the same *PoP* and *PoF*. This is due to the fact that the "just-in-margin" factor is exactly k_{95}, regardless of the number of degrees of freedom.

5.3 Example III

Again, Meas #2 and #6 show the same *PoP* and *PoF* as in previous examples. Note that the coverage factors become larger as the number of degrees of freedom is decreased.

In Examples I, II and III, we have fixed the expanded uncertainty for didactical purposes. However, in real life, a decrease in the number of degrees of freedom usually leads to a larger measurement uncertainty (see Examples IV and V in paragraphs 7.1 and 7.2 below).

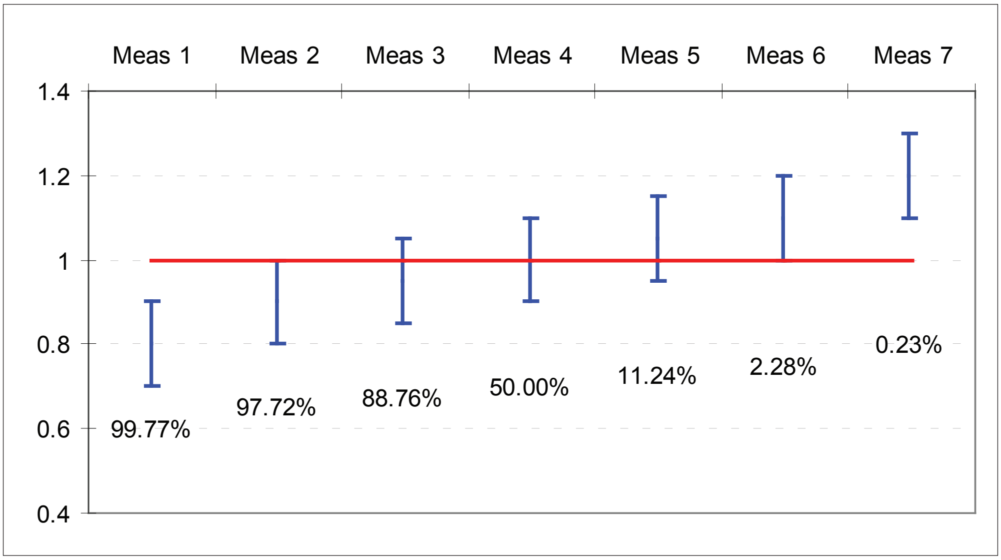


Figure 2. T_{max} =1, U=0.1. Number of effective degrees of freedom υ_{eff}=4

	Value	Uncertainty	k_{95}	k_p	p(%) "In-margin"	p(%) of Pass	p(%) of Fail
Meas 1	0.8	0.1	2.87	5.74	99.54	99.77	0.23
Meas 2	0.9	0.1	2.87	2.87	95.45	97.72	2.28
Meas 3	0.95	0.1	2.87	1.43	77.53	88.76	11.24
Meas 4	1	0.1	2.87	0.00	0.00	50.00	50.00
Meas 5	1.05	0.1	2.87	1.43	77.53	11.24	88.76
Meas 6	1.1	0.1	2.87	2.87	95.45	2.28	97.72
Meas 7	1.2	0.1	2.87	5.74	99.54	0.23	99.77

Table 2. Probability of "just-in-margin," Probability of Pass and Probability of Fail

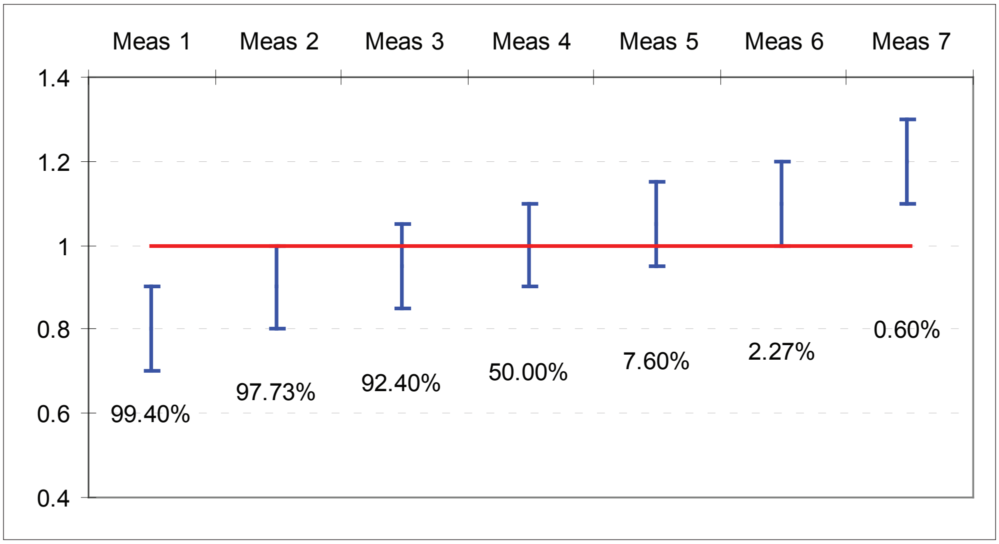


Figure 3. T_{max}=1, U=0.1. Number of effective degrees of freedom υ_{eff} =2

	Value	Uncertainty	k_{95}	k_p	p(%) "In-margin"	p(%) of Pass	p(%) of Fail
Meas 1	0.8	0.1	4.53	9.05	98.80	99.40	0.60
Meas 2	0.9	0.1	4.53	4.53	95.45	97.73	2.27
Meas 3	0.95	0.1	4.53	2.26	84.81	92.40	7.60
Meas 4	1	0.1	4.53	0.00	0.00	50.00	50.00
Meas 5	1.05	0.1	4.53	2.26	84.81	7.60	92.40
Meas 6	1.1	0.1	4.53	4.53	95.45	2.27	97.73
Meas 7	1.2	0.1	4.53	9.05	98.80	0.60	99.40

Table 3. Probability of "just-in-margin," Probability of Pass and Probability of Fail

5.4 Probability of Pass as a Function of the Measured Value

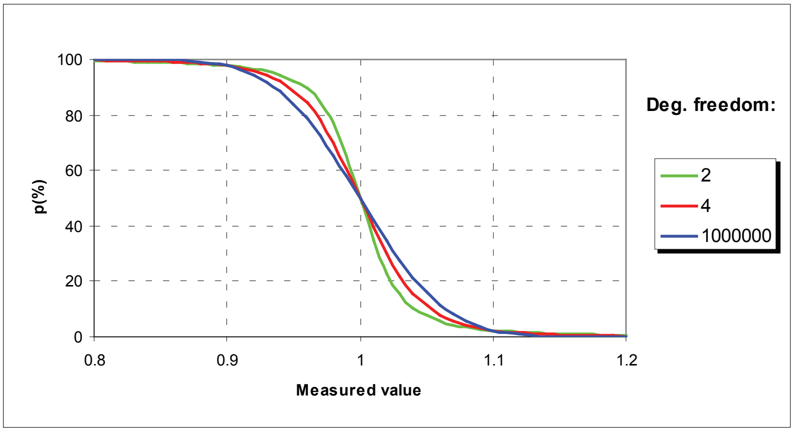


Figure 4. Probability of Pass as a function of the measured value. T_{max}=1. *U*=0.1

Having seen different examples for different numbers of effective degrees of freedom, let us now examine how the Probability of Pass is changed as the measured value approaches the threshold limit, T_{max}.=1. In Figure 4, the three previous examples are represented. The measurement uncertainty is *U*=0.1.

As it can be seen, there are three probability levels at which all curves cross each other: 50% (where the measured value coincides with the threshold), 97.725% (where the expanded uncertainty exactly comprises the maximum limit and the measured value lies below the threshold) and 2.275% (where the expanded uncertainty exactly comprises the maximum limit and the measured value exceeds the threshold). This is the same effect already observed in the examples.

6. Some Statistical Considerations

6.1 Coverage Factors and Level of Confidence

In the next two figures, the probability or level of confidence is shown as a function of the coverage factor k, for different values of υ_{eff}. The greater the effective number of degrees of freedom, the less relative weight Type A contributions have within the overall uncertainty budget, and thus the more confident one can be with respect to the quality of the obtained experimental results. This is consistent with the observation that, for a given k, the probability p increases as the number of degrees of freedom does.

In Figure 6, we have represented k normalized with respect to k_{95}, that is the coverage factor for a level of confidence of 95.45%. For $k_{norm}<1$, the level of confidence seems to decrease for a given k as υ_{eff} increases, but this effect is due to the normalization made.

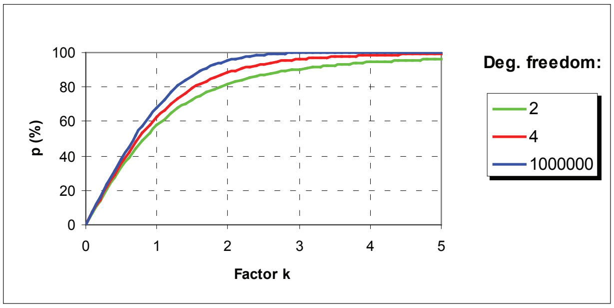


Figure 5. Probability *p*(%) as a function of the coverage factor *k*

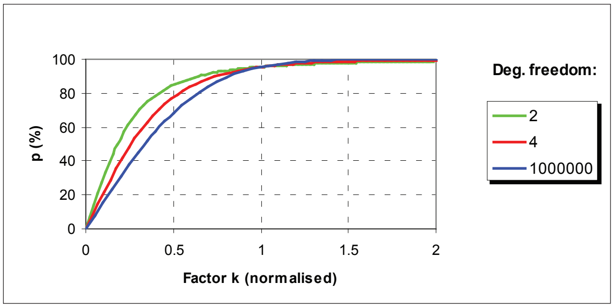


Figure 6. Probability *p*(%) as a function of the coverage factor *k* normalised to k_{95}

6.2 Probability Density Functions for Different Student´s t Distributions

By definition, the probability density function for the Student´s *t* Distribution is given by:

$$p.d.f.\ (y;\upsilon_{eff}) = \frac{\partial tDistribution(y;\upsilon_{eff})}{\partial\, y} = lim_{\Delta y \to 0} \frac{tDistribution(y+\Delta y;\upsilon_{eff}) - tDistribution(y;\upsilon_{eff})}{\Delta y}$$

As any probability density function, it has to satisfy the following condition:

$$\int_{y=-\infty}^{\infty} p.d.f.(y;\upsilon_{eff}) = 1$$

The integral between $-k$ and k gives us the probability for the measurand to lie within the interval $[-k, k]$:

$$\int_{y=-k}^{k} p.d.f.(y;\upsilon_{eff}) = 1 - tDistribution(k;\upsilon_{eff})$$

In the next two figures, different probability density functions are shown as a function of y and y normalised with respect to k_{95}. They are all symmetrical around 0, so we have represented them for positive values of y exclusively.

As it has been said, the following condition has to be satisfied for all curves shown:

$$2 \cdot \int_{y=-0}^{\infty} p.d.f.(y;\upsilon_{eff}) = 1$$

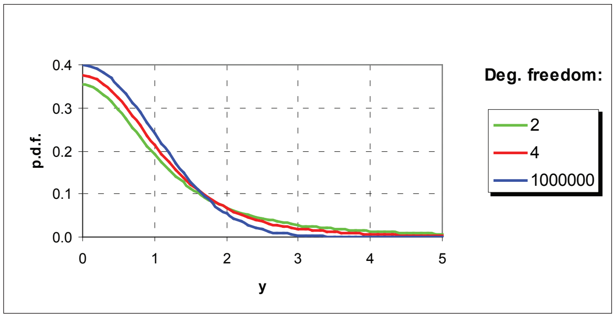


Figure 7. *P.d.f.* as a function of *y*

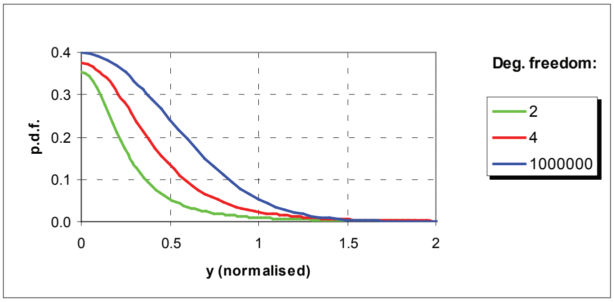


Figure 8. *P.d.f.* as a function of *y* normalised to k_{95}

6.3 Gaussian Probability Density Function

In Figure 7, the p.d.f. for the Student's t Distribution with υ_{eff} =10^6 corresponds to the Normal or Gaussian Distribution with mean value 0 and standard deviation 1:

$$f(y) = \frac{1}{\sqrt{2 \cdot \pi}} \cdot e^{\frac{-y^2}{2}}$$

As a matter of verification, one could assess by integration the following levels of confidence for integer number of times the standard deviation. Integration can be also applied to any of the curves shown in Figures 7 and 8.

$$2 \cdot \int_{y=0}^{1} f(y) = 0.6827 \qquad 2 \cdot \int_{y=0}^{2} f(y) = 0.9545$$

$$2 \cdot \int_{y=0}^{3} f(y) = 0.9973$$

6.4 Probability Density Functions in Pass-or-Fail Tests

In Figure 9 and Table 4, several examples of probability density functions are shown. The threshold value considered is again T_{max}=1. As a matter of verification, one could integrate each of the curves below and above T_{max} and compare the results obtained with *PoP* and *PoF* in Table 4.

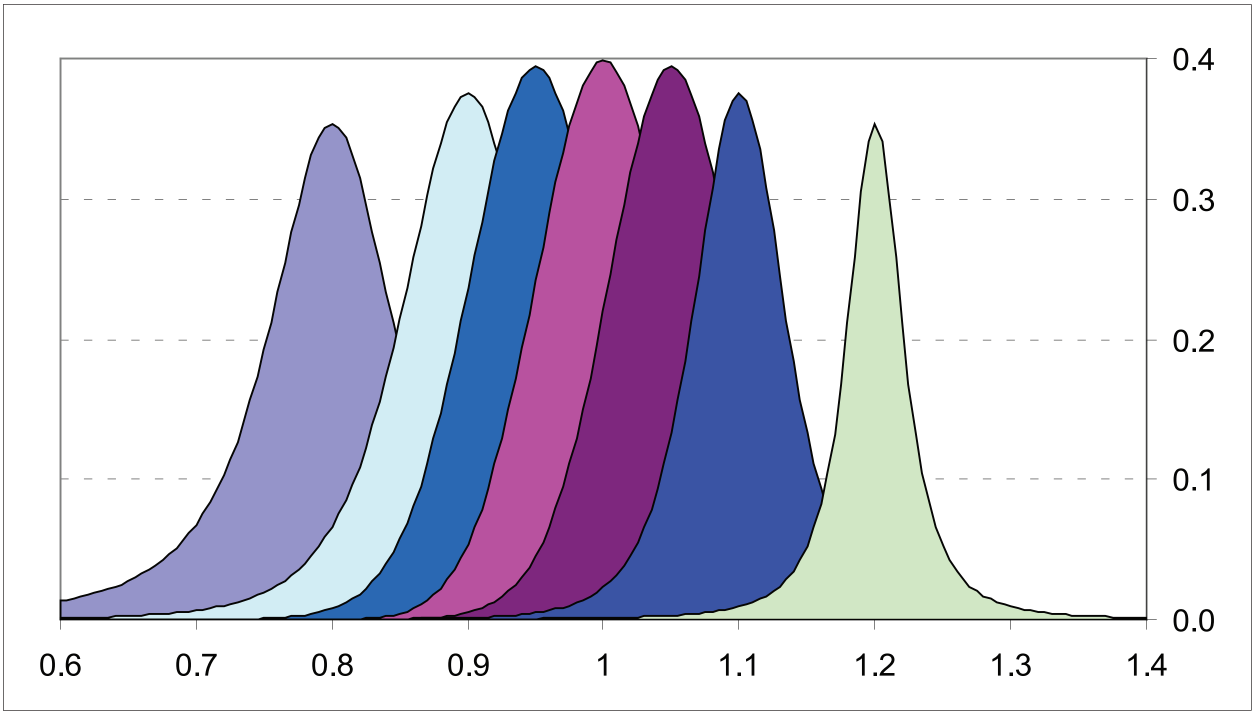


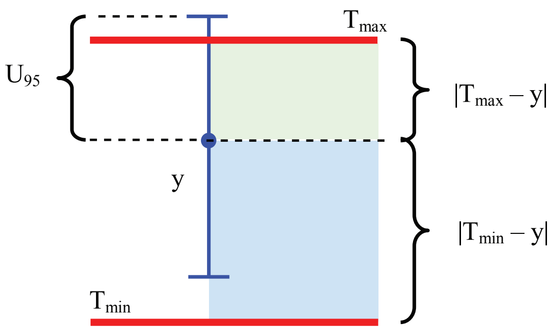
Figure 9. Examples of probability density functions

	Value	Uncertainty	k_{95}	Degr. of freedom	k_p	p(%) "In-margin"	PoP(%)	PoF(%)
Meas 1	0.8	0.226	4.53	2	4.00	94.28	97.14	2.86
Meas 2	0.9	0.143	2.87	4	2.00	88.39	94.19	5.81
Meas 3	0.95	0.107	2.13	20	1.00	67.07	83.54	16.46
Meas 4	1	0.100	2.00	1000000	0.00	0.00	50.00	50.00
Meas 5	1.05	0.100	2.13	20	1.07	70.11	14.94	85.06
Meas 6	1.1	0.100	2.87	4	2.87	95.45	2.28	97.72
Meas 7	1.2	0.100	4.53	2	9.05	98.80	0.60	99.40

Table 4. Degrees of freedom, Probability of "just-in-margin," *PoP* and *PoF*

7. Double Pass-or-Fail Tests

In a "Double" Pass-or-Fail Test, two limiting values are defined. We shall thus define two "just-in-margin" coverage factors related to $|T_{max} - y|$ and $|T_{min} - y|$. They are in general not the same, as it can be seen in the following figure. Therefore, the associated levels of confidence p_1 and p_2 are also different in a general case.



The two "just-in-margin" factors and their related probabilites p_1 and p_2 are given by:

$$k_{p1} = \frac{|T_{max} - y| \cdot k_{95}}{U_{95}}$$

$$p_1\,(\%) = 100 - tDistribution\left(k_{p1};\, v_{eff}\right)$$

$$k_{p2} = \frac{|T_{min} - y| \cdot k_{95}}{U_{95}}$$

$$p_2\,(\%) = 100 - tDistribution\left(k_{p2};\, v_{eff}\right)$$

7.1 The Measured Value Lies Between the Two Limits

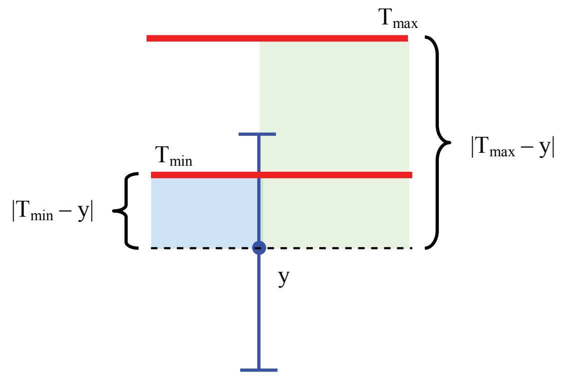
For the maximum limit: the measurand is estimated to lie within the interval **[y, T_{max}]** with a probability **$p_1/2$**. For the minimum limit: the measurand is estimated to lie within the interval **[T_{min}, y]** with a probability **$p_2/2$**. See Figure above.

Therefore, the probability for the measurand to lie within the interval [T_{min}, T_{max}] is $(p_1+p_2)/2$. In other words:

- The measurand is estimated to <u>Pass the Test</u> with a probability $(p_1+p_2)/2$
- The measurand is estimated to <u>Fail the Test</u> with a probability $100 - (p_1+p_2)/2$

7.2 The Measured Value Lies Below the Two Limits

For the maximum limit: the measurand is estimated to lie within the interval **[y, T_{max}]** with a probability **$p_1/2$**.

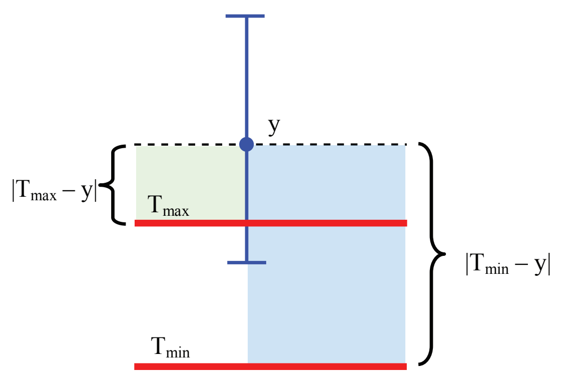


For the minimum limit: the measurand is estimated to lie within the interval **[y, T_{min}]** with a probability **$p_2/2$**.

Therefore, the probability for the measurand to lie within the interval [T_{min}, T_{max}] is $(p_1 - p_2)/2$. In other words:

- The measurand is estimated to <u>Pass the Test</u> with a probability $(p_1 - p_2)/2$
- The measurand is estimated to <u>Fail the Test</u> with a probability $100 - (p_1 - p_2)/2$

7.3 The Measured Value Exceeds Both Limits



For the maximum limit: the measurand is estimated to lie within the interval **[T_{max}, y]** with a probability **$p_1/2$**. For the minimum limit: the measurand is estimated to lie within the interval **[T_{min}, y]** with a probability **$p_2/2$**.

Therefore, the probability for the measurand to lie within the interval [T_{min}, T_{max}] is $(p_2 - p_1)/2$. In other words:

- The measurand is estimated to <u>Pass the Test</u> with a probability $(p_2 - p_1)/2$
- The measurand is estimated to <u>Fail the Test</u> with a probability $100 - (p_2 - p_1)/2$

8. Some Examples of Double Pass-or-Fail Tests

8.1 Example IV

In Figure 10 and Table 5, several cases for a Double Pass-or-Fail Test are shown. As usual, the probability level considered is p = 95.45%. The maximum threshold value T_{max} is 1 and the minimum limit T_{min}=0.6. The measurement uncertainty U is 0.1 times the coverage factor k_{95}. This is perhaps more representative of real-life measurements, where the expanded uncertainty increases as the number of effective degrees of freedom decreases.

From Figure 10, it can be seen that the Probability of Pass reaches a maximum as the measured value enters the zone between the two limits. Interestingly enough, Meas #5 confirms for us that the Probability of Pass is exactly p = 95.45%, just because the expanded uncertainty exactly comprises both limits.

There are no "paired" cases as in previous examples, although common sense also tells us that the Probabilities of Pass and Fail would repeat under certain circumstances. For instance, if the measured value were 1.2, *PoP* and *PoF* would be exactly the same as in Meas #1.

8.2 Example V

Again, several cases of measured values are shown, together with *PoP* and *PoF* (Figure 11 and Table 6). From comparison with Example IV, it can be seen that there are no particular cases for which the probabilities remain unchanged. This is due to the fact that the measurement uncertainty is not constant, but dependent on the number of degrees of freedom.

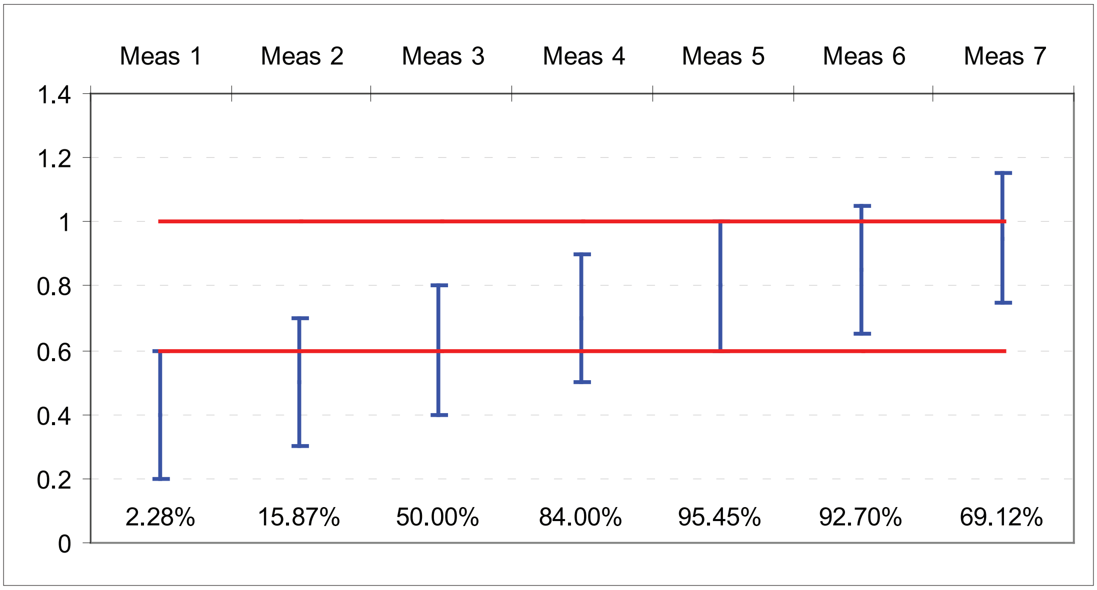


Figure 10. T_{max}=1, T_{min}=0.6, U=0.1 times k_{95}. Number of effective degrees of freedom υ_{eff}=10^6

	Value	Uncertainty	k_{95}	k_{p1} sup	p_1(%)	k_{p2} inf	p_2(%)	PoP(%)	PoF(%)
Meas 1	0.4	0.2	2.00	6.00	100.00	2.00	95.45	2.28	97.73
Meas 2	0.5	0.2	2.00	5.00	100.00	1.00	68.27	15.87	84.13
Meas 3	0.6	0.2	2.00	4.00	99.99	0.00	0.00	50.00	50.00
Meas 4	0.7	0.2	2.00	3.00	99.73	1.00	68.27	84.00	16.00
Meas 5	0.8	0.2	2.00	2.00	95.45	2.00	95.45	95.45	4.55
Meas 6	0.85	0.2	2.00	1.50	86.64	2.50	98.76	92.70	7.30
Meas 7	0.95	0.2	2.00	0.50	38.29	3.50	99.95	69.12	30.88

Table 5. Probabilities of "just-in-margin," Probability of Pass and Probability of Fail

8.3 Probability of Pass as a Function of the Measured Value

In Figure 12, *PoP* is represented as a function of the measured value in a Double Pass-or-Fail Test with the same threshold values as in Examples IV and V above. Both examples are included in the blue and red curves, respectively. The measurement uncertainty is 0.1 times k_{95}.

We can try maintaining U constant, as in paragraph 4.4. Under these circumstances, the results shown in Figure 13 are obtained. Apparently, there are now three probability levels at which all curves cross each other: 97.725% (where the expanded uncertainty comprises one of the thresholds and the measured value lies within both limits), 50% (where the measured value coincides with one of the threshold limits) and 2.275% (where the expanded uncertainty comprises one of the thresholds and the measured value lies outside the limits). This is only approximate, though, and depends on the ratio between U and $|T_{max} - T_{min}|$.

Finally, we can fix the number of effective degrees of freedom and see the effect of the measurement uncertainty. In Figure 14, *PoP* is represented as a function of the measured value, for an expanded uncertainty U ranging from 0.1 to 0.3. The number of degrees of freedom is 10^6.

The effect of a greater uncertainty—in relation to the absolute difference $|T_{max} - T_{min}|$—can be seen to be a certain "spread" of the curves. As the uncertainty decreases, the *PoP* tends to follow a square curve changing abruptly between 0% and 100%.

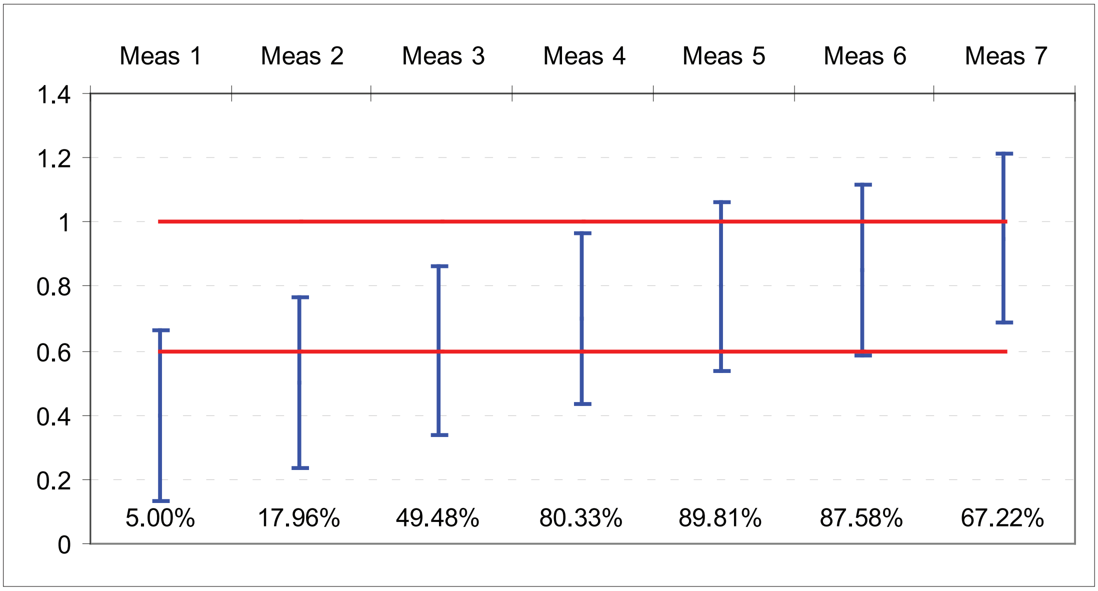


Figure 11. T_{max}=1, T_{min}=0.6, U=0.1 times k_{95}. Number of effective degrees of freedom υ_{eff}=5

	Value	Uncertainty	k_{95}	k_{p1} sup	p_1(%)	k_{p2} inf	p_2(%)	PoP(%)	PoF(%)
Meas 1	0.4	0.265	2.65	6.00	99.82	2.00	89.81	5.00	95.00
Meas 2	0.5	0.265	2.65	5.00	99.59	1.00	63.68	17.96	82.04
Meas 3	0.6	0.265	2.65	4.00	98.97	0.00	0.00	49.48	50.52
Meas 4	0.7	0.265	2.65	3.00	96.99	1.00	63.68	80.33	19.67
Meas 5	0.8	0.265	2.65	2.00	89.81	2.00	89.81	89.81	10.19
Meas 6	0.85	0.265	2.65	1.50	80.61	2.50	94.55	87.58	12.42
Meas 7	0.95	0.265	2.65	0.50	36.17	3.50	98.27	67.22	32.78

Table 6. Probabilities of "just-in-margin," Probability of Pass and Probability of Fail

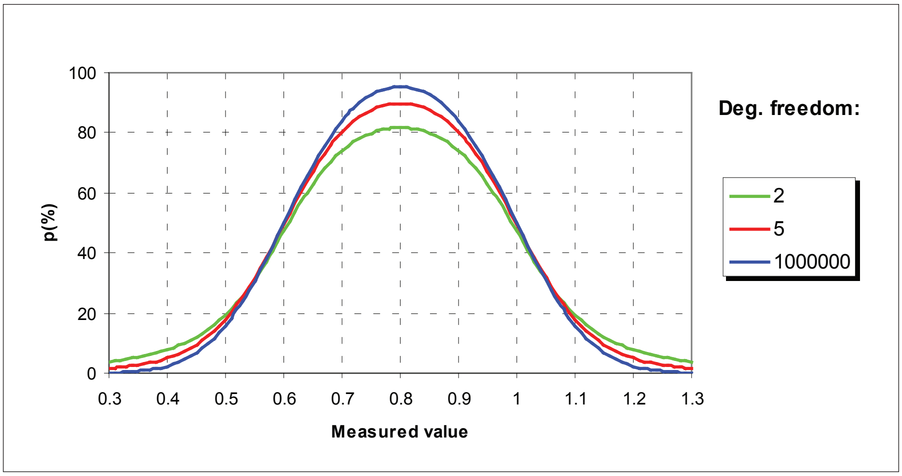


Figure 12. Probability of Pass as a function of the measured value. T_{max}=1. T_{min}=0.6. U=0.1 times k_{95}

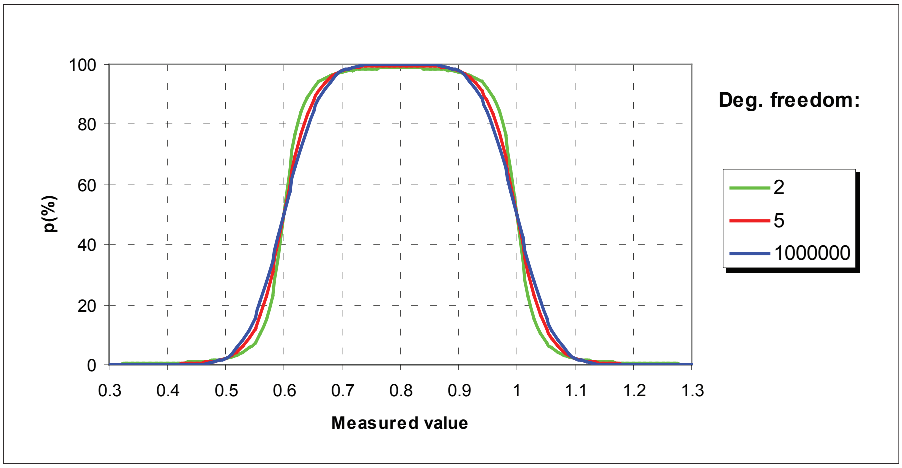


Figure 13. Probability of Pass as a function of the measured value. T_{max}=1. T_{min}=0.6. U=0.1

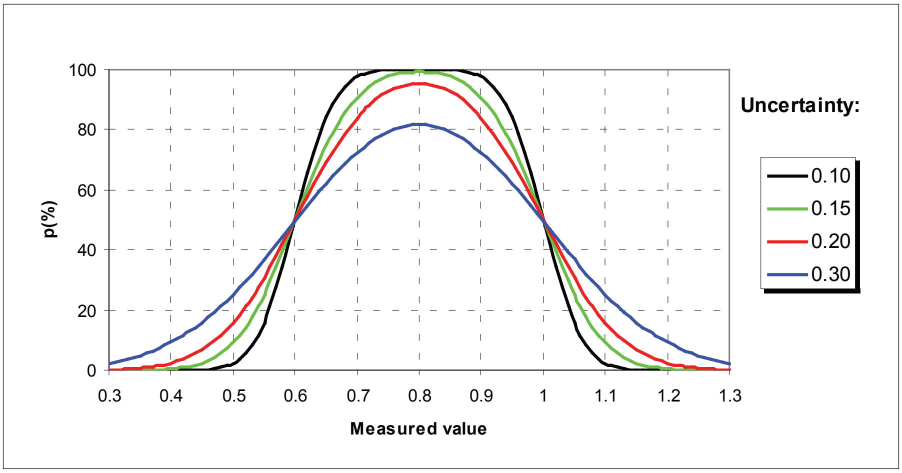


Figure 14. Probability of Pass as a function of the measured value. T_{max}=1. T_{min}=0.6. υ_{eff}=10^6

9. The Expression of Pass-or-Fail Results in a Calibration Certificate

There are, in principle, two ways of expressing the result of a Pass-or-Fail Test in a metrological environment:

Option A) Measured Value + Measurement Uncertainty + Probability of Pass

$$y \pm U$$

"The measurand is estimated to lie within the interval [$y-U$, $y+U$] with a level of confidence of 95.45%[1]. The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor of k. The probability for the measurand to Pass the Test[2] is PoP(%)."

Option B) Measured Value + Probability of Pass + Nr. of Effective Degrees of Freedom

$$y$$

"The measurand is estimated to Pass the Test with a level of confidence or Probability of Pass PoP(%). The number of effective degrees of freedom is υ_{eff}." In the author´s opinion, option B is preferred. It is a self-contained formula which contains all relevant information with a minimum of parameters.

10. Pass or Fail?

The author would suggest to define "compliance with specification" in relation to the computed Probability of Pass (PoP). For example, it seems reasonable to assess that the product complies with the required limits whenever the PoP is greater than 95.45%. (Of course this should be made application-dependent. One could state a limit of 99% for critical applications in the aerospace industry, whereas for other applications a limit of 66% could suffice).

Decision rules can be found in ILAC-G8 [6]. Based on this guide, the author proposes the following wording: in a Single Test, the device under test is considered to meet specifications whenever the positive difference between the measured value and the minimum limit (or between the maximum limit and the measured value) is greater than or equal to the expanded uncertainty, calculated for a confidence level of 95.45%. This ensures that the maximum PFA (Probability of False Acceptance) is less than 2.28%, i.e., that the PoP is greater than or equal to 97.72%.

In a Double Pass-or-Fail Test, the device under test is considered to meet specifications when: (i) the positive difference between the measured value and the minimum limit; AND (ii) the positive difference between the maximum limit and the measured value are BOTH greater than or equal to the expanded uncertainty, calculated for a confidence level of 95.45%. This ensures that the maximum PFA is less than 4.55%, i.e., that the PoP is greater than or equal to 95.45%.

1 Or any other agreed probability level.

2 Either: to lie below T_{max},
to lie above T_{min}, or
to lie within the interval [T_{min}, T_{max}].

11. Conclusions

We have presented a metrological approach to the popular "Pass-or-Fail" Tests, which deals with measurement uncertainties, coverage factors and levels of confidence.

We have considered different types of tests, depending on whether a maximum limit, a minimum limit or a double threshold condition are specified, and have examined them in the light of the computed Probability of Pass and Probability of Fail.

We have made some considerations about probability density functions which may help us understand the probability for the measurand to lie within a given interval around the measured (or most probable) value.

Finally, the discussion about the most convenient way to incorporate such results into a calibration certificate remains open. In particular, the question about whether the product under test complies with specification or not, seems difficult to answer.

References

[1] *The Treatment of Uncertainty in EMC Measurements*, NAMAS NIS 81, Edition 1, May 1994.

[2] Keith Birch. *Estimating Uncertainties in Testing, Measurement Good Practice Guide No. 36*, Appendix B: "Assessment of Compliance with Specification," March 2003.

[3] *The Expression of Uncertainty and Confidence in Measurement for Calibrations*, Appendix M, "Assessment of Compliance with Specification," UKAS M3003, Edition 3, November 2012.

[4] *Expression of the Uncertainty of Measurement in Calibration*, EAL-R2 Publication Reference, Edition 1. April 1997.

[5] Barry N. Taylor and Chris E. Kuyatt. *NIST Technical Note 1297: Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, 1994 Edition.

[6] *Guidelines on Decision Rules and Statements of Conformity*. ILAC-G8:09/2019.

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Aircraft and Truck Scale Calibration

Henry Zumbrun
Morehouse Instrument Company

Introduction

Aircraft and truck scales come in all different shapes and sizes and typically serve one purpose, to approximate the weight of an aircraft or truck. Why might that be important? For aircraft, it's about knowing the center of gravity (CG). The center of gravity will influence stability and performance. Different airplanes have specified limits for longitudinal and lateral limits. If the airplane does not meet these requirements, it will not fly properly. Not operating properly could result in a bad landing, handling problems, exceeding the needed runway length for takeoff, or an all-out crash. Weighing is important not only with the aircraft empty but with cargo and fuel. The airplane can have a good CG on takeoff and the decreased fuel can cause an imbalance to develop into the flight. Knowing the weight is also important as the structural strength of the aircraft has limits on the maximum weight the aircraft can safely carry.

Figure 1. Aircraft and Truck Scale Calibrator

For trucks, it's a matter of safety and profitability. Safety is going to be the biggest concern for most of us as an overweight truck would have the capability to cause severe structural damage over time or immediate damage to bridges and overpasses. Being overweight, which can lead to increased profitability for the company transporting the products, can also interfere with the driver's ability to maneuver quickly, control the truck going uphill or downhill, and to stop. It can result in loss of balance, busted or blown out tires due to the pressure of the excess weight, and all of which can lead to severe accidents. The exact limit of how heavy a truck can vary by state laws and the type and number of axles on the truck. Federal law dictates trucks must weigh below 80,000 lbs.

What We Can Do To Improve Calibration

Now that we've explained why knowing the weight is essential, we can now look at the calibration side and the four things we can do to improve the calibration of these types of scales.

1. We can control the equipment we purchase for calibration.

To achieve proper calibration, equipment used to generate forces should be plumb, level, square, and rigid. Pictured in Figure 1 is a Morehouse Aircraft and Truck Scale Calibrator. This new machine was designed to minimize the bending of the top beam and load bearing table, which is imperative to achieve proper calibration. The plates are designed to be square and level with custom machining processes and ground to maintain a level surface. If there is an increase in bending or uneven surfaces, the strain elements in the scale will vary. These errors could easily be a magnitude from two to ten times the tolerance.

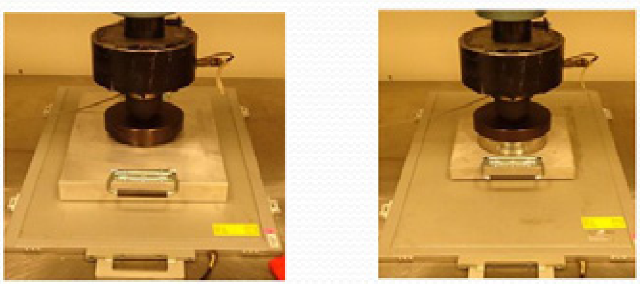
Also, the right equipment is stable with enough resolution to not have a significant impact on the overall uncertainty. Deadweight machines would be the best, but they are not the most cost-effective and generally are not built to support large scales. Therefore, several load cell transfer standards calibrated by deadweight and used in a machine with fine control will allow the operator to achieve the desired force point. The machine (Figure 1) can generally apply forces to within 0.5 lbf, with the proper load cell and indicator combination. On a 10,000 lbf load cell, used with an indicator capable of reading mV/V output of 0.00001 mV/V (400,000 counts) would have a resolution of 0.025 lbf. The hydraulics and control will vary and can typically be held to 4-8 counts so that the control will vary between 0.01 and 0.02 lbf. A skilled operator can usually control the machine to within four counts or 0.01 lbf on a 10,000 lbf load cell. The stability is also dependent on adapters and the Unit Under Test (UUT).

2. We can control the adapters we use to simulate the footprint of the tires.

Aircraft and Truck scale calibration often requires special adapters to simulate a tire contact area with the scale, as shown in Figures 2 and 3 below. Scales come in a variety of sizes and have specific tolerances. The problem is that not many calibration laboratories use the right adapters. Not using the proper adapters can result in significant measurement errors.

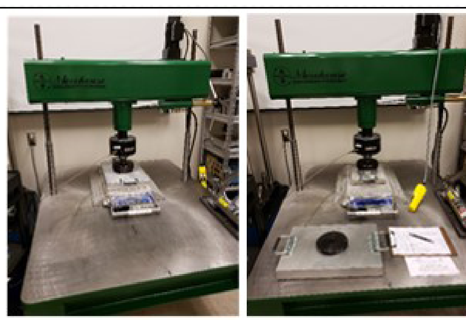
When an adapter used is different from the tire footprint on the scale, we have found substantial errors. Figure 3 shows calibration of a scale with a tolerance of 0.5 % of

Morehouse has test truck and aircraft scales and there is a large difference in output from using different size plates



Force Applied lbf	Scale Reading w/ Large pad	Scale Reading w/ Small pad	Diff in lbf	%
0	0	0		
4000	3950	3980	-30	-0.759%
8000	7980	8030	-50	-0.627%
12000	11990	12020	-30	-0.250%
16000	15980	16090	-110	-0.688%
20000	19980	20140	-160	-0.801%
24000	23990	24210	-220	-0.917%
28000	27990	28270	-280	-1.000%
32000	31990	32350	-360	-1.125%
36000	35990	36460	-470	-1.306%
40000	40010	meter saturated		

Figure 2. Difference in Adapters



Notes: Calibration of a truck scale in our Morehouse USC-60 Scale Calibrating Machine. This test is comparing the difference in the footprint of different tires on the scale.

Force Applied lbf	Instrument Reading normal pad	Instrument Reading small pad	Difference in lbf	% Difference	Tolerance 1% of Applied	Tolerance % by using different pads
2000	2000	2000	0	0.00%	20	0%
4000	4000	4000	0	0.00%	40	0%
6000	6020	6020	0	0.00%	60	0%
8000	8020	8020	0	0.00%	80	0%
10000	10040	9980	60	0.60%	100	60%
12000	12040	11980	60	0.50%	120	50%
14000	14060	13980	80	0.57%	140	57%
16000	16060	15960	100	0.63%	160	63%
18000	18060	17940	120	0.67%	180	67%
20000	20060	19920	140	0.70%	200	70%

Figure 3. Difference in Adapters on a Truck Scale

full scale using two different size adapters. The adapter on the left better simulates the tire of a truck, the adapter on the right simulates that of an airplane. The difference between the adapters is over 1.3 % on a 0.5 % device. It becomes apparent quickly that this scale, like several others, will not be within the specification, if different size tires are used that vary from the footprint of the adapter used during calibration. Figure 3 shows a change in the output of 140 lbf on a 1 % device. Though it is possible to stay in tolerance, the different size adapters consume about 70 % of the overall tolerance. Therefore, all scales should be calibrated with the appropriate adapters to simulate the application best.

3. We can use the proper units for calibration.

We highly recommend calibrating any scale in force units. The scales would be calibrated in lbf, N, or kgf at the site of calibration. Force is mass times acceleration and calibration in lbf, N would be constant over the planet's surface. If someone calibrated in mass, lb, or kg, and used the scale in a different location, they would have errors from gravity, as well as material and air density. Mass, under almost every terrestrial circumstance, is the measure of matter in an object. If the lab calibrated a scale in mass and used it elsewhere, they would need to correct for gravity at the location the device was calibrated. Finding that location of calibration can sometimes be a challenge. If the location is known, a correction needs to happen. If the location is not known, the scale will have an additional error.

Measuring force takes additional factors into account: air density, material density, and gravity. It's the effect of gravity, which can produce significant errors when comparing mass and force measurements. Gravity is not constant over the surface of the earth. The most extreme difference is 0.53 % between the poles and the equator (983.2 cm/s^2 at the former compared to 978.0 cm/s^2 at the latter). A force measuring device calibrated in one location using mass weights then deployed somewhere else will produce different strains on the physical element. The resulting measurement errors can be significant.

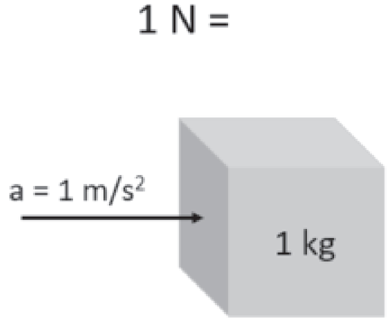


Figure 4. Force Units

Luckily, NOAA's website has a tool for predicting local gravity anywhere on Earth. Here in York, Pennsylvania, Morehouse's gravity is 9.801158 m/s^2. If we compare that to the gravity of Houston, TX (9.79298 m/s^2), we find the difference is −0.00084 ((9.79298 m/s^2 – 9.801158 m/s^2) / 9.79298 m/s^2). As a percentage, that's −0.084 %. If a lab in Houston calibrated a force measuring device with mass weights for use at Morehouse, we could expect anything we weigh to be heavy by 0.084 %. The consequences of not correcting for differences in gravity when calibrating using masses can be significant. If we were shipping steel by the tonnage, we would ship less steel, reducing our cost but possibly upsetting our customers. Reversing the scenario, a scale calibrated in York with mass weights and used in Houston without correction, the steel supplier in Houston would ship more steel per ton. Correcting for the difference in force and mass measurements is possible. A device adjusted for force measurements, will measure force without additional error for gravity correction, air density correction, and so on.

Additionally, Morehouse has an app that can assist in converting force to mass. That app is called the Morehouse Local Gravity App, which is free in the Google Play store.

4. We can account for Calibration and Measurement Capability (CMC) uncertainty of measurement correctly.

Most legal metrology standards such as ASTM E617-18 and OIML R111 require uncertainties to be less than 1/3 of the tolerance. CMC uncertainty of measurement is used to express the laboratory's measurement capability. CMC also includes measurand of reference material, calibration measurement method, measurement range, and uncertainty of measurement. The International Laboratory Accreditation Cooperation (ILAC) and the International Bureau of Weights and Measures (BIPM) defines CMC as the calibration and measurement capability available to customers under normal conditions. CMC represents a process of frequent measurement made by the laboratory regularly.

ILAC P-14 Procedure section 6.4 requires that contributions such short-term contributions during calibration and contributions that can reasonably be attributed to the customer's device such as the resolution of the Unit Under Test (UUT) be included in the uncertainty per point value reported on the certificate of calibration. EURAMET, the European Association of National Metrology Institutes, CG4 v2.0 *Uncertainty of Force Measurements* also requires the resolution of both the standard and the UUT to be reported as standard contributors. The Expanded uncertainty per point uncertainty analysis consists of the UUT resolution and the CMC measurement uncertainty of our standard

Morehouse Measurement Uncertainty Calibration and Measurement Capability Worksheet

START ON THIS SHEET AND FILL IN ONLY LIGHT GREY BOXES

SECTION 1 DATA ENTRY			NOTE: ONLY ENTER INFORMATION IN LIGHT GREY BOXES
Laboratory	Morehouse		
Technician Initials	Torque McForcerson		All information entered must converted to like units.
Date:	10/10/2019		This spreadsheet is provided by Morehouse Instrument Company
Range	60K		It is to be used as a guide to help calculate CMC for Force or Torque Measurements
Standards Used Ref and UUT	Ref S/N U-7644 UUT S/N 0423PR12003		
Resolution UUT	2	LBF	This is the resolution of the Unit Under Test you are Using for the Repeatability Study (What you are testing)
REFERENCE STANDARD INFORMATION			
ASTM E74 LLF	1.46	LBF	* This is your ASTM E74 LLF Found on Your ASTM E74 Report. It will be converted to a pooled std dev
Resolution of Reference	0.15	LBF	This should be found on your calibration report.
Temperature Spec per degree C %	0.0015%		This is found on the load cell specification sheet. Temperature Effect on Sensitivity, % RDG/100 F
Max Temperature Variation per degree C of Environment	1		During a typical calibration in a tightly controlled the temperature varies by no more than 1 degree C.
Morehouse CMC (REF LAB)	0.0016%		This is the CMC statement for the range calibrated found on the certificate of calibration. Leave blank if entering Eng. Units
Non ASTM or ISO 376 (TOLERANCE,NL,SEB)	0	%	If non ASTM E74 or ISO 376 use this field & use Tolerance with nonlinearity or SEB if making ascending and descending measurements
Miscellaneous Error	0	%	This can be measurement error, creep, side load sensitivity or other known error sources. Enter and select Eng. Units or %
Conv Repeatability Data To Eng. Units	NO		

	Ref Standard Stability				Temperature Effect
	FORCE APPLIED	Change From Previous %	Interpolation Value	Actual LBF	0.000015
1	2000	0.0050%	0.10	0.1	0.03
2	5000	0.0050%	0.10	0.25	0.075
3	10000	0.0050%	0.25	0.5	0.15
4	20000	0.0050%	1.00	1	0.3
5	30000	0.0050%	1.50	1.5	0.45
6	40000	0.0050%	2.00	2	0.6
7	50000	0.0050%	2.50	2.5	0.75
8	60000	0.0050%	3.00	3	0.9
9			0.00		
10			0.00		
11			0.00		
12			0.00		

ISO 376 UNCERTAINTY COEFFICIENTS		
C0	C1	C2
0.1	0.00071	0.00071
Expanded Uncertainty = C0 + (C1 * F) + (C2 * F)^2		
Where F = Force Applied, C0 = Intercept, C1 = Slope		

	Repeatability of UUT								
	Applied	Run1	Run2	Run3	Run4	Average	Resolution	STD DEV	CONVERTED
1	2000	2000	2000	2000	2000	2000.0	1	0.00000000	0
2	5000	5000	5000	5000	5000	5000.0	1	0.00000000	0
3	10000	10000	10000	10000	10000	10000.0	1	0.00000000	0
4	20000	20002	20002	20002	20002	20002.0	1	0.00000000	0
5	30000	30004	30004	30004	30004	30004.0	1	0.00000000	0
6	40000	40004	40004	40004	40006	40004.5	1	1.00000000	1
7	50000	50004	50006	50004	50006	50005.0	1	1.15470054	1.15470054
8	60000	60004	60006	60004	60004	60004.5	1	1.00000000	1

Ref Laboratory Uncertainty Per Point					MUST SELECT
Force	%	Eng. Units	Conv %	Force	% or Eng.
2000	0.0016%		0.000016	2000	%
5000	0.0016%		0.000016	5000	%
10000	0.0016%		0.000016	10000	%
20000	0.0016%		0.000016	20000	%
30000	0.0016%		0.000016	30000	%
40000	0.0016%		0.000016	40000	%
50000	0.0016%		0.000016	50000	%
60000	0.0016%		0.000016	60000	%

Figure 5. CMC Measurement Uncertainty Analysis Main Sheet

(which includes the resolution of the reference). Any lab accredited to ISO/IEC 17025: 2017 would follow ILAC P-14 which requires the Calibration Process Uncertainty to be reported to the end-user.

The typical contributions for the CMC measurement uncertainty for force measurements are as follows:

Type A Uncertainty Contributions

1. ASTM llf reported as 1 Standard Deviation (k=1). ASTM llf is reported with k= 2.4.[1]
2. Repeatability conducted with the Best Existing Force measuring instrument
3. Repeatability and Reproducibility[2]

Type B Uncertainty Contributors

1. Resolution of the Best Existing Force measuring instrument
2. Reference Standard Resolution (If Applicable)
3. Reference Standard Uncertainty
4. Reference Standard Stability
5. Environmental Factors
6. Other Error Sources

1 The reason ASTM llf is called out is that many reports do not list the standard deviation. In actuality, the Standard Deviation per section 8 of the ASTM E74 standard is what is required.

2 Repeatability and Reproducibility are from an R & R study and should not be confused with Repeatability with the Best Existing Force measuring instrument as noted in 2. It is up to the end-user to determine if these errors are significant and need to be included in the final uncertainty budget.

All uncertainty contributions should be combined, and if appropriate, the Welch-Satterthwaite equation as described in JCGM 100:2008 should be used to determine the effective degrees of freedom for the appropriate coverage factor for a 95 % confidence interval. Using the information above, we can break the CMC measurement uncertainty analysis down into the contributions for the Unit Under Test, and the Calibration or Reference Standard. The following example is Morehouse's recommended guidance for any lab needing to calculate measurement uncertainty for force-measuring devices used to calibrate a 60,000 lbf aircraft scale.

In this example, the UUT Contributors are:

- Repeatability of UUT in the Morehouse Press Using a Per Point Analysis
- Resolution of UUT – We used an upgraded Aircraft scale supplied by JAWS (Jackson Aircraft Weighing) with a 2 lbf resolution for this example

The Reference Standard Contributors are:

- Reproducibility – For this, we use the ASTM LLF, which is a pooled standard deviation of 1.926 lbf
- Reference Standard Resolution – The resolution of the ref load cell used was 0.24 lbf
- Reference Standard Stability – 0.005 % was used for a 60,000 lbf Morehouse Ultra-Precision Load Cell
- Environmental Factors – 0.0015 % per degree C
- Repeatability study using four measurements at each point for several points throughout the range
- Repeatability and Reproducibility between technicians

Repeatability and Reproducibility Worksheet						
	Technician 1	Technician 2	Technician 3	Technician 4	Technician 5	Technician 6
1	60006	60006				
2	60006	60006				
3	60006	60006				
4	60006	60006				
5	60006	60006				
6	60006	60006				
7	60006	60008				
8	60008	60008				
9	60008	60008				
10	60008	60008				
Std. Dev.	0.966091783	1.032795559				
Average	60006.6	60006.8				
Variance	0.933333333	1.066666667				
Repeatability		**1**		1.00	**0.99988668**	LBF
Reproducibility		**0.141421356**			**0.14140533**	LBF
Std. Dev. Of the Mean		0.1	Convert to Eng Unit (Use Values Above)			NO
			Force Value corresponding to R & R Output			60000.00

Figure 6. CMC Measurement Uncertainty Repeatability and Reproducibility Analysis

Repeatability and Reproducibility between technicians: This should be performed whenever there is a change in personnel, equipment, or the first time a budget is established. In most force machines, the R and R is going to be at its worst at capacity. The capacity of the machine is when any bending, torsion, and side loading tend to present the most error. Therefore, it is recommended that R and R be done at capacity. For optimum results, several R & R studies should be done throughout the range.

This example uses two technicians recording readings at the same measurement point on the same equipment in lbf. Repeatability between technicians is found by taking the square root of the averages of the variances of the readings from the technicians (Pooled Standard Deviation). Reproducibility between technicians is found by taking the standard deviation of the averages of readings for each technician (refer to bottom three rows in Figure 7).

Measurement Uncertainty Budget Worksheet									
Laboratory	Morehouse								
Parameter	FORCE	Range	60K	Sub-Range					
Technician	HZ	Standards Used							
Date	10/10/2019								
Uncertainty Contributor	Magnitude	Type	Distribution	Divisor	df	Std. Uncert	Variance (Std. Uncert^2)	% Contribution	u^4/df
Repeatability Between Techs	1	A	Normal	1.000	18	1.00E+0	1.00E+0	16.06%	55.6E-3
Reproducibility Between Techs	0.141421356	A	Normal	1.000	1	141.42E-3	20.00E-3	0.32%	400.0E-6
Repeatability	1.0000E+0	A	Normal	1.000	3	1.00E+0	1.00E+0	16.06%	333.3E-3
ASTM E74 LLF	608.3333E-3	A	Normal	1.000	32	608.33E-3	370.07E-3	5.94%	4.3E-3
Resolution of UUT	2.0000E+0	B	Resolution	3.464	200	577.35E-3	333.33E-3	5.35%	555.6E-6
Environmental Conditions	900.0000E-3	B	Rectangular	1.732	200	519.62E-3	270.00E-3	4.34%	364.5E-6
Stability of Ref Standard	3.0000E+0	B	Rectangular	1.732	200	1.73E+0	3.00E+0	48.19%	45.0E-3
Ref Standard Resolution	150.0000E-3	B	Resolution	3.464	200	43.30E-3	1.88E-3	0.03%	17.6E-9
Non ASTM or ISO 376 (TOLERANCE,NL,SEB)	000.0000E+0	B	Rectangular	1.732	200	000.00E+0	000.00E+0	0.00%	000.0E+0
Miscellaneous Error									
Morehouse CMC (REF LAB)	960.0000E-3	B	Expanded (95.45% k=2)	2.000		480.00E-3	230.40E-3	3.70%	
			Combined Uncertainty (u_c)=			2.50E+0	6.23E+0	100.00%	439.5E-3
			Effective Degrees of Freedom			88			
			Coverage Factor (k) =			1.99			
			Expanded Uncertainty (U) K =			4.96	0.00826%		
Slope Regression Worksheet									
	Applied	Run 1	Run 2	Run 3	Run 4	Average	Std. Dev.	Ref CMC	LBF
1	60000.00	60004.00	60006.00	60004.00	60004.00	60004.5	1.0000	0.0016%	0.96
Repeatability (Of Error)			Average Standard Deviation of Runs			1.000000			

Figure 7. CMC Measurement Uncertainty Analysis 60,000 lbf point

Repeatability Data: Data needs to be taken for various test points throughout the loading range. This example only shows one data point. Calculations should be performed for several data points throughout the loading range.

Note 1: Force measuring instruments calibrated in accordance with the ASTM E74 standard are continuous reading force measuring instruments and any uncertainty analysis should be conducted on several test points used throughout the loading range to meet the requirements of ILAC P-14 as well as ISO/IEC 17025:2017.

Note 2: There are Excel spreadsheets available for calculating measurement uncertainty from various force calibration laboratories. If the spreadsheets are used, the laboratory should conduct validation of the spreadsheet templates.

Note 3: The % Contribution Column is useful in determining significant contributors to uncertainty. In this example, the reference standard stability is the largest source of error with 48.19 % of the total contribution.

Conclusion

If the Uncertainty of the measurement is not less than the tolerance required, there will be a significant risk. OIML R111-1 states "The error in a weight used for the verification of a weighing instrument shall not exceed 1/3 of the maximum permissible error for an instrument," hence, the recommendation for several load cells. We have found the CMC measurement uncertainty component of 0.03 % to be attenable at approximately 20 % of the capacity of the reference standard load cell. Meeting the 1/3 requirement on a device with an accuracy specification of 0.1 % of applied force, will often require using two load cells. In the example below, 0.03 % or better was achieved from 10,000 lbf through 60,000 lbf. A second load cell would be required to capture force points below 10,000 lbf to maintain 1/3 of the tolerance requirement. Measurement uncertainty often includes the reference standard uncertainty, resolution of both the reference and the UUT, environmental conditions, reproducibility, repeatability, stability, and other error sources. If the machine has uneven surfaces or bending, reproducibility and repeatability will vary greatly. Any system used for calibration should be designed to be plumb, level, rigid, square, and free from torsion. In force transfer machines, the transfer of force should be facilitated through a force-measuring device, and adapters need to duplicate the footprint of the tires of the airplane or truck the scale will be used to weigh. The errors associated with not using the proper equipment, units, or adapters can make achieving tolerances impossible. When using the proper adapters and machine, if you need to certify an instrument within a tolerance of 0.1 % of applied force, more than one load cell may be required to calibrate the scale over the entire measurement range.

References

[1] JCGM 100:2008 *Evaluation of measurement data — Guide to the expression of uncertainty in measurement.*

[2] ILAC P14:01/2013 *ILAC Policy for Uncertainty in Calibration.*

[3] ASTM E74-18 *Standard Practices for Calibration and Verification for Force-Measuring Instruments.*

[4] A2LA R205 *R205 - Specific Requirements: Calibration Laboratory Accreditation Program*, American Association for Laboratory Accreditation, 2015.

[5] ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories.*

[6] OIML R111-1 Weights of classes E1, E2, F1, F2, M1, M1–2, M2, M2–3 and M3.

[7] ASTM E617-18 *Standard Specification for Laboratory Weights and Precision Mass Standards.*

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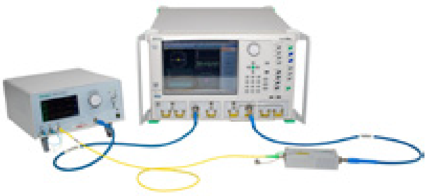
	Applied	Expanded Uncertainty	Expanded Uncertainty %
1	2000	2.64255	0.13213%
2	5000	2.64478	0.05290%
3	10000	2.66466	0.02665%
4	20000	2.89856	0.01449%
5	30000	3.19707	0.01066%
6	40000	4.16730	0.01042%
7	50000	4.72192	0.00944%
8	60000	4.95855	0.00826%

Figure 8. CMC Measurement Uncertainty Using a 60,000 lbf Morehouse Scale Press and Morehouse Load Cell



Anritsu Company Introduces Modular Opto-electronic Network Analyzer

MORGAN HILL, Calif., Sept. 25, 2019 /PRNewswire/ — Anritsu Company introduces the ME7848A Opto-electronic Network Analyzer (ONA) system, a flexible solution integrating the VectorStar® vector network analyzer (VNA) with an O/E calibration detector and E/O converters that conducts cost-effective E/O, O/E and O/O measurements on optical devices operating at 850 nm, 1310 nm, and 1550 nm. Incorporating a modular approach, the ME7848A provides engineers with an unprecedented level of flexibility and the ability to customize the system with their own devices to meet specific test requirements, for significant time and cost benefits.

The ME7848A modular system provides engineers with the ability to design optimal opto-electronic solutions and speed time-to-market by improving first-time yields. In addition to the VectorStar VNA operating up to 40 GHz and 70 GHz, the solution consists of the MN4765B O/E calibration module detector and MN4775A E/O modulator. Because the system is modular, the E/O modulator can be added when necessary, for added cost efficiency.

The system can be adapted for different wavelengths with the addition of the appropriate O/E calibration module or E/O converter. The VNA can be reconfigured for different wavelengths through calibration with the MN4765B, eliminating the need for additional VNAs to accommodate various wavelengths.

Offering a traceable path with excellent performance specifications, the ME7848A ONA is well-suited for R&D and production of opto-electronic components used in optical network data transfer systems. The system capabilities allows engineers to quickly identify measurement parameters and component performance for a high degree of confidence in their designs.

To learn more visit www.anritsu.com and follow Anritsu on Facebook, LinkedIn, Twitter, and YouTube.

ALIO True Nano® Precision Rotary Stages

(Arvada, CO, USA 5th July 2019) ALIO Industries is synonymous with best-in-class nanometer-level motion control solutions, and is well known as the only motion control technology supplier that offers true nanometer-level accuracy and repeatability.

Exemplifying the company's grip on the ultra-precise motion control sector, ALIO Industries recently introduced its market-leading Hybrid Hexapod® technology. The Hybrid Hexapod® is a game-changer in the field of motion control, and stimulates innovation as an enabler of next-generation manufacturing processes.

However, with upwards of 20 years working in the area of nanometer-level motion control, ALIO Industries has also developed TRUE NANO® precision rotary stages to meet and exceed today's demand for high precision rotary motion. ALIO's line of rotary stages continues to expand as the company works with each customer on a one-to-one basis to provide customized motion control solutions, not off-the-shelf mass motion control products.

Mechanical Rotary Stages

ALIO's mechanical bearing rotary stages have been designed with crossed roller bearings for improved stiffness for offset loads and rotational precision. Integrated with servo torque frameless motors, these stages can handle applications where the mass and acceleration needs are extreme, while still maintaining nanometer-level precision performance.

Standard ALIO rotary stages have 0.2 arc-second repeatability using ALIO supplied motion controllers. Standard mechanical crossed roller bearings are rated at 13 to 20 microns of radial and axial run-out, with optional run-outs of certain models below 5 microns.

The mechanical bearing rotary stage family has multiple motor sizes to meet duty cycles as well as mass and acceleration needs from 80 mm to 300 mm in diameter. Vacuum rotary union options are available on the inner diameter for mounting a vacuum chuck.

Low Angle Mechanical Rotary Stages

ALIO has also designed mechanical bearing rotary stages with angular contact bearings representing the most compact design on the market. Integrated with servo ironless motors, these stages best fit metrology applications where small angular adjustment is needed with nanometer-level precision performance.

Air Bearing Rotational Stages

When ultra-tight run-out precision motion is needed, manufacturers can choose from ALIO's continually growing line of air bearing rotary stages. Whether it is exceptional stiffness or cost-effective motion that is the priority, ALIO Industries can offer a variety of options to meet the needs of today's nano-precision applications.

Dual Axis Rotary Systems

ALIO's two-axis systems are designed around the customers' mass with variable counterbalance, cable guidance, and cable and air feed-through capabilities. With hard-stops allowing for ± 110 and ± 170 degrees of rotation for nearly unlimited part access on the horizontal axis, ALIO's dual axis rotary systems exhibit angular travel ± 180 for the rotation about the vertical axis.

Two-Axis Gimbal

Incorporating ALIO's industry-leading torque ratings, the company's two-axis gimbal rotary systems are capable of high rotational speeds while maintaining the stand-out precision levels expected from ALIO Industries' systems. Metrology, laser processing, additive manufacturing, and many other industry sectors have benefited from these ALIO products., and air purge is incorporated for contaminant protection and longer life. Internal cable and air line routing provide an extremely clean finished product.

AZ-EL Rotary Assembly

ALIO Industry's AZ-EL rotary assembly systems also incorporate the company's exceptional torque-ratings and are capable of high rotational speeds while maintaining the precision levels synonymous with any ALIO motion control systems. As with the two-axis gimbal system, the AZ-EL rotary assembly systems are used in metrology, laser processing, additive manufacturing, and numerous other industry applications.

Any company interested in ALIO's nanometer-level motion control solutions are advised to contact the company, and discuss the ways in which bespoke solutions can be designed to precisely fit with specific application requirements.

CONTACT ALIO INDUSTRIES, Walter Silvesky, Vice President of Sales, +1 303-339-7500, walter.silvesky(at)alioindustries.com, www.alioindustries.com

CALIBRATED

BY TRANSCAT®

NEW PRODUCTS AND SERVICES

Shaw Moisture Meters Opens USA Sales, Service and Calibration Location

Shaw Moisture Meters announces the establishment of Shaw Moisture Meters (USA) in Hudson, Massachusetts, offering for the first time, direct sales, repair and calibration services to its customers in North America.

Shaw Moisture Meters (USA) has a fully equipped calibration laboratory with ISO/IEC 17025 accreditation and stocks the full range of Shaw Moisture Meters products. Trained, experienced staff are available at the new location to advise on dewpoint applications and specific requirements. All calibrations are supplied with a calibration certificate as standard, traceable to the Humidity Standard at NIST/NPL.

To ensure customers consistently receive high quality products and services, Shaw Moisture Meters is registered to ISO 9001, the international standard that sets out specific requirements for an effective quality management system.

With the opening of this new facility, Shaw Moisture Meters is continuing its investment and commitment to regional and local markets around the world. Customers in North America can now receive sales and service support directly from the Shaw Moisture Meters (USA) office.

Shaw Moisture Meters was established in Bradford, UK in 1960. This pioneering business was the brainchild of Leonard Shaw and the culmination of years of specialist study and industry knowledge. With over 60 models of moisture meters being manufactured for different industries, Shaw Moisture Meters continues to move forward through the constant process of research, design and technological innovation.

For more information contact: Bob Kenney, CEO, Shaw Moisture Meters (USA), 399 River Road, Hudson, MA 01749, (978) 333-7140, usa@shawmeters.com, https://www.shawmeters.com/new-location-usa/

MB Dynamics Multi-DUT Accelerometer Calibration System

Posted September 24, 2019 by Molly Chamberlin — MB Dynamics, Inc. (www.mbdynamics.com)(MB), field-proven industry experts in the design, manufacture and supply of vibration test systems and equipment, including buzz, squeak and rattle (BSR), steering, and suspension component test systems; modal exciters and amplifiers; automated calibration systems; dynamic controllers; transducer calibration systems; and test engineering services, today announced the global market launch of its Win475 MULTI-DUT CRASH-CAL (MDCC) automated accelerometer calibration system.

The MB Dynamics Win475 MDCC increases metrology center throughput and productivity by facilitating the accurate, efficient, and simultaneous automated calibrations of up to eight (8) single axis piezoresistive accelerometers (DUT's) of the same model and type, over a frequency range of 10 to 4000 Hz, complying with SAEJ211, SAE2570, and other global automotive industry test standards. Its versatile design further supports the automated single calibrations of non-piezoresistive DUT's, including piezoelectric, IEPE, voltage and velocity sensors, over frequencies from 5 Hz to 15 kHz. These combined features can help calibration technicians to achieve a measurable 70%-time savings over single-DUT calibration methods with greater accuracy and repeatability.

As a complete turnkey system, the industry-exclusive design of the Win 475 MDCC automated accelerometer calibration system seamlessly integrates MB's own Model CAL25AB air bearing exciter, together with its Model 407-8X multi-channel signal conditioner; MB 500VI power amplifier; and proprietary MB Win475 MDCC software, further supported by an industry standard NI DAQ card.

Other system components include an internal removable reference (REF) accelerometer with 100 mV/g sensitivity and usable frequency range to 15 kHz, further traceable to national standards and ISO 17025; an eight-DUT test instrument mounting fixture (TIMF) adaptor plate; a single-DUT TIMF; a 475PCM module; a Windows 10 PC, monitor, keyboard and printer; a calibration accessory kit; user manuals; and system installation, start-up and training support.

As a multi-DUT automated calibration system, the MB Win475 MDCC quickly and efficiently measures and saves relevant accelerometer characteristics, such as ZMO, Zin and Zout, as well as input & output impedance values. Its versatility and flexibility allow an end-user to choose from among seven individual (six internal, one external) high-precision resistors for shunt calibration. The system also reads onboard sensor electronic identifications, such as 1-Wire Dallas ID memory chips or TEDS piezoelectric accelerometers (per IEEE 1451). The MB MDCC system may be further integrated into customer-specified databases for additional automation capabilities with reduced calibration data transference errors.

The automation afforded by the MB Win475 MDCC mitigates the risks of human errors inherent to manual accelerometer calibration systems, thereby freeing up technicians for other measurement tasks. The increased frequency of accelerometer calibrations afforded by system further helps technicians to improve in-laboratory test data quality and productivity while reducing documentation errors. The system has proven especially useful within crash test and automotive safety test laboratory environments, in applications where larger volumes of piezoresistive accelerometers are in use, therefore requiring more frequent recalibrations. In addition, the MB Win475 MDCC provides a number of value-added end-user benefits, including bottom-line cost savings, with its elimination of outsourced calibration service needs; implementations of more efficient and effective in-house calibration processes; and simplifications of internal record-keeping accuracy, further aiding in ISO audit compliance. The Win475 MDCC automated accelerometer calibration system is also accompanied by full technical support, with in-house customer training provided by the 40-year calibration experts at MB Dynamics.

For more information about the MB Win475 MDCC automated accelerometer calibration system or other products and services from MB Dynamics, please contact the company at +1-216-292-5850, via email at sales@mbdynamics.com, or visit www.mbdynamics.com.

Morehouse Local Gravity App for Android

When someone asks us about converting force to mass, Morehouse can now say we have an app for that. Not only will our app convert force to mass, but it will convert mass to force as well as convert units. It will convert force, torque, and pressure units. Anyone interested in downloading the app can visit the Google Play store: https://play.google.com/store/apps/details?id=com.mhforce.localgravity.

Let's look at why this app is needed.

Using force instruments to calibrate in mass has measurement error.

Forces are defined by Newton's second law of motion expressed by F =kMA. Forces are not the same as or can they be substituted for mass without correction. Phillip Stein once wrote in his paper Gravity of the Situation, "Some measurements and calibrations require knowledge of little g. Errors and uncertainties in little g fall right to the bottom line (a 1% error in g results in a 1% error in the force reported) and therefore exert an important influence on the correctness of measurement results."

A common example of these measurement errors occurs with scales (a mass measurement device). If 1000 lbs mass is used to calibrate a scale at Morehouse and that scale is shipped to Denver, CO, it would have to be calibrated again or corrected by formula to obtain the proper mass. Just comparing the gravity in York (9.801158 m/s2) and Denver (9.79620 m/s2), we find a difference of about 0.05 %. Without correction, 1000 lbs applied would read as 999.5 lbs. If the accuracy of the scale were 0.01 %, then the device would be at least five times greater than the accuracy specification.

Dynamometers, crane scales, tension links, handheld force gauges, and other similar devices are not always "Legal for Trade Scales." Mainly, they can be used as force measuring devices because their displayed value can be adjusted based on a known force. If a known mass is used on-site, there is insignificant gravitational measurement error. The device can be used as a low-accuracy mass comparator. Since many of these instruments are used for measuring loads of 1 ton through 300 tons, it's impractical to have the mass weights necessary to calibrate on-site and calibrating using force may be the only practical method to certify the device.

Therefore, the best solution is to have your load cells, proving rings, crane scales, etc., calibrated in force and convert the force readings at the location the instrument is being used to mass. If this is not done, the end-user can live with the error, or they can have someone with large amounts of masses come on location and calibrate the weighing device on-site. It's often a logistics matter and calibrating in force and converting to mass is simple enough. It's been further simplified by downloading the free Morehouse local gravity app.

The Ralston Quick-test Connection Platform

The Ralston Quick-test Connection Platform is a universal pressure hose system engineered to facilitate fast, leak-free connections for pressure testing, calibration, and leak testing. The unique design of our hoses and adapters offers secure, time-saving connections - without the need for a wrench or thread tape - for low volume, high pressure connections to virtually any device being tested.

Ralston Quick-test hoses are an industry first. They have a smaller inner diameter than most hoses, which makes them ideal for transmitting high pressure without wasting large amounts of compressed gas or fluid. And because they're made with a polyamide-reinforced inner core, they can twist and bend without losing volume across the hose. Ralston Quick-test Adapters are a perfect complement to the hoses. They allow direct connection to male or female NPT, BSPP, Tube Fittings, Metric, AN 37° Flare and CGA 580 fillings without any additional tools or thread sealant. They can also vent pressure while still connected, and because they eliminate the need for wrenching, the threads don't wear out.

The Ralston Quick-test Connection Platform was designed for simplicity and ease of use. For more information, contact Ralston Instruments at ralstoninst.com/cmqt or call +1 440-564-1430 for more information.

New Book on the 3458A

Sampling with 3458A: Understanding, Programming, Sampling and Signal Processing by Rado Lapu, is an exellent reference on the high-end multimeter model 3458A, first introduced by Hewlett Packard in 1988.

This instrument stands out from other multimeters due to its features, such as its self-calibration capability, the linearity of its ADC and its high-speed sampling modes. Three decades after its introduction, the 3458A is still unrivaled in some of its characteristics.

In electrical measurements, sampling methods are superseding more and more of the traditional analog bridge techniques. This book explains and describes the sampling capabilities of the 3458A multimeter and it gives many examples of its applications. The book is an ideal reference for support of calibration staff at metrological laboratories around the world.

More information about the book may be found here: https://rlbook.flox.cz/

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Comments on Unsustainable Software

Michael Schwartz
Cal Lab Solutions, Inc.

I recently visited one of my largest customers. They have a huge internal self-maintainer calibration program and years ago they decided they wanted to get all their calibration system on a single platform.

They went from having one metrology engineering position to four metrology engineers today. But I noticed their ratio of engineers to technicians had changed. Before, they had one metrology engineer for five technicians. Today, they have one engineer for every two technicians. Why such a change in the ratio?

So, I asked what they were doing. "The current project was to rewrite a bunch of procedures because they have the new Fluke meter." I then asked how they were doing this. Their answer was "We open up the current procedure, copy it into the new project file and go through changing all the commands. We keep the original procedure in case we need to use it if the meter is out for calibration." I asked "So if you find an error or a specification change in the UUT you have to fix it in several places?" Their answer was "YES."

This is an example of software that is NOT SUSTAINABLE! Lab managers, if your staff is increasing because your code base is increasing exponentially, your software development effort is not sustainable! You need to rethink the investment in your software development efforts.

The root cause of the problem is: Every line of code you write is a line of code you have to debug and support! The hidden cost (i.e. the REAL COST) of software is not in the development of the software, it is in the support and maintenance of the code.

In school I had some amazing instructors. One taught part-time, because his day job was writing code. He always said "This is what will be on the test; this is a better way to write the algorithm and why." But the most import thing he said was "Anytime you want to copy and paste something, think again, then write a function and call it. Because, now that you have less code, if there is a problem, you can fix it in one place."

So, back to my customer. I understand their problem; they don't have the time to design a better solution and need to get the new DMM integrated and product going out the door. But by doing this, they are trading a short-term gain and creating a long-term problem!

What's the solution? To be honest, I don't know the perfect solution, but I do know what works for us at Cal Lab Solutions. We have the world's largest library of MET/CAL® procedures and don't spend a lot of time doing technical support. What we did to support all the UUTs using all the possible standards was architect a development methodology using Object Oriented Programming principals.

We write ONE piece of code for the UUT and ONE piece of code for the standard, and then link them in a _Config Sub Procedure. A little confusing at first, but if you download the free procedure for the Agilent DSO-X3000 scopes from our website, you can see how a single UUT procedure works with a Fluke 5520, 5820, 9500, even a Fluke 5700 and PSG. That one file—and good architecture—makes it all work.

The driver method we created 20 plus years ago in MET/CAL® was a great step forward in the progress towards sustainable software. It was a good foundation to build on, but it has limitations. For one, it only works at compile time, meaning all the standards have to be known when the automation is written. And two, it only works in one language. These two limitations are bad for sustainability.

As I said before, I don't have all the answers to sustainable metrology software, but I have been writing automation for 25 years. I have learned what works and what doesn't. Big long monolithic scripts in MET/CAL®, LabView® or any other language is a bad idea. Modularity is the key. We proved that with our MET/CAL® procedures, by creating the largest library in the world, with a fraction of the people.

Now with Metrology.NET®, we are taking another big leap forward on the evolution of sustainable software for metrology. The demo we did at this year's NCSLI Workshop & Symposium showed the new Fluke 8588 calibrating AC Volts on the Fluke 5522A. It's not a 4 to1 TUR, but it took less than two weeks to write the driver. And, it worked calibrating the 5522A with absolutely zero code changes to the 5522A test package. Now you can use the 8588A anywhere you used the 3458A, 8508A, 5790A, LCR Meter, etc., and do it with one engineer… way more sustainable! ❧