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### **An Introduction to Measurement Uncertainty**

Saturday, August 16, 2003 1:00 pm – 5:00 pm  
Mike Ouellette  
National Research Council Canada  
Ottawa, ON Canada

Why is it important to express the uncertainty in measurement? Quite simply, there is no traceability in measurements that lack statements of uncertainty at every link of the traceability chain. For this and other reasons, ISO/IEC 17025 requires calibration laboratories, in particular, to provide estimates of uncertainty of their measurements using accepted practices. The instructor will discuss the basics for preparing uncertainty estimates for typical uncomplicated measurement processes. His approach is consistent with the GUM but it dispenses, wherever possible, with the algebraic notations, statistical jargon, arithmetic modeling, and differential calculus operations found in the GUM that perhaps encumber a person who requires no more than a simple, conservative estimate of the uncertainty in the result of a simple measurement process. For these situations, it will be shown that the mathematics is quite straightforward and that the actual challenge, if any, to estimating uncertainty in measurement is in defining the factors that affect the measurement; namely, in understanding the metrology. Participants will receive an example Excel spreadsheet for making simplified uncertainty calculations. The tutorial will include a group exercise. Participants should bring stationary and pocket calculators.

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### **Accreditation: View by a Lead Assessor**

Sunday, August 17, 2003 8:00 am – 12:00 pm  
John A. Wehrmeyer  
Quality Consultants of New York  
Maryville, TN

This tutorial will review the process of accreditation of a calibration laboratory. Brief comparisons to the process of accreditation of a testing laboratory will also be presented. The focus will be on those areas where most laboratories struggle, such as measurement uncertainty, validation of non-standard methods, proficiency testing, and document control, although time will not allow for an in-depth discussion of each of these topics. The goal of the tutorial is to help a laboratory preparing for accreditation to be aware of the assessor's expectations and thereby be more prepared for the accreditation experience.

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### **The Fundamentals of Pressure Metrology**

Sunday, August 17, 2003 8:00 am – 12:00 pm  
Kurt Solis  
Ruska Instrument Corporation  
Houston, TX

This tutorial will cover fundamental aspects of the measurement of the pressure parameter. The discussion will include definition of pressure (as derived from base SI units), terminology, and sensing/transduction technologies and associated principles. Also presented will be basic principles associated with 'primary' standards (liquid manometers and piston gauges). The transfer of pressure knowledge (including traceability issues) will be discussed which includes application/process considerations required for the competent 'transfer' of pressure to other devices, i.e. the calibration process. To facilitate the presentation some active demonstration hardware will be made available as well.

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## **Good, Bad, or Indeterminate: Using Guardbands to Help Make the Call**

Sunday, August 17, 2003

8:00 am – 12:00 pm

David Deaver

Fluke Corporation

Everett, WA

When calibration data is provided on a certificate, ISO 17025 requires a statement of the measurement uncertainty. In addition, if a statement of compliance with specifications is made, the uncertainty of measurement must be taken into account. This tutorial will describe some practical ways to consider uncertainties when making in-tolerance or out-of-tolerance declarations.

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## **Temperature Calibration: Systems & Turnkey Solutions**

Sunday, August 17, 2003

8:00 am – 12:00 pm

John Tavener

Isothermal Technology Limited

Pine Grove, Southport, England

The focus of this tutorial will be on complete calibration systems. The two main methods of calibration will be described, comparison calibration and fixed point or absolute calibration. The tutorial will then focus on combinations or systems which permit the calibration to be done automatically or semi-automatically and if time permits turnkey options in which the complete calibration project including laboratory size, supplies, air conditioning requirements and health and safety consideration are all provided.

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## **Weighing in on Mass**

Sunday, August 17, 2003

8:00 am – 12:00 pm

Randall Schoonover

Independent Consultant

Cedaredge, CO

and

Frank E. Jones

Independent Consultant

Surfside Beach, SC

This tutorial deals in detail with the key elements in the determination of mass. Subjects treated include definition of mass; mass standards, "apparent mass" (conventional value of the result of weighing in air); mass measurement (direct measurement of mass and mass comparison; air density equations and practical use, and the buoyancy effect; cleaning of weights; balance observations and use; balance and weighing errors; necessity of thermal equilibrium between a mass artifact and air in the balance chamber; weighing equation, parameters that can cause error in mass determinations, uncertainty estimates and statistical tools (standard deviation, F test, t test); between-time component of error or uncertainty; and the importance of density determination to mass determination.

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## **Laboratory Compliance with ISO/IEC 17025 – Keeping it Simple!**

Sunday, August 17, 2003

1:00 – 5:00 pm

Roxanne M. Robinson

A2LA

Frederick, MD

The new standard for accreditation of laboratories, ISO/IEC 17025:1999, was published in December 1999, replacing ISO/IEC Guide 25:1990. Internationally recognized accreditation bodies agreed to have full compliance with this standard from all of their accredited laboratories by December 31, 2002. Meeting this goal has been a two-year adventure for both the laboratories and the accreditation bodies, including A2LA. Along the way, we have found all of the strengths and weaknesses of ISO/IEC 17025, and have worked to interpret the requirements in ways that are economical for the laboratories and are technically sound. This presentation will review the requirements of ISO/IEC 17025 and offer guidance on implementing the standard in simple, economical ways while maintaining the necessary technical rigor of the laboratory.

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## **Gas Flow Measurements**

Sunday, August 17, 2003

1:00 – 5:00 pm

Thomas Kegel

Colorado Engineering Experiment Station, Inc.

Nunn, CO

This tutorial focuses on measurement uncertainty aspects of gas flow measurement; it is organized into two parts. The first part is an overview of the metering hardware with emphasis on the uncertainty issues associated with the different technologies. The second part describes the process of correctly interpreting calibration results for particular application conditions. This process includes issues associated with fluid properties, installation effects and performance correlations.

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## **Estimating the Uncertainty in Deadweight Piston Gauge Pressure Measurements**

Sunday, August 17, 2003

1:00 – 5:00 pm

Ken Kolb

Ruska Instrument Corporation

Houston, TX

This tutorial will include advanced discussions and demonstration of the key application considerations using the deadweight piston gauge as a pressure reference. The primary focus of the presentation will be an exercise to estimate the uncertainty of measured pressure for an actual calibration system. The exercise will emphasize the methods and procedures applied in the statistical determination of the "expanded uncertainty" in accordance with NCSLI RISP-4 and the ISO Guide to the Expression of Uncertainty in Measurement. Attendees with some experience in the application and metrology of deadweight piston gauge pressure measurements will benefit the most from this tutorial, but all experience levels are welcome.

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## **Introduction to Sound Measurement and Microphones**

Sunday, August 17, 2003

1:00 – 5:00 pm

Niels V Boegholm

Bruel & Kjaer

Denmark

This tutorial will explain what sound is and how (and why) it is measured. Different sound fields like the pressure-field, free-field and random-field is explained. Sound parameters like Sound Pressure Level and Sound Power as well as different frequency weighting functions is explained. Different types of microphones are introduced, with major focus on the condenser measurement microphone. Which microphone parameters are important for different applications? Introduction to different microphone calibration methods (using primary (reciprocity) calibration, comparison, actuator and pistonphone /calibrator) is provided. The major uncertainty contribution elements in sound measurement are defined and examined in some detail. Finally the latest trends in microphone technology, like MEMS and microphones with integrated data sheets (TEDS) are briefly explained.

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## **Force Calibration: Methods and Uncertainties**

Sunday, August 17, 2003

1:00 – 5:00 pm

Michael Tovey

Tovey Engineering, Inc.

Phoenix, AZ

Force calibration is a special discipline with many considerations not common to other areas of metrology. Often measurement uncertainties are underestimated due to the omission of significant error sources. Metrologists must consider both mechanical and electrical boundary conditions to achieve calibrations with low measurement uncertainties. Factors such as second order material responses, and interaction of undesired parasitic loading due to fixture characteristics, misalignment of load frame components, stiffness, etc. can have significant influence on the measurement result. This tutorial will cover the structure and characteristics of force transducers, force calibration methods, force calibration standards (E74 and ISO 376) and measurement uncertainty models. The tutorial begins at a basic level and leads to discussion of more complex issues.

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## **Humidity Measurement**

(Sponsored by RH Systems and Rotronics)

Sunday, August 17, 2003

1:00 – 5:00 pm

Bob Pragnell

Consultant

Dartford, Kent, UK

After a brief introduction this tutorial will pursue four themes which between them cover all the most common aspects of humidity measurement. Questions and discussion will be encouraged throughout, and a short time will be allowed at the end of the tutorial for further discussion.

### **Theme 1 Hygrometric definitions and relationships.**

The most commonly used measurement units will be defined with the emphasis on understanding the principles which govern the behaviour of water vapour in a gas and the reasons why there are so many ways of expressing humidity.

### **Theme 2 Humidity measurement principles and commercially available hygrometers.**

The operating principle, accuracy, range, advantages, disadvantages and suitable applications, will be discussed for the more commonly available types of hygrometer.

### **Theme 3 Calibration Standards and calibration methods for hygrometers.**

Calibration methods used by standards laboratories and industrial calibration laboratories will be covered. The discussion will be developed to cover methods available for in-house calibrations, and checks which can be performed by typical instrument users.

### **Theme 4 Humidity measurement uncertainty in rooms and enclosures.**

Measurement uncertainty is a difficult topic in any field of metrology. For relative humidity the significance of temperature is often poorly understood. The main common sources of uncertainty will be identified and ways in which they can be estimated will be discussed. A typical analysis will be presented.

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## **Running an Effective Laboratory – Measuring Performance**

(Sponsored by the NCSL International Small Business Initiative Committee)

Friday, August 22, 2003

8:00 am – 12:00 pm

Greg Powell

The Signal Group

Vancouver, BC Canada

and

Malcolm Smith, Ph.D.

NCS Laboratories

Seattle, WA

This tutorial will be of interest to owners, managers, and supervisors of calibration laboratories, both in-house and commercial. The tutorial will cover four areas where performance measurement is important in the running of a laboratory: productivity, finance, marketing and customer satisfaction. The range of measures that can be used to monitor performance in each of these areas will be discussed. Suggestions on how these measures might be used in practice and in concert will be reviewed. Examples of measurements, with discussion of their effectiveness and appropriateness for process improvement, will be given.

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## **Interlaboratory Comparisons: Their Use for Proficiency Testing, Uncertainty Statements, Traceability and More!**

Friday, August 22, 2003

8:00 am – 12:00 pm

Carroll Brickenkamp, Sharrill Dittmann, Ernest Garner

The Pi Group, Inc.

Gaithersburg, MD

Competitive issues, the possibility of “bad press,” and the impact on a laboratory’s workload can seem to be insurmountable obstacles to participating in interlaboratory comparisons. This INTERACTIVE workshop will describe some of the critical values to be derived from participation, ways to circumvent the obstacles, and economical ways to design and operate intercomparisons. Experts leading the discussions will include Henrik Nielsen of HN Proficiency Testing, Jeff Gust of Quametec, and Carroll Brickenkamp of the Pi Group, Inc.

Subjects to be discussed will include:

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- WHY: Objectives for intercomparisons
    - Looking for “agreement” in measurement values
    - How is uncertainty to be handled?
    - What facets of a laboratory’s proficiency does an intercomparison seek to determine?
    - Determining and improving procedures, standard test methods, etc.
  - HOW: Organization of intercomparison
    - Coordinator and technical advisor roles
    - Invitations and instructions
    - Timetable and sequence of participation
    - Ways to preserve anonymity; protect confidentiality
    - Ways to get routine measurements rather than the best measurement
    - Steps of the process from initial design objectives, through troubleshooting, to streamlined operations
    - Analysis of data
  - WHAT: Artifacts and/or samples to be measured
    - Stability and homogeneity
    - Packaging and transportation issues
    - Obtaining a reference value for the measurement
    - Can calibrating artifacts provide traceability?
    - Youden or split level design providing two separate test items

#### CASE STUDIES

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### **Basics of Vibration, Shock, Accelerometers and their Calibration**

Friday, August 22, 2003

8:00 am – 12:00 pm

Robert D. Sill

Endevco

San Juan Capistrano, CA

This tutorial will introduce the fundamentals of vibration and shock, the various types of accelerometers used in its measurement, and accelerometer calibration. The physics of motion and the design of accelerometers will be summarized to support the discussion of calibration, with an emphasis on the parameters that are sources of uncertainties. A description will be given of comparison and absolute calibration techniques, with examples of the typical uncertainties to be expected. A brief list of calibration “Do’s” and “Don’ts” is discussed.