Teaching MU with a minimum of mathematical content

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Outline

- Target audience for NSAI MU Training Course and common reasons for attending
- Evolution of the course content
- Some learnings from our experience
- Noteworthy features of the current offering
- Challenges and future developments

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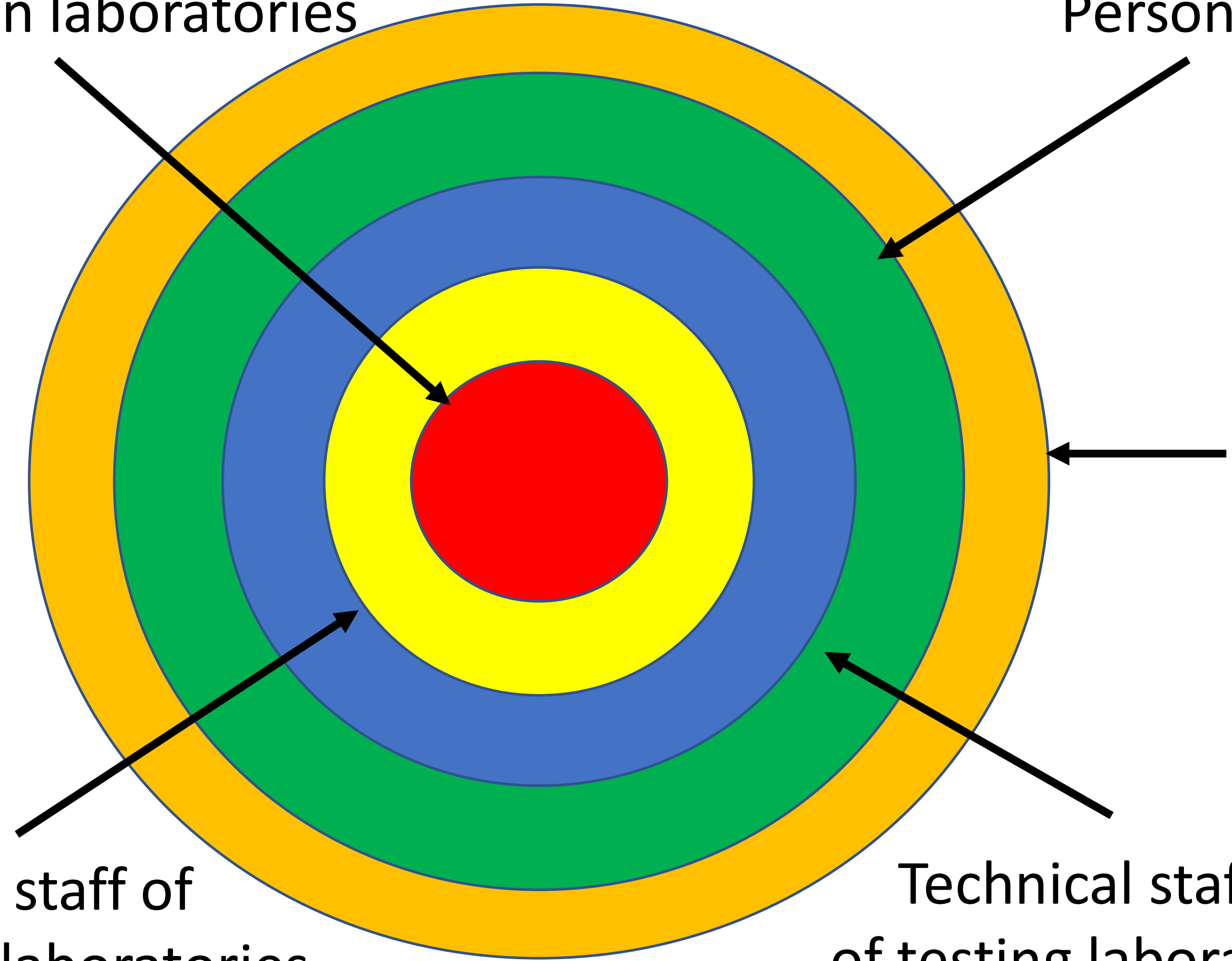
Target Audience

MU Training



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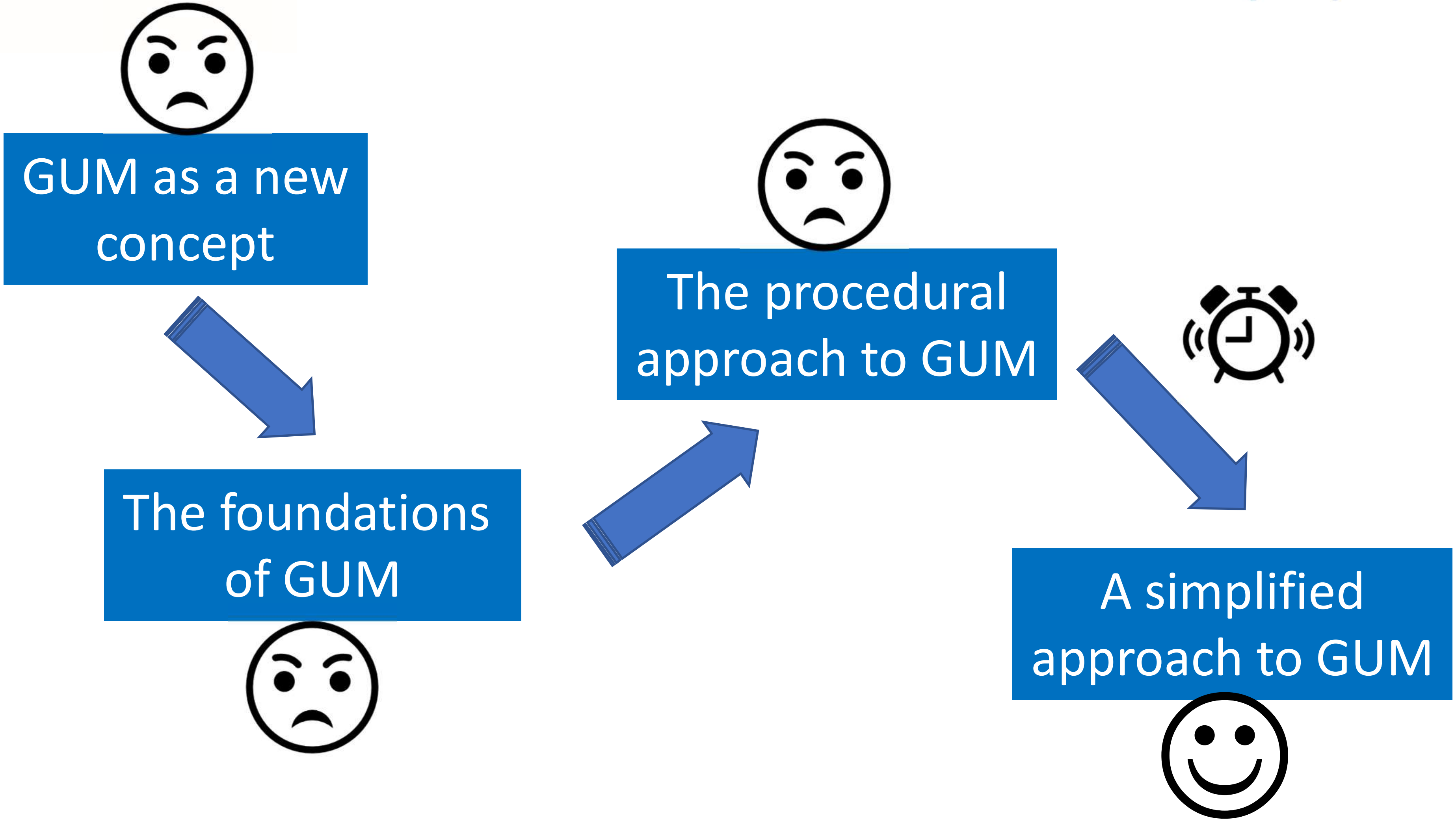
The most common reasons for attending NSAI MU Training Course

MU Training

- Addressing a non-conformance identified during a
  a technical assessment (ISO17025, ISO16859, ISO9001, FDA……)
- Setting up a new calibration/testing service
- Taking on a management role in a calibration/testing laboratory
- Managing a calibration inventory (understanding contents of calibration certificates)
- Company policy of staff development
- "My manager told me to come"

Evolution of the course content



Some Learnings from our experience

- Formulation stage is the most important
- Difficult to teach the formulation stage due to diversity of measured quantities and measurement techniques
- Resistance to writing down a measurement equation (practical aspects are preferred to abstract representations)
- It's OK to mention the word "true value" and "error" (at our level)
- Fear of statistics and statistical methods must be overcome
- "Demand" for a template needs to be addressed
- THE GUM approach does not fit well to analytical measurements
- Follow-up access is vital

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MU Training

Introduce a "hands-on" element to illustrate the formulation stage

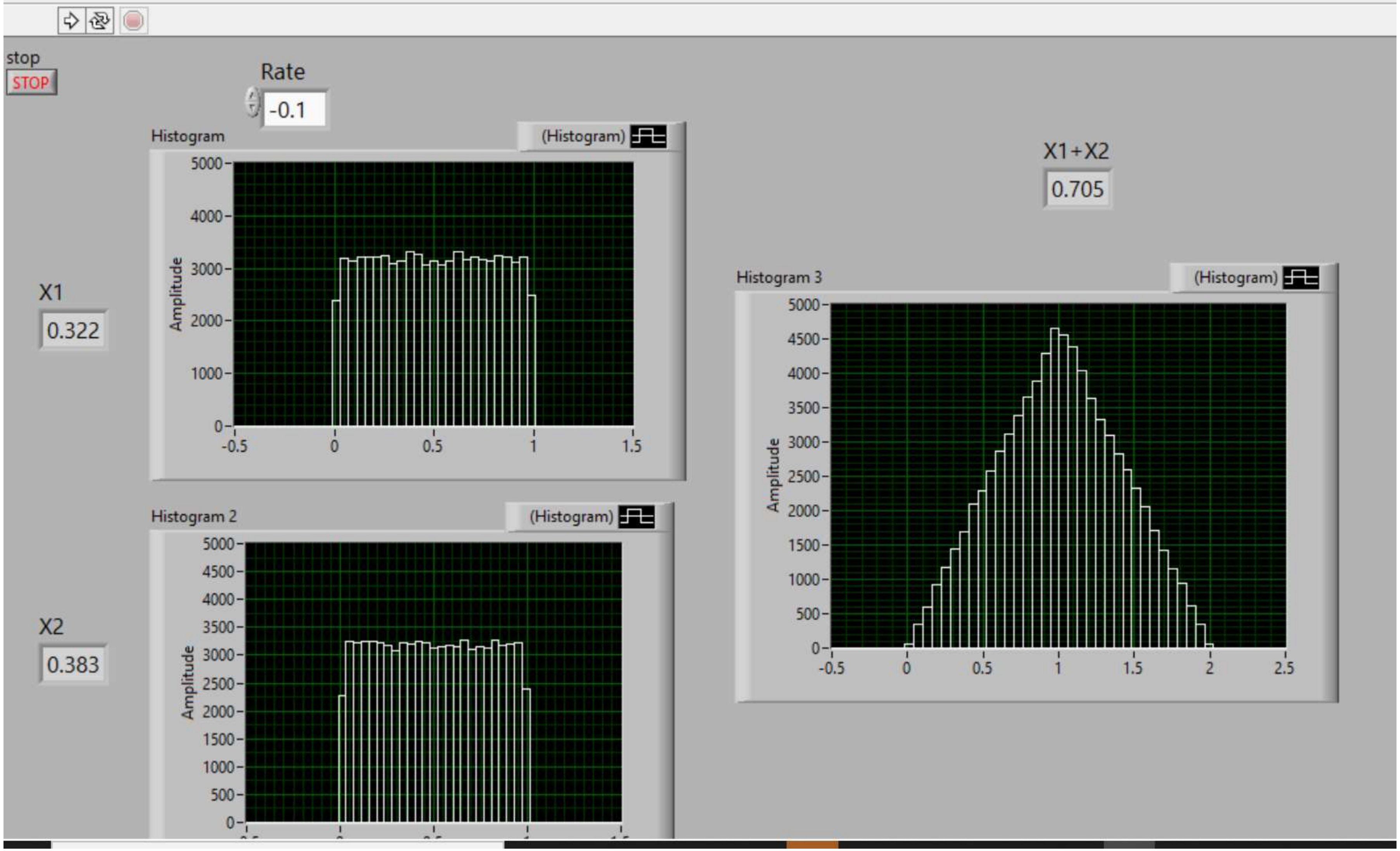
Volume of flask

$$V = \frac{m_w}{\rho_W}$$

ISO 4787 (2010)

$$V_0 = (I_L - I_E) \times \frac{1}{\rho_W - \rho_A} \times \left(1 - \frac{\rho_A}{\rho_B}\right) \times [1 - \gamma(t - t_0)]$$

Use live "visual" demonstrations to introduce statistical ideas



Provide a fully worked example of MU evaluation for a simple calibration, including an annotated uncertainty budget in spreadsheet form (course participants ALWAYS ask for a copy of this)

Module 4. - Balance calibration - Uncertainty Budget

$$\varepsilon = \overline{X} - (m_{SCAL} + \delta_{DRIFT})$$

Uncertainty taken from the calibration certificate for the standard weight. This uncertainty is an expanded uncertainty with k=2. This is a type B evaluation

In the measurement model there is a one-to-one relationship between the input quantities and the measurement result so all the sensitivity coefficients are equal to 1

Input Quantity	Input quantity - limits of variability (g)	Probability distribution	Divisor	Standard Uncertainty (g)	Sensitivity Coefficient	Uncertainty contribution (g)
lass standard - al. Unc	0.0020	norm	2	0.0010	1	0.0010
lass standard - rift	0.0050	uniform	1.732	0.0029	-1	-0.0029
Repeatability	0.0059	norm	1	0.0059	-1	-0.0059
				Standard Uncertainty		0.0066
				Expanded uncertainty		0.0133

This is the uncertainty associated with the correction for drift in the value of the standard weight. The correction is taken to be zero with limits of one half of the manufacturer's tolerance for the wieght (M1 class tolerance is 0.010 g. A uniform (rectuangular) pdf is assumed. This is a type B evaluation.

This is the standard deviation associated with the mean of 10 readings of the balance. The data is shown in worksheet DATA. This is a type A evaluation.

This is the RMS sum of the uncertainty contributions

The expanded uncertainty is the standard uncertainty multiplied by a coverage factor, chosen to produce a confidence level of 95%. IN this case, the coverage factor is k=2.

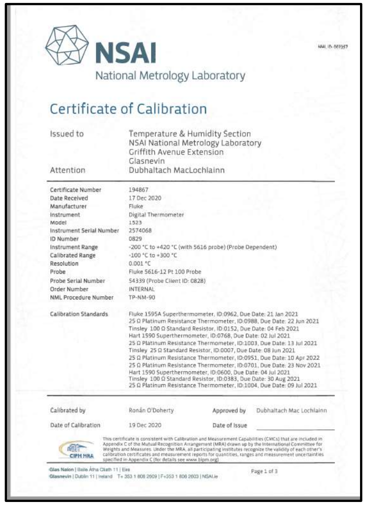
Participants perform a straightforward measurement task in the laboratory and are asked to generate an uncertainty budget

(A model solution is provided)

For the on-line version of the course a video is used

Thermometer Calibration Results

Reference Temperature	UUT Indication	Error Of Indication
°C	°C	°C
29.96	30.1	0.14
29.95	30.2	0.25
29.97	30.1	0.13
29.97	30.2	0.23
29.97	30.2	0.23
29.97	30.2	0.23
29.97	30.2	0.23
29.98	30.2	0.22
29.97	30.2	0.23
29.98	30.2	0.22
	Mean Error	0.21
	Standard Deviation	0.041



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NML ID: 669387

Certificate of Calibration

Issued to	Temperature & Humidity Section NSAI National Metrology Laboratory Griffith Avenue Extension Glasnevin
Attention	Dubhaltach MacLochlainn
Certificate Number	194867
Date Received	17 Dec 2020
Manufacturer	Fluke
Instrument	Digital Thermometer
Model	1523
Instrument Serial Number	2574068
ID Number	0829
Instrument Range	-200 °C to +420 °C (with 5616 probe) (Probe Dependent)
Calibrated Range	-100 °C to +300 °C
Resolution	0.001 °C
Probe	Fluke 5616-12 Pt 100 Probe
Probe Serial Number	54339 (Probe Client ID: 0828)
Order Number	INTERNAL
NML Procedure Number	TP-NM-90
Calibration Standards	Fluke 1595A Superthermometer, ID:0962, Due Date: 21 Jan 2021 25 Ω Platinum Resistance Thermometer, ID:0988, Due Date: 22 Jun 2021 Tinsley 100 Ω Standard Resistor, ID:0152, Due Date: 04 Feb 2021 Hart 1590 Superthermometer, ID:0768, Due Date: 02 Jul 2021 25 Ω Platinum Resistance Thermometer, ID:1003, Due Date: 13 Jul 2021 Tinsley 25 Ω Standard Resistor, ID:0007, Due Date: 08 Jun 2021 25 Ω Platinum Resistance Thermometer, ID:0951, Due Date: 10 Apr 2022 25 Ω Platinum Resistance Thermometer, ID:0701, Due Date: 23 Nov 2021 Hart 1590 Superthermometer, ID:0600, Due Date: 04 Jul 2021 Tinsley 100 Ω Standard Resistor, ID:0383, Due Date: 30 Aug 2021 25 Ω Platinum Resistance Thermometer, ID:1004, Due Date: 09 Jul 2021

Calibrated by Ronán O'Doherty — Approved by Dubhaltach Mac Lochlainn

Date of Calibration 19 Dec 2020 — Date of Issue

CIPM MRA

This certificate is consistent with Calibration and Measurement Capabilities (CMCs) that are included in Appendix C of the Mutual Recognition Arrangement (MRA) drawn up by the International Committee for Weights and Measures. Under the MRA, all participating institutes recognize the validity of each other's calibration certificates and measurement reports for quantities, ranges and measurement uncertainties specified in Appendix C (for details see www.bipm.org)

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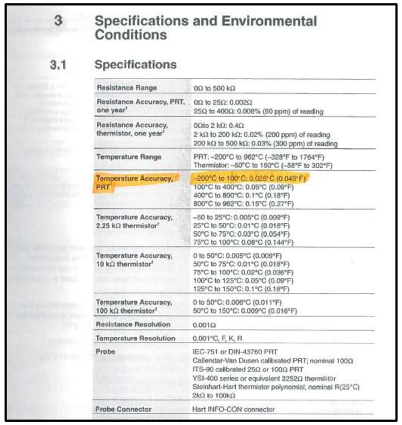
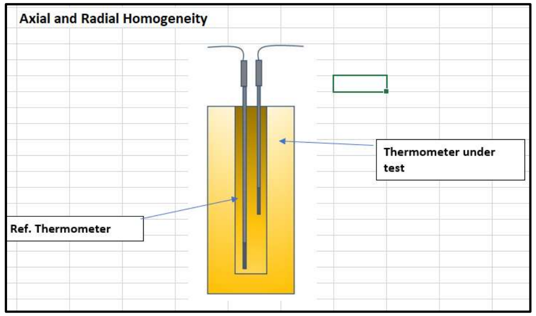
- ❑ Non-repeatability
- ❑ Calibration of Reference
- ❑ Drift of reference
- ❑ Temperature gradient effect



3 Specifications and Environmental Conditions

3.1 Specifications

Resistance Range	0Ω to 500 kΩ
Resistance Accuracy, PRT, one year[1]	0Ω to 25Ω: 0.002Ω 25Ω to 400Ω: 0.008% (80 ppm) of reading
Resistance Accuracy, thermistor, one year[1]	0Ωto 2 kΩ: 0.4Ω 2 kΩ to 200 kΩ: 0.02% (200 ppm) of reading 200 kΩ to 500 kΩ: 0.03% (300 ppm) of reading
Temperature Range	PRT: –200°C to 962°C (–328°F to 1764°F) Thermistor: –50°C to 150°C (–58°F to 302°F)
Temperature Accuracy, PRT[1]	–200°C to 100°C: 0.025°C (0.045°F) 100°C to 400°C: 0.05°C (0.09°F) 400°C to 800°C: 0.1°C (0.18°F) 800°C to 962°C: 0.15°C (0.27°F)
Temperature Accuracy, 2.25 kΩ thermistor[1]	–50 to 25°C: 0.005°C (0.009°F) 25°C to 50°C: 0.01°C (0.018°F) 50°C to 75°C: 0.03°C (0.054°F) 75°C to 100°C: 0.08°C (0.144°F)
Temperature Accuracy, 10 kΩ thermistor[1]	0 to 50°C: 0.005°C (0.009°F) 50°C to 75°C: 0.01°C (0.018°F) 75°C to 100°C: 0.02°C (0.036°F) 100°C to 125°C: 0.05°C (0.09°F) 125°C to 150°C: 0.1°C (0.18°F)
Temperature Accuracy, 100 kΩ thermistor[1]	0 to 50°C: 0.006°C (0.011°F) 50°C to 150°C: 0.009°C (0.016°F)
Resistance Resolution	0.001Ω
Temperature Resolution	0.001°C, F, K, R
Probe	IEC-751 or DIN-43760 PRT Callendar-Van Dusen calibrated PRT; nominal 100Ω ITS-90 calibrated 25Ω or 100Ω PRT YSI-400 series or equivalent 2252Ω thermistor Steinhart-Hart thermistor polynomial, nominal R(25°C) 2kΩ to 100kΩ
Probe Connector	Hart INFO-CON connector



Common problems and misunderstandings

- Dealing with uncertainties arising from measuring instruments (calibration, drift, interpreting accuracy specifications…..)
- Dealing with non-repeatability or limited resolution of the meter calibrated (e.g. using pooled standard deviation)
- Understanding the concept of sensitivity coefficients
- Dealing with a dominant component of uncertainty
- Addressing bias in uncertainty evaluation

Awkward Questions – An Example

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I.S. EN ISO 8655-6:2002

EUROPEAN STANDARD — EN ISO 8655-6

NORME EUROPÉENNE

EUROPÄISCHE NORM — September 2002

ICS 17.060

English version

Piston-operated volumetric apparatus - Part 6: Gravimetric methods for the determination of measurement error (ISO 8655-6:2002)

Under the above-mentioned conditions, the following simplified equation can be used, e.g. for piston pipettes, to assess the uncertainty u of the delivered volume at the 95 % confidence level:

$$u = |e_s| + 2s_r \qquad \text{(B.1)}$$

Repeatability Standard Deviation

The measured indication error of the pipette

The coverage interval for the measured error of indication will ALWAYS include zero

ISO 21748:2017

Guidance for the use of repeatability, reproducibility and trueness estimates in measurement uncertainty evaluation

"-Evaluation of measurement uncertainties using data from studies conducted in accordance with ISO 5725-2"

TECHNICAL SPECIFICATION

ISO/TS 20914

First edition 2019-07

Medical laboratories — Practical guidance for the estimation of measurement uncertainty

"Medical laboratory measurement procedures are well-suited to utilizing internal quality control (IQC) and other available data to estimate MU without the need for measurement models and complex statistics"

Conclusion

- After many years of trial and error we have a training course that is suitable for our typical audience
- Practical, “hands-on” training elements are very important
- Follow-up contact needs to be encouraged
- There is a need for a more basic course that omits the “mechanics” of the MU evaluation
- On-line resources and modern teaching techniques will have an increasing impact on the training