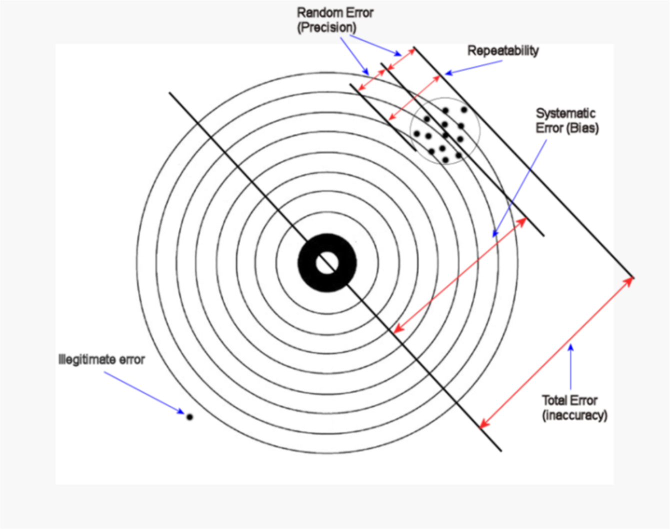


Uncertainty in Humidity Measurement

Helping you make a better measurement.

rotronic
MEASUREMENT SOLUTIONS

Webinar Presenters

Bruce McDuffee

Michael Boetzkes

Agenda

- Terms & Definitions
- Understand the Uncertainty of Your Instrument
- Understanding the Uncertainty on the Calibration Certificate
- How to Avoid the Dreaded O.O.T.
- Final Q&A

Terms & Definitions

The Truth About Measurement

- There is no such thing as a true or perfect measurement.
- A proper measurement result is incomplete without a statement of uncertainty.
- Knowing the uncertainty helps us determine the fitness of the measurement
- Understanding uncertainty is the first step to reducing it.

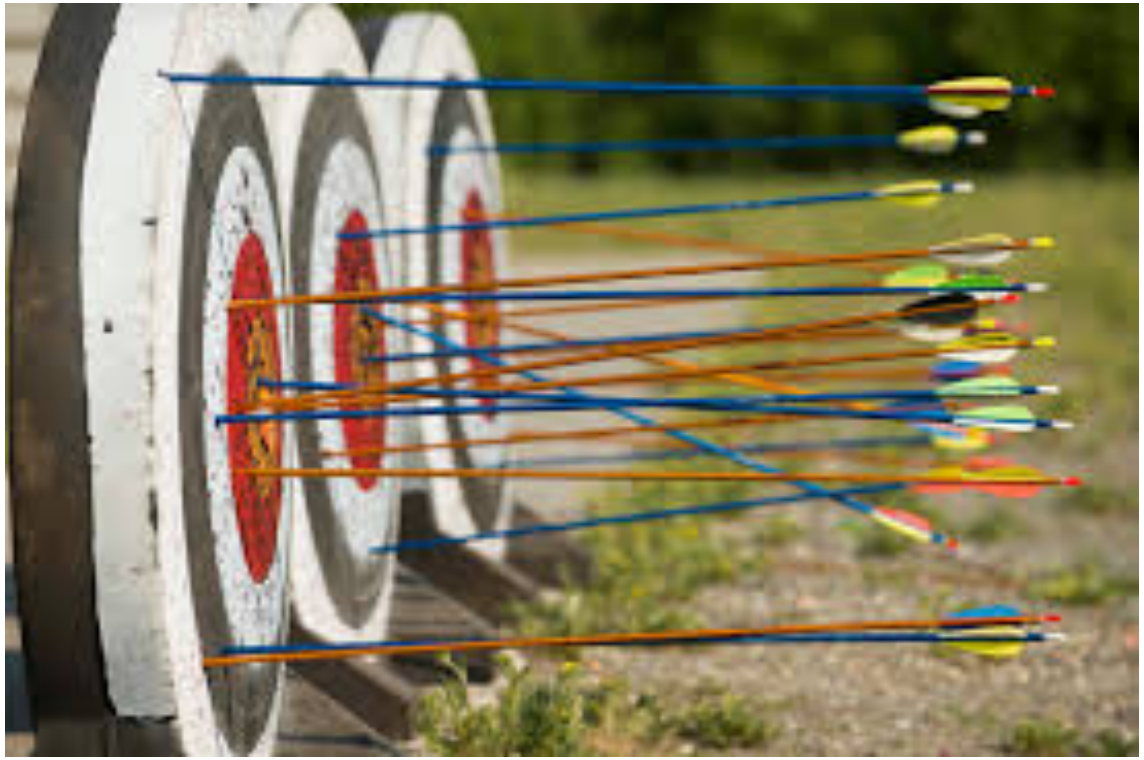
Accuracy

"closeness of agreement between a measured quantity value and a true quantity value of a measurand"

- **Measurand** - quantity intended to be measured
- **Measured Quantity Value** - quantity value representing a measurement result
- **True Quantity Value** - quantity value consistent with the definition of a quantity
- **Quantity Value** - number and reference together expressing magnitude of a quantity, for example 5 °C, 543 meters

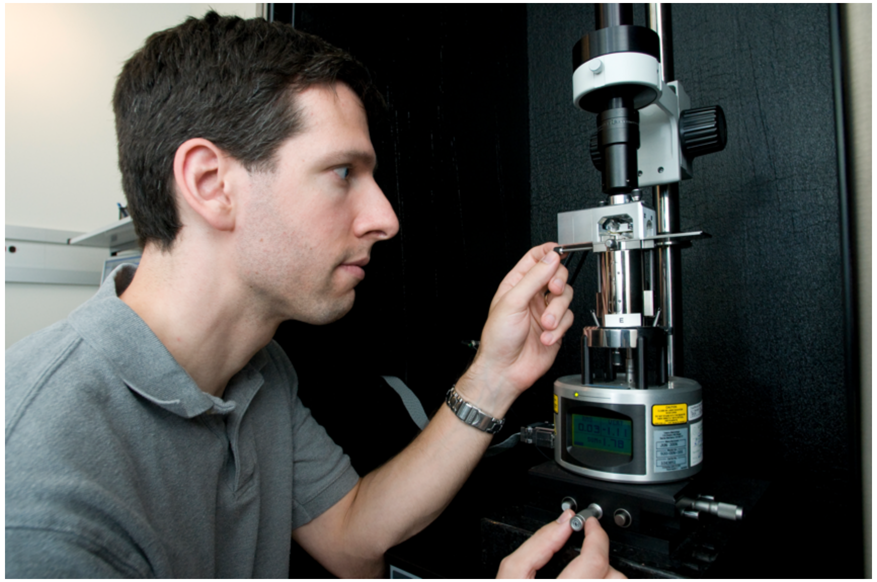
Error

- Error is the difference between the measured value and the ‘true value’ of the thing being measured.
- Like ‘accuracy’, it is qualitative, not quantitative



Uncertainty

- “Uncertainty is the quantification of the doubt about the measurement result.”
- “A calculated statement concerning the level of confidence in a reported measurement.”



Statement of Uncertainty:

50 %RH ± 1 %RH k=2

Understanding the Uncertainty of the Humidity Instrument

Calculating the Instrument Uncertainty

- Instrument Calibration
- Resolution
- Long term drift
- Temperature effects
- Hysteresis
- Linearity (accuracy)
- Sensitivity to contamination

Calculating the Instrument Uncertainty

Uncertainty Contributor	Uncertainty (U)	Distribution	Divisor	Standard Uncertainty (u)	Comment
Accuracy	0.8 %RH	Rectangular	1.732	0.462	From Data Sheet
Calibration Uncertainty	0.5 %RH	Normal	2	0.250	From Calibration Certificate
Annual Drift	1.0 %RH	Rectangular	1.732	0.577	From Data Sheet
			Combined Uncertainty	0.780	
			Expanded Uncertainty k=2	**±1.6 %RH**	

Level of Confidence	Coverage Factor (k)
68.27%	1
90%	1.645
95%	1.96
95.45%	2
99%	2.576
99.73%	3

$$U = k\sqrt{u_1^2 + u_2^2 + u_3^2 + u_4^2 + u_5^2 \ldots}$$

Impact of the Instrument Uncertainty

- Each instrument is unique in behavior
- Environmental factors can change drift characteristics
- Understand the impact of calibrations

Understand total instrument performance!

Comments & Questions

If we don't get to your question today, we'll respond via email after the webinar.

Calibration Certificate Uncertainty

Divided Flow System with Chilled Mirror

Test Point: 80 %RH at 23 °C
Temperature Sensitivity 4.96 %RH/°C

Reference	Uncertainty Source	Value	Units	Distribution	Divisor	Standard Uncertainty	Sensitivity Coefficient	Standard Uncertainty (%RH)	% of Total Expanded Uncertainty
1	Chilled Mirror Uncertainty	0.05	°C	Normal	2	0.025	4.96	0.124	18%
2	Chilled Mirror Drift (1 year)	0.04	°C	Rectangular	1.732	0.023	4.96	0.115	16%
3	Temperature Uncertainty	0.007	°C	Normal	2	0.004	4.96	0.018	3%
4	Repeatability of humidity	0.10	%RH	Normal	1	0.100	1	0.100	14%
5	Chamber temperature gradients	0.05	°C	Rectangular	1.732	0.029	4.96	0.143	20%
6	Temperature stabilization	0.01	°C	Rectangular	1.732	0.003	4.96	0.014	2%
7	Temperature repeatability	0.05	°C	Normal	1	0.050	4.96	0.248	35%
8	Humidity stabilization	0.05	%RH	Rectangular	1.732	0.029	1	0.029	4%
9	Humidity fluctuations	0.05	%RH	Rectangular	1.732	0.029	1	0.029	4%

Standard Uncertainty	0.350
Expanded Uncertainty (95% confidence level)	0.70

Divided Flow System with Internal Probe

Test Point: 80 %RH at 23 °C

Temperature Sensitivity 4.96 %RH/°C

Reference	Uncertainty Source	Value	Units	Distribution	Divisor	Standard Uncertainty	Sensitivity Coefficient	Standard Uncertainty (%RH)	% of Total Expanded Uncertainty
1	Reference Probe Uncertainty	1.10	%RH	Normal	2	0.550	1	0.550	32%
2	Reference Probe Drift	1.00	%RH	Rectangular	1.732	0.577	1	0.577	34%
3	Reference Probe Resolution	0.05	%RH	Rectangular	3.464	0.014	1	0.014	1%
4	Repeatability of humidity	0.10	%RH	Normal	1	0.100	1	0.100	6%
5	Chamber temperature gradients	0.05	°C	Rectangular	1.732	0.029	4.96	0.143	8%
6	Temperature stabilization	0.01	°C	Rectangular	1.732	0.003	4.96	0.014	1%
7	Temperature repeatability	0.05	°C	Normal	1	0.050	4.96	0.248	15%
8	Humidity stabilization	0.05	%RH	Rectangular	1.732	0.029	1	0.029	2%
9	Humidity fluctuations	0.05	%RH	Rectangular	1.732	0.029	1	0.029	2%

Standard Uncertainty	0.854
Expanded Uncertainty (95% confidence level)	1.71

Why is Uncertainty Important

- Required for Metrological Traceability
- Insight into the quality of the calibration
- Makes the difference between instrument meeting manufacturer specification or not!

Divided Flow with Chilled Mirror

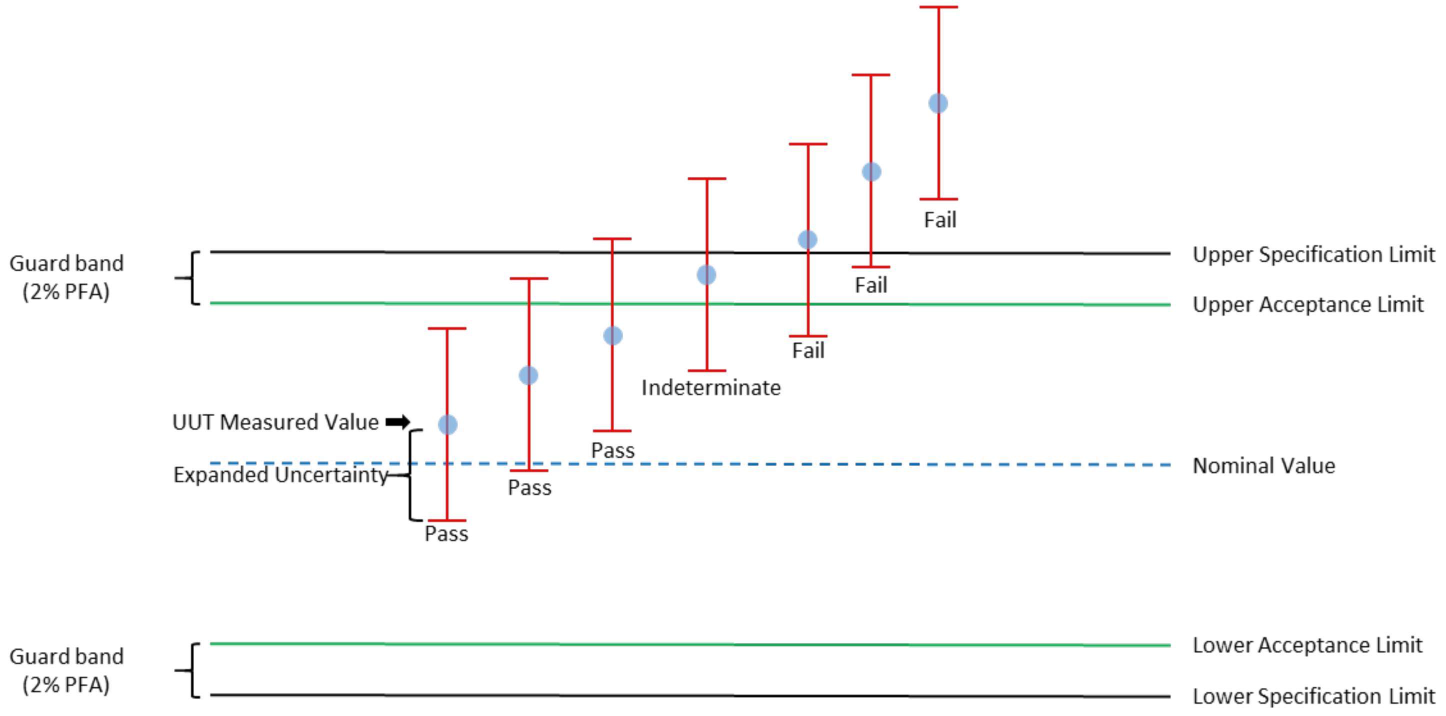
Parameter	U	Distribution	Divisor	Standard Uncertainty	Comment
Accuracy	0.8	Rectangular	1.732	0.462	From Data Sheet
Calibration Uncertainty	0.7	Normal	2	0.350	From Calibration Certificate
Annual Drift	1	Rectangular	1.732	0.577	From Data Sheet
			Combined Uncertainty	0.818	
			Expanded Uncertainty k=2	**±1.7 %RH**	

Divided Flow with Internal Probe

Parameter	U	Distribution	Divisor	Standard Uncertainty	Comment
Accuracy	0.8	Rectangular	1.732	0.462	From Data Sheet
Calibration Uncertainty	1.71	Normal	2	0.855	From Calibration Certificate
Annual Drift	1	Rectangular	1.732	0.577	From Data Sheet
			Combined Uncertainty	1.130	
			Expanded Uncertainty k=2	**±2.3 %RH**	

Taking Uncertainty into Account

- Uncertainty of measurement leads to risk of False Accept
- Guardband methods available to define and limit the risk
- Creates 3rd option for result: Indeterminate



How to Avoid the Dreaded OOT

Causes of OOT

- Instrument/Sensor Drift
- Accuracy specification used instead of 1-year uncertainty
- Previous calibration was not suitable

Typically can be traced back to an error in or lack of uncertainty analysis!

Avoiding OOT

- Know the sensitivities of the instrument
- Use the Long Term Uncertainty as the acceptance limit
- Ensure appropriate calibration provider can provide suitable calibration uncertainties

Takeaways

1. Instrument performance is more than just an accuracy specification
2. Two instruments of the same model can have different measurement uncertainties
3. OOT results can be reduced by understanding the instrument uncertainty

Comments & Questions

If we don't get to your question today, we'll respond via email after the webinar.

Measurement Academy

- Resources for making a better measurement
  - Psychrometric charts
  - Technical notes
  - Humidity calculator
  - Application notes
  - More

www.rotronic-usa.com/academy

Next Webinar

Dew Point Temperature in Compressed Air

Thursday, October 19th 1:00PM EDT

Register at www.rotronic-usa.com/webinars

Post webinar survey

Thank you!

email: info@rotronic-usa.com

Website: www.rotronic.com

Future webinar registrations & on-demand viewing:

www.rotronic-usa.com/webinars