Infrastructure Commission (INFCOM)

Standing Committee on Measurements, Instrumentation and Traceability (SC-MINT)

Expert Team on Quality, Traceability and Calibration (ET-QTC)

Calibration of humidity instruments

Part-4: Uncertainties

4.1 Uncertainty in relative humidity calibration - Part 1

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Presented by Stephanie Bell (NPL)

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Calibration of humidity instruments

Overview:

1. Introduction
2. Description of technology
3. Calibration procedures
4. Humidity uncertainties
   - **4.1 Uncertainty in relative humidity calibration - Part 1**
   - 4.2 Uncertainty in relative humidity calibration - Part 2

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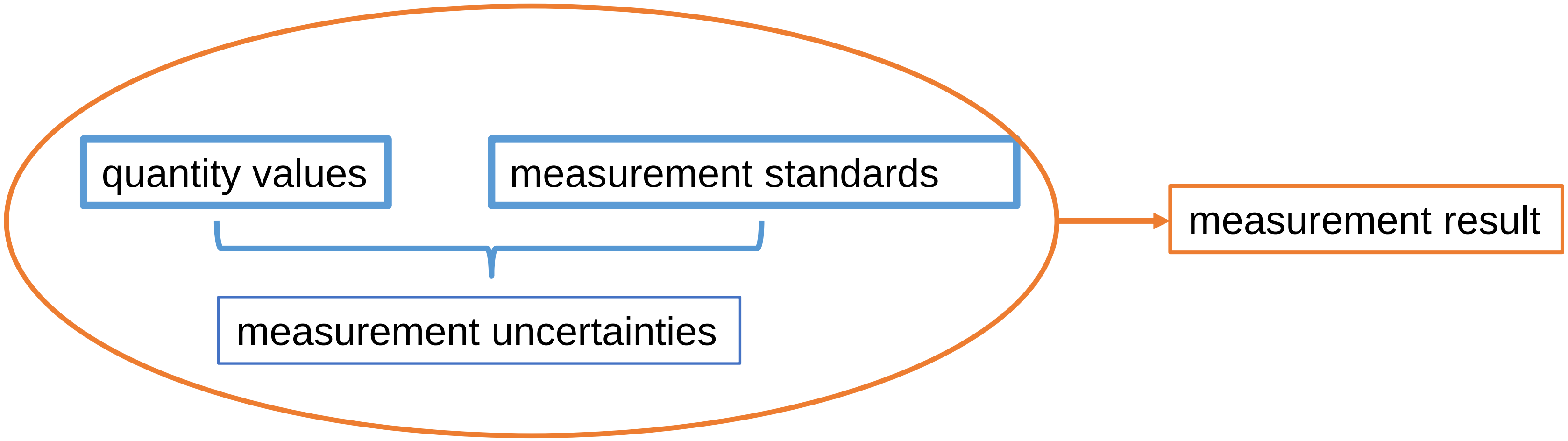
Remember



2.39 (6.11) **calibration**
operation that, under specified conditions, in a first step, establishes a relation between the **quantity values** with **measurement uncertainties** provided by **measurement standards** and corresponding **indications** with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a **measurement result** from an indication.

NOTE 1: A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.
NOTE 2: Calibration should not be confused with adjustment of a measuring system, often mistakenly called “self-calibration”, nor with verification of calibration.
NOTE 3 Often, the first step alone in the above definition is perceived as being calibration.

Reference: JCGM 200:2012 International Vocabulary of Metrology (VIM)

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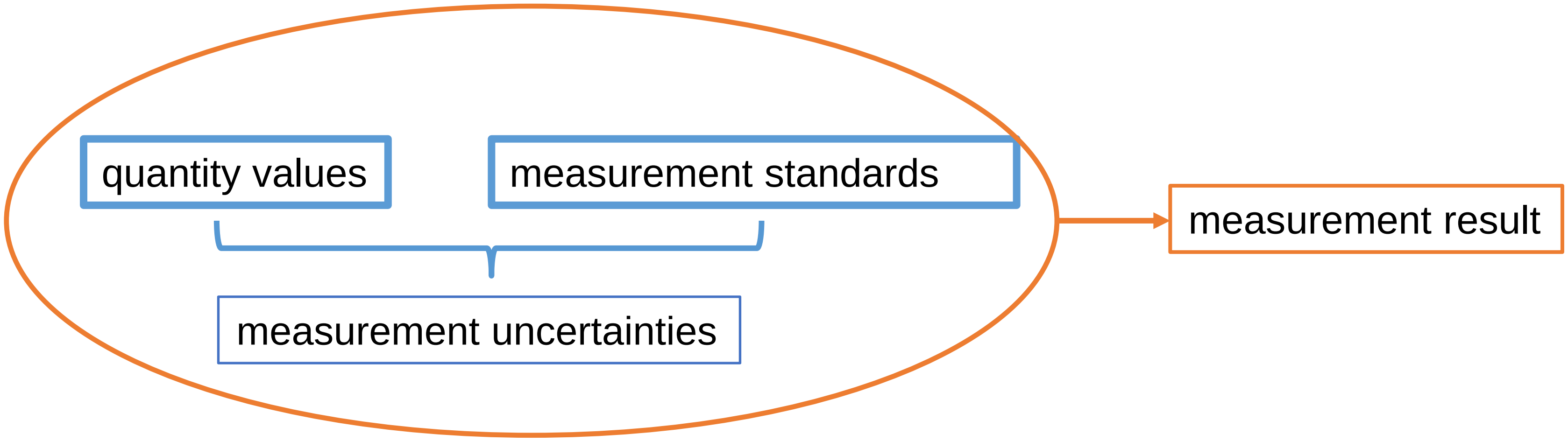

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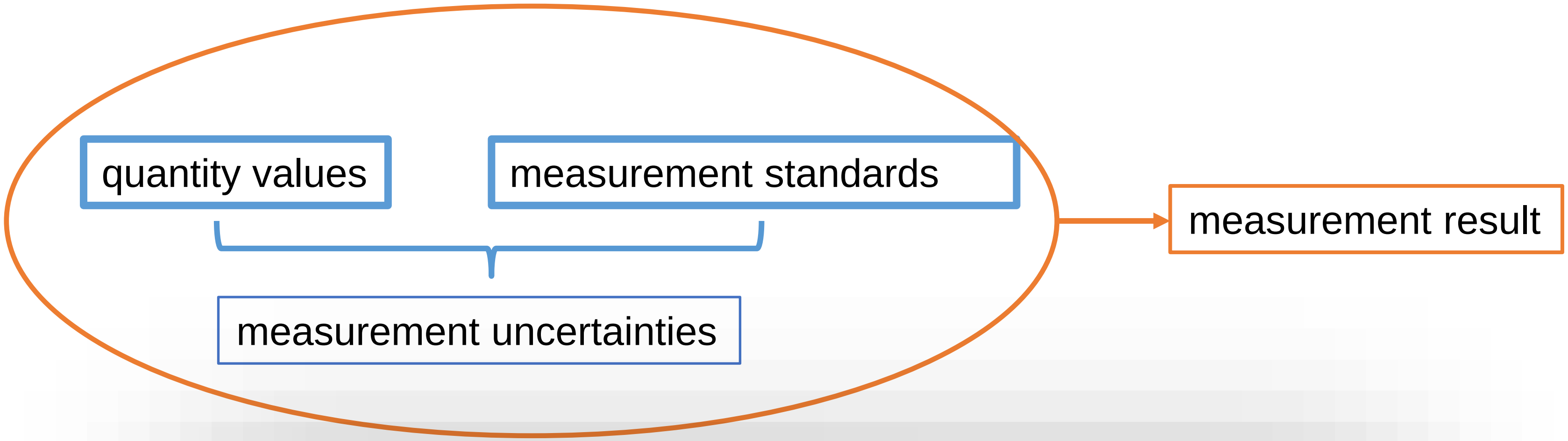

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2.26 (3.9) **measurement uncertainty**
uncertainty of measurement
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NOTE 1 Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned quantity values of measurement standards, as well as the definitional uncertainty. Sometimes estimated systematic effects are not corrected for but, instead, associated measurement uncertainty components are incorporated.

NOTE 2 The parameter may be, for example, a standard deviation called standard measurement uncertainty
(or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

NOTE 3 Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by standard deviations. The other components, which may be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

NOTE 4 In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quantity value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty.

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Calibration set-up main components

Humidity environments for calibration

Role: producing stable and homogeneous humidity environment

Types: humidity generators, climatic chamber, salt solutions

Reference standard

(Usually a chilled-mirror dew point hygrometer calibrated externally, in other laboratory)

Role: measuring actual value of the humidity, reference value

Types: chilled mirror hygrometer, capacitive hygrometer, psychrometer

Device under calibration (DUC)

(Usually capacitive hygrometer, psychrometer to measure in field)

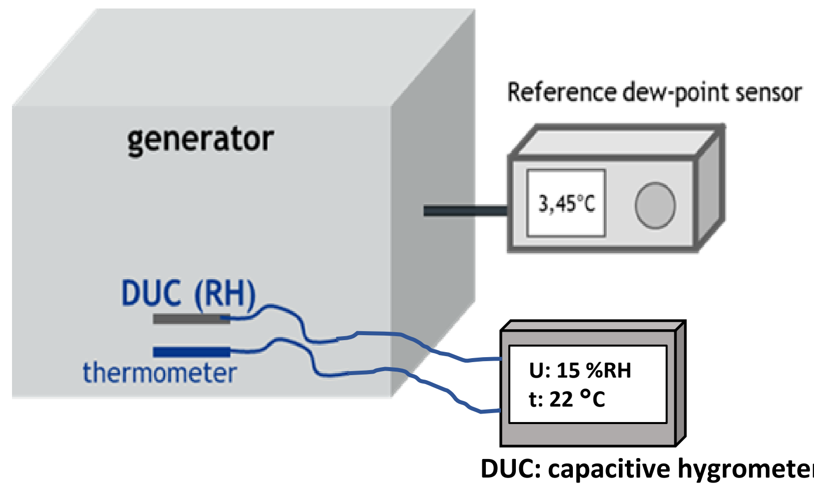
Role: device to be calibrated, to determine the deviation or correction and its calibration uncertainty

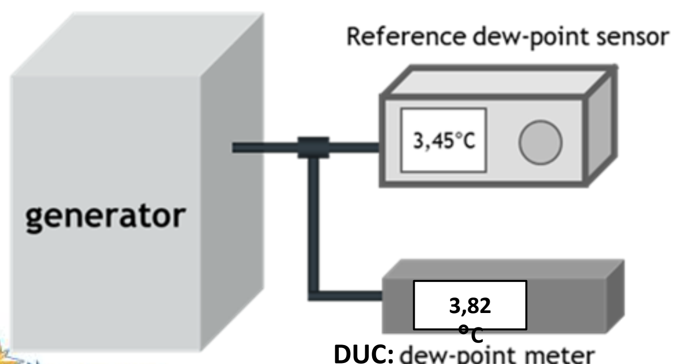
Types: chilled mirror hygrometer, capacitive hygrometer, psychrometer

Humidity calibration setups / procedures - reminder

Calibration procedure considerations:

- Calibrate device in the quantity/unit of use.
- Sampling – parallel better than serial.
- Air temperature measurement in calibrations of relative humidity probes mostly.
- Possible pressure drops (affects dew point).
- Sample path as small as possible.
- Chamber uniformity.
- Humidity calibration takes time. Temperature and humidity stability takes time.





Be careful

- Leaks – ambient air leaking into the system either raising or lowering the humidity.
- Saturation – water condensing in the pipes etc. reduces dew point at the point of measurement.
- Water droplets or mist in the air stream.
- Temperature gradients within the system.
- Too high flow rates lead to excessive pressure gradients.

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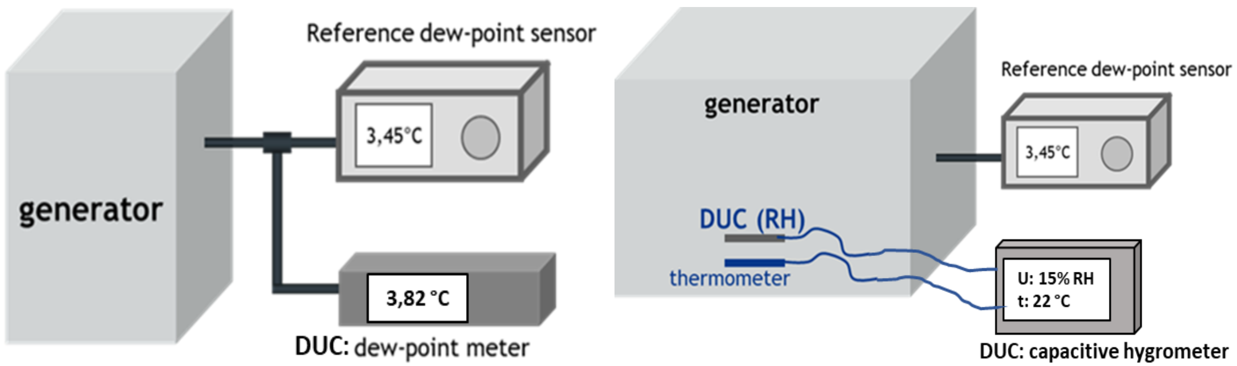
Measurement model and uncertainty



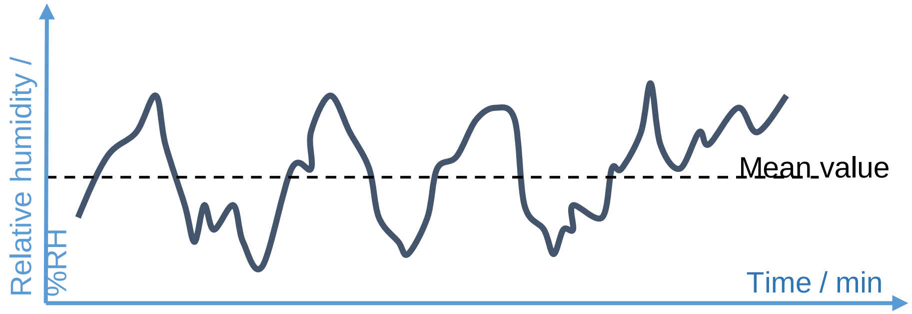
Calibration uncertainty budget main aspects:

- due to humidity generation
- due to uncertainty of reference standard
- due to the instrument being calibrated
- due to calibration method and ambient conditions

Uncertainty of humidity generation

✓ time instability of generated humidity:

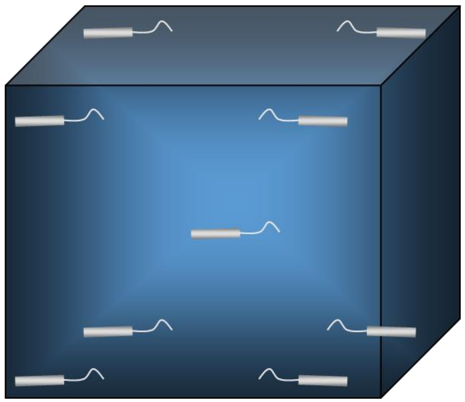
Can be measured during the calibration using stable reference humidity and/or temperature standard. Standard uncertainty due to instability is taken as standard deviation of the reference instrument, a combination of both dew-point and temperature



✓ inhomogeneity of generated relative humidity

Humidity gradients in the measurement area, mainly due to temperature gradients. So, temperature inhomogeneity needs to be quantified – can be very significant in terms of RH.

- Can evaluate temperature gradients prior to calibration – less expensive possibility...
- ...or each time during the calibration, the set of thermometers has to be used all the time, more cost. But better evaluation, because the influence of the DUC is considered, too.



To evaluate inhomogeneity, thermometers are typically placed in corners of calibration area and one in the geometrical centre.

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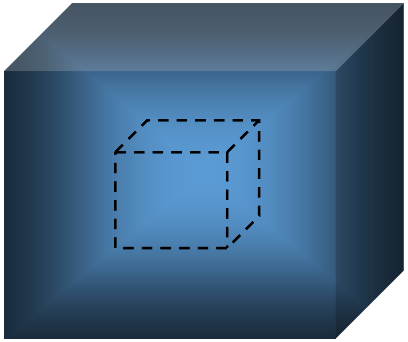
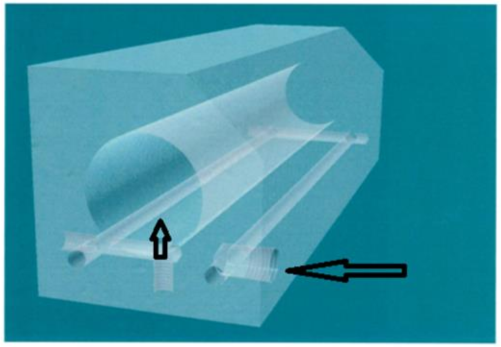
Uncertainty of humidity generation

Inhomogenity of generated humidity

- Typical uncertainties of relative humidity due to temperature inhomogeneity – from 0.1 %RH to several %RH.
- The inhomogeneity can be reduced if smaller calibration space is used or appointed or use a device to temperature equalize





Uncertainty of reference standard

In general, the following uncertainty contributions are to be determined:

- Uncertainty, taken from the calibration certificate (dew point and thermometer for air temperature)
- Drift of reference standard
- Resolution
- Uncertainty of calculation of relative humidity from dew point and temperature (empirical equations $f(P,T)$ and $e_{w/i}(T)$)
- Uncertainty of electrical instrument (bridge, multimeter,...)

In the relative humidity calibration, the measurement uncertainty of the dew point reference and the measurement uncertainty of the air temperature reference must be combined by propagating in the relative humidity formula : $U = \frac{e_{w/i}(t_{d/f})}{e_{w/i}(t_a)} \, . \, 100$

Uncertainty of reference relative humidity:

$$u_{Uref} = \sqrt{\left(\frac{\partial U}{\partial t_a} u_{t_a}\right)^2 + \left(\frac{\partial U}{\partial t_{d/f}} u_{t_{d/f}}\right)^2}$$

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Uncertainties due to the device under calibration (DUC)

- instability of DUC readings
- resolution (impacts every instrument reading)
- hysteresis, typically it is evaluated first measuring in increasing order and then in decreasing order in humidity to quantify DUC indication change
- uncertainty of electrical devices (bridge, multimeter)
- drift of electrical devices
- the influence of DUC to calibration environment
  (self-heat, humidification – psychrometer)
- also – future drift must be added by end user, cannot be accounted in calibration uncertainty

Thank you.

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