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Uncertainty of relative humidity calibration

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Humidity “generator” and reference standard

- Its role is producing stable and homogeneous humidity environment
- Actual value of the humidity is measured with a reference dew-point meter
- Types of humidity generators (two pressure, two temperature, mixed flow, climatic chamber, ...)

Reference standard

- Reference standard for humidity measurement is usually dew point meter calibrated externally (in other laboratory)
- It can be also RH hygrometer and psychrometer, but the uncertainty is then typically larger
Measurement methods

- Depending on the DUC (RH/dew point)
- Parallel sampling
- Serial sampling
- Measurement of air temperature
- Potential pressure drops
- Leakage
Set-up for dew-point calibration
(Device under calibration – DUC - is dew-point meter)
Set-up for RH calibration
(DUC is RH hygrometer)
In calibration uncertainty budget calculation following uncertainty components should be considered:

- due to generation of humidity
- due to uncertainty of reference standard
- due to DUC
- due to calibration method and ambient conditions
The reference value (RV) is measured by calibrated dew-point sensor, so only the deviations from the measured RV need to be characterised.

The major uncertainty contributions are therefore:

- **time instability of generated humidity:**
  
  Instability can be measured during the calibration with stable reference humidity and/or temperature standard. Standard uncertainty due to instability is taken as a combination of standard deviation of both dew-point and temperature

- **inhomogeneity of generated humidity**
✓ almost insignificant in dew-point calibration
   \textit{(if the inlet of the sampling tube of standard and DUC are in parallel and close to each other)}

✓ problems, if reference standard and DUC as dew-point meter are sampling in serial (pressure drop, contamination,...)
in RH calibration - large influence of temperature on relative humidity

Therefore temperature inhomogeneity needs to be quantified - can be very significant:

1. Temperature gradients can be evaluated previous to calibration – less expensive possibility...

2. ... or each time during the calibration (the set of thermometers has to be used all the time)

   the second one is better, because the influence of DUC can also be determined, however more expensive

To evaluate inhomogeneity, thermometers are typically placed in corners of calibration area and one in the geometrical center.
• Typical uncertainties of RH due to temperature inhomogeneity - from 0.1% r.h. to several % r.h.

• The inhomogeneity can be reduced if smaller calibration space is used or appointed

\[3 \div 4 \text{ times smaller} \] or more
In general the following uncertainty contributions are to be determined:

- uncertainty, taken from the calibration certificate (dew-point thermometer & thermometer for air temperature)
- standard’s drift
- resolution (if not included in certificate)
- uncertainty of calculation of relative humidity from dewpoint, temperature (water sat. pressure eq., enh.f.eq.)
- uncertainty of electrical instrument (bridge, multimeter,...)
Uncertainty of reference standard

In RH calibrations, if the reference is dew-point sensor, then the temperature and dew-point contributions have to be considered separately.

\[ u_{rh,ref} = \sqrt{ \left( \frac{\partial RH}{\partial t_a} u_{t_a} \right)^2 + \left( \frac{\partial RH}{\partial t_{dp}} u_{t_{dp}} \right)^2 } \]
Sources of uncertainty of DUC

- instability of DUC’s readings
- resolution
- hysteresis
- drift (to be added by the end user)
- uncertainty of electrical devices (bridge, multimeter)
- drift of electrical devices
- the influence of DUC to calibration environment (self-heat, humidification - psychrometer)
Other sources of uncertainty (errors)

- leakage (stem of the sensor, cables)
- contamination (salts, oil, dirt)
- difference between calibration measurement range and actual range (temperature, pressure, ...)
- reproducibility
### Example of uncertainty budget calculation

<table>
<thead>
<tr>
<th>Uncertainty source</th>
<th>Uncertainty contribution $U(\eta)$</th>
<th>Probability law</th>
<th>Coefficient</th>
<th>Standard uncertainty $u(\eta)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-tip reference dew point</td>
<td>0.2 [%]</td>
<td>Normal</td>
<td>0.5</td>
<td>0.1 [%]</td>
</tr>
<tr>
<td>A-tip DUC</td>
<td>0.2 [%]</td>
<td>Normal</td>
<td>0.5</td>
<td>0.1 [%]</td>
</tr>
<tr>
<td>Time instability of humidity generator</td>
<td>0.91 [%]</td>
<td>Normal</td>
<td>0.5</td>
<td>0.46 [%]</td>
</tr>
<tr>
<td>Spatial unhomogeneity of humidity generator</td>
<td>0.84 [%]</td>
<td>Normal</td>
<td>0.5</td>
<td>0.42 [%]</td>
</tr>
<tr>
<td>Uncertainty of reference dew point</td>
<td>$0.017*RH+0.2$</td>
<td>Normal</td>
<td>0.5</td>
<td>0.53 [%]</td>
</tr>
<tr>
<td>DUT</td>
<td>0.1 [%]</td>
<td>Rectangular</td>
<td>1</td>
<td>0.1 [%]</td>
</tr>
<tr>
<td>Multimeter</td>
<td>$64 \mu V$</td>
<td>Rectangular</td>
<td>$\times 100$</td>
<td>0.0074 [%]</td>
</tr>
</tbody>
</table>

**Expanded uncertainty** 1.71 [%]

* Uncertainty calculation at $Ta=20^\circ C$ and $RH=95%$
Reference


- Jovan Bojkovski, Domen Hudoklin, *Uncertainty in calibrations with secondary standard*, Laboratory of Metrology and Quality (LMK), Faculty of Electrical Engineering (FE), University of Ljubljana