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-3: Procedures

3.1 Humidity environments for calibration – dew point

Written by Drago Groselj (ARSO)

Adapted by Javier Garcia Skabar (INTI) and Stephanie Bell (NPL)

Presented by Stephanie Bell

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Calibration of humidity instruments

Overview:

1. Introduction

2. Description of technology

3. Calibration procedures
- **3.1 Humidity environments for calibration – dew point**
- 3.2 Humidity environments for calibration – relative humidity
- 3.3 Humidity calibration – tips and traps

4. Humidity uncertainties

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Humidity environments for calibration

- We want an environment with humidity and temperature that are stable over time and uniform in space.
- We want to set the temperature and humidity at different values.
- A humidity reference instrument will be used to provide traceability

Climatic chamber

Salt solutions

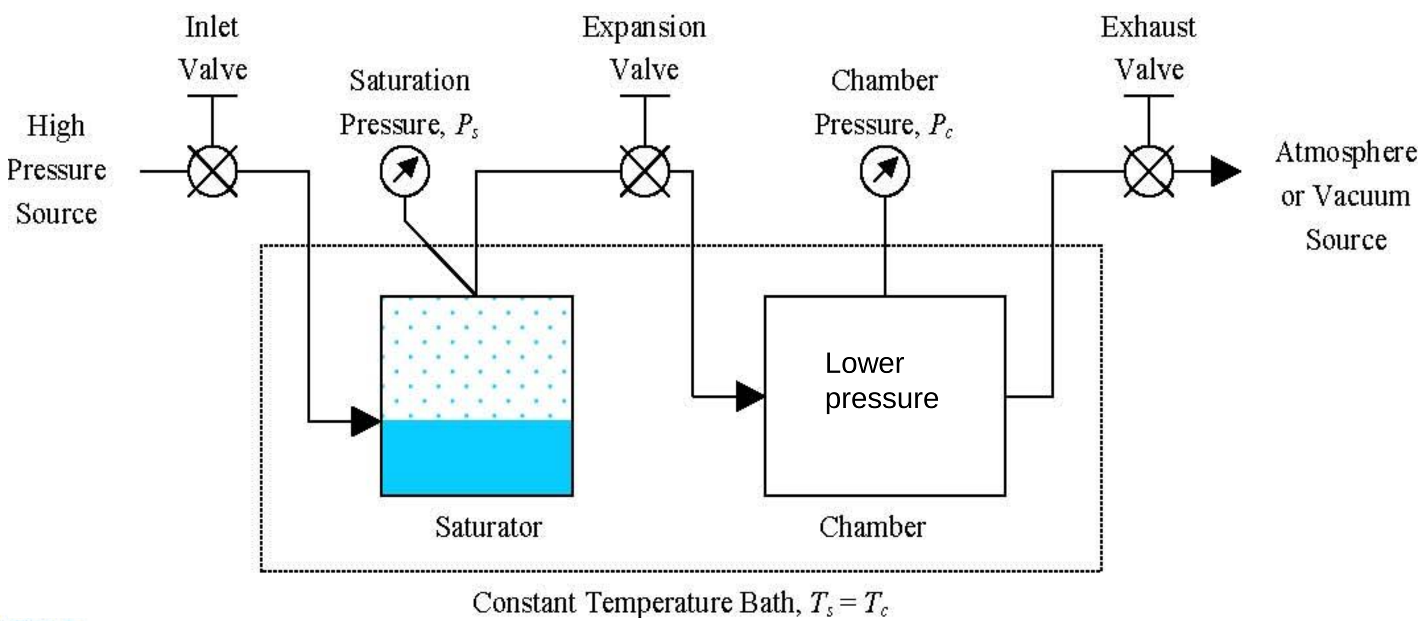
Humidity generator

Humidity environments for calibration

Two-pressure humidity generator

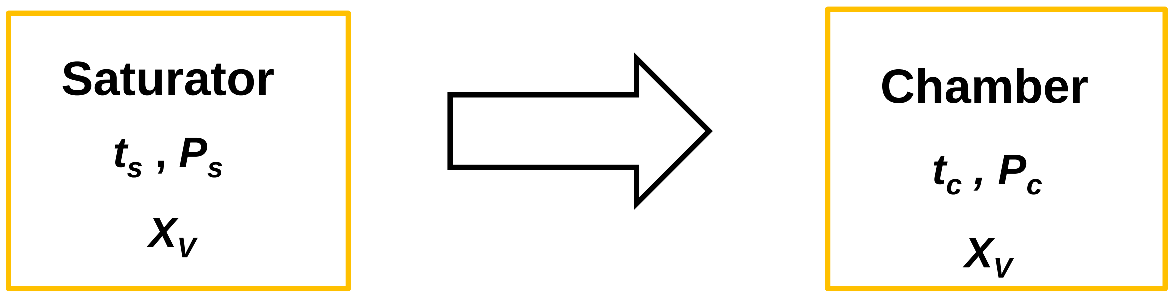
- “Two-pressure" humidity generation involves saturating air with water vapour at a known temperature and pressure.

- The saturated high-pressure air flows from the saturator, through a pressure reducing valve, where the air is isothermally reduced to test pressure at the test temperature.



Humidity environments for calibration

Two–pressure / Two-temperature humidity generator



Where:
t_s / t_c temperature in saturator / chamber
P_s / P_c pressure in saturator / chamber
X_V vapour mole fraction

Two–pressure: $P_s \geq P_c$ and $t_s \approx t_c$
Two–temperature: $P_s \approx P_c$ and $t_s \leq t_c$

For traceability, common to use a reference calibrated mirror dew-point hygrometer

Use of a reference hygrometer avoids dependence on accuracy of system temperature and pressure.

Can also be used for relative humidity and air temperature – with reference thermometers for chamber air temperature.

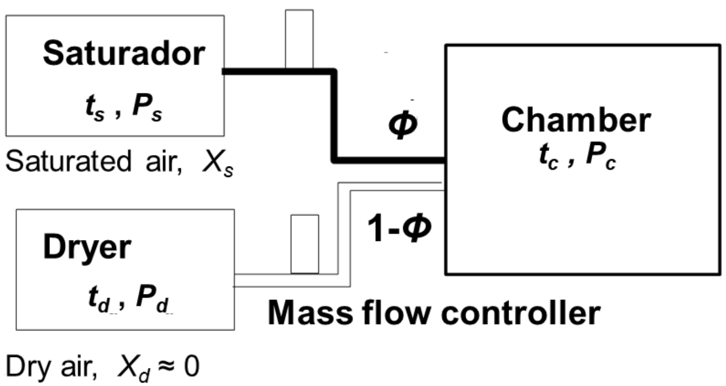
Humidity environments for calibration

Split stream humidity generator (flow mixing, divided flow)

Air of known water content and dry air are mixed in known proportions, then fraction of vapor in the mixture is controlled and known (volume or mole fraction).

Humidity setpoints can be changed quickly.

Flow mix generator



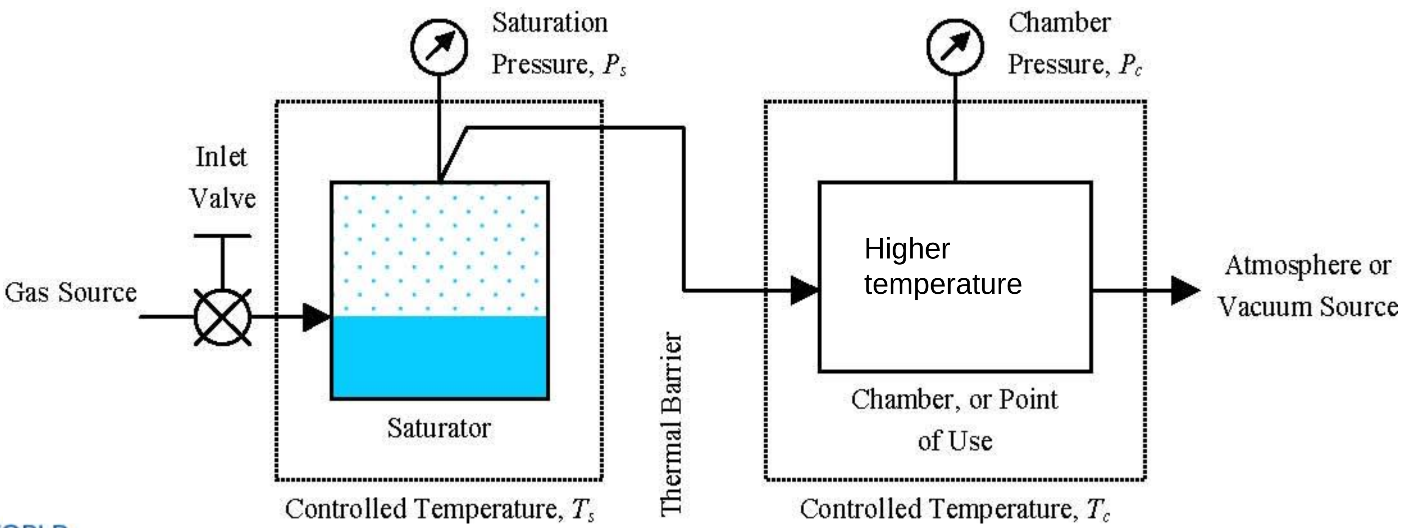
$$X_{vapor} = \frac{n'_S \cdot x_S + n'_d \cdot x_d}{N'}$$

N' : Total molar flux
n'_s : Saturated air molar flux
n'_d : Dry air molar flux

Humidity environments for calibration

Two-temperature humidity generator

- In a two-temperature system, a stream of gas is saturated with respect to the liquid or solid phase of water at a set (lower) temperature.
- Flow is then **warmed isobarically** to a higher temperature for use.
- Measurements of the temperature and pressure of the cooler, saturated gas stream, and in the warmer test chamber (or other point of use), are used to calculate the resulting humidity of the gas stream.



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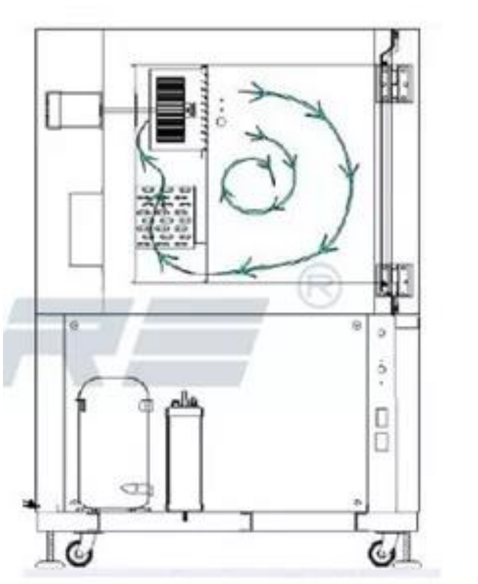
Humidity environments for calibration

Climatic chambers

Control the humidity of air circulating in a closed space by controlled addition and/or removal of water vapour at a given chamber air temperature.

Different humidification techniques, cold humidifier / steam humidifier / ultrasonic humidifier / flows mixture



- Example temperature range –20 °C to +40 °C or can be much wider
- Example humidity range 10 %RH to 95 %RH (usually no humidity control below 0 °C)
- Temporal and spatial stability - varies
- Can be slow to change between set points
- Long settling times, can be 1 hour

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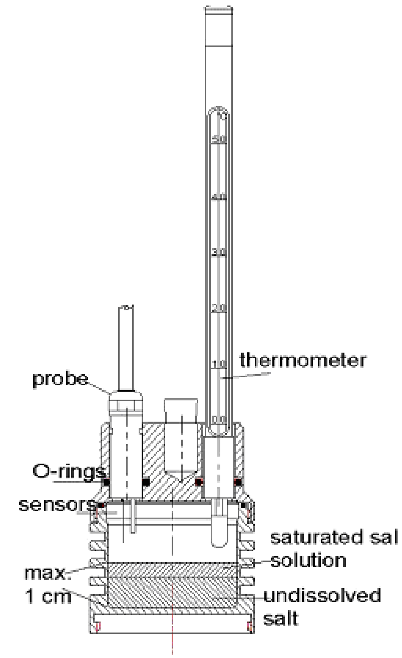
Humidity environments for calibration

Salt solutions

- Salt-water solutions can produce atmospheres of relative humidity from approximately 5 %RH to 98 %RH, depending on the salt.
- The system adjusts to an equilibrium, with less water vapour in the air than there would be over a surface of pure water.
- If the composition of the mixture remains fixed - a solution with both liquid and excess salt crystals - the relative humidity depends only on the temperature and the choice of salt.
- A less well-known problem is that the salt solution is bad at dehumidifying (slow).
- Some systems have a barrier to avoid direct contact with the salt. If not, there is risk of salt contaminating and destroying the sensors.
- Traceability is provided using a relative humidity instrument as a reference, calibrated with traceability to SI.
- A variety of published standards exist*, indicating humidities generated by different salts, but these are nominal values only. It is important to provide traceability via a calibrated instrument.
- Published tables of humidities generated by different salts are not a source of measurement traceability.



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* Examples are: OIML R121, ASTM E104-85, IEC 260, ISO 483, WMO-No.49.

Humidity environments for calibration

Salt solutions – example nominal values of relative humidity

Temperature [°C]	LiCl [%RH]	$MgCl_2$ [%RH]	NaCl [%RH]	K_2SO_4 [%RH]
0	*	33.7	75.5	98.8
5	*	33.6	75.7	98.5
10	*	33.5	75.7	98.2
15	*	33.3	75.6	97.9
20	11.3	33.1	75.5	97.6
25	11.3	32.8	75.3	97.3
30	11.3	32.4	75.1	97.0
35	11.3	32.1	74.9	96.7
40	11.2	31.6	74.7	96.2
45	11.2	31.1	74.5	96.1
50	11.1	30.5	74.4	95.8

WARNING: The data in the table not traceable to the SI. Generated humidity values should be measured using a reference instrument. Uncertainty will also depend on the environment stability and uniformity (including temperature).

Humidity environments for calibration
Salt solutions - Precautions on preparation

- Use non-hygroscopic materials for the chamber, trays, etc.
- Certified High Purity Salts (OIML R121) and deionized water, avoiding contamination, in order to not affect vapor pressure.
- Chamber set-up: large solution surface in relation to air volume, reduces stabilization time (which can be long).
- Example: dry salt spread 3 mm deep in shallow pan that takes up most of the chamber floor, just enough water to make the salt appear wet.
- Temperature control of air and the solution.
- Air circulation to avoid stratification caution.
- Do not get any trace of salt on the sensors!
- Chemicals - risk assessment. Follow label instructions for safe use and responsible disposal of salts.
- Consider uniformity, stability, as uncertainties.

NOTE: Measurement traceability to the SI requires a calibrated reference hygrometer, using the salt only to generate a nominal humidity environment.

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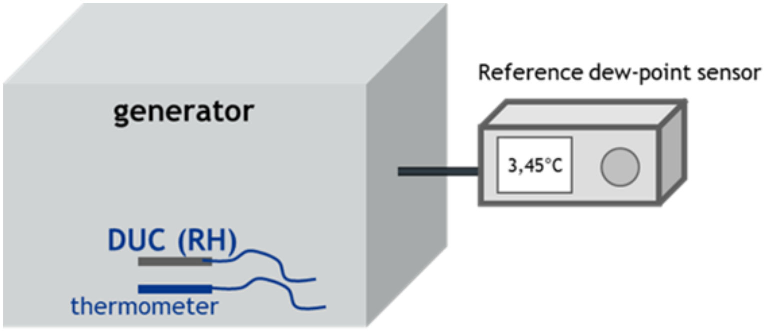
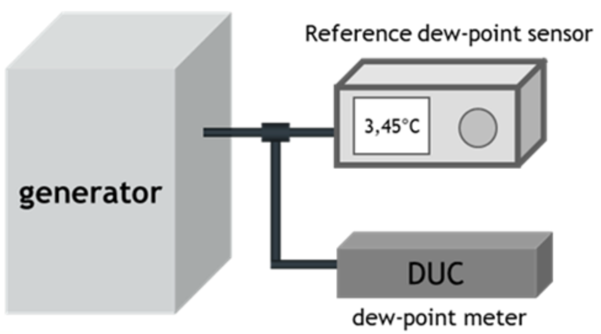
Calibration tips…and traps

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.
- Excessively high flow rates lead to excessive pressure gradients.

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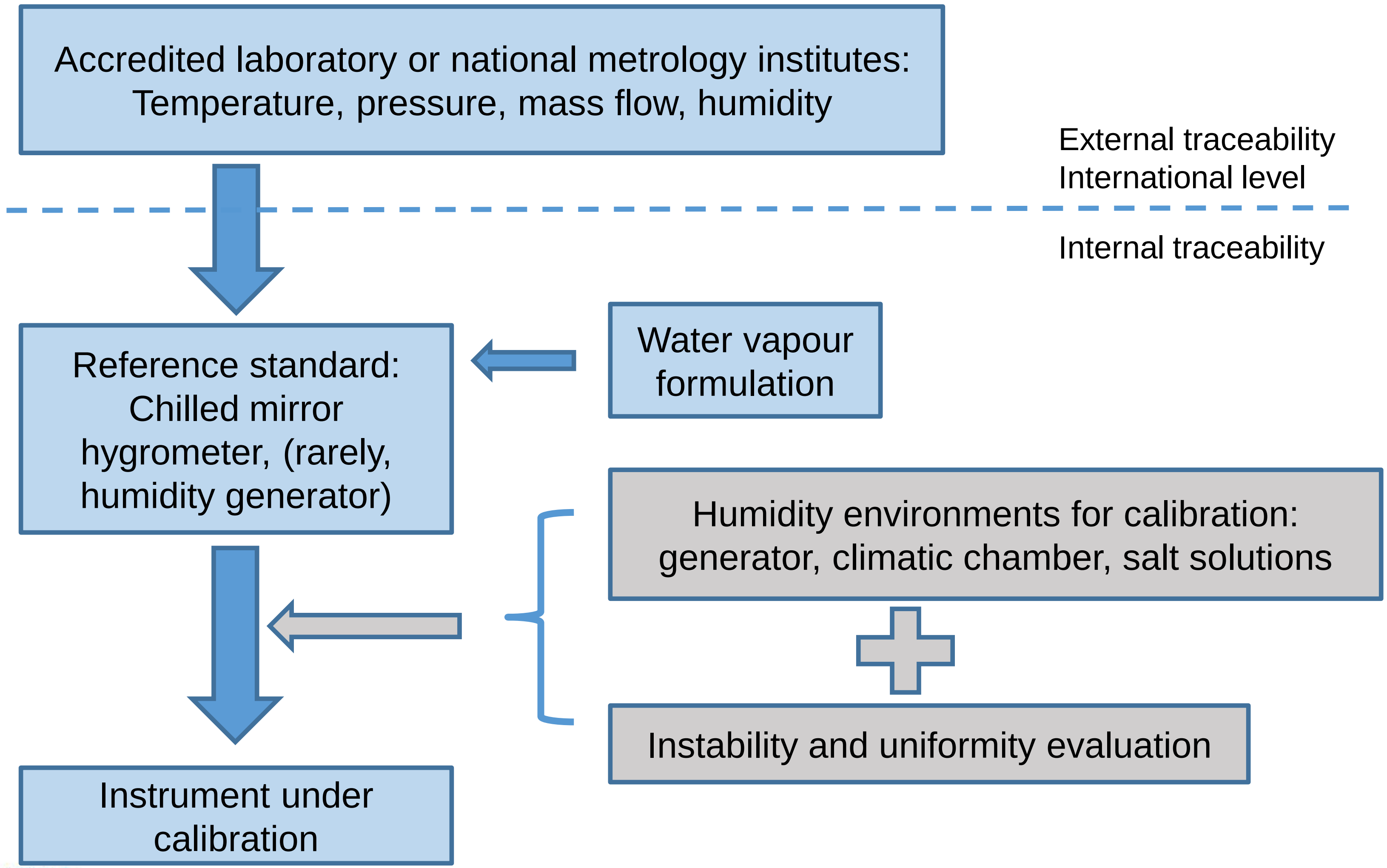
Calibration tips…and traps

Traceability chart



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Humidity calculators

Calculation software

There are several options:

- You can work a bit and learn a lot, programming your own calculation software
    - for example, in an open-source language such as Python
- Or download calculation software from the website of a trusted source, such as an equipment supplier
- Usually free to download or to use online
- These are commonly reliable (accurate), but the user is responsible for validating the results
    - check against calculation equations.

Thank you.

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