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-2: Technology

2.1 Condensation-principle hygrometers

Written by Drago Groselj (ARSO)

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

Presented by Stephanie Bell

WORLD METEOROLOGICAL ORGANIZATION

Calibration of humidity instruments

Overview:

1. Introduction

2. Description of technology
   - **2.1 Condensation-principle hygrometers**
   - 2.2 Capacitive instruments for relative humidity
   - 2.3 Psychrometers for relative humidity

3. Calibration procedures

4. Humidity uncertainties

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Measurement methods

- Condensation – dew-point mirror
- Electrical impedance (resistance or capacitive)
- Wet- and dry-bulb - psychrometer
- Mechanical - hygrograph

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Measurement methods

Classification of humidity instruments (example ranges and uncertainties)

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Gravimetric hygrometer	Primary	-50 °C to 100 °C	0.01 percent of value
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Measurement methods

Dew-point mirror hygrometer

How does it work?

- Air sampled from the environment to be measured flows over a temperature-controlled mirror.
- The mirror is cooled until dew forms on the mirror.

What do we measure?

- The controlled mirror temperature at which a stable dew layer is maintained.
- This is a direct measurement of dew-point temperature.

Key:
[1] LED light source
[2] Photodetector
[3] Resistance thermometer PT100
[4] Peltier supply
[5] Peltier thermoelectric two stage heat pump
[6] Mirror

The air temperature of the sampled environment is also measured. From these two measurements the relative humidity can be calculated.

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Measurement methods

Dew-point mirror hygrometer

Advantages	Disadvantages
Uncertainty around 0.2 °C	Expensive
Can provide precise measurement	Contamination can cause incorrect readings
Good long-term performance	Dew points below 0 °C require careful interpretation
Wide measurement range	Can be slow in response

Measurement methods

Dew-point mirror hygrometer

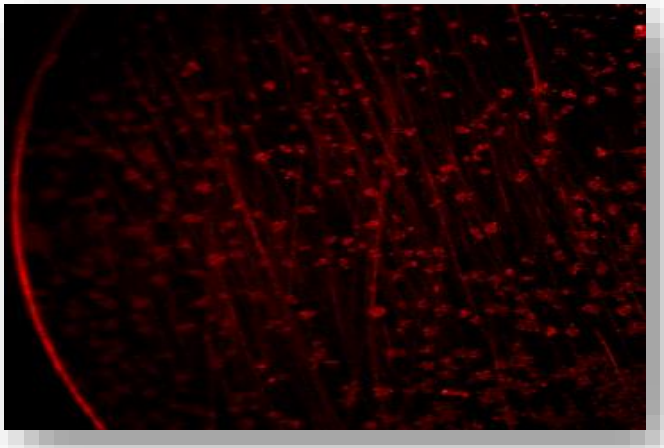
- Some main uncertainty sources:

  - non-soluble contaminants on mirror surface

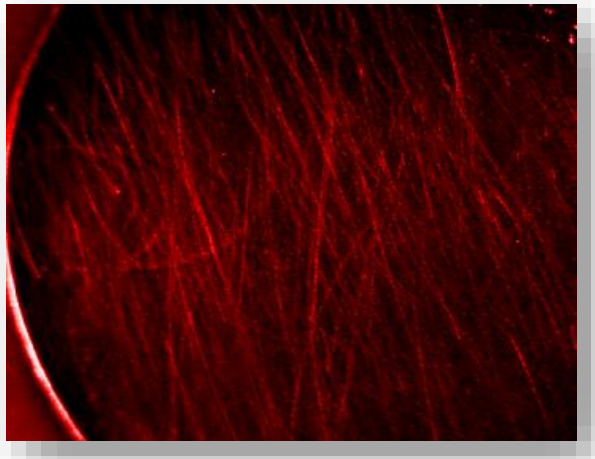
  - soluble contaminants on mirror surface

- **Be careful**: The mirror should be monitored at dew points lower than 0 °C to assess either is a frost or dew point so the correct formula is used in RH calculation.

Ice at –10 °C



Supercooled water at –11,1 °C



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Measurement methods

Dew-point mirror hygrometer

Relative humidity determination

$$U = \frac{e_{w/i}(t_{d/f}) \,.\, f(P, t_{d/f})}{e_{w/i}(t_a) \,.\, f(P, t_a)} \,.\, 100$$

Where:

- $e_{w/i}(t_{d/f})$ saturation vapor pressure at dew/frost point temperature $t_{d/f}$
- $e_{w/i}(t_a)$ saturation vapor pressure at air temperature t_a
- $f(P, t_{d/f})$ enhancement factor at dew/frost point temperature $t_{d/f}$
- $f(P, t_a)$ enhancement factor at air temperature t_a

Since $f(P, t_{d/f}) \approx f(P, t_a)$ the approximate formula can be used

$$U = \frac{e_{w/i}(t_{d/f})}{e_{w/i}(t_a)} \,.\, 100$$

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Measurement methods

Dew-point mirror hygrometer

Practical recommendations

- Filter the air supply to the device to avoid contamination of the mirror with dust, droplets or mist.
- The mirror should be regularly cleaned with deionised or distilled water. Alcohol can be used to remove oil-based contaminants.
- Use a cotton bud to clear the mirror. Drops should pull away cleanly – drops that continue to adhere are a sign of mirror contamination.
- The mirror should be cleaned daily or at least weekly
- In the positive range (above 0 °C), the condensate is dew. In the negative range, condition could be frost point or (in the several degrees below 0 °C) dew point over supercooled water. This is important when calculating vapour pressure.

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2.2 Capacitive instruments for relative humidity

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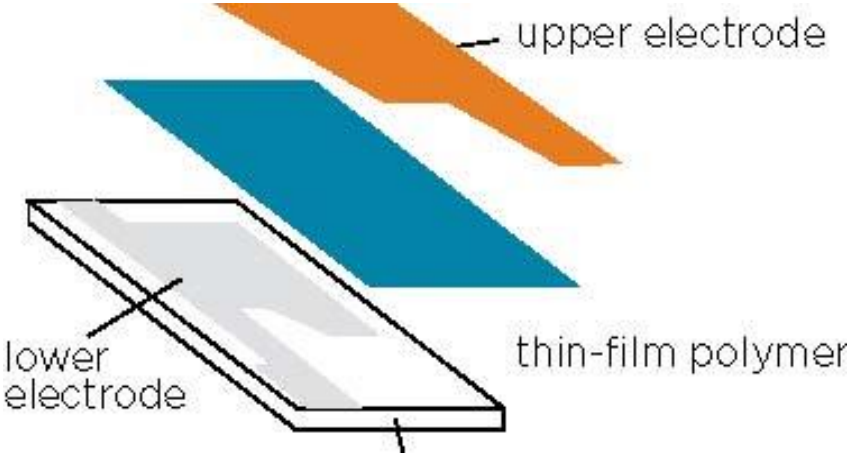
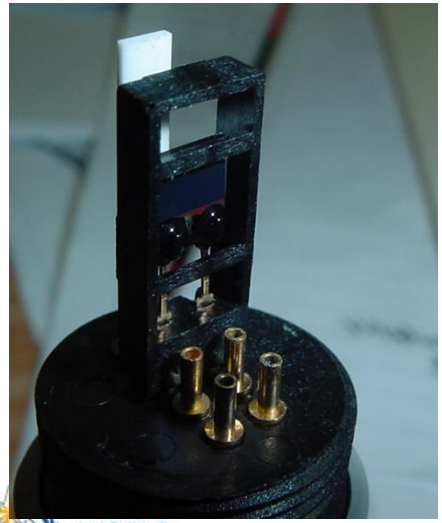
Measurement methods

Capacitive hygrometer

- They are constructed from polymer material with a hygroscopic dielectric and are designed to provide an electrical response corresponding to relative humidity.
- The thin-film polymer either absorbs or releases water vapor as the relative humidity of the ambient air rises or drops.





- They can achieve uncertainties of around 2 – 3 %RH.
- They may suffer calibration shifts after experiencing high temperatures (> 40°C) or high humidities.
- May suffer drift and hysteresis.
- Can be damaged by aggressive chemicals.
- Usually tolerate condensation, but calibration may be affected.

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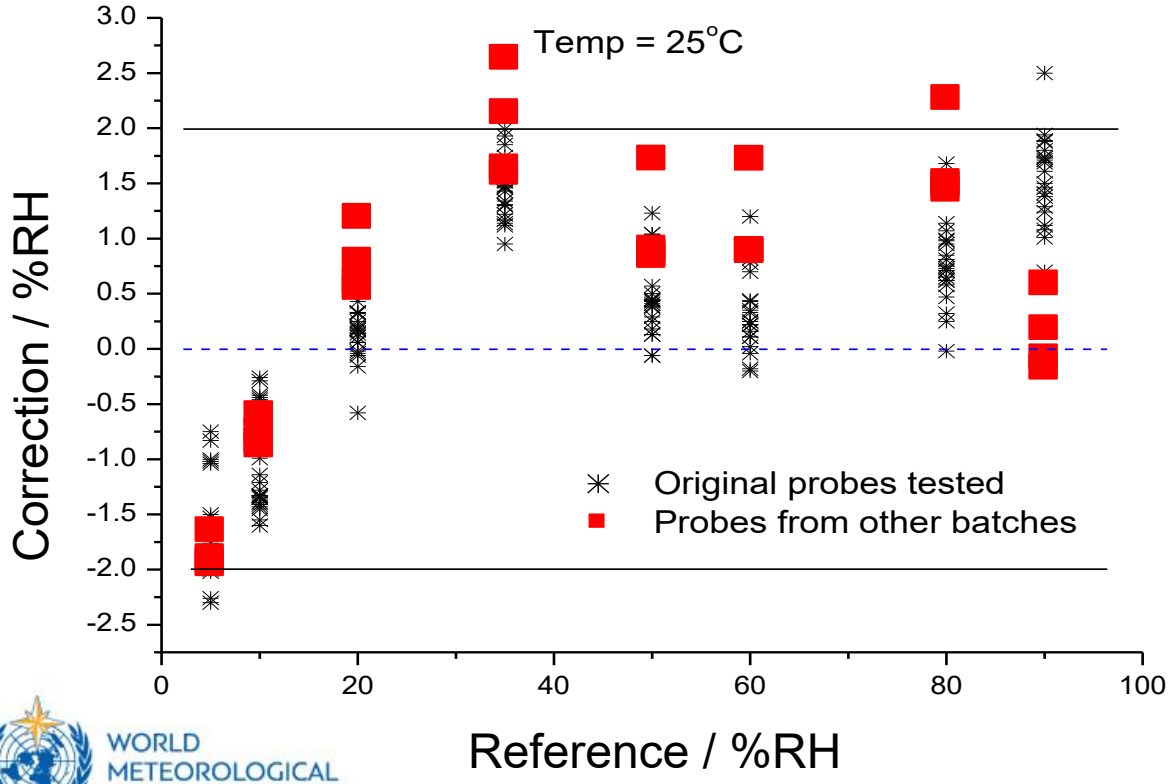
Measurement methods

Capacitive hygrometer

- In the picture the corrections for 26 Vaisala HMP45 humidity probes.
- Note also the corrections may become larger at high and low relative humidities.



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Measurement methods

Capacitive hygrometer

Practical recommendations

- Take care to avoid mechanical and thermal shocks.
- Sensors should be protected from steam, water sprays and direct sunlight.
- Appropriate filters should be used – these are condition dependent.
- Don’t breathe on the sensor to confirm it is working – the sensor can be contaminated.
- In general, do not immerse the sensors in liquids - may destroy them (unless following supplier instructions).
- Always consider air temperature and its effect on relative humidity.

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2.3 Psychrometers for relative humidity

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Measurement methods

Psychrometer

- An aspirated wet- & dry-bulb hygrometer consists of two matched temperature sensors over which humid air is drawn.
- One sensor is enclosed in a porous medium (wick) which is maintained wet by capillary action from a reservoir of water.
- Water evaporates from the wick at a rate related to the humidity and temperature of the air.
- The evaporation causes the wet sensor to chill. The difference between the dry-bulb temperature and the wet bulb temperature is the “wet-bulb depression”.
- Ideally the wet-bulb is shielded from thermal radiation.
- Uncertainties of around 2 – 5 %RH are obtainable.

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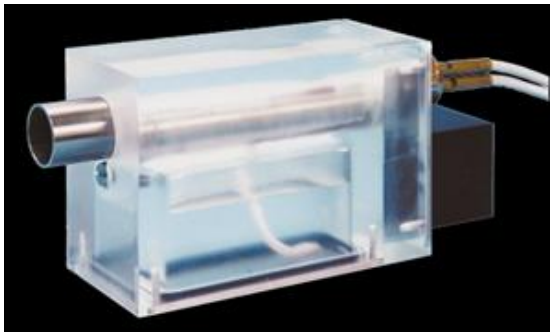
Measurement methods

Psychrometer

Advantages	Disadvantages
Simple, cheap, and robust.	Some skill is required to use and maintain the instrument.
Can have good stability	A large air sample is required for measurement.
Wide range of humidity	The sample will be humidified by the wet wick. Less accurate at low relative humidity.
Tolerate high temperatures and condensation.	Measurement is complicated at low air temperatures (dew or ice point).
	Wick can become contaminated.
	Results have to be calculated from tables or software.
	Whirling types are prone to serious errors.



Measurement methods

Psychrometer

Relative humidity determination

Basic formula (Sprung), adopted by WMO:

$$U = \frac{e'_{w/i}(t_{wb}) - A.P.(t_{db} - t_{wb})}{e'_{w/i}(t_{db})} \; . \; 100\ \%\text{RH}$$

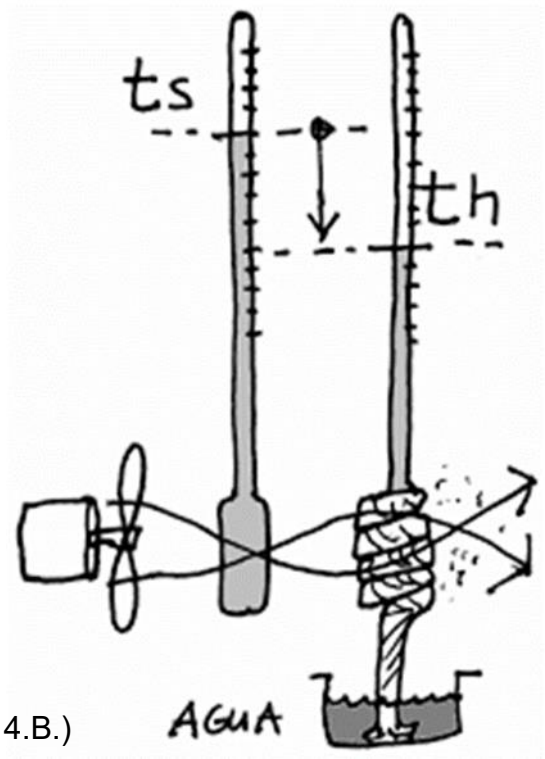
Where:

$e'_{w/i}(t_{db})$ saturation vapour pressure of moist air with regard to water / ice at *t* temperature;

P is the pressure of the air;

t_{db} is the temperature of the dry bulb, air temperature;

t_{wb} is the temperature of the wet / ice bulb;



A is the psychrometer coefficient. (WMO-No.8 –Vol I, Ch 4,Annex 4.B.)

$A = 6{,}53.10^{-4}.(1 + 0{,}0000944\,.\,t_{wb})$ for water.

$A = 5{,}75.10^{-4}$ for ice.

Psychrometer coefficient depends on air flow speed, thermodynamic properties of water and vapor pressure and geometry of wet bulb thermometer and is difficult to determine precisely. There are generic established values of psychrometer coefficient. The instrument calibration may provide a value or function for the psychrometer coefficient to each particular instrument.

Measurement methods

Psychrometer

Practical recommendations

- The wick used should be of the type supplied with the instrument, fit properly, be clean and absorbent.
- Wicks should be cleaned before use by boiling in water with little detergent for approximately 10 minutes.
- Water used for operation must be highly pure – either deionized or distilled.
- The wick must be changed (cleaned) daily or at least weekly depending on the contamination level in the environment (dust, pollen, salt spray etc).
- A psychrometer is said to be aspirated if the airflow is controlled in a target range using a fan or similar device and used the correct psychrometric tables.
- Failure to ensure the conditions above will usually lead to the psychrometer over-estimating humidity.

Thank you.

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