Humidity Measurement Technology – pros & cons

Helping you make a better measurement.

Webinar Presenters & Humidity Experts

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Agenda & Takeaways

Agenda

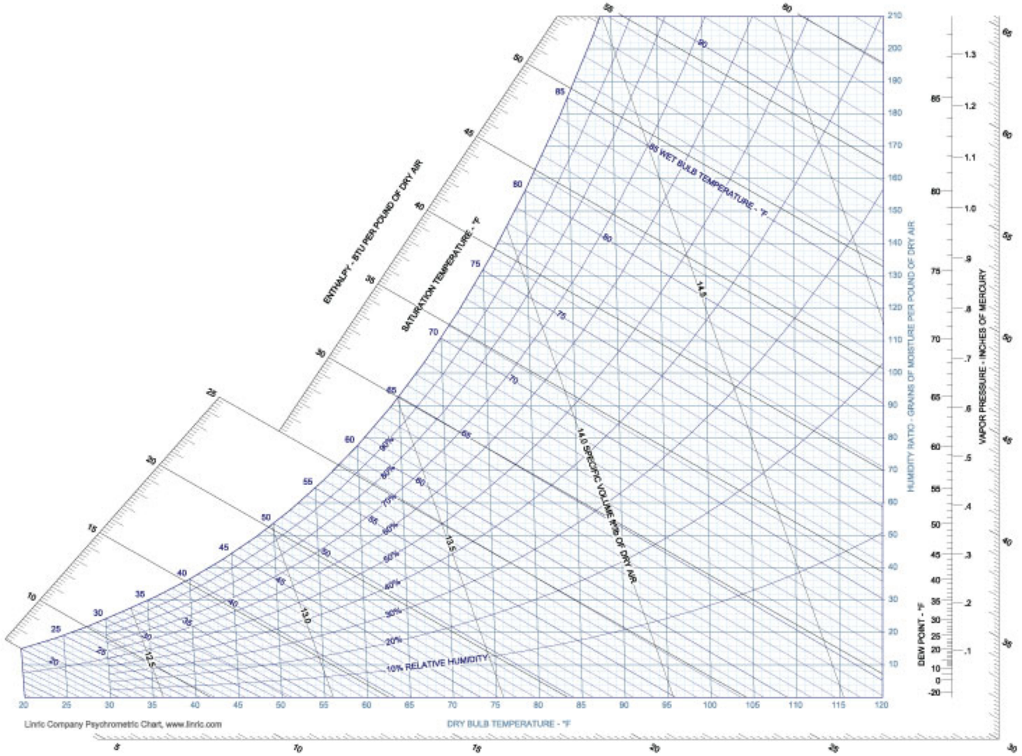
- Parameter review
- Mechanical
- Psychrometer (wet-bulb)
- Capacitive Sensors
- Resistive Sensors
- Chilled mirror
- Metal oxide
- Application cases

Takeaways

- Know which sensor makes sense for your application.

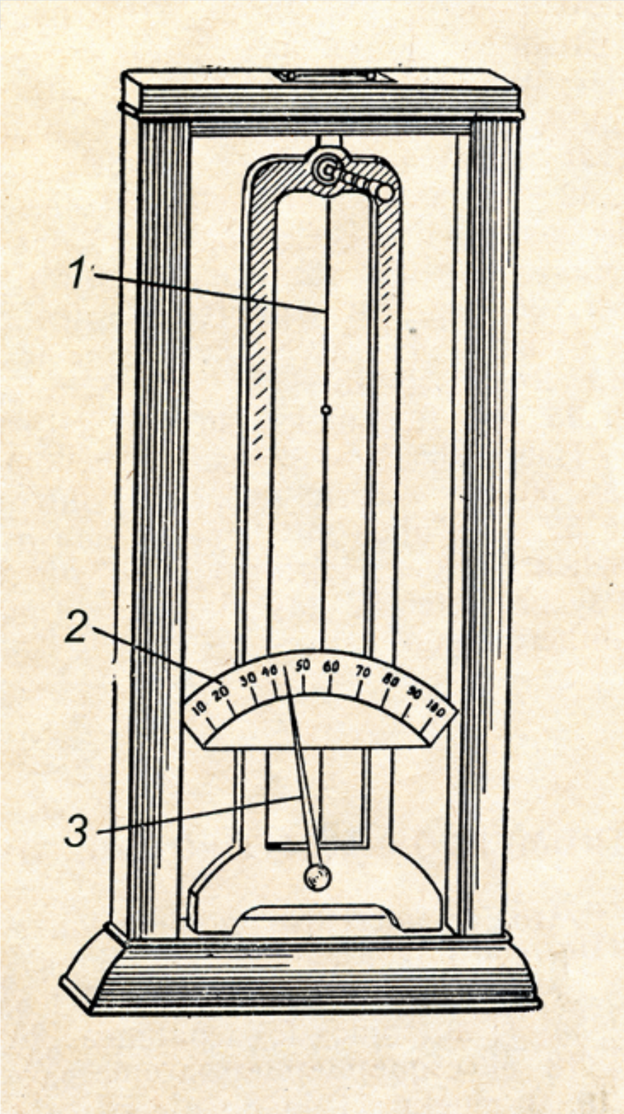
Parameter overview

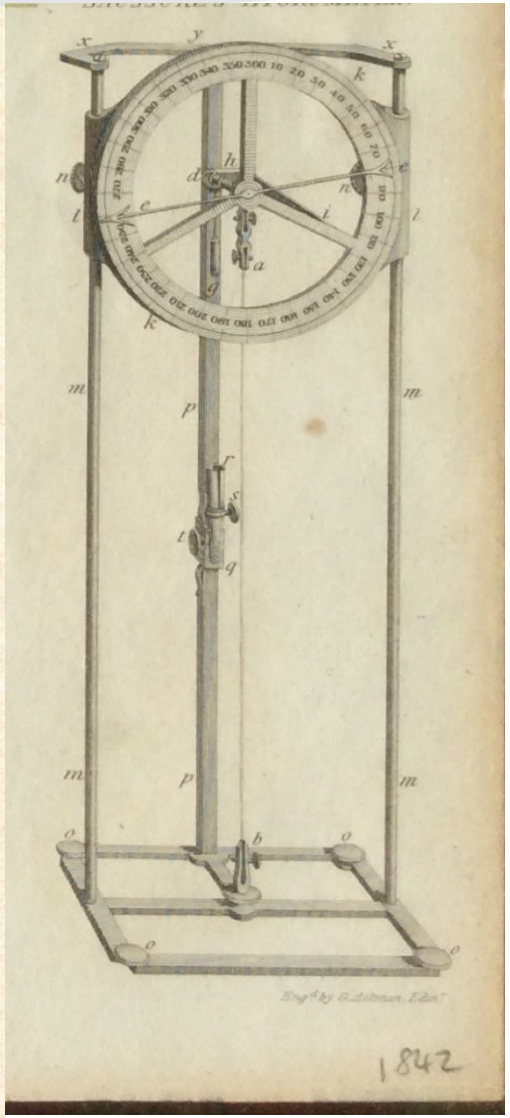
- Relative Humidity
- Vapor pressure
- Dew point
- Wet bulb



Mechanical

- Uses organic materials that change in shape due to changes in relative humidity.
- Shape change is connected to mechanical levers, springs, etc. to output a reading
- Human hair, catgut, textile, goldbeater's skin





Mechanical

Pros	Cons
No electricity needed	Not reliable
Fun	Impossible to calibrate
	Only accurate mid range (30 to 80% RH)
	High in hysteresis
	Very slow response

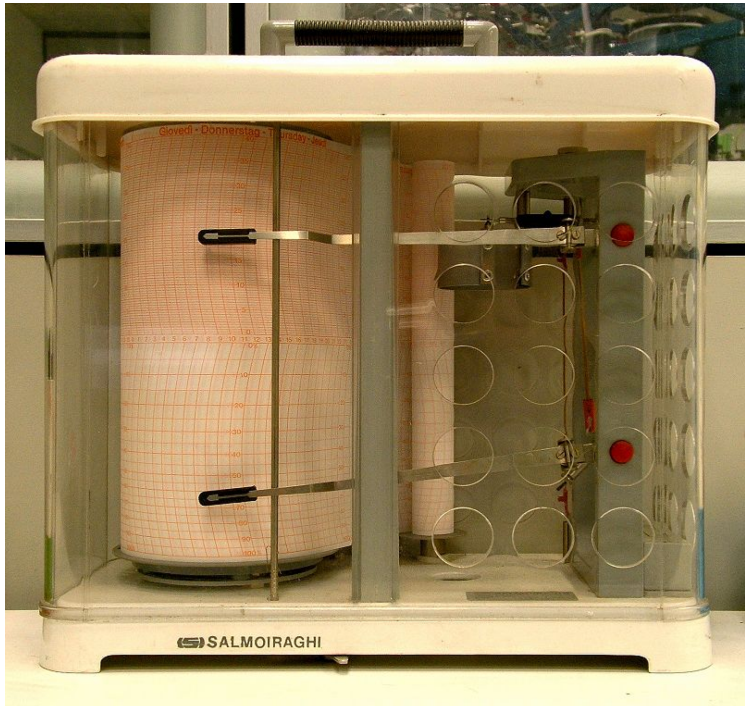


Image source - Wikipedia

Use a mechanical when:

- When you need a general idea
- If you don't have much money to spend on humidity measurement
- For fun if you're a humidity geek

Psychrometer (wet-bulb)

- Requires 2 temperature sensors.
- One is covered with wet sock.
- Air is drawn over the temperature sensor.
- The difference or depression between the two measurements indicates the amount of water vapor present.

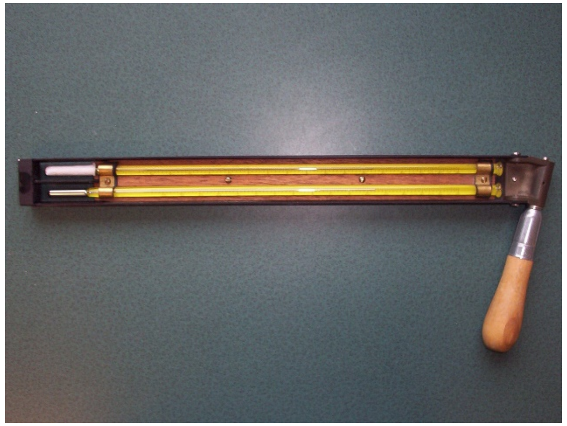
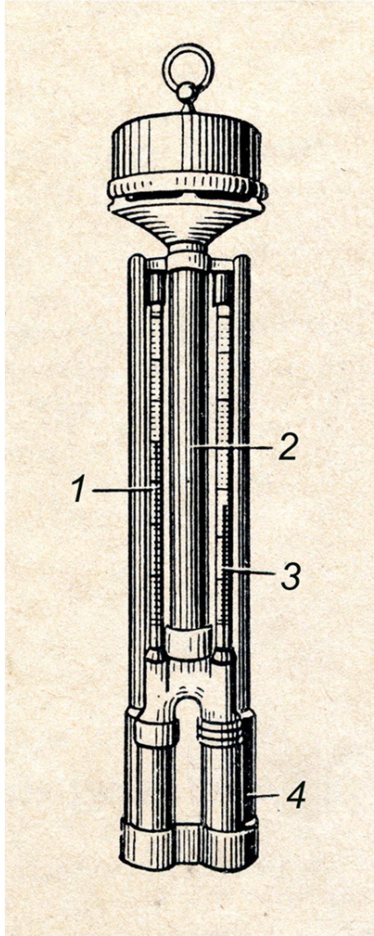


Image source: Wikipedia



Psychrometer (wet-bulb)

Pros	Cons
Inexpensive ($30 to $90 on Amazon)	Requires skill and consistency to operate well
No problem with condensation	Not accurate in small spaces
Easy conversion with charts or graphs	Many variables = high uncertainty

Image source: commons.Wikimedia.com

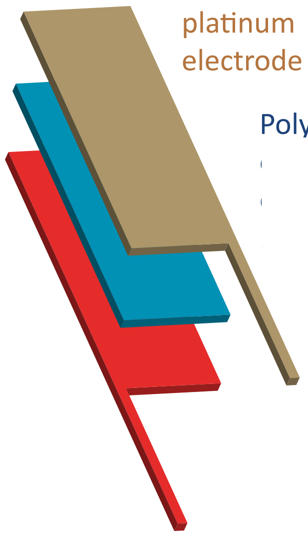
Use a psychrometer when:

- Working with evaporative cooling installations
- Large air sample is available
- Able to control the variables
- Operators remain consistent
- No electricity is available (and don't want to rely on or carry batteries)

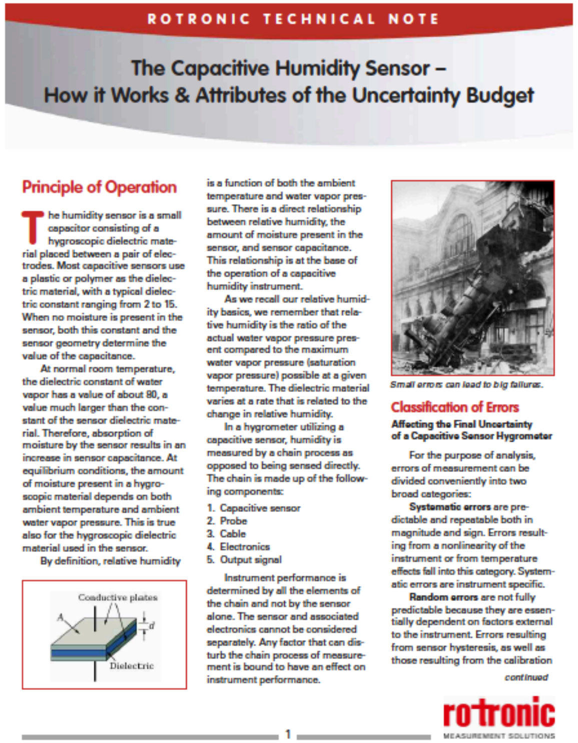
Capacitive Sensors

- As relative humidity changes, the amount of water molecules absorbed by the polymer changes the dielectric constant of the capacitor, varying the capacitance.
- As the relative humidity increases, the capacitance increases almost in a linear fashion.

Electronic Humidity Sensor



Capacitive



ROTRONIC TECHNICAL NOTE

The Capacitive Humidity Sensor – How it Works & Attributes of the Uncertainty Budget

Principle of Operation

The humidity sensor is a small capacitor consisting of a hygroscopic dielectric material placed between a pair of electrodes. Most capacitive sensors use a plastic or polymer as the dielectric material, with a typical dielectric constant ranging from 2 to 15. When no moisture is present in the sensor, both this constant and the sensor geometry determine the value of the capacitance.

At normal room temperature, the dielectric constant of water vapor has a value of about 80, a value much larger than the constant of the sensor dielectric material. Therefore, absorption of moisture by the sensor results in an increase in sensor capacitance. At equilibrium conditions, the amount of moisture present in a hygroscopic material depends on both ambient temperature and ambient water vapor pressure. This is true also for the hygroscopic dielectric material used in the sensor.

By definition, relative humidity is a function of both the ambient temperature and water vapor pressure. There is a direct relationship between relative humidity, the amount of moisture present in the sensor, and sensor capacitance. This relationship is at the base of the operation of a capacitive humidity instrument.

As we recall our relative humidity basics, we remember that relative humidity is the ratio of the actual water vapor pressure present compared to the maximum water vapor pressure (saturation vapor pressure) possible at a given temperature. The dielectric material varies at a rate that is related to the change in relative humidity.

In a hygrometer utilizing a capacitive sensor, humidity is measured by a chain process as opposed to being sensed directly. The chain is made up of the following components:

1. Capacitive sensor
2. Probe
3. Cable
4. Electronics
5. Output signal

Instrument performance is determined by all the elements of the chain and not by the sensor alone. The sensor and associated electronics cannot be considered separately. Any factor that can disturb the chain process of measurement is bound to have an effect on instrument performance.

Conductive plates
A
d
Dielectric

Small errors can lead to big failures.

Classification of Errors

Affecting the Final Uncertainty of a Capacitive Sensor Hygrometer

For the purpose of analysis, errors of measurement can be divided conveniently into two broad categories:

Systematic errors are predictable and repeatable both in magnitude and sign. Errors resulting from a nonlinearity of the instrument or from temperature effects fall into this category. Systematic errors are instrument specific.

Random errors are not fully predictable because they are essentially dependent on factors external to the instrument. Errors resulting from sensor hysteresis, as well as those resulting from the calibration

continued

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Capacitive Sensors

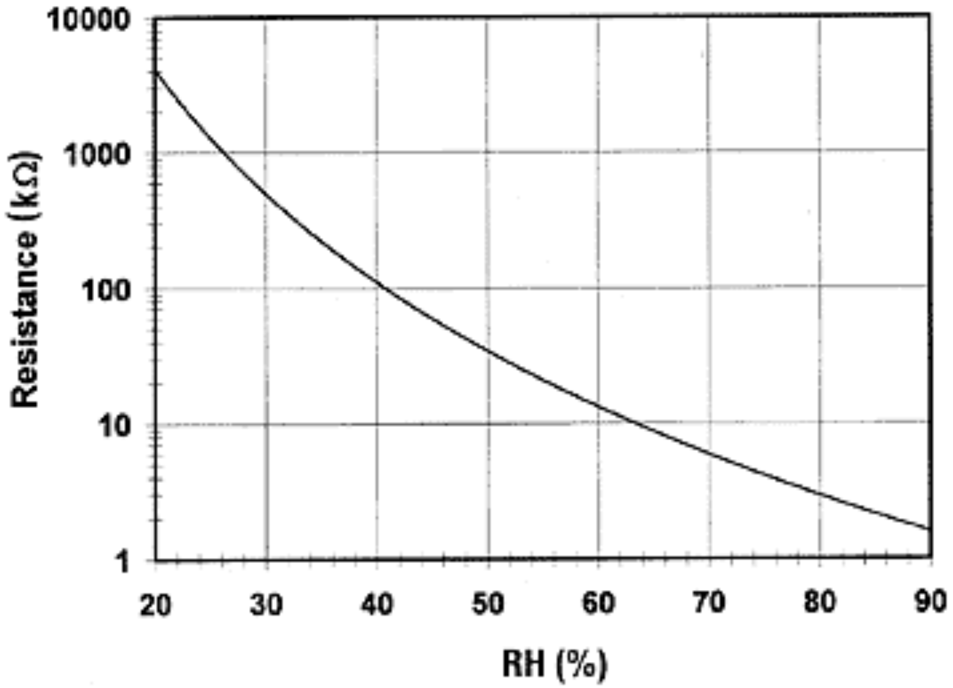
Pros	Cons
Accurate and reliable	Limited accuracy in very dry conditions
Resilient to water, dust and chemicals	Dependent on the manufacturer
Small size	Requires electronics to generate the signal
Fast response	High temp + high RH can affect calibration
Wide measurement range (0 to 100% RH)	More expensive than resistive
Wide temperature range (-70 to +200C)	

Use a capacitive sensor when:

- Condensation is possible
- Dirty environment
- Need good performance (accuracy, repeatability, stability, etc.)

Resistive Sensors

- As relative humidity changes, the resistance changes.
- Increase in RH causes lower resistance.



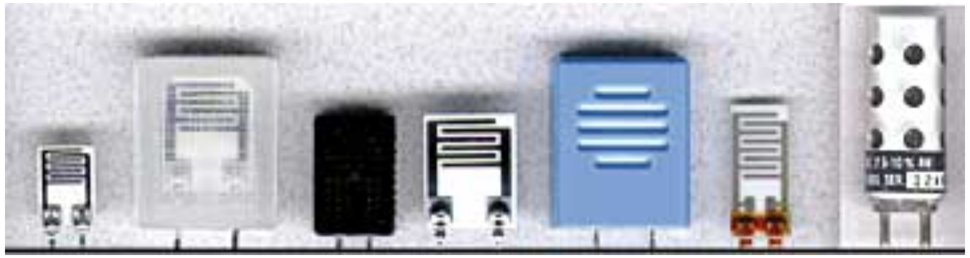


Image source: Sensor Magazine

Resistive Sensors

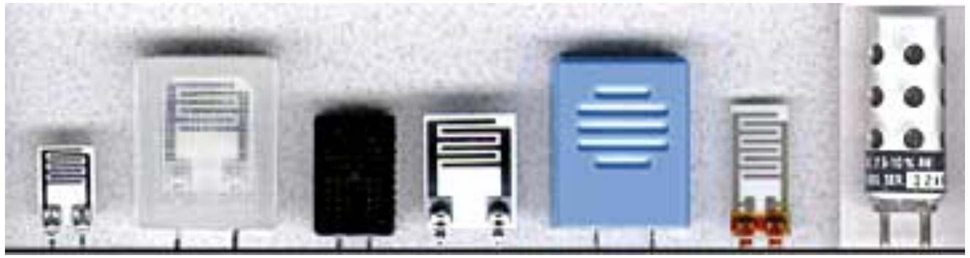


Image source: Sensor Magazine

Pros	Cons
Field replaceable without calibration	Not suitable for extremes
Inexpensive	Not resistant to harsh conditions
Good for mid-range RH (20% to 90%)	Repeatability questionable
	Cannot tolerate condensation

Use a resistive sensor when:

- conditions are moderate
- 20% - 90% RH
- Condensation is not expected to occur
- Accuracy and repeatability are not critical

Chilled Mirror

- Fundamental measurement
- Dew point temperature is determined by the temperature of the mirror when dew or frost forms on the mirror.
- Be aware of dew point vs frost point.
- Know the pressure at the point of interest.

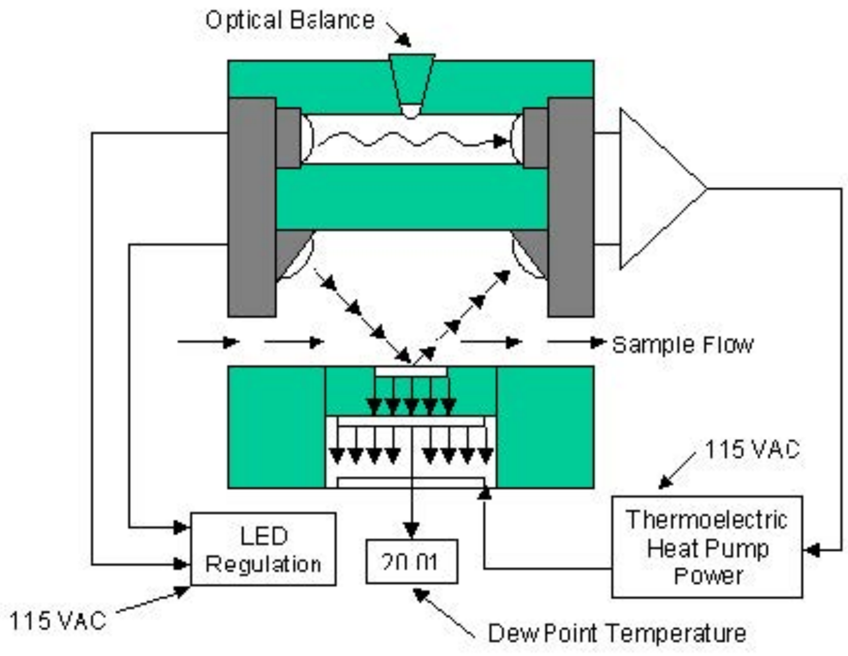


Image source: Thunder Scientific

Chilled Mirror or Condensation Hygrometer

Pros	Cons
Low uncertainties; (+/- .1C k=2)	Expensive compared to other technologies
Highly stable	Requires very clean environment
Broad range (-100C to +100C)	High level of maintenance
Fundamental measurement	Requires a skilled, trained operator
	Airflow through sensing head

Use a chilled mirror when:

- Low uncertainty and high stability are a requirement (Lab, R&D)
- Measurement environment is clean and controlled
- You have a lot of money and you don't know what to do with it.
- Not recommended for inline or field applications.

Metal Oxide

- Aluminum Oxide (Al_2O_3) most common
- Water vapor adsorbs to oxide
- Conductivity varies with amount of water vapor molecules
- Gives an absolute measure
- Need pressure and temperature for conversions

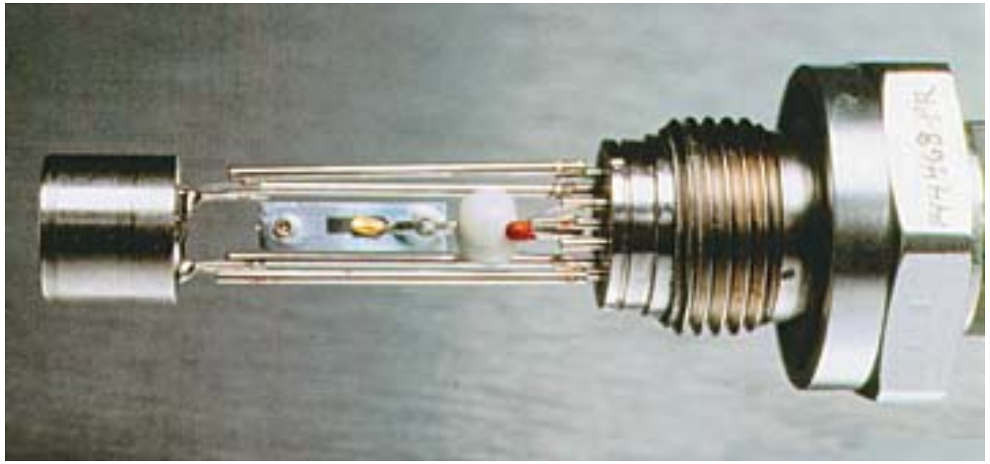


Image source: Sensor Magazine

Metal Oxide

Pros	Cons
Excellent for very dry conditions (as low as -100C)	Slow response to changes
Very small footprint	Large calibration shifts from wet air
	Requires numerous calibrations
	Calibration is usually very expensive
	Not stable over time

Use a metal oxide when:

- Very dry, very clean air/gas
- For dew point temperature < -70C
- Stable, uneventful air streams
- Measuring trace moisture in absolute terms (ppm, mixing ratio, p)

Summary of Technologies

1. Mechanical
2. Psychrometer (wet-bulb)
3. Capacitive Sensors
4. Resistive Sensors
5. Chilled mirror
6. Metal oxide

Other technologies:

- Spectroscopy
- Color changing chemicals
- Saturated lithium chloride
- Electrolytic
- Acoustic
- Adiabatic expansion
- Gravimetric
- And more

Comments & Questions

Please type your questions into the chat box at the lower left portion of your screen.

Takeaways for a Better Measurement

Choose the Best Technology for Your Application

Glovebox where you have to maintain 5 ppm water vapor.

- Temperature is 23C
- Air is very clean
- Minimal chance of condensation
- Need very high accuracy, reliability and stability.
- Money is no object

Image source: Flickr: Glovebox; Author: Idaho National Laboratory

Choose the Best Technology for Your Application

- **Compressed air system**
  - Desiccant dryers -40C dew point
  - 90 psig operating pressure
  - Industrial environment
  - Condensation likely at some point in the system **(unreliable dryers)**
  - Need inline measurement at critical points of use
  - Low budget operation

Choose the Best Technology for Your Application

Clean room

- Temperature is 23C
- Humidity 40%
- Particle size Class ISO3
- Air pressure difference
- Air change rate
- Air flow velocity

Summary of Choosing the Correct Instrument

1. Measurement environment
2. Performance requirements
3. Parameter required

Comments & Questions

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

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