

Does it feel a little humid in here, or is it just me?

Humidity Measurement

Nathaniel Hilliard

September 29th, 2014

Humidity Represents

- Humidity is a measure of moisture in a gas
- Important in manufacturing, testing, and storage
- Also in weather and personal comfort

- Measures
 - Absolute- actual mass of water in volume or mass of air
 - Specific- actual mass of water in volume or mass of dry air
 - Relative- ratio of absolute:max capacity at a temperature
 - Dew Point- temperature at which air becomes saturated

Although we typically consider humidity as the amount of water in the air

It can be a measure of moisture in any gas

The presence of water can have many detrimental effects so monitoring it is of great importance to industry

It also directly effects weather patterns and personal comfort

When measuring

Absolute and Specific humidity is a ratio of moisture mass to wet or dry gas mass

Relative humidity is the most common measure and is temperature dependent

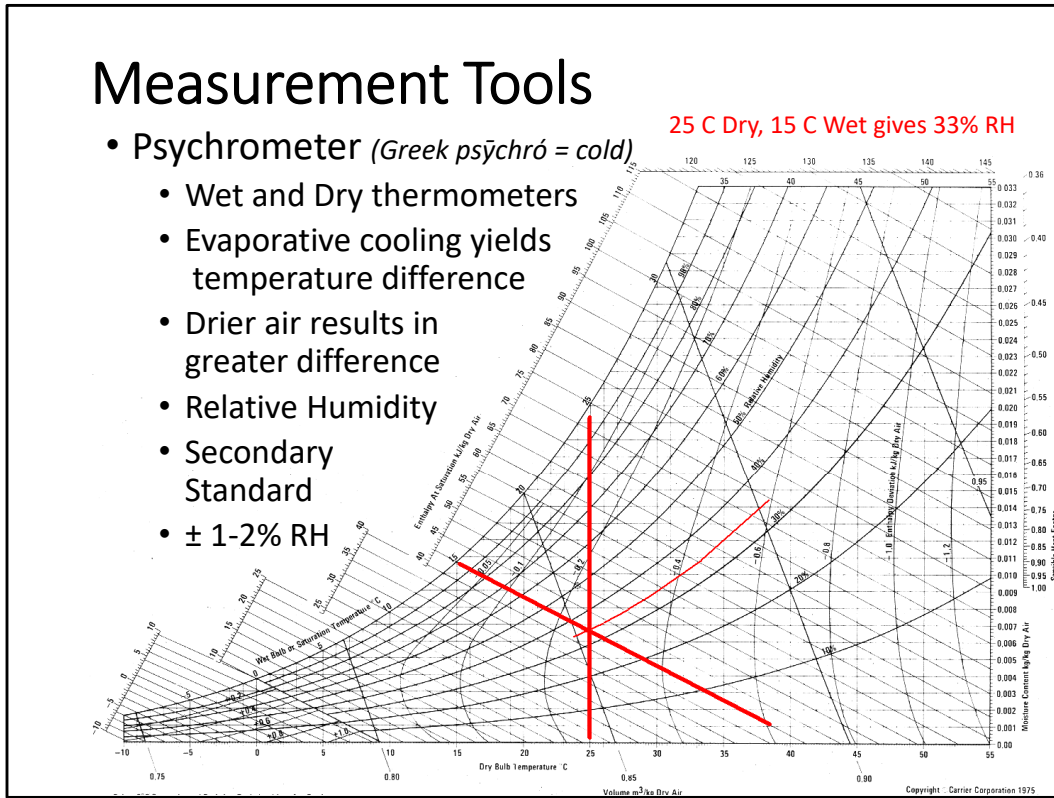
It is the ratio of absolute humidity to maximum capacity at a given temperature

Dew point indicates the point at which air would be saturated

Measurement Tools

- Psychrometer (*Greek psȳchró = cold*)
 - Wet and Dry thermometers
 - Evaporative cooling yields temperature difference
 - Drier air results in greater difference
 - Relative Humidity
 - Secondary Standard
 - $\pm 1-2\%$ RH

25 C Dry, 15 C Wet gives 33% RH



There are two basic classes of measurement tools

The Psychrometer is one, measuring relative humidity

It uses a wet and dry thermometer to measure evaporative cooling

Drier air will yield greater cooling

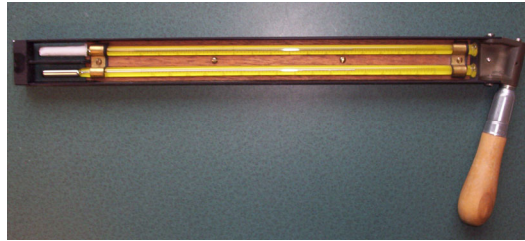
The relative humidity can be read from a chart, at the intersection of the two points

Example- 25C dry and 15C wet intersects at about 43% relative humidity

These are relatively accurate and commonly used as secondary standards

- Examples

- Sling Psychrometer



- Motorized Psychrometer



Top- Hand held psychrometer

Wet sleeve on one thermometer and spin in the air to elicit cooling

Immediately read wet temperature and then dry

Bottom- Automated wetting device in an enclosed weather station

- **Hygrometer** (*Greek *hygrós* = wet, moist*)
 - Measures physical effects of water on materials
- **Displacement (relative humidity)**
 - Hair, coiled metal with salt impregnated backing
 - Absorption of moisture causes expansion and physical movement of indicator
 - Slow response, susceptible to drift and hysteresis but resistant to most contamination
 - Lower accuracy ($\pm 10\%$ RH)



The second class of devices are Hygrometers

These measure the physical effects of water on other substances

The simplest are Displacement Hygrometers, measuring Relative Humidity


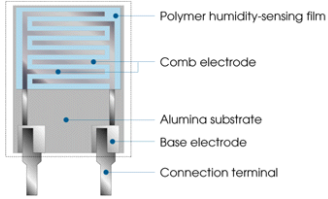
On the right, a hair type hygrometer

On the bottom, a metal/paper coil type



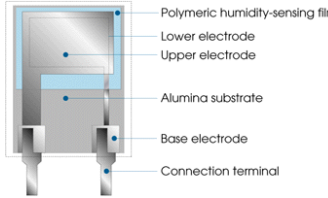
Both work by the hair or salt impregnated coil gaining or losing moisture, changing size and moving a gauge

Inexpensive and simple to make but slow to respond and the least accurate.

- Electrical (relative humidity)
 - Resistive Polymer
 - Good range, stability, response, accuracy ($\pm 1-2\%$ at $>15\%$ RH), low cost
 - Resists contamination but response may slow
 - Replaces similar but older and more restrictive Dunmore and Pope Cells

- Capacitive and Impedance
 - Absorbed moisture affects dielectric constant
 - Fast response, good accuracy for lower ranges ($\pm 2-3\%$ at $<85\%$ RH)
 - Impedance values are more linear than capacitance for RH

Another type are Electrical Hygrometers, also measuring Relative Humidity

Resistive Polymer units are inexpensive, accurate for higher RH values and very common

They measure the changing resistance of an insulating material separating the leads as moisture levels change

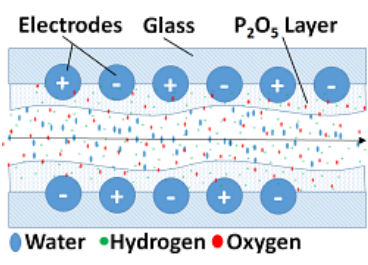

The Capacitive and Impedance units work similarly, with a varying dielectric layer

These give a rapid response and are preferable for lower humidity levels

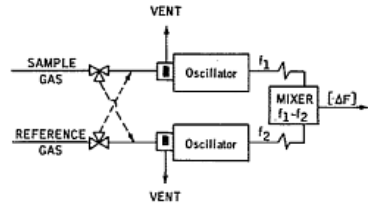

Measuring impedance rather than capacitance alone provides a more linear response

Accuracies are similar to the Psychrometer

- **Electrolytic** (this one is **absolute** humidity)
 - Electrolysis of water vapor absorbed by desiccant between electrodes in flow tube
 - Current = H₂O molecules dissociated/sec
 - 1 ppb to 5000 ppm ± 5ppb

- **Piezoelectric**
 - Moisture absorbed in coating on crystal changes frequency with mass change
 - 1 ppb to 1000 ppb

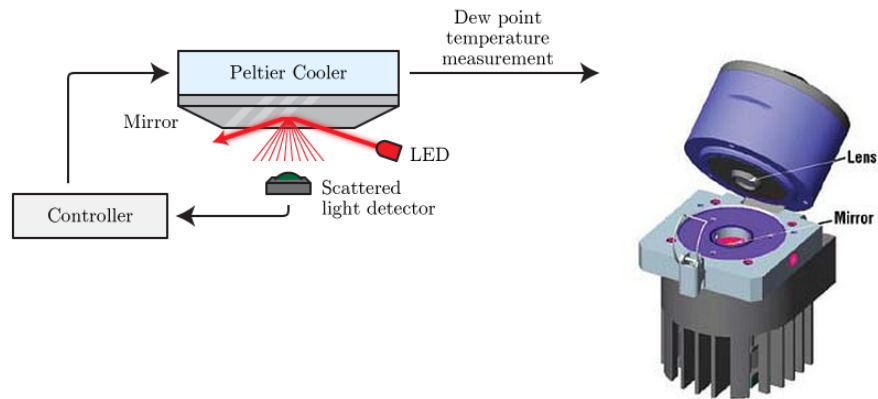
The Electrolytic and Piezoelectric units are used for very low moisture levels (PP 1000 and less)

The Electrolytic measures the current required to dissociate all of the water molecules in a flowing gas
 This is actually measures absolute humidity as it depends only on the moisture in the gas

The Piezoelectric uses moisture to change the mass and resonating frequency of a crystal,
 Comparing it to a second reference crystal. The change will yield moisture content

Both of these can detect below 10 parts per billion

- Condensation (dew point)
 - Chilled Mirror
 - Mirror oscillates between cooled and warmed
 - Light beam disruption indicates condensation
 - Dew point from thermistor or RTD on mirror
 - RH from dew point and air temperature
 - Accuracy to ± 0.2 °C



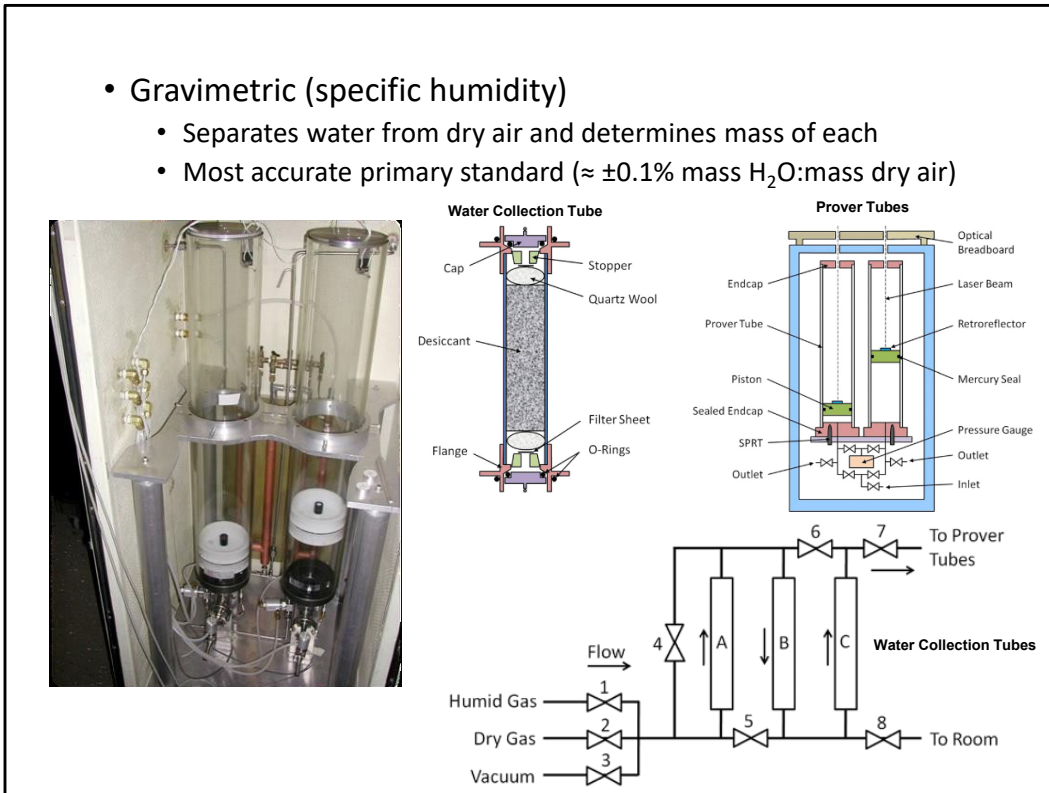
Condensation Hygrometers measure the Dew Point directly

A chilled mirror will scatter a light beam when moisture condenses
The mirror will then warm until it clears

The mirror will oscillate above and below the condensation point, giving an accurate indication of Dew Point

Relative humidity can be obtained when combined with air temperature

- Gravimetric (specific humidity)
 - Separates water from dry air and determines mass of each
 - Most accurate primary standard ($\approx \pm 0.1\%$ mass H_2O :mass dry air)



Gravimetric Hygrometers are the most accurate primary standards, measuring Specific Humidity

They are also the most cumbersome to use and so are never used in the field

They draw in an arbitrary amount of gas

All moisture is absorbed by an array of collection tubes

The dry gas is then collected in specialized Prover tubes, measuring pressure, temperature and laser accurate volume

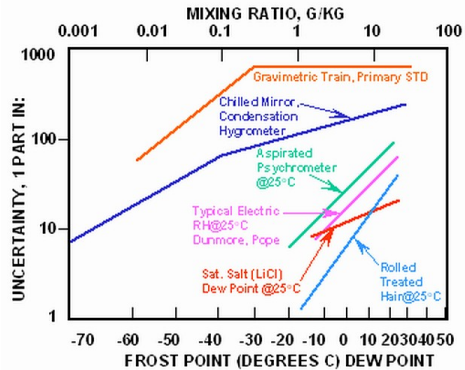
The density is determined and a mass derived

The water collection tubes are weighed to determine total moisture

Accurate to +/- 0.1% Mass:Mass

- Contamination and Accuracy

- All types susceptible to chemical and particulate contamination
- In actual working conditions, factory specifications can be significantly exceeded within a few months
- Consideration of long term *in situ* accuracy may be of more value than out-of-box accuracy when purchasing
- Accuracies subject to type and working temperatures



All types of hygrometer subject to contamination

May affect response time, accuracy or useful life of instrument

Working conditions are rarely the same as test conditions

Listed specifications may be exceeded within weeks or months of working conditions

Should consider long term installed accuracy rather than rated accuracies when purchasing

Chart shows some accuracy ranges for various types and temperatures

References and Information Sources

- *Introduction to Measurements and Instrumentation*, 2nd & 3rd ed., Arun K. Ghosh, PHI Learning Pvt. Ltd., 2007, 2009
- *Introduction to Instrumentation and Measurements*, 2nd ed., Robert B. Northrop, Taylor & Francis, 2005
- *Water Vapor Measurement: Methods and Instrumentation*, Pieter R. Wiederhold, Marcel Dekker, 1997
- *Anesthesia Equipment: Principles and Applications*, 2nd ed., Jan Ehrenwerth, James B. Eisenkraft, and James M. Berry, Elsevier, 2013 (chapter 7)
- Farahani H, Wagiran R, Hamidon MZ, (2014), "Humidity Sensors Principle, Mechanism, and Fabrication Technologies: A Comprehensive Review", *Sensors*, 14(5):7881-7939
- Ma C, Shadman F, (1995) "Evaluating the Trace-Moisture Measurement Capability of Coulometric Hygrometry", *Micro*, April
- Meyer CW, Hodges JT, Scace GE, Whetstone JR, Hyland RW, (2010), "A Second-Generation NIST Gravimetric Hygrometer", *Metrologia*, 47:192-207
- "Training Material on Automated Weather Observing Systems", *Instruments and Observing Methods, Report No. 87*, World Meteorological Organization, Module B2, 2006
- *Evaluation of Trace Moisture Sensors*, Stephanie Bell, Tom Gardiner, Mark Stevens, Keith Waterfield, National Physical Laboratory, 2002
- *A Beginner's Guide to Humidity Measurement*, Stephanie Bell, National Physical Laboratory Ltd., 2011
- Pieter R. Wiederhold, "True Accuracy of Humidity Measurement", *Sensors Online*, Sept. 1997
- David J. Beaubien, "The Chilled Mirror Hygrometer: How It Works, Where It Works, and Where It Doesn't", *Sensors Online*, May 2005
- "Relative Humidity: Measuring with a Dewpoint Hygrometer", *Nordtest Method*, NT Build 474, 1996
- <http://www.acurite.com/how-to-measure-humidity>
- <http://www.nist.gov/pml/div685/grp01/grav-hyg.cfm>
- <http://rs20.mine.nu/w/2012/08/chilled-mirror-humidity-sensor-project-1/>
- http://www.iceweb.com.au/Analyzer/humidity_sensors.html
- http://product.tdk.com/en/techjournal/tfl/sensor_actuator/CHS/