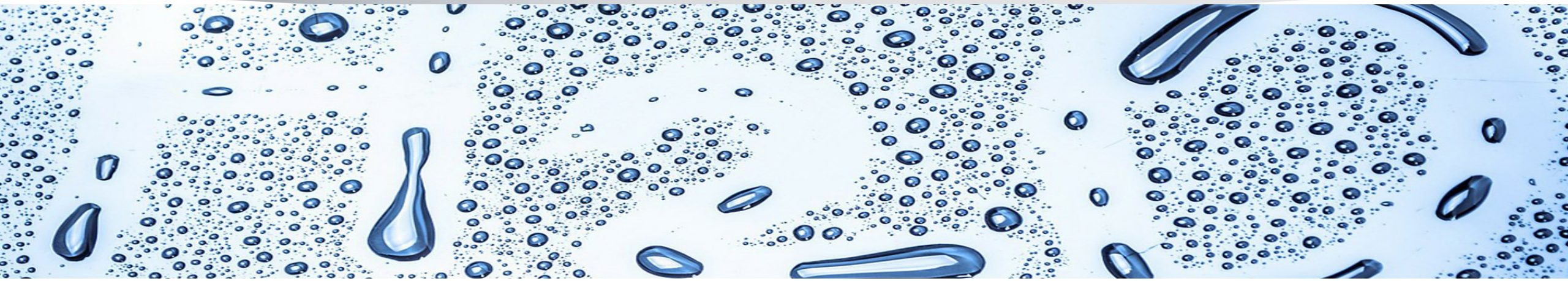

Humidity – How to Make a Better Measurement

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Webinar Presenters & Humidity Experts

Bruce McDuffee

Michael Boetzkes

Agenda & Takeaways

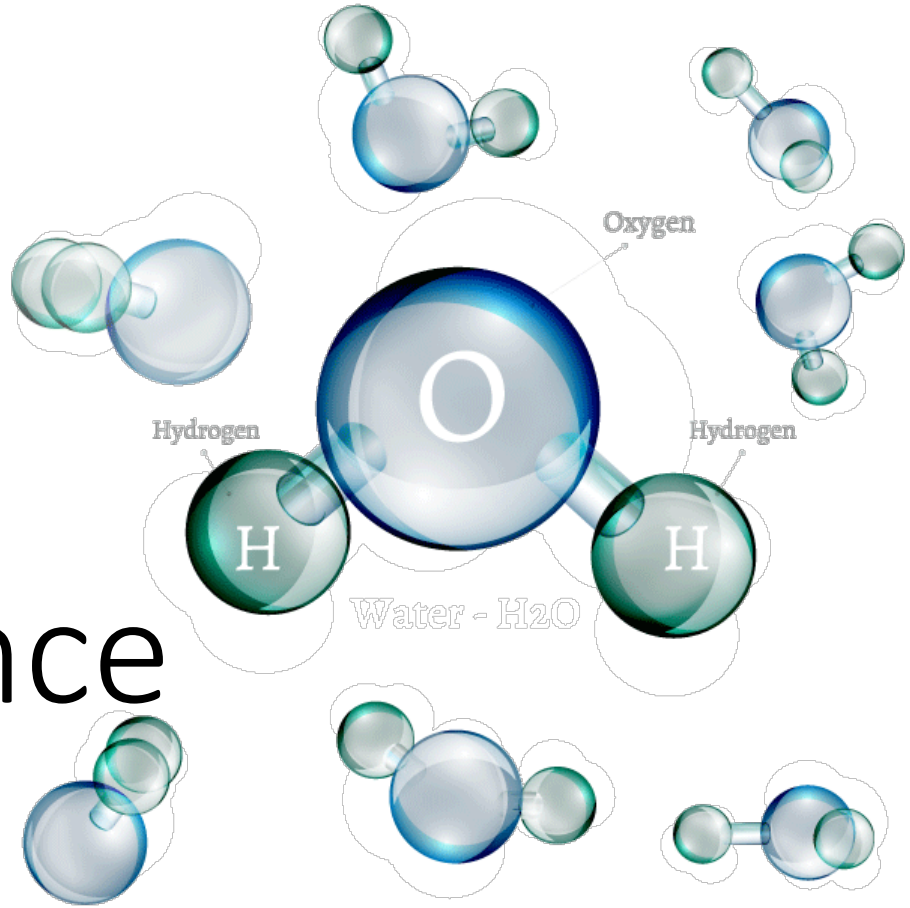
Agenda

1. Science of Humidity
2. Temperature effect
3. Pressure effect
4. Technology

Takeaways for a Better Measurement

- Knowledge helps avoid poor processes
- Temperature effects
- Pressure effects
- Avoid temperature inconsistencies
- Match technology to your application and requirements
- Know what your sensor is measuring and instrument calculating

Relative Humidity Science

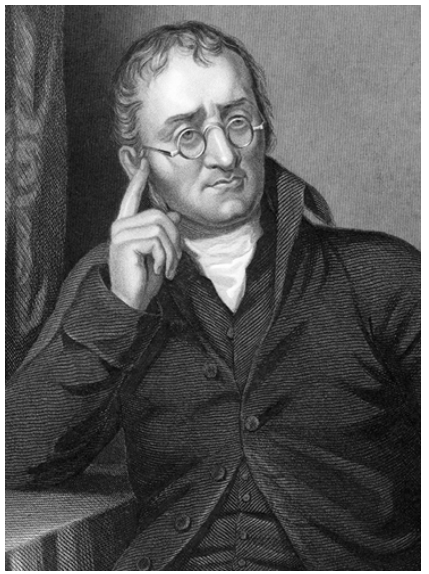


Partial Pressure of Water Vapor (p)

aka vapor pressure

Dalton's Law of Partial Pressures:

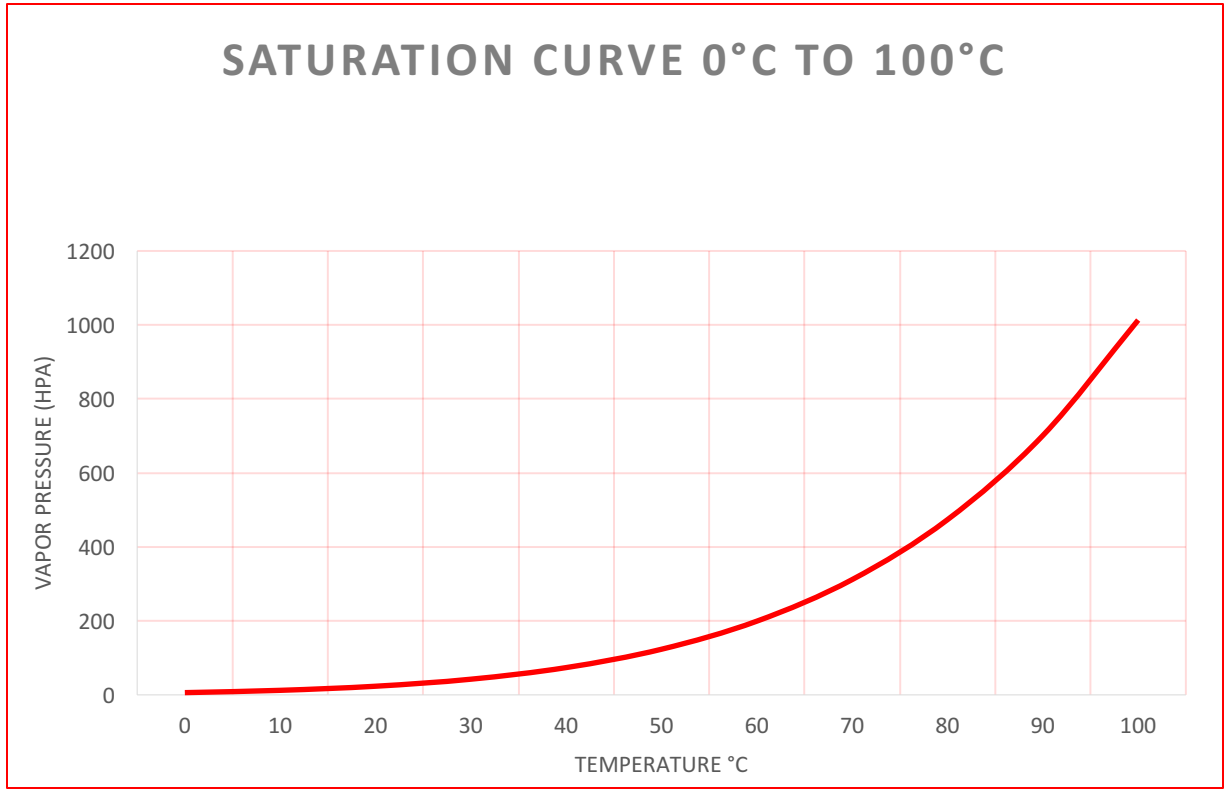
- *The total pressure of a gas mixture is equal to the sum of the partial pressures of the individual gas components.*



John Dalton

$$P_t = P_1 + P_2 + P_3 + \ldots P_n$$

Saturation Vapor Pressure (p_s)



The saturation vapor pressure is the pressure of a vapor when it is in equilibrium with the liquid phase. It is solely dependent on the temperature. As temperature rises the saturation vapor pressure rises as well. - CMMAP.org

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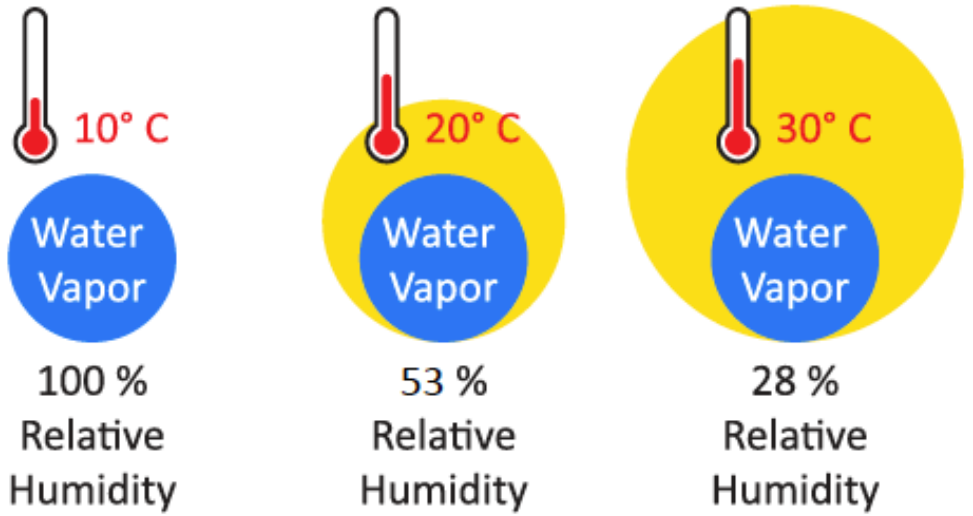
Relative Humidity

$RH = p/p_s$

p=partial pressure

p_s=saturation pressure



p=12.3 hPa
p_s=12.3 hPa

p=12.3 hPa
p_s=23.4 hPa

p=12.3 hPa
p_s=42.4 hPa

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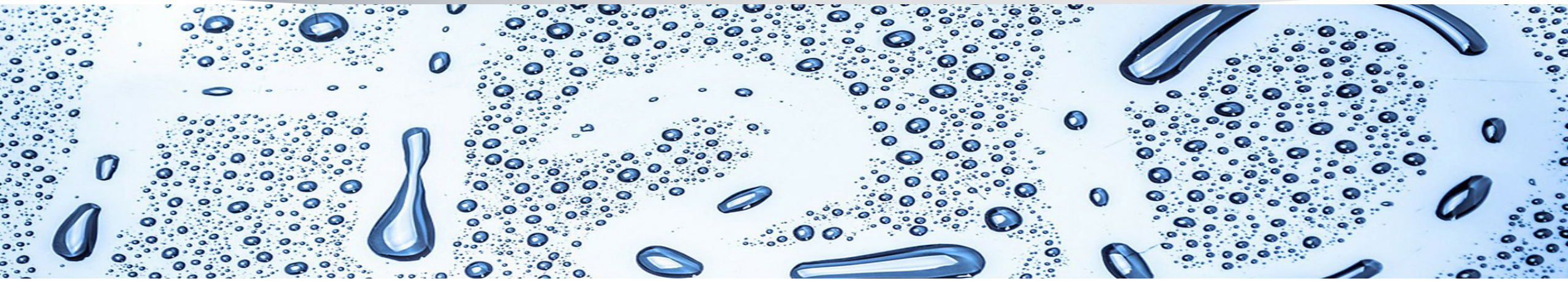


Temperature Effect on RH

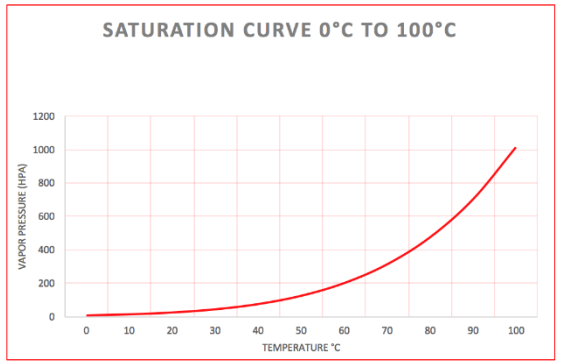
RH Requires Uniform Temperature

- RH sensors are very sensitive to temperature.
- Measurement probe must be uniform temperature.
- Measurement point must be representative.

$$RH = p/p_s$$

p=partial pressure

p_s=saturation pressure



Why is temperature so critical?

- p (partial pressure) does not change as the temperature changes.
- p_s does change as temperature changes

T	p	p_s	RH	△
40℃	40 hPa	73.8 hPa	54.2%	
39℃	40 hPa	69.9 hPa	57.2%	+ 3.0%
41℃	40 hPa	77.8 hPa	51.4%	- 2.8%
38℃	40 hPa	66.3 hPa	60.3%	+ 6.1%
42℃	40 hPa	82 hPa	48.8%	- 5.4%

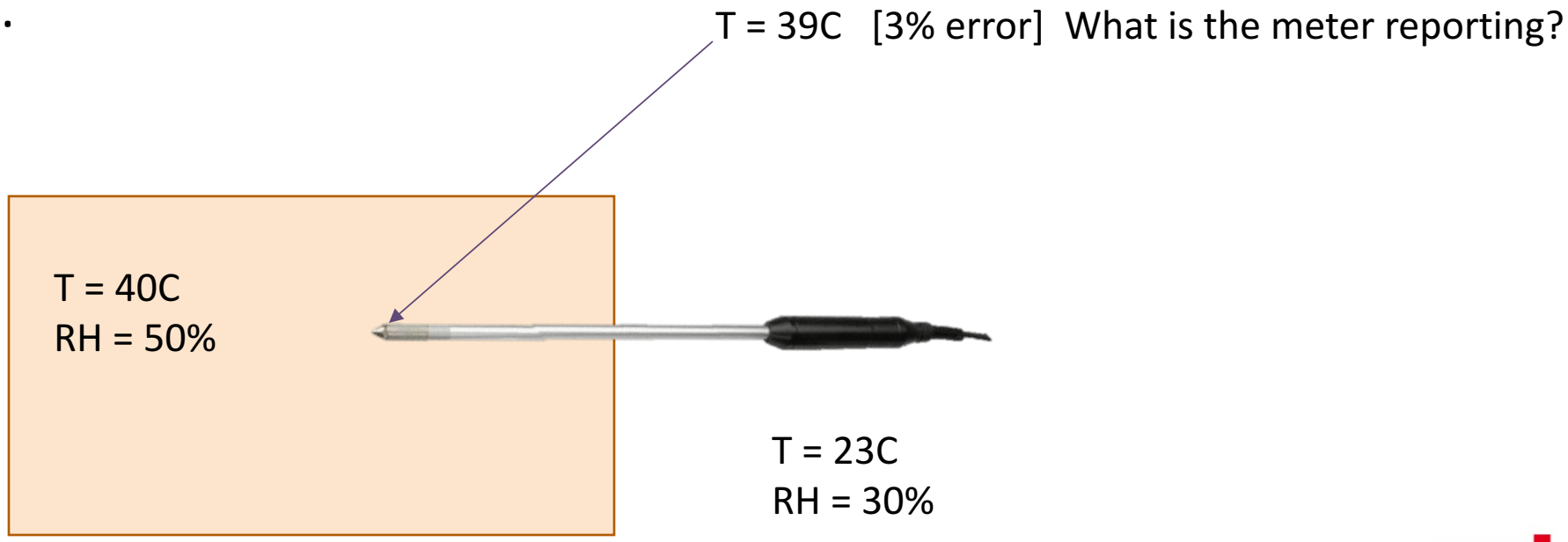
$$RH = p/p_s$$

p=partial pressure

p_s=saturation pressure

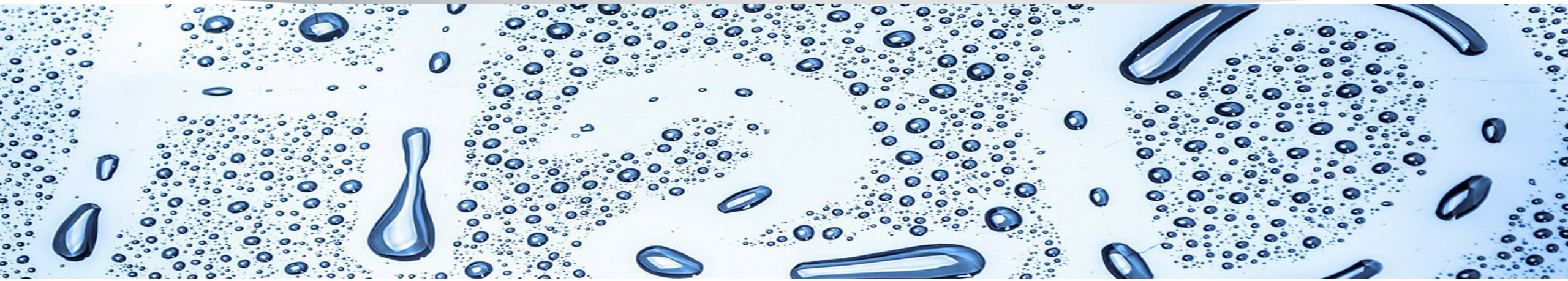
The RH Measurement Challenge

- Non-representative sources of heat or cold
- Non-uniform temperature between measurement device and gas being measured.



Causes of the Temperature Effect

- Standing too close to the point of measurement
- Holding the probe in your hand
- Probe is colder or warmer than the ambient air
- Not waiting long enough for temperature equilibrium
- Cooling fans for equipment
- Direct air flow from HVAC



What about pressure?

Pressure Effects

- RH not affected unless pressure varies in same air stream.
- Dew point is affected by pressure
- Be sure pressure is input to instrument for absolutes (ppm, x)

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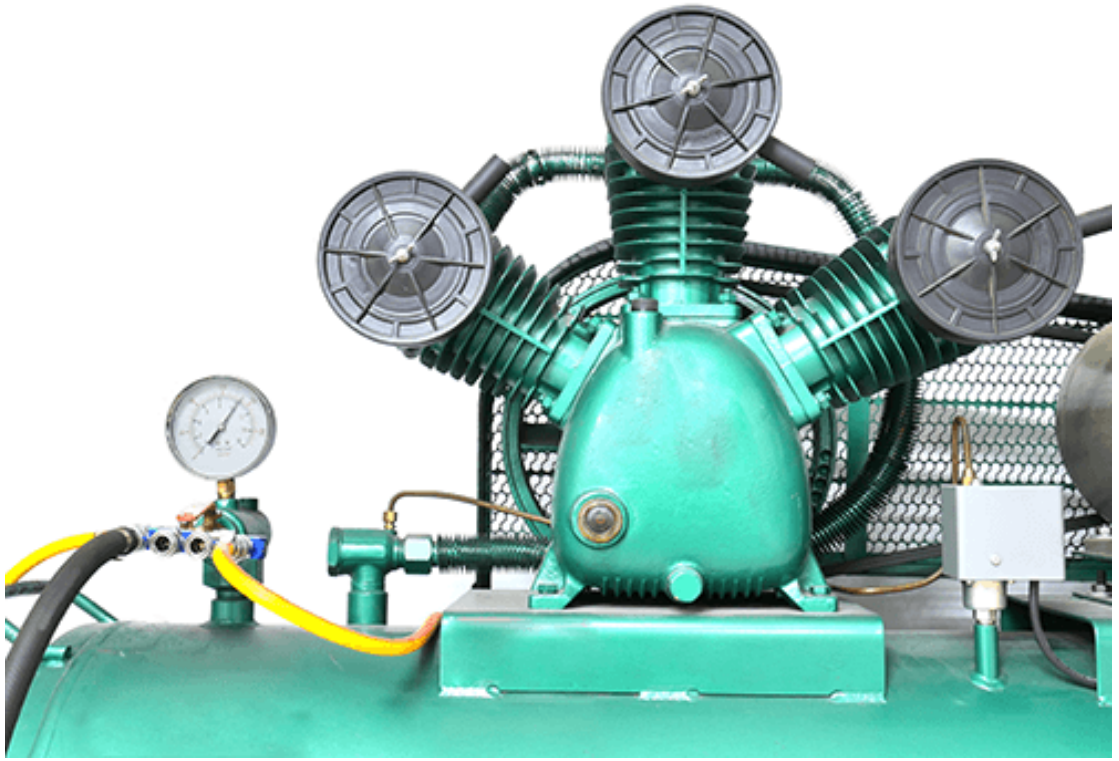
Dew Point and Pressure

- Pressure increases – dew point temperature goes up
- Pressure decreases – dew point temperature goes down
- Be aware of pressure differences between point of interest and point of measure



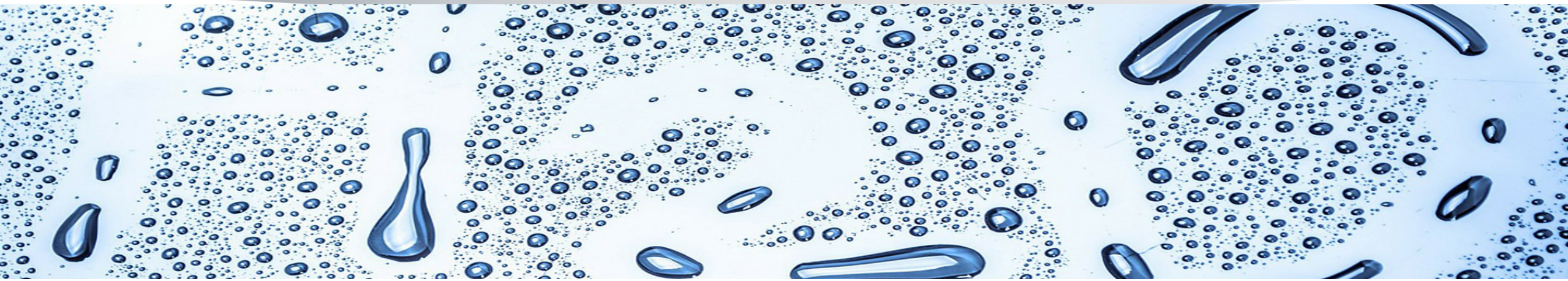
Pressure Effects on Parameters

- Dew point – yes
- Wet bulb temperature – no
- Mixing ratio – no
- PPM – no

Know what your sensor is measuring!

Comments & Questions

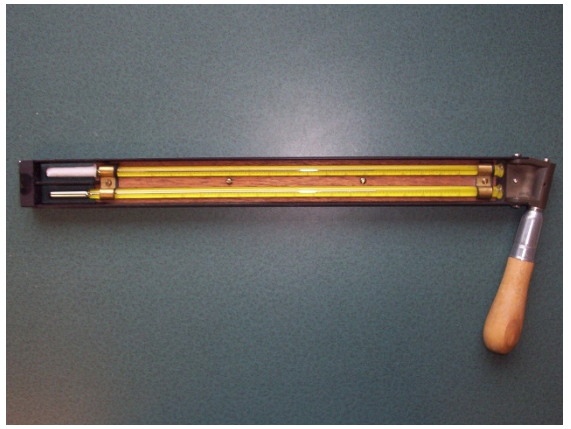
If we don’t get to your question today, we’ll respond via email after the webinar.

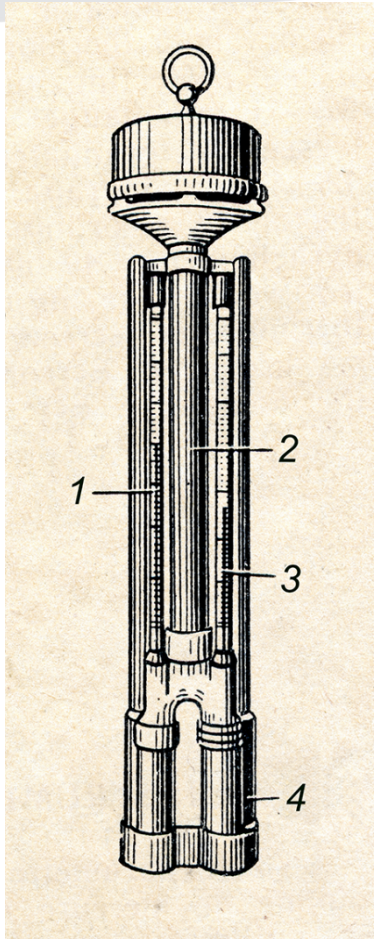


Technology

Psychrometer (wet-bulb)

Parameters	Measures	Calculates
Relative Humidity		X
Dry Bulb Temperature	X	
Wet Bulb Temperature	X	
Dew Point		X
Frost Point		X
Vapor Pressure of Water		X





- requires 2 temperature sensors
- one is covered with wet sock
- depression indicates RH

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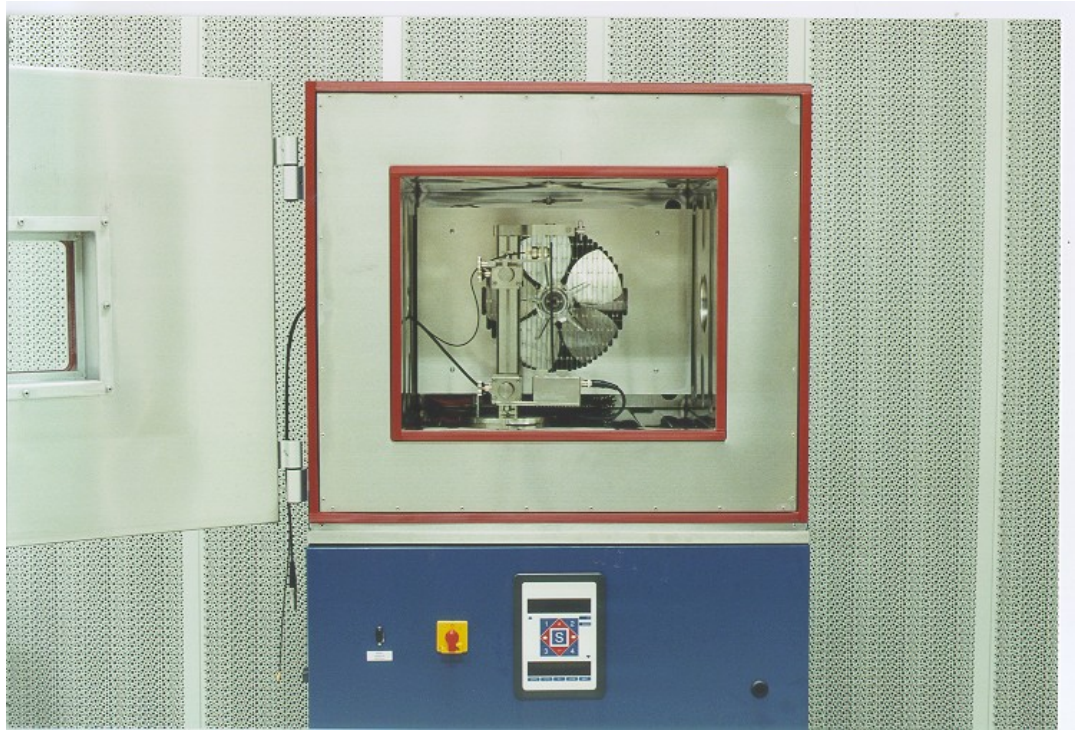
Psychrometer Applications

Environmental Chamber

- Control Sensor

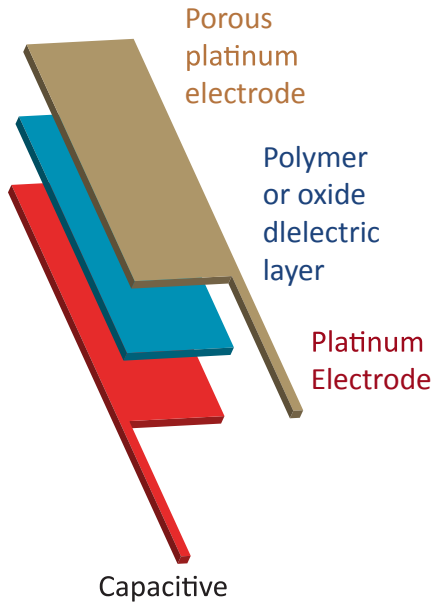
- Considerations
  - Clean water available for wet bulb
  - Constant air flow over sensors
  - Calculated RH
  - Temperature gradients in chamber
  - Does evaporation from wet bulb affect chamber RH



Capacitive Sensors

Parameters	Measures	Calculates
Relative Humidity	X	
Dry Bulb Temperature	X*	
Wet Bulb Temperature		X
Dew Point		X
Frost Point		X
Vapor Pressure of Water		X

Electronic Humidity Sensor



- As the relative humidity increases, the capacitance increases.
- * this is a separate sensor in the probe

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Capacitive Sensor Applications

Process Control/Monitoring Systems/HVAC/Weather

- Monitor/control storage facilities, server rooms, clean rooms, meeting rooms, office or warehouse space

- Considerations
  - Directly measure T and RH
  - Heat sources (lights, HVAC, equipment)
  - Humidity sources (people)

Chilled Mirror or Condensation Hygrometer

Parameters	Measures	Calculates
Relative Humidity		X
Dry Bulb Temperature	X**	
Wet Bulb Temperature		
Dew Point	X	X*
Frost Point	X	
Vapor Pressure of Water		X

- Dew point temperature is determined by the temperature of the mirror when dew or frost forms.

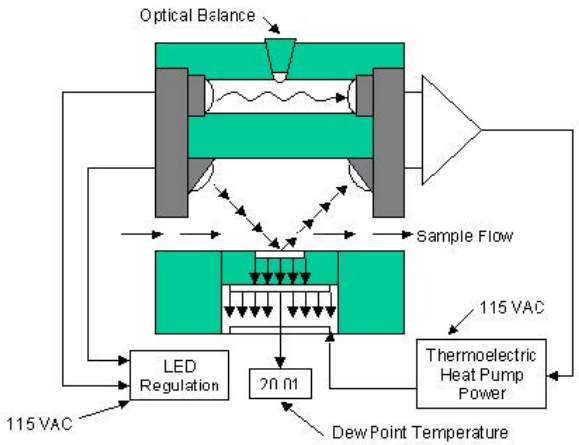

Image source: Thunder Scientific

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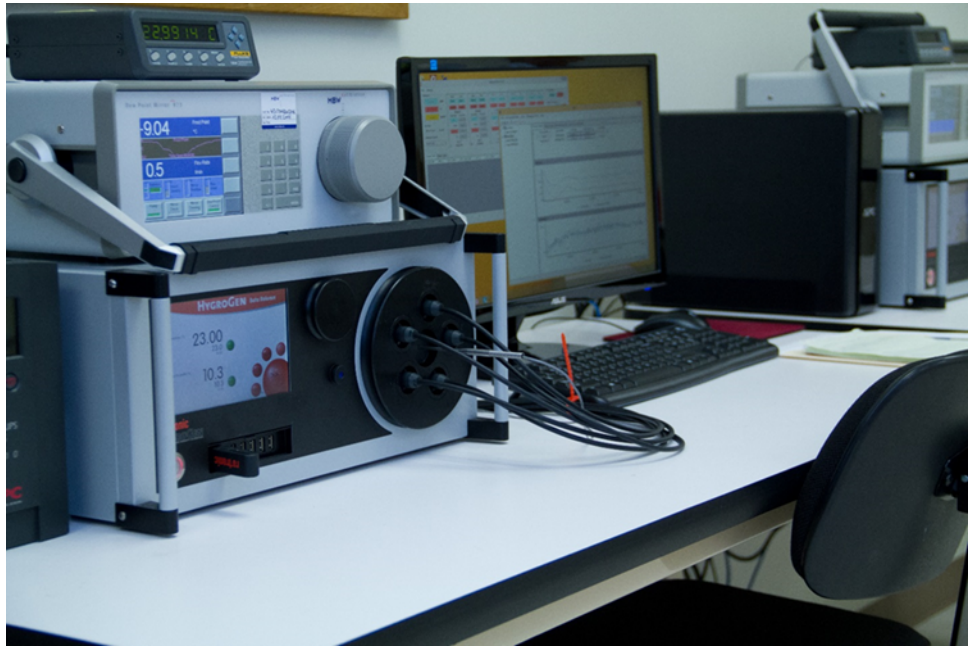
Chilled Mirror Application

Calibration Laboratory

- Reference instrument for RH Calibrations
  - Low uncertainties

- Considerations:
  - RH calculated based on Temperature, Dew/Frost Point, Pressure
  - Temperature, Pressure Gradients
  - Dew Point or Frost Point being measured
  - Condensation in sampling tubes



Metal Oxide

Parameters	Measures	Calculates
Relative Humidity		X
Dry Bulb Temperature	X	
Wet Bulb Temperature		X
Dew Point		X
Frost Point		X
Vapor Pressure of Water	X	

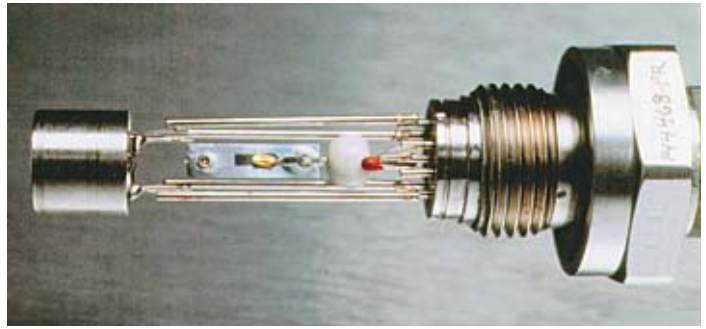


Image source: Sensor Magazine

- Aluminum Oxide (Al_2O_3) most common
- Water vapor adsorbs to oxide
- Gives an absolute measure
- Need pressure and temperature for conversions
- Trace moisture into ppb or -120C

Aluminum Oxide Application

- Very Dry Compressed Air
- Nitrogen

- Considerations:
  - Air should be very dry (-40)
  - Air should be very clean
  - Dryer should be very reliable
  - Can measure as low as -120C dew point

Summary of Takeaways

Takeaways for a Better Measurement

- Knowledge helps avoid poor processes
- Temperature & RH matters
- Pressure considerations
- Avoid temperature inconsistencies & anomalies
- Match technology to your application and requirements
- Know what the sensor is measuring and calculating

Comments & Questions

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

Humidity Academy

- Resources for making a better measurement
  - Psychrometric charts
  - Technical notes
  - Humidity calculator
  - Application notes
  - more

www.rotronic-usa.com/academy

Next Webinar

Calibration of Humidity Instruments

Thursday, June 15th 1:00PM EDT

Post webinar survey

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