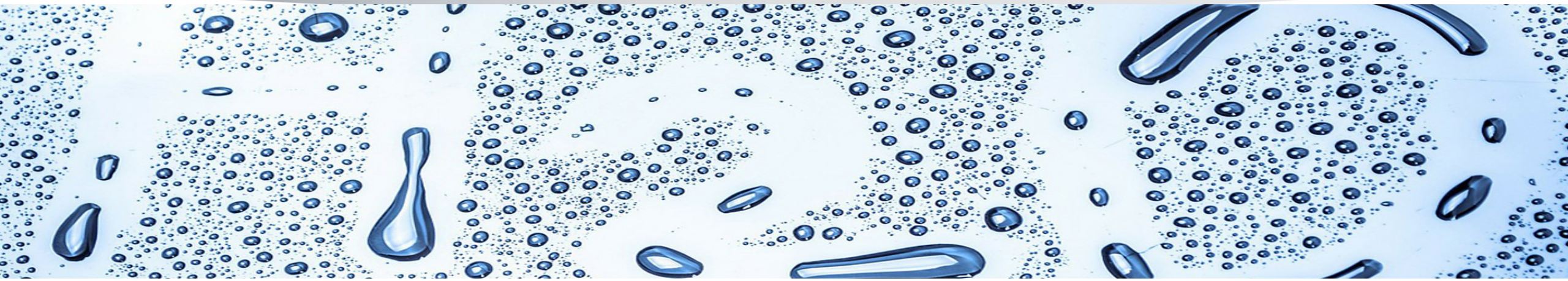


Humidity Theory & Terms

Webinar Presenters & Humidity Experts

Bruce McDuffee

Michael Boetzkes

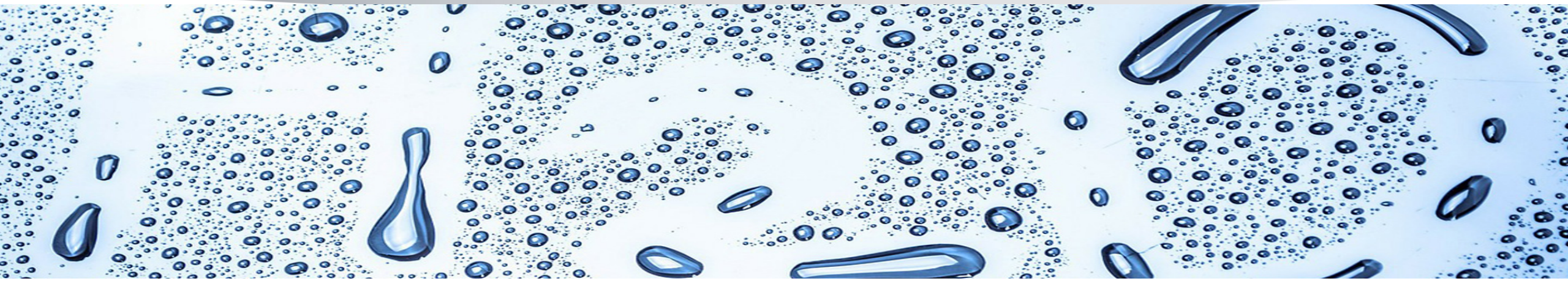
Agenda & Takeaways

Agenda

1. Science of Humidity
2. Temperature effect
3. Common Parameters
4. Better measurement

Takeaways for a Better Measurement

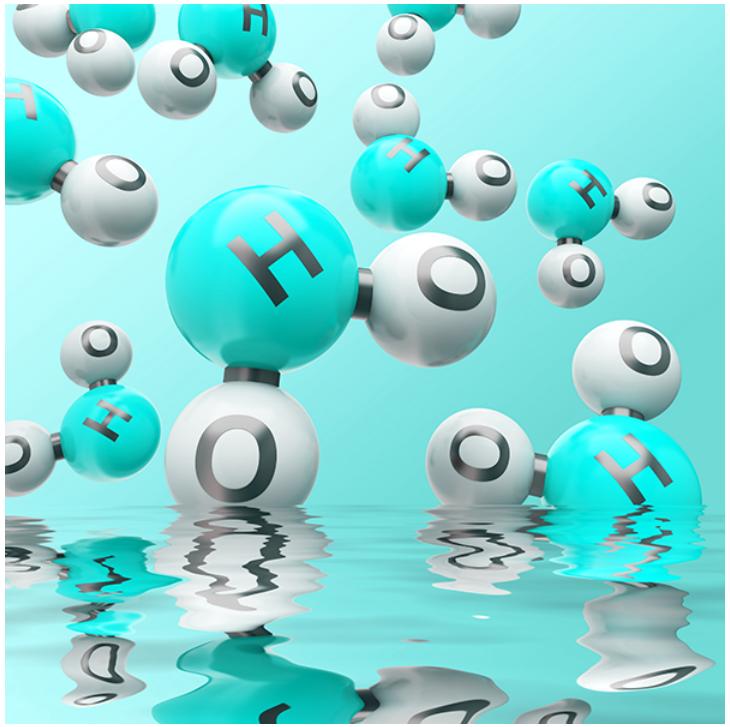
- Knowledge helps avoid poor processes
- Temperature & RH matters
- Avoid temperature inconsistencies
- Avoid introducing anomalous sources of heat or cold



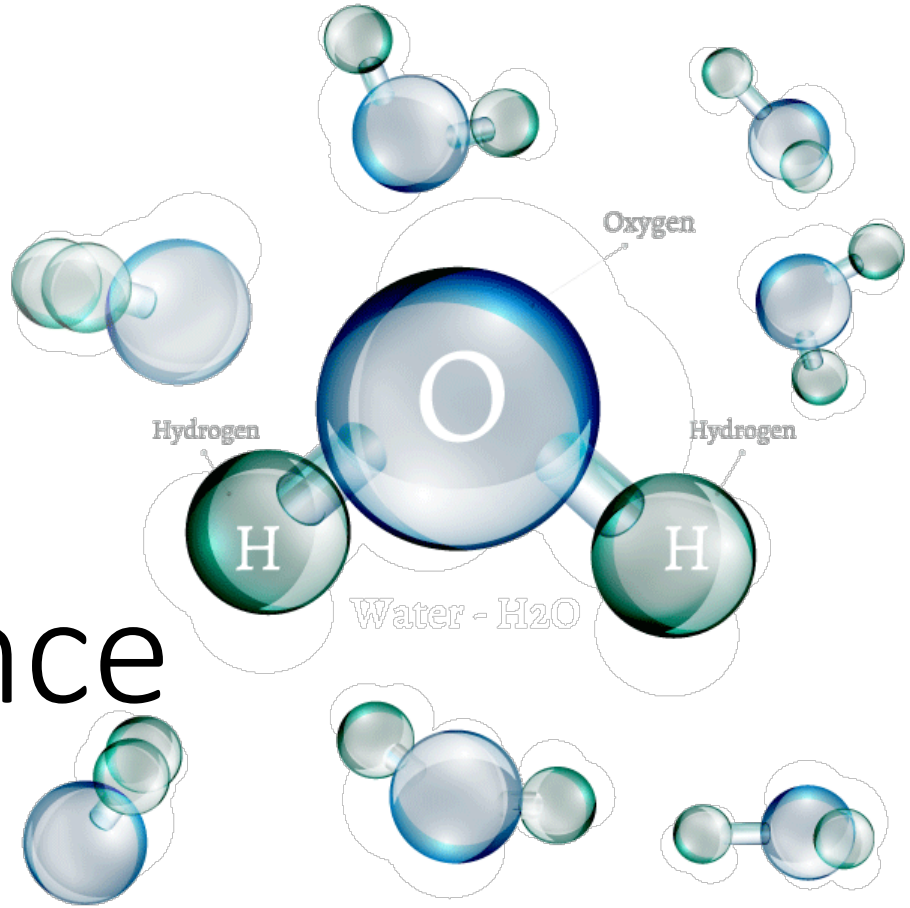
The Science of Humidity

What is humidity?

- The state of water as a gas amongst other gases
- A quantity representing the amount of water vapor as a portion of a greater gas
- Sometimes ‘humidity’ is used interchangeably with ‘relative humidity’



Relative Humidity Science

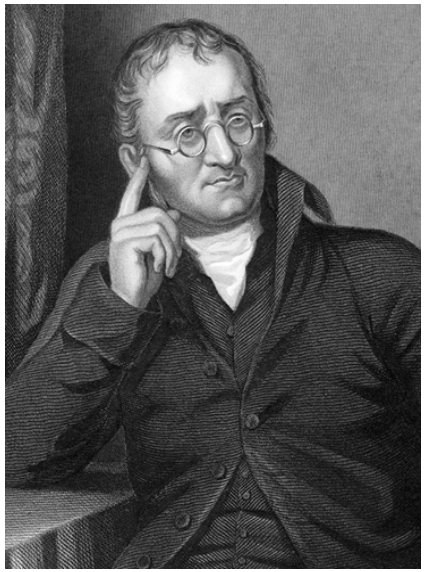


Partial Pressure of Water Vapor (p)

aka vapor pressure

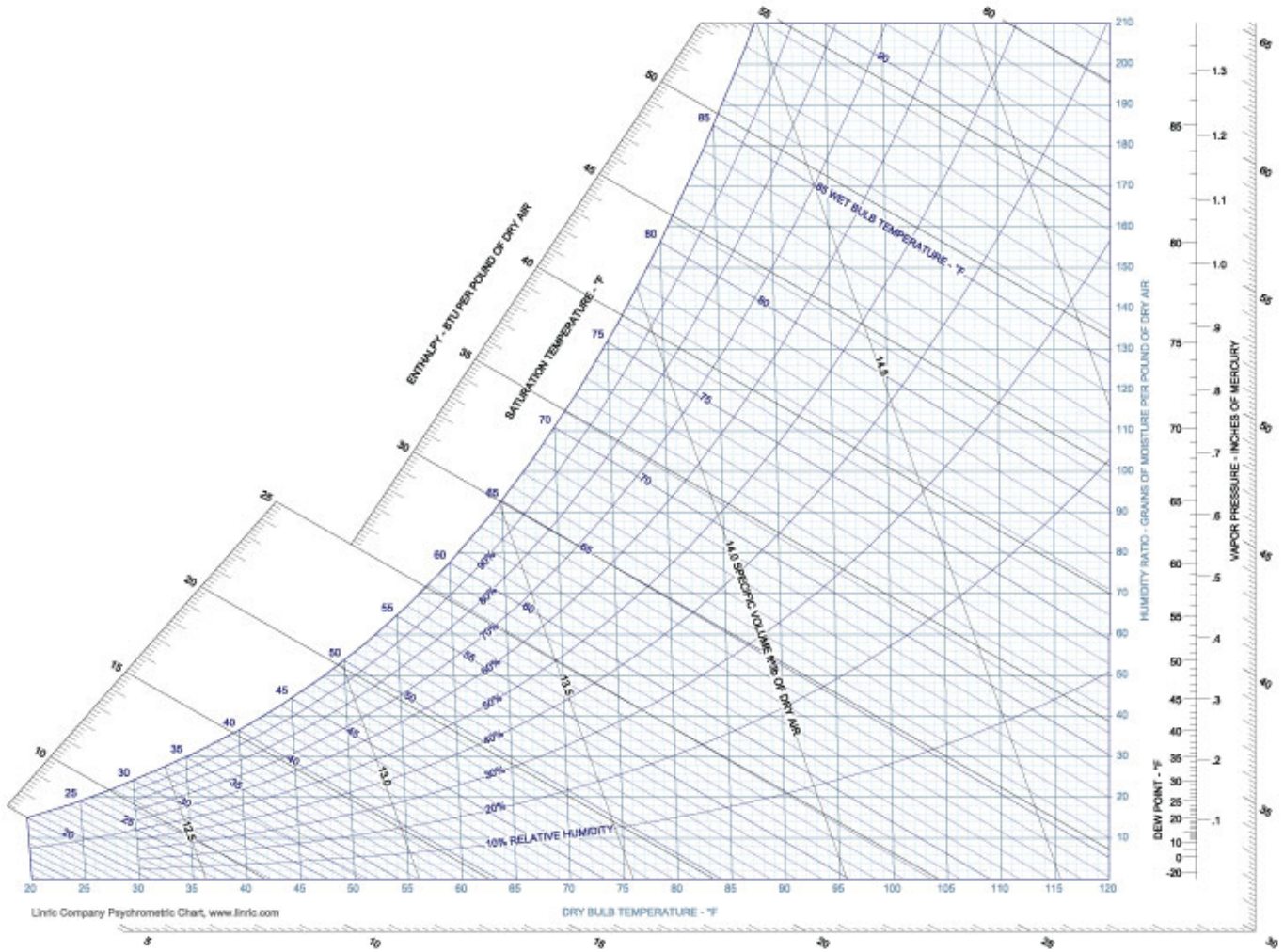
Dalton's Law of Partial Pressures:

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



John Dalton

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



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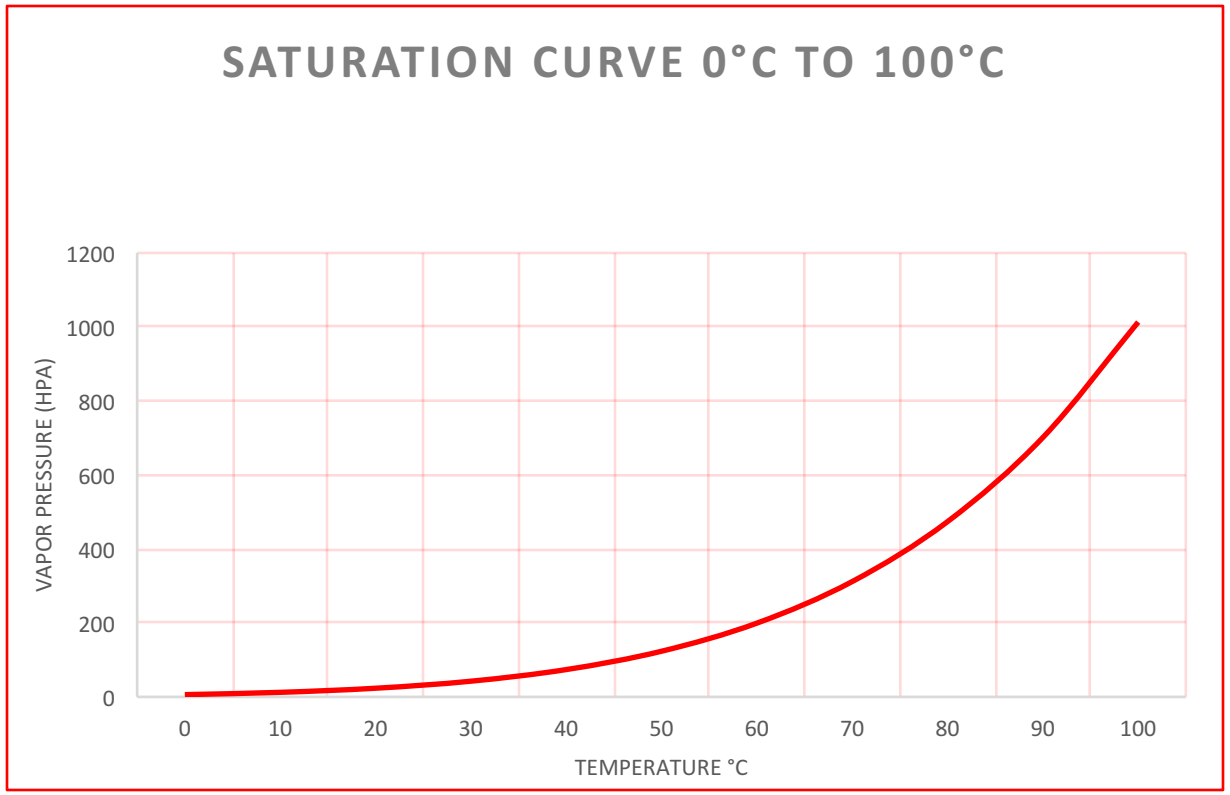
Saturation Vapor Pressure (p_s)



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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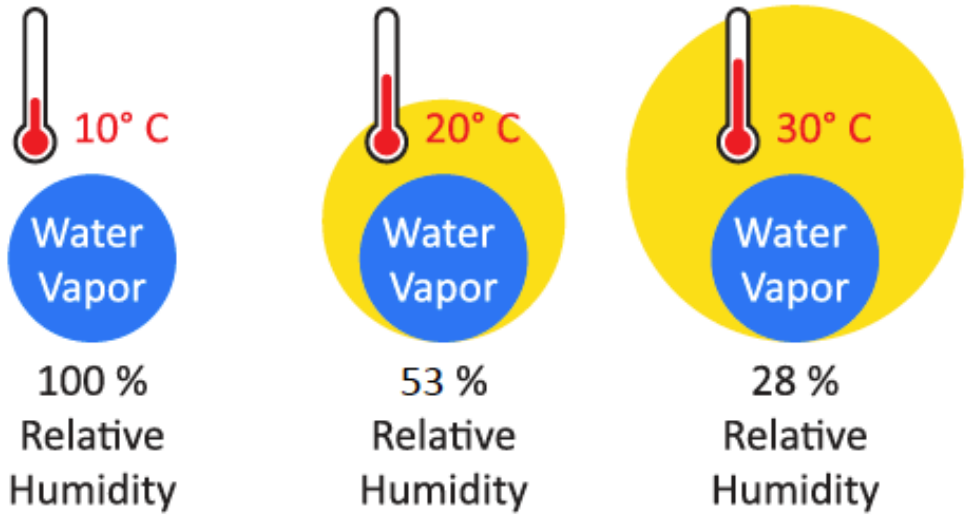
Relative Humidity

$RH = p/p_s$

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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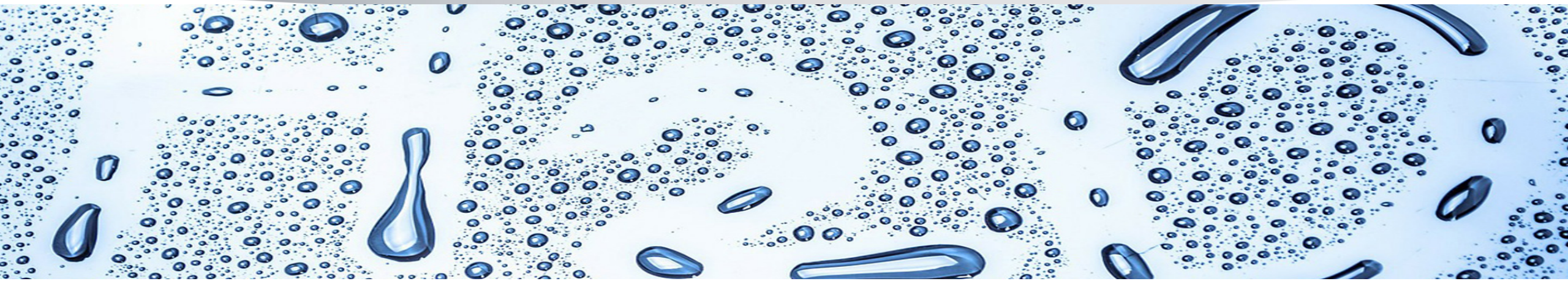
- Quiz – which is not true
  - Saturation vapor pressure does not change with changes in moisture content
  - SVP changes with temperature variations
  - Relative humidity changes with temperature variations
  - Vapor pressure changes with temperature changes
  - Humidity is fun



Temperature Effect on RH

Why is temperature so critical?

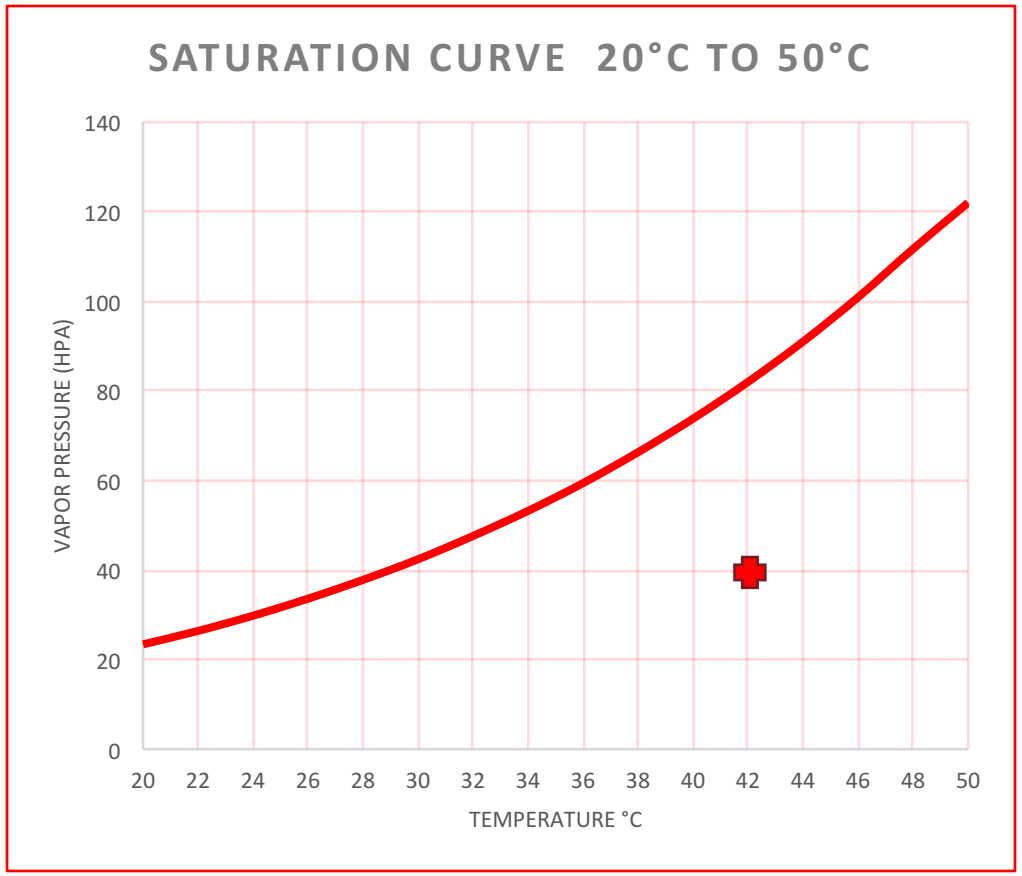
- p (partial pressure) does not change as the temperature changes.
- p_s does change as temperature changes

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

Temperature Effects



T = 42°C
p = 40 hPa
p_s = ?
RH = ?

Increase T = 50°C
p = ?
p_s = ?
RH = ?

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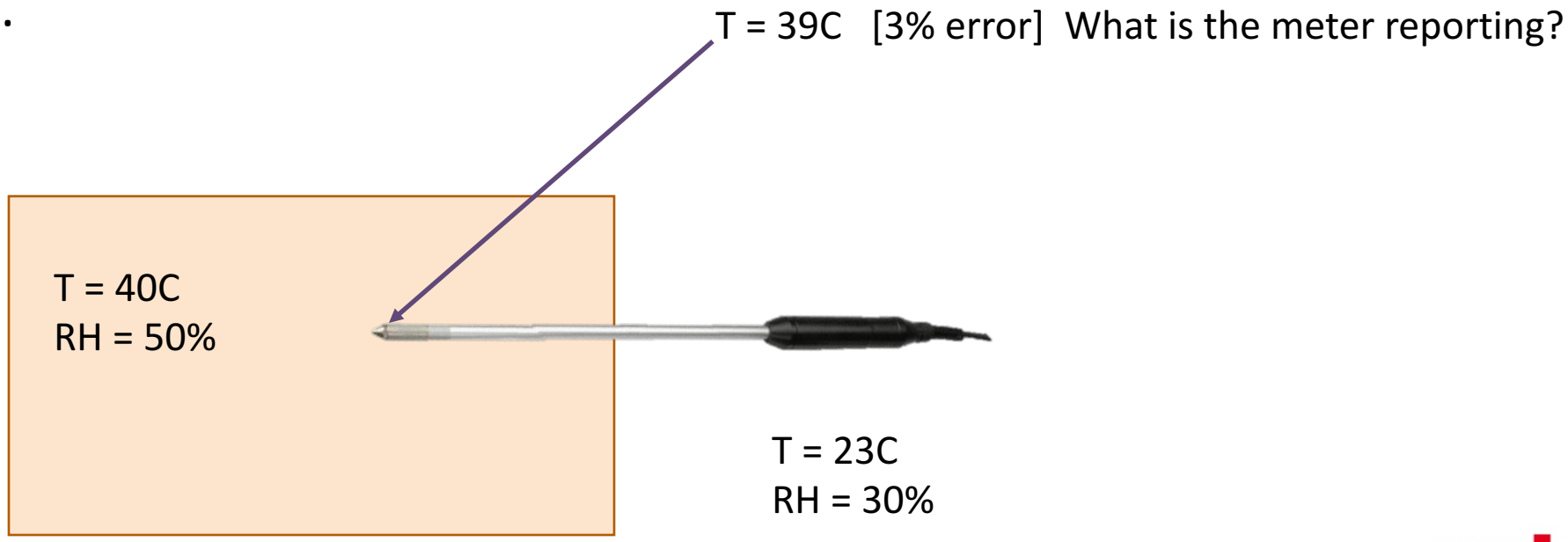
The RH Measurement Challenge

- 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
- Probe is in mixed air temperatures
- Not waiting long enough for temperature equilibrium
- Cooling fans for equipment
- Direct air flow from HVAC

Comments & Questions

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

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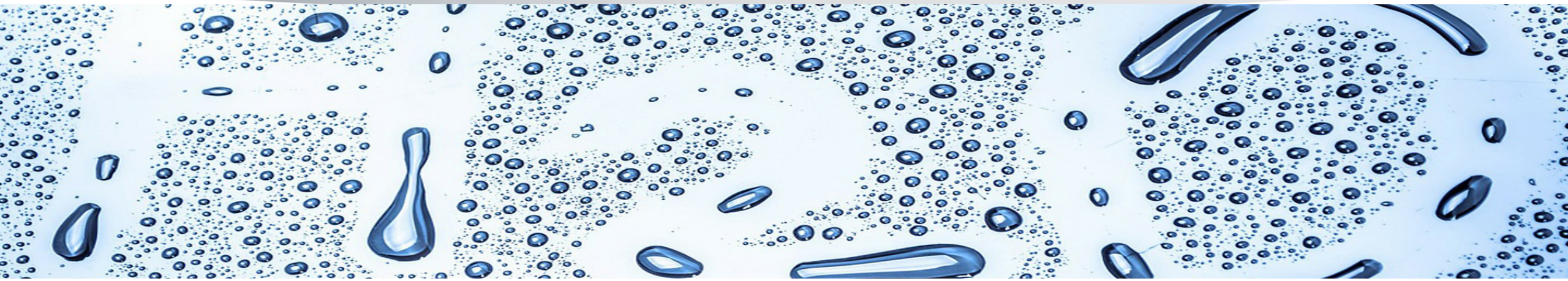


Common Humidity Parameters

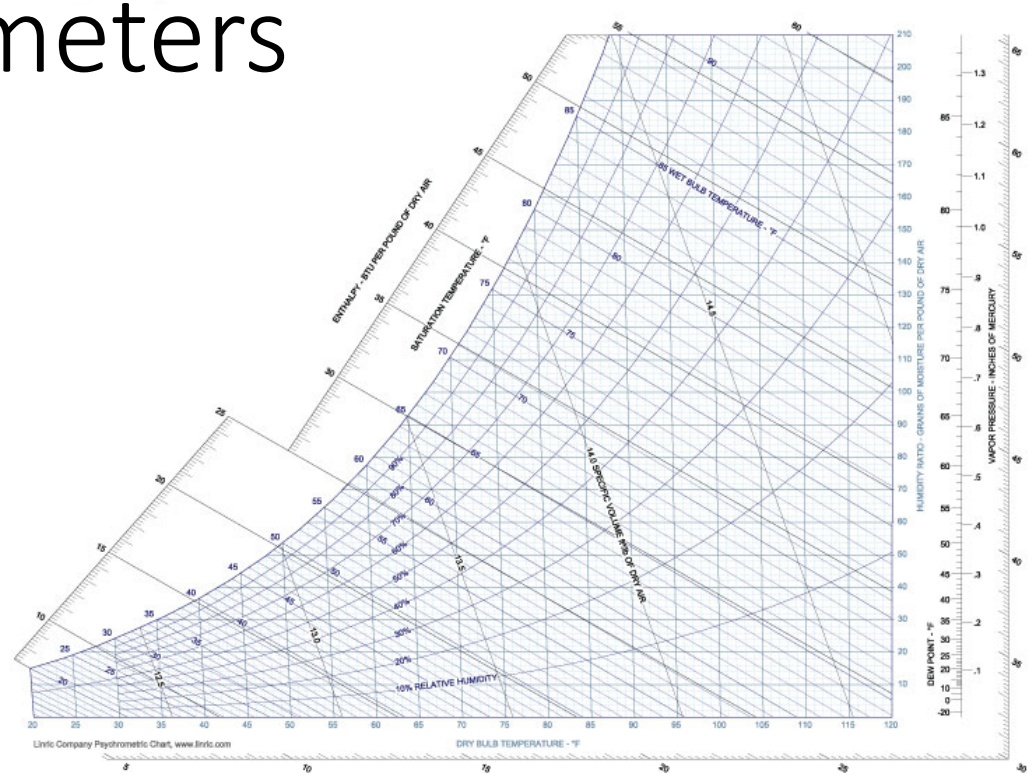
Other Humidity Parameters

Dew/Frost Point

Mixing ratio

ppm_v

Wet bulb



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Definition of Dew Point Temperature

- Dew point temperature is the temperature at which water vapor will begin to condense.
- The temperature at which a moist gas is saturated over a plane surface of pure liquid water.

Takeaway – Dew point temperature does not change as temperature changes.

What about Frost Point?

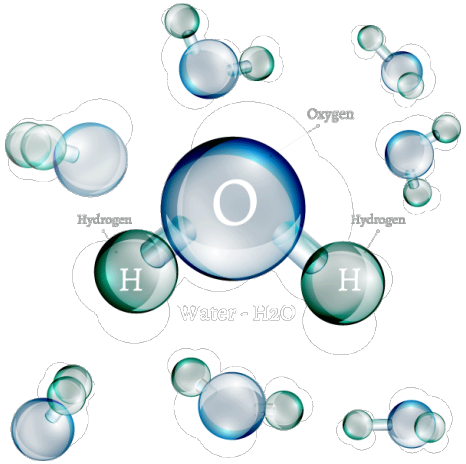
- The temperature at which a moist gas is saturated over a plane surface of pure ice.

Note – Dew point is lower than frost point (by about 4C at -40).

Mixing Ratio or Humidity Ratio

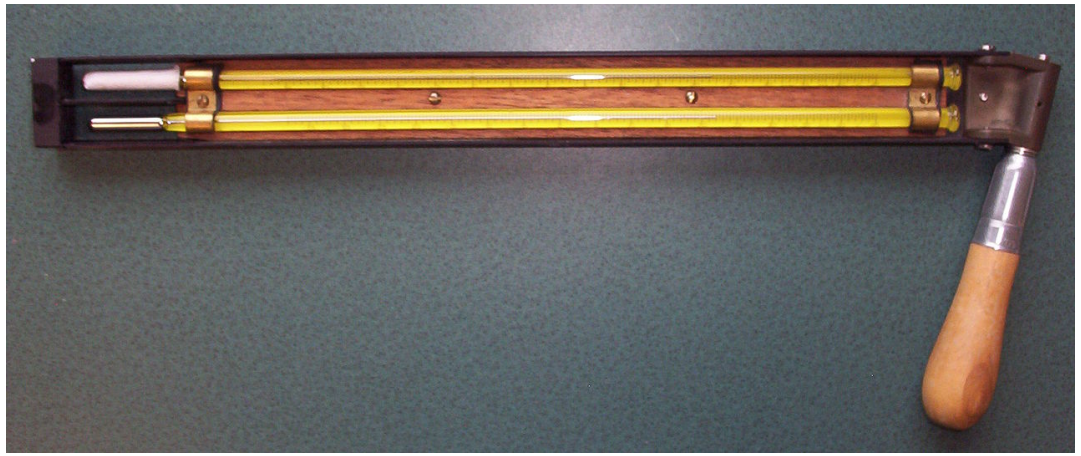
- ratio of the mass of water vapor present to the mass of dry air present.
- this is an absolute measure which will not vary with temperature or pressure variations

Units
grams/kilogram
grains/pound



Wet bulb temperature

- Wet bulb temperature is a measure of the air temperature as water evaporates and is proportional to the relative humidity.
- Wet bulb is measured with a thermometer wrapped in a wet sock.
- Depending on the relative humidity, wet bulb will vary as the rate of evaporation varies.



Sling Psychrometer

Parts per Million (PPM)

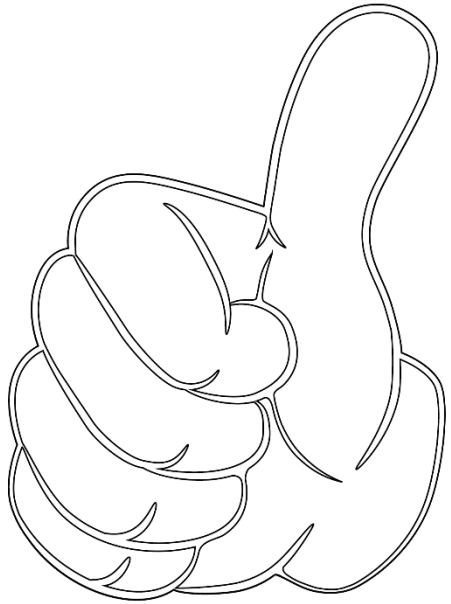
- the volume of water vapor to the total volume of the dry gas
- an absolute measure, not affected by temperature or pressure
- can also be expressed as mass/mass

Takeaways for a Better Measurement

Rules of Thumb Relative Humidity

Takeaway for better measurement:

- As temperature rises, RH decreases.
- As temperature goes lower, RH increases.
- As pressure in a closed container increases, RH increases
- As pressure in a closed container decreases, RH decreases

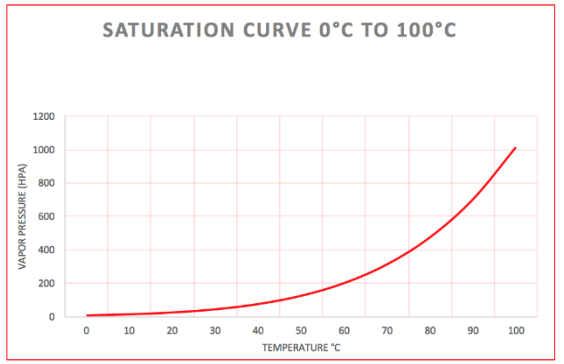


RH Requires Uniform Temperature

- 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



Dew Point

- Dew point changes with pressure.
- Dew point does not change with temperature.
- Ensure pressure is consistent with point of interest.
- Use dew point when condensation is a concern or in very dry gas.

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

rotronic-usa.com (academy)

Next Webinar

Humidity Measurement Technology Pros and Cons

- Thursday, October 27th
- Register at rotronic-usa.com - academy
- We'll cover these humidity measurement technologies;
  - chilled mirror
  - resistive
  - capacitive
  - psychrometer (wet-bulb/dry-bulb)
  - mechanical
  - metal oxide

Thank you!

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