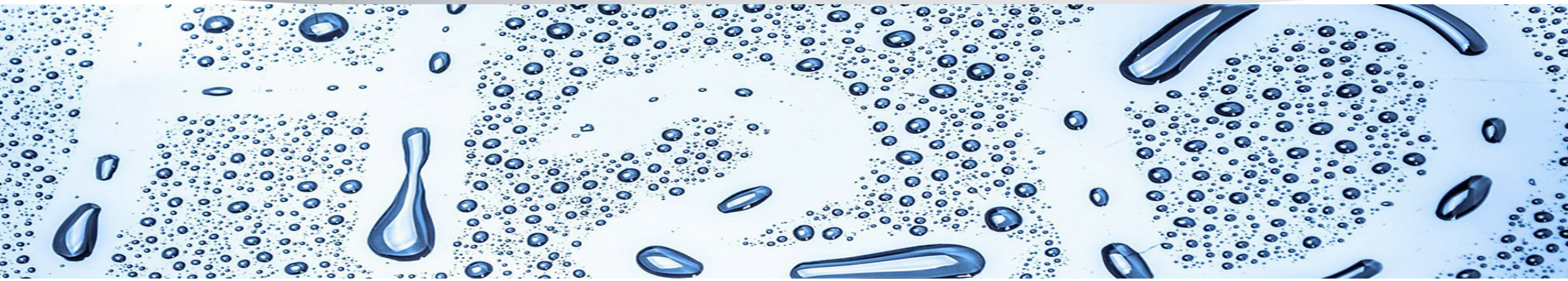

Humidity Theory, Terms, & Tips

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Webinar Presenters & Humidity Experts

Bruce McDuffee

Michael Boetzkes

Agenda & Takeaways

Agenda

1. Common Humidity Parameters & Measurement Tips
2. Deep Dive - RH
3. Temperature effect
4. Pressure effect

Takeaways for a Better Measurement

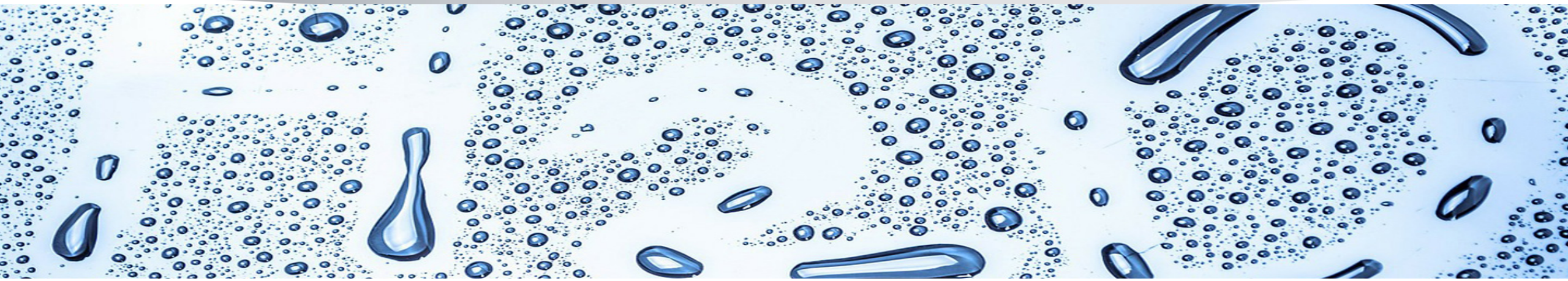
- Learn the fundamentals of humidity theory to support better measurement
- Know the different terms used to define the amount of water vapor present in a moist gas
- Find out which term or parameter is best for your application
- Know how to make a better measurement of humidity by understanding the effects of temperature and pressure

Poll

- What is your industry?
  - Pharmaceutical and Biotech
  - Heavy manufacturing
  - Food production
  - HVAC contractor
  - Consultant
  - Other

Poll

- What is your level of expertise?
  - Expert
  - I know enough to get the job done, but want to learn more
  - This is my first humidity lesson



Common Humidity Parameters

Humidity Terms & Definitions

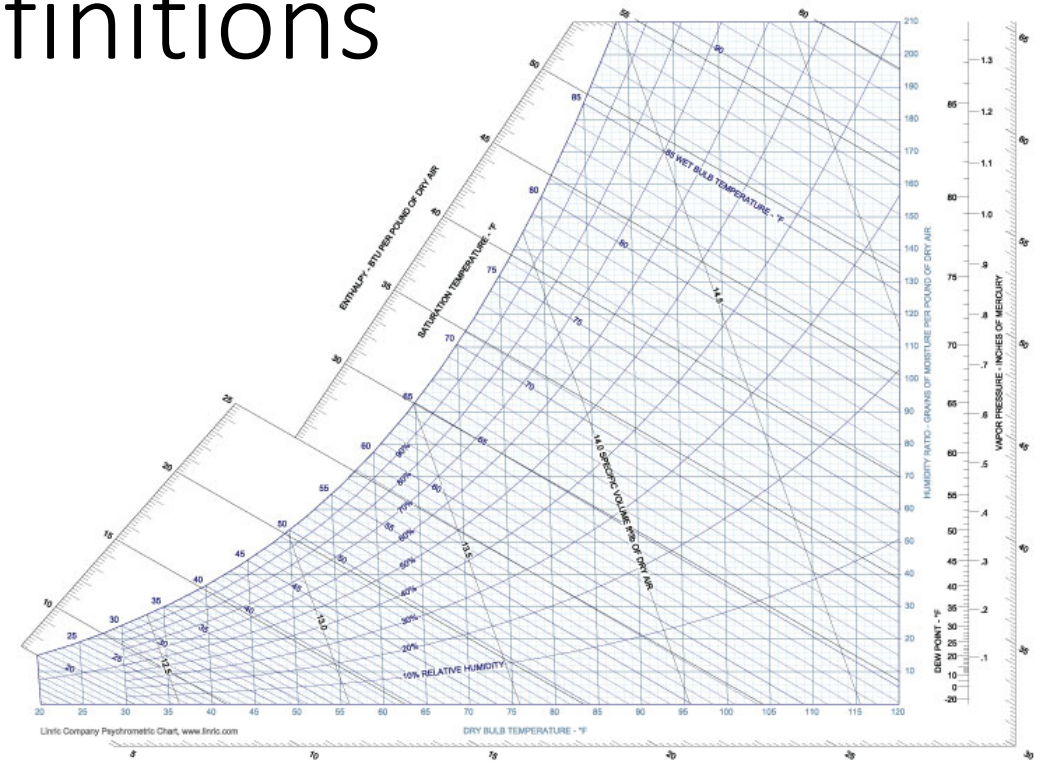
Relative Humidity

Dew/Frost Point

Mixing ratio/Humidity 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.

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

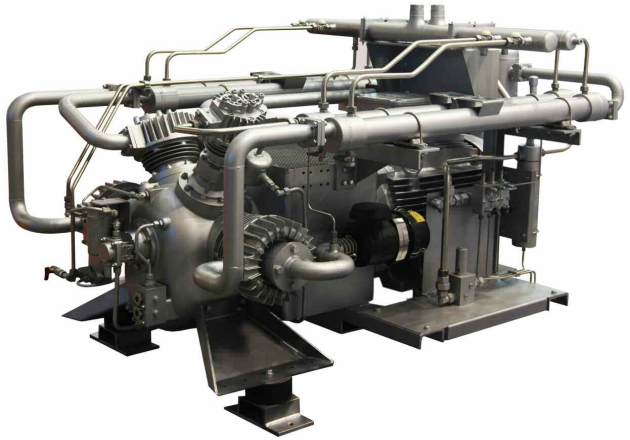
What about Frost Point?

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

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

Dew Point Measurement Tips

Tip – dew point changes with pressure, not with temperature



- Use Dew point when condensation is a concern
- Use Dew point when measuring in very dry conditions
- Use Dew point when pressure varies in a closed system

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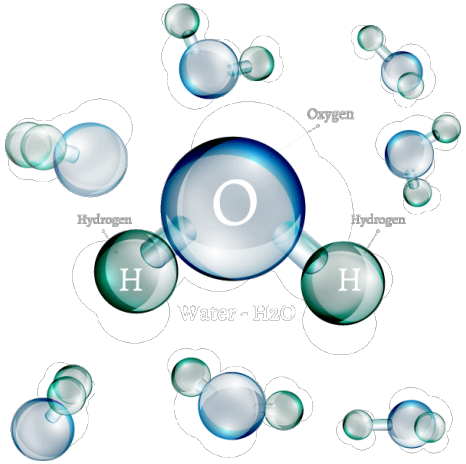
Mixing Ratio or Humidity Ratio

- 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



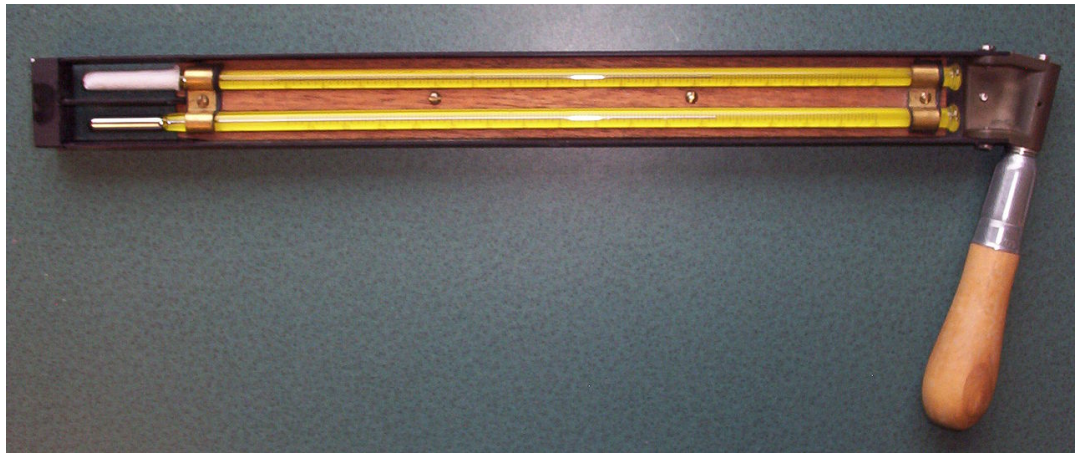
Mixing Ratio Measurement Tip

Tip – mixing ratio is an absolute measure, does not change with temperature or pressure

- Use Mixing Ratio for drying applications like paper or food

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.

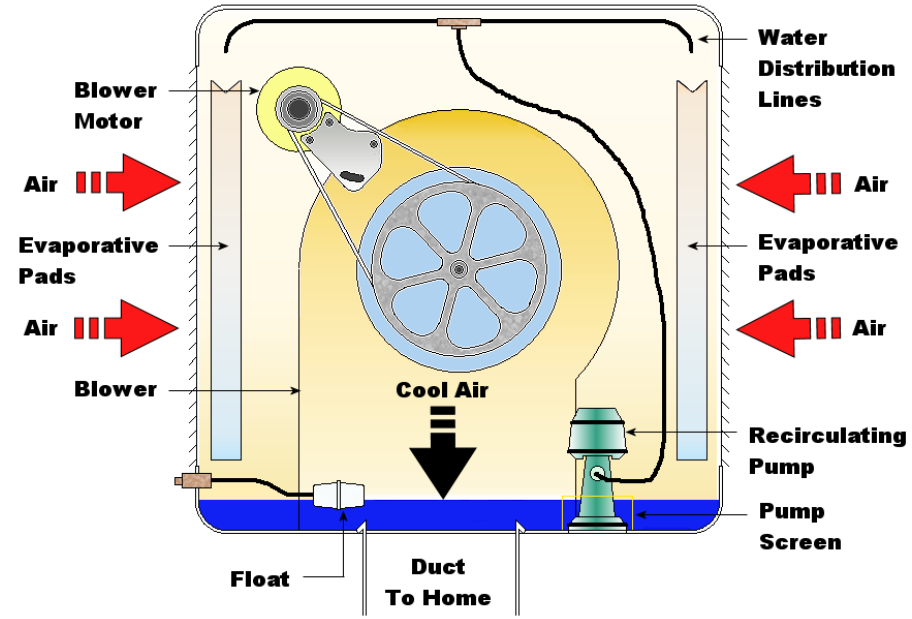


Sling Psychrometer

Wet Bulb Measurement Tip

Tip – many variables and inconsistent operation make this measurement prone to high error

- Use wet bulb when you don't have access to power
- Use wet bulb for evaporative cooling



Parts per Million (PPM_v)

- the volume of water vapor to the total volume of the dry gas
- mass of water vapor per total mass of dry gas
- an absolute measure, not affected by temperature or pressure

$$PPM_v = \frac{P_w}{(P_{tot} - P_w)} 10^6$$

$$PPM_m = \frac{M_w P_w}{M_d (P_{tot} - P_w)} 10^6$$

Mw is molecular mass of water ; Md is molecular mass of dry air

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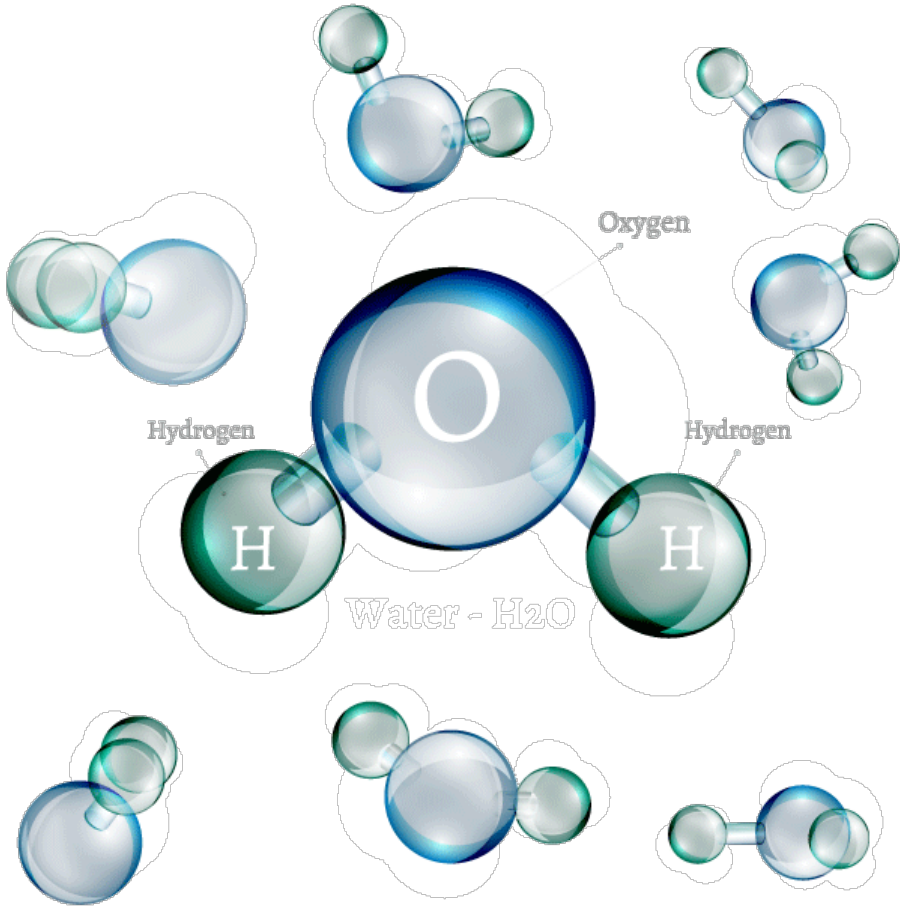
PPM Measurement Tip

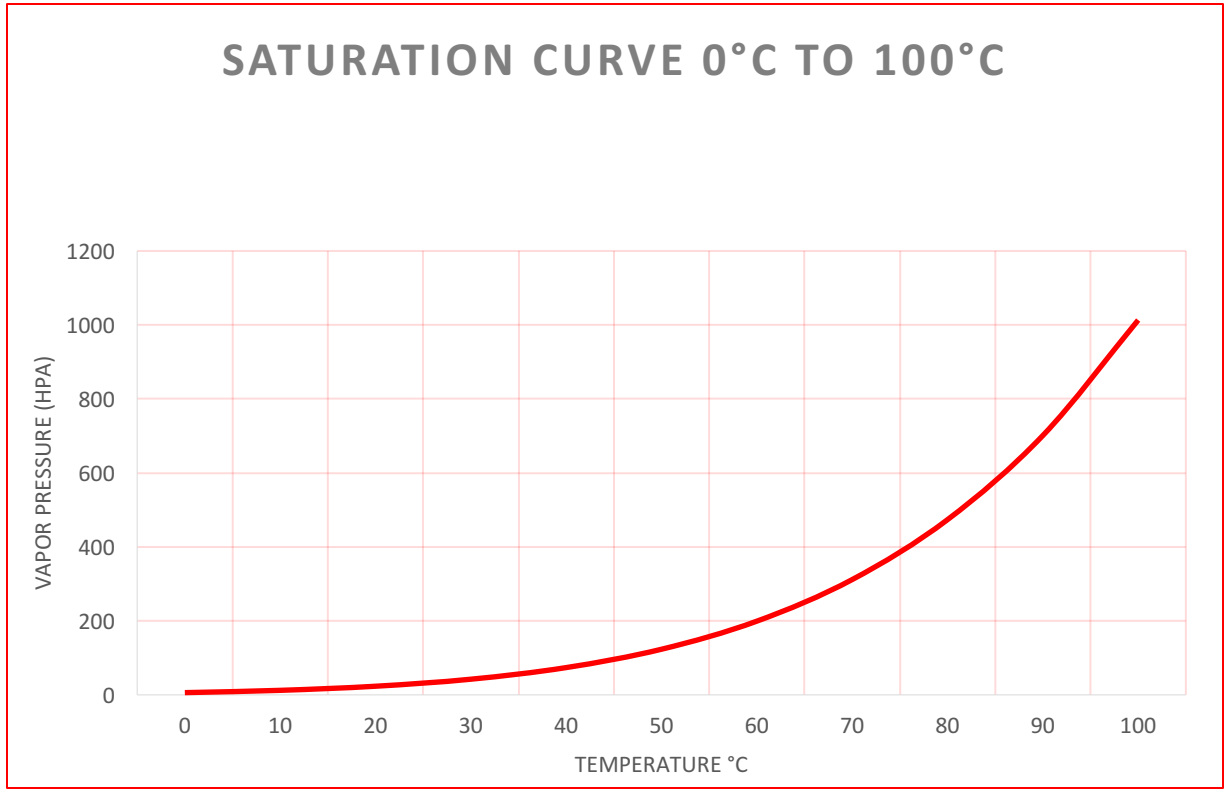
Tip – ppm is calculated from T, RH, Pressure

- Use ppm for trace moisture applications like a glove box
- Use ppm when you need precise measurement of air content like a cleanroom

Relative Humidity



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 – bucket analogy

$$RH = p/p_s$$

p=partial pressure

p_s=saturation pressure

10 gallon bucket
1 gallon of water
RF = 10%

5 gallon bucket
1 gallon of water
RF = 20%

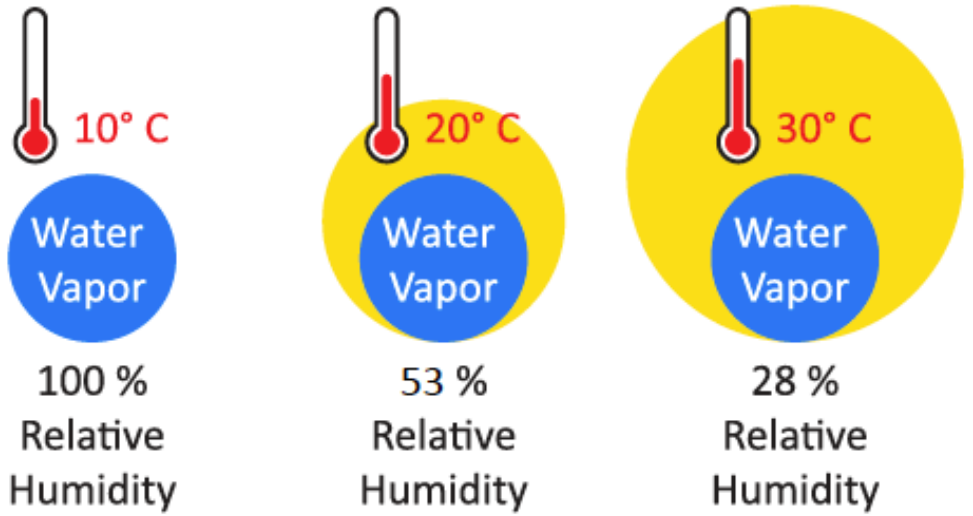
1 gallon bucket
1 gallon of water
RF = 100%

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
  - SVP changes with pressure
  - SVP changes with temperature
  - Relative humidity changes with temperature
  - Partial pressure changes with pressure
  - Humidity is fun

Which parameter do you measure?

- Relative Humidity
- Dew Point
- Frost Point
- Parts per million
- Mixing ratio
- Wet bulb
- Other

Comments & Questions

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

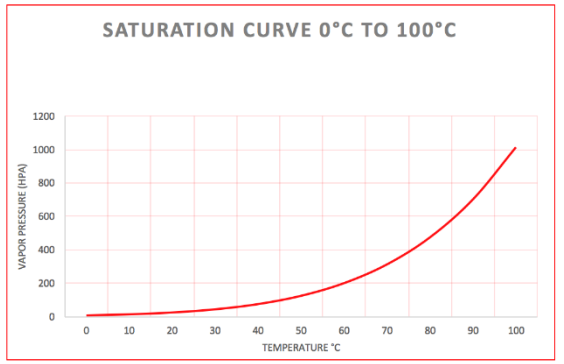
RH Requires Uniform Temperature

- 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%

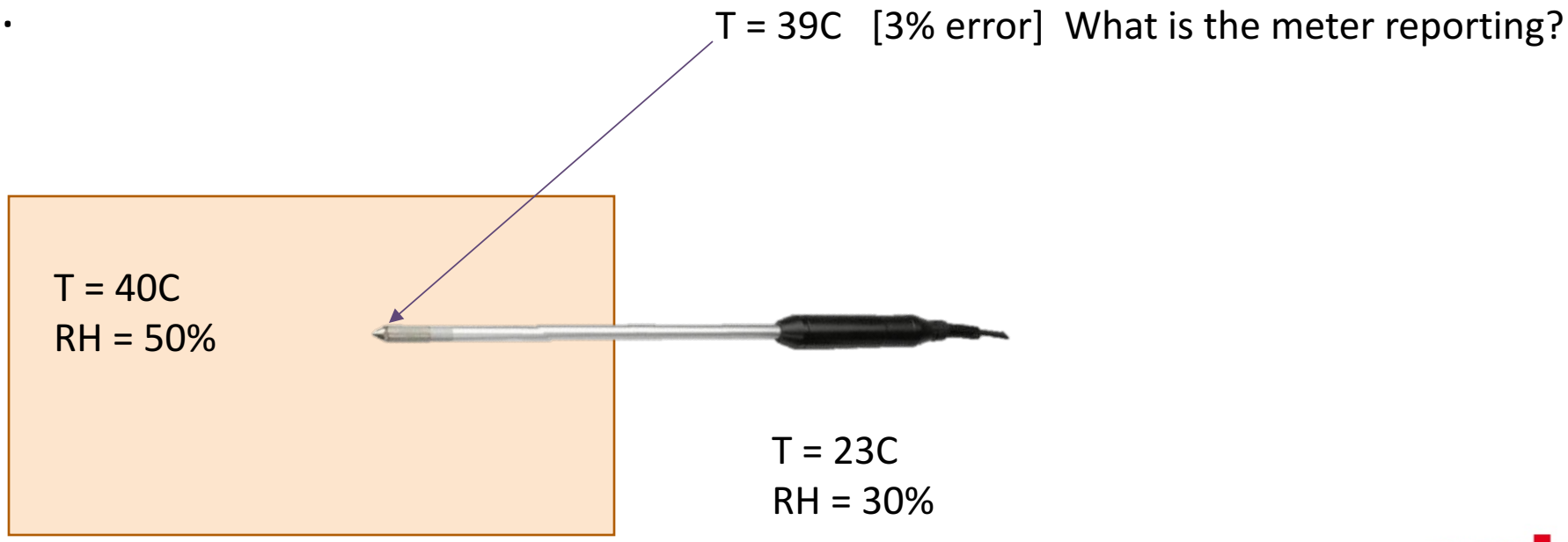
$$RH = p/p_s$$

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

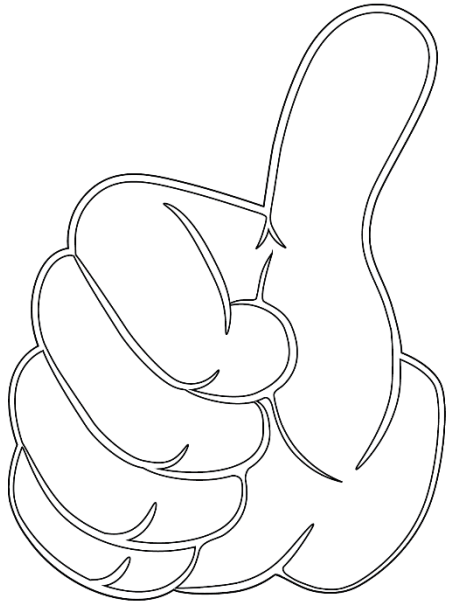
Quiz

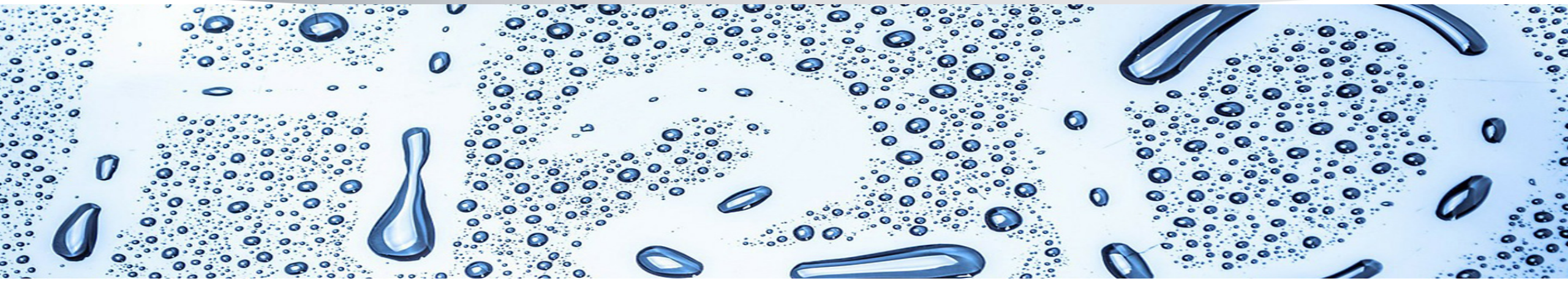
- True or False
  - As temperature increases, relative humidity will increase

Rules of Thumb Relative Humidity

Takeaway for better measurement:

- Temperature must be uniform and representative.
- 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





Pressure Effects?

RH and Pressure (closed container)

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

$$RH = p/p_s$$

p=partial pressure
p_s=saturation pressure

Pressure Effects on Parameters

- Relative humidity - yes
- RH measurement – yes and no
- Dew point – yes
- Wet bulb temperature – yes
- Mixing ratio – no
- PPM – no

Pressure tips for making a better measurement

- Know if your instrument is measuring or calculating.
- Know what the calculation is based on; pressure or ambient, dew or frost.
- Know if pressure differences will change the measurement.

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Quiz

- True or False
  - As pressure decreases Dew Point temperature increases

Summary of Takeaways

Takeaways for a Better Measurement

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Next Webinars

Humidity Measurement Technology Pros & Cons

Thursday, December 21, 1:00PM EST

Register at rotronic-usa.com/webinars

How to Choose a Best-fit Humidity Instrument

Thursday, January 18, 1:00PM EST

Register at rotronic-usa.com/webinars

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