



Relative Humidity: Theory, definitions and technologies

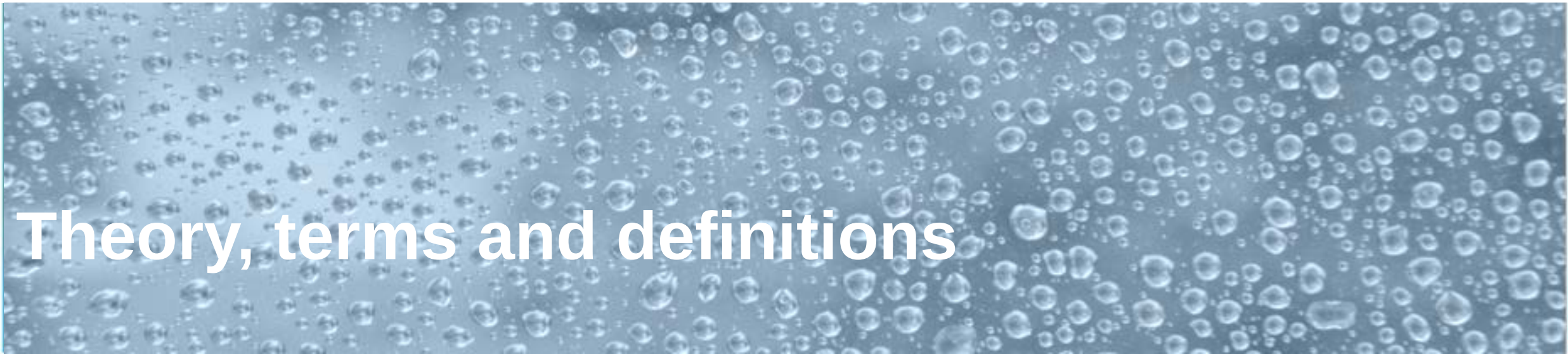
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Content

- Theory, terms and definitions
 - Vapor pressure, saturation vapor pressure, relative humidity, dew point temperature, frost point temperature
- Measurement technologies
- Choosing a correct instrument

How does humidity affect your day?





Theory, terms and definitions

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Concepts

- Definition of humidity
- Vapor pressure, partial pressure
- Evaporation, condensation, equilibrium
- Saturation vapor pressure
- Relative humidity
- Dew point temperature

What is humidity

- Humidity is in gas phase
- Moisture - wetness of the solid material



If you can see it, it is not humidity

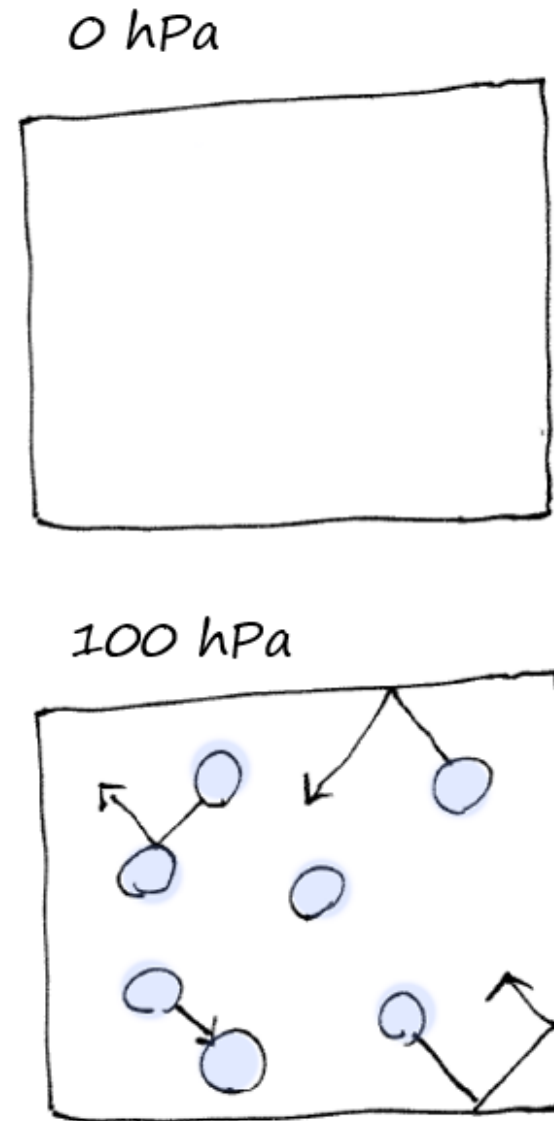
The water molecule



- Polarity – uneven distribution of electrical charge, causing attraction between molecules

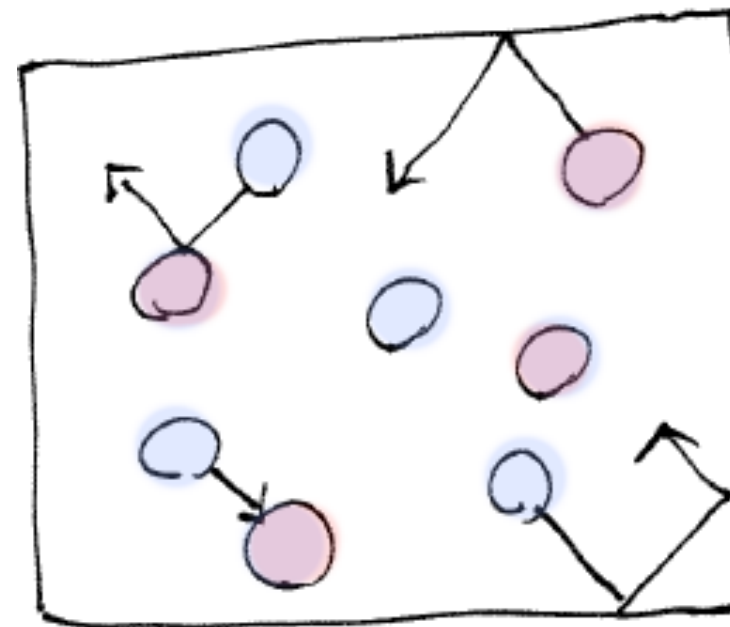
Vapor pressure

- Molecules in gas phase are in constant random motion
- This motion exerts **pressure**
 - The more molecules, higher the vapor pressure
- The energy of the molecules depends not only on the amount, but also **temperature**



Partial pressure of water

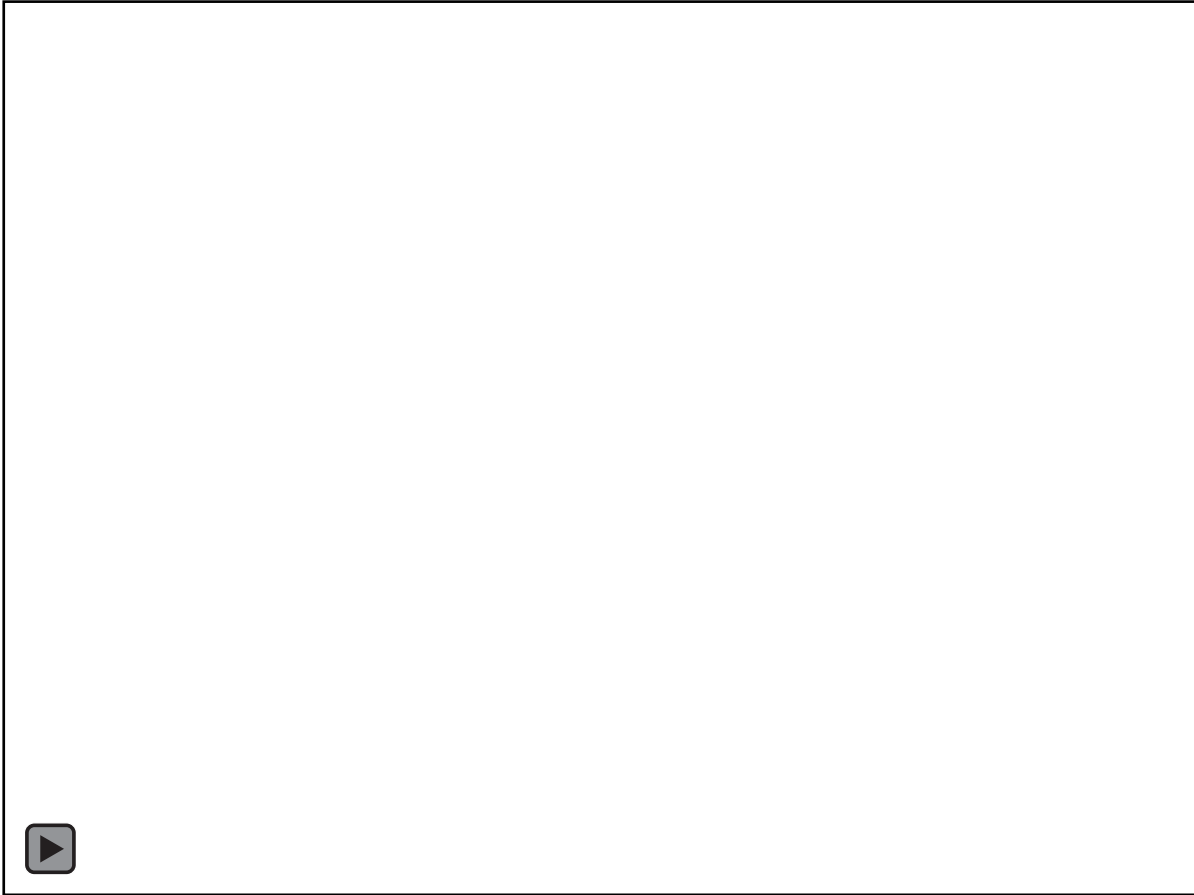
- The total pressure is the sum of the partial pressures of the components in the gas (Dalton's law)
- The partial pressure exerted by water vapor is called the vapor pressure P_w



500 hPa water
500 hPa Air
= 1000 hPa total

$$P_{\text{tot}} = P_1 + P_2 + P_3 \dots$$
$$= P_{\text{air}} + P_{\text{water}}$$

Example: Water in a Closed Container

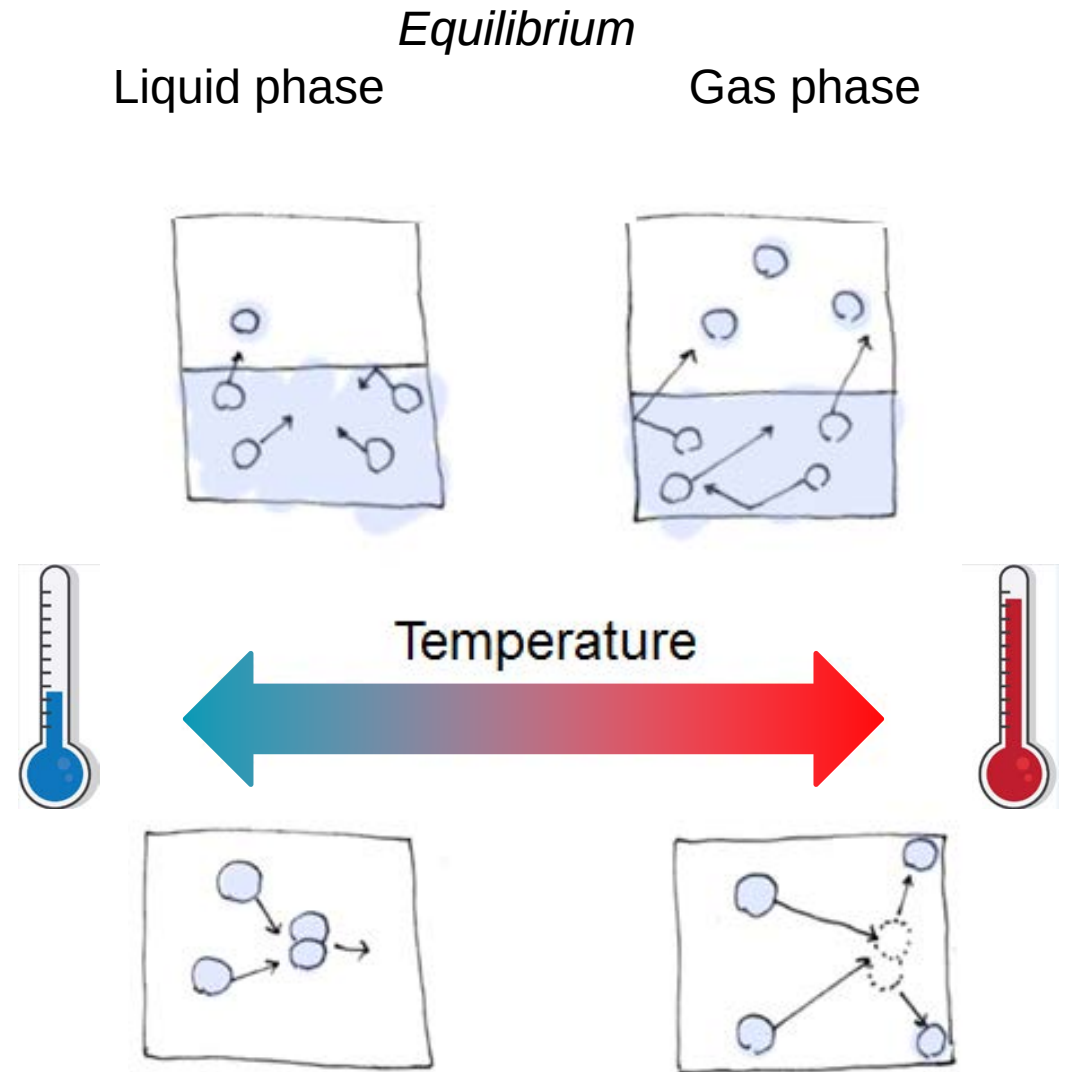


- **Evaporation:** As a result of the random movement of molecules, some molecules have enough energy to escape through the water film
- **Condensation:** As a result of random movement of molecules, some move so slow they get trapped back in water.
- **Equilibrium:** With time, rate of evaporation equals rate of condensation

The Effect of Temperature



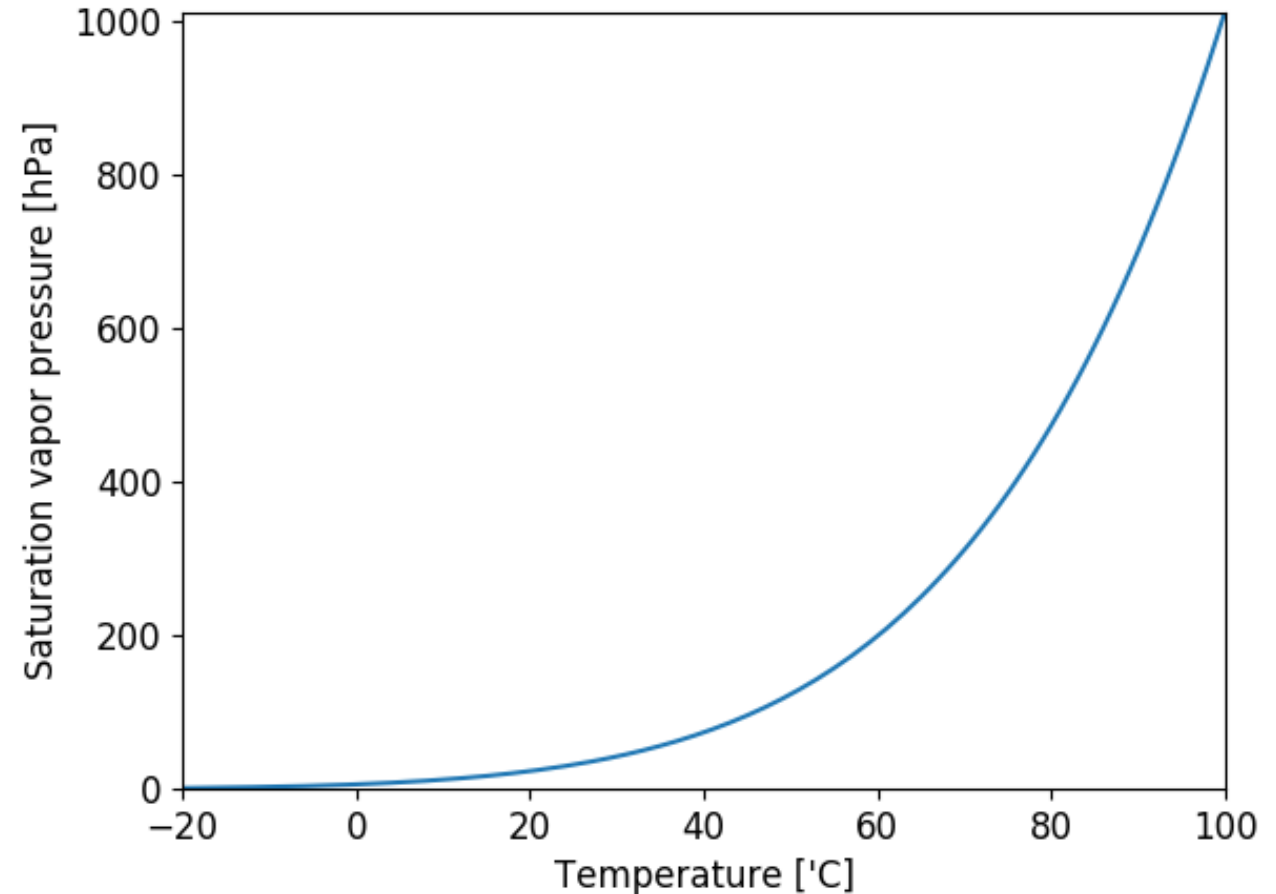
Notice the impact of **temperature** on equilibrium vapor pressure!



Saturation vapor pressure

- The equilibrium of water vapor in a closed container is the **saturation vapor pressure** in that particular temperature
 - Condensation rate equals evaporation rate
 - Air cannot hold any more water vapor

Saturation vapor pressure is highly temperature dependent



Relative Humidity

*The proportion of **water vapor pressure** (P_w) to the maximum vapor pressure in the given temperature [$P_{ws}(t)$]*



$$\%RH = \frac{\text{Vapor pressure}}{\text{Saturation vapor pressure in the particular temperature}}$$

Example

- Let's assume we have vapor pressure of 100 hPa

..And temperature 100 °C

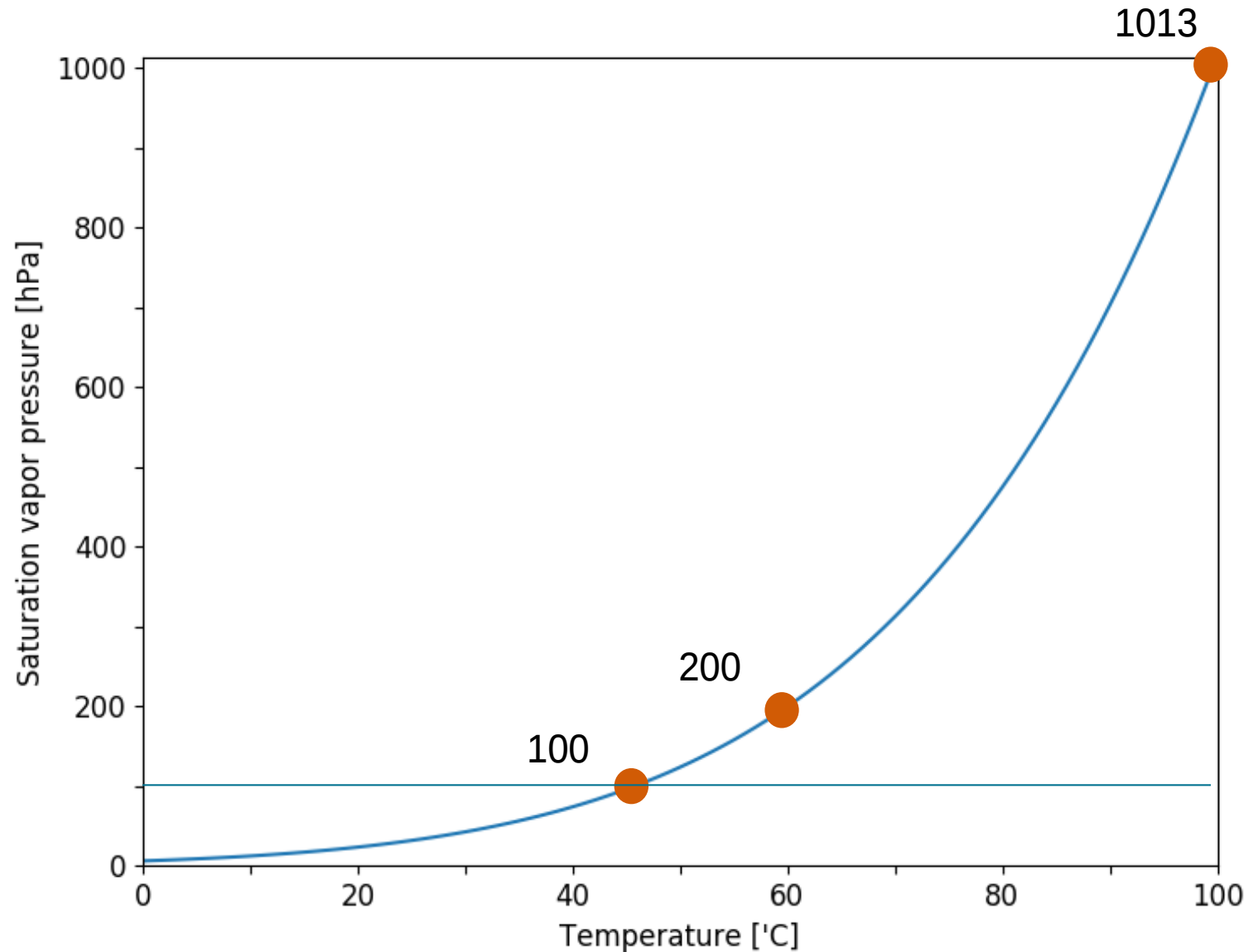
$$RH = \frac{100}{1013} = \sim 10 \%$$

..And temperature 60 °C

$$RH = \frac{100}{200} = \sim 50 \%$$

..And temperature 45,8 °C

$$RH = \frac{100}{100} = \sim 100 \%$$



Dew Point Temperature

- Dew point temperature is the temperature, where the vapor pressure would equal to saturation vapor pressure
- This is the temperature, where the given humidity level condenses by effect of temperature
- Proportional to amount of water vapor



Impact of pressure

- Let's assume a closed container with water vapor pressure of 10 hPa (dew point temperature of 7 °C) and total pressure of 1 bar
- When we compress the gas isothermally to 4 bars, the vapor pressure increases linearly
- As a result, the vapor pressure would be 40 hPa and corresponding dew point temperature 28 °C. Under room temperature, condensation would occur



Compressing until vapor pressure reaches saturation:
"squeezing" water out in compression dryers

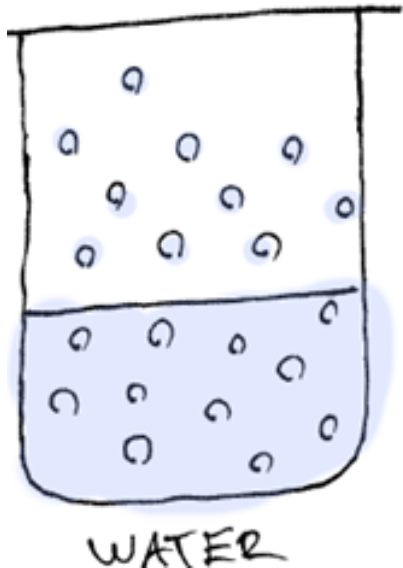
Frost Point Temperature

- Frost point temperature is the temperature, where the water vapor condenses directly to solid ice, or frost
- Relevant in dry conditions where saturation temperatures are well below freezing point

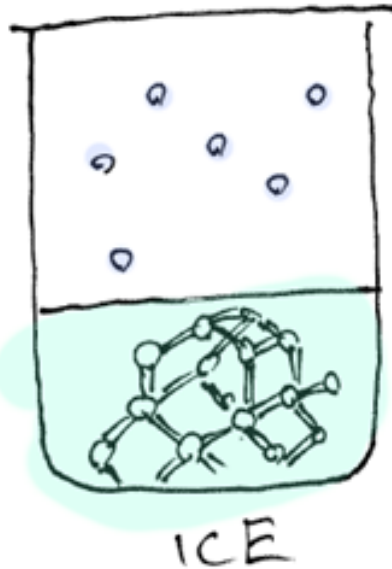


Frost point temperature

$P_w = 5.3 \text{ hPa}$



$P_w = 5.1 \text{ hPa}$



- Temperature: $-2 \text{ }^{\circ}\text{C}$
- Saturation vapor pressure over ice is slightly lower than over supercooled water

Key takeaways

- Relative humidity by definition depends on temperature
- Dew point temperature only depends on amount of water vapor
- When gas or volume becomes saturated, relative humidity equals 100 % and condensation happens

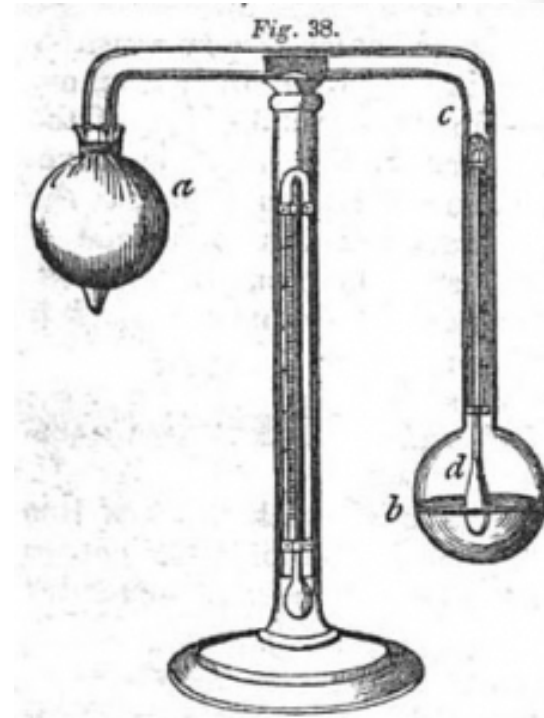
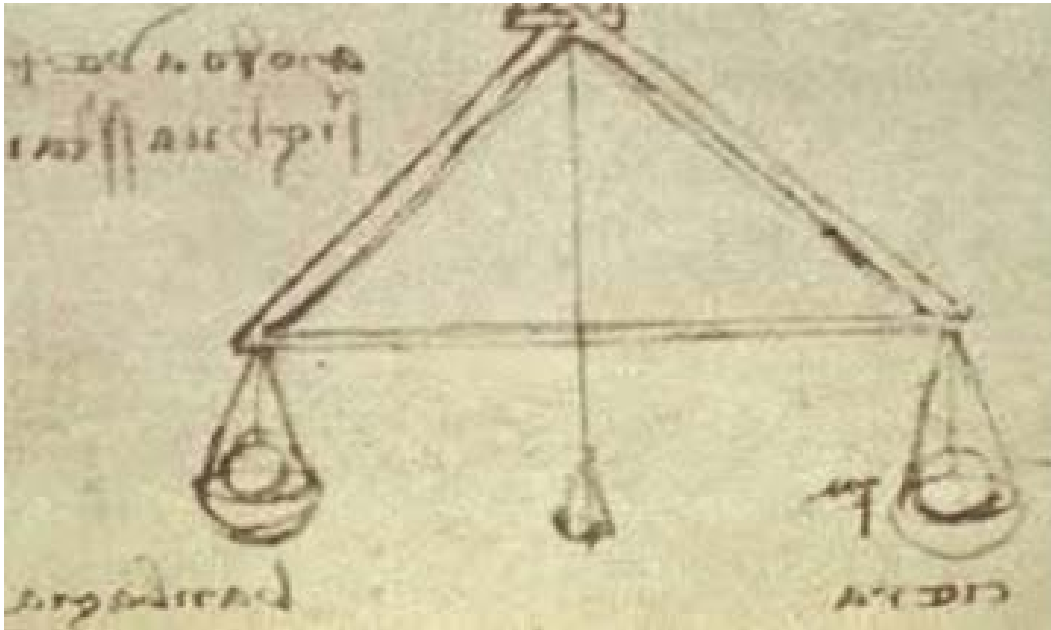




Humidity measurement technologies

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History of Humidity Measurement



Comparison of traditional technologies

	Mechanical	Psychrometer	Chilled mirror	Resistive
Range minimum	10 %	15 %	-95 .. -20 °C Tf	5 %
Range max	100 %	100 %	< 100 °C Td	100 %
Accuracy typ.	+/- 5%	+/-2..5 %	~1 %RH	+/- 5 %
Hysteresis	Very high	None	None	High
Stability	Very poor	Poor	Very good	Poor
Maintenance need	High	High	Moderate	Moderate
Response time	Very slow	Moderate	Moderate	Moderate
Temp. range	Room temp.	0..100 °C	Room temp	Up to 100 °C

Performance



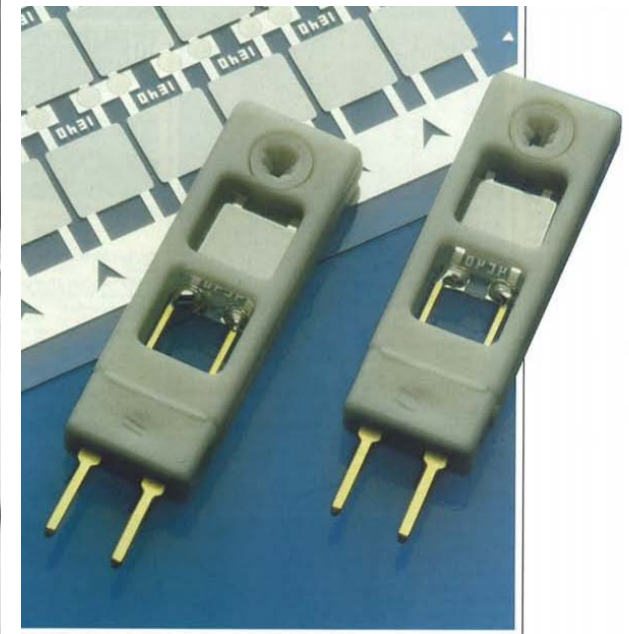
- Chilled mirror hygrometer
- Laboratory reference etc.
- Requires maintenance
- Accuracy: +/- 0.1 °C in dew point (+/- 0.1..0.9 %RH at room temp)



- HMT330 with capacitive HUMICAP sensor
- Field instrument for industrial use
- No regular maintenance need
- Accuracy: +/- 1.0 %RH at room temperature

Vaisala innovation: Capacitive thin-film polymer sensor

- Vaisala founded by prof. Vilho Väisälä in 1940's
- Humicap invented in 1973
 - For radiosonde application
 - Current de facto technology
- Later on productized for industrial applications



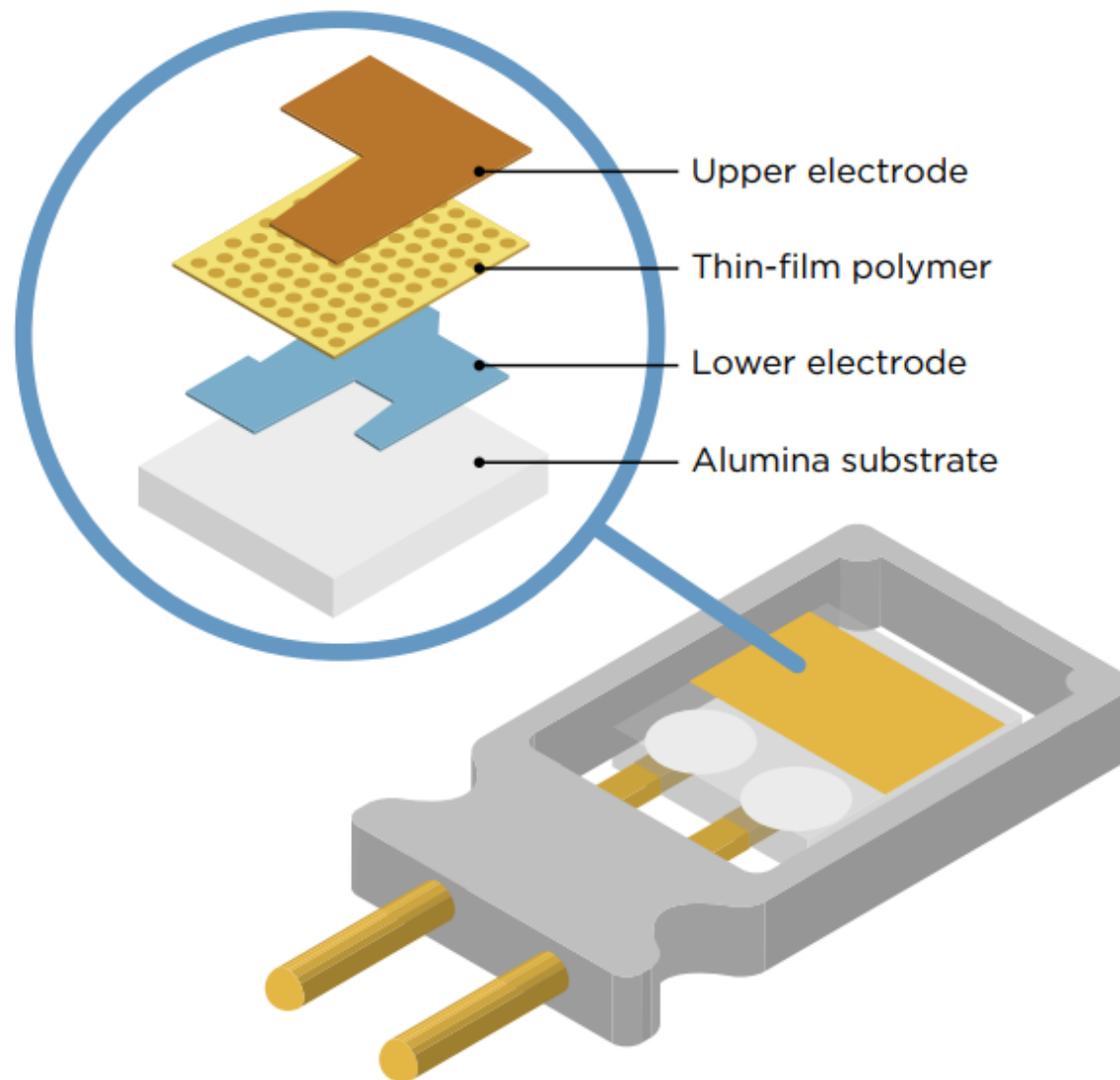
Vaisala HUMICAP®

The sensor capacitance responds directly to changes in **relative humidity**

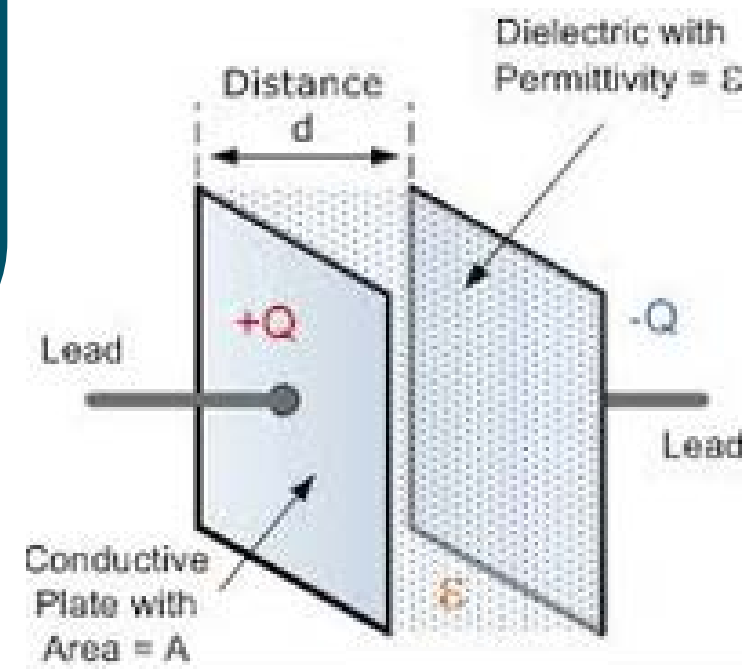
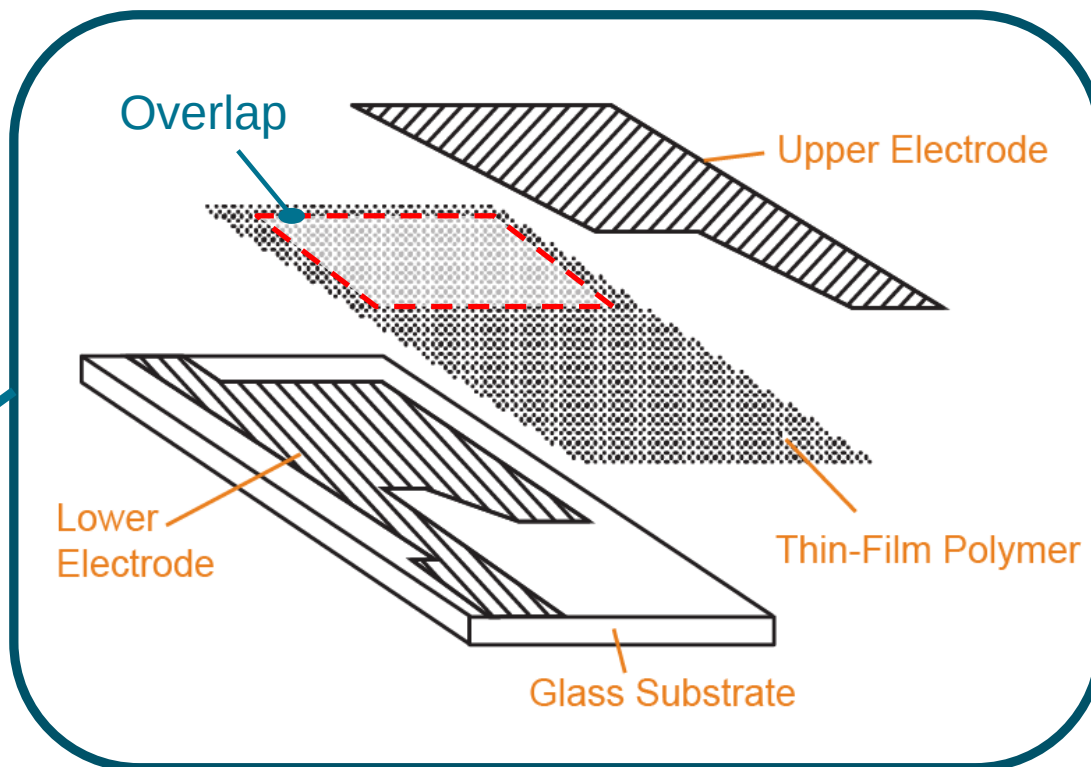
Operating range:

Relative humidity 0..100 %RH
Temperature -40..+180 °C

Withstands chemicals
Withstands wetting
Fast response time
Low hysteresis



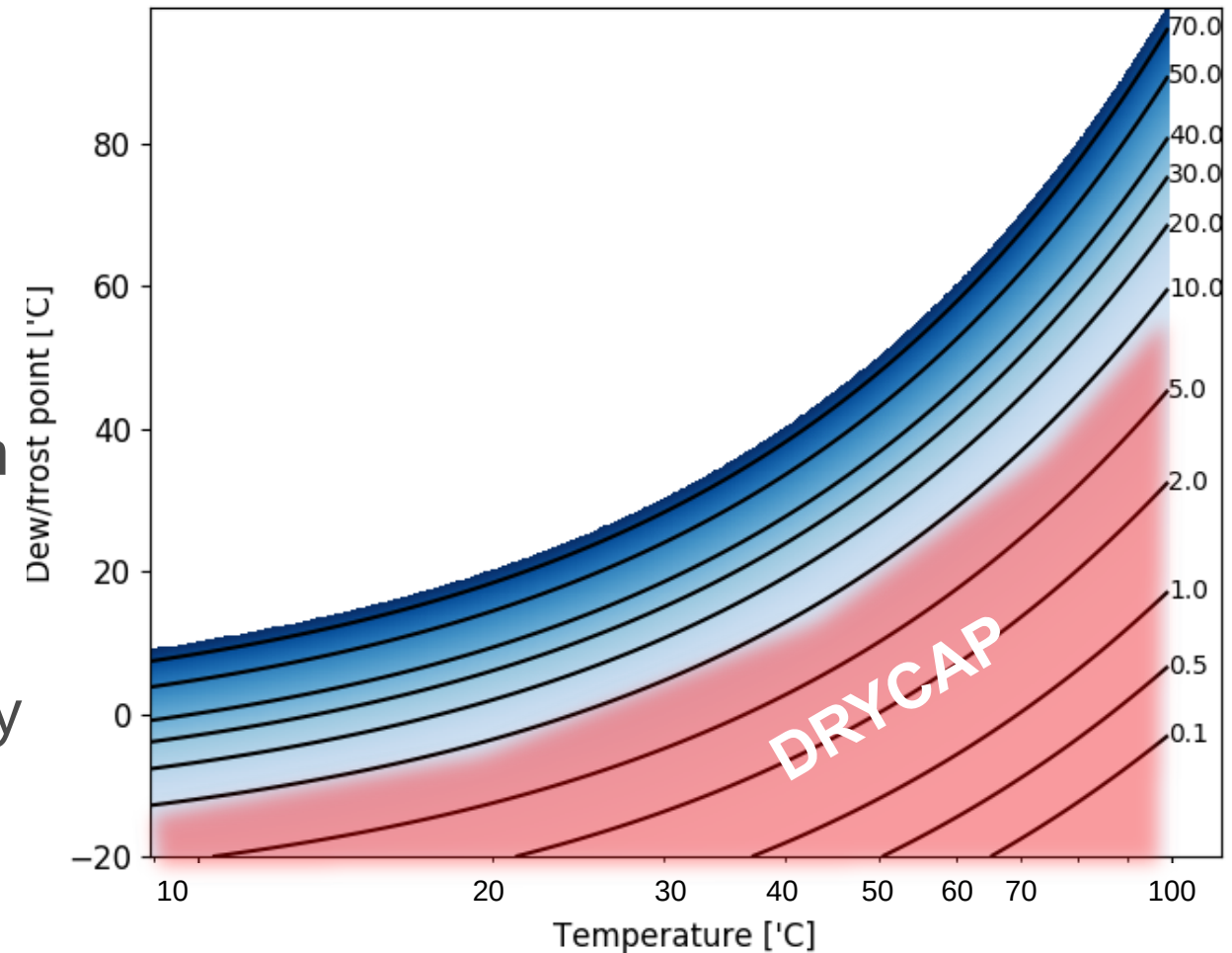
Theory of operation



HUMICAP® vs DRYCAP®

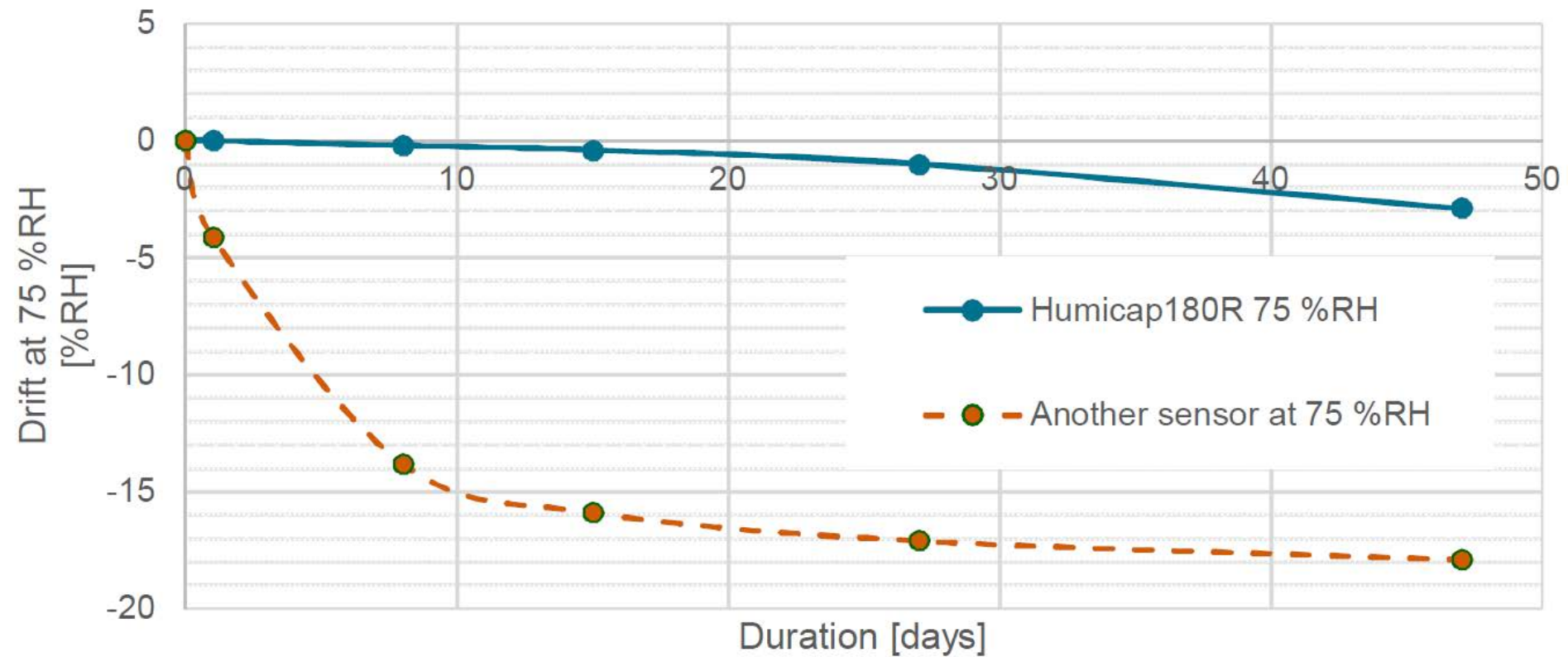
- Capacitive humidity sensors are sensitive to **relative humidity** as the primary physical variable
- **HUMICAP®** withstands continuous high humidity and immersion 0..100 %RH
- **DRYCAP®** is optimized for low humidity measurements, generally for < 5 %RH
 - In general, when frost point is below 10 °C

Relative Humidity as a function of T and Td

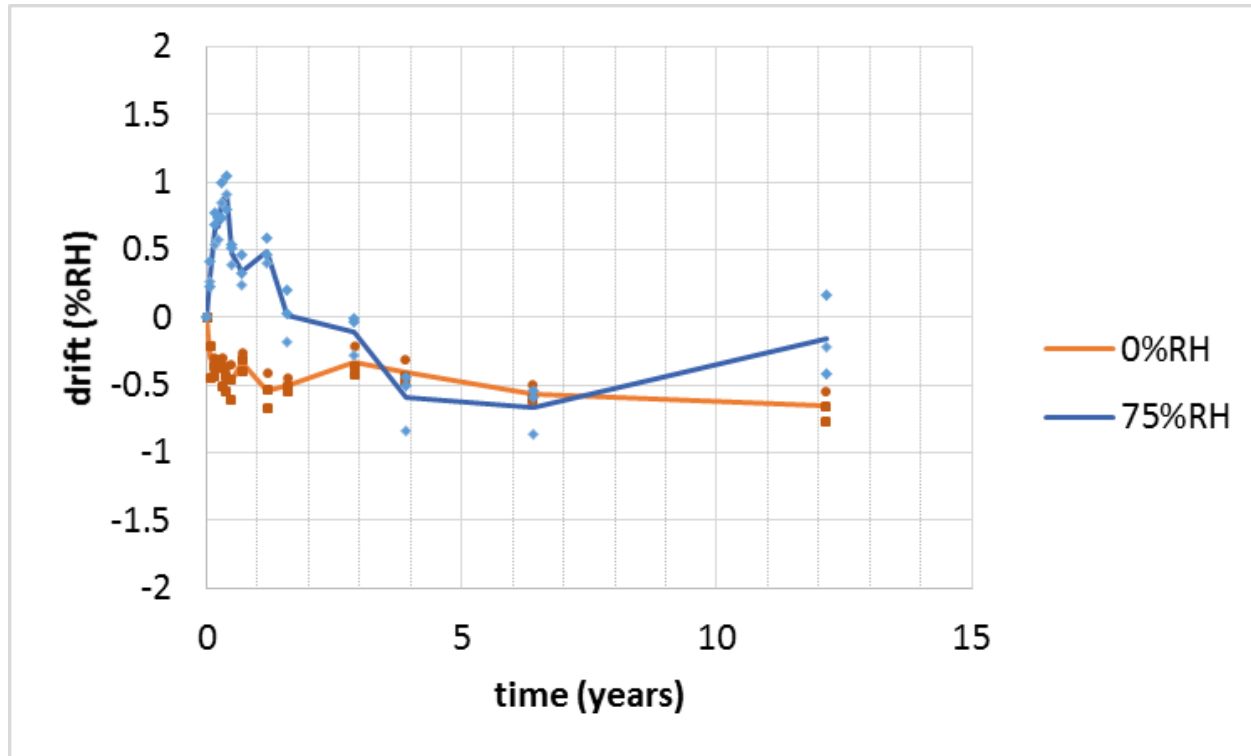


HUMICAP[®] robustness

Saturated Isopropyl Alcohol exposure



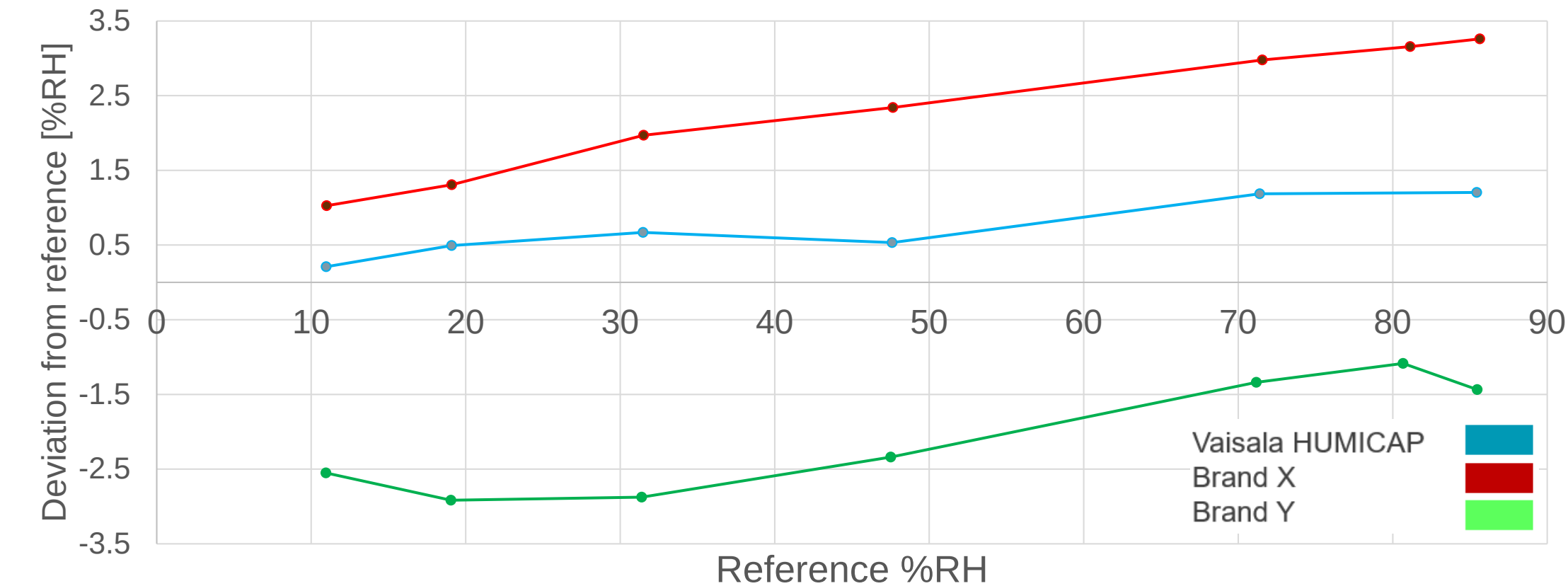
HUMICAP[®] stability



- Three Humicap180R sensors in outdoor test
- Drift less than 1 %RH over full range during 12 years!

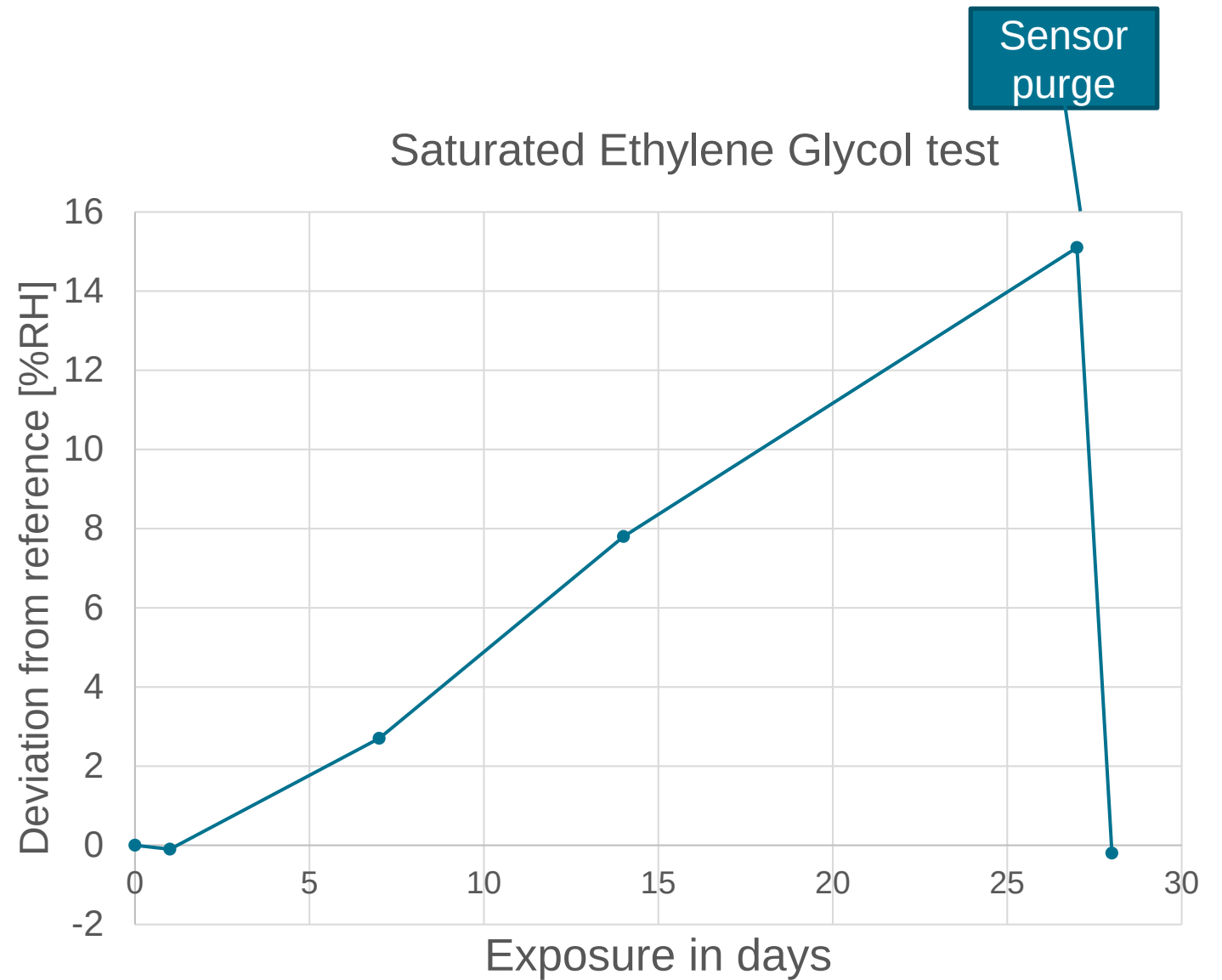
Full Temperature Range Linearity

Calibration at 70 °C



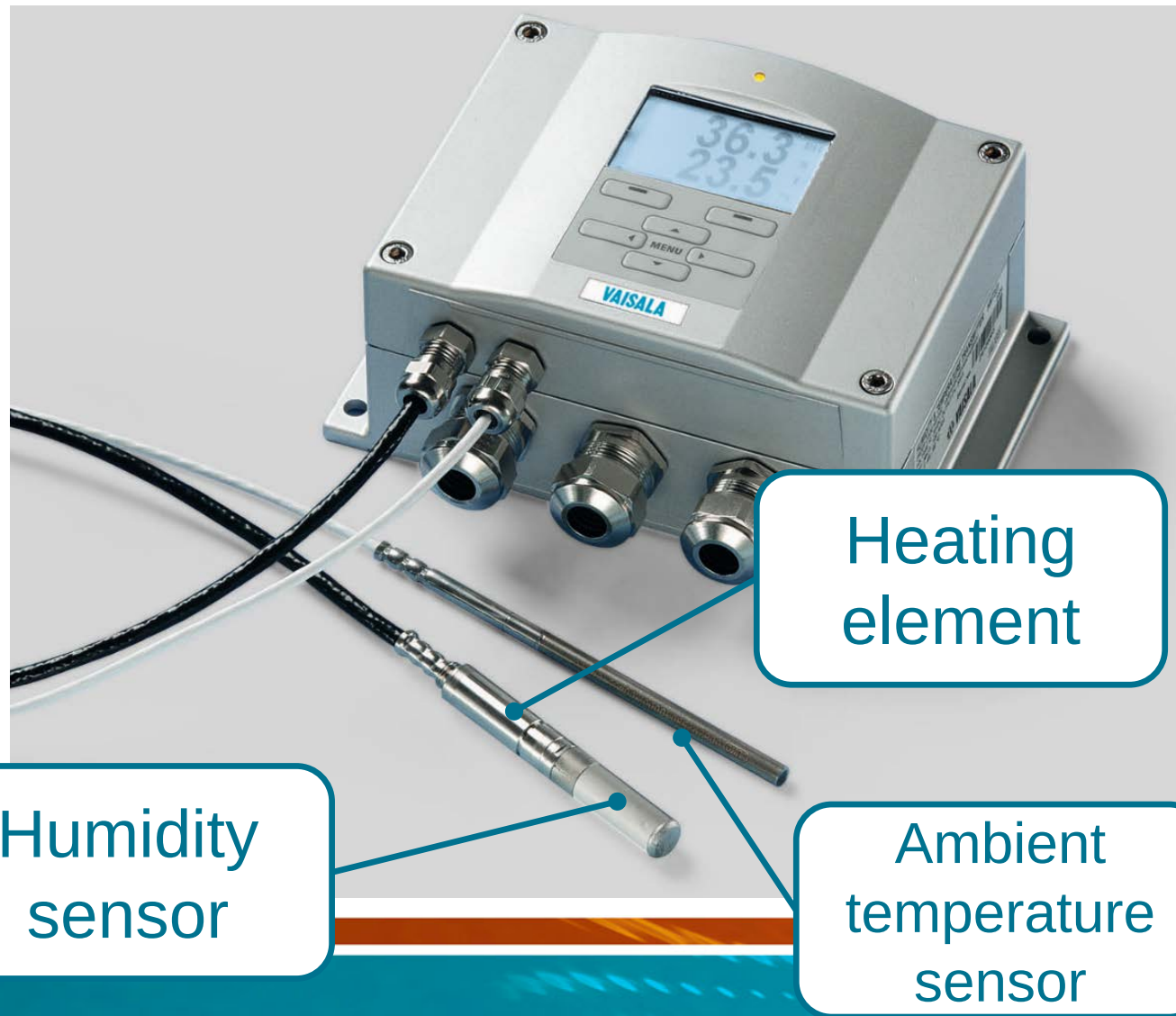
Sensor purge

- Regeneration of the sensing element by brief heating
- Evaporates volatile contaminants from the active polymer



Warmed probe technology

- Heating element warms the probe above the dew point
 - No condensation
- Reduced relative humidity at the sensor
 - Sensor maintains it's accuracy
- Additional temperature probe for back-calculating RH at actual ambient temperature



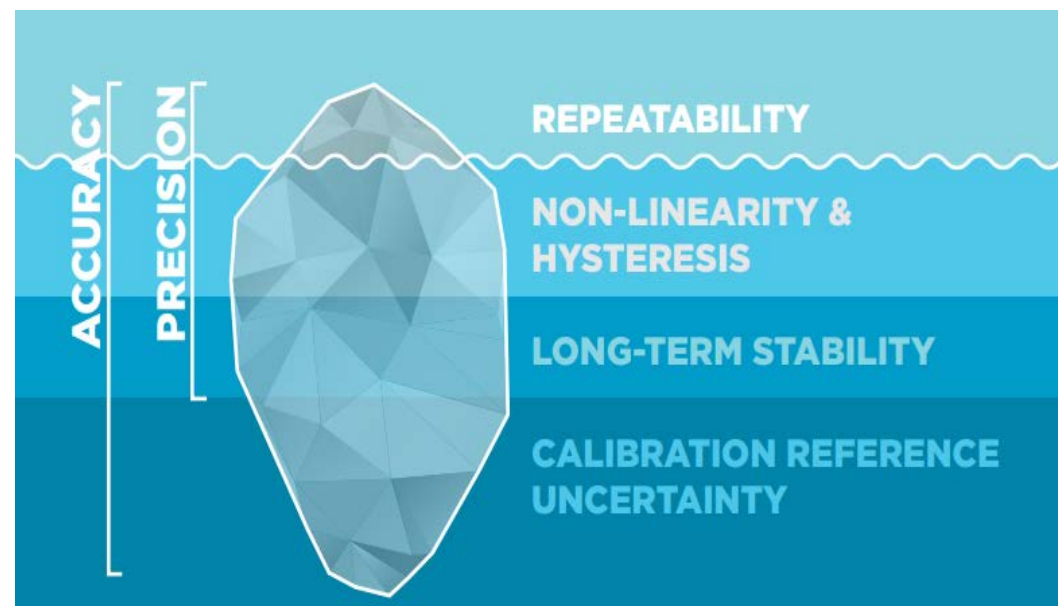


Choosing the humidity instrument

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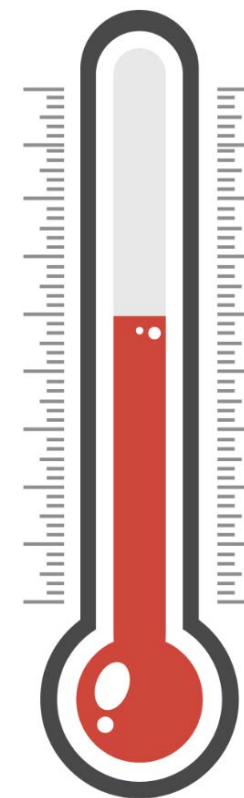
What is my accuracy requirement?

- Most humidity instruments are specified in terms of RH.
 - Use Humidity calculator to convert the accuracy specification to the unit you need
- Do I need individually calibrated and adjusted device?



What is my temperature range?

- What is the maximum temperature at the measurement position?
- Is the instrument specified for accuracy in my temperature range?
- What is the instrument's accuracy in terms of the engineering unit I am using?



What is my measurement parameter?

- Do I wish to measure relative humidity, dew point temperature or absolute humidity?
 - Is my variable sensitive to temperature?
 - Remember heat leaks!
- What is the pressure at my installation position?
 - Pressure compensation parameter!

RH [%]

Td [°C]

Td/f [°C]

X [g/kg]

a [g/m³]

h [kJ/kg]

Installation location?

- Mechanical installation
 - Duct, wall, pole, outdoor
- Installation outdoors?
 - Effect of radiation
- Contamination
 - Chemical purge?
 - Choice of filter



Maintenance

- Field check?
- Replacement of filter or sensor?
- Field calibration?
- Periodic calibration
 - Make or buy?



Response time

- The response time of the sensor is ~15 s in room temperature and still air.
- **Diffusion** – temperature
- **Gas exchange** – flow
- **Temperature** – Thermal mass

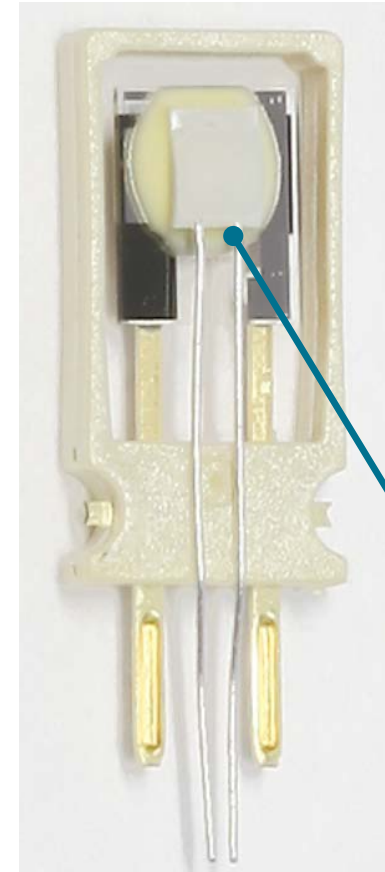
Diffusion time multiplies by factor of ~2 for every 10 °C decrease in temperature. Humicap180 is slightly faster for diffusion than Humicap180R



Choice of filter affects to the thermal mass, gas exchange and response time

HUMICAP[®] sensor types

- HUMICAP180
- HUMICAP180R
- HUMICAP180L2
- HUMICAP180V



Composite
temperature
sensor
for chemical
purge

C for Composite
Humicap180RC
HumiACP180C

Products and offering



OEM modules

HMM modules
HMP probes

HVAC family

80 series
90 series
110 series

Handhelds

HM40 series
HM70 series
DSS70 sampling kit

Field instruments

HMT330
HMT120
HMT130

Continuous Monitoring Systems

The background of the slide is a teal color with abstract, wavy patterns and a grid-like texture on the right side.

Wrap-up

A horizontal bar with a gradient from orange to yellow.

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Quiz

- Relative humidity is relative to _____?
- Humicap sensor is sensitive for _____?
- Sensor purge is available with _____ sensor
- For extreme humidity, _____ is recommended

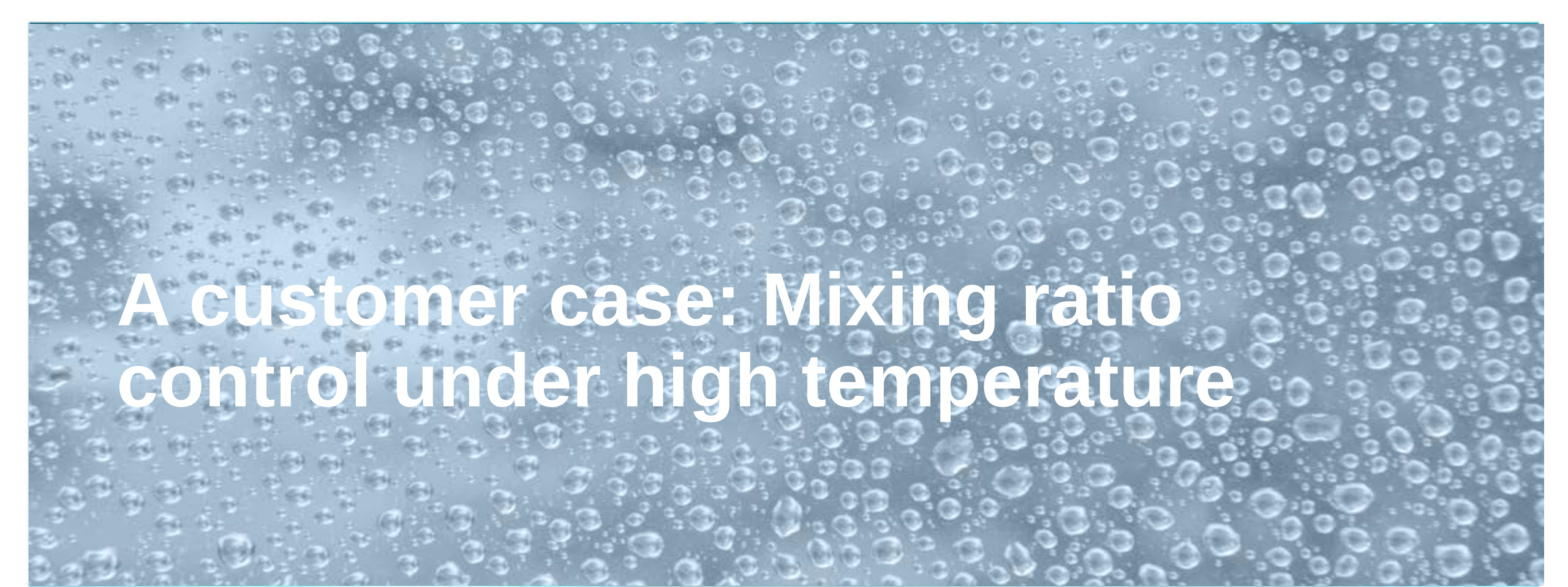


Humidity – application notes and product offering

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Content

- Best measurement practices
 - Customer case: Mixing ratio control under high temperature
 - Customer case: Installation problem in a timber drying kiln
 - Customer case: High humidity measurements in ceramics drying kiln
- Calibration and traceability
 - Field Calibration
 - Laboratory calibration
 - Accredited calibration
 - Traceability



A customer case: Mixing ratio control under high temperature



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A customer case



- Ceramics dryer
- Control options
 - No control
 - Indirect control by feed rate
 - Humidity based control

**Control variables:
temperature and
humidity mixing ratio**

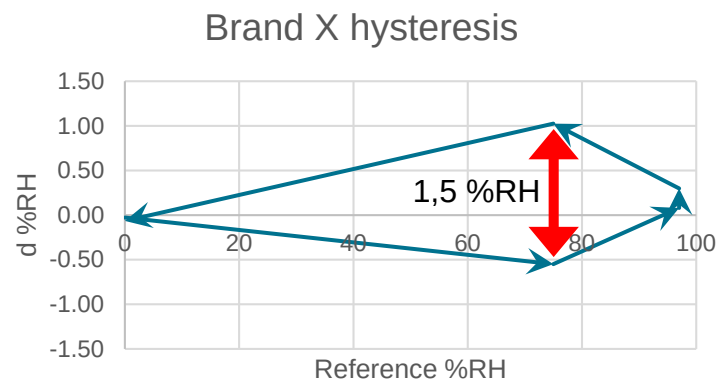
$t = 130..140\text{ }^{\circ}\text{C}$
 $x = 100\text{ g/kg}$ ($t_d = 53\text{ }^{\circ}\text{C}$)

RH = 5 %

Another supplier said..

- Brand X distributors proposed solution:

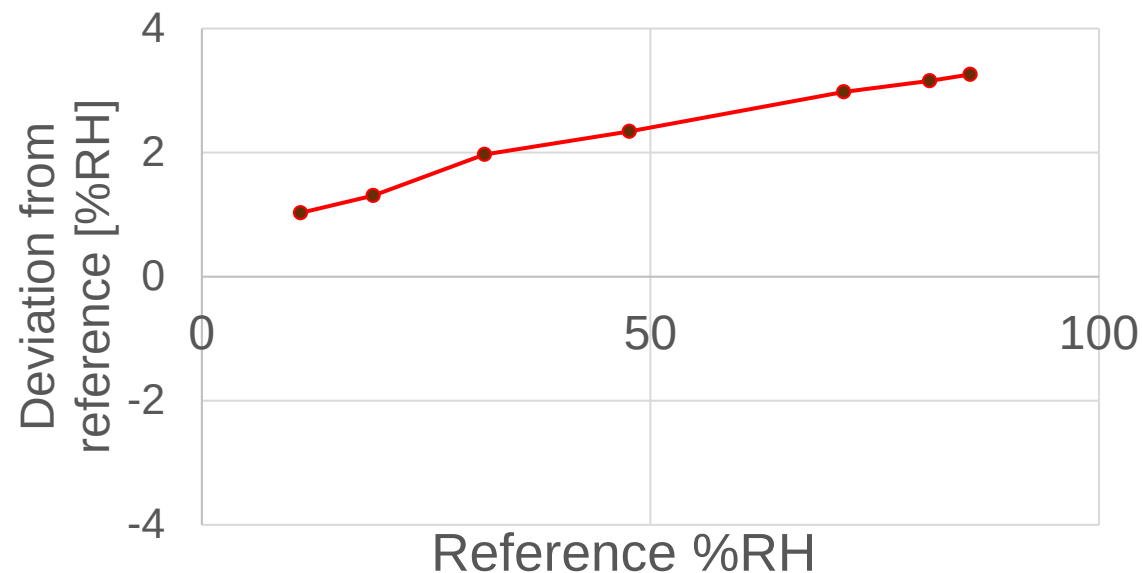
"calibration at process temperature will provide the necessary accuracy"



Specified accuracy at 23°C: 0,8 %RH

Another brand

Calibration at 70 °C



Accuracy of control

- $T = 130\text{ }^{\circ}\text{C}$
- $RH = 5\% \pm 3\%$
 - Brand X specified repeatability short-term: 0,5 %RH
 - Brand X hysteresis: 1,5 %RH
 - Brand X estimated drift in 1 year: 1 %RH

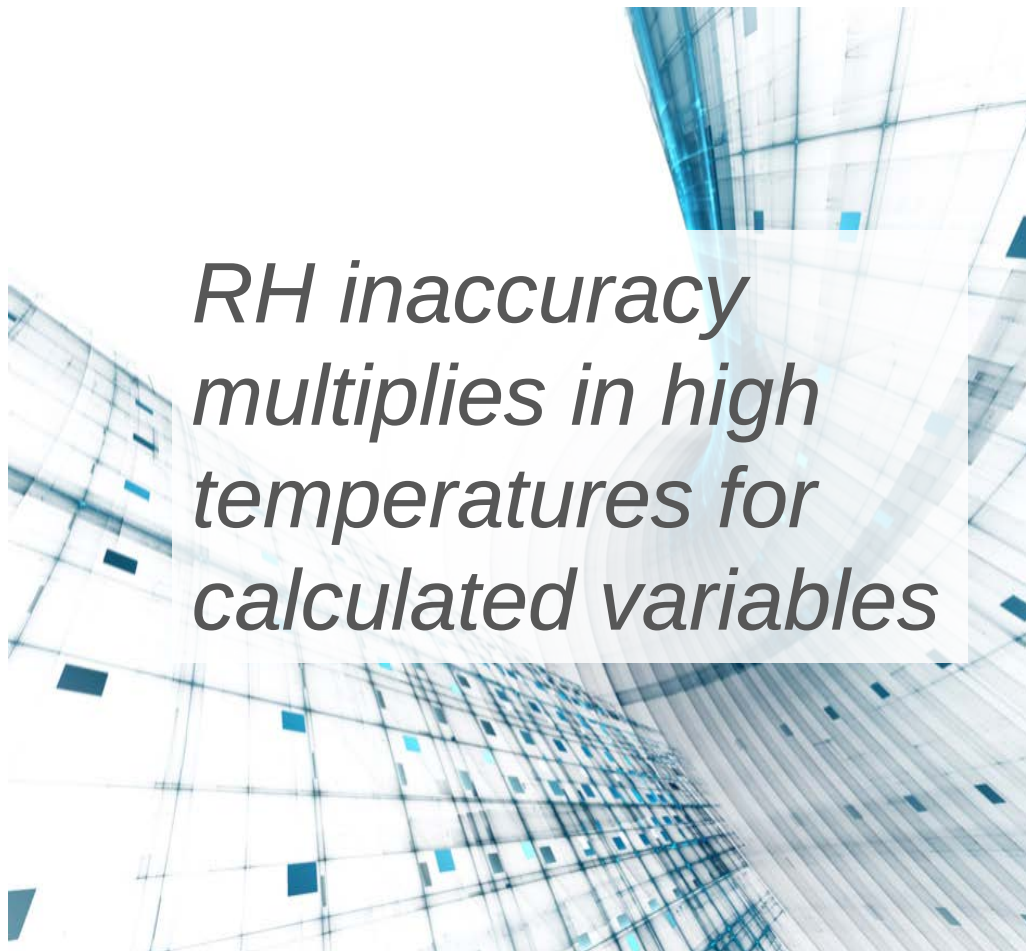
$x = 100 \pm 70\text{ g/kg}$ **Another brand**

- **DMT345** specified accuracy full scale:

$T_d = 53 \pm 2\text{ }^{\circ}\text{C}$

$x = 100 \pm 10\text{ g/kg}$

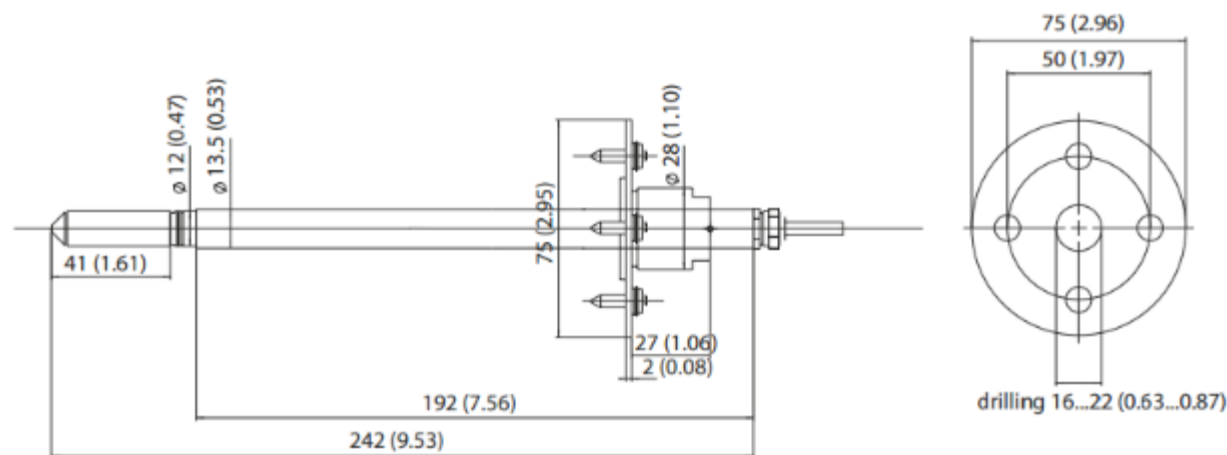
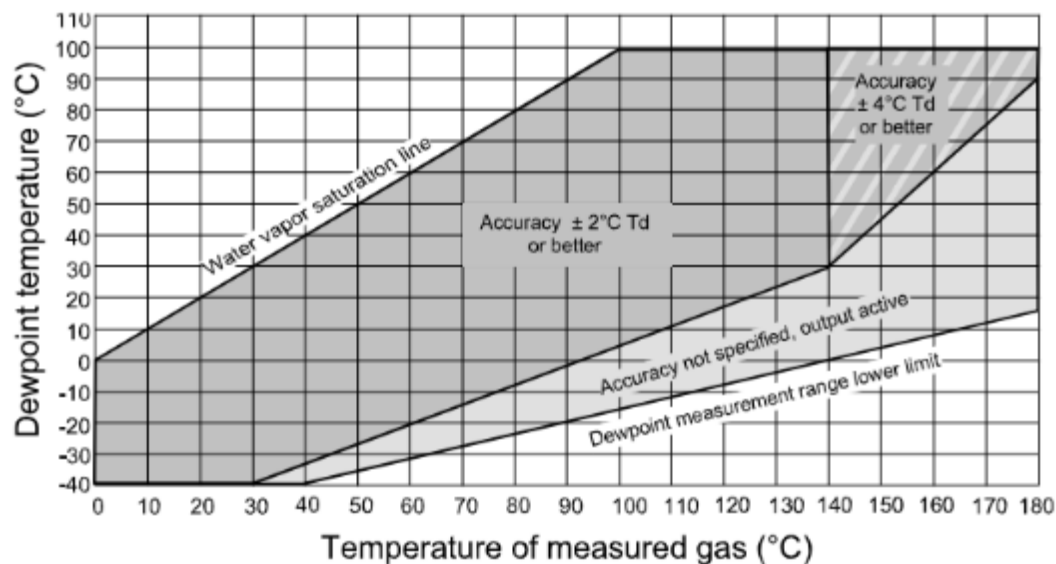
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*RH inaccuracy
multiplies in high
temperatures for
calculated variables*

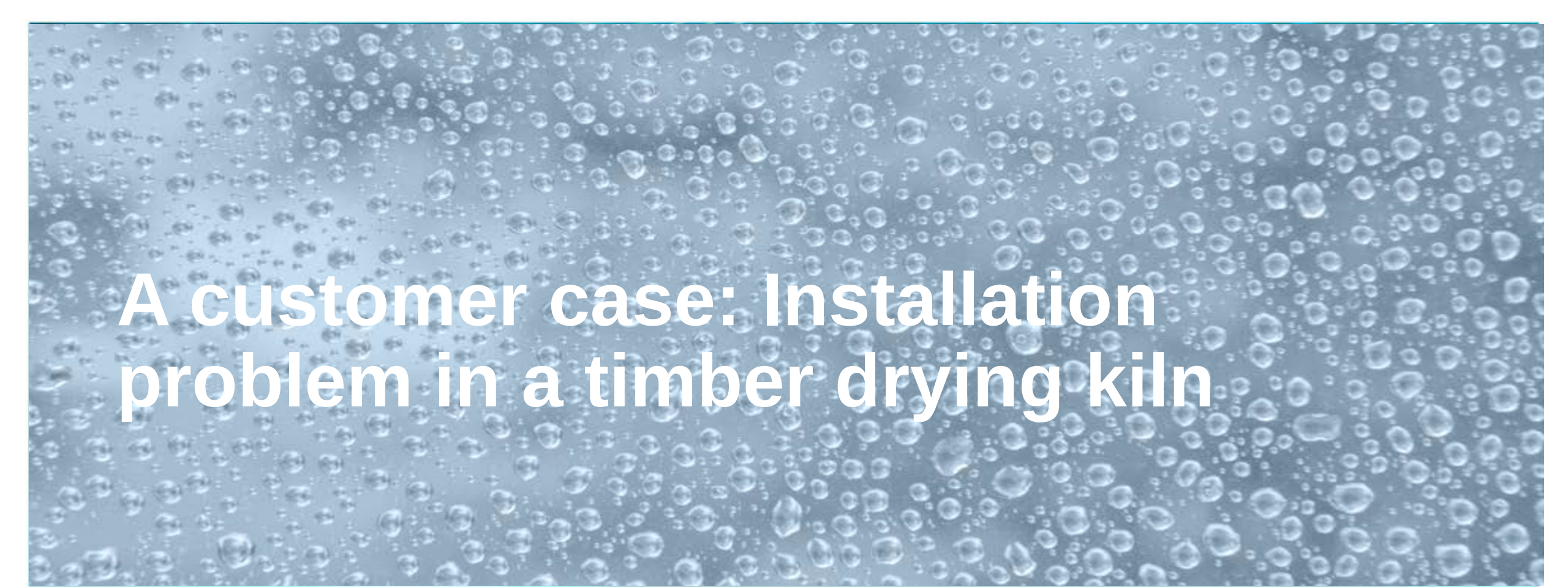
DMT345 for high temperatures

- **DRYCAP180S sensor**
- High dew point measurements up to 140 °C
- Low dew-point applications (ovens and similar) up to 100 °C dry-bulb temperature
- Installation flange and long probe provide easy installation through insulation materials



High temperature applications

- Notice the full temperature range accuracy specification of the instrument
- Notice the accuracy in engineering units you are using
- Beware of temperature leaks and insufficient stabilization
- Notice the resulting low RH



A customer case: Installation problem in a timber drying kiln

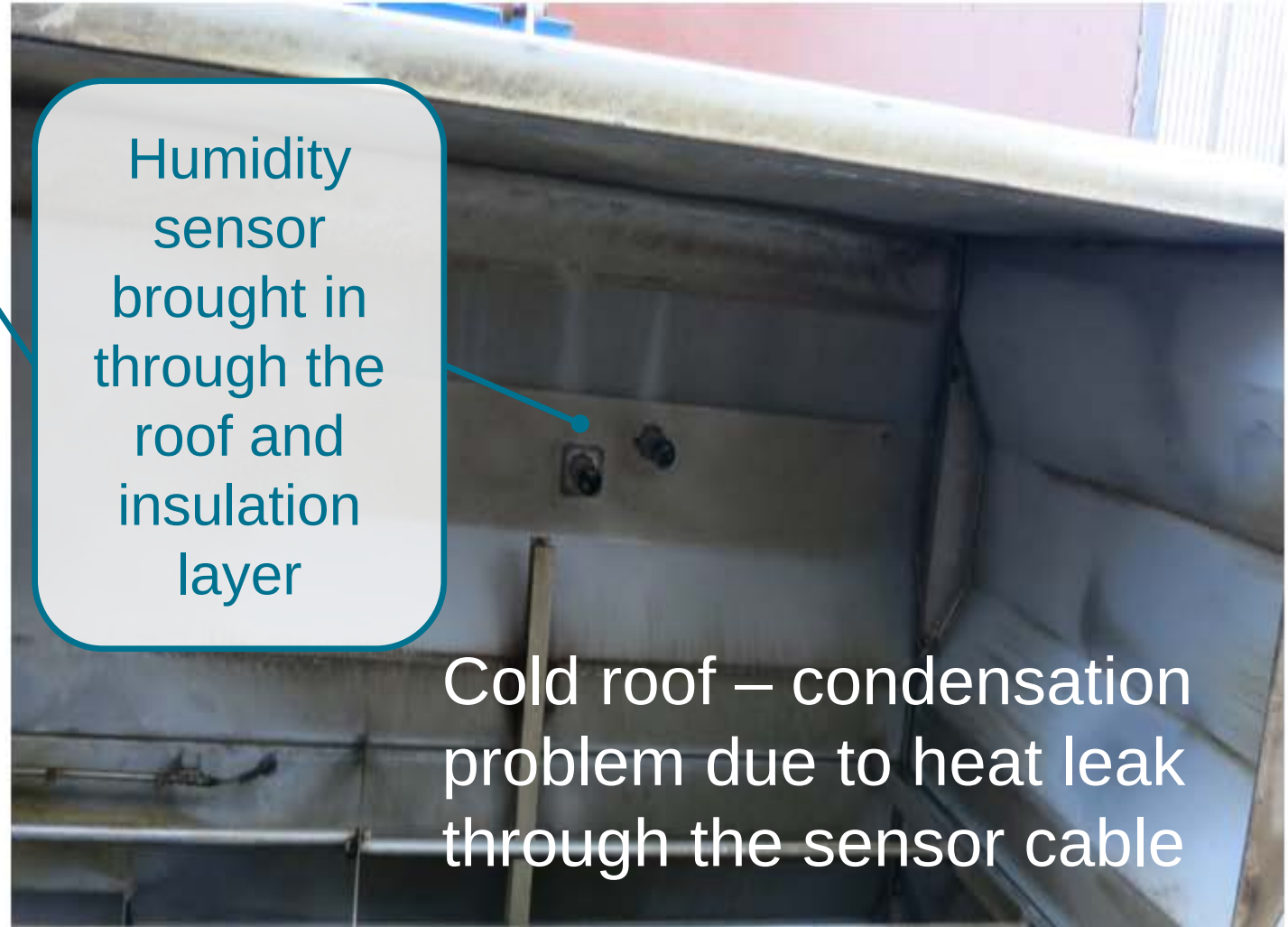


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A customer case: Timber drying kiln



Humidity
sensor
brought in
through the
roof and
insulation
layer



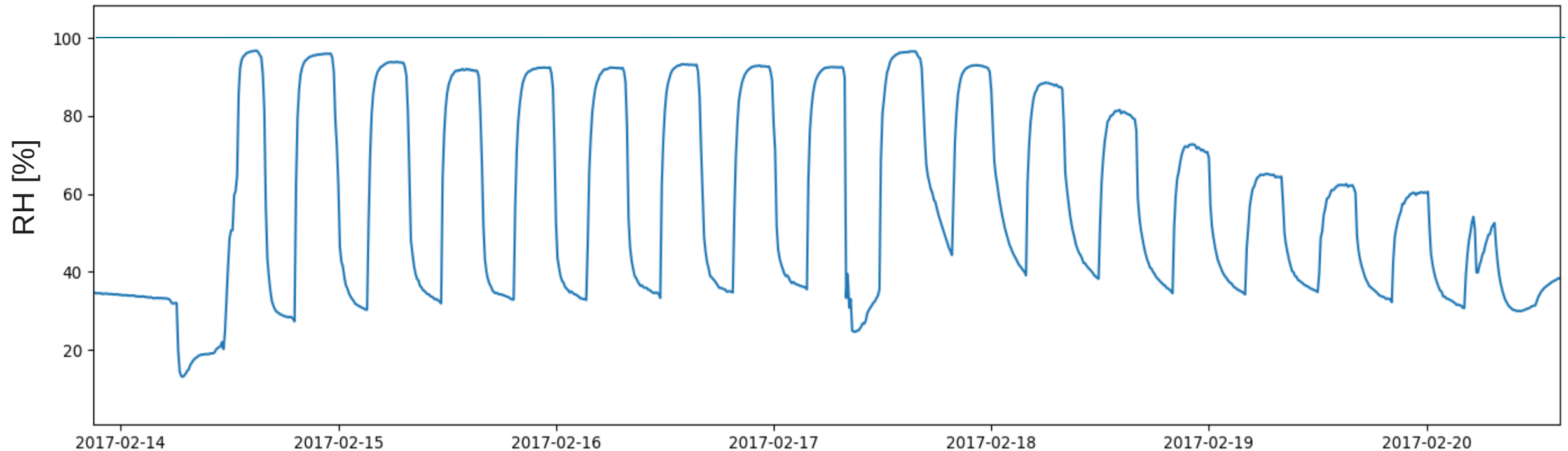
Cold roof – condensation
problem due to heat leak
through the sensor cable

Humidity
Sensor
feed
through
pipe

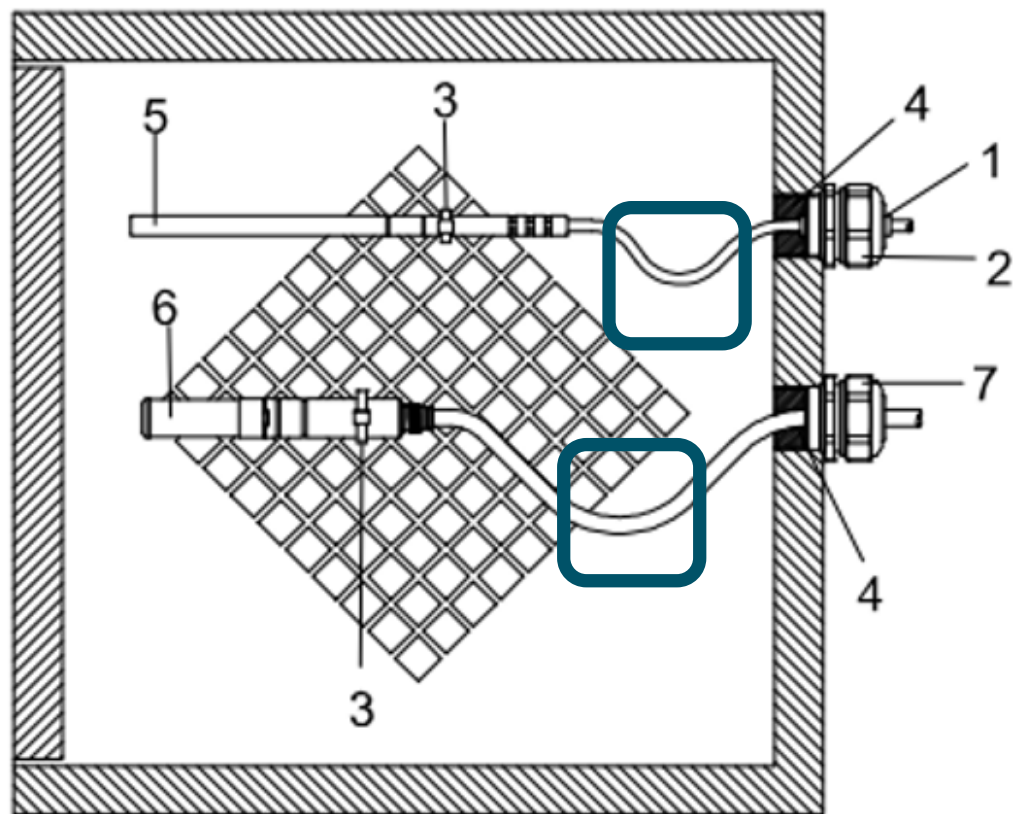
Sealing
gland
added

No condensation due to heat leak during February

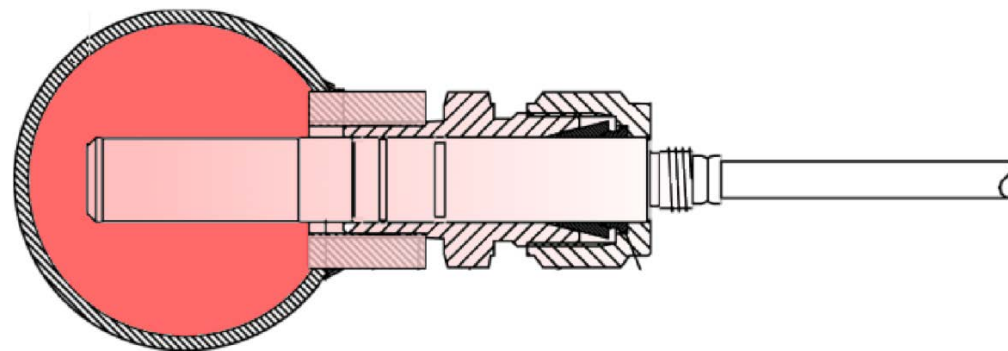
Heat leak and condensation problem removed



Heat leaks and drip



If the probe is installed in non-ambient temperature, make sure the effect of heat leaks is minimized





A customer case: High humidity measurements in ceramics dryer

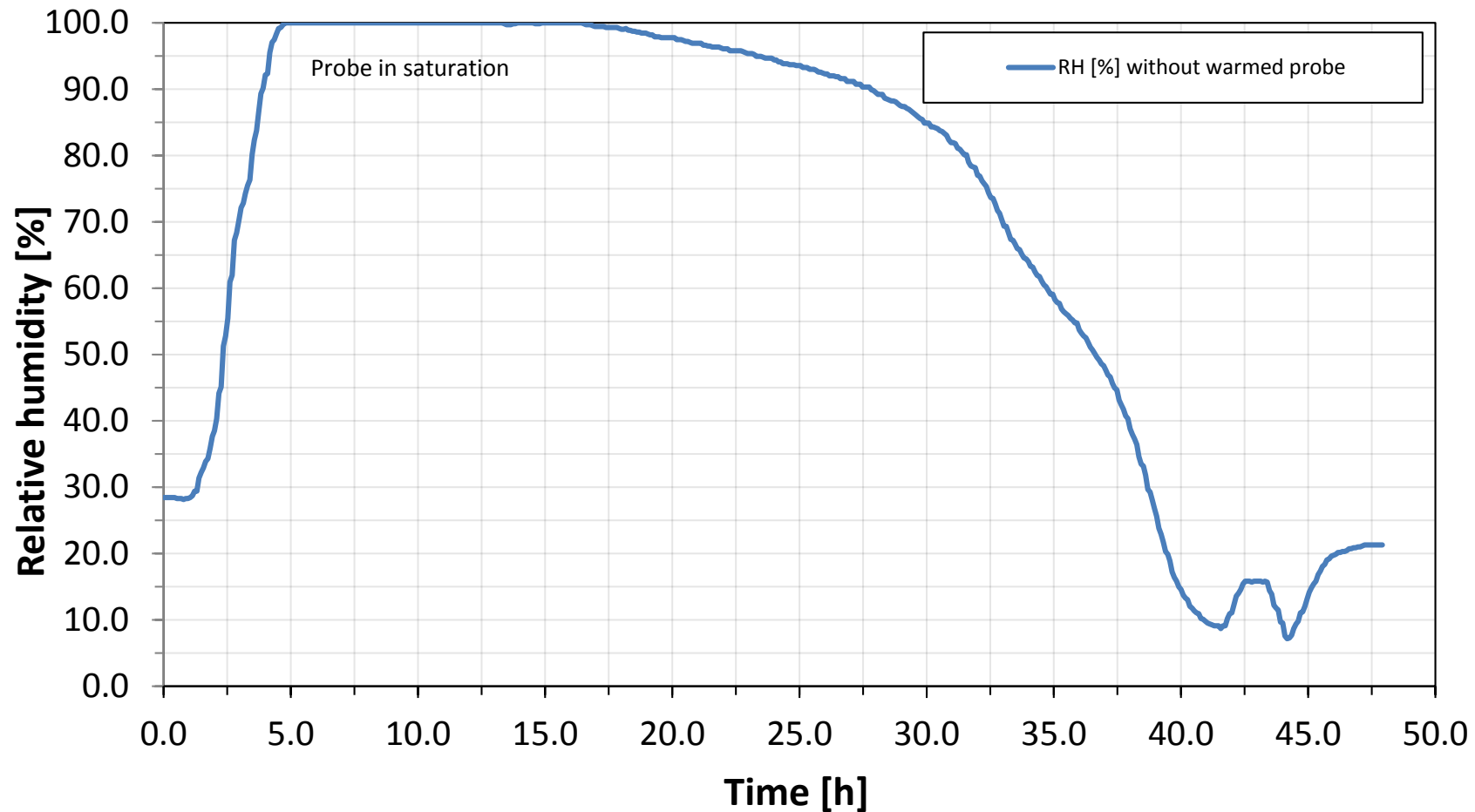


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A ceramics drying kil



Normal probe in high humidity application (ceramics dryer)



Warmed Probe Technology

- With additional T –probe; temperature elevated from ambient
 - Without additional T-probe (heated dewpoint measurement) seeks to 70..80 %RH
- Constant heating; affects also the filter
- **XHEAT** for rapid condensation recovery



Whole probe heated above ambient

a must in a fuel-cell applications

dew-point and T back-calculated to Relative humidity

How probe warming works?



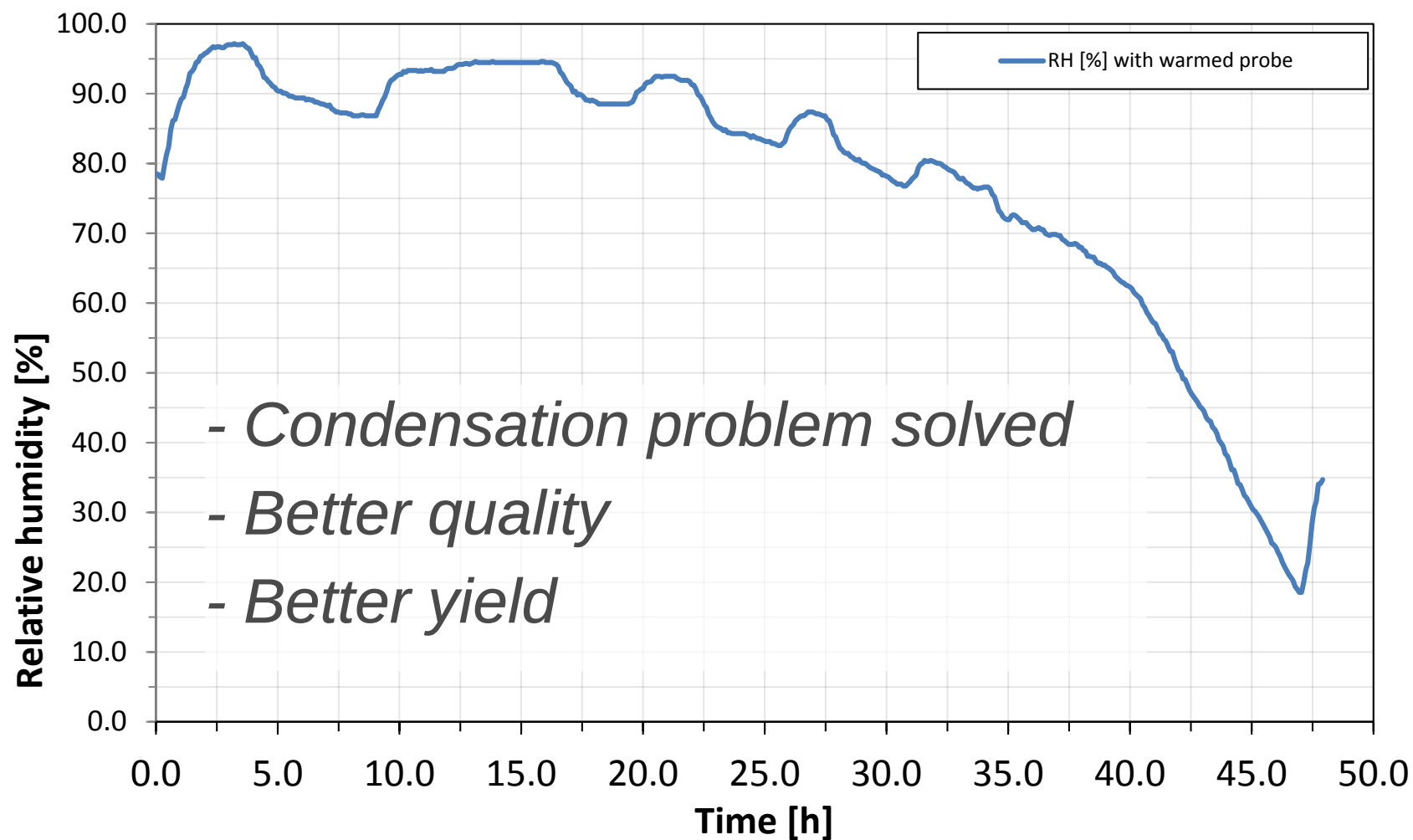
$T_{\text{ambient}} = 14\text{ }^{\circ}\text{C}$
 $\text{RH}_{\text{ambient}} = 97\text{ \%RH}$

$T_{\text{ambient}} = 14\text{ }^{\circ}\text{C}$

$T_{\text{sensor}} = 16\text{ }^{\circ}\text{C}$
 $\text{RH}_{\text{sensor}} = 83\text{ \%}$
 $\text{RH}_{\text{at } 14^{\circ}\text{C}} = 97\text{ \%RH}$

Probe warming resistor

HMT337 warmed probe



A detailed close-up photograph of a mechanical watch movement. The image shows various gears, including a large yellow gear and several smaller silver and gold-toned gears. There are also small red jewels (sapphire crystals) visible, which are part of the watch's internal mechanism. The background is a light, textured surface.

Calibration and traceability

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What is calibration?

- **Calibration** means comparing the instrument reading with a reference (a calibration standard)
- Quality of calibration is defined by the following
 - The **competence** of the laboratory
 - The **management system** of the laboratory
 - The **methods** used by the laboratory
 - The **equipment** and the references of the laboratory

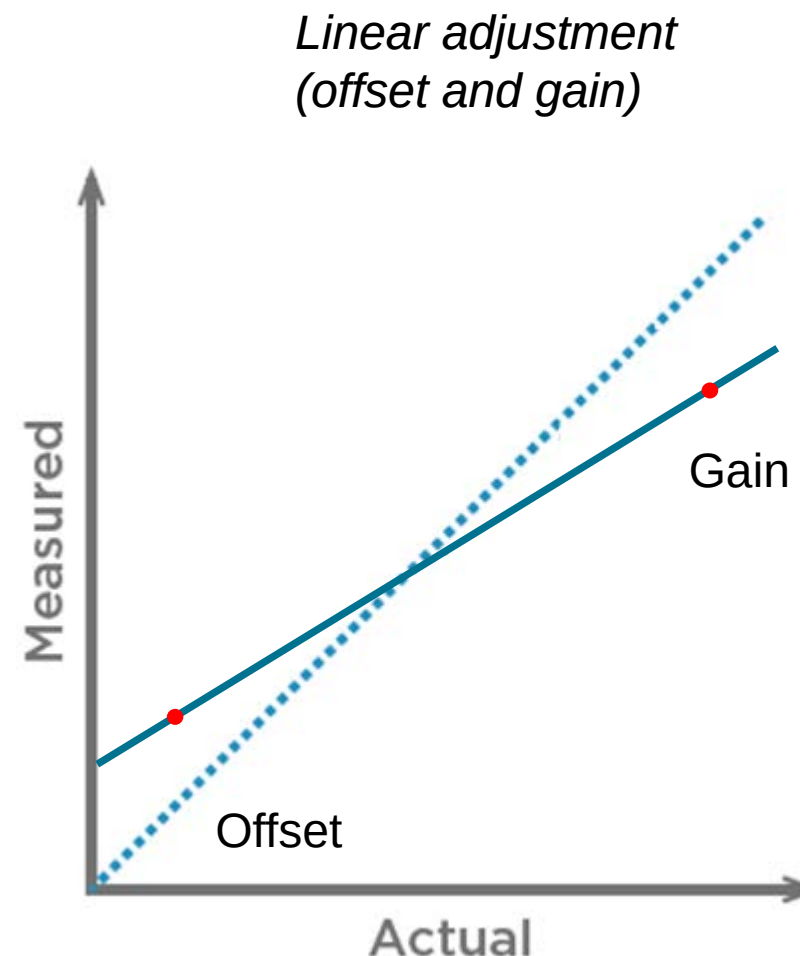


By definition, every measurement has some degree of uncertainty

Calibration is a way to validate and maintain the performance of a measurement instrument

What is adjustment?

- Adjustment is correcting the instrument to minimize deviation from the calibration reference
- Normal service procedure is calibration ("as-found") and adjustment + calibration ("as-left")
 - This is sometimes called "Calibration"



Things to ask?



What does your quality system require?

What does your application require?

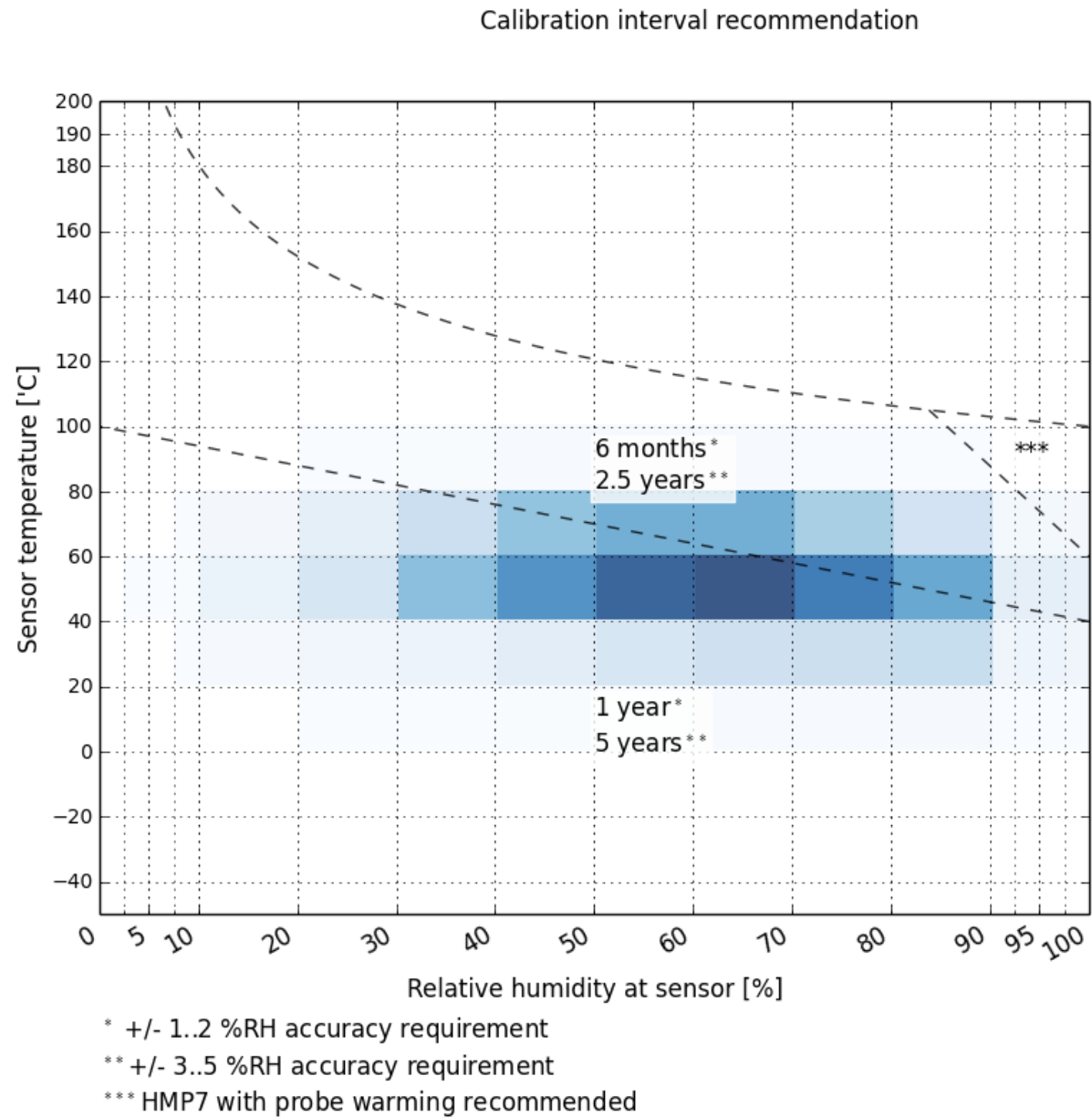
Quality Management System

- **ISO9001: Quality Management Systems – Requirements**
 - ISO9001 clause 7.6: *Control of measurement and monitoring equipment*
 - ISO10012:2003: *Measurement management systems - Requirements for measurement processes and measuring equipment*
- **ISO17025:2005: General requirements for the competence of testing and calibration laboratories**
- **AQAP (NATO Allied Quality Assurance Program) 2110: Design, development, production, sales and service of instruments, systems, solutions and information for environmental and industrial applications**



How often to calibrate?

- Calibration interval is subject to the operating conditions
 - Humidity/temperature
 - Chemical contaminants
- As-found certificates help in determining suitable calibration interval



What options do I have for calibration?

- Field calibration
 - Reference instrument
 - Portable calibrator
- Laboratory calibration
 - In-house
 - Service
- Factory service



Quality of calibration:

- Competences
- Management system
- Methods
- Equipment and the references



A detailed close-up photograph of a mechanical watch movement. The image shows various gears, including a large yellow gear and several smaller silver and gold gears. There are also three prominent red jewels (sapphire crystals) visible. The background is a light-colored metal plate with some engraved markings.

Field Calibration

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Field calibration

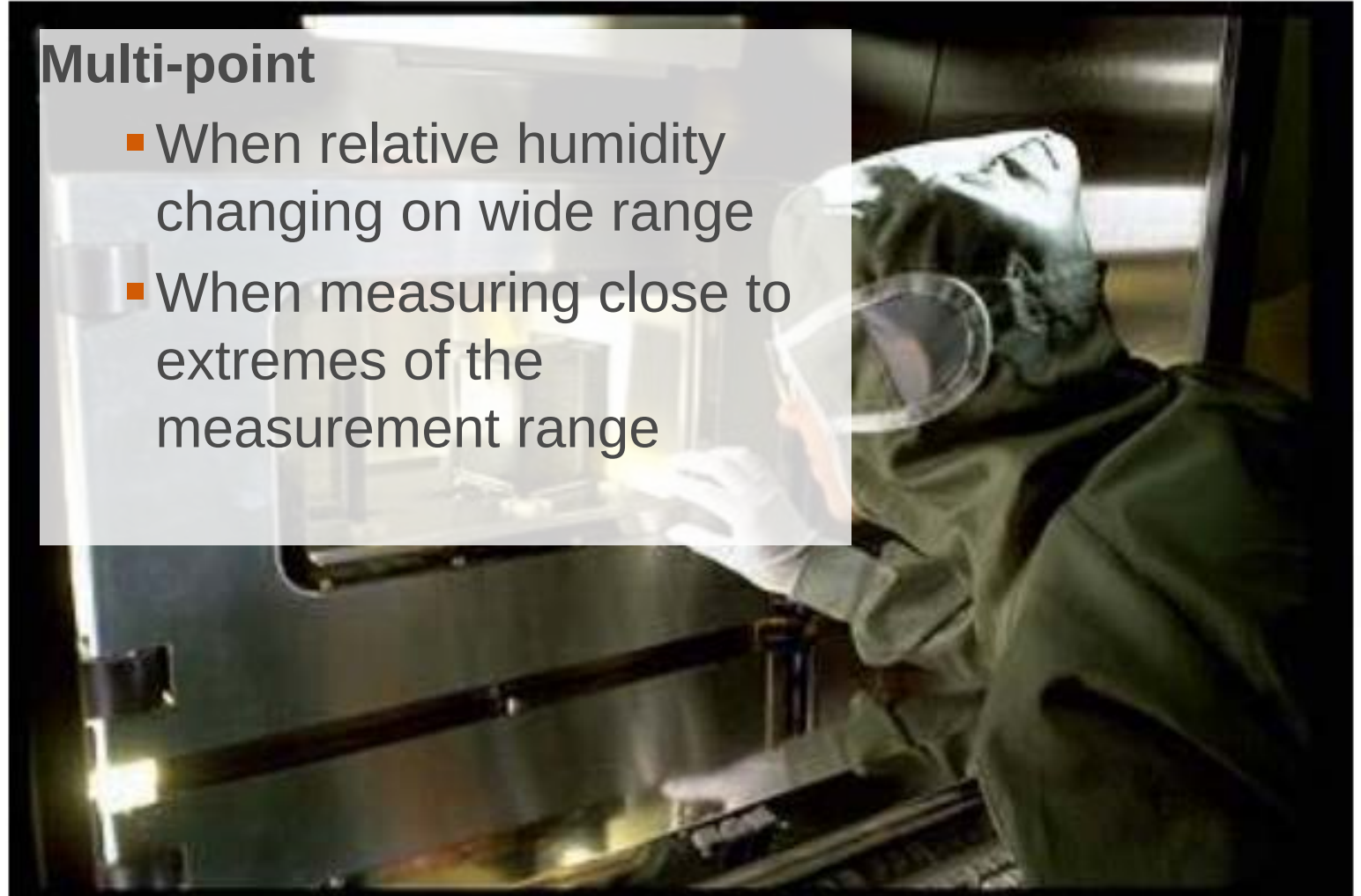
Single-point

- When stable condition
- When not close to extremes of measurement range



Multi-point

- When relative humidity changing on wide range
- When measuring close to extremes of the measurement range



Field calibration references

Handheld
Single-point



HMK15 Salt calibrator
Multi-point



Humidity generator
Multi-point



HM70 handheld field reference

- Designed for spot-checking and field calibration
- Multilingual user interface
- Shows measurement trends graphically
- Connects to various Vaisala transmitters
- 6-point traceable calibration (certificate included)



HMK15 salt calibrator

- Intrinsic reference based on known property of saturated salt solutions generating known relative humidity levels
- Uncertainty 1.2..2 %RH
- Batch traceable

Salt	Equilibrium RH at 20 °C
LiCl	11.3 %RH
MgCl	33.1 %RH
NaCl	75.5 %RH
K ₂ SO ₄	97.6 %RH



Applicable standards:
ASTM E104-85
DIN 5008
JIS Z8806

HMK15 salt calibrator

- A reference instrument can be used as a reference for additional accuracy or traceability reasons

Common mistakes:

- Insufficient stabilization time
- Temperature gradients
- Adjustment in too narrow RH range



A detailed close-up photograph of a mechanical watch movement. The image shows several interlocking gears, some with gold-colored teeth, and a circular dial with a white face and a dark center. The background is a light-colored metal plate with various screws and components visible.

Laboratory calibration

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Laboratory calibration references

- **Two-temperature or pressure humidity generator**
 - Slow to stabilize after setpoint change
 - No separate reference required
 - Uncertainty appr. $\pm 0.6\%$ RH
- **Chilled mirror instrument**
 - Dew point measurement
 - Uncertainty appr. $\pm 0.9\%$ RH



A detailed close-up photograph of a mechanical watch movement. The image shows various gears, including a large yellow gear and several smaller silver and gold gears. A prominent white circular component with a dark center is visible on the left. The background is a light-colored metal plate with some screws and a small cross-shaped mark.

Accredited calibration

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What is accredited calibration?

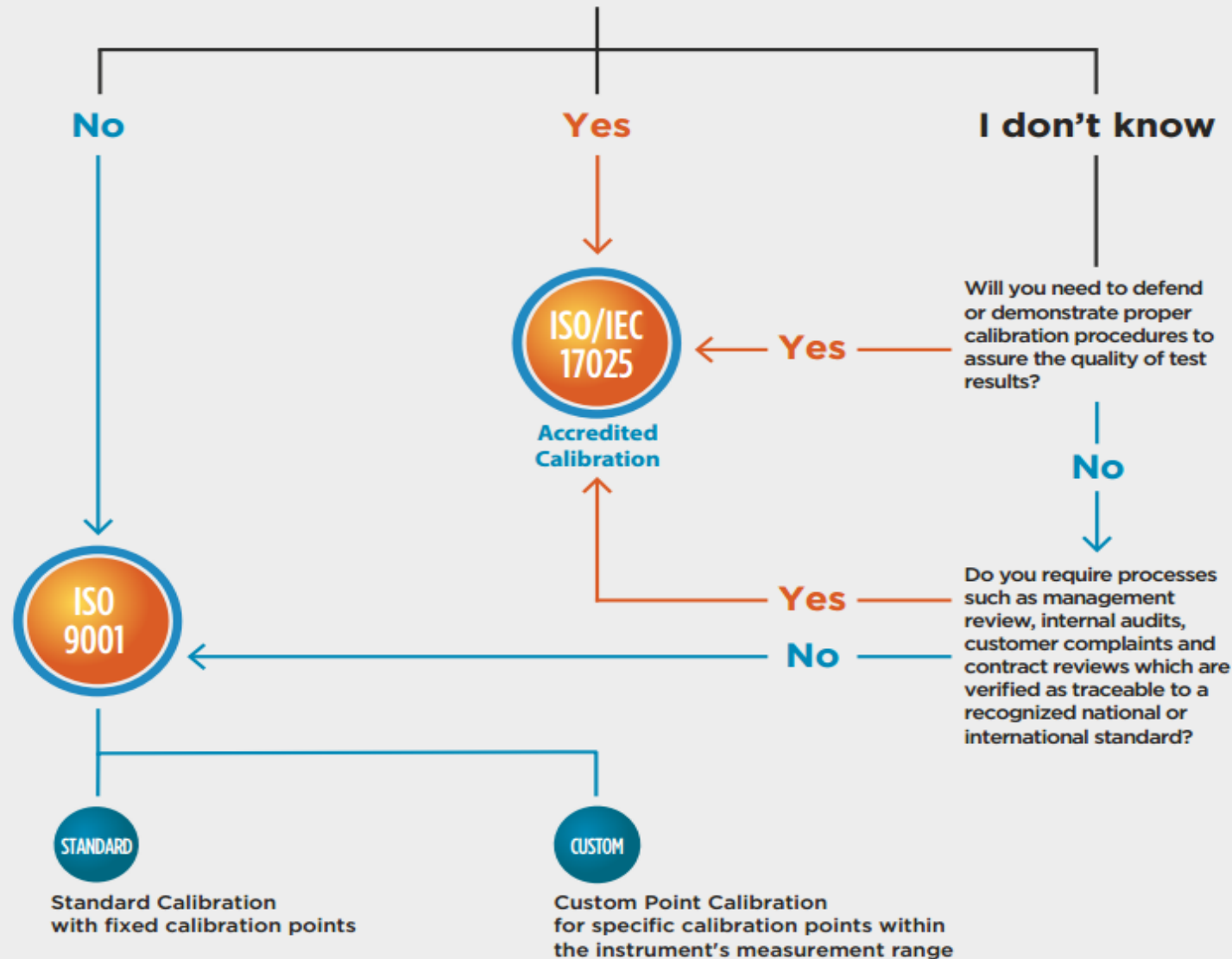
- Accredited calibration laboratory is running a Quality Measurement System in compliance to ISO/IEC 17025, ANSI/NCSL Z540 or other standard
 - Management system
 - Technical requirements

- Professionally made and validated uncertainty calculations
- Verified traceability to international standards
- Use of accepted and agreed methods
- Competence of personnel
- Independence of the organization
- Privacy of data and records



What Type of Calibration Do I Need?

Does your company's Quality Management Standards (QMS) require an ISO17025 Accredited Calibration?





Boston, USA	Helsinki, Finland	Beijing, China	Tokyo, Japan
STANDARD CALIBRATION SERVICES			
Relative Humidity	Relative Humidity	Relative Humidity	Relative Humidity
Temperature	Temperature		Temperature
Dew Point	Dew Point	Dew Point	Dew Point
Barometric Pressure	Barometric Pressure	Barometric Pressure	Barometric Pressure
Carbon Dioxide	Carbon Dioxide	Carbon Dioxide	Carbon Dioxide
ACCREDITED CALIBRATION SERVICES			
 	 		 
Relative Humidity	Relative Humidity		Relative Humidity
Temperature	Temperature		
Dew Point	[Name]		Dew Point
Barometric Pressure	Barometric Pressure		



A detailed close-up photograph of a mechanical watch movement. The image shows various gears, including a large yellow gear and several smaller silver and yellow gears. There are also small red jewels (sapphire crystals) visible, which are part of the watch's internal mechanism. The background is a light-colored metal plate with some engraved markings.

Traceability

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International System of Units: SI

Système international d'unités

SI base units

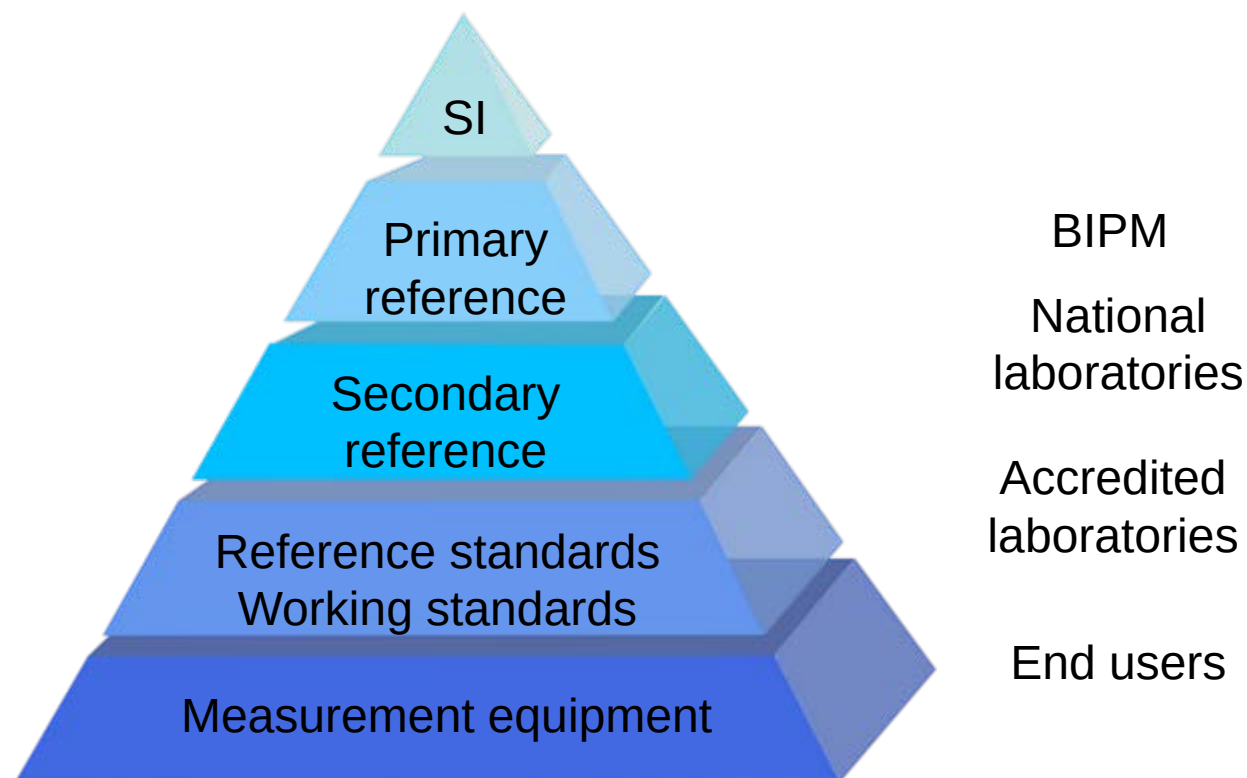
Length	1 metre
Mass	1 kilogram
Time	1 second
Electric current	1 Ampere
Temperature	1 Kelvin
Amount of substance	1 mole
Luminous intensity	1 candela

Measurement standard, in which all traceable measurements can be traced

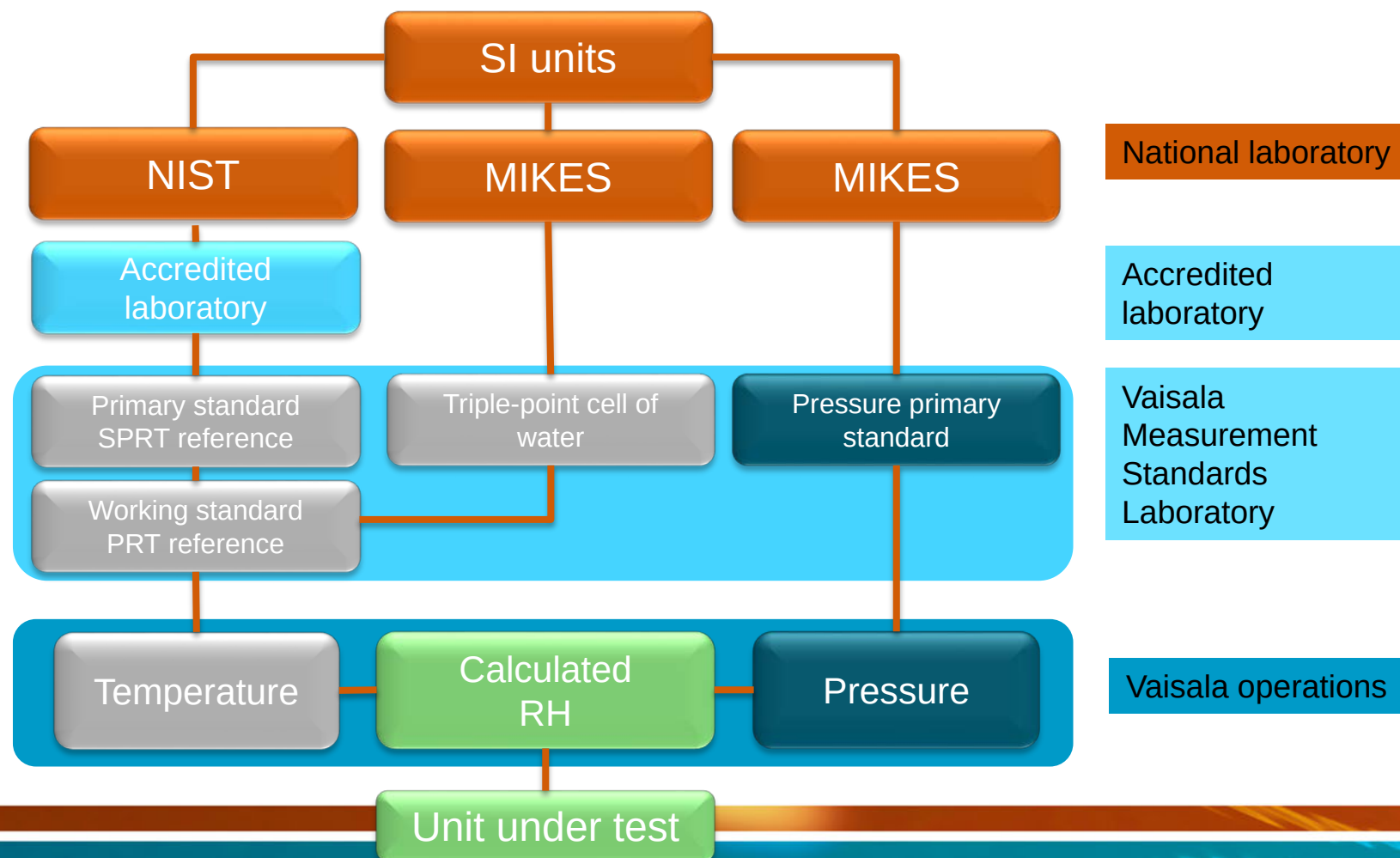


Traceability

“Property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty”



Simplified example: Traceability of Vaisala RH instrument



Which option works best for you?

- QMS requirements
- Number of points needed
- Humidity range
- Temperature range
- Accuracy requirement

■ Field calibration

- Own staff or sourced

■ In-house laboratory

- Manage your own lab, training, standards, traceability, documentation...

■ External service provider

- Evaluating service provider, auditing

■ Factory calibration

- Highest quality references
- Calibration + Adjustment
- Functional check
- Small repairs included
- No worries

Quiz

- Calibration means _____ with a known reference?
- _____ management system guides maintenance of the instruments?
- _____ point calibration works best for applications with narrow operating range
- Traceability means the _____ of the measurement is calculated and documented in relation to the international standard

What is Dew Point and How It is Measured?

Juhani Lehto
Product Manager

VAISALA

Agenda

1. What is Dew Point?
2. How to Choose the Right Dew Point Instrument
3. Application Examples
4. Quiz – Test Yourself

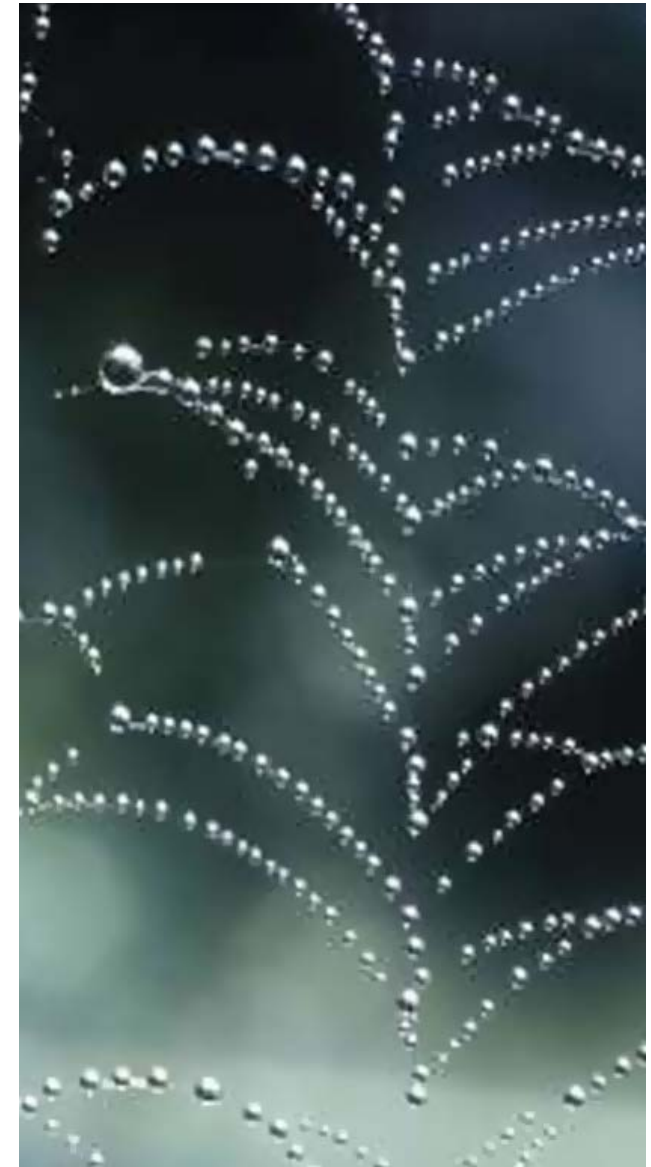


1. What is Dew Point?

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Dewpoint - Simple View

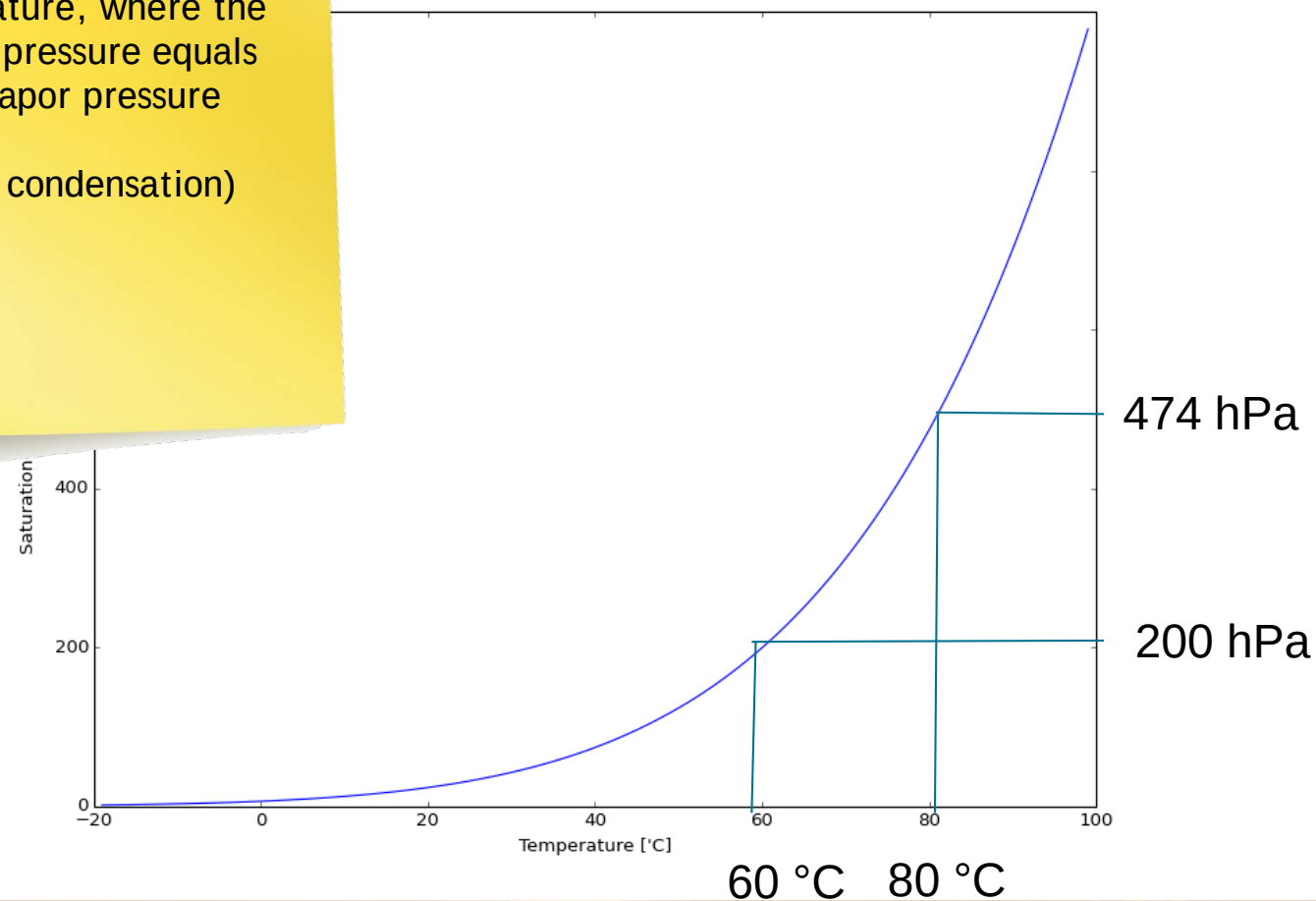
- Dewpoint is the temperature to which a gas must be cooled for the water vapor to condense into water
 - At dewpoint, the relative humidity is 100 %RH
 - The gas is saturated: contains its full capacity of water vapor



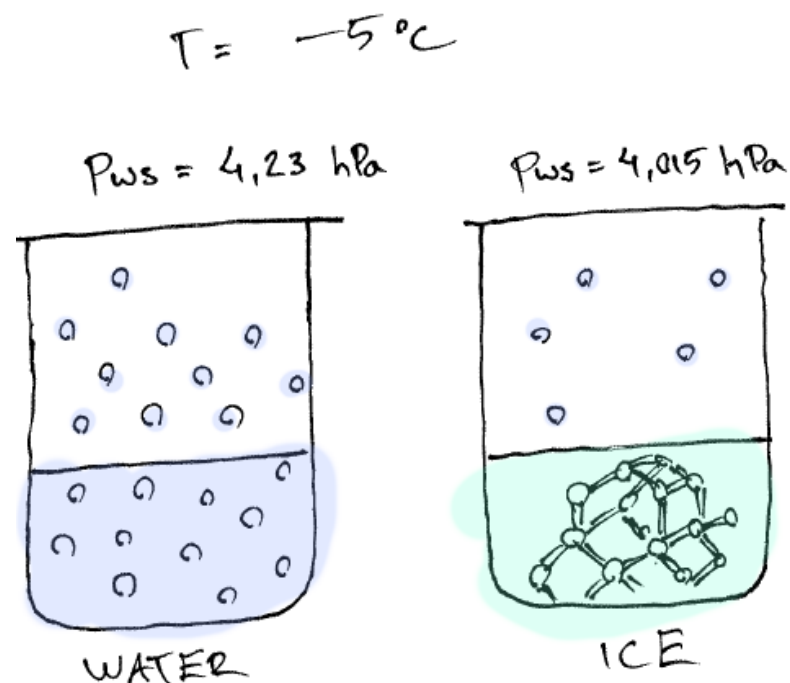
Dewpoint and Vapor Pressure

Dew point temperature is the temperature, where the given vapor pressure equals saturation vapor pressure

(RH = 100%, condensation)

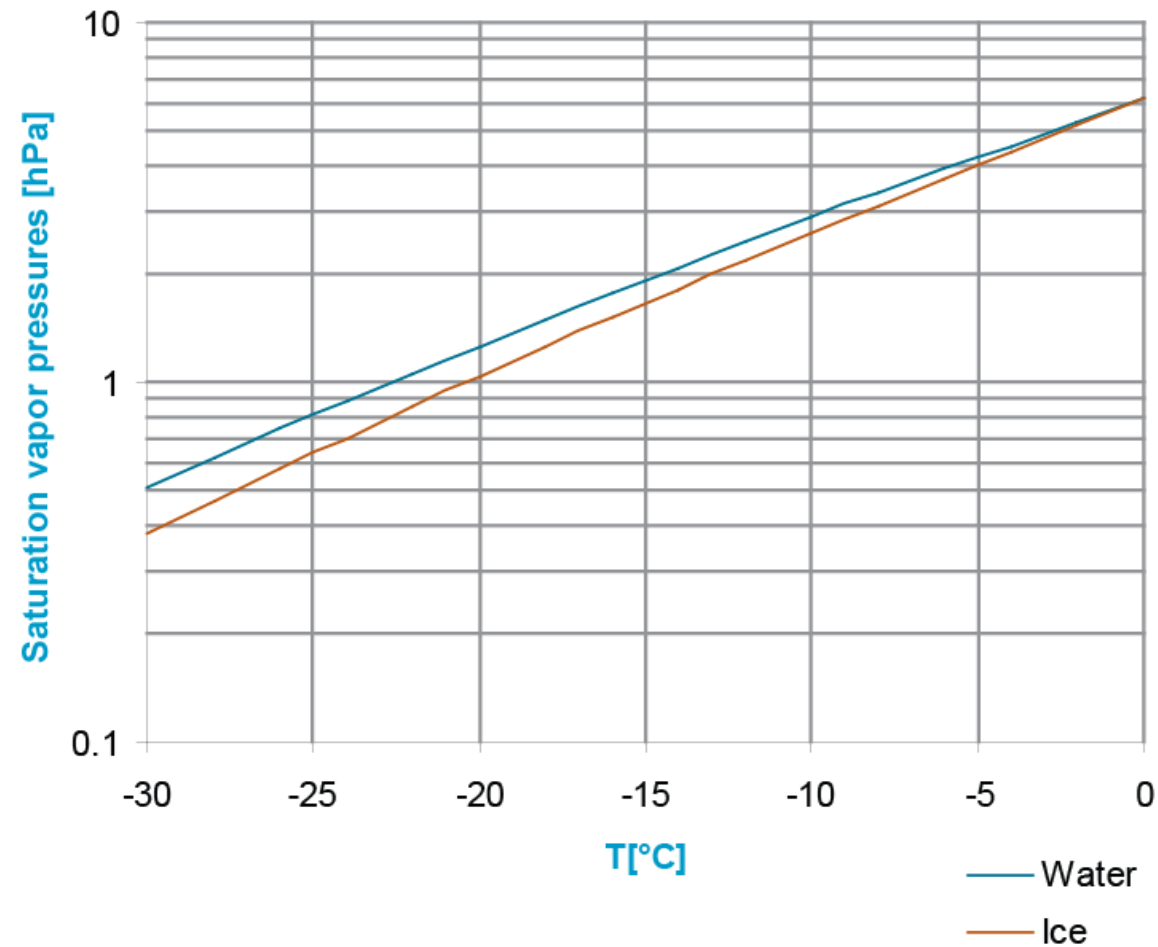


Dew Point and Frost Point

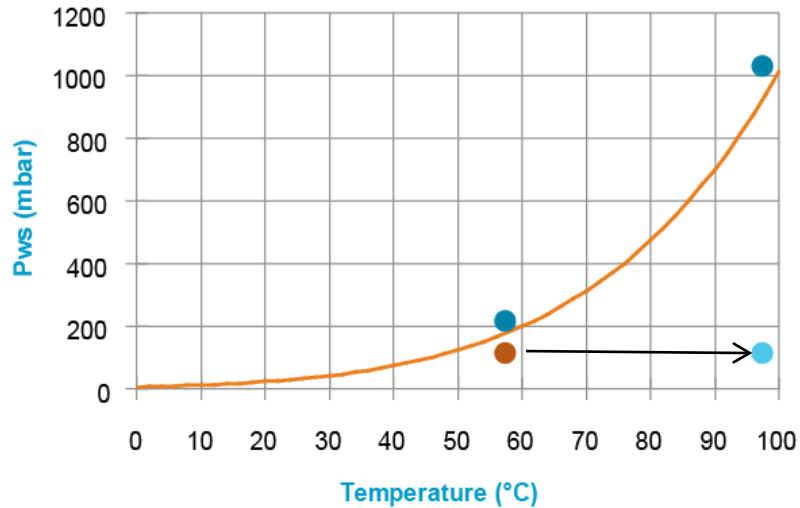


- "Dew point is the temperature where water vapour saturates with respect to *plane of water*"
- "Frost point is the temperature where water vapour saturates with respect to *plane of ice*"

Difference Between Dewpoint and Frostpoint



Temperature Doesn't Change Dew Point



Changing the temperature doesn't change the dew point, it depends only on the vapor pressure

$$T_a = 60\text{ °C}$$
$$T_d = \underline{47\text{ °C}}$$

$$P_{ws} = 200\text{ hPa}$$
$$P_w = 100\text{ hPa}$$

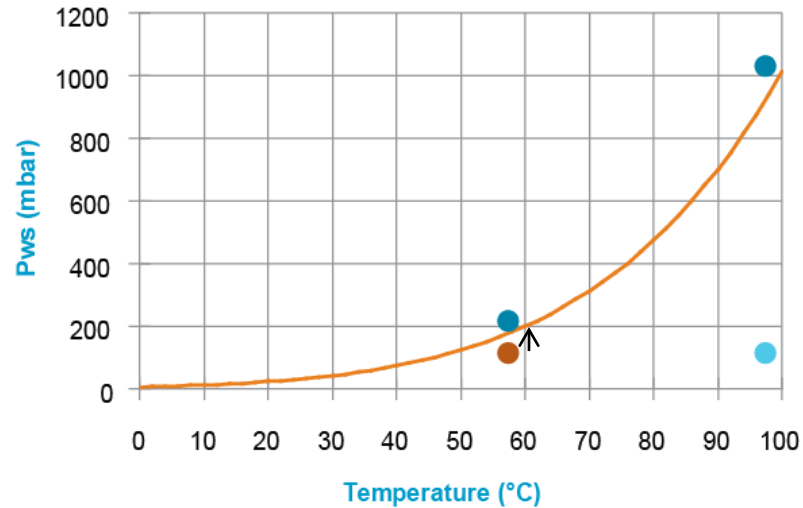
$$RH = 100 \times 100/200 = \mathbf{50\%RH}$$

$$T_a = 100\text{ °C}$$
$$T_d = \underline{47\text{ °C}}$$

$$P_{ws} = 1013\text{ hPa}$$
$$P_w = 100\text{ hPa}$$

$$RH = 100 \times 100/1013 = \mathbf{10\%RH}$$

Pressure Changes Dew Point



Changing the Pressure changes the dew point as the vapor pressure also changes

The vapor pressure is directly proportional to total pressure

$$T_a = 60\text{ }^{\circ}\text{C}$$

$$T_d = \underline{47\text{ }^{\circ}\text{C}}$$

$$P_{ws} = 200\text{ hPa}$$

$$P_w = 100\text{ hPa}$$

$$P_{tot} = 1\text{ bar}$$

$$RH = 100 \times 100/200 = \mathbf{50\text{ \%RH}}$$

$$T_a = 60\text{ }^{\circ}\text{C}$$

$$T_d = \underline{60\text{ }^{\circ}\text{C}}$$

$$P_{ws} = 200\text{ hPa}$$

$$P_w = 200\text{ hPa}$$

$$P_{tot} = 2\text{ bar}$$

$$RH = 100 \times 200/200 = \mathbf{100\text{ \%RH}}$$

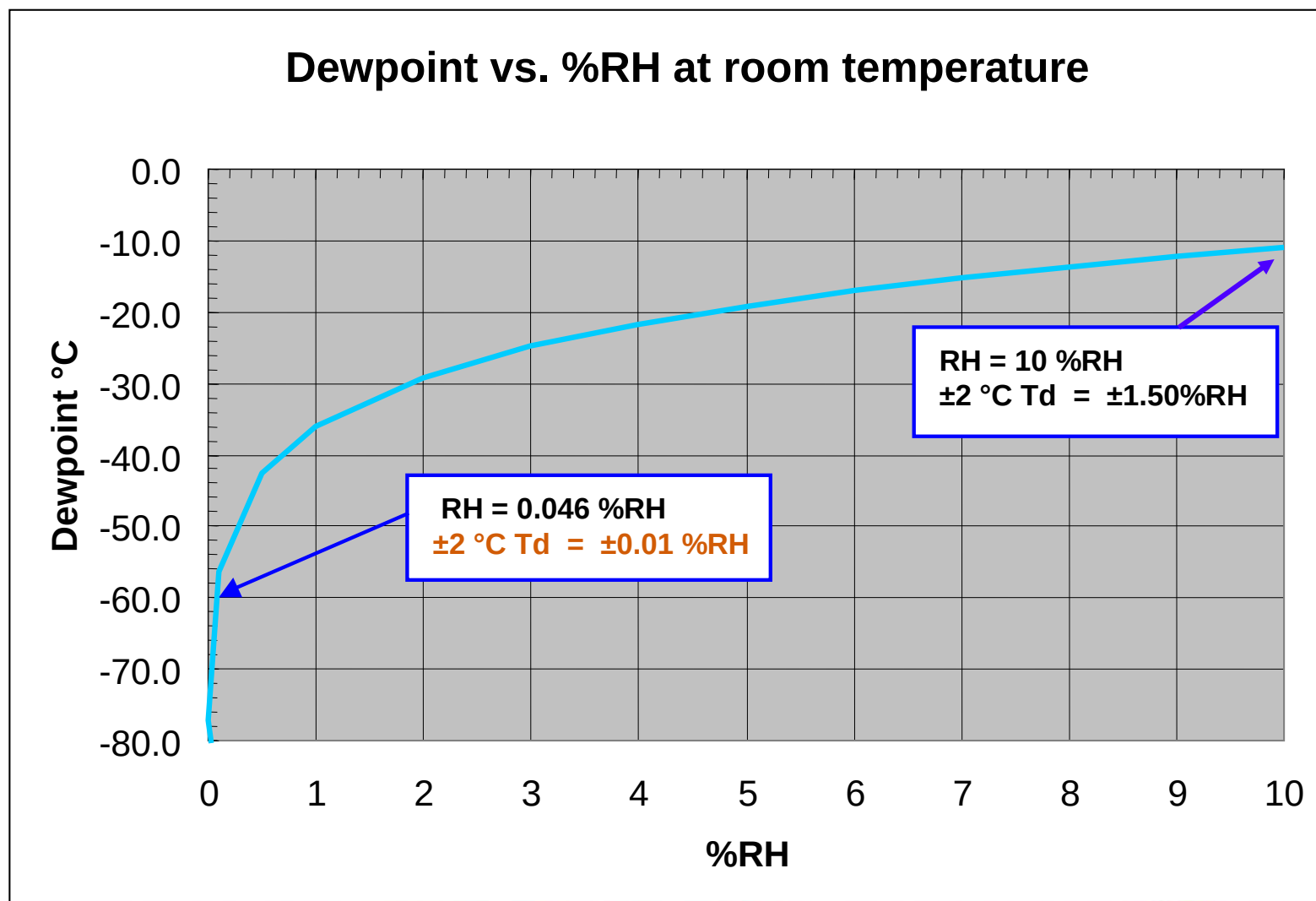
2. How to Choose the Right Dew Point Instrument

VAISALA

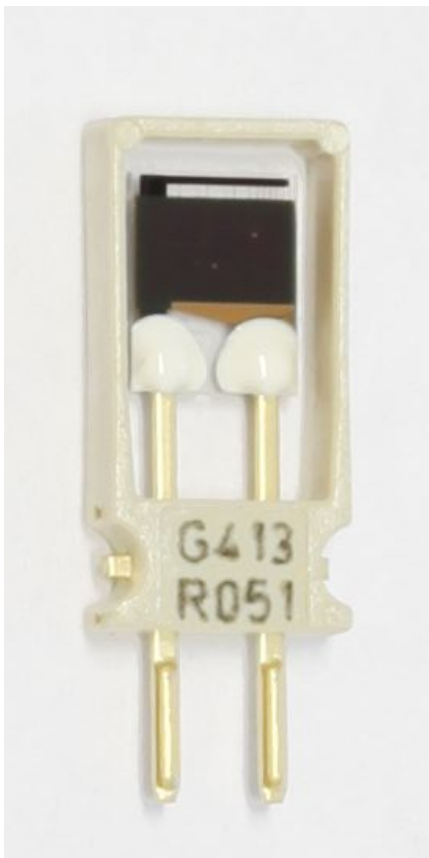
Vaisala Technologies for Humidity/ Dewpoint Measurement

- Vaisala instruments:
 - DRYCAP® technology for **low humidity** (below 10%RH)
 - HUMICAP® technology for **high humidity** (over 10 %RH)
- Both DRYCAP® and HUMICAP® instruments may have RH and Td/f outputs available. The choice of technology is not about parameter but humidity range of the application

When Dew Point, When Relative Humidity?



Capacitive RH Sensor

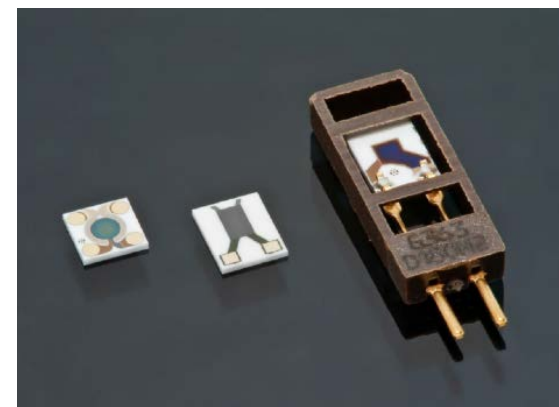


*The sensor capacitance responds directly to changes in **relative humidity**, not vapor pressure, absolute humidity or dew point temperature.*

- Additional parameters (saturation vapor pressure, vapor pressure, dew-point temperature, etc.) require information on the actual temperature
- A platinum RTD thermistor is located near the relative humidity sensor for temperature measurement.

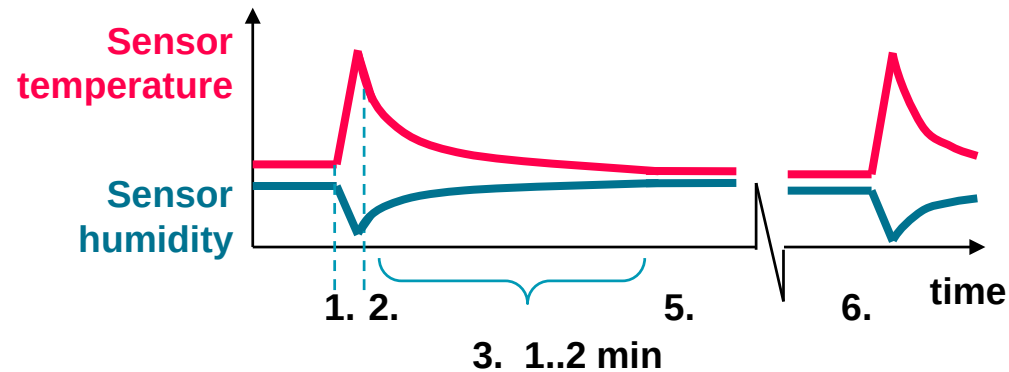
Vaisala Autocalibration

- Vaisala DRYCAP® technology utilize autocalibration procedure for accurate dew point measurement
- Autocalibration warms up the sensor automatically and makes the offset (= zero point) correction:
 - 1) guarantees the very good accuracy in low dew points
 - 2) offers excellent long term stability



Autocalibration in Detail

1. Auto-calibration start: Sensor warmed for a few seconds. RH value decreases when T increases
2. Sensor starts to cool down after short warming. RH reading starts to increase.

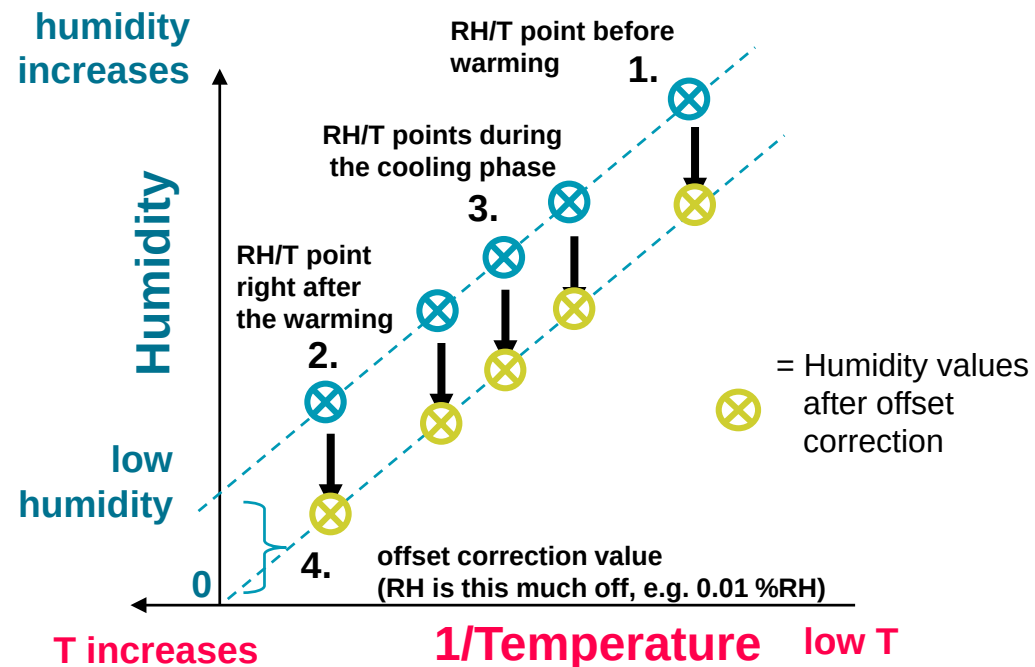


3. RH and T values logged during cooling phase

4. When drawing a straight line through the collected RH&T points the offset correction value is got as a result

5. Auto-calibration ends: Sensor is cooled and normal measurement mode gets active again using the correction value

6. After set interval (once/hour) auto-calibration repeated



DRYCAP® has Inbuilt Intelligence

- Auto-calibration

- typically once an hour and when the instrument switched on
- offset correction (zero point correction)

- Sensor purge

- once a day and when the instrument switched on
- gain correction (wet point correction)



- **Long term stability**

- **2 years recommended calibration interval**

- Sensor head warming

- in case of humidity > 70 %RH
- to avoid sensor wetting

Industrial Dew Point Products

WALL

DMT340 series

- Rugged housing with user interface
- ± 2 °C accuracy, Vaisala DRYCAP® sensor
- Wide hot temperature range -60..+80 °C / +180 °C / +350 °C
- Enhanced autocalibration, two years calibration interval
- Wide selection of options
 - variety of probes, datalogging, LAN, calculations



“When the going is tough”

OEM PROBE TRANSMITTERS

DMT152 Transmitter

- Compact and robust design for low dewpoint OEM applications
- ± 2 °C accuracy, Vaisala DRYCAP® sensor
- Wide cold temperature range -80..-10 °C / -112..+14 °F
- Enhanced auto-calibration, two years calibration interval



“Highest sensitivity”

DMT143 Transmitter

- Miniature size dewpoint transmitter for OEM applications
- ± 2 °C accuracy, Vaisala DRYCAP® sensor
- Dewpoint measurement range -60..+60 °C / -76..+140 °F
- Enhanced auto-calibration, two years calibration interval



“Compact”

DMT132 Transmitter

- Affordable dewpoint transmitter for refrigerant dryers
- Measurement range -20..+50 °C / -4..+122 °F
- ± 1 °C accuracy (-3..+20 °C / +26.6..+68 °F)
- Vaisala Humicap sensor, 2 year calibration interval



“High humidity”

Industrial Dew Point Products

HAND-HELD

■ DM70 Dewpoint Meter

- For industrial spot checking and field calibration
- ± 2 °C accuracy, Vaisala DRYCAP® sensor
- Easy-to-use user interface



“Spot checks”

MULTIPAREMETER

■ DPT145 Transmitter

- For SF6 insulation gas on-line monitoring
- Measures dewpoint, pressure and temperature
- Outputs seven SF6 parameters
- Multiple connection options available



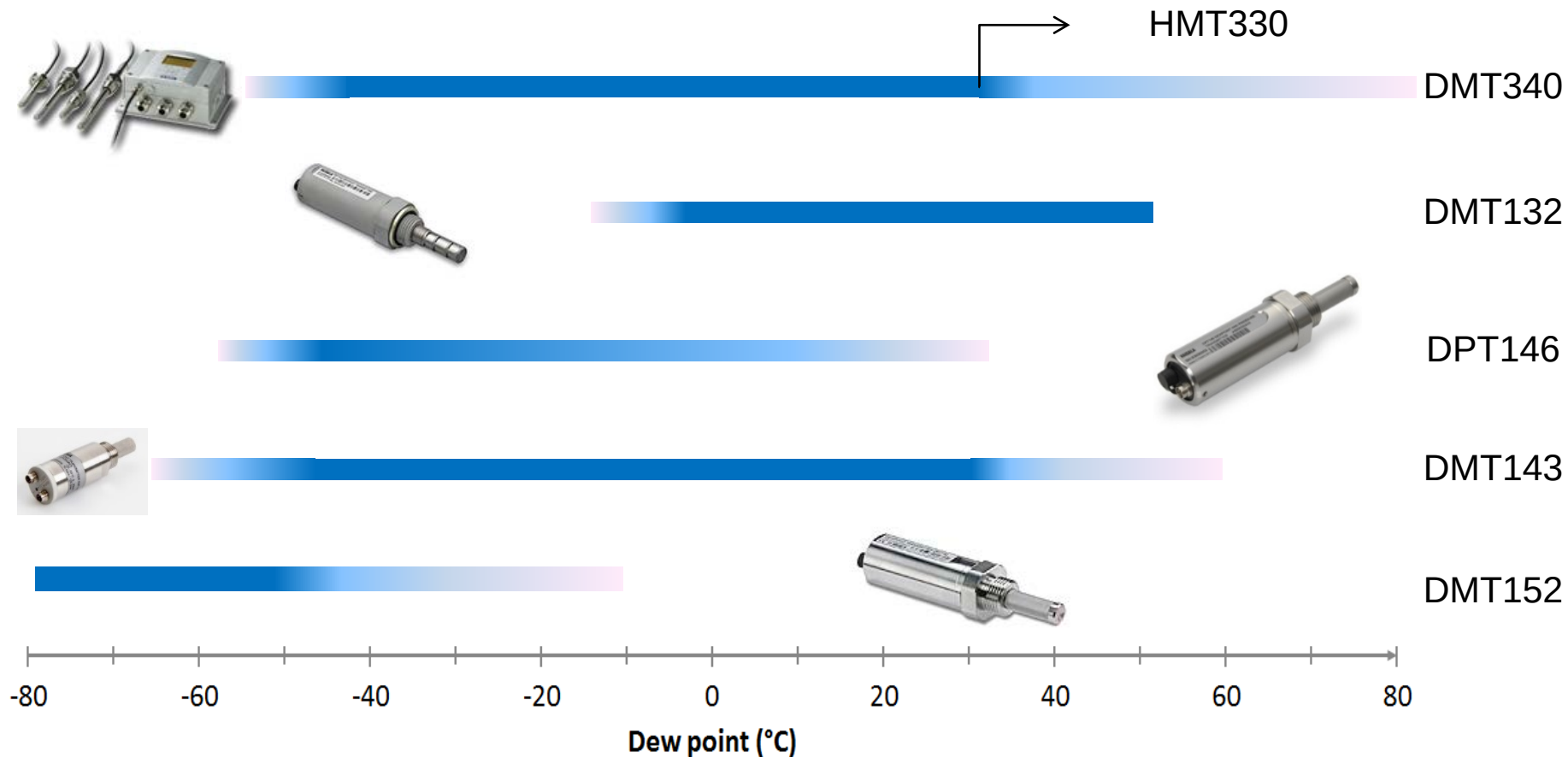
■ DPT146 Transmitter

- For compressed air network quality monitoring
- Measured dewpoint, pressure and temperature
- real-time pressure compensation, range up to 12 bara



“Pressure included”

Selecting Dewpoint Sensors - Measurement Range



Sampling Cells



DMT242SC

- G3/8", G1/4" ISO (inlet, outlet)
- G1/2" for probe

DMT242SC2

- Like above, but with 1/4" swagelok fittings

DSC74C

- For pressurized air, quick connector and leak screw
- Pressurized measurement

DSC74C

- For measurement in atmospheric pressure
- Fixed leak screw 3 ..1 0 bar

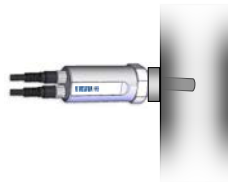
DMCOIL

- For venting the sample out in low dew point measurements

Process Pressure vs. Ambient

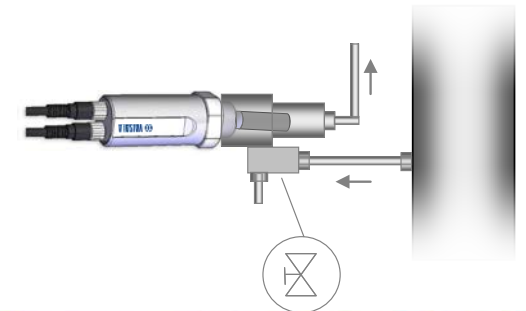
■ Measurement process at pressure

- + typically true specified dewpoint
 - Value that user wants to know e.g. in dryers
- + no sampling system needed
- + effect of pressure fluctuation is marginal.
Example:
 - $T_d = -40\text{ °C}$ at $p = 7\text{ bar}$ $\Rightarrow$
 - $T_d = -40.6\text{ °C}$ at $p = 6.5\text{ bar}$
- System shut down needed in case of sensor change
 - Solution available: use of pressurized sampling cell DSC74 with quick connector
- installation place and direction critical
 - sensor warming may not be able to keep sensor dry in most harsh conditions



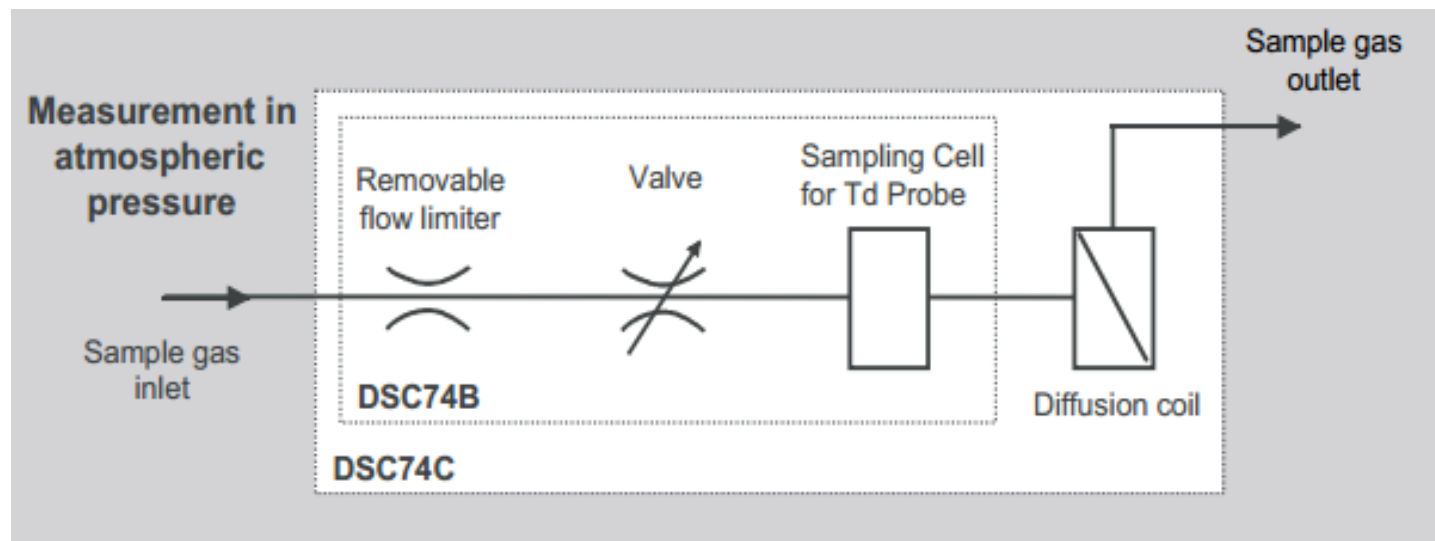
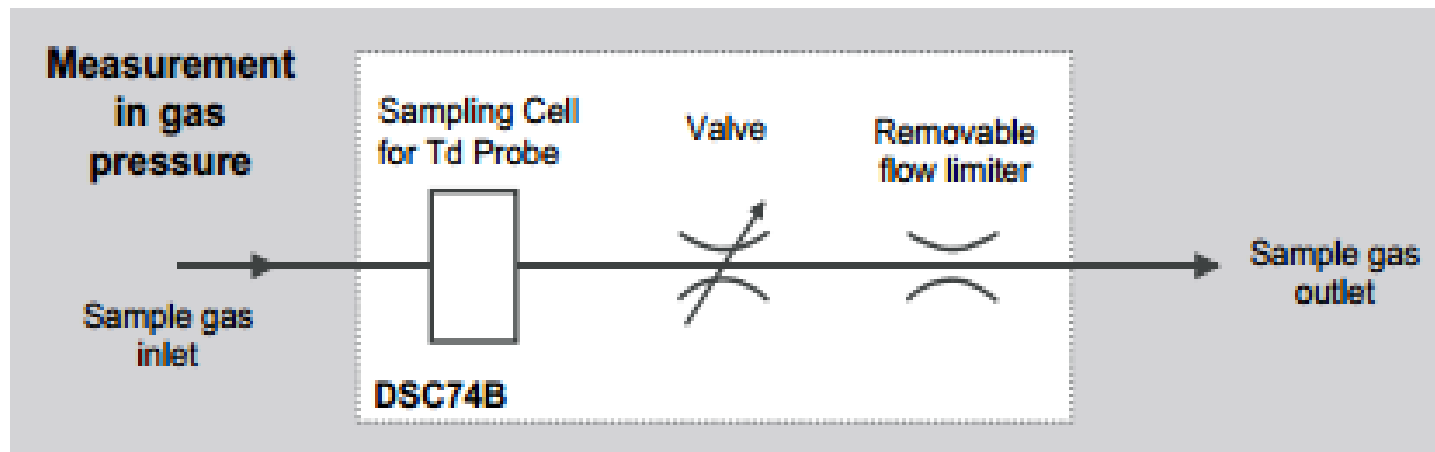
■ Measurement at ambient pressure

- + line pressure fluctuation has no effect
- + easy to remove instrument for service
- + protects sensor against humidity peaks (not typically necessary for DRYCAP®)
- - dewpoint not in the user specified pressure
 - depends of the application
- - sampling system with needle valve and venting coil needed
 - Solution available: Sampling cell DSC74B/C



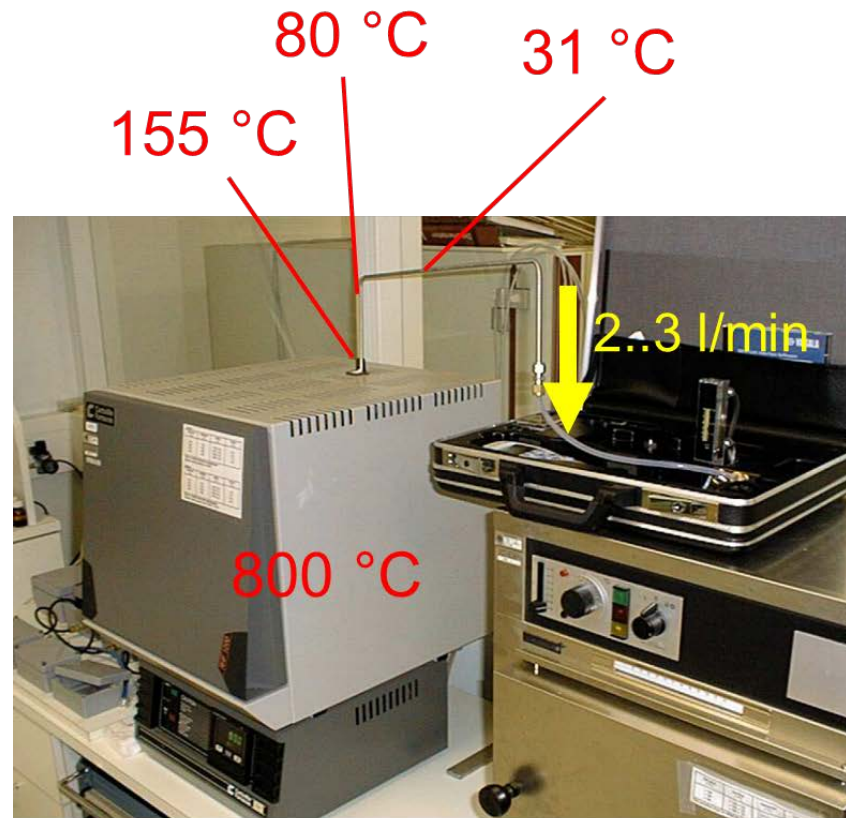


Vaisala DSS70A



Temperature

- Temperature affects relative humidity directly
- Beware of temperature leaks and insufficient stabilization
- For dew point, the pressure is more relevant
- Sometimes the application is too hot to be measured
 - Sampling is needed



1 °C temperature error may contribute to 6 %RH error in measurement

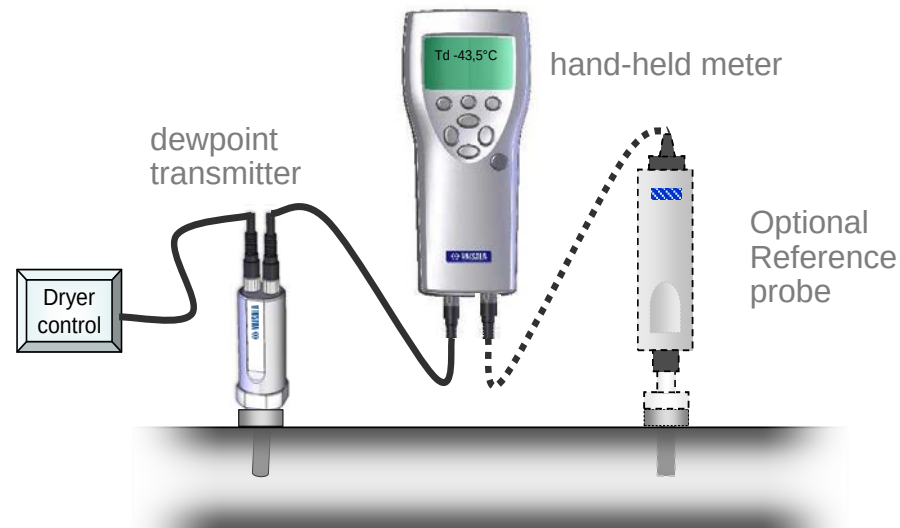
50 cm of 6 mm stainless steel tube cools down the sample to ~30 °C with 2..3 l/min flow

Sample temperature must remain above dew point temperature to avoid condensation!

Field Check with a Hand-Held Probe

- **DM70 hand-held meter**

- with a connection cable
 - field check of fixed instruments to determine service need
 - use as a temporary display or datalogger



3. Application Examples

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1) Compressed Air

Compressed air is often called the fourth utility in industry, right behind water, electricity and natural gas

- *Energy storage:*
 - *Instrument air for tools, robots, pneumatic actuators..*
 - *Trains: brakes, couplings, pneumatic doors..*
 - *Vortex cooling*
- *Conveyor media for powder, granulate or aerosol*
 - *Spray painting*
- *Drying, bottling, spraying, coating, packaging, cleaning..*
- *Medical air, diving, firefighting equipment..*



Why to Measure Dew Point?

- Dryer performance monitoring
 - Condition monitoring
- Dryer switching endpoint
 - Time controlled vs Dewpoint demand controlled
 - Efficiency
- Compressed air quality at point of use
 - Quality assurance

2) Drying Processes

move water to surface

promote evaporation

maintain low rh at
surface by removing
humid air

- Convective drying
- Spray drying
- Fluid bed drying
- Freeze drying
- Contact drying
- Vacuum drying
- Natural drying
- Supercritical drying
- ..



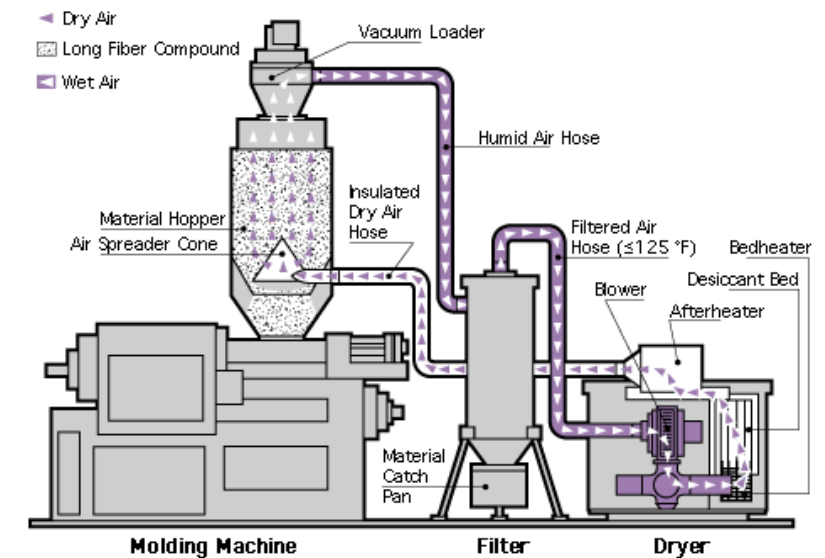
Example: Plastics Drying

- **Plastics are dried prior to processing**
 - Hydrolysis under elevated temperature
 - Reduces strength
 - Deteriorates appearance
 - Increases opacity in transparent plastics
- **Different plastics grades differ in sensitivity**
 - PET especially sensitive to moisture
 - Polyolephines not sensitive
 - Raw material supplier specifies drying
 - Recycled material may differ from new



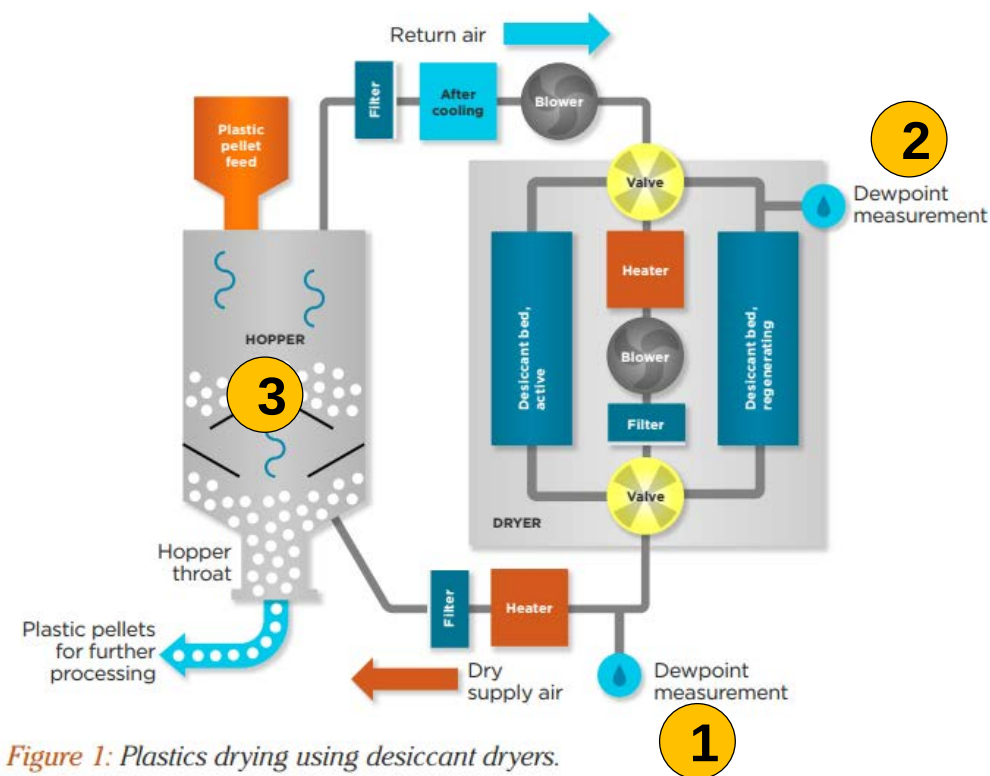
Desiccant Dryer

- Closed air circulation through desiccant bank
- Dew points typically
-10..-40 °C, down to -60 °C
- Temperatures in hopper
150 .. 300 °C



Measurement Positions

- 1) Continuous or spot checking from dryer outlet
 - Ensuring dryness of drying air
- 2) Continuous or spot checking from return air
 - For more accurate analysis on dryer operation
- 3) Spot checking within the silo
 - Empirical knowledge on granulate dryness



3) Heat Treatment Processes

- Metallurgical processing under controlled atmosphere i.e. blanketing gas to prevent work pieces from oxidizing and/or decarburizing
 - Severe oxidation of carbon steel begins at about 425°C (795°F)
 - Above 1200°C (2190°F), the oxidation rate increases exponentially
 - At high temperatures the carbon in steel also can react with the atmosphere to lower the carbon content

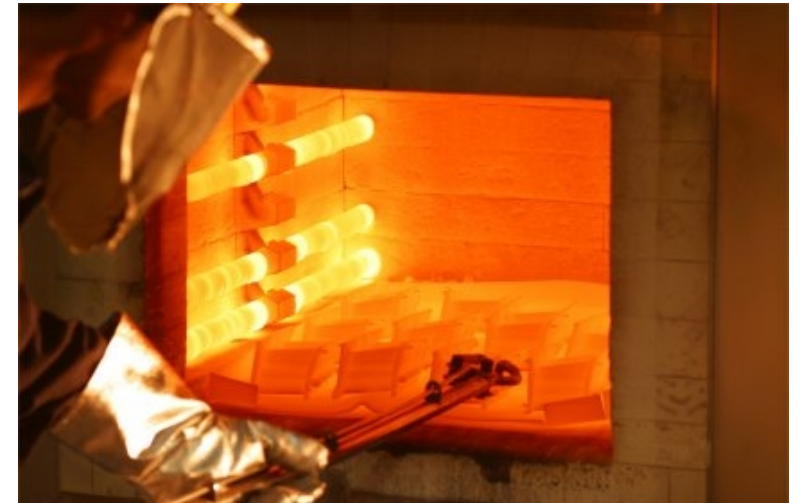


Carbon content (0,12 .. 2%) determines the hardness of steel

Oxidation affects quality

Measurement Requirements

- A heat treating furnace is not an ideal environment for measurement instruments.
 - The temperatures are mostly clearly above the operating limits of most sensors.
 - Furnace environment may contain different chemical vapors and contaminants such as oils, salts and particulate.
 - Sampling systems are required to enable dew point monitoring in furnace atmospheres.
- Conditions
 - Td -80 to +10 °C (-112 to +50 °F) (varies a lot between processes and furnace parts)
 - $p \approx$ atmospheric
 - T 500-1400 °C (1000-2500 °F)
 - Contaminants metal vapors, particles, H₂ durable sensor needed



4. Quiz – Test Yourself

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Quiz Questions

- Q1: Dewpoint is sensitive to _____ change
- Q2: You are measuring dewpoint below 0 °C (for ice), what is the parameter?
- Q3: The room has +20 °C and relative humidity is 50 % RH
 - a) What happens to the RH if we heat the room to +30 °C?
 - b) Does the dew point change? Why?
- Q4: Please explain what is happening in the picture and why?
- EXTRA: At +20 °C and 1 % RH, Td is a) -38 °C b) -33 °C c) -30 °C d) don't know



Answers

- 1. Pressure (T_d is independent of temperature)
- 2. Frostpoint (T_f)
- 3. a) RH decreases to 27 %, b) No. Pressure not changed
- 4. Bottle is colder than the dew point in the ambient air
- EXTRA: d) (don't know) is correct. No pressure information was given 😊

A photograph of a modern, multi-story building with a combination of red brick and large glass windows. The building has a distinctive architectural style with cantilevered upper floors. In front of the building, there are three flagpoles with blue and white flags. The foreground shows a paved area and some small trees. The text 'Thank You!' is overlaid in the center of the image.

Thank You!



What Is CO₂ and How Is It Measured?

Maria Uusimaa, Product Area Manager, Industrial Instruments

VAISALA

Agenda



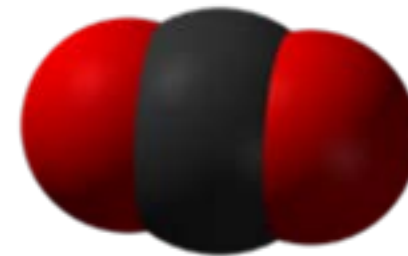
1. Why CO₂ Measurements?
2. Technology Background
3. Vaisala CARBOCAP® Technology and why it's unique?
4. Application Examples and How To Choose The Right Product?
5. Conclusion
6. Quiz

1. Why CO₂ Measurements?

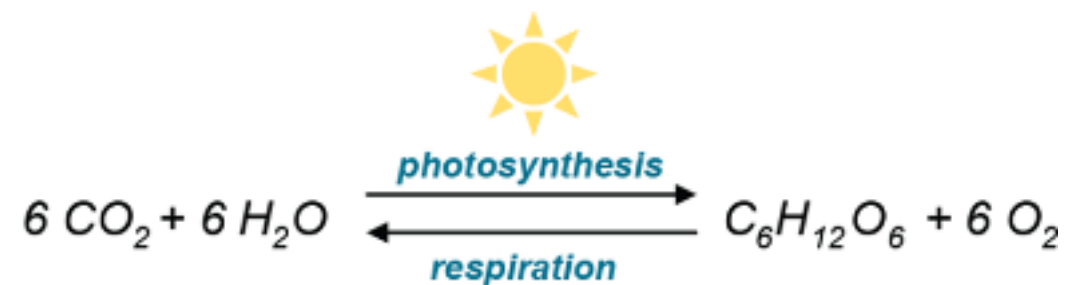
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What is CO₂?

- A colorless gas soluble in water
- A greenhouse gas
- A solid material called "dry ice" below -79 °C
- Formed in
 - combustion of carbon-containing materials
 - respiration and metabolism of living organisms
- Non-combustible and inert
- Used by plants in photosynthesis



CO₂ molecule



What are Typical CO₂ Concentrations?



AMBIENT

400 ppmCO₂



INDOOR

<1000 ppmCO₂



GREEN HOUSE

700 ... 800 ppmCO₂



CO₂ INCUBATOR

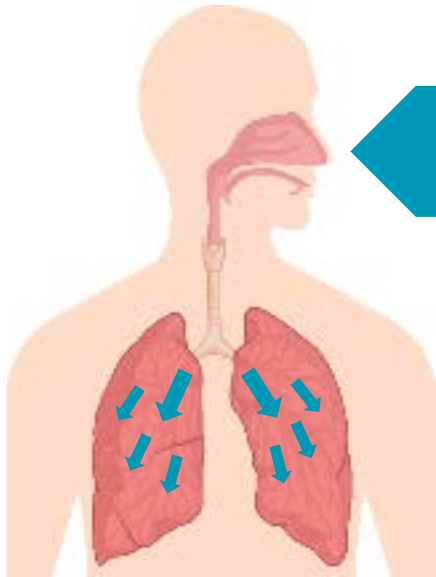
5 %CO₂ 37 °C >90 %RH



GARAGE

Elevated ppm level
(exhaust gases produce up to 20 %CO₂)

Indoor Air Quality

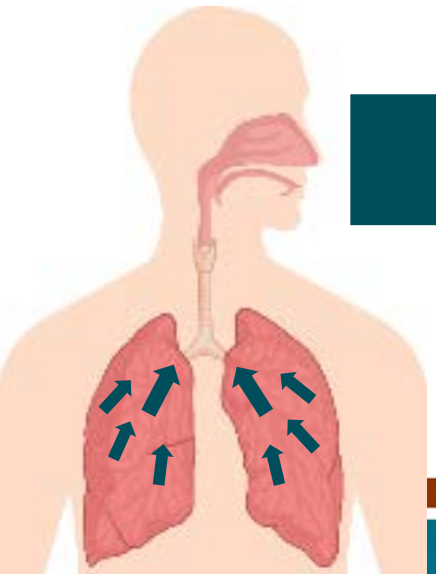


INHALE

Recommended indoor quality:
<1000 ppmCO₂

Maximum allowable concentration 8h/day:
5000 ppmCO₂

Acceptable peak limit:
10 000... 15 000 ppmCO₂



EXHALE

20 000...50 000 ppmCO₂
(2...5 %CO₂)

Effects of Overexposure

2...3 %CO₂

Symptoms of simple asphyxia occur

3...8 %CO₂

Increased respiration and heart rate, headache

...10 %CO₂

Headache, nausea, vomiting, and unconsciousness

10... %CO₂

Unconsciousness in less than 1 minute, death



Applications for CO₂ Measurements



**Energy management
& ventilation control**



Livestock husbandry



Egg setters and hatchers



**Food packaging and
processing**



Brewing/fermentation



Safety



Greenhouses



Mushroom farming



Fruit storage/transport/ripening



Incubators



Ecological research

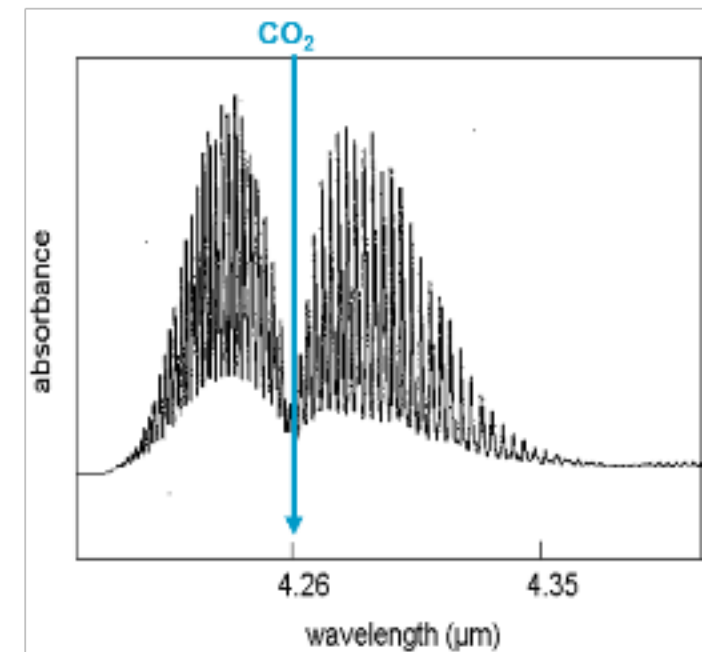
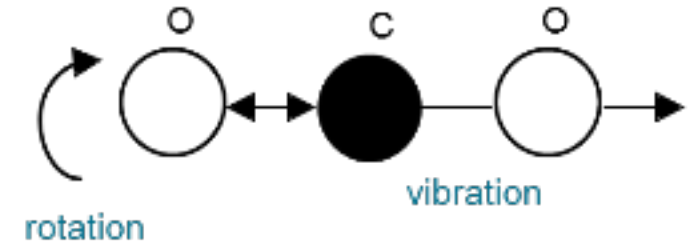
2. Technology Background

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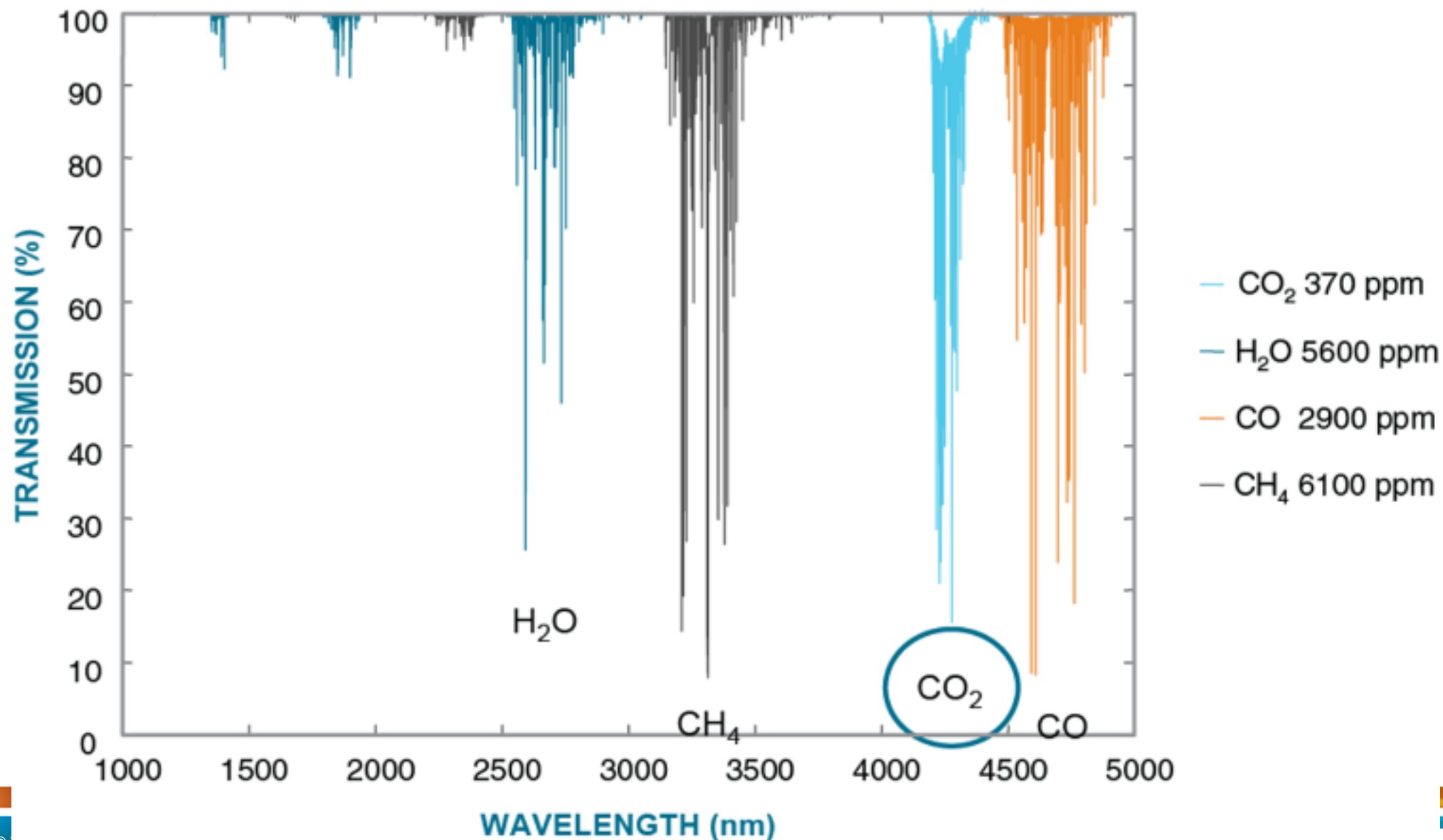
TECHNOLOGY BACKGROUND:

Infrared Absorption of the CO₂ Molecule

- Absorption spectrum occurs when light is absorbed by the gas molecule due to vibrations and rotations of the molecule and its atoms
- Unique fingerprint characteristics can be found for most gases
- The strongest CO₂ absorption band is found at 4.26 μm (mid infrared)
- Absorption of other gases is normally negligible in CO₂ absorption band



IR Absorptions of Some Gases



The CARBOCAP® Technology



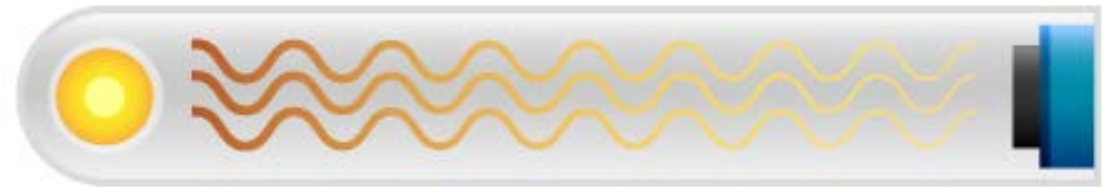
- Developed at Vaisala in the early 1990's, first products in 1997
- Is based on the absorption of infrared radiation by gases
- Utilizes a Vaisala proprietary silicon based tunable infrared filter (Fabry-Perot Interferometer, FPI)
- The amount of infrared light passing through the gas is measured at two discrete wavelengths:
 - the absorption wavelength (4.3 μm), where CO_2 absorbs strongly
 - the reference wavelength (3.9 μm), where CO_2 has no absorption
- CO_2 concentration is calculated from the ratio of the two

3. Vaisala CARBOCAP® Technology and why it's unique?

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Optical Infra-Red CO₂ Measurement Technology

- Light source, filter and detector → CO₂ measurement at 4.26 μm
- Attenuation in intensity gives the CO₂ concentration (e.g. 1000 ppmCO₂)
- Changes in sensor structure cause drift:
 - Light source intensity change
 - Dirt in optical cuvette
 - Any mechanical changes!



One IR source, one filter → CO₂ absorption wavelength

Ways to Overcome Drift: Different Optical Measurement Technologies

- Ways to compensate for drift
 - adding components
 - using software tricks, such as so-called ABC (Automatic background calibration)

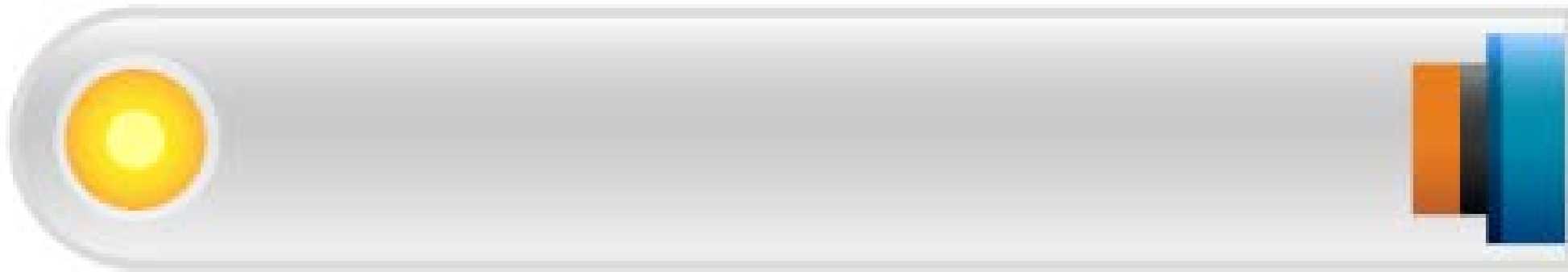


Two IR sources, one filter → reference source



One IR source, two filters → CO₂ and reference wavelengths

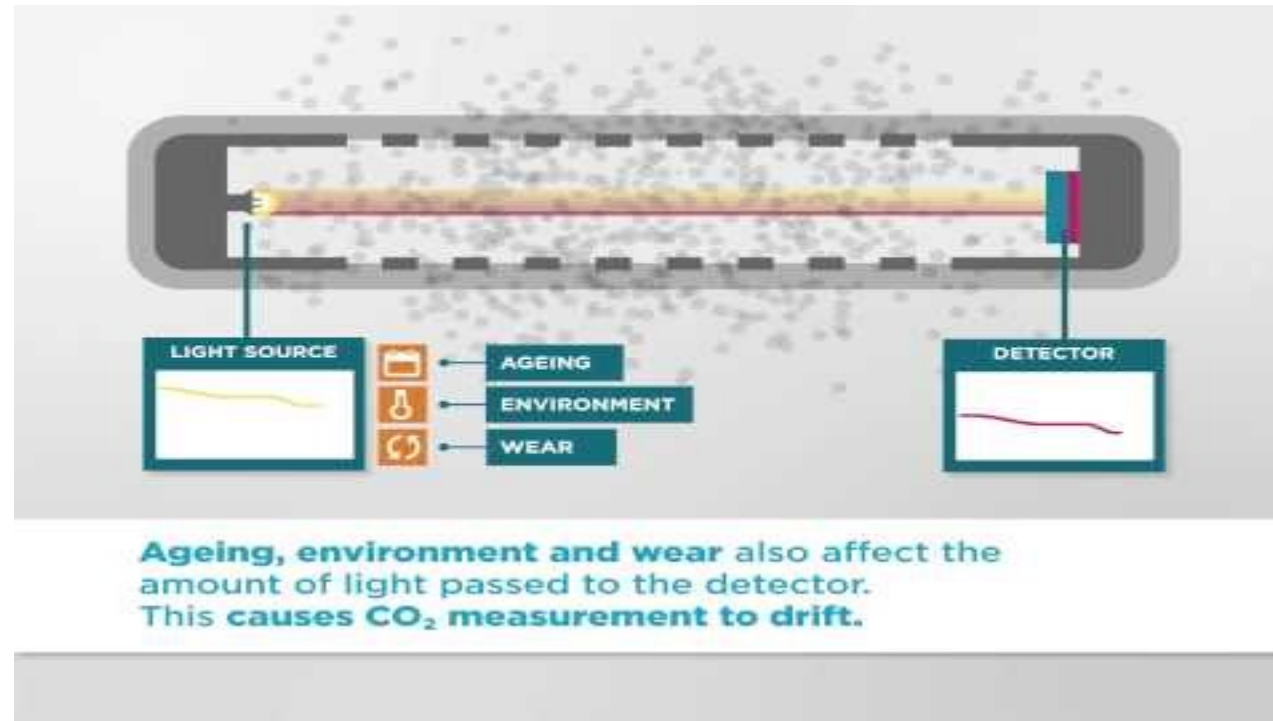
The CARBOCAP® - It's Unique



Vaisala CARBOCAP® sensor

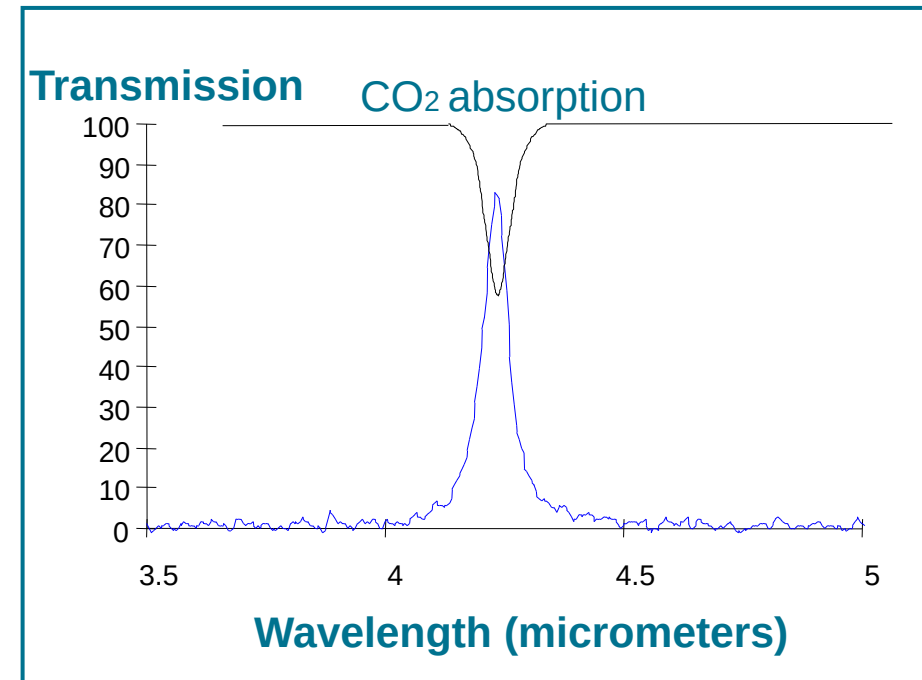
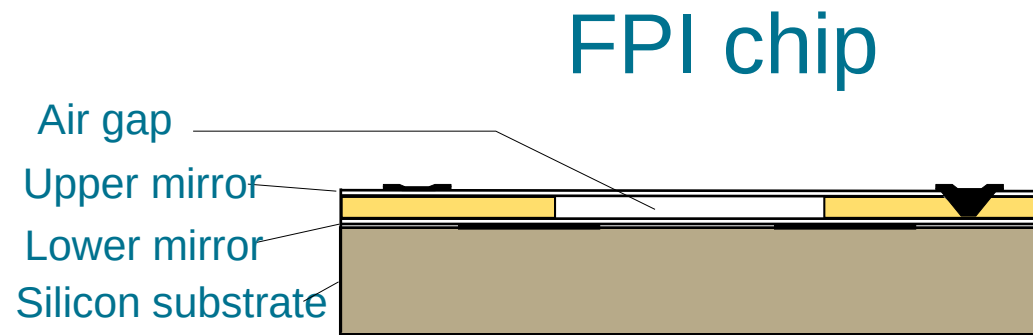
*One IR source, one tunable filter →
CO₂ and reference wavelengths = true referencing!*

Vaisala CARBOCAP® Technology



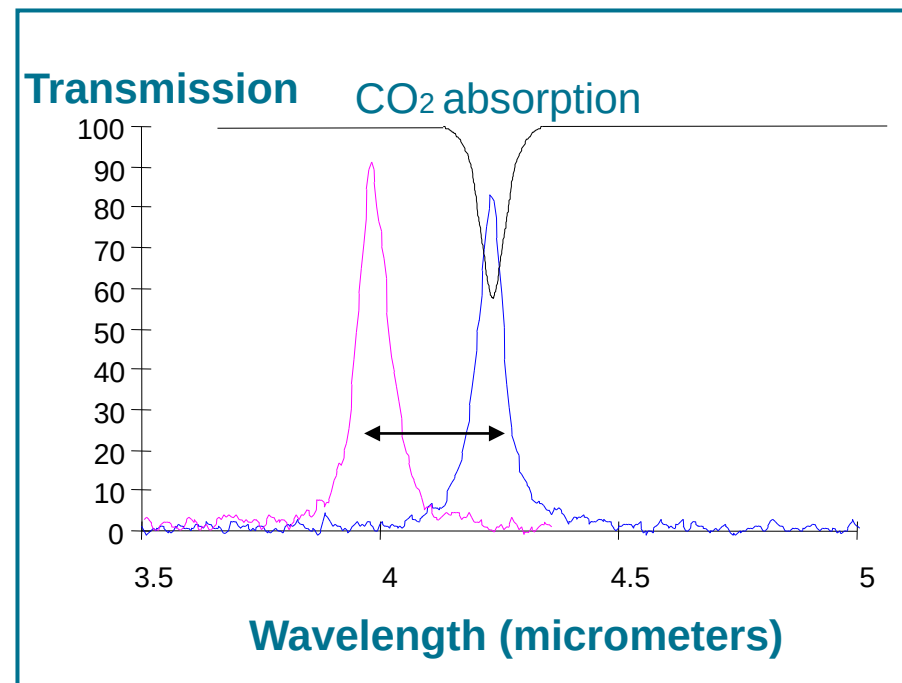
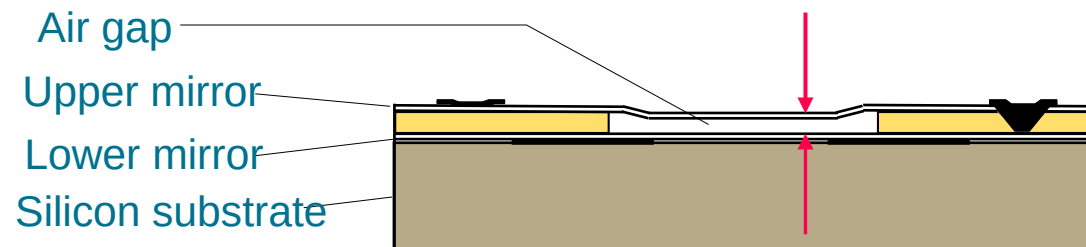
Tunable Bandpass Filter

Absorption Measurement

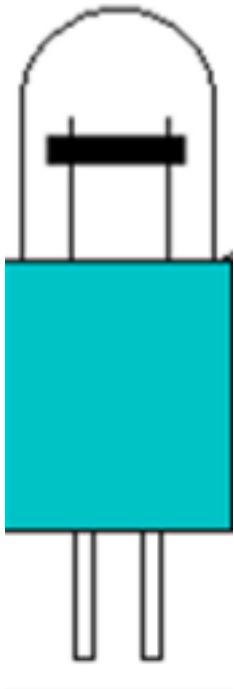


Tunable Bandpass Filter

Reference Measurement



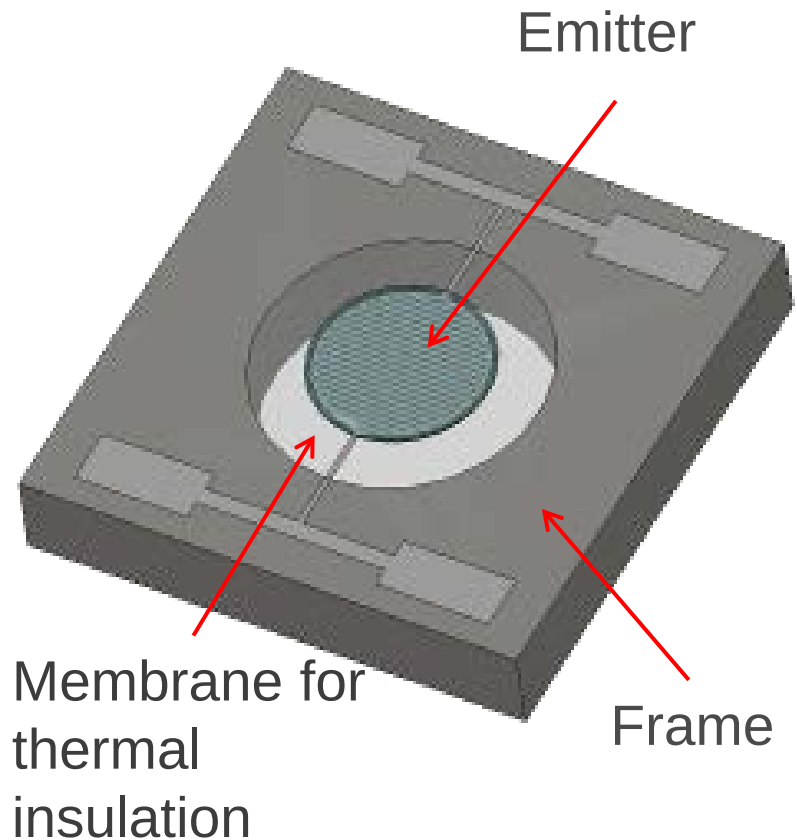
The 1st Generation: Traditional Filament Lamp as Light Source



- Limited lifetime
- Light power decreases over time
- High power consumption

The 2nd Generation: New Light Source

Now: The Microglow



- Long lifetime
- Stable light output
- Low power consumption
- Automatic assembly

We do everything ourselves

From chips



To calibrated
measurement
modules

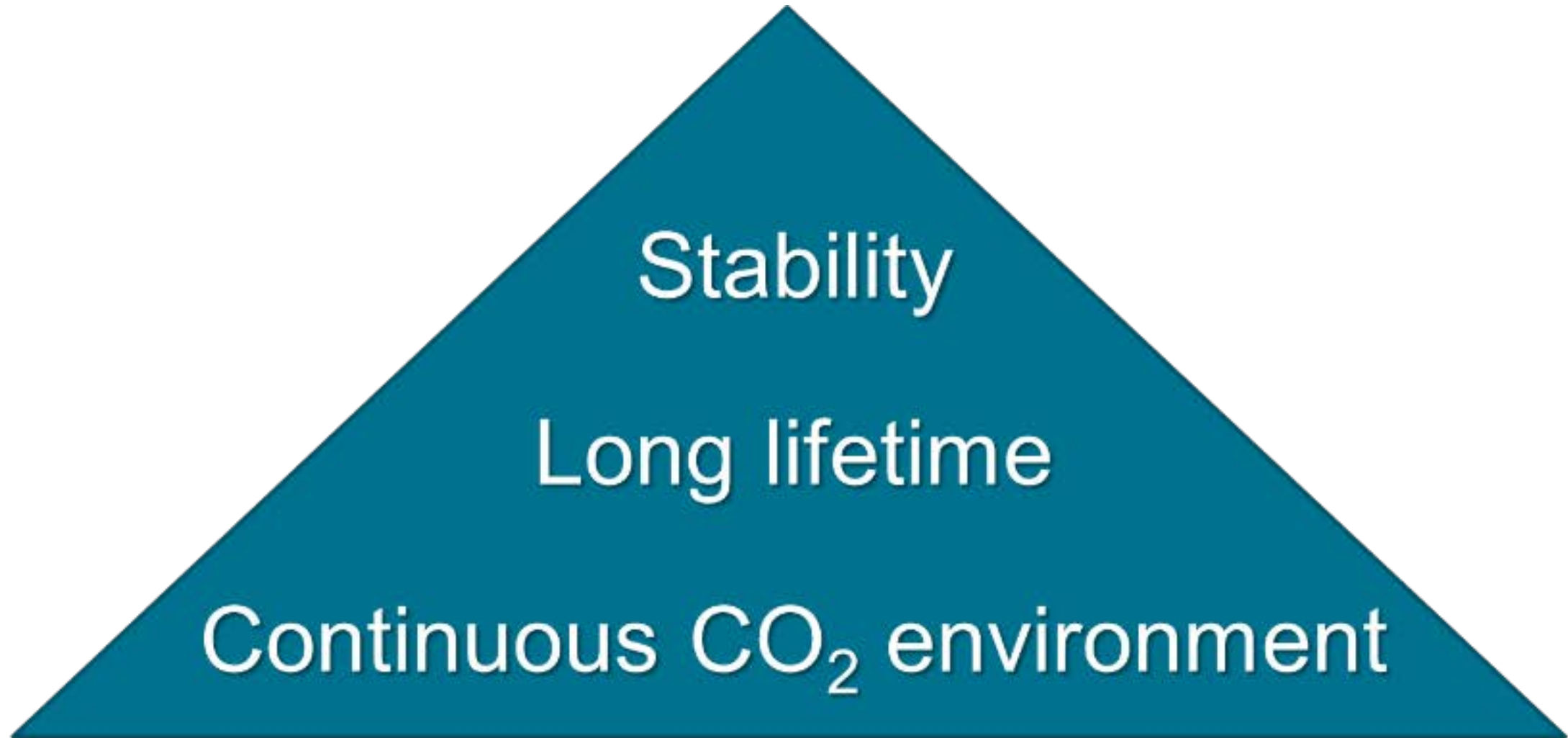


To a variety of products for different
measurement ranges and purposes



..with experience of CO₂ measurements since 1997

Vaisala CARBOCAP® Benefits



4. Application Examples and How To Choose The Right Product?

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Energy Management in HVAC

- Heating, Ventilation and Air Conditioning (HVAC) systems
- Motivation for measurement and demand controlled ventilation (DCV):
 - energy savings up to 40-50%
 - well-being of building
 - human comfort and health
- A recent Harvard study - cognitive performance is directly impacted by CO₂ level:
 - Baseline levels measured at 550 ppm CO₂
 - At 945 ppm scores decrease by 15%
 - At 1400 ppm scores decrease by 50%



CARBOCAP® Benefits in HVAC

- Good measurements = money saved on energy
- Desired indoor air quality
- Trouble-free operation for at least 15 years
- Works in constantly occupied spaces
- Immediate verification of operation



HVAC Products



■ GMW80 Series

- 0...2000 ppmCO₂, (RH+T)
- Analog outputs (mA, V)
- Display, setpoint, LED, relay and plain models



■ GMW90 Series

- 0...5000 ppmCO₂, RH and T
- Analog (mA, V) and digital (BACnet, Modbus)
- Exchangeable modules, certificated included

A wide-angle photograph of a large-scale commercial poultry farming operation. The facility is a vast, brightly lit indoor space with a high ceiling supported by numerous white pillars. The floor is densely packed with thousands of white chickens, likely broilers, which are distributed throughout the area. Interspersed among the birds are rows of orange, cone-shaped water dispensers connected by a network of white plastic pipes. The perspective is from a slightly elevated position, looking down the length of the building, which emphasizes the sheer number of animals and the scale of the infrastructure. The overall atmosphere is one of intense industrial production.

Measurement applications in Demanding Conditions

CO₂ in Agricultural Applications



Mushroom farms

<7000 ppmCO₂



Setters and Hatchers

Typically 3000...10 000 ppmCO₂



Storage of Fruit and Vegetable

Depends on fruit, %CO₂ level



Breweries, Wineries

Safe levels – both ppm and % used



Greenhouses

800...1000 ppmCO₂

Greenhouses: What Are The Benefits?

- Humidity tolerance
- Chemical durability
- Long-term stability
 - CO₂ fertilization is expensive, unstable measure can cost a lot of money



Why Measure in CO₂ Incubators?

- Special climate chambers used in life science laboratories to grow biological samples e.g. cell cultures
- Life-science incubators are mostly used at
 - 5 %CO₂
 - 37 °C
 - >90 %RH
 - Sometimes RH control/measurement is needed

➡ The same condition as in human body, the optimal conditions for cell growth!



CO₂ Incubators: What Are The Benefits?

Due to internal reference in constant 5 %CO₂ and high humidity and temperature:

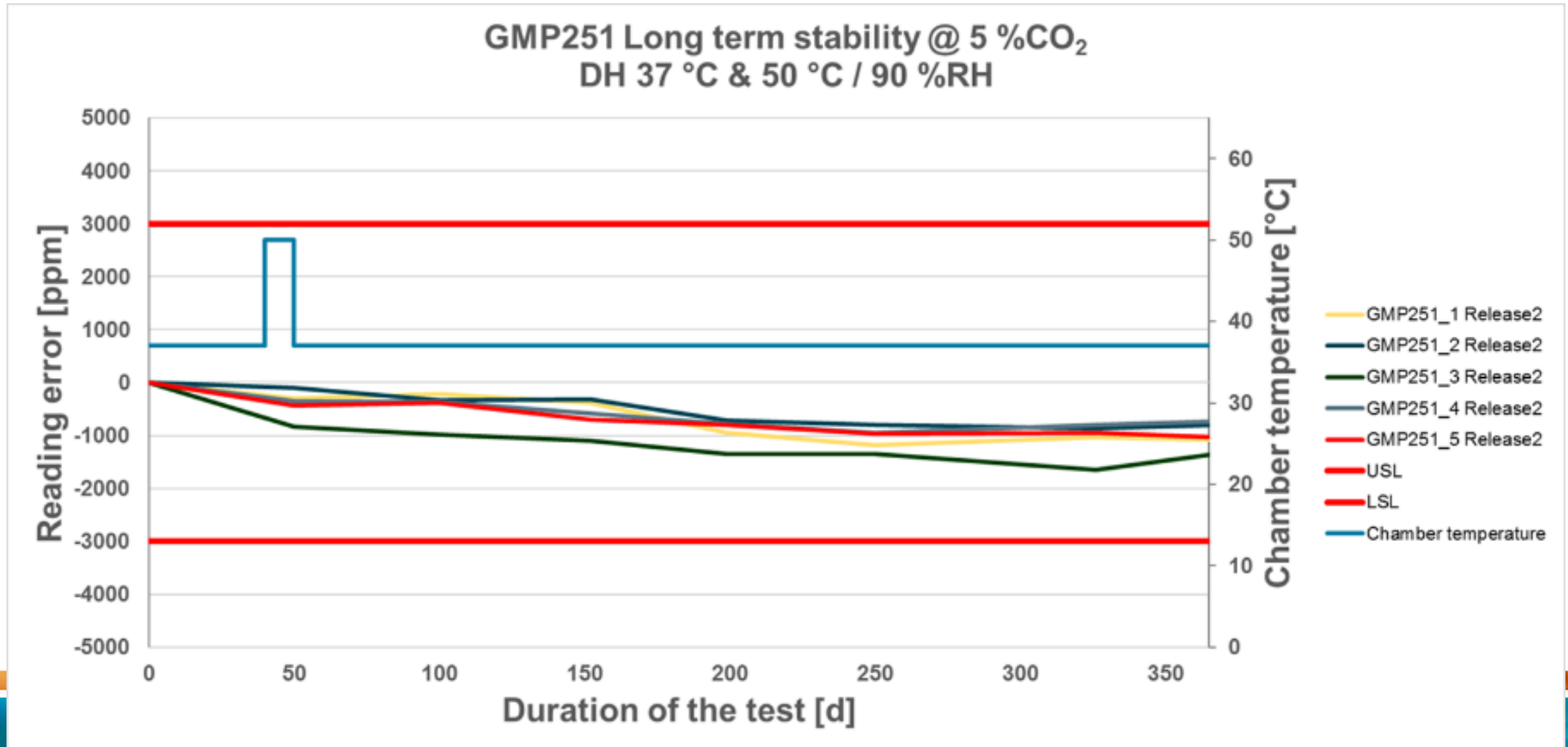
- Stability
- Long lifetime

For CO₂ incubator OEM's and monitoring:

- Wide range of products available:
 - 2nd generation products: GMP231, GMP251
- Heat sterilization durability (GMP231)
- Fast recovery when opening a door



Long-term Stability in a CO₂ Incubator



Food Packaging/Processing

- Adding CO₂ to food packaging extends storage and shelf life
 - E.g. high CO₂ concentration in meat packaging inhibits bacterial growth and retains the natural color of the meat
- CO₂ measurements are needed in places where CO₂ or dry ice is produced or used:
 - Breweries, pubs, soft drink industry, fruit storages, cold storages, grain silos, cargo ships for grain and fruit



Brewing/Fermentation

- CO₂ is formed as by-product in fermentation process
 - In soft drink industry, wineries, and breweries CO₂ is measured for safety reasons
 - In fermentation processes, e.g. enzyme manufacturing, CO₂ measurement is needed to control the process



Safety

- Alarms are needed where the CO₂ level can rise dangerously high, like
 - CO₂ gas production
 - CO₂ ice production
 - CO₂ (gas or ice) storage, shipping, use
 - CO₂ refrigerated facilities

- System requirements
 - reliable and fail safe
 - equipped with alarm outputs
 - Vaisala CO₂ measurement can be used as a part in a ***properly designed safety system***



Ecological Research

- Soil chambers
 - CO₂ soil respiration
 - Net Ecosystem Exchange NEE
- In-soil CO₂ measurements
 - CO₂ profile measurements
 - The measurement of microbial activity in agricultural, forest and soil research
- Measurement of dissolved CO₂
 - Effect of photosynthesis
 - The measurement of the CO₂ exchange in air-to-water layer
- Ecological measurement stations



Industrial CO₂ Products

*GMP343 for
Environmental/O
utdoor
Measurements*



*GMP231 for CO₂ incubators
and heat sterilization durability*



*GMP251/GMP252
and Indigo 200
Series*

*GM70 Hand-
Held CO₂
Meter*



5. Conclusion

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Things to Remember



- CO₂ can be measured optically from air-like gases
- Unique internal referencing of CARBOCAP® provides
 - **Stability**
 - **Long lifetime**
 - **Measurements in continuous CO₂ environments**
- Vaisala CARBOCAP® technology can be applied for a wide range of products
 - **ppm to % level**
 - **HVAC transmitters to probes for ecological research**

6. Quiz

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Open Questions

1. 1 %CO₂ in ppm is?
2. What CO₂ level is considered good indoor air quality?
3. What does a CO₂ incubator simulate?
4. Why does CARBOCAP® have good long term stability?
5. What is the weakness of ABC (automatic background calibration)?
6. **BONUS:** Why does Vaisala have CO₂ measurement probes of different lengths?

Thank You!

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Hydrogen Peroxide (H_2O_2) Measurement

Maria Uusimaa, Product Area Manager

VAISALA

Agenda

1. Why H₂O₂ Measurements?
2. Technology Comparison
3. Vaisala Technology
4. New Solution for H₂O₂ Measurement
5. Conclusion
6. Quiz



1. Why H₂O₂ Measurements?

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How and Why H₂O₂ is Used?



Benefits of H₂O₂ Bio-Decontamination

- Easy to use
- Destroys all biological contaminants
- Works in low temperature processes
- Processes can be validated
- Compatible with a wide variety of materials
- Environmentally friendly process
- Leaves no real residues – only water vapor and oxygen



2. Technology Comparison

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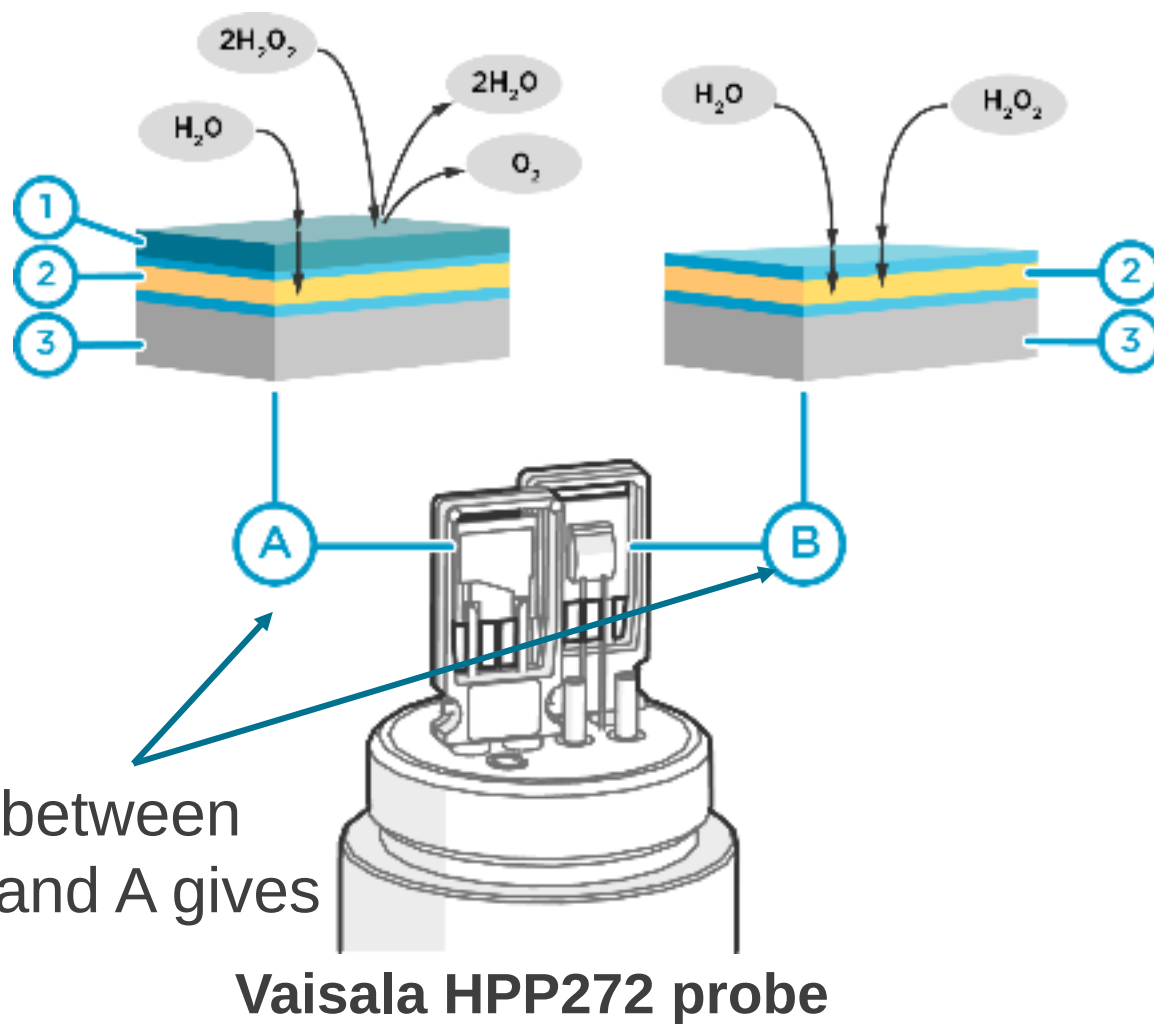
H₂O₂ Measurement Technologies

Technology	Benefits	Challenges	Measurement parameters
Electrochemical cells	Sensor cell easy to change	Short lifespan, repeatability	ppm (H ₂ O ₂)
NIR (near infrared technologies)	Stable, for R&D	Expensive, big size, not for low measurements	ppm (H ₂ O ₂ /H ₂ O), a (H ₂ O ₂ , µg/m ³), a (H ₂ O, g/m ³)
Gas analyzers (laser technology)	High selectivity, detection limit, low measurements	Expensive, big size, heavy, noncontinuous measurement	ppb, only low level measurements
Capacitive thin-film polymer sensor	Several measurement parameters, stable, repeatability, small size	Vaisala HPP272 not for safety applications (≤1 ppm)	RH%, RS%, °C, ppm (H ₂ O ₂), absolute H ₂ O ₂ , absolute H ₂ O, H ₂ O ppm by volume, saturation vapor pressure

3. Vaisala Technology

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Capasitive Thin-Film Polymer Sensor



1 = Catalytic layer

2 = Thin film polymer between two electrodes

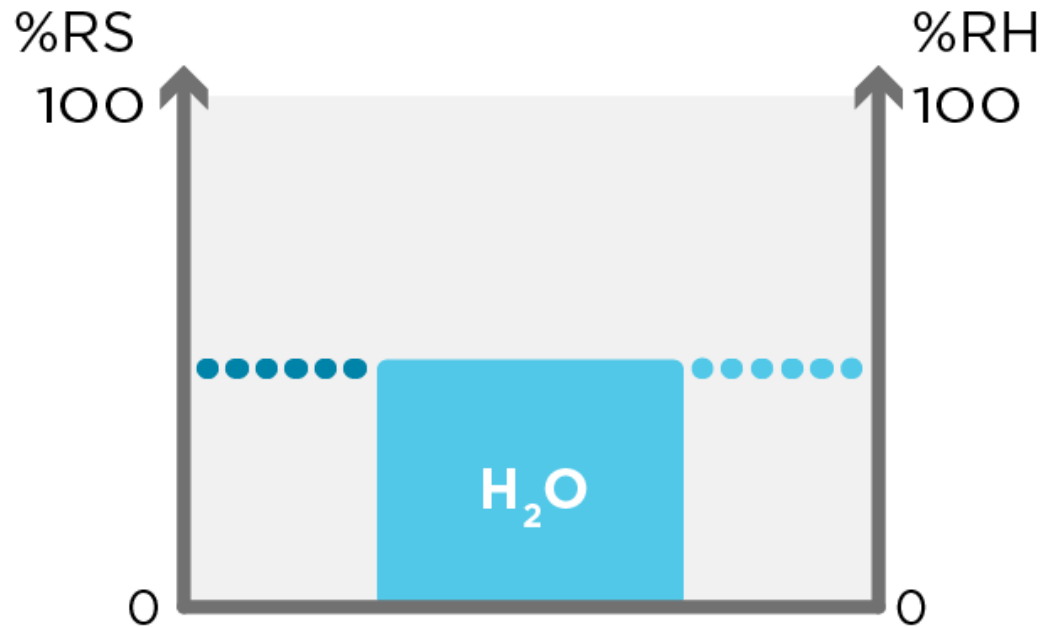
3 = Glass substrate

A = Sensor with catalytic layer

B = Sensor without catalytic layer

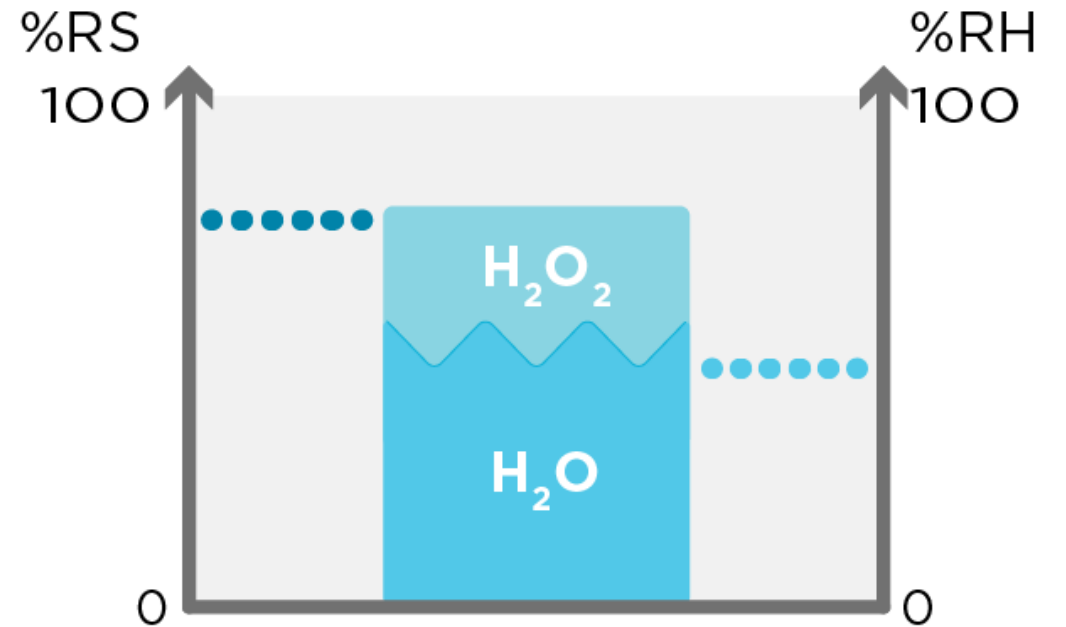
Sensor measures: **ppm, RS, RH, °C** + many other calculated parameters

Relative Saturation vs. Relative Humidity



1

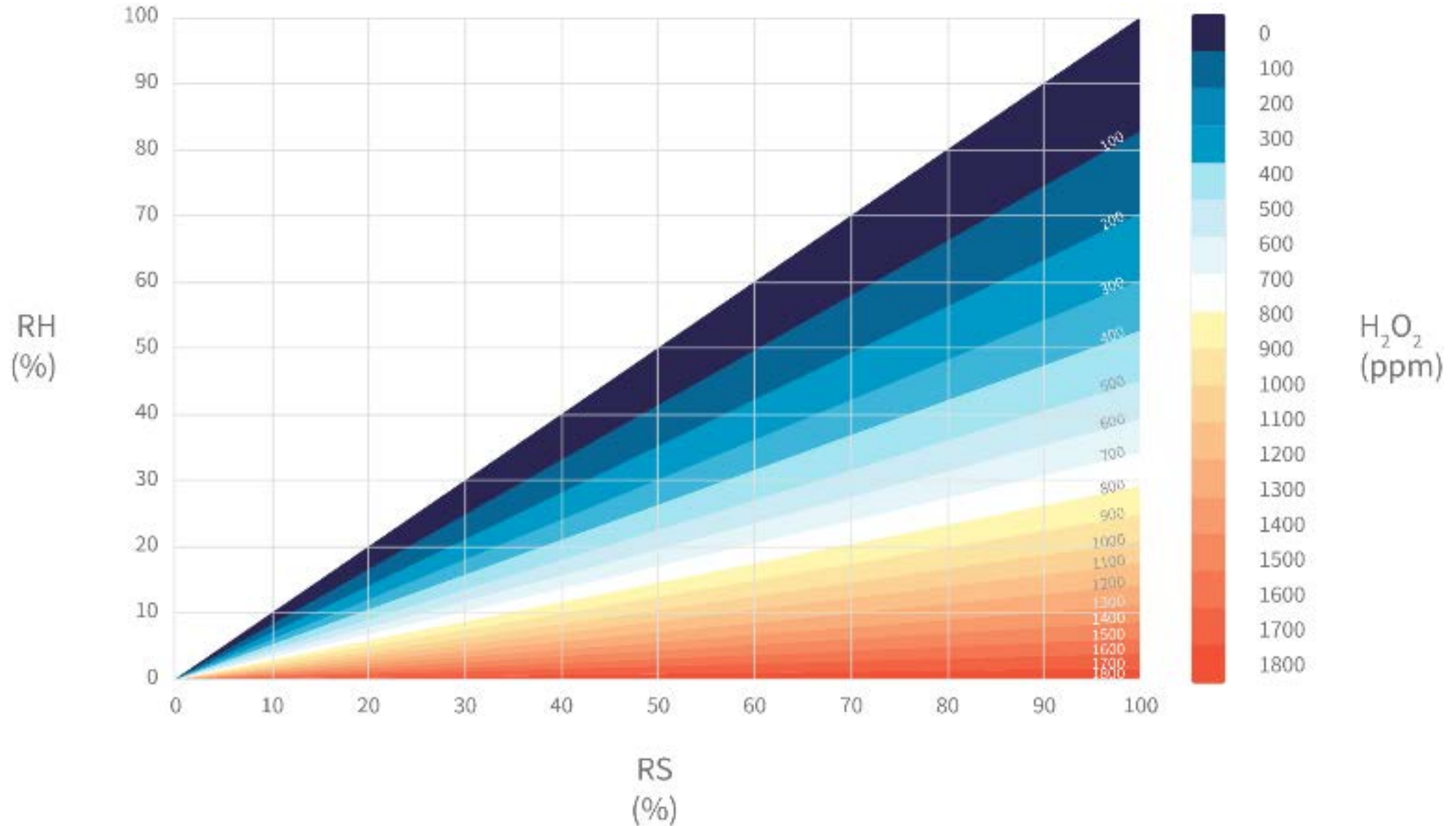
Only H_2O vapor present



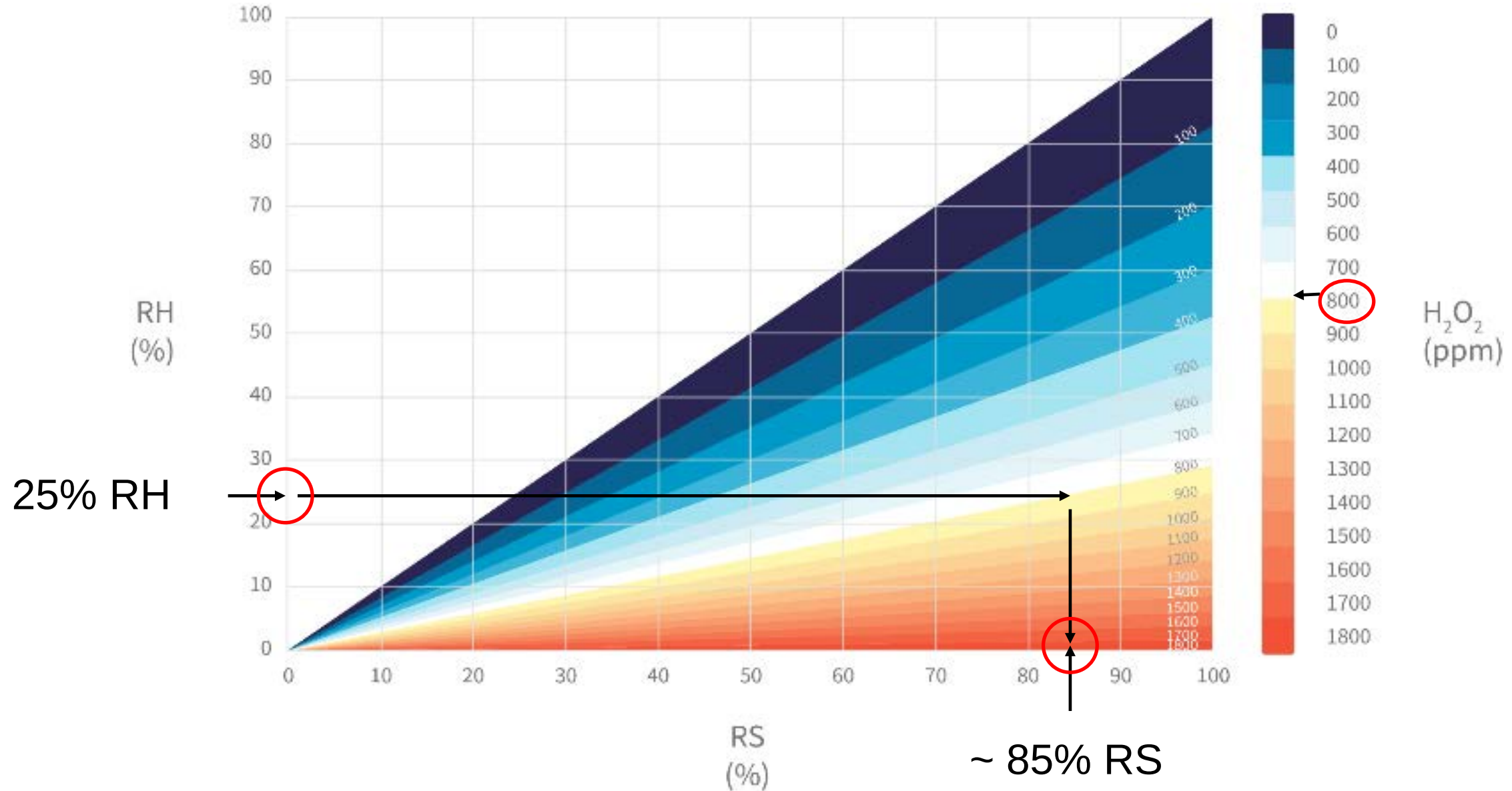
2

H_2O and H_2O_2 vapor present

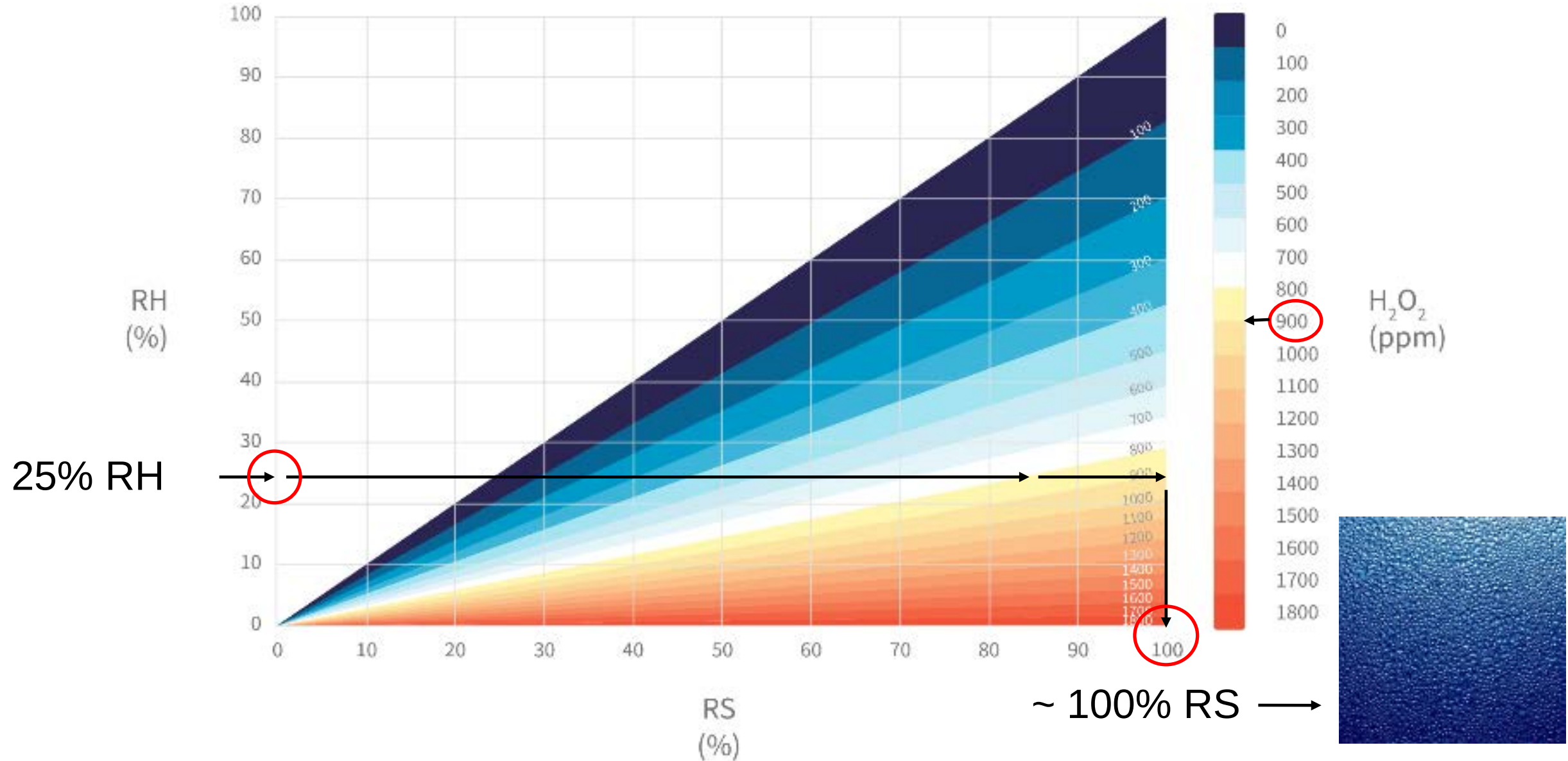
RH/RS sensor readings at 20.0°C when changing H₂O₂ ppm



RH/RS sensor readings at 20.0°C when changing H₂O₂ ppm



RH/RS sensor readings at 20.0°C when changing H₂O₂ ppm



4. New Solution for H₂O₂ Measurement

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New Solution for H₂O₂ Measurement

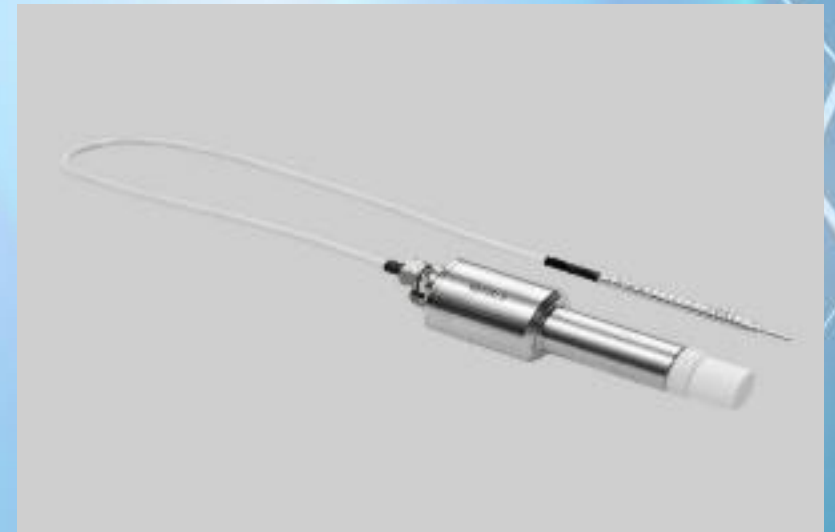
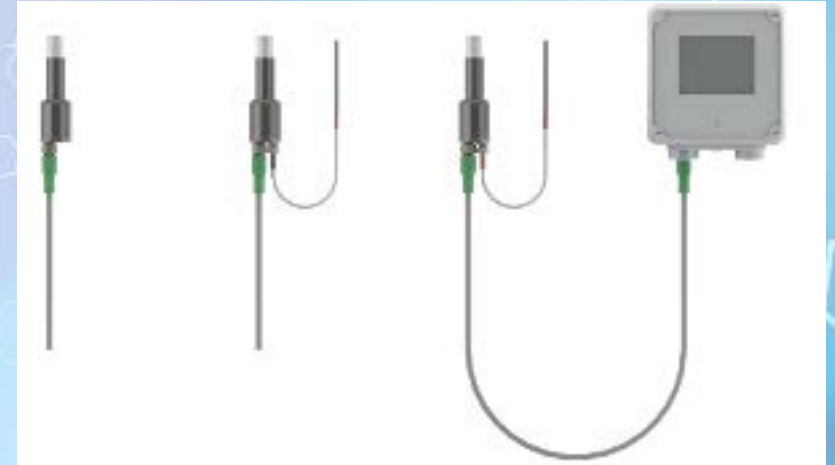


HPP270 series

Capacitive thin-film polymer sensor

PEROXCAP® measurement technology

Based on the Vaisala world leading humidity measurement technology (HUMICAP®)



Vaisala Offering Highlights

- 3 in one with a display (°C, RH/RS, ppm)
- Repeatable
- Stable
- Easy to validate
- Traceable calibration certificate
- Withstands highly condensing H₂O₂ environments (IP65)



5. Conclusion

VAISALA

Things to Remember



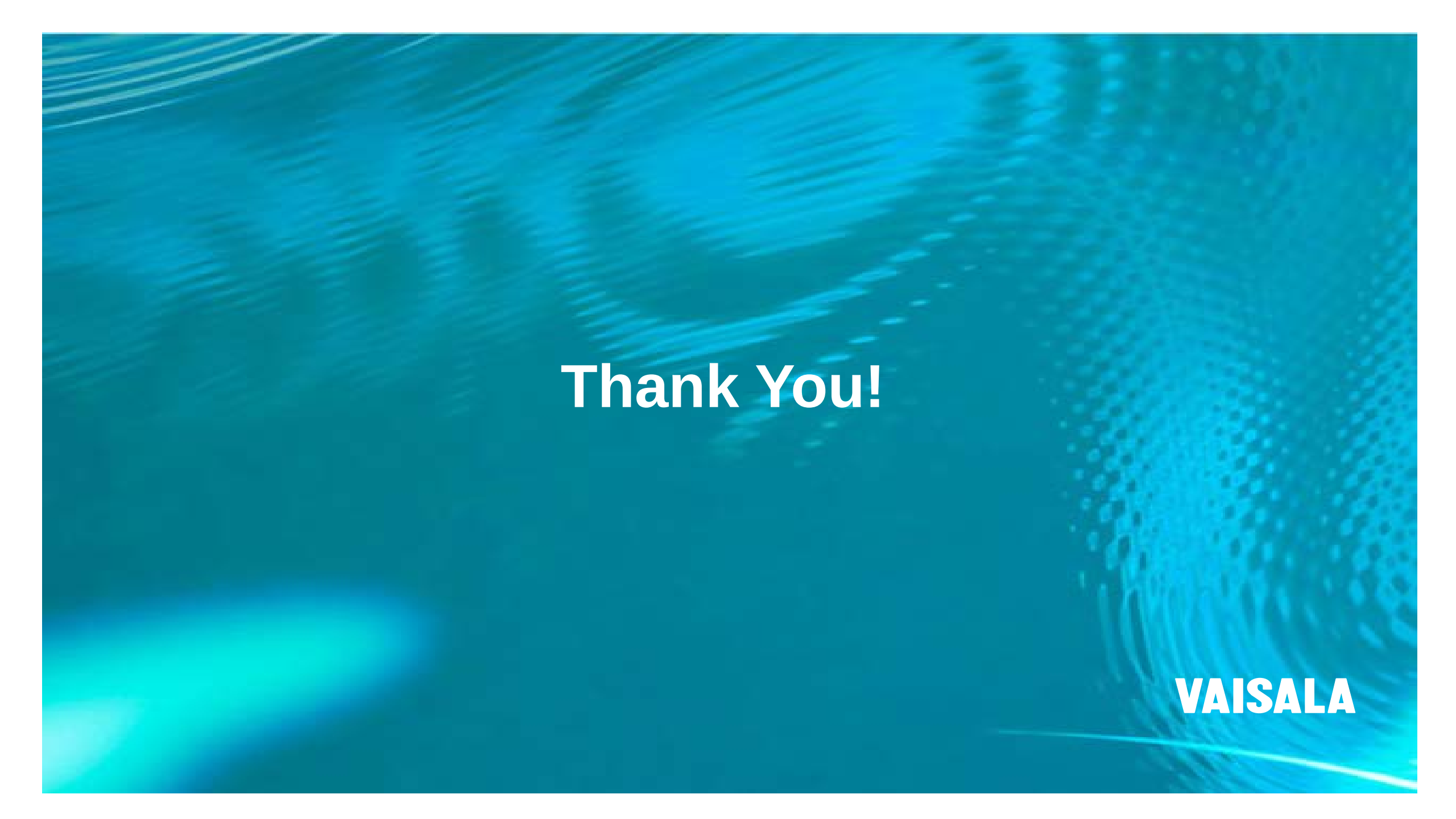
- H_2O_2 is effective and safe to use
- H_2O_2 is mainly used in low temperature bio-decontaminations
- Comparison of different measurement technologies
- New repeatable Vaisala sensor:
 - Measures up to three parameters: Temperature, H_2O_2 (ppm) and RH/RS
 - Controls condensation

6. Quiz

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Open Questions

1. Why is H_2O_2 an ideal bio-decontamination agent?
2. What's the difference between RH% and RS%?
3. Why is it important to measure also relative saturation at the same time when measuring H_2O_2 vapor content?



Thank You!

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