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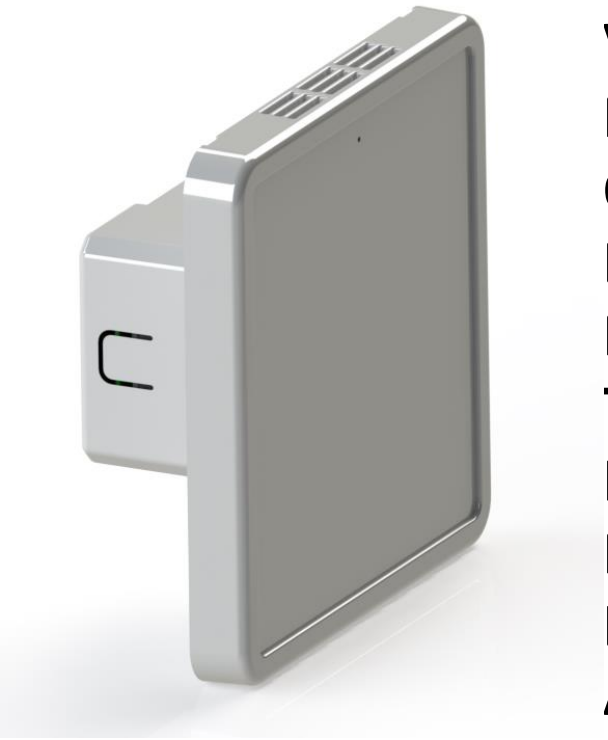
EP5000M datasheet

Flush mounted Modbus Indoor Air Quality Probe



CO2
VOCT
NOx
Ozone
Bad Odors
Particles
Temperature
Humidity
Noise
Light
Atmospheric pressure

Ver	Date	Update
V1	25/05/2020	Initial version
V2	10/08/2020	Details on units
V3	17/09/2020	Control and set points added
V4	01/10/2020	ABC details for single and double bands CO2 sensors
V5	11/02/2021	New VOC sensor with different sensitivity and Sulphurous odors, NOx and Ozone added
V6	24/02/2022	Evolution physio effects control at night + stabilization VOC sensor
V7	29/04/2022	TVOC range extended
V8	15/07/2022	TVOC range updated
V9	26/05/2023	Physio indexes definition added + odor unit

Summary

1. Keynote

To comply with in force regulations on buildings energy efficiency, ventilation must be automatically on demand controlled.

2. Measuring indoor Air quality for HVAC control

Energy losses by air renewal in a conventional building are estimated to 30% of the heating and air conditioning cost. Losses become predominant for very isolated buildings even with heat exchanger. The increasing airproofing of buildings also imposes on demand air renewal based on IAQ to ensure productivity, comfort and health.
By controlling the ventilation on human occupancy materialized by the expiration of CO2 (meeting rooms, offices, bedroom) and air quality (VOC, toxic compounds and odors, particulate maters), significant energy savings can be achieved.

3. Multi sensors probe.

This probe is the most comprehensive on the market and can combine the following measurements:

- CO2
- Total VOC
- Sulphurous Odors
- NO_x (Optional)
- Ozone (Optional)
- PM1, PM2.5, PM10
- Humidity
- Temperature
- Light intensity
- Color temperature (in °K)
- Audible Noise
- Flickering (Optional)

4. Commissioning

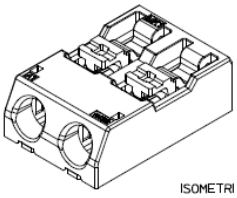
Commissioning: Address, speed and type of Modbus (RTU or ASCII), parity… can be set via a smartphone and NFC.

5. Power supply

Voltage	12V to 30VCD, nominal 24V DC
Average current	15mA @ 12V
Peak current	40mA @ 12V
Average power consumption	360mW max (all LEDs ON)

6. Connection

Power supply:	2 pins (polarized).
Modbus:	2 pins (polarized).
Connector type:	Push In.
Release:	Push button.
Type of cable:	Solid or Stranded.
Diameter of cable:	AWG 18-24 i.e. 1 to 0.5mm in diameter (Rigid), 22-26 i.e. 0.8 to 0.65mm in diameter (Stranded).



7. Maintenance free

Each component of the IAQ probe has been selected and are managed in order to achieve at least 10 years' life span without any maintenance or recalibration.

This probe is designed to work in a ventilated area where sensors have the opportunity to see outdoor CO2 and VOCt concentration at least once every 15 days. In the contrary the NDIR dual band CO2 sensor option shall be selected.

The automatic baseline calibration for CO2 and VOC are set on a 2 weeks' period. In order to get a good auto calibration after commissioning, it is recommended to open windows for at least 5 minutes with the probe powered.

8. Durability index

Some countries require indicating the Durability index but calculation is not yet harmonized among counties.
As a consequence, we provide raw and detailed information as follow:

The design of the probe is made for a durability of at least 30 years.
PM, CO2, VOC and O3 sensors have a 10 years' life span but can be replaced (plug and play) by end user without special tool. See reparability for details.

9. Reparability index

The design of the probe is made of a stack of 5 PCB as follow (mounting order from rear to top)

- Power supply board.
- PM sensor.
- Inter board interface.
- Main board with the following sensors: CO2 (pluggable), TVOC (pluggable), Atmospheric pressure, noise.
- The front board with NFC and the following sensors: T°, RH, light

The main board has a built in test feature for each FRU (**F**ield **R**eplaceable **U**nit) with a status report through the digital communication and LED interface.
Each above board is designed to be a FRU and each FRU is a SKU (**S**tock-**K**eeping **U**nit).
In the event of a failure, each board can be ordered and changed by a qualified end user in accordance with the maintenance and repair manual.

Most of sensors are SMD digital sensor with small drift along the life span of the probe.
Sensor with 10 years' lifespan are pluggable and considered as FRU: PM, CO2, TVOC.
FRU only requires a simple screwdriver for replacement operation. LRU are SKU that can be ordered separately.
Plastic parts are SKU and can be ordered separately in the frame of the reparability and sustainability policy. Details of FRU/SKU part number are given in the "Maintenance and repair manual".

10. Firmware update

The EP5000 probe benefit from an OTC feature (update **O**ver **T**he **C**able).
An OTC firmware update takes about 7 minutes from a PC and less from an automat.
The VOCt, Odors, NOx and Ozone sensors data processing is a separate firmware that can be updated separately by OTC too. Please read the detailed in the EP5000-Modbus Firmware Update document.

11. Flush-mounting

The flat design of the IAQ probe has been studied to be flush mounted in standard electric boxes. Integrated in the wall, the visible part is just few millimeters thick.
The air is sensed by the air diffusion going between the front panel and the wall (few millimeters).

12. Specifications of sensor after integration in the probe

12.1. Technologies

Protocol	RS485 Modbus (See Modbus protocol specification for details). Input protected over 12V. Default RTU, 9600 bauds.
Power supply	12V to 30V DC, Protection against transient-voltage-over 35V
CO2 sensor	Single band NDIR (Dual bands NDIR in option) with auto zero
TVOC sensor	Digital Metal Oxide pulsed MEMS with auto zero
O3 Sensor	Digital Metal Oxide pulsed MEMS with auto zero
PM sensor	Light scattering with laser source
Temperature sensor	Digital MEMS
Relative humidity sensor	Digital MEMS
Atmospheric Pressure	Digital MEMS
Noise sensor	Digital sensor
Light sensors	Digital MEMS

12.2. Lifespan and drifts

Probe: 30 years (MTBF >48 years).
Gas and PM sensors: 10 years under normal conditions of use. Beyond 10 years, a replacement message is activated.
Humidity: Max drift 0.5% RH / year.
Temperature: Max drift of 0.04 ° C per year.
Noise: No drift mentioned by the manufacturer.
Atmospheric Pressure: +/- 1mbar/year.

12.3. Measurement ranges and accuracies

12.3.1. Single band NDIR CO2 (EP5000XX-YN)

+/- 50ppm and 3% at 25°C and 1013mbar, measuring range: 390 to 5000 ppm, resolution 1ppm.
Automatic Baseline Calibration (ABC): lowest value on 15 days adjusted at 400ppm.
The accuracy of the CO2 measurements indicated above requires that the room be unoccupied and ventilated for some time at least once every 15 days.

12.3.2. Double bands NDIR CO2 (EP5000XX-YD)

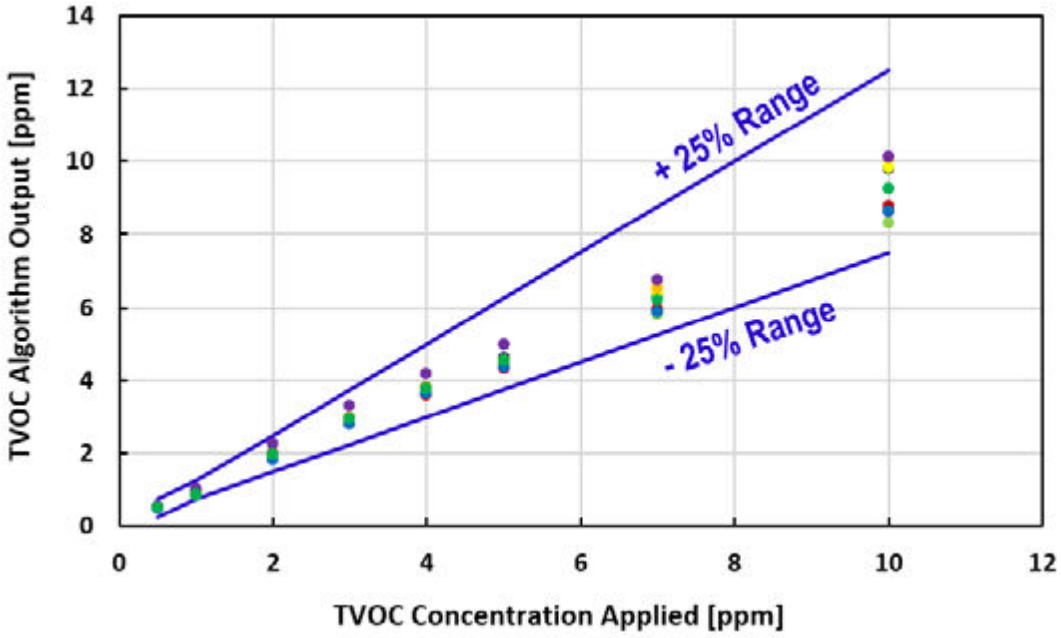
+/- 50ppm and 3% at 25°C and 1013mbar, measuring range: 390 to 5000 ppm, resolution 1ppm.
Long Term Adjustment (LTA): lowest value on 45 days adjusted at 400ppm.
The accuracy of the CO2 measurements indicated above doesn't requires that the room be unoccupied and ventilated for some time (Hospital patient room. Etc.).

12.3.3. TVOC

12.3.3.1. Total VOC according to UBA standard with auto zero.

Range from 0 to 65 535 µg/m^3.
Resolution: 1 µg/m^3.
First measures after 10 minutes.
Stability: after 48 hours conditioning in clean air.
The automatic baseline adjustment requires the probe to be exposed to clean air at least once every 15 days.

Accuracy, consistency and repeatability: ±25%.

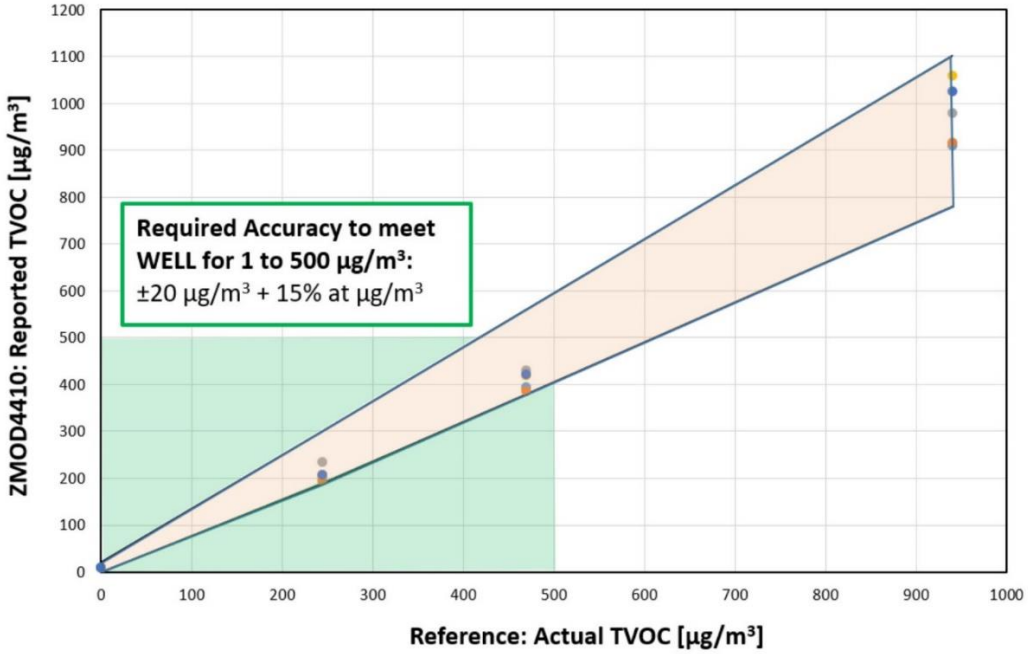


Self-calibration: Yes (ABC type, relative measurement).
Self-calibration period: 15 days.
Manual auto zero: By smartphone in the same time than for CO2.
Lifespan: 10 years without exposure to stressful environment.
Poisoning: less than ±8% sensitivity with siloxanes exposure at high concentration during hundreds of hours.
Relative measurement: The lowest possible value achievable by ventilation or air treatment becomes the zero on a 15 days' period.
As the accuracy of VOC measurement is relative as indicated above, the probe must be associated with active ventilation.

12.3.3.2. Total VOCs according to the WELL V2 and RESET standards (absolute value).

Range from 0 to 65,535 µg/m3.
Resolution: 1µg/m3.
Stability: after 48 hours of conditioning in healthy air.
The baseline setting should be re-calibrated annually in accordance with the WELL V2 standard.

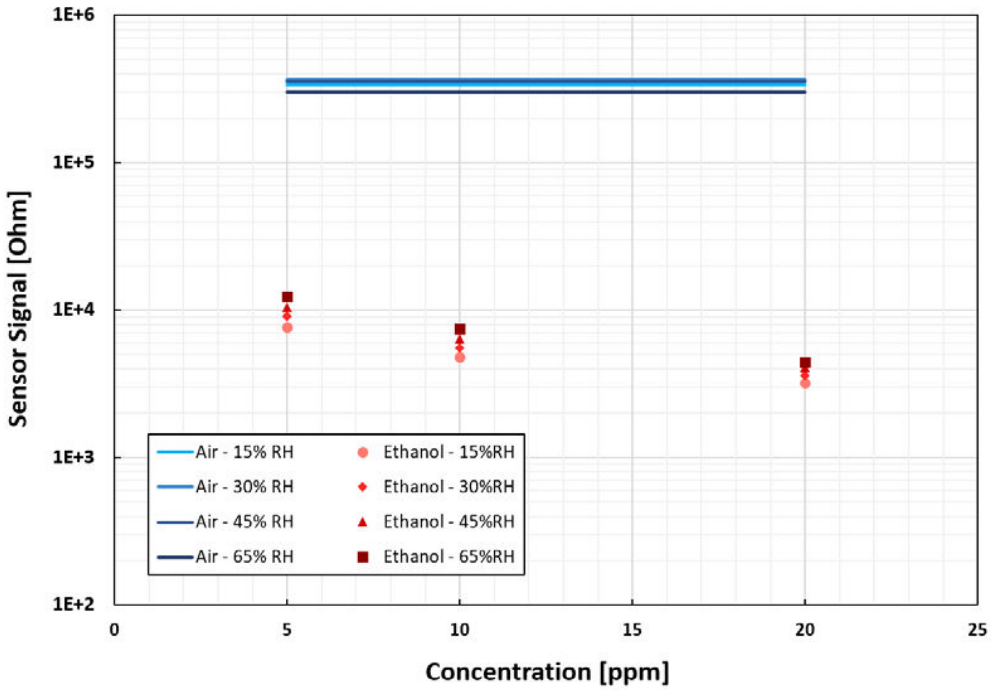
Accuracy, consistency and repeatability: between 1 and 500 µg/m3: ±20 µg/m3 + 15% of the measurement.



Self-calibration: No (absolute measurement).
Calibration: annual.
Lifespan: 10 years without exposure to a stressful environment.
Poisoning: Less than ±8% sensitivity with exposure to high concentration siloxanes for hundreds of hours.

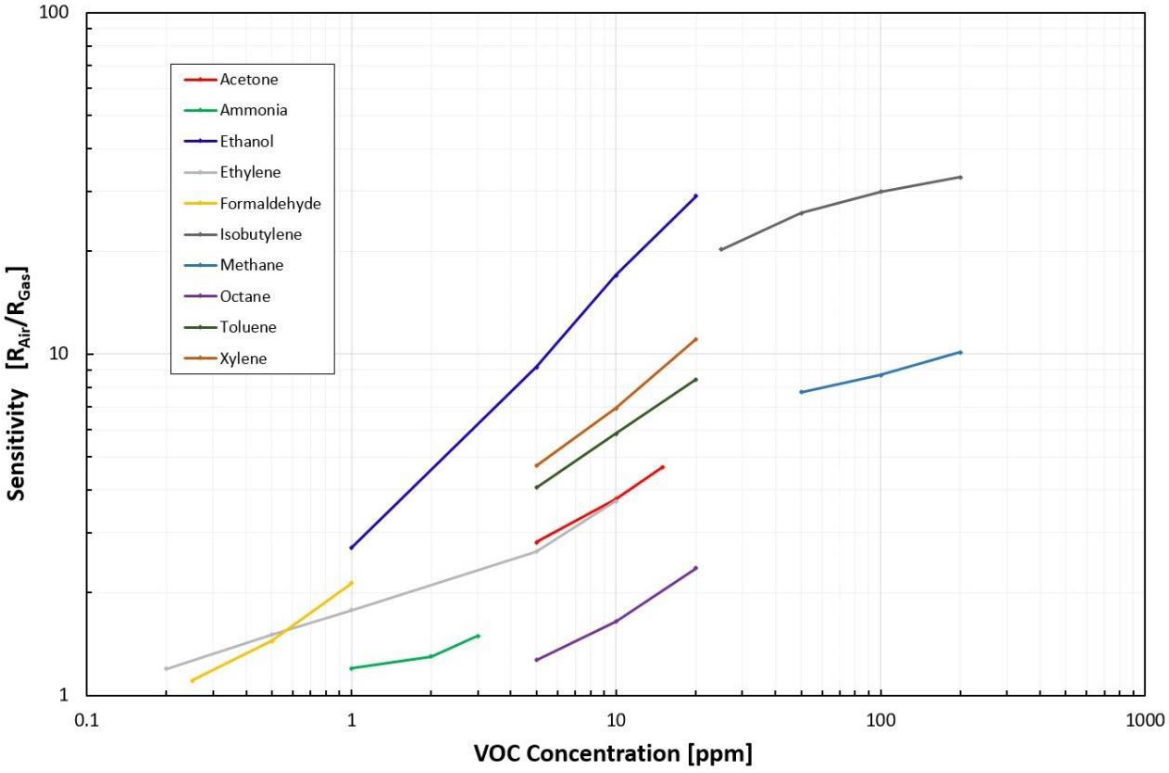
12.3.3.3. Other performances for both versions (relative or absolute measurement):

Moisture Sensitivity to humidity

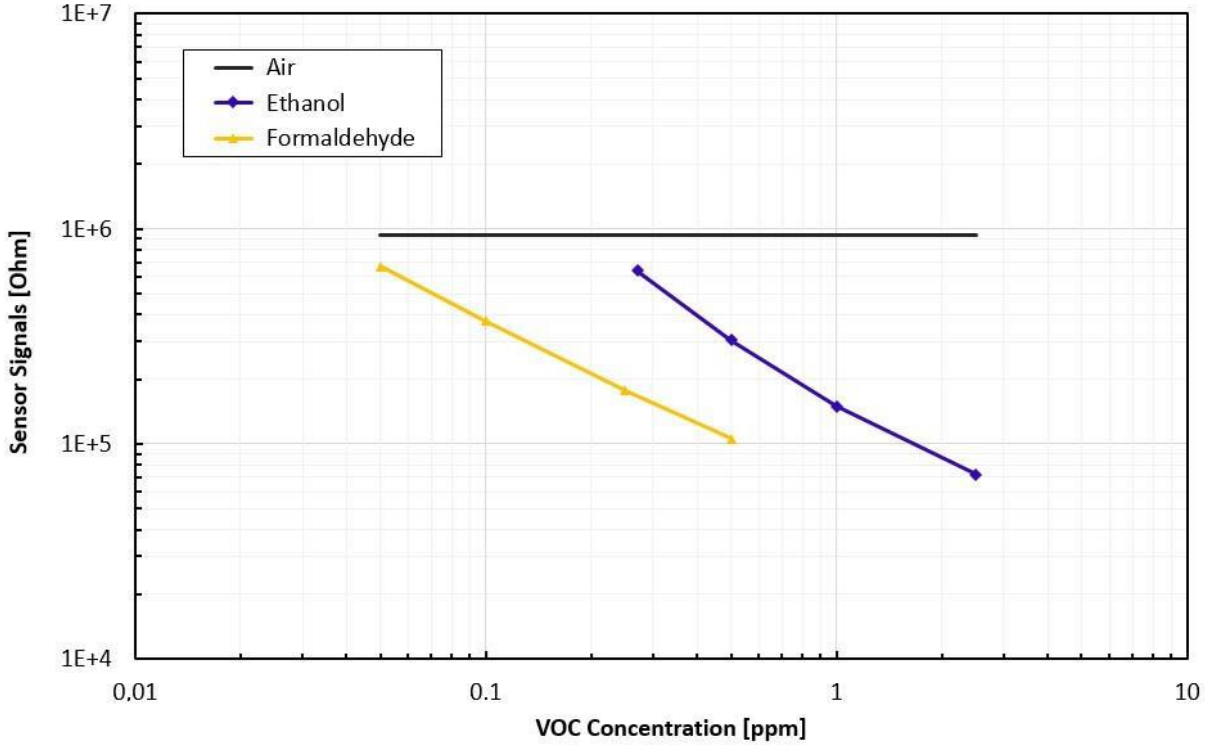


Weak influence of humidity, however since firmware # 3 of the COVt module or with the Well V2 library, compensation is performed for better accuracy.

Sensitivity to various VOC:



Sensitivity to formaldehyde:



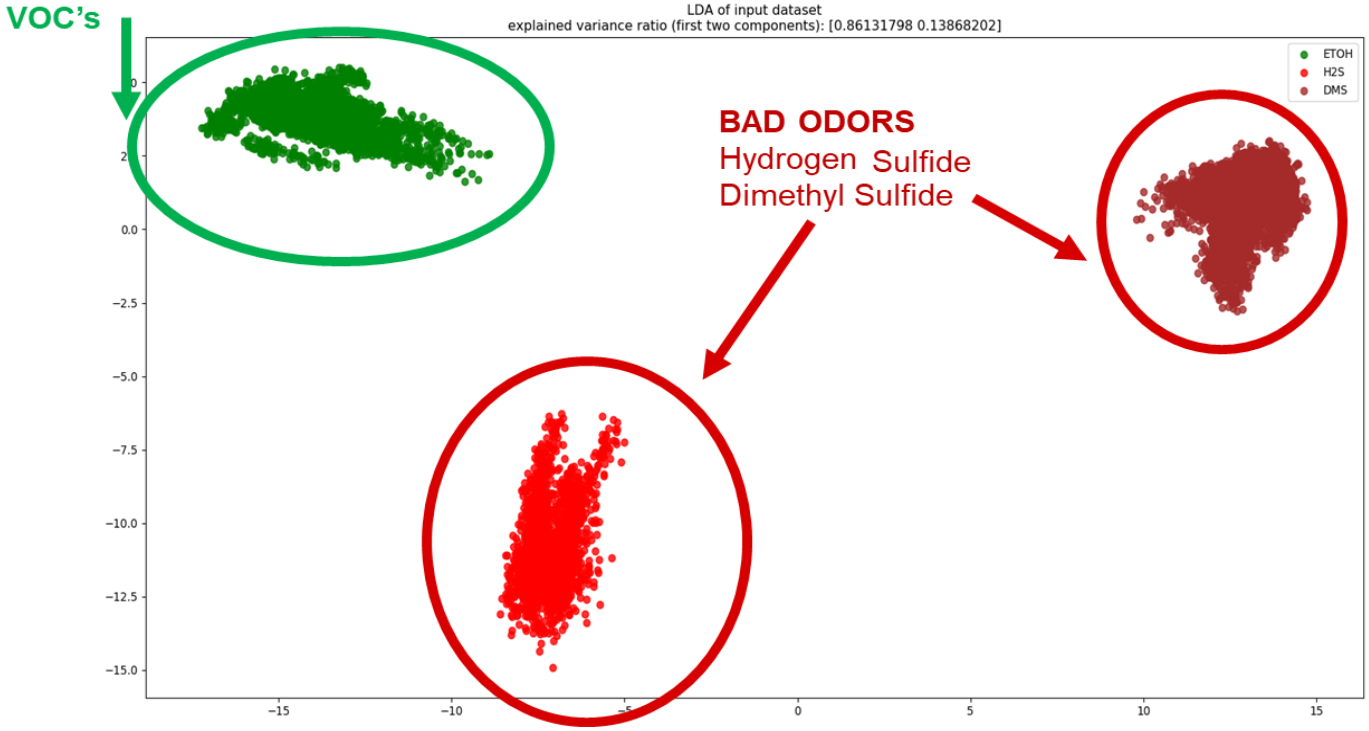
12.3.4. Sulphurous odors

Bad odors are assigned a range of 0 to 100.
The standard unit (UO/m^3) corresponds to a range of 0 to 5 as shown in the below table.
The unit UO_{100}/m^3 (Unit of Odor per m^3 on a scale of 100) corresponds to the second column of the table. The 100 scale is used to be consistent with the physiological indices.

Concentration in odor unit (UO/m3)	Odor unit UO100/m3 of the EP5000 probe	Definition	Perception Indication
1	1 x 20 =20	Odor Perception Threshold: The level of odor where 50% of the population detects the odor and 50% of the population does not.	Absence of a noticeable odor.
2 à 3	2 à 3 x 20 = 40 à 60	Olfactory recognition threshold: Odor detected by 50% of the population.	Noticeable odor level.
4	4 x20 = 80	-	Odor levels commonly sensed in a city.
5	5 x 20 =100	Threshold of discernment: Odor clearly detected by 50% of the population.	Level of frank detection of odors, likely to cause nuisance.

When olfactory threshold of Sulphurous odors is reach the general odors index is provided on a range of 0 to 100.
Sulphurous odors are universally considered as bad odors. Olfactory threshold is different from one person to another and this threshold shall be considered for an average human nose.
Method of discrimination: Multi virtual sensors by temperature cycling + Trained neural net in inference state. Training based on H2S, C2H6S (DMS) versus ethanol.
Resolution: 0.2.
Attention, beyond $1.5mg/m^3$ of TVOC the selectivity of sulfurous odors cannot be guaranteed with the first firmware generation of the first quarter of 2022. A later version of the sensor module firmware is likely to improve the selectivity in a busy atmosphere. It will be made available on the NanoSense website when available.

Classification of odors by categories (Illustration):

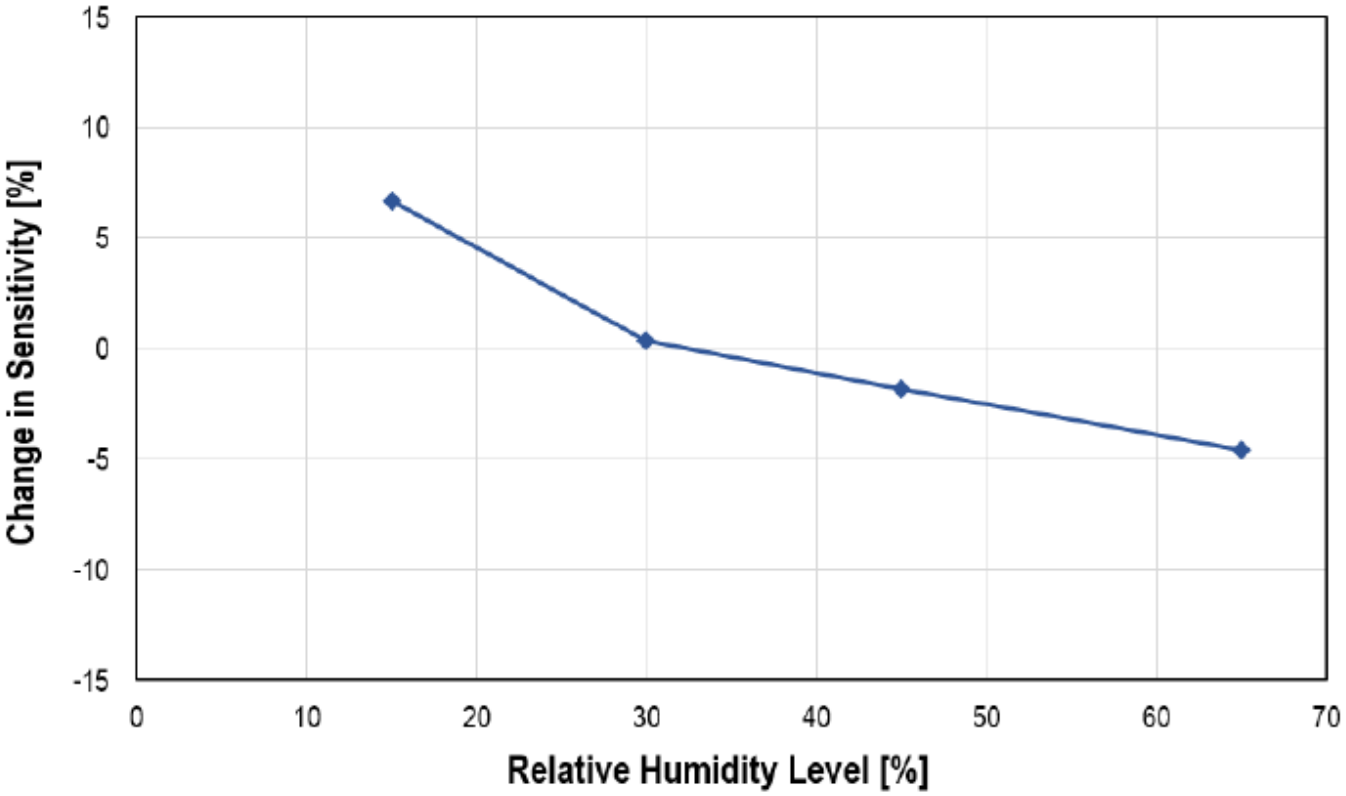


12.3.5. Stabilization time

The VOC and sulfurous odors sensor works with an algorithm designed for 24-hour a day sensor operation. The sensor needs at least 48 hours on first start-up to reach its nominal sensitivity and calculate its baseline. This stabilization time may vary depending on the environment (Humidity, VOC, etc.)
In the event of a power cut, the sensor will regain its performance according to the cut-off time. For a cut-off between 4 hours and one day, evaluate a relative measurement error of less than 25% after 30 minutes of running then < 5% after 2 hours.

12.3.1. Ozone (O_3) (Optional sensor)

Range from 20 to 500ppb.
Resolution: 1 ppb.
First measures after 30 minutes.
Stability: after 48 hours conditioning in clean air.
Repeatability ±25%.
Self-calibration: Yes (ABC type, relative measure).
Manual automatic zero: By smartphone at the same time as for CO2
Lifespan: 10 years without exposure to stressful environment.
Poisoning: less than ±8% sensitivity with siloxanes exposure at high concentration during hundreds of hours.



Weak influence of humidity but algorithmic compensation implemented.

12.3.2. NOx (Optional sensor)

The current algorithm discriminates Ozone from NOx from the same metal oxide sensor but the NOx are not quantified.
A later evolution will allow the measurement of NOx and can be implemented via the OTC.
Range from 20 to 500ppb
Resolution: 1ppb.

12.3.3. PM1

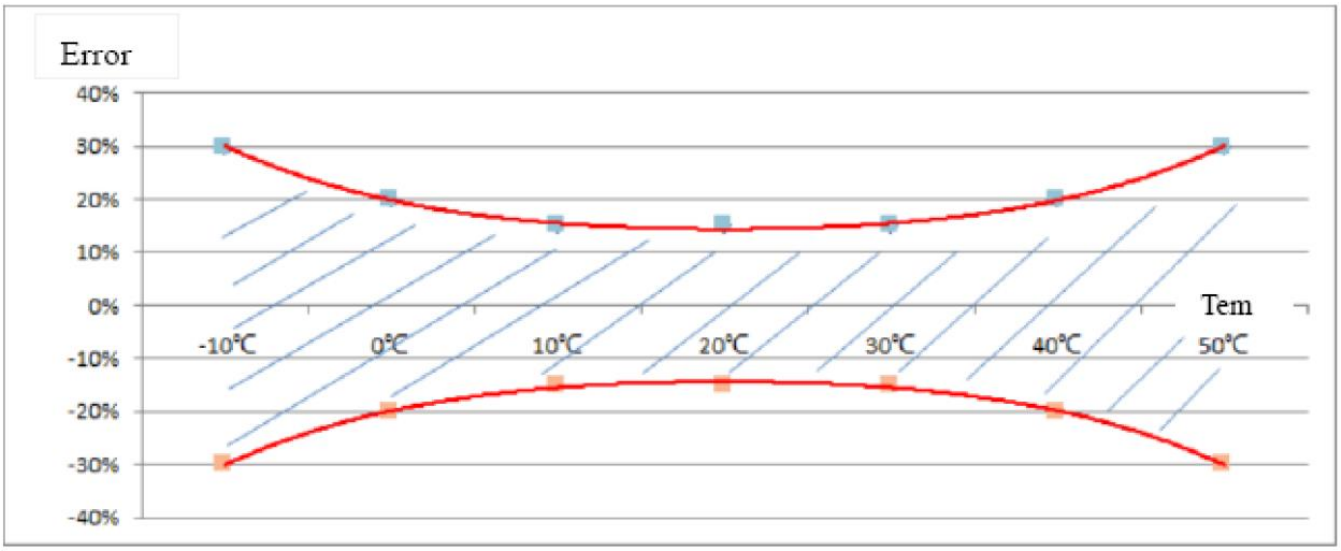
Range of measurement 0 to 1000 µg/m^3.
Accuracy: indicative, no accuracy commitment. Calibration with cigarette smoke.

12.3.4. PM2.5

Range of measurement 0 to 1000 µg/m^3
Accuracy: < 50µg/m^3: ± 10µg/m^3, 50~100µg/m^3： ± 15µg/m^3 > 100µg/m^3: ± 15% reading.
Temperature influence: 0.5 to 1%/°C or 0.5 to 1µg/m^3/°C around 20°C, whichever is larger.

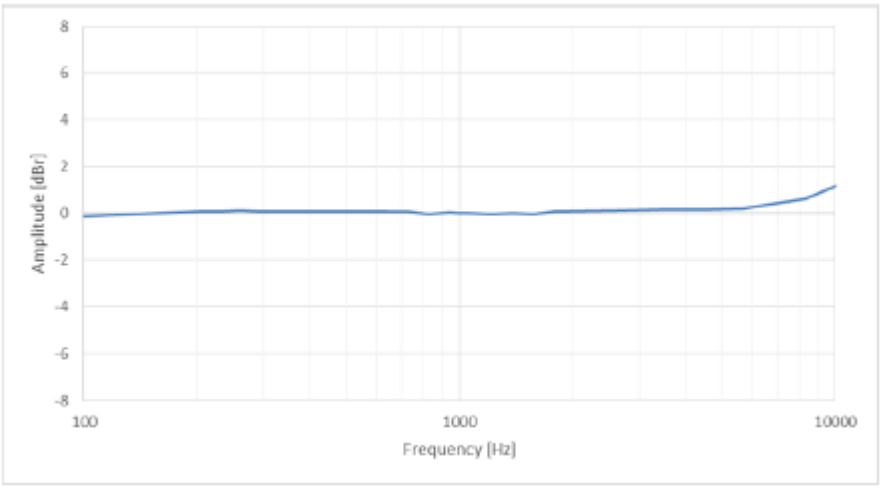
12.3.5. PM10

Range of measurement 0 to 1000 µg/m^3
Accuracy: indicative, no accuracy commitment. Calibration with Arizona sand.



12.3.6. Noise sensor

Range: 122.5 dBA SPL.
Peak and average calculated on 30 seconds period.
Signal to Noise Ratio: -64 dBA.
Omnidirectional sensitivity: -26 dBA FS ±3 dB sensitivity.
Drift: not significant.
Frequency response.



12.3.7. Atmospheric pressure sensor

Range: 0 to 1638.4 mbar.
Error band, 700 to 1100 mbar,25°C: +/- 1.5 mbar.
Error band, 700 to 1100 mbar, 0°C to 50°C: +/- 2mBar.
Resolution: 0.1 mbar.

12.3.8. Light sensor

Illuminance: Lux computed from RGB and Clear channel.
Color temperature: computed from RGB and Clear channel.
Characteristic of channels:

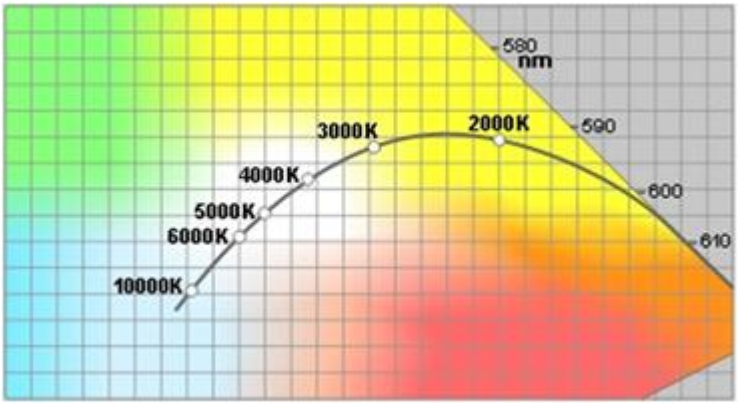
Parameter	Test Conditions	Red Channel		Green Channel		Blue Channel		Clear Channel			Unit
		Min	Max	Min	Max	Min	Max	Min	Typ	Max	
R_e Irradiance responsivity	$\lambda_D = 465$ nm(2)	0%	15%	10%	42%	65%	88%	11.0	13.8	16.6	counts /µW /cm^2
	$\lambda_D = 525$ nm(3)	4%	25%	60%	85%	10%	45%	13.2	16.6	20.0	
	$\lambda_D = 615$ nm(4)	80%	110%	0%	14%	5%	24%	15.6	19.5	23.4	

Notes:
1. The percentage shown represents the ratio of the respective red, green, or blue channel value to the clear channel value.
2. The 465 nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics: dominant wavelength λD = 465 nm, spectral halfwidth Δλ. = 22 nm.
3. The 525 nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics: dominant wavelength λD = 525 nm, spectral halfwidth Δλ. = 35 nm.
4. The 615 nm input irradiance is supplied by a AlInGaP light-emitting diode with the following characteristics: dominant wavelength λD = 615 nm, spectral halfwidth Δλ. = 15 nm.

Range of measurement 0 to 30 000 Lux
Resolution: 1 lux.

12.3.8.1. Color T°:

Range: 600°K to 10 000°K
Resolution: 1°K



Attention: The higher the temperature, the colder the light.

Examples of light temperatures:

Light Source	Color Temperature (K)
Candle	1900
Sunlight at sunset	2000
Sodium bulb	2200
Incandescent bulb	2500 / 2800
Cold white fluorescent lamp	2700 / 3000
Halogen lamp	3300
Carbon arc lamp	3780
Neutral white fluorescent lamp	4000 / 4200
Sun light plus sky light	5500
Sun at its zenith	5800
Xenon strobe light	6000

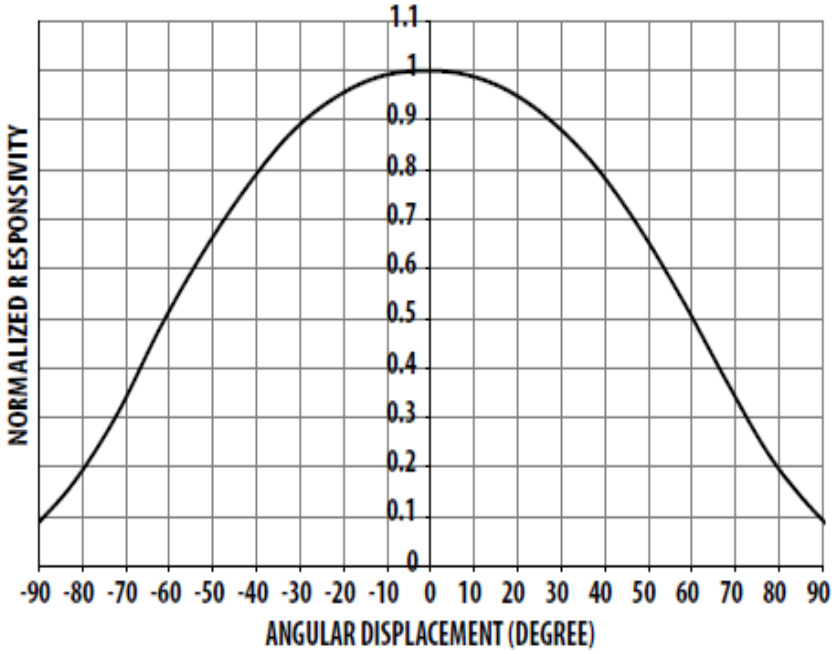
Overcast sky	6500 / 8000
Electric arc	10000

12.3.8.2. Lux:

Range: 0 to 30 000 lux
Resolution: 1 Lux

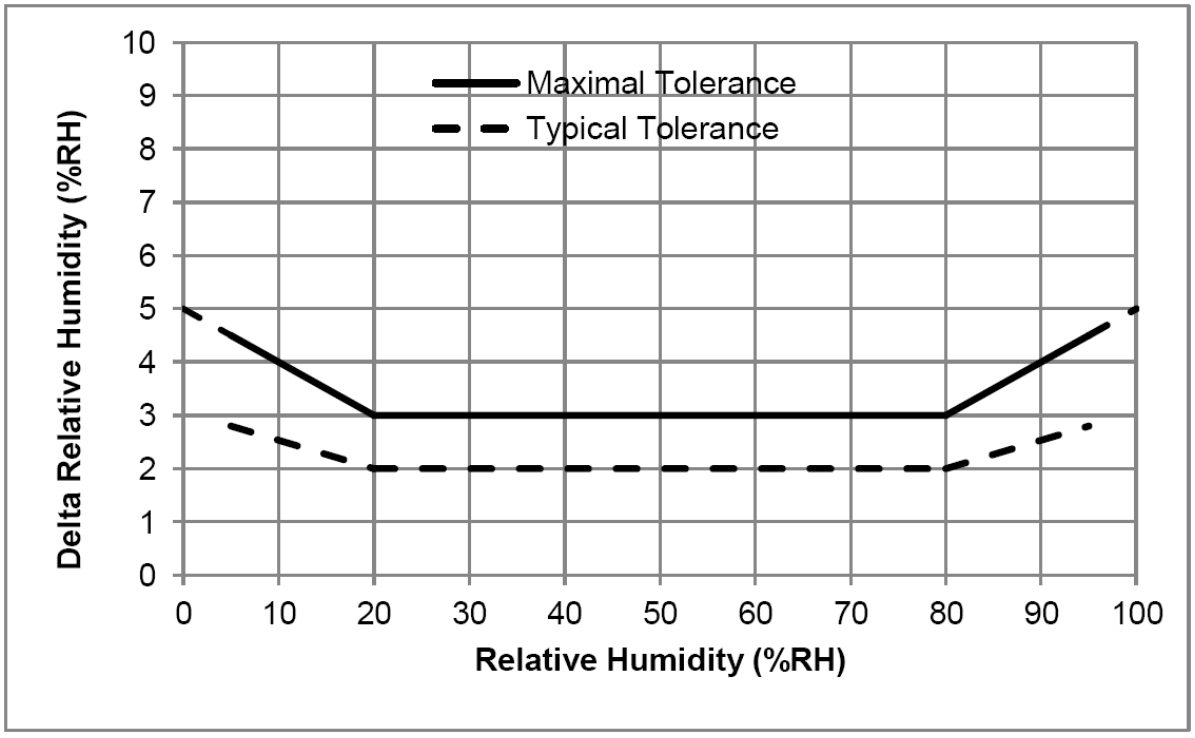
12.3.8.3. Responsivity

Normalized Responsivity vs. Angular Displacement



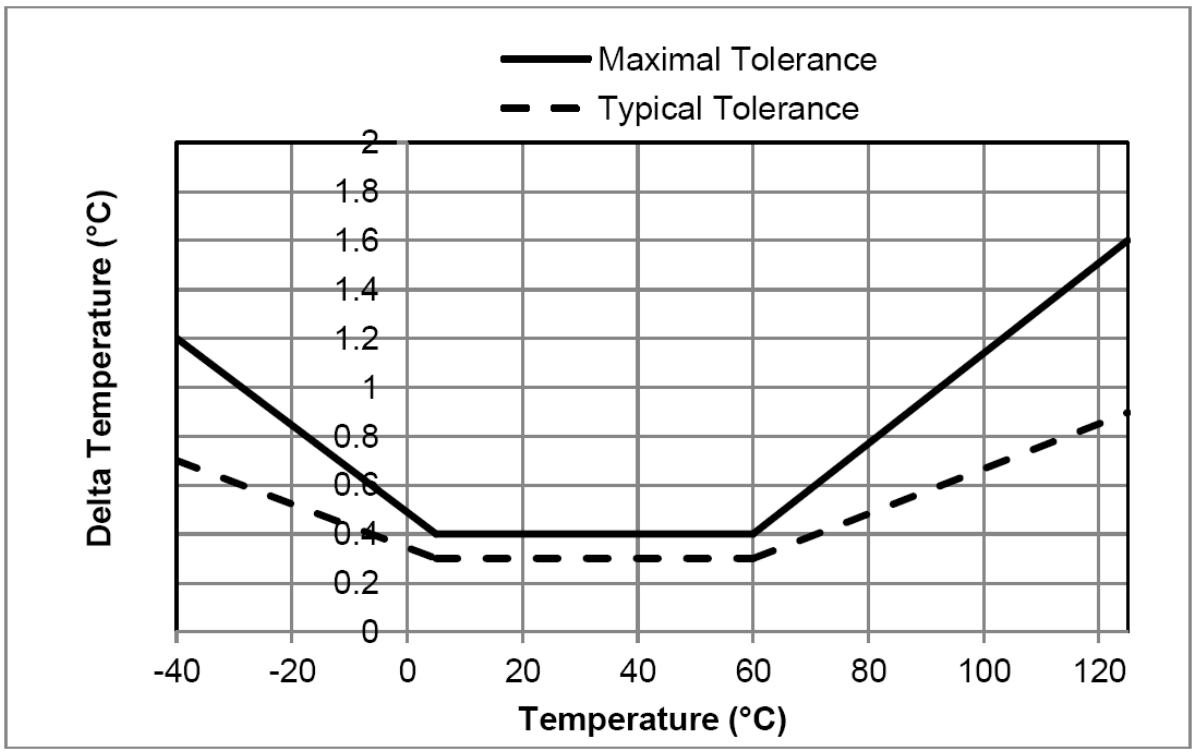
12.3.9. Humidity:

+/- 3% RH, minimum measurement range: 0% to 100% RH, resolution 1%.



12.3.10. Temperature:

+/- 0.3°C, measuring range from 0° to + 50°C, resolution 0.1°C.



13. Improvement of the ABC auto zero

The probe automatically activates an over ventilation (max flow) once every 15 days during a period of vacancy to improve the ABC process which requires a CO2 concentration as close as possible to the outdoor level over a similar period (single band) and a TVOC level close to that outdoor air. The duration of over-ventilation is not fixed and ends when the change in CO2 and VOC are stable for at least 10 minutes (<10ppm CO2). There is a big chance than the NOx and O3 level been higher than indoor when over ventilating so this process doesn't concern NOx and O3.

The probe can receive over-ventilation opportunity data from ecosystem based on occupancy sensors. In the absence of occupancy sensors, the occupancy period is estimated based on a low CO2 value (<500ppm) and low CO2 variations (<20ppm in 30 minutes).

If the probe has over-ventilated, it no longer takes into account the opportunity information (sufficiently long absence) that it receives during the next 15 days.

To trigger over ventilation on the basis of opportunity information provided by the eco system, the CO2 stability criteria must also be valid.

If the probe does not receive opportunity information from the ecosystem at least once every 24 hours, it will only rely on the unoccupancy estimated via CO2.

14.CO2 and VOC manual calibration

A manual CO2 and VOC recalibration can be launched via NFC (smartphone App) or Modbus.

The maintenance LED will blink during 20minutes. During this time, the windows shall be opened and the room unoccupied to reach the outdoor CO2 and VOC levels. At the end of the 20 minutes, the CO2 sensor baseline is set to 400ppm and the VOC to zero then the LED stop blinking.

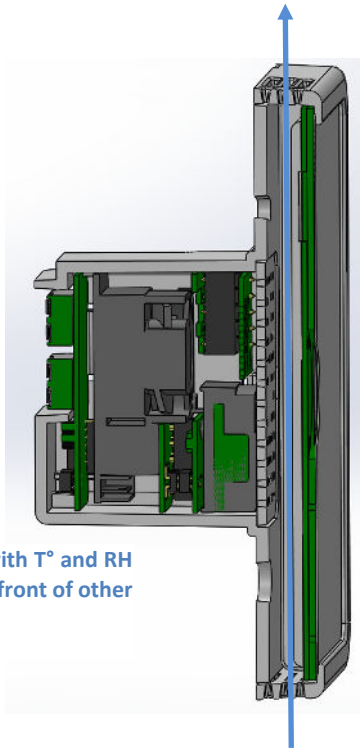
15. Controls

- Ventilation: On Off or Continuous on PI.
- Heating Control: Continuous on Fuzzy logic PID.
- Cooling control: Continuous on Fuzzy logic PID.

16. Set points

- Ventilation: on thresholds or physiological effects objectives.
- Heating.
- Cooling.

17. Air flow



EP5000 probe vertical cut view: The front PCB with T° and RH sensor is away from the wall to allow air flow in front of other sensors.

18. Operation and storage conditions

Working temperature range:	0°C to +45°C.
Working humidity range:	0 to 95% non-condensing.
Storage temperature range	-30°C to 60°C.
Storage humidity range:	0 to 95% non-condensing.

19. Noise

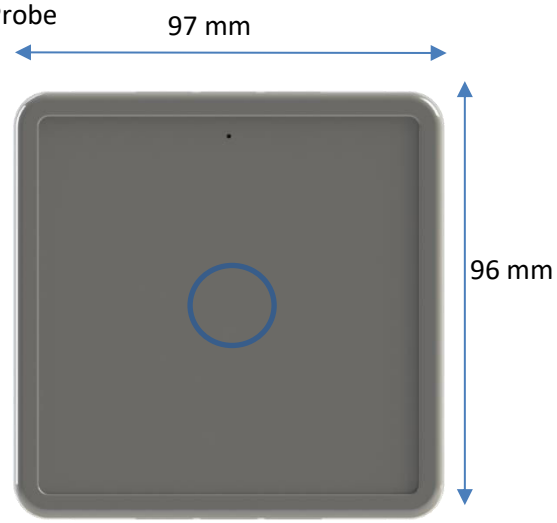
PM sensor fan activated 6 seconds every minutes: < 20dBA at 30cm (background noise < 16dBA).

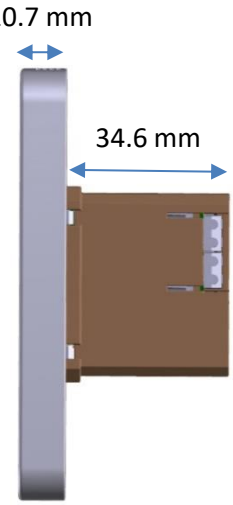
20. Protection index

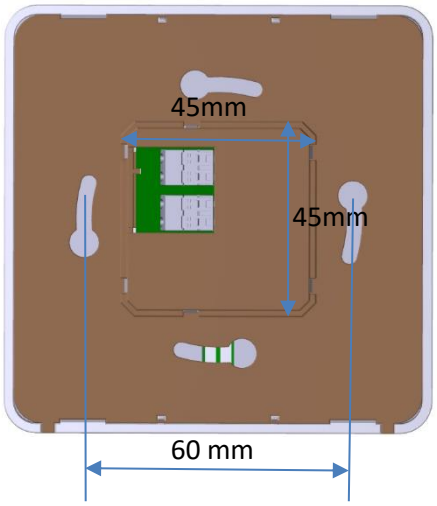
Protection class: III.
Protection grade: IP 30.

21.Dimensions

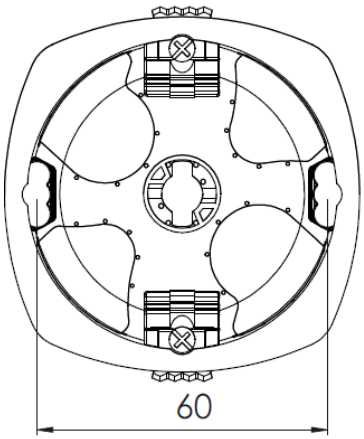
Probe

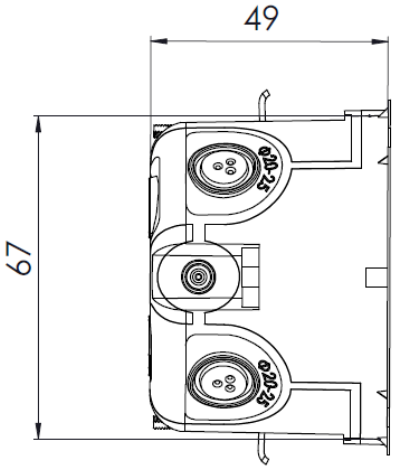


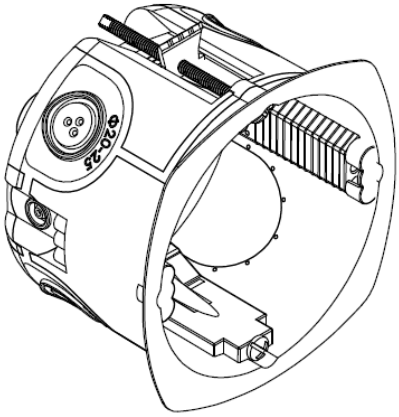




Wall box







22. **Weight**
Probe alone: 120g.

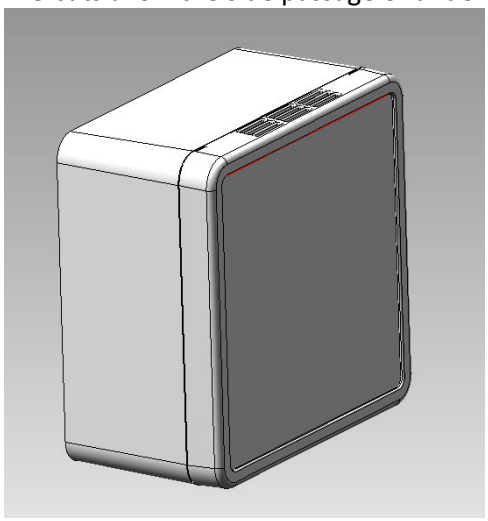
23. **Packaging**
Ecological natural carton gift box.
Dimensions: 195 x 140 x 48 mm.
Weight: 222 grams.

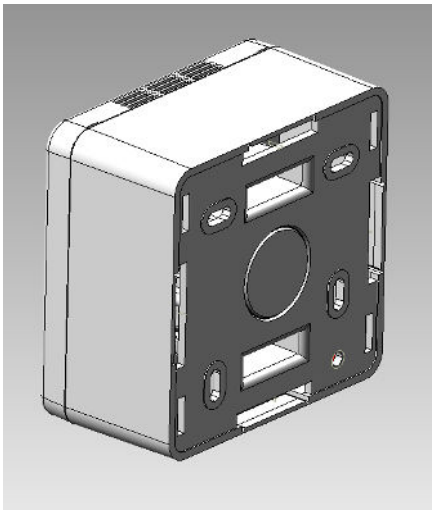
24. **Packing list**
Probe.
Silicone free Wall box.
Card with QR code link for online documentation.

25. **Product Label**
The label in the back of the product identify the model.
M termination means **Modbus**.
The serial number is registered in NFC and can be read via NFC with a dedicated smartphone's App.

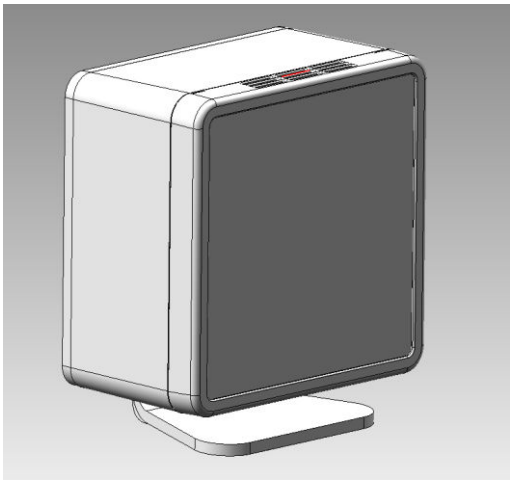
26. **Marking**
The type of connection (power supply) is indicated in front of each connector as well as polarities.

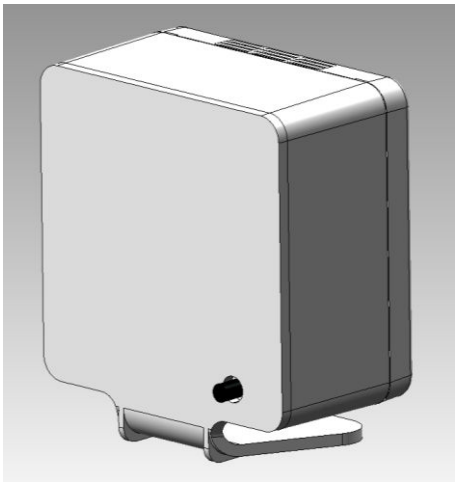
27.**Mounting Option**
In case of renovation, a surface box is available as an option.
Pre-cuts allow the side passage of under gutter cables and a rear pre-cut allows the passage of a recessed cable.





28.**Diagnostic Option**
Although intended primarily for remediation control, the EP5000 probe can also be used to perform diagnostics and has a tabletop support for this purpose.





29. Applicable Standard

EN 60730-1 (electrical controls for household machines and the like).
The unit complies with European Directive 73/23/EEC (Low Voltage Directive) and 89/336/EEC (EMC Directive).

30. Flammability

Flammability class according to UL 94: V0.

31. RoHS / Reach compliance

See separate certificate for details.

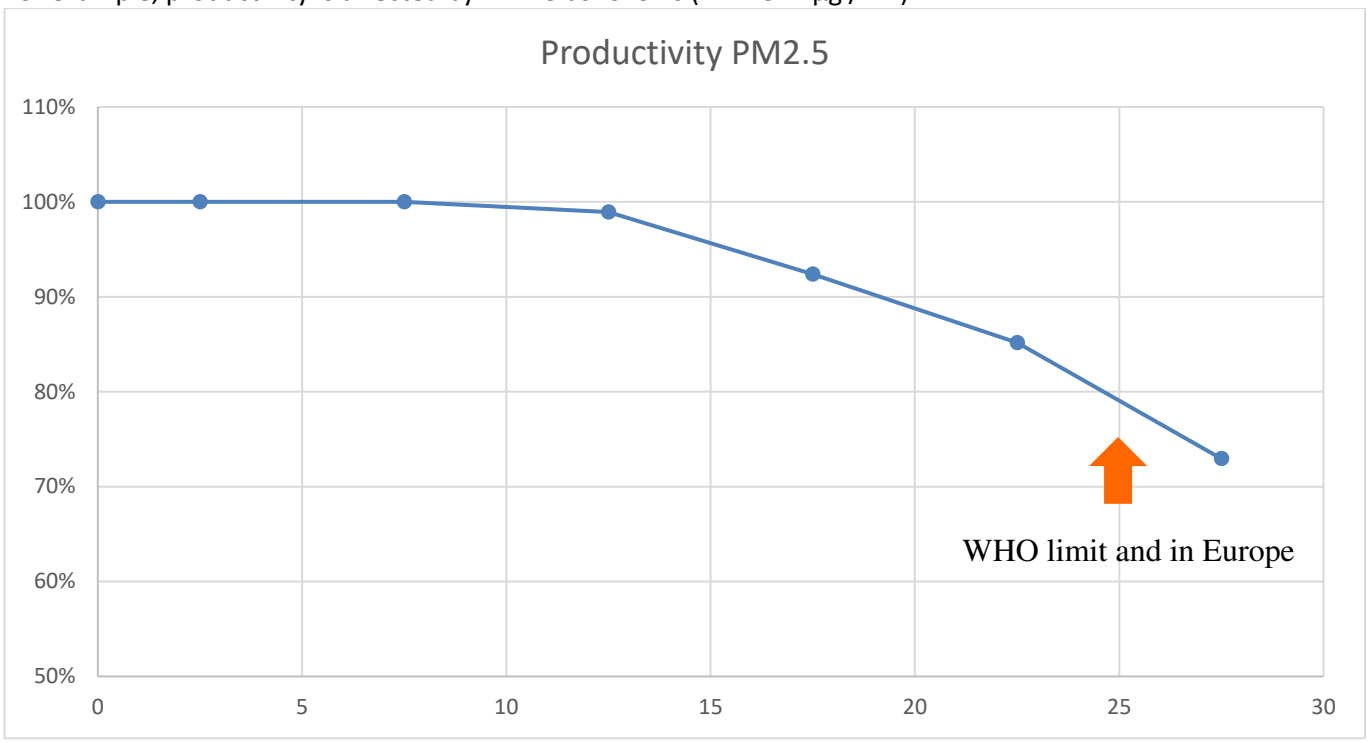
32.Physiological effects

This algorithm is based on international university studies quantifying the physiological impacts of air quality on humans.
The following table shows contributors for different physiological impacts:

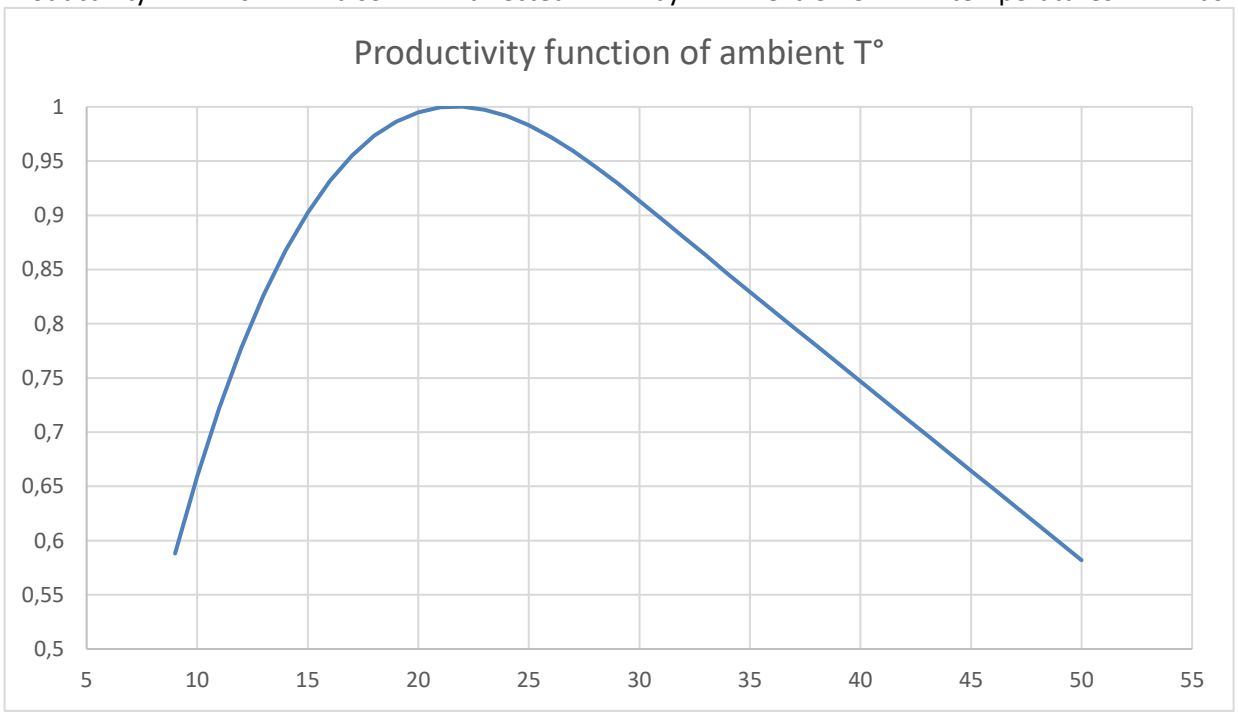
	CO2	COVt	PM	Formaldehyde, Benzene	Radon	Noise	Odors	T°	RH	NOX O3	Lux	Light color	Light flickering
Cognitivity / Productivity	✓	✓	✓			✓	✓	✓			✓	✓	✓
Health		✓	✓	✓	✓	✓		✓					
Quality of sleep	✓					✓		✓			✓	✓	
Asthma attack		✓	✓				✓	✓	✓	✓			
Olfactory Comfort		✓					✓						
Thermal Comfort								✓					
Sound comfort						✓							
Dry air Comfort									✓				
Respiratory tract irritation			✓						✓	✓			
Growth of mold, spores and mites									✓				

All those indexes indicate healthy air and beneficial ambiances when they are at 100%. The health index means Healthy at X%, the respiratory tract irritation index means no risk of irritation of the respiratory tract at X%. Sleep Quality Index means X% restful sleep.

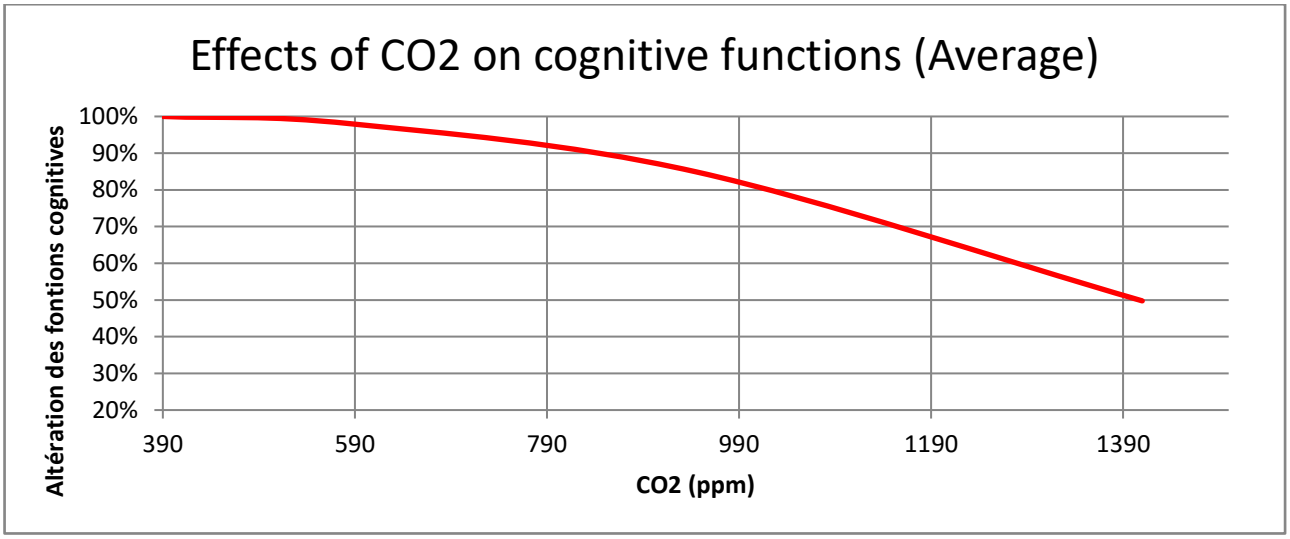
For example, productivity is affected by PM2.5 as follows (PM2.5 in µg / m^3):



Productivity is also affected by extreme temperatures as follows:



Source https://iaqscience.lbl.gov/si/performance-temp-office



Source NIH National Institute of Environmental Health Sciences

32.1. Indexes definition

Reminder: The use of ventilation regulation on physiological effects is dedicated to ventilation systems that filter the incoming air (air treatment station, double flow, Insufflated ventilation, etc.)

32.1.1. Cognitive functions and productivity

This index is expressed with a value ranging from 0 to 100.
This index is in fact a percentage of the optimal cognitive functions corresponding to an ideal (pure air, optimal atmosphere, i.e. 21°C, no noise and neutral light of an intensity >= 500 Lux)
So an index of 100 corresponds to 100% of the cognitive functions and therefore of the productivity for a workstation.
An index of 80 corresponds to 80% of cognitive functions and productivity or an alteration of 20%.

This index is an intuitive indicator that can be used as a setpoint for the ventilation.

As a setpoint, this index is particularly useful for work spaces (including manual work).
Beware, it is not necessary (unjustified energy expense) to have too high requirements in terms of cognition in homes (residential spaces). For a bedroom, use the sleeping quality index.

Example with regulatory thresholds and optimal temperature:

Contributors	Thresholds	Individual indexes	Global index
C02	1000ppm	80	**43**
VOC	500 µg/m^3	70	
PM2.5	15µg/m^3	95	
Noise	80dB	95	
Temperature	21	100	
Lux	500 lux	90	
Light temperature	6000°K	90	

Be careful, the regulatory thresholds are not taken into account in the calculation of the cognitive functions index, we use the above indicated curves. This example above is just to have an idea of the cocktail effect when all thresholds are supposed to be acceptable.

Contributors

	CO2	VOCt	PM	Noise	Odors	T°	RH	NOX O3	Lux	Light T°
Cognitivity / Productivity	✓	✓	✓	✓	(✓)	✓			✓	✓

32.1.2. Health

With a single contributor, an index of 100 (therefore, healthy air) corresponds to 100% of the WHO regulatory exposure threshold.
The contributors are fine particles, Ozone and NOx
PM10 particles include PM2.5. It is therefore not realistic to combine the effects of PM10 and PM2.5 in the overall Index. We will therefore take the highest value of PM10 or PM2.5 after common scaling according to their respective TWA 24h thresholds.
Thus, when several contributors are taken into account, the value 100 is more demanding and takes into account their cumulative effect (two contributors at 50% of their regulatory threshold will give a value of 100).
The value 0 corresponds to an overrun of 10 times the regulatory thresholds taking into account their cumulative effect.

This index is an intuitive indicator that can be used as a setpoint for ventilation (value from 0 to 100).
It is therefore possible to use a higher setpoint (within the limit of 10 times) than the regulatory thresholds, but it must be borne in mind that the fact of calculating a cocktail effect and much more is demanding (an index of 80 is reached with only two contributors to their regulatory threshold).
For probes that do not have a NOx or ozone sensor, the index being only based on PM, it is best not to set it below 100.

To compare national regulatory levels to WHO, here under is a reminder table.

PM10	TWA WHO 2021, long term : 15 µg/m^3, **24h: 45 µg/m^3**
PM2.5	TWA WHO 2021, long term : 5 µg/m^3, **24h: 15 µg/m^3**
NO2	STEL WHO 2021, **24h : 25 µg/m^3**, Peak 60 µg/m^3, so respectively **13ppb** & 31ppb
O3	STEL OMS 2021, **24h : 100 µg/m^3, so 50ppb**

Values in bolt are taken into account in this index.
Measures taken into account are averaged on a 20 minutes' timeframe.

Contributors

	CO2	VOCt	PM	Noise	Odors	T°	RH	NOX O3	Lux	Light T°
Health Bonus		✓	✓	(✓)		✓		✓		

32.1.3. Quality of sleep

Sleeping is a recurrent state of loss of consciousness (but without loss of sensory reception) of the external world, accompanied by a progressive decrease in muscle tone, occurring at regular intervals. The alternation of sleep and wakefulness is one of the fundamental cycles of the circadian rhythm in animals.

For humans, sleep occupies an average of one third of our lives.

The quality of sleep is based on different criteria:
- Number of awakenings during the night (related to T°, humidity and noise)
- Time to get back to sleep (related to T°)
- Time spent sleeping (related to the presence of noise)
- Quality or recovery during sleeping time (related to CO2, VOCs and PM)
- Percentage of total time spent in bed dozing (related to temperature and humidity)

The consequences of poor quality of sleep are numerous. People who sleep poorly may be tired, irritable and have concentration problems during the day. They may also be more prone to illness, anxiety and depression.

Which sleep is more healing? It is during the **deep slow wave sleep phase** that the body recovers the most from the physical and cerebral fatigue accumulated throughout the day.
A restful sleep is one whose cycles have not been disturbed by waking up (noise, heat, smells) and where the sleeper has been exposed to an air quality that ensures good cognitive functions if he had been awake.

Therefore, an index of 100 corresponds to 100% healing sleep.
An index of 80 corresponds to 80% healing sleep, i.e. an alteration of 20%.

Contributors: CO2, VOC, PM, T°, peak noise.

This index is an intuitive indicator that can be used as a guideline for ventilation.

This index being quite similar to that of cognitive functions, refer to the example table of combined regulatory thresholds to determine a reasonable instruction.

Contributors

	CO2	VOCt	PM	Noise	Odors	T°	RH	NOX O3	Lux	Light T°
Quality of sleep	✓	✓	✓	✓	(✓)	✓				

32.1.4. Olfactory comfort

Based on sulfurous smell (bad odor).
The value of the odor is expressed in Unit of Odor (UO) in a range from 0 to 100 (UO_{100}).
The strongest odor value is 100; but here it is a comfort index, the olfactory comfort index is therefore the inverse of the measurement: Olfactory comfort index = 100 - the odor value. (100 = comfortable)
Beyond 1.5mg/m^3 of tVOC, the sensor is no longer able to discriminate sulfurous odors from tVOC and the sulfurous odor value is saturated. However, the ventilation that will be engaged for olfactory comfort will reduce the tVOCs below 1.5mg/m^3. If there are really sulfurous compounds, the ventilation will continue. If there are only tVOCs, the tVOC level will be maintained at 1.5mg/m^3.
Note that 1.5mg/m^3 (1500µg/m^3) is 3 times higher than the Well V2 threshold of 500 µg/m^3, so even if tVOC are not taken into account in the health index, maintaining a threshold at this level is not a source of unnecessary over-ventilation.

Air that is pleasant to smell is air that does not smell at all or that, if it does, does not smell bad.
An index 100 corresponds to an olfactory good air.
An index 0 corresponds to an olfactory air unbearable.
This index is an intuitive indicator that can be used as a set point for ventilation.

Contributors

	CO2	VOCt	PM	Noise	Odors	T°	RH	NOX O3	Lux	Light T°
Olfactory Comfort					✓					

32.1.5. Absence of irritation risk

Dry air affects the skin, the mucous membranes and eyes. PM10 combined with dry air, ozone (irritants) and NOx (irritants), result in respiratory tract irritation. To make things easier and to limit the number of indexes, we combine these two aspects under the name of "Absence of Irritation risk".

The index is expressed with a value ranging from 0 to 100.
An index of 0 indicates a high risk of eye irritation, mucous membrane, skin dryness and respiratory tract irritation.
An index of 100 indicates that there is no such risk.

Contributors: PM10, Ozone, NOx, Humidity (air sec, < 30% RH).

Note that humid air likely to contribute to the growth of mold, mites, etc., which increases the risk of an attack for people suffering from asthma and allergies is not dealt with in this index but in the health chapter. of the building.

This index is an intuitive indicator that can be used as a guideline for ventilation.

Attention, it is not necessary (unjustified energy expenditure) to have too high requirements in terms of irritation. It all depends on the occupants, especially if there are people with asthma or chronic eczema.

Contributors

	CO2	VOCt	PM	Noise	Odors	T°	RH	NOX O3	Lux	Light T°
Absence of irritation risk			✓				✓	✓		

32.1.6. Building's Health

Humidity:

Too dry: Risk of shrinkage of wood or other materials.
Too wet: Material will swell and become distorted + condensation with a risk of mold and microbial growth with stains on paint, even paint peeling.

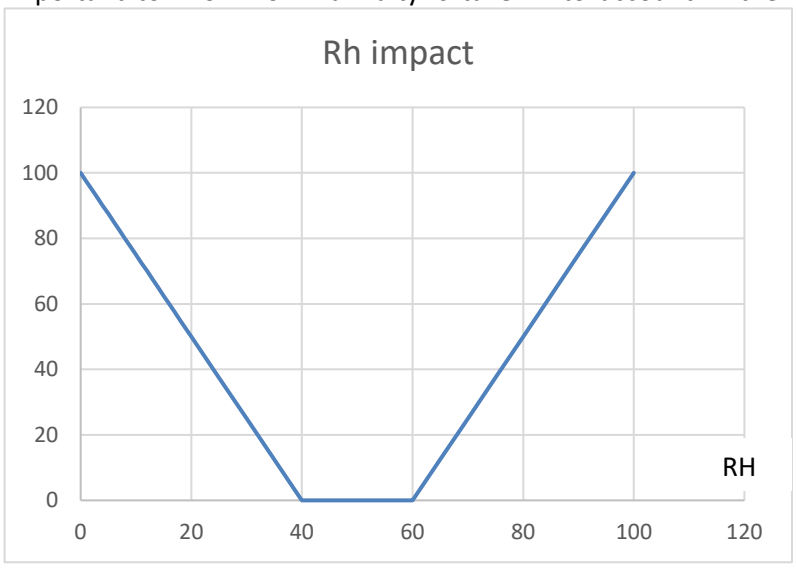
The optimal humidity for the building is between 40 and 60% (similar to that of humans but without taking into account the occupation).

Too many particulates generate deposits on the cold parts and age the paint. We take into consideration the total of particulate matter, i.e. PM10 (includes PM2.5 and PM1).

The main pollutants affecting materials are sulfur dioxide and sulfates, nitrogen oxides and nitrates, chlorides, nitrogen oxides and ozone.
In buildings containing books, historical artifacts, or other works of art, indoor pollutants can cause significant degradation, especially of colors.
Only ozone and nitrogen oxides are currently measured. Both can be taken into account.

Contributors: Humidity, PM10, Ozone

As the main use of this index in remediation regulation is intended for damp rooms (bathroom, kitchen, WC), it is important to know how humidity is taken into account in the index. The following graph is taken into account.



The range is from 0 to 100, with 100 being a healthy environment for the building.

This index is an intuitive indicator that can be used as a set point for ventilation.

Contributors

	CO2	VOCt	PM	Noise	Odors	T°	RH	NOX O3	Lux	Light T°
Building health			✓				✓	✓		

32.1.7. Risk of viral spreading

Unlike the other index which indicate cognitive performance, sleep, health or no risk of irritation, that are intended to control ventilation, this index indicates a risk.

100% represents a major risk of viral contamination.
0% represents a very low risk of contamination (but never zero in case of direct proximity or a contact with an infected person).

Contributors

	CO2	VOCt	PM	Noise	Odors	T°	RH	NOX O3	Lux	Light T°
Viral diffusion risk	✓					✓	✓			

33. Display

IAQ LEDs summarize health, productivity and quality of sleep indexes and display the lowest.

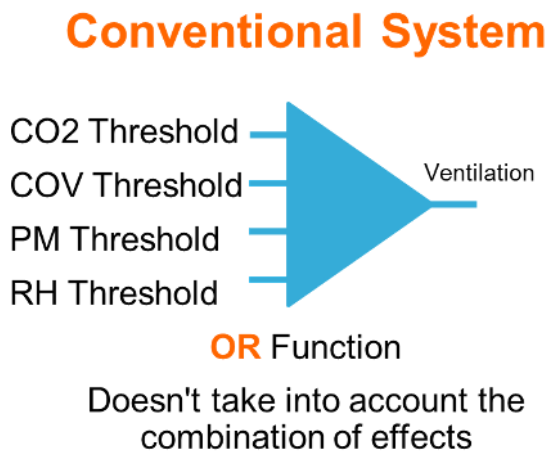
The ventilation regulation loop is based on settable health, productivity and quality of sleep objectives or by exceeding conventional thresholds.

The comparison between IAQ and AAQ is based on the comparison of physiological effects. An indication by LED for windows on street and backyard. It can be set to WELL V2 criterias.

34. Remediation control

The probe can control means of remediation (generally ventilation) according to the IAQ set points (By threshold for each pollutant or by threshold for each physiological effect). In all cases, the control is of Proportional Integral (PI) type, which makes it possible to converge quickly towards the setpoint value. The threshold and the proportional band can be configured via NFC and the smartphone application.
The set points are specific to each mode: Comfort (presence), Eco (absence), Night.

34.1. Conventional remediation control with multi sensors



In a conventional system, a threshold is determined for each pollutant. From this threshold, a PI control loop is calculated for linear control or threshold overrun with hysteresis for On Off control.

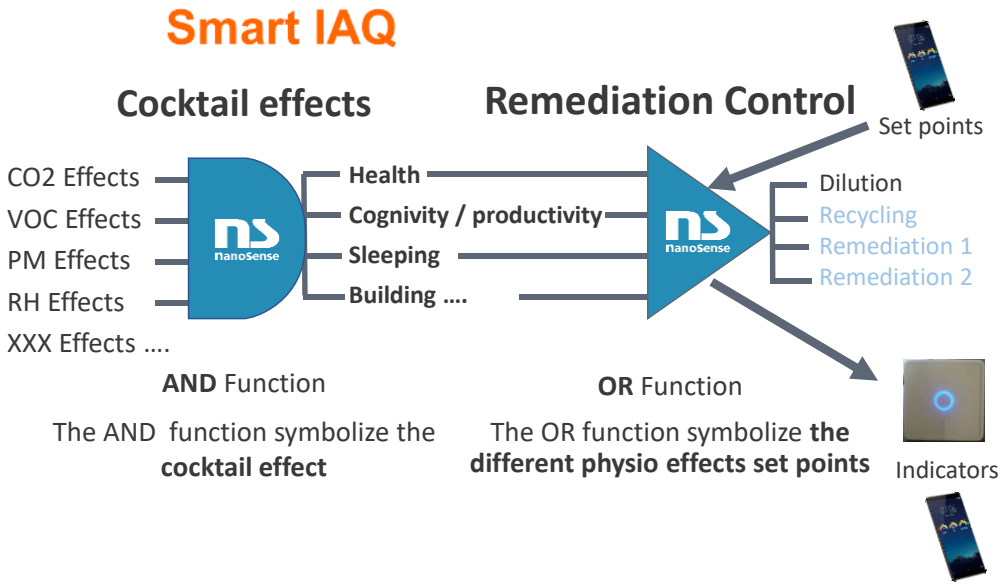
The command associated with each pollutant is compared and the strongest command is applied. It is therefore an OR function because either one pollutant generates the strongest command or another and there is therefore no cumulative effect of the pollutants.

34.2. Remediation control via Physiological Effects

There are several physiological effects calculated simultaneously:

- Cognitive / Productivity
- Health
- Quality of sleep
- Olfactory comfort
- Irritation of the respiratory tract
- Building health

The principle of remediation on physiological effects is that the index serves as a setpoint value. An index calculation is based on several sensor measurements and their combined effects (cocktail effect). Productivity takes, for example, temperature, light and noise into account without being able to act on them. To be able to achieve the defined objective, the probe has no choice but to reduce the impact of the IAQ which weighs in the calculation of the index. To sum up: in summer, in a non-air-conditioned building, the EP5000 probe will compensate for the loss of productivity linked to excessive heat by over-ventilation in an attempt to meet the desired productivity objective.
The setpoints setting addresses each physiological effect objective independently for each modes (Comfort, Eco, Night).
Each mode normally requires the use of an additional sensor (Occupancy, night sensor or clock). But the EP5000 probe can also use its own sensors to determine occupancy (on C02) and night (light). Failing this, the EP5000 sensor will operate 24 hours a day in comfort mode.



For each physiological setpoint, an index is calculated then a PI control (proportional integral) is computed according to the setpoint.
The applied control is the most important value of all computed PI controls (Or function).

However, since light affects melatonin (sleep hormone), the index of productivity and cognitive functions, when darkness is less than 10 Lux, it is considered that it is no longer possible to see and therefore to work and index becomes zero. In this case the probe could try to compensate for the negative influence of light by over-ventilating. To avoid this extreme and inappropriate operation, as soon as the light level drops below the threshold defined for the night via the smartphone application, the probe replaces the cognitive setpoint with a sleep quality setpoint. As this last index is not influenced by the luminosity, the ventilation will not try to unnecessarily compensate for the lack of light.

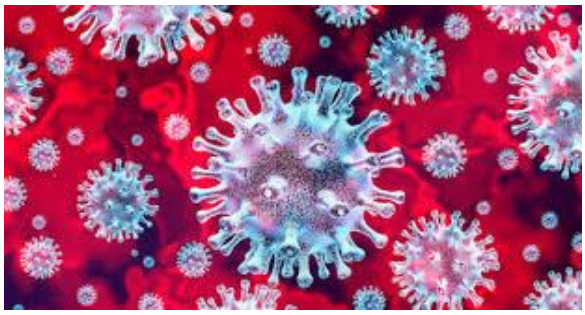
Please note that this switching of the physiological effect setpoint should not be confused with the switching to Night mode.

35.Index of viral contamination risk details

Virus transmitted through the air as well as direct and indirect contact depends of different factors:

Transmission	Temperature	Humidity	UV	Human density	Air flow	PM2.5
Airborne	✓	✓	✓	✓	✓	✓
Contact	✓	✓	✓			

Virus survival conditions are temperature and humidity dependent. Virus are also sensitive to UV. This explain partially why the flu is more prevalent in winter. Crowded environment (confinement) is also a factor of virus spreading. The EP5000 probe can estimate the number of people in a room from the CO2 measurement and the controlled ventilation flow rate. This index evaluates the risk of viral contamination in a building.



Contributors:

	CO2	VOCt	PM	Noise	Odors	T°	RH	NOX O3	Lux	Light T°
viral contamination risk	✓					✓	✓			