



Safety is for life.™

REMBE® CO.Pilot

A safety investment
that pays off.

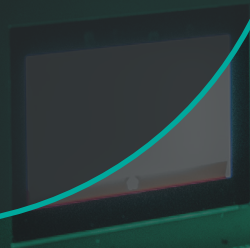


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CO.Pilot



GmbH Safety-Control





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1. Introduction

Typically safety systems are predominantly addressing occupational safety and health requirements. Hence, for some it is a critical investment into the resiliency of their business. But what if a safety system could both in addition to it's original job also **safeguard the business**, and **increase performance**?

The REMBE® CO.Pilot does exactly that: It detects carbon monoxide (CO) from smouldering product in dryers to prevent fires or explosions, and also helps improve the efficiency of drying operations by delivering reliable humidity measurements.

This paper discusses critical safety and efficiency challenges in drying operations, introduces the CO.Pilot, and shows how this system can enhance both safety and efficiency resulting in a true return on investment.

2. Daily Dryer Production Challenges

Drying processes can experience several common challenges:

- Product can build up within the process. One example is buildup near the nozzles, which can form cauliflower-like deposits and can only be controlled by using optical cameras for monitoring during operation. Other deposits

often occur due to the poor flowability or adhesive properties of the product. These deposits can built up in various parts of the system, such as in the cone of the dryer, in fluid beds, cyclones, or in conveying lines. Product deposits are exposed to high temperatures for extended periods, leading to the risk of self-ignition depending on the product properties. Self-ignition involves an exothermic reaction, also known as a run-away reaction, that heats up until the product ignites. When self-heating is detected early, however, the dryer can be stopped fires and explosions be prevented.

- Another issue is the instability of the drying process due to fluctuations in the intake air humidity. Without reliable humidity measurements, it is difficult to account for environmental effects on the drying process, resulting in process inefficiency and inconsistent product quality.

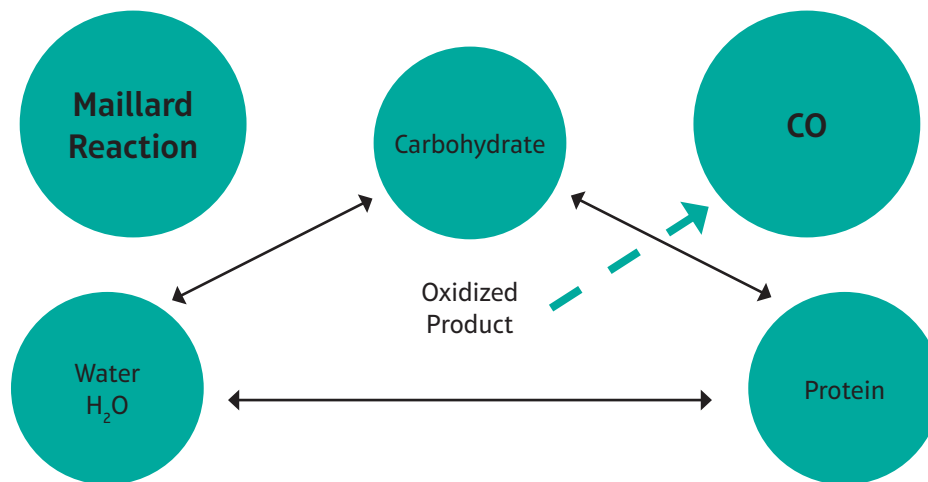
Ensuring stable, efficient, and safe dryer operations require addressing a wide range of interrelated factors: managing product buildup through enhanced design and process control, stabilizing humidity levels despite external variability and implementing comprehensive safety measures to prevent self-ignition. The following sections will delve deeper into these challenges, offering targeted solutions and best practices for improving safety and drying performance.



3. Maillard Reaction in the Drying Process

One of the most well-known reactions that can lead to self-ignition in dryers is the Maillard reaction, which involves the interaction of amino acids, sugars and water, leading to browning and the formation of complex flavours and aromas. The Maillard reaction can lead to overheated powder up to the onset of smouldering. If the product contains ingredients that can be oxidized, such as fats, it will produce CO already at an early stage of the reaction, which can be detected before smouldering may transition to flaming combustion and a fire or explosion may occur. Both temperature and the product moisture level affect how fast the Maillard reaction proceeds. In the drying

process, wet product is heated and becomes dry product, thus crossing a region susceptible to Maillard reaction. Ideally, the product residence time in this region is short, avoiding any threat; If, however, product builds up, reaction rates can become significant. It is therefore critical to control the drying process to avoid buildup and to detect any indication of Maillard reaction by measuring CO emission. This is feasible even in dryers with a very large air flow by using sensitive detection equipment and advanced interpretation of the measurement. Beyond preventing fires and explosions, humidity control is necessary to achieve a constant quality of the product.



4. Process Control

The Role of Humidity in Drying Processes

Humidity is a critical parameter in drying processes, influencing product quality, process efficiency and process safety. Proper control of humidity is essential for stabilizing drying conditions, optimizing energy usage, and mitigating risks associated with fouling (deposit formation) and self-ignition. Relative humidity (RH) is a critical factor in drying technology. Defined as the ratio of the current water vapor content in the air to the saturation concentration at a given temperature (expressed as a percentage), RH serves as a key driving force in moisture removal. In industrial drying systems, the interaction between RH and the drying process is fundamental to understanding moisture dynamics and optimizing process efficiency.

Dynamic Fluctuations and Process Control

Maintaining a stable RH is challenging due to the dynamic nature of drying environments. External factors such as seasonal and daily weather changes or internal variables like slurry and raw material variations cause fluctuations in RH. These variations can lower the drying rates and affect product consistency, underscoring the need for accurate and responsive control and measurement systems.

Absolute Humidity: A Stable Reference for Process Control

While RH provides valuable insights into the drying efficiency, absolute humidity (AH) offers a more stable measure of the actual water vapor content in the air,

independent of temperature changes. Expressed in grams of water per kilogram of dry air (g/kg), AH remains consistent as long as the moisture content in the air does not change, making it a reliable parameter for process control. In drying applications, controlling AH helps stabilize the drying environment by maintaining a consistent moisture load in the air. If the operator can keep both the AH and outlet temperature stable, this consistency directly translates to predictable drying performance and consistent product quality. Unlike RH, which varies with temperature, AH provides a fixed reference, allowing for better control over the drying process even under variable environmental conditions.

Balancing RH and AH in Process Optimization

Both RH and AH are essential in managing drying operations, but they serve different purposes. RH is crucial for understanding how readily the air can absorb moisture from the product, while AH gives a clear picture of the total moisture load that the air can carry. In practical terms: RH as a Dynamic Indicator: RH is the primary parameter for adjusting the drying air's capacity to absorb moisture. It is particularly useful when fine-tuning the drying process for efficiency, especially in systems where temperature is tightly controlled and process variability is minimal. AH for Process Stability: AH provides a stable control point, especially in environments with fluctuating temperatures or external weather changes. It ensures that the moisture content in the air remains consistent, preventing issues such as over-drying, powder clumping, or uneven product quality.

Understanding the interplay between RH and AH is key to optimizing drying performance. For example, even if the RH indicates low moisture absorption potential, high AH might mean that the air is already saturated with moisture, reducing the drying efficiency. Conversely, low AH coupled with low RH ensures that the air can absorb significant amounts of moisture, leading to faster and more consistent drying.

Controlling Humidity under Variable Conditions

In real-world operations, drying processes often encounter variability due to changing feed characteristics, environmental conditions or process fluctuations. This variability makes it challenging to maintain consistent drying conditions if only one parameter – either RH or AH – is monitored. By integrating both RH and AH into the control strategy, engineers can better adapt to these fluctuations, ensuring consistent product quality and process efficiency.

For instance, during seasonal changes, outdoor air may have the same AH but different RH levels due to temperature shifts. Monitoring both parameters allows for more accurate adjustments, such as pre-conditioning the inlet air to maintain optimal drying conditions regardless of external factors.

Understanding the Sticky Point and its Impact

The Sticky point is a critical concept in drying technology, particularly in spray drying. It refers to the point at which a product becomes sticky and begins adhering to surfaces within the drying equipment. This behaviour is influenced by temperature, relative humidity and the product material properties.

If the process conditions exceed the Sticky point (i.e., if the air humidity and/or temperature are too high), product deposits can form on equipment surfaces like cyclones, ducts and dryer walls. These deposits can lead to reduced efficiency, frequent cleaning needs, increased fire and explosion risks and product quality issues.

Leveraging the Mollier Diagram for Process Optimization

The Mollier Diagram (psychrometric chart or h,x -diagram) is an invaluable tool for managing and optimizing drying processes. It helps visualize and adjust the relationships between temperature, humidity and enthalpy, leading to more efficient, stable and safe operations. By leveraging the diagram, one can effectively control process conditions, adapt to environmental changes and manage variability, ensuring high drying performance.

Process Efficiency, Safety, and Risk Mitigation

Controlling humidity effectively not only enhances process efficiency but also addresses critical safety concerns:

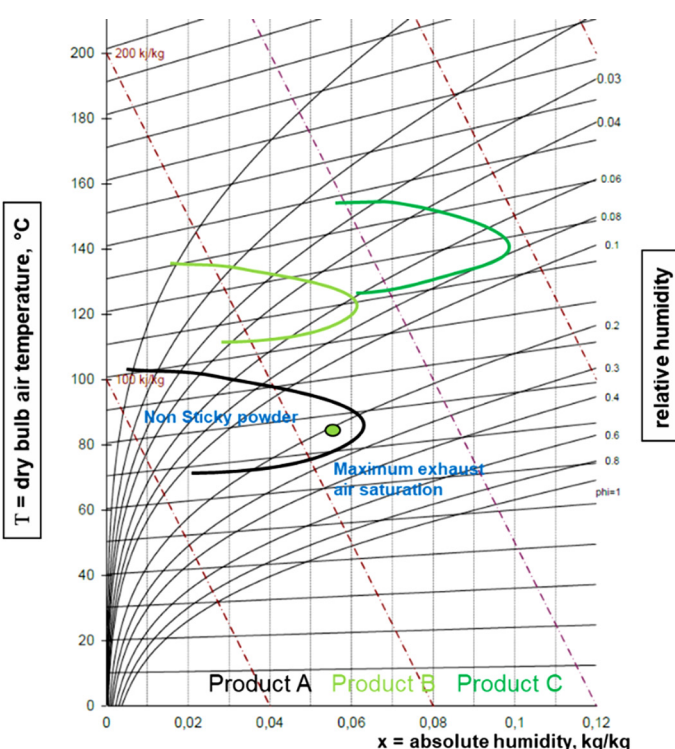
- **Process Stability and Safety:** Consistent control of RH and AH reduces the likelihood of deposit formation, which could lead to localized overheating and spontaneous ignition. By preventing conditions above the Sticky point, operators can avoid product deposits, reducing fire and explosion risks.
- **Energy Efficiency:** Precise humidity management optimizes drying efficiency, avoiding unnecessary energy consumption from overdrying and ensuring uniform product yield and quality.
- **System Reliability and Safety:** Maintaining optimal humidity levels prevents the accumulation of sticky residues that could clog equipment, increasing cleaning intervals, reducing maintenance time and mitigating fire hazards.

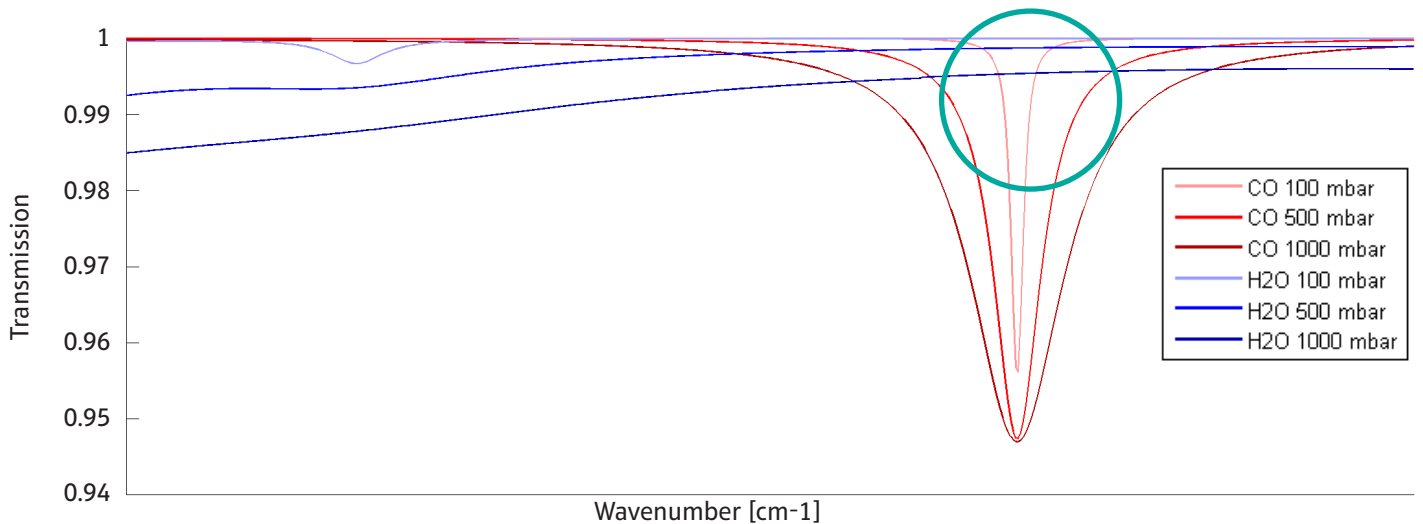
5. CO.Pilot Skills

The CO.Pilot takes continuous samples from the process at multiple locations and analyses them simultaneously for CO and H₂O content, using laser absorption spectroscopy (LAS). This technique measures light absorption in a gas sample using a laser light source and leverages the specific absorption properties of gas molecules, where each molecule absorbs light in a specific wavelength range.

At atmospheric pressure, the absorption spectra of CO and H₂O molecules overlap, which would lead to interference between the two measurements. Under high vacuum, however, the spectra narrow and the concentrations can be individually measured. The CO.Pilot therefore immediately expands the sample to high vacuum, allowing for CO and H₂O measurements and additionally preventing condensation.

In the following figure, the blue and red lines represent the H₂O and CO absorption spectra at different pressures, respectively. In the region highlighted with a green circle, it is clearly visible that, for a pressure of 100 mBar abs, the





H₂O absorption is zero where CO peaks, i.e., at such low pressure, individual measurements can be taken without interference.

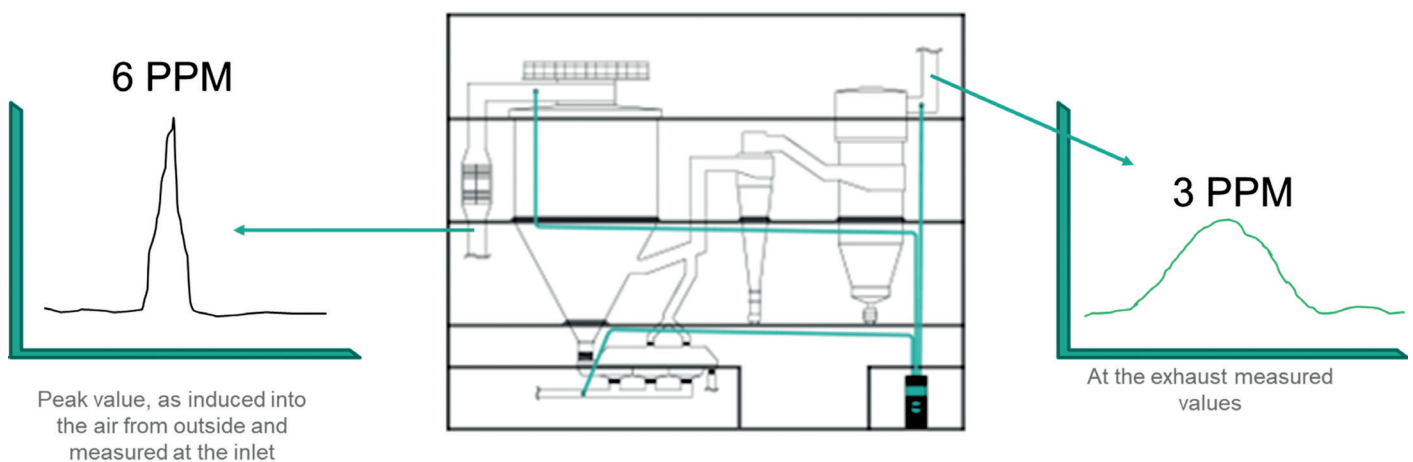
To be able to see how much CO is produced in the process, the CO.Pilot has to calculate the differential CO value between the inlet and outlet of the process. As the dryer quite often has also a mixing function, the concentration and temporal development of CO at the outlet of the dryer is different from measurements taken from the environment. To be able to calculate a reliable difference, the CO.Pilot utilizes the REMBE® Flow Algorithm (RFA) that simulates the dryer behaviour and predicts the outlet CO created by the environmental inlet. The dryer behaviour is characterized during commissioning, which is needed for an effective compensation of the varying environmental CO input as produced, for instance, by a truck passing the air intakes of the dryer. The other important factor is that the measurements must be taken at least twice as fast as

the flow exchange in the dryer. The CO.Pilot achieves a very fast measurement that only takes a few seconds to analyse the CO content of a measurement point. The illustration below shows an example of how the inlet and outlet CO could look if a truck passes the dryer air inlet, accounting for the effect of the dryer in between.

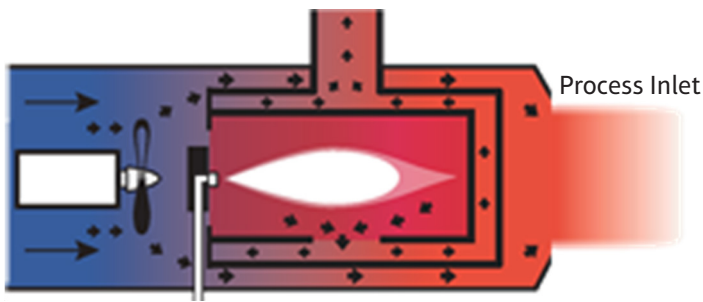
Two operational aspects are critical for the end user of such a safety system:

1. There should be no false alarms that are not created by problems in the dryer and
2. There should be no unplanned shutdowns of the system.

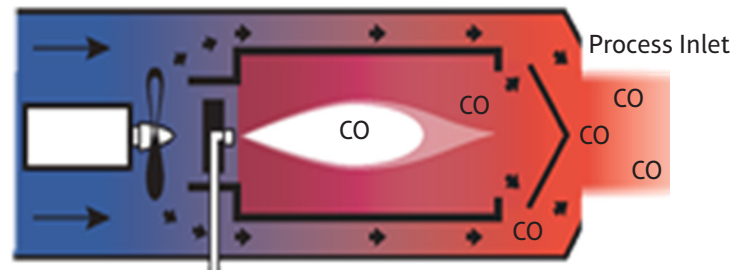
The first point has been discussed above and the RFA does a great job avoiding false alarms. To address the second point, the system uses highly reliable components that have demonstrated their reliability in practice and have long service intervals. An annual check and exchange of wear parts prevents unplanned shutdowns of the CO.Pilot.



Indirect heaters
*Air with no direct Contact
with the Flame*



Direct heaters
*Air with direct Contact
with the Flame*



6. Challenges in operational practice

There are many types of dryers, but all of them ultimately make a dry product from a wet product. Dryers need hot air that can be produced using a range of energy sources, from fossil or alternative fuels to electrical, with either direct or indirect heaters. Towers with indirect heaters have already a very good track record being protected by CO-detection systems as only the lower amounts of CO from environmental sources have to be compensated. Direct heaters however, send a mixture of flue gas with fresh air to the dryer. Of course, depending on the state of the burner, such a configuration sends also CO from the combustion process into the dryer, making the detection of CO that is formed in the dryer more challenging. Due to the REMBE® Flow Algorithm, the CO.Pilot can handle all these configurations, as long as the burner is in a good state and does not generate excessive variations in CO levels. This must be analysed before a CO.Pilot system can be implemented.

As for the humidity measurement, it is difficult to find a system that can measure in the exhaust for long times without maintenance. All systems on the market need regular cleaning, are not stable in their calibration and most cannot handle a wet clean-in-place CIP. This makes them unreliable for the control.

The CO.Pilot has overcome these challenges as it is a measurement without drift, can handle the product residues and also the CIP cycle has no effect on the measurement. Thus, it delivers a reliable H₂O measurement that the dryer can be controlled with.

7. Conclusion

The REMBE® CO.Pilot is an essential tool for enhancing the safety and efficiency of industrial drying processes. By focusing on precise CO detection, it addresses critical risks, such as self-ignition from the Maillard reaction. Early CO detection allows for prompt intervention, preventing potential fires or explosions and ensuring a stable drying environment.

Challenges like product residue buildup and fluctuating humidity levels can compromise process stability. The CO.Pilot effectively manages these risks by providing real-time CO and H₂O measurements, which work in tandem to control and maintain consistent drying conditions.

In summary, the CO.Pilot's advanced CO detection system improves safety, boosts process stability and enhances overall drying efficiency, making it the world's first safety tool with a true ROI and an improvement towards reliable, sustainable and cost-effective industrial operations.



Safety is for life.™

Consulting. Engineering. Products. Service.



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