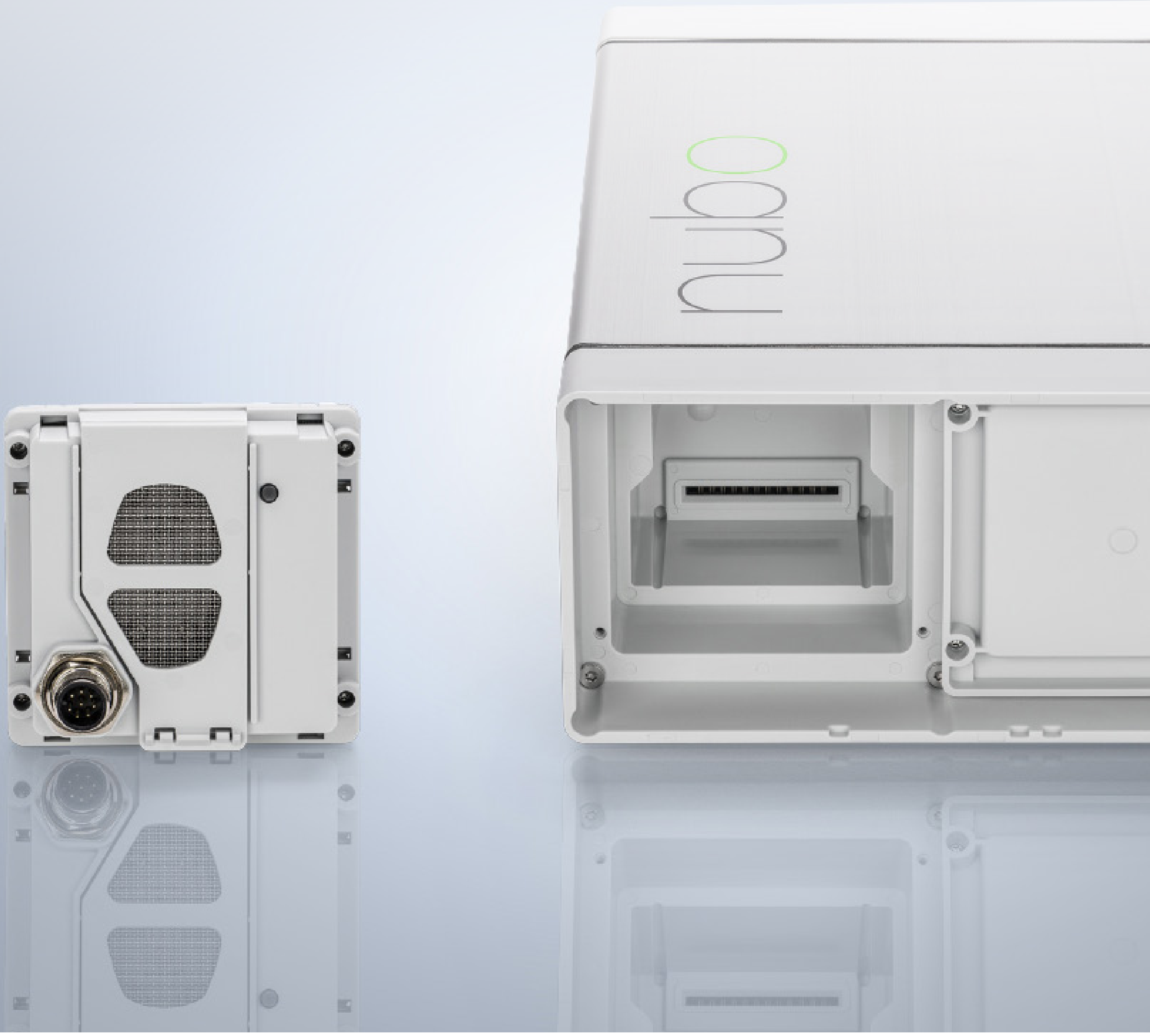
The best raw data comes from the best sensor technology

How Nubo Sphere turns raw data into actionable insights, part one



SENSIRION
connected solutions

The best raw data comes from the best sensor technology

Nubo Sphere is designed from the ground up to provide a complete picture of methane emissions throughout the year and deliver actionable insights that oil and gas operators can rely on to localize and quantify emissions. This article is the first of three revealing how Nubo Sphere achieves this goal. It starts with high-fidelity raw data—a crucial input for advanced data analytics. In this article, we focus on the proprietary Nubo Sphere methane sensor technology that delivers quality inputs for the solution's quality outputs.

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Executive Summary

Measuring unintended, fugitive methane emissions at oil and gas sites is challenging. Methane, the main component of natural gas, is lighter than air, odorless, easily disperses through open spaces and moves with the wind. The accidental nature of these emissions means we don't know when or where they occur. Accordingly, we don't know when and where to start measuring, nor do we know which equipment is leaking or the size of the leaks.

Sensirion Connected Solutions takes on this challenge with Nubo Sphere: a continuous methane emissions monitoring solution comprising purpose-built sensor technology, informed siting procedures and advanced analytics.

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Making the best of many ways to measure methane concentrations in air

Emissions monitoring is defined—and in many ways constrained—by the economic, practical and physical realities of oil and gas sites. But it should not be constrained by sensor technology. When Sensirion Connected Solutions started working on Nubo Sphere, it was with the future in mind and the best sensor for the task at the heart of the solution.

There was only one problem: no sensor technology was readily available offering the right performance at the right price to render a fixed-point sensor network successful from a technical and commercial standpoint.

In its first generation, Nubo Sphere used a metal oxide (MOx) methane sensor. These sensors, however, were always place-holders—a unique feature of every Nubo Sphere node is a modular sensor cartridge design (see figure 1), which allows for seamless on-site upgrades. At launch, Sensirion was already working on a replacement for the MOx sensor cartridge, de signed for the specific needs of the oil and gas industry. Building on Sensirion’s expertise in photoacoustic sensing (PASens® Technology), Sensirion Connected Solutions has since fielded a miniaturized, laser-based absorption spectros-copy sensor in the second-generation Nubo Sphere.

This technology has retained many of the strengths of MOx sensors, such as size, cost and power consumption, but eliminated many of their weaknesses. Delivering clear advantages in accuracy, cross-sensitivities and response time, all over a longer and lower-maintenance lifespan, these sensors still remain cost-effective enough to reap the advantages of deploying a wide sensor network to effectively monitor numerous oil and gas assets in different geographical regions.

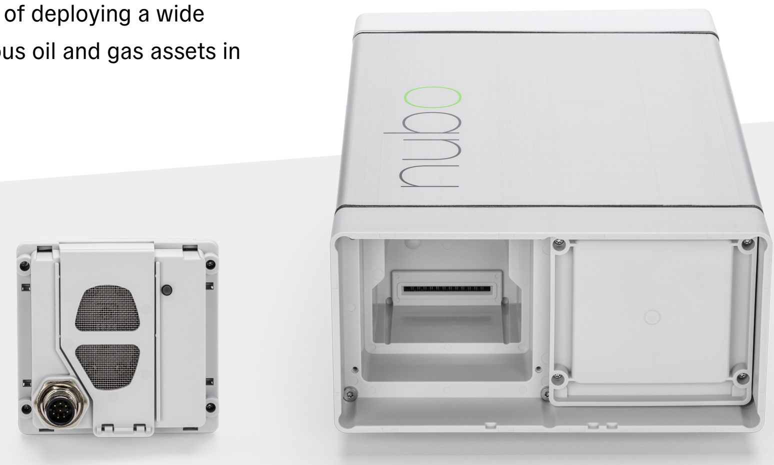

Figure 1: Nubo Sphere sensor node and photoacoustic-based laser spectroscopy sensor cartridge

“ Laser spectroscopy is the most suitable technology for measuring outdoor methane concentrations.

Dominik Niederberger, Director R&D, Sensirion Connected Solutions

Photoacoustic-based laser spectroscopy: a breakthrough in continuous emissions monitoring

The Nubo Sphere methane sensor uses mid-infrared laser spectroscopy based on photoacoustics. Laser light absorbed by CH_4 molecules results in an increase in the translational energy of those molecules, which is reflected in an increase in pressure within the optical measurement cell. Modulation of the laser causes a periodic pressure change inside the optical measurement cell—the photoacoustic signal—which is measured with a microphone.

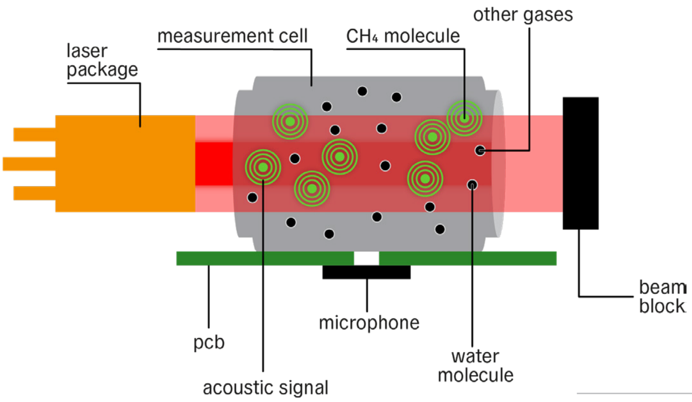

Figure 2: Working principle of Sensirion Connected Solutions' photoacoustic-based laser spectroscopy sensor technology

Dominik Niederberger, Director of R&D at Sensirion Connected Solutions, says laser spectroscopy is “the most suitable technology for measuring outdoor methane concentrations.” Having worked for years developing Sensirion's MOx sensors before joining the Sensirion Connected Solutions team, he is uniquely qualified to speak to the advantages of the laser spectroscopy sensor: robustness, accuracy, speed, precision, low cross-sensitivity, and immunity to drift.

The latter point, especially, speaks to two of several related problems inherent to MOx sensors: a drift of the sensor's baseline as well as its sensitivity.

Drift, cross-sensitivities and accuracy: why not MOx?

MOx sensors work on a chemical reaction principle—air, depending on its chemical makeup, produces different reactions with the surface of the MOx sensor, and those reactions change the electrical resistance below the surface (see figure 3). Because this reaction only happens when conditions change, MOx sensors can only measure methane concentrations relative to a calibrated baseline. Unfortunately, that baseline is prone to drifting over time, commonly referred to as "baseline drift".

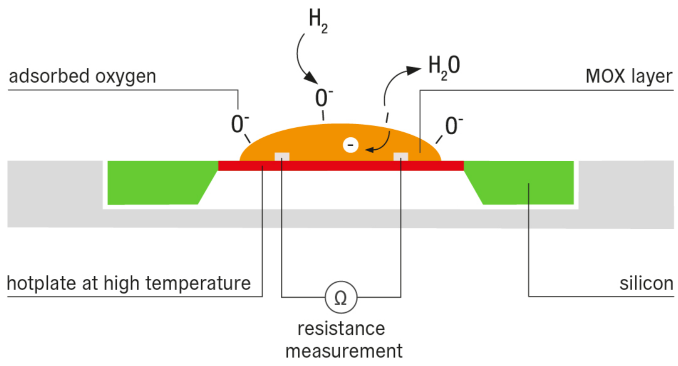

Figure 3: The working principle of metal-oxide sensor technology

There is a common strategy to deal with baseline drift: baseline correction in the field. This is generally based on an assumed baseline concentration equal to an atmospheric methane background of ~1.8 ppm. "This approach has a significant disadvantage because this assumption is not true worldwide—we checked—and it's also not true all the time," Dominik says. Indeed, according to NASA, within the USA alone ground-level methane concentrations deviate by more than five percent.

That's not the only problem when compensating for baseline drift. Dominik continues: "the MOx sensor features a logarithmic response rather than the linear signal correlation of our laser spectroscopy sensor, which means that if there is a small deviation between reality and the set baseline at low concentrations, this would lead to a large deviation in the sensor signal at high concentrations... For example, if the baseline is not 1.8 ppm but 0.3 ppm higher, which is 17 % more, then the error measuring 100 ppm would be 17 % higher, too, which is an error of 17 ppm." The case for baseline correction only looks worse when considering that background levels on oil and gas sites can measure around 50 ppm—a concentration that baseline correction would return to 1.8 ppm.

There is no way to compensate for the second type of drift. "Sensitivity drift" affects MOx sensors over time in operation with them being exposed to various, yet unknown exact environmental conditions and other gases, taking sensor readings further and further from reality. The only solution is to completely replace the MOx sensor every other year. For this reason, Sensirion Connected Solutions had chosen to limit the specified lifetime of first-generation Nubo Sphere MOx sensor cartridges to two years.

"Sensirion has a very extensive experience in MOx sensors," Dominik explains. "We've identified many different chemicals that influence sensitivity drift, and compensation is very difficult. It's actually almost impossible. Only in controlled indoor environments, where you have more or less the same temperature and humidity, MOx sensors work well—which is why Sensirion is successfully using MOx sensors for indoor air applications—but for outdoor applications, it's very challenging especially over an extended time period across many different geographical regions. In contrast, accelerated lifetime tests show that the sensitivity of our laser spectroscopy sensor only drifts negligibly."

For sensor nodes deployed in remote locations, frequent in-field interventions to maintain sensor accuracy is not viable. Needing years of reliable, accurate and absolute measurements led to Sensirion Connected Solutions deploying a miniaturized laser spectroscopy sensor for methane emissions monitoring.

Choose Nubo Sphere for lower cross-sensitivity, speed and accuracy

When monitoring for methane emissions, detecting methane only, rather than other VOCs or even water vapor, is of the essence. This is not a problem for Nubo Sphere: due to the physics of the sensor technology's working principle, Nubo Sphere detects methane specifically. With MOx sensors, though, detecting only methane is not a given. According to Dominik, "in general, MOx sensors are known as broadband sensors, measuring almost everything, and compensation of these cross-sensitivities turns out to be very, very difficult."

Cross-sensitivities create a serious problem for operators, especially at remote sites: reports typically categorized as false positives. Time spent chasing these is time wasted.

Cross-sensitivities in typical natural gas composition (90% methane 5% ethane)

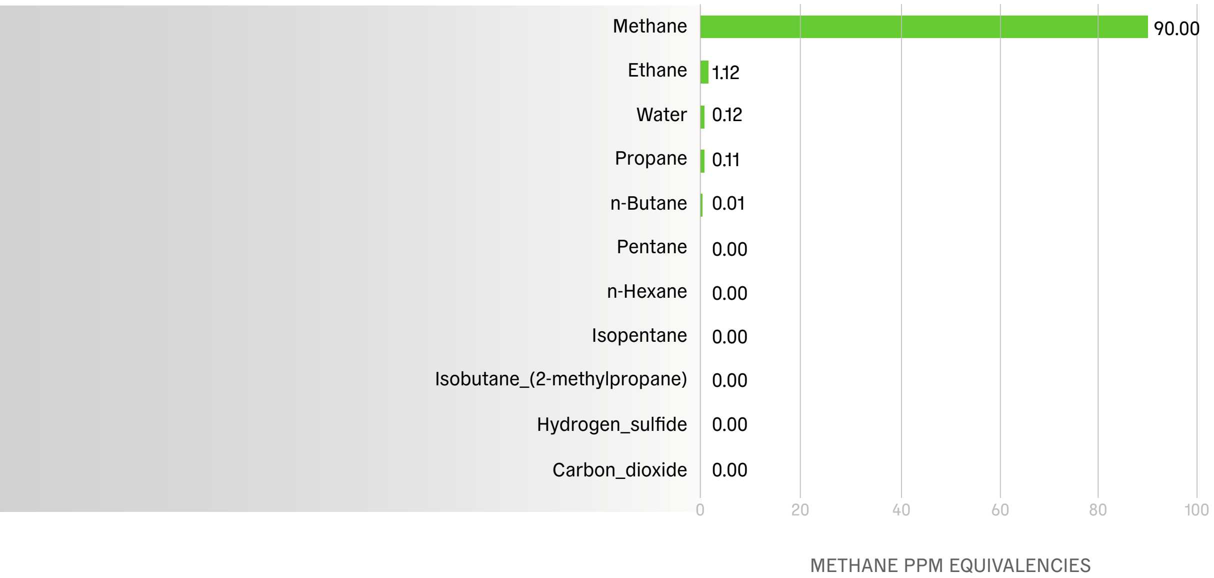

Figure 4: Sensirion's proprietary methane sensor technology achieves a high methane specificity of 99%, with cross-sensitivity to other gases minimal at 1%. This graph shows the sensor measurement contributions of the gases present in a typical natural gas mixture. Assuming a natural gas mixture of 90% methane and 5% ethane, this gives a sensor output of ~91 ppm, of which 90 ppm is actually methane and only 1 ppm is due to ethane absorption.

99%

high methane specificity is achieved by Sensirion's proprietary methane sensor technology

> “ It’s very hard to measure these short peaks at all with a MOx sensor, and even if you can, it’s all but impossible to measure them accurately.
>
> Dominik Niederberger

Furthermore, when measuring methane in a dynamic environment, speed is of the essence. “If the outdoor methane concentration is changing rapidly due to wind,” Dominik says, “then you need a sensor that can respond rapidly... In our application of continuous methane emissions monitoring, the methane peaks change within seconds. “It’s very hard to measure these short peaks at all with a MOx sensor, and even if you can, it’s all but impossible to measure them accurately.”

Fundamentally, the chemical process at work in MOx sensors takes far longer than the physical process at work in laser-spectroscopy sensors. The laser spectroscopy speed advantage yields quick detection and more reliable detection of small or intermittent leaks. It also yields more precision, allowing a higher level of detail when modeling methane plumes, bringing contours into focus. This is because, by sampling about 20 times faster, the laser spectroscopy sensor can sample more, and therefore provide more information per sensor than a MOx sensor.

Finally, the Nubo Sphere sensor delivers more accurate measurements of methane concentrations. With the laser spectros-scopy sensor, Sensirion Connected Solutions has achieved a significant improvement in absolute accuracy performance. This means that Nubo Sphere sensors consistently take methane concentration readings that closely correspond to reality. Also, measurements are repeatably accurate; device-to-device variation is minimal.

Accuracy is key when estimating the locations and rates of emissions. It also minimizes false positives and mis-reporting. With accurate absolute measurements, operators can count on reliable site-level emissions quantification over years of operation.

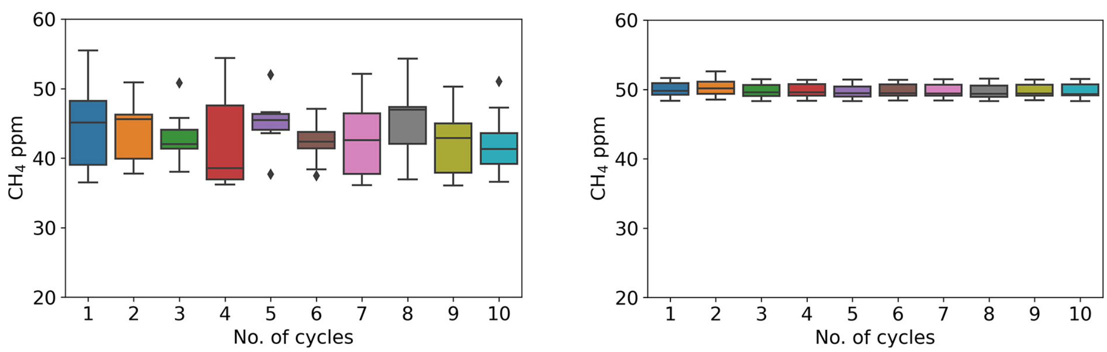

Figure 5: Results of laboratory testing, releasing 10 cycles of 50 ppm methane in a gas measurement chamber. The plots above represent measurements from six sensors for both MOx sensors (left) and Nubo Sphere’s proprietary photo-acoustic- based sensor technology (right). Nubo Sphere’s results indicate absolute accuracy (measurements correspond to actual concentrations), high repeatability (measurements of all releases are consistent) and low device-to-device variations (measurements from all devices fall into a narrow range).

Conclusion: quality in, quality out

Operators can count on Nubo Sphere for reliable emissions measurements and actionable insights in support of LDAR activities and regulatory compliance. This is, in part, because Nubo Sphere's photoacoustic-based laser spectroscopy sensors deliver reliable, specific, accurate and precise methane concentration readings at a high temporal resolution.

Quality outputs need quality inputs. The Nubo Sphere sensor furnishes the solution with the speed to detect intermittent emissions and accurately identify when emissions start and stop, the precision required to model plumes at high resolution and pinpoint emission sources, the specificity to methane to avoid false positives, and it does this with minimized maintenance requirements and at a low overall cost of operation.

Raw sensor data is the bedrock on which the Nubo Sphere solution is built. But sensor data alone can't provide a complete picture of methane emissions. To generate actionable insights, Nubo Sphere combines raw sensor data with site-specific information in advanced analytics. In the next article in this series, we look at Nubo Sphere's siting procedure. This not only ensures that sensors are optimally placed, but it also provides valuable information to Nubo Sphere's analytics. Read part two of this series to learn more about how Nubo Sphere turns raw data into actionable insights.

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Sensirion Connected Solutions specializes in sensor-based IoT-solutions and services for emissions monitoring in the energy sector. By integrating proprietary sensor technology, advanced data analytics and an intuitive user interface, Sensirion Connected Solutions provides the transparency and actionable insights needed to reduce emissions.

The company aims to help oil and gas operators comply with regulations, meet their ESG goals, improve safety and enhance operational efficiency. Headquartered in Stäfa, Switzerland, and Chicago, Illinois, USA, Sensirion Connected Solutions is part of Sensirion Holding, a leading global manufacturer of high-performance digital microsensors for environmental and flow sensing applications.

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