High-Precision CO_2 Sensor Compliant with Title 24

Cubic Innovative NDIR CO_2 Sensor Achieves Accuracy of 30ppm ± 3% for Demand Control Ventilation Systems

Table of Contents

Title 24, California Building Energy Efficiency Standards, is a set of energy efficiency standards, which establishes multiple requirements for building design and construction, aiming to reduce energy consumption and improve indoor air quality (IAQ).

It is worth noting that in the field of indoor ventilation, Title 24 has set stringent standards for Demand Control Ventilation (DCV) System as follows:

DCV system shall be required for spaces that are more than 500 square feet (46.45 m^2) and with a design occupancy for ventilation of not less than 25 people per 1000 square feet (92.9 m^2) of floor area and served by systems with one or more of the following:

1)Air-economizer.

2)Automatic modulating control of outdoor air damper.

3)Design outdoor airflow more than 3000 ft^3/min (1.4158 m^3/s).

Under this context, Title 24 mandates the adoption of a DCV system for new and renovated buildings in California, which has sparked widespread attention to DCV implementation. This article aims to provide insightful interpretations of Title 24 and offers valuable solutions for compliance with Title 24 Standards.

1.What is CO_2-based Demand Control Ventilation?

When it comes to DCV, the fresh air system will come first. A fresh air system is a system for indoor air treatment and ventilation, with the main function of introducing fresh air, discharging indoor dirty air, and filtering and conditioning the air to provide good indoor air quality, and creating a comfortable environment.

DCV is a kind of effective control system used in fresh air systems to improve indoor air quality and achieve energy savings by automatically adjusting the ventilation rate. Typically, one of the most popular and widely available applications is a CO_2-based DCV system.

CO_2-based DCV system adopts CO_2 sensors strategically placed in specific indoor spaces to continuously and accurately monitor indoor CO_2 concentration levels in real-time. CO_2 sensors will transmit the captured CO_2 concentration data to the control unit of the ventilation control system, where the data is processed and analyzed. Usually, before the CO_2-based DCV system starts running, the corresponding indoor CO_2 concentration threshold is set in advance, and the set thresholds are generally in accordance with ASHRAE standards. When the CO_2 concentration exceeds a set threshold, the control unit will send a control signal to the fresh air system to increase ventilation. Once the CO_2 concentration drops below the set CO_2 threshold, the fresh air system will reduce indoor ventilation. By applying CO_2 sensors, the DCV system can better control ventilation based on actual demand.

*DCV working mode

2.The benefits of a CO_2-based DCV system

CO_2-based DCV systems could achieve significant energy savings and improve indoor air quality.

2.1 Achieving Energy Savings

DCV is an effective method for achieving energy savings. Taheri and Razban (2021) conducted an experiment to discuss the difference in total energy consumption between the ventilation system (Current) and the CO_2-based DCV system. As is shown in Table 1., a CO_2-based DCV system at a CO_2 setpoint of 1000 ppm could save 51.4% of energy compared to a ventilation system (Current) with an average fan flow rate of 0.90 m^3/s.

System	Average fan flowrate [m^3/s]	Operation hours	Total fresh air [m^3]	Energy consumption [kWh]	Energy saving [%]
Current	0.9000	10	32400.0	36.0	—
DCV-500 ppm	0.7435	10	26766.0	29.7	17.5
DCV-600 ppm	0.6233	10	22438.8	24.9	30.8
DCV-700 ppm	0.5238	10	18860.6	21.0	41.6
DCV-800 ppm	0.4873	10	17542.8	19.5	45.8
DCV-900 ppm	0.4513	10	16246.8	18.1	49.7
DCV-1000 ppm	0.4366	10	15717.6	17.5	51.4

Table 1. The difference in total energy consumption between the ventilation system (Current) with an average fan flowrate of 0.90 m^3/s and the DCV system at different CO_2 setpoints (Taheri & Razban,2021)

The reason why the DCV system achieves more energy savings is simply because the system regulates the ventilation volume by adjusting the fan speed. When there is a need for large ventilation volumes, the fans will operate at high or full speed to meet the demand. Conversely, when only a small amount of ventilation is required, the fans can be operated at low speed or at part load to minimize energy consumption.

2.2 Improving Indoor Air Quality

Indoor air quality is essential in closed spaces with high occupancy levels. When the indoor CO_2 concentration increases, the indoor air quality will be substandard, and occupants will gradually experience physical discomfort if the condition of high CO_2 concentration continues. As shown in Table 2, especially when indoor CO_2 concentration exceeds 1000ppm, it indicates an indoor environment that deviates from the fresh air conditions, and people will feel uncomfortable. Therefore, a CO_2-based DCV system is fundamental, as it could help maintain a comfortable indoor air environment.

Carbon dioxide concentration	Description of indoor air quality
350-400 ppm	Fresh air, perfect conditions
<600 ppm	Acceptable conditions of indoor air quality in rooms
1000 ppm	The upper limit of fresh air
1500 ppm	Air perceived as stuffy and not fresh
2000 ppm	People with respiratory illnesses may receive cough, weakened people may faint
>10000 ppm	Bad air quality causes increased breathing rates, problems with respiration, headaches, nausea

Table 2. Description of Indoor Air Quality based on carbon dioxide concentration (Pietrucha, 2017)

3. Title 24 requirements for high-precision CO_2 sensors in DCV system

Title 24 mandates the application of the DCV system in certain spaces and presents specific requirements for the CO_2 sensors incorporated within the DCV system.

"CO_2 sensors shall be certified by the manufacturer to be accurate within plus or minus 75 ppm at a 600 and 1000 ppm concentration when measured at sea level and 25°C factory calibrated, and certified by the manufacturer to require calibration no more frequently than once every 5 years. Upon detection of sensor failure, the system shall provide a signal which resets to supply the minimum quantity of outside air to levels required by Section 120. 1(b)2 to the zone serviced by the sensor at all times that the zone is occupied."

Based on the rules outlined in Title 24, CO_2 sensors should meet the following five key points:

1) CO_2 sensors in the DCV system should be highly accurate, meeting the accuracy requirements within the concentration range of 600 to 1000 ppm, with a deviation not exceeding ± 75 ppm.
2) CO_2 sensors should be free from frequent calibration and maintain stability for at least 5 years.
3) CO_2 sensors should have a long lifespan, consistent with a fresh air system.
4) CO_2 sensors should provide continuous monitoring and measurement capabilities.
5) CO_2 sensors should be cost-effective to be integrated into the DCV system on a large scale.

4.Selection of CO_2 sensors for DCV system

CO_2 sensors, integrated into the DCV system, play a crucial role in achieving energy efficiency and maintaining indoor air quality. Based on the requirement from Title 24 about the CO_2 sensor in the DCV system, it is essential to select the appropriate CO_2 sensor used in the DCV system.

Three widely known technical technologies for measuring CO_2 concentration are NDIR (Non-Dispersive Infrared) Technology, PAS (Photoacoustic Spectroscopy) Technology, and Electrochemical Technology.

- NDIR technology relies on the principle of infrared absorption by CO_2 based on Lambert-Beer's Law: the higher the CO_2 concentration, the more infrared energy will be absorbed. The infrared source directly emits the infrared light and passes through the gas chamber to the optical filter before reaching the detector. The filter allows only the 4.26μm wavelength, corresponding to the absorption peak of CO_2 gas, to pass through it. The detector measures the intensity of infrared light and converts it into an electrical signal. As the CO_2 concentration in the gas chamber increases, less infrared intensity reaches the detector, resulting in a weaker electrical signal. CO_2 concentration can be calculated based on the electrical signal.

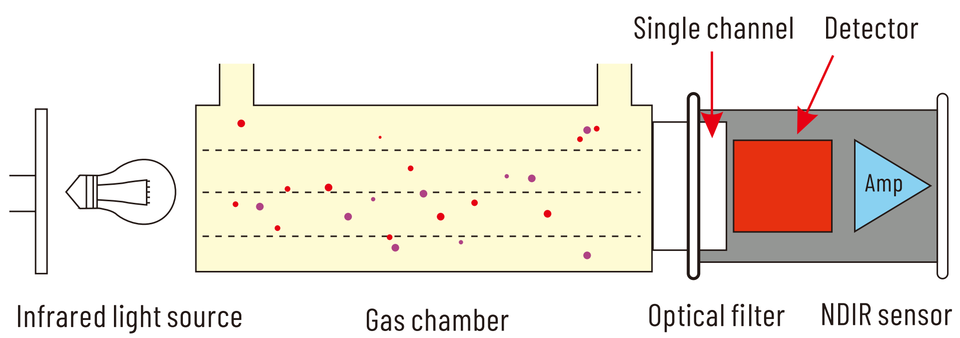

Figure1. Principle of Non-Dispersive Infrared

- In a PAS CO_2 sensor, an infrared light source works periodically and emits light. The optical filter only allows 4.26μm wavelength light to pass and reach the chamber with CO_2 gas. CO_2 molecules periodically absorb the infrared light, which causes additional molecular vibrations, resulting in a pressure wave inside the chamber. The higher the CO_2 concentration, the more light is absorbed, and thus the greater the amplitude of this acoustic wave becomes. A microphone inside the gas chamber measures the acoustic wave and then transfers it to an electrical signal, from which the CO_2 concentration can be calculated.

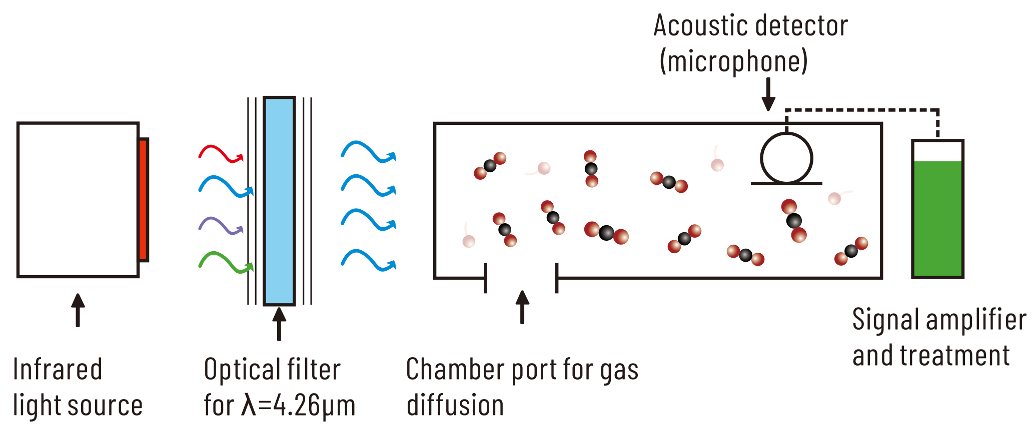

Figure 2. Principle of Photoacoustic Spectroscopy

- Electrochemical sensors for CO_2 detection employ a sensing electrode coated with an electrolyte. When CO_2 comes into contact with the electrolyte, a reaction occurs, generating ions that move to the other electrode, thus producing an electric current in the circuit. According to Nernst's Theory, the higher the CO_2 concentration, the faster the reaction speed and the larger the current so that the CO_2 concentration can be calculated according to the measured current.

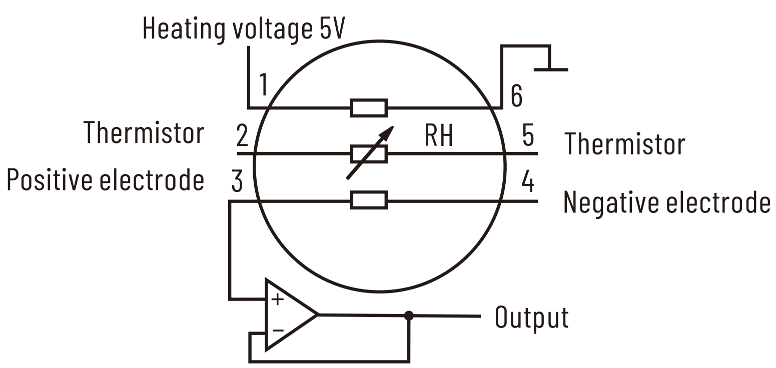

Figure 3. Principle of Electrochemical

According to the above mentioned principles, Table 3 has summarized the essential cons and pros of NDIR sensor, PAS sensor, and electrochemical sensor. After conducting a comprehensive comparison of three distinct methods for measuring CO_2 based on different technological principles and considering the specific high-precision requirements mandated by Title 24 regulations, it becomes evident that the NDIR CO_2 sensor represents the most optimal solution. The NDIR CO_2 sensor's remarkable performance positions it as the ideal choice for meeting the stringent demands of accuracy in compliance with the regulations.

Comparison	NDIR	PAS	Electrochemical
Advantage	• High accuracy for CO_2 concentration measurement • Strong anti-interference, anti-vibration • Long lifespan • Low maintenance costs	• Small size, easy to integrate and install	• Lower cost compared to PAS and NDIR
Disadvantage	• Specific wavelengths of infrared light need to be used, resulting in a sensor that cannot be very small while maintaining high accuracy	• Greatly affected by vibration • Easily affected by temperature and humidity changes and requiring complex corrections • Measurement accuracy cannot meet RESET Grade A	• Susceptible to interference • Low sensitivity and accuracy • Easily affected by temperature and humidity changes • Required regular calibration and maintenance • Long warm-up • Short lifespan

Table 3. Comparison of Three Main Technologies

5. Why NDIR CO_2 sensor is the best selection for DCV system?

Based on the advantages of the NDIR technology, the reason why the NDIR CO_2 sensor is the optimal selection for a DCV system under Title 24 requirements can be further illustrated from below five dimensions.

5.1 NDIR CO_2 Sensor Meets High Accuracy at (30 ppm ± 3% of reading) @ -10°C~50°C

NDIR CO_2 sensor perfectly meets precision requirements in Title 24, as Title 24 requires CO_2 sensors in the DCV system to demonstrate high accuracy within plus or minus 75 ppm at a 600 and 1000 ppm concentration at 25°C. NDIR CO_2 sensors can achieve high accuracy of (30 ppm ± 3% of reading) @ -10°C~50°C, 0-85%RH, by precisely designing the light source, filters, and optical path. Current commercial CO_2 sensors based on PAS typically achieve accuracy up to (50 ppm ± 5%), which cannot fully satisfy the accuracy requirements of Title 24.

Based on the NDIR principle, NDIR CO_2 sensors exhibit high selectivity to measure CO_2 concentrations without interference by other gases accurately. At the same time, NDIR CO_2 sensors demonstrated the superior performance of being unaffected by vibration. CO_2 sensors used for DCV systems are usually placed near ventilation pipelines, where vibration cannot be avoided. It may be challenging for PAS CO_2 sensors due to their susceptibility to vibrations, which would affect the accuracy of CO_2 concentration measurements.

5.2 Auto-zero-Calibration Mechanism Reduces Frequent Manual Calibration

Title 24 also specifies that CO_2 sensors in DCV systems should maintain stability for at least five years. NDIR CO_2 sensors adopt auto-zero-calibration mechanism, which detects and corrects sensor drift or deviations during the calibration process. The automated calibration approach ensures accurate measurements over the lifetime of CO_2 sensors and enables NDIR CO_2 sensors to maintain long-term stability without frequent manual calibration within five years.

5.3 NDIR CO_2 Sensor Achieves Long Lifespan, Indispensably Consistent with Fresh Air System

CO_2 sensors' lifespan should be consistent with the DCV system lifespan for at least 15 years. The optical elements of NDIR sensors are typically made of durable materials with excellent stability for long-term performance. Therefore, NDIR CO_2 sensors can easily achieve lifespans exceeding 15 years. In contrast, electrochemical sensors have a short lifespan (often months) and must be replaced frequently, which are not well-suited for fresh air systems.

5.4 NDIR CO_2 Sensor Enables Continuous Monitoring to Offer Real-Time CO_2 Concentration Data

NDIR CO_2 sensors could provide continuous monitoring and real-time feedback on indoor CO_2 concentration levels. The capability of timely response is vital for the DCV system, as the adjustment of indoor ventilation strongly relies on changes in CO_2 concentration levels.

5.5 Cost-effectiveness of NDIR CO_2 Sensor Realizes Large-scale Application in DCV Systems

The demand for CO_2 sensors used in DCV systems has increased, especially with the regulatory pressure of adopting DCV systems in multiple indoor spaces under Title 24 requirements. Opting for cost-effective CO_2 sensors that meet the requirements becomes crucial. In the past years, NDIR CO_2 sensors have been widely applied in IAQ monitoring and HVAC systems and the annual global market NDIR CO_2 sensors volume have been surpassed millions. These increasing market demands have led to a continuous cost reduction for NDIR CO_2 sensor core components and manufacturing expenses., which creates impetus to enable NDIR CO_2 sensor low-cost advantage to be widespreadly adopted in DCV systems.

Additionally, due to the auto-zero-calibration mechanism, NDIR CO_2 sensors could save time and maintenance costs without manual calibration.

With the advantages of high accuracy, long lifespan, auto-zero-calibration mechanism, and continuous monitoring capability, NDIR CO_2 sensors are ideal for DCV systems in compliance with Title 24. Harnessing the real-time CO_2 concentration data provided by CO_2 sensors, the DCV system dynamically adjusts ventilation rates to meet optimal indoor air quality requirements and achieve energy savings.

6.Cubic advanced CO_2 sensor for DCV system

Specializing in smart gas sensors and superior gas analyzers, Cubic has established a gas sensing technology platform based on NDIR technology to provide CO_2 sensors with the advantages of high accuracy, long lifespan, auto-zero-calibration mechanism, and continuous monitoring capability. In compliance with Title 24 regulations and requirements for fresh air systems, Cubic has specially designed the NDIR CO_2 Sensor, CM1106H-NS, which can be used in DCV systems to realize meticulous control to improve indoor air quality and energy efficiency.

Catalogue	Title 24 CO_2 sensor Requirements	Cubic CO_2 Sensor CM1106H-NS Specification
Measurement Range	• Verify that the CO_2 sensor is accurate to within plus or minus 75 ppm at a 600 ppm and 1000 ppm concentration when measured at sea level and 25°C. (Rule NA7.5.5.1(a)§120.1(d)4F§160.2(c)5Dvi) • Verify that the DVC system is set to assume that outdoor air CO_2 concentrations are 400 ppm. • Verify that the DCV control CO_2 setpoint is set to less than or equal to 600 ppm plus the outdoor air CO_2 concentration in all rooms with CO_2 sensors • If the system includes Direct Digital Control, then verify that the CO_2 sensor(s) reading for each zone is be displayed continuously and recorded.	0-2000ppm; 0-10000ppm
Accuracy		(30ppm ± 3% of reading) @ -10°C~50°C , 0-85%RH
Temperature		Working temperature: -10°C ~ 50°C Storage temperature -30°C ~ 70°C
Calibration	• Verify that the sensor is certified by the manufacturer to require calibration no more frequently than once every 5 years. • Verify access to any applicable factory calibration certificate(s). • With all controls restored, apply CO_2 calibration gas at a concentration slightly above the setpoint to the CO_2 sensor. Verify that the outdoor air damper modulates open to satisfy the total ventilation air called for in the NRCC-MCH-E, Table J or LMCC-MCH-E, Table J.	Maintenance-free for normal indoor application with Auto-zero-calibration mechanism
Lifetime	—	Lifetime ≥15 years
Cost	—	Low cost based on Cubic own supply chain

Table 4. Cubic CM1106H-NS in Compliance with Title 24

CM1106H-NS, developed from NDIR technology, is ideal for the DCV system, which stands at the forefront of technological innovation. It is designed with the specific infrared wavelengths and exhibits the critical advantage of high accuracy at (30ppm ± 3% of reading) @ -10°C~50°C, 0-85%RH, ensuring excellent performance in diverse environments.

- **High accuracy at (30ppm ± 3% of reading) @ -10°C~50°C**
- **Temperature calibration within whole measurement range**
- **Long lifespan**
- **Auto-zero-calibration mechanism for maintenance free**
- **Continuous monitoring**

Figure 4. Cubic High Accuracy NDIR CO_2 Sensor-CM1106H-NS

CM1106H-NS sensor is developed from NDIR technology, leveraging Cubic's extensive 20-year expertise in the field. Adopted with matrix calibration at low (-10°C), normal (25°C), and high (40°C) temperatures and multiple points of CO_2 concentration, the CM1106H-NS sensor ensures high accuracy across a wider temperature and measurement range. Additionally, selecting a strict component for the NDIR CO_2 sensor guarantees a 15-year lifespan. Based on Cubic's auto-zero-calibration mechanism, CM1106H-NS can autonomously maintain accuracy across its entire lifetime without frequent manual calibration. Besides, CM1106H-NS also features continuous monitoring of CO_2 concentration levels to provide real-time concentration data to the DCV system.

Complemented by a robust and reliable supply chain, Cubic capitalizes on the virtuous synergy of technological innovation, supply chain management, and lean production practices to effectively meet customers' burgeoning demands and provide holistic gas sensing solutions. At the same time, by implementing large-scale production and melding self-developed components for integration, Cubic offers meticulous cost control to provide highly cost-effective products to customers. Cubic also provides tailored service to meet customers' flexible and diverse product requirements.

Conclusively, with 20-year dedication to gas sensing technology, Cubic, as a leading manufacturer, will pay continuous attention to policy shifts in Title 24 regulations to provide qualified and reliable gas sensing solutions to customers all over the world. Cubic will also keep to devote the best efforts in the DCV and HVAC application for more influential technological innovations.

For more product information, please click on

https://en.gassensor.com.cn/IndoorCO2 Sensors/list.html

info@gassensor.com.cn.

Related Products

High Accuracy NDIR
CO_2 Sensor
CM1106H-NS

Super Low Power
CO_2 Sensor
CM1106SL-NS

Dual Beam NDIR
CO_2 Sensor
CM1107N

Integrated Air Quality
Sensor Module
AM1002
Particle+VOC and RH&T

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