Alternative Test Method (MATM-008)

March 14, 2025

1. Scope and Application

1.1 Scope

This method is applicable for demonstrating compliance with the procedures in 40 CFR §60.5398b(b) for fugitive emissions components affected facilities and compliance with periodic inspection and monitoring requirements for covers and closed vent systems, specifically demonstrating compliance through periodic screening in 40 CFR §60.5398b(b), as approved, per §60.5398b(d). Affected facilities could include but are not limited to single wellhead only sites, small well sites, multi-wellhead sites, well sites with major production and processing equipment, centralized production facilities, and compressor stations. This method details the procedures and information required for the implementation, operation, and use of the Qube Technology Methane Monitoring System as a tool for periodic screening, in accordance with the regulations set forth in §60.5398b(b) and §60.5398b(d).

1.2 Application

1.2.1 This method describes the Qube Technologies (Qube) emissions monitoring system used for periodic screening at minimum detection thresholds of 5 kg/hr, 10 kg/hr, and 15 kg/hr of methane. The Qube emissions monitoring system is used for the detection of methane emissions using a network of fixed devices on a site designed to detect, locate, and quantify methane emissions. This method uses technology that consists of three components: (i) an Industrial Internet of Things (IIoT) device housing metal oxide semiconductor (MOS) sensors and environmental sensors that measure meteorological data. The IIoT device is battery powered and solar recharged and transmits data to the cloud via cellular or wireless networks, (ii) a cloud-based platform that records and analyzes data received by the IIoT device and uses physics-based models to convert device data into leak locations and quantities, and (iii) a web-based dashboard that aggregates critical insights of the analyzed data. The Qube IIoT devices are placed at or near the facility property boundary.

1.2.2 The application of this method is per the Environmental Protection Agency's 40 CFR part 60 New Source Performance Standards (NSPS): Subparts OOOO, OOOOa, and OOOOb, and Emissions Guidelines (EG): OOOOc for the Oil and Natural Gas Source Category.

1.2.3 The test method is applicable to methane (CH_4, CAS No. 74-82-9) emissions from oil and gas facilities. This method can be used, as approved by the Administrator, in lieu of the applicable fugitive monitoring requirements in either §60.5397a or §60.5397b and inspection and monitoring of covers and closed vent systems in either §60.5416a or §60.5416b. This test method may be used for fugitive monitoring requirements in §60.5397c and monitoring of covers and closed vent systems under §60.5416c when a state, local, or tribal authority incorporates the model rule (i.e., OOOOc) for the emission guidelines as part of their State Implementation Plan (SIP) or elsewhere approved as applicable.

1.2.4 The test method is a performance-based method to determine whether individual component emissions remain below prescribed thresholds.

1.3 Method Sensitivity

1.3.1 This method encompasses detection sensitivities of 5 kg/hr, 10 kg/hr, and 15 kg/hr with a 90% probability of detection. Operators will select sensitivity based on their specific site characteristics and operator practices and will define the appropriate threshold in their site-specific monitoring plan.

1.3.2 This method applies to well sites, centralized production facilities, and compressor stations in the crude oil and natural gas source category in all basins of the United States.

1.3.3 This method characterizes emissions at a facility-level spatial resolution, meaning this method identifies emissions within the boundary of a well site, centralized production facility, or compressor station.

1.3.4 This method relies on local meteorological data (wind speed and direction, temperature, barometric pressure, and humidity) in addition to location data to assist with the identification of emission source locations.

1.4 Data Quality Objectives

1.4.1 Adherence to the requirements of this method will ensure the data supporting the technology's objective will be accurate and of quality.

1.4.2 The technology's objective is to screen for fugitive emissions exceeding the specified emission rates detected at the specified screening frequencies identified in Tables 1 and 2 and to provide an alert to an operator that triggers a leak detection and survey response.

Table 1: Method Detection Limits and Screening Frequencies - Oil and gas multi-wellhead sites, well sites with major production and processing equipment, centralized production facilities, and compressor stations

Method Detection Limits	Screening Frequency
5 kg/hr	Monthly
10 kg/hr	Bimonthly
15 kg/hr	Monthly

Table 2: Method Detection Limits and Screening Frequencies – Oil and Gas Single Wellhead Sites and Small Well Sites

Method Detection Limits	Screening Frequency
5 kg/hr	Quarterly
10 kg/hr	Triannual
15 kg/hr	Bimonthly or Quarterly

2. Summary of Method

2.1 Description of System

The Qube emissions monitoring system is a network of fixed devices on a site designed to detect, locate, and quantify methane emissions in real time. The technology consists of three components: (i) an Industrial Internet of Things (IIoT) device houses various sensors that measure gas concentration and environmental data and transmits this data to the cloud, (ii) a cloud-based platform records and analyzes data received by the IIoT device and uses physics-based models to convey device data into leak locations and quantities, and (iii) a web-based dashboard aggregates critical insights such as emission rates (e.g., block averages) and alarms generated by the platform and identifies the remedial actions necessary to address the detected emissions.

2.2 Deployment

This method describes the procedures associated for the deployment of Qube IIoT devices, including the determination of the number of devices needed for each site and the placement of these devices.

2.3 Qube IIoT Devices

The Qube IIoT devices use metal oxide (MOS) sensors to detect methane concentrations. The working principle of MOS involves the absorption of methane into the active sensing layer, which leads to a change in electrical resistance and correlates to a methane concentration. As ambient methane concentration increases, more methane molecules interact with the tin oxide, resulting in a reduction in the sensor's electrical resistance. This change in resistance allows for the quantification of methane concentration in the air. By comparing the sensor's resistance in clean air to its resistance in the presence of methane, the concentration of methane in the environment can be determined. This comparison yields a mixing ratio that reflects the amount of methane present. Additional information on how MOS sensors detect gases is included in Reference 1 of Section 16.

2.4 Data Collection and Transmission

Methane concentrations and environmental data (e.g., wind speed, wind direction, temperature, barometric pressure, humidity, and device location) are transmitted to Qube's cloud-based analytics platform, where the data is converted from concentrations into mass emission rates using physics-guided models.

2.5 Data Storage

Individual dashboards are utilized by Qube to provide operators with summary information including site emissions, and alerts from periodic screening surveys with confirmed detections. Operators utilize these dashboards to provide information such as ground-based confirmation of emissions, and mitigation steps. All data is owned by the customer but maintained by Qube. Qube also retains the right to access customer data for internal development purposes. Equipment is typically purchased and owned by the customer, with the exception of short-term leases where Qube retains ownership of the equipment.

3. Definitions of Method

3.1 Definitions

3.1.1 *Block average* means a calculated average emission rate across a given window of time (e.g., 7-day period)

3.1.2 *Clean air* refers to conditions when the methane concentration in the ambient air is at the programmed background value (typically 1.9 – 2 ppm)

3.1.3 *Data packet* means device-level data (e.g., methane ppm, wind speed/direction, sensor voltages, temperature, pressure, relative humidity, and other diagnostics data) that is transmitted to the cloud. Transmission is optimized by waiting until enough data is collected, with a maximum interval of one hour.

3.1.4 *DEC sensor* means a digital electrochemical sensor used to collect information on other gases, such as carbon monoxide, hydrogen sulfide, and sulfur dioxide.

3.1.5 *Detection radius* means the radius from a single device within which a methane concentration reading can reasonably be expected to be detected. The detection radius of this method must not exceed 100m.

3.1.6 *Device Concentration Time Series* means the continuous recording and analysis of concentration levels of methane, measured by a device over a period. This data is collected at regular intervals, creating a sequence of concentration values that reflect changes over time.

3.1.7 *Industrial Internet of Things (IIoT)* means an industrial internet of things, which is a network of devices, sensors, and other instruments that are connected to industrial applications via the internet.

3.1.8 *MOS sensor* means a metal oxide semiconductor sensor used to detect concentrations of methane gas.

3.1.9 *Qube IIoT device* means an Industrial Internet of Things device which houses the MOS methane sensor along with the power and communications systems required to send continuous data from the field to the cloud.

3.1.10 *Qube Platform* refers to the comprehensive software suite including the web-based dashboard and cloud-based data processing and analytics algorithms.

3.1.11 *Sensor baseline* means the standard or reference level of measurement that a MOS sensor records under normal, stable conditions without the presence of any external stimuli or targeted substances. This baseline serves as a control or benchmark against which any deviations or changes in sensor readings can be compared.

3.1.12 *Wind rose* means the visual diagram used to show prevailing historical wind directions. Frequency of each wind direction is shown by the length of the spoke for a given direction.

3.2 Abbreviations

ATM – Standard atmospheric pressure

CH4 – Methane

DEC – Digital electrochemical sensor

IIoT – Industrial Internet of Things

MOS – Metal oxide sensor

NIST – National Institute of Standards and Technology

OGI – Optical gas imaging

PoD – Probability of Detection

PPM – Parts per million

PSI – Pounds per square inch

QA/QC – Quality assurance / quality control

RH – Relative humidity

SOC – State of charge

4. Method Interferences and Envelope of Operation

Table 3: Method interferences for Qube system

Condition	Summary	Mitigation
Source coverage	Qube's IIoT devices must be positioned within a leak's plume to acquire methane measurements.	Siting must follow Qube's deployment protocol described in Section 8.2 to ensure coverage of sources under prevailing wind directions.
Off-site and confounding emissions	Qube's sensors may detect methane emissions from non-target oil and gas facilities or unrelated sources, such as livestock or wetlands.	Qube's models include an evaluation to determine if the emission is coming from offsite sources and allow corresponding concentrations from upwind offsite sources to be removed for modelling inferences.
Communication from devices to the cloud	Communication of data from the Qube IIoT devices to the cloud is critical to ensure that methane emissions are identified. Devices are resilient to certain types of network failures.	Periods with lost data due to lack of device connectivity will not be used for periodic test.
Power	The Qube IIoT devices included in this method are battery-powered and solar-charged. The battery is rechargeable down to temperatures of -20°C (-4°F) and is sized for up to 8 days of operation in the absence of solar generation or extreme cold temperatures.	Periods with lost data due to lack of device power will not be used for periodic test.
Temperature	Device internal temperature range for detection depends on the sensor being used. Standard sensor temperature range is -40°C (-40°F) to +50°C (122°F), while high-temperature sensor range is -10°C (14°F) to 70°C (158°F).	Periods outside the operating temperature range will not be used for periodic test.
Relative humidity	Device internal relative humidity range varies depending on whether standard or high-temperature sensors are deployed. Standard sensor range is 10-90% RH, while the high-temperature sensor range is 10-100% RH.	Periods outside the operating relative humidity range will not be used for periodic test.
Wind speed	Average wind speed must be greater than 0.1 km/hr (non-zero) to enable localization and quantification of detected methane concentrations.	Periods with an average wind speed of 0.1 km/hr will not be used for periodic test.

5. Safety

5.1 Disclaimer

This method may not address all potential safety scenarios associated with its use. It is the responsibility of the user of this methane alternative test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to performing this methane alternative test method.

5.2 Field Safety

Except during installation of the Qube IIoT devices, this method is fully automated and does not require personnel on site unless manual maintenance is required. The following safety considerations are made during the installation of the Qube IIoT devices. Devices are not intrinsically safe and must be installed outside of hazardous areas and away from oil and gas equipment. All personnel who install or perform maintenance must have appropriate safety certifications, use personal protective equipment, and observe standard safety protocols for oil and gas sites.

6. Equipment and Supplies

This section describes the primary physical equipment and supplies required to deploy the Qube IIoT device described in this method.

6.1 Qube Industrial Internet of Things (IIoT) Device

Figure 1 provides an illustration of each Qube IIoT device deployed at a site included in this method. Further description of the key components is provided in the subsections below.

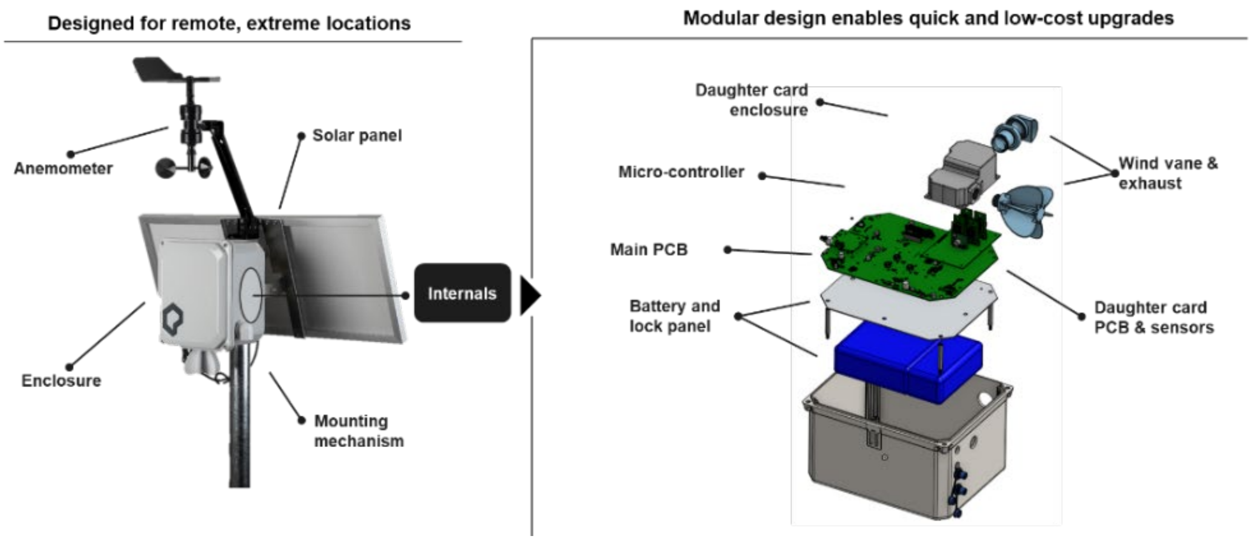

Figure 1: Qube IIoT device and individual components included in this method

6.1.1 Enclosure

The enclosure has been designed for outdoor operations with waterproofing and UV-resistant coating making it capable of withstanding significant exposure to the elements (e.g., extreme temperatures, wind, sun, etc.). The enclosure is designed to protect the internal components from airborne solid materials (e.g., dust and sand), liquids (e.g., rain), and flame, making it ideal for use in oil and gas operations.

6.1.2 Micro-controller and communications module

Each Qube IIoT device deployed for this test method contains a micro-controller, allowing it to collect and process sensor data. Data is collected every 3-8 seconds unless there are limitations for that specific device (e.g., low power). Embedded on the microcontroller is a modem that is designed to transmit data through a variety of cellular and wireless internet networks enabling deployment of the same Qube device in various regions around the world.

6.1.3 Power source (solar panel and battery)

A solar panel (sized depending on region) designed to operate in remote, off-grid locations is required to support power generation for the Qube IIoT device. Devices are powered by a rechargeable battery with an expected 10-year lifespan. The rechargeable pack can provide power for approximately 179 hours or 7.5 days without sunlight.

6.1.4 Environmental sensors

The Qube IIoT devices include commercially available environmental sensors that provide data as follows:

6.1.4.1 Anemometer and wind direction sensor to measure and record wind speed and direction

6.1.4.2 Temperature sensor to measure and record temperature (operating range -40-85 °C, accuracy of ± 0.5°C)

6.1.4.3 Barometer to measure and record barometric pressure(operating range -40-85 °C, accuracy of ± 0.6 hPA)

6.1.4.4 Humidity sensor to measure and record humidity (operating range -40-85 °C, accuracy of ± 3%)

6.1.4.5 GPS for asset tracking purposes

6.1.5 Gas sensors

Each Qube IIoT device deployed on a site using this test method is equipped with a metal oxide sensor on a proprietary printed circuit board. When a MOS sensor is purchased off the shelf from a manufacturer, it typically has an accuracy of ~300 ppm. While the sensor itself is highly sensitive to methane, the sensor is also cross-sensitive to temperature, humidity, and pressure. In addition, the sensor has a non-linear response to methane at lower concentrations. Thus, to detect small emissions at the fence line of a facility, the effects of temperature, humidity, and pressure need to be accounted for and the response to methane needs to be linearized. Qube's proprietary calibration process (described in Section 10.1) improves the sensor accuracy to at least 1 ppm or 1% of reading, whichever is greater.

Additional electrochemical sensors can be added to the Qube devices to augment the methane readings or to leverage the Qube IioT platform for other use cases (e.g., hydrogen sulfide and sulfur dioxide sensors to detect odors). These additional sensors are not relevant to this method.

6.1.6 Computing equipment for user access

In order to access the web-based dashboard, users require a computer running Microsoft Windows or Apple macOS, an internet connection and a web-browser such as Google Chrome, Microsoft Edge or Mozilla Firefox.

7. Reagents and Standards

The Qube solution uses calibration gases for laboratory calibration of each sensor prior to deployment in the field (described in Section 10.1). Field calibration after deployment is done remotely and does not require any bump testing (described in Section 10.3).

7.1 Calibration gas used in laboratory calibration chamber

7.1.1 The primary calibration source is NIST traceable gas, or equivalent, with approximately 0.25% (2,500 ppm) CH4 in air.

7.1.2 The gas must be hydrated with a gas bubbler after leaving the cylinder to achieve a relative humidity of at least 10% in the calibration chamber.

7.1.3 The gas is mixed with dry air (D300) to reach the target CH4 levels in the chamber for the calibration procedure.

7.2 Calibration gas used in optional bump testing in the field (additional details in Appendix B)

7.2.1 The gas must contain a methane concentration of less than 2,500 ppm (100 ppm is recommended and widely available)

7.2.3 The gas must be a "balanced air" gas, i.e., the blend must contain air and methane (rather than an inert gas and methane). Qube's sensors require the presence of oxygen to function. Therefore, any calibration gas used must contain oxygen

7.2.4 The gas must be hydrated. Calibration gases are typically dry, meaning that the partial pressure of H_2O in the air constituent of the gas is zero. This places the relative humidity of the gas below Qube's minimum of 10%

7.3 Weather stations used for historical wind data

7.3.1 Wind data used for pre-deployment planning as part of the siting procedures needs at least 12 months of data to account for seasonal variability.

8. Data Collection and Method Input Sourcing

This section describes the process for deploying Qube's emissions monitoring system including pre-deployment and planning, installation and registration, and data collection and processing. Some of these processes are considered proprietary and are identified as such in this section.

8.1 Siting information

The pre-deployment and planning steps described in this section must be completed prior to any field deployment of Qube IIoT devices. Qube uses a proprietary device placement algorithm to optimize the number of devices required at a site with the goal of maximizing source (equipment) coverage given the prevailing wind direction. Table 4 summarizes the inputs required for the proprietary device optimizer tool.

Table 4: Summary of method inputs for device optimizer tool

Instrument/Source	Variables	Use
MOS sensor	Methane concentration	Device-level data used to detect emissions by assessing methane concentrations relative to expected baselines
Anemometer	Wind speed and direction	Device-level data used to localize and quantify methane sources when emissions are detected
Operator	Site coordinates	Identify the approximate site centroid to which the Qube system will be deployed
Operator	Emission source coordinates	Identify the location and height of each potential emission source (e.g., separator, tanks, compressors, flare stack, vapor recovery unit, etc.)
Operator	Off-site interferences	Identify and record potential off-site source interferences (e.g., neighboring industrial facilities, livestock operations, or wetlands)
Operator	Potential device placement locations	Identify areas where devices can be placed without interferences from areas of routine operation (e.g., truck traffic), structures, or natural features (e.g., trees, buildings) that may impact placement and/or solar panel performance
Operator	Device connectivity	Confirm ability to connect devices to the cloud through cellular network, local WiFi connection, or satellite internet
Public weather station	Historical wind data	Analyze prevailing wind directions to optimize device coverage of identified sources

8.1.1 For each deployment, the deployment optimizer uses “wind roses” (example shown below in Figure 2) to reflect representative wind directions and speeds expected at the given site for the purpose of optimizing the placement of devices. The Qube Platform has access to over 5,000 regional wind roses generated from public wind station data spanning multiple years, as well as wind roses from nearby sites being monitored by Qube devices spanning multiple years. Qube’s support team members use this data and their judgement to determine the best wind rose based on proximity to the site, topographic features, time frame, and seasonal characteristics.

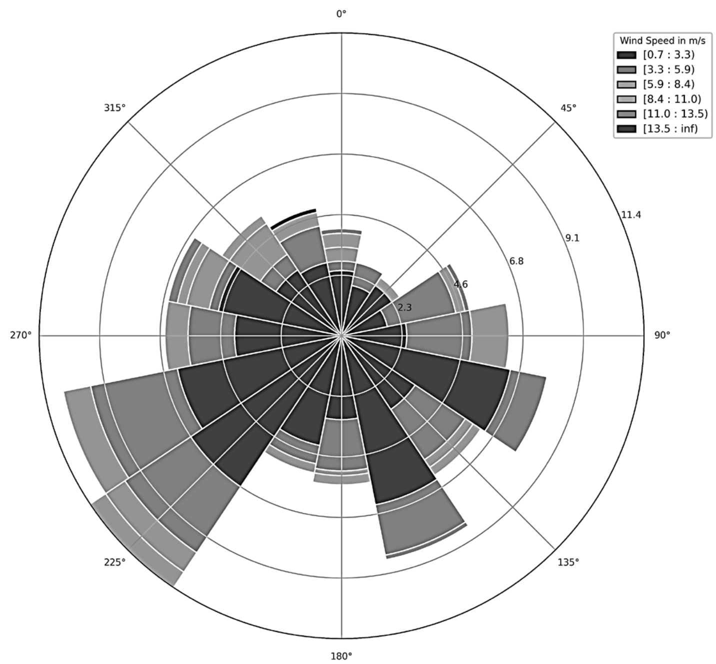

Figure 2: Example Wind rose

8.1.2 For each deployment, the planning process must also incorporate the additional variables listed in the Method Inputs section from the operator. With this information the “deployment optimizer” creates a development plan as shown in Figure 3.

8.1.3 Qube staff develop draft deployment plans and share them with the operator for iterative feedback, ensuring that all potential emission source locations are included, and the proposed device placements are operationally feasible (i.e., not located in hazardous areas and do not interfere with site operations). The finalized deployment plan sent to the operator includes recommended lat/long coordinates for all devices and potential emission sources. Coordinates are intended to be approximate; actual installation may be within ~3m depending on site conditions and installer judgement. Larger deviations can be updated/fixed in the deployment optimizer to determine impact. The finalized deployment plan can be used to verify device placement locations after installation and is maintained as a record by Qube.

8.1.4 The number of devices included in a deployment plan are dependent on the size, orientation, and complexity of the site being monitored. Deploying devices such that the device detection radii overlap all potential sources on a site ensure that there is adequate coverage, as shown in Figure 3.

Note: Additionally, deploying devices in this way provides redundant coverage should a device require maintenance. A single well site will have a different required device count than a site with major production and processing equipment, small well sites, centralized production facilities, and compressor stations to ensure adequate site coverage.

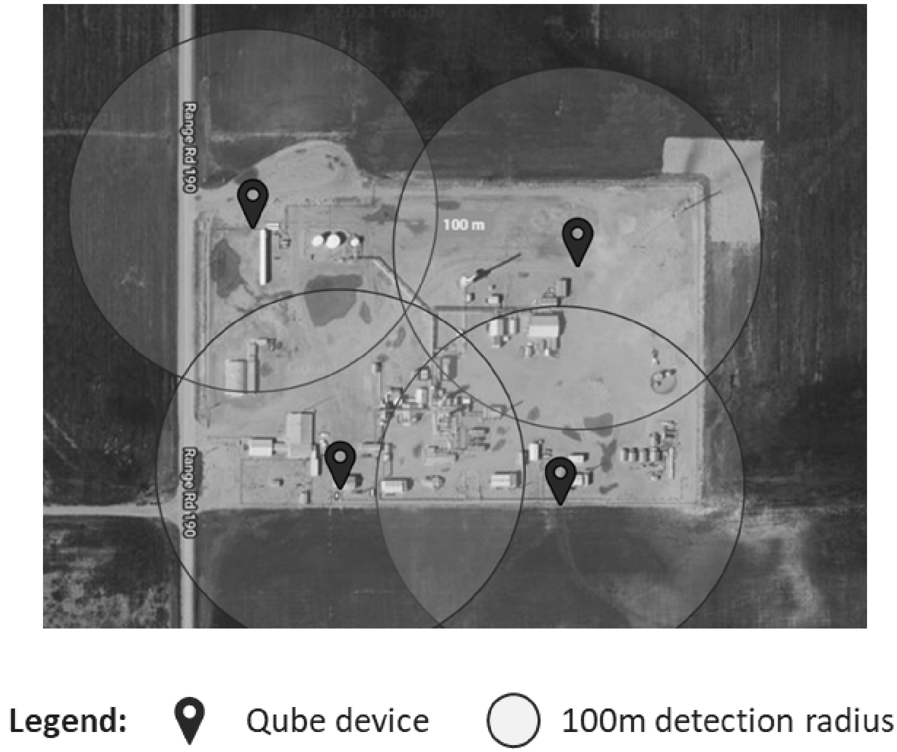

Figure 3: Example Qube device detection coverage per device using 100m radii circles

8.1.5 Typical device counts deployed to sites are summarized in Table 5 below.

Table 5: Typical Qube device counts by site type

Site Type	Minimum device count	Typical device count
Single Well Sites	1	2
Major Production and Process Equipment, Small Well Sites, Centralized Production Facilities, and Compressor Stations	3	4-6

8.1.6 Siting requirements should be re-evaluated annually or when additional major equipment is added to the site to ensure proper coverage is maintained.

8.2 Qube device installation and registration

Devices are installed and registration by trained Qube personnel or Qube trained 3rd parties and operator personnel according to the procedures in Appendix A of this method.

8.3 Data Collection

8.3.1 After deployment, Qube IIoT devices continuously convert input signals from the sensors into concentration data using a predefined calibration curve and sensor-specific calibration coefficients. The devices send the resulting processed values (along with other data as described in section 3.1) to the Qube Platform.

8.3.2 The devices store the data in an internal storage buffer using a real-time data compression algorithm, which detects which data points are necessary for rebuilding the signal. If subsequent readings are similar within a small threshold, they are marked as unnecessary and discarded. The remaining necessary points are kept and ultimately transmitted from the device to the Qube Platform.

8.3.3 The compression algorithm ensures that all meaningful data is sent, allowing Qube's models to localize and quantify emissions accurately as they happen (see section 12.2 below). In the absence of any detected methane, the devices conserve bandwidth and power by transmitting only the important information.

8.3.4 In the case of a communications issue, where the platform does not confirm receipt of the sent data, the device will continuously retry. The device storage buffer can store between 4-8 hours of raw data, depending on compression. Once the buffer is filled, the oldest data will be discarded first. Since data is expected from each device at least once every hour, the platform can flag a device or communications issue for the Qube support team as soon as an hour passes without receiving any data.

8.3.5 Device data is transmitted securely over 2G, 3G, LTE, or Wi-Fi. Where cellular network connectivity is an issue, a Wi-Fi variant can be used, connecting to a local LTE backed Wi-Fi modem, SpaceX Starlink, or a facility's existing Wi-Fi network.

8.3.6 Concentration data is continuously analyzed by Qube's proprietary auto-baseline process to minimize sensor drift and assure data quality as outlined in Section 10.3.

8.3.7 Device health data will also be sent continuously to ensure site coverage and minimize downtime, as described in Section 9.2.1.

8.3.8 All data transmitted by Qube devices is stored on cloud-based servers that are maintained and managed by Qube.

8.4 Data Processing

8.4.1 Raw data from Qube devices is processed to calculate the mass emission rate, as outlined in Section 12.

8.4.2 The average emission rate is then calculated over a 7-calendar day period and compared to the detection thresholds of 5 kg/hr, 10 kg/hr, and 15 kg/hr.

8.4.3 Emissions exceeding the threshold are reported in the periodic screening report.

9. Quality Control

9.1 Device QA/QC

Qube implements a QA/QC process before deploying devices to clients. The following steps are included in this method:

9.1.1 Design verification

This phase involves thoroughly reviewing the product's design specifications, engineering drawings, and simulation models to identify and resolve any potential issues or design flaws.

9.1.2 Final product testing

Once manufactured, the Qube IIoT devices goes through comprehensive functional, environmental, and reliability testing. This includes individually testing each device for electrical, mechanical, and sensor performance. Sample testing such as destructive testing may also be carried out on finished products including thermal cycling, vibration, and other stresses to assess durability. Should sample tests indicate any unexpected results then an assessment of the entire manufacturing run is completed which may result in rejecting and replacing faulty components.

9.2 QA/QC following deployment and installation of Qube devices

9.2.1 Summary QA/QC metrics for Qube devices

A summary of all the key QA/QC metrics and corresponding acceptance criteria that ensure the system is operating in a nominal state can be found in the table below.

Table 6: QA/QC metrics

Component/ process	Specification	Acceptance criteria	Frequency of check	Corrective action
CH_4 sensor	Accuracy	Within ±1% when tested with 50, 100 and 250 ppm CH4 calibration gas	Manufacturer	Do not deploy
CH_4 sensor	Precision	Within ± 1ppm when tested with 50, 100 and 250 ppm CH4 calibration gas	Manufacturer	Do not deploy
CH_4 sensor	Baseline drift	Measured background methane concentration is 3x the programmed value (default of 1.9 ppm)	Every data packet from each device	Auto-baseline and recalibration algorithm triggered when baseline drift is detected (further detail in Section 10.3)
Anemometer	Wind speed accuracy	± 5% at 50 km/hr	Manufacturer	Do not deploy
Anemometer	Wind direction accuracy	± 3° at 50 km/hr	Manufacturer	Do not deploy
Anemometer	Wind speed bounds	Wind speed is not constant at 0km/hr or >150km/hr for 15-minute rolling periods	Every data packet from each device	Support team triage (See Section 9.2.2)
Anemometer	Wind direction variance	Direction varies by more than 1° every 15-minute rolling periods	Every data packet from each device	Support team triage (See Section 9.2.2)
Data transmission	Sensor data	Data transmitted and uploaded to cloud database	Every data packet from each device	Wait for connectivity to return, support team triage if needed
Power management	State of charge (SOC)	SOC > 20%	Every data packet from each device	Device enters intelligent standby mode to conserve power. Support team triage if needed
Device installation	Device location	Matches deployment plan	Every data packet from each device	Move devices to proper locations as needed

9.2.2 Reasonableness Checks

The Support Team at Qube is responsible for monitoring issues and recommending appropriate corrective actions (Support team triage). In practice, issues typically present symptoms that are difficult to disambiguate from normal operation. Various tools and techniques are used by trained support technicians and their experienced judgement is used to determine when intervention is necessary. For example, in the case of anomalous wind or sensor readings, support technicians may compare performance to nearby weather stations, neighboring devices, or devices at nearby sites. Weather events (e.g., freezing rain, snowfall, windstorms, etc.) may be used to explain and/or diagnose charging issues or anemometer performance. Corrective actions are left to the Support Team's discretion and may include no-action (non-issue), continue to monitor (inconclusive), or device/component replacement required (issue identified). The aspects of the reasonableness checks are described in Qube's proprietary maintenance manual.

10. Calibration and Standardization

This method requires the calibration of each MOS sensor that is deployed with the Qube IIoT device following the calibration procedures described in this section.

10.1 Laboratory calibration

10.1.1 Each individual MOS sensor is calibrated prior to deployment in the field. This calibration is performed in a specially designed calibration chamber that is controlled for release rate using a mass flow controller, temperature, humidity, and pressure. Table 7 outlines the specifications of these key pieces of equipment.

Table 7: Specifications of laboratory calibration equipment

Equipment	Accuracy
Mass flow controller	± 0.8%
Temperature controller	± 1°C
Relative humidity	± 3%
Pressure measurement	± 1.5 Pa/K

10.1.2 The calibration procedure is designed to take approximately 50 hours and enables the MOS sensor to compensate for changes in temperature and humidity while accurately measuring the concentration of the gas. Calibration curves are complex empirically derived proprietary formulas developed by Qube, that accept unique sensor-specific coefficients to offset the unique performance characteristics of each individual MOS sensor. Each MOS sensor is calibrated to the expected ranges of operating conditions and gas concentration (outlined in Table 8). During the calibration, the data for each sensor is logged and stored locally. Precision is verified by calculating the mean relative error of sensor accuracy.

Table 8: Variables used for laboratory calibration

Variable	Parameters used in calibration process
Methane concentration	25 ppm, 50 ppm, 100 ppm, 250 ppm
Relative humidity	15%, 20%, 50%
Temperature	-35°C, -10°C, +5°C, +40°C, +60°C
Atmospheric pressure	1 atm, 1 atm +1 psi

10.2 Manufacturing quality control

Multiple quality control checkpoints are employed during device production. In-process inspections are conducted to verify part dimensions, materials, assembly procedures, and workmanship. Statistical process control techniques are used to monitor key parameters and maintain design tolerances. Tests are performed at the subassembly and final assembly stages to identify any defects before the product is completed. Figure 4 presents these quality control processes. All individual building blocks of the device are tracked including the printed circuit board, individual sensors, battery, solar panel, anemometer, and microcontroller/modem. Test reports and historical data are stored on Qube's database.

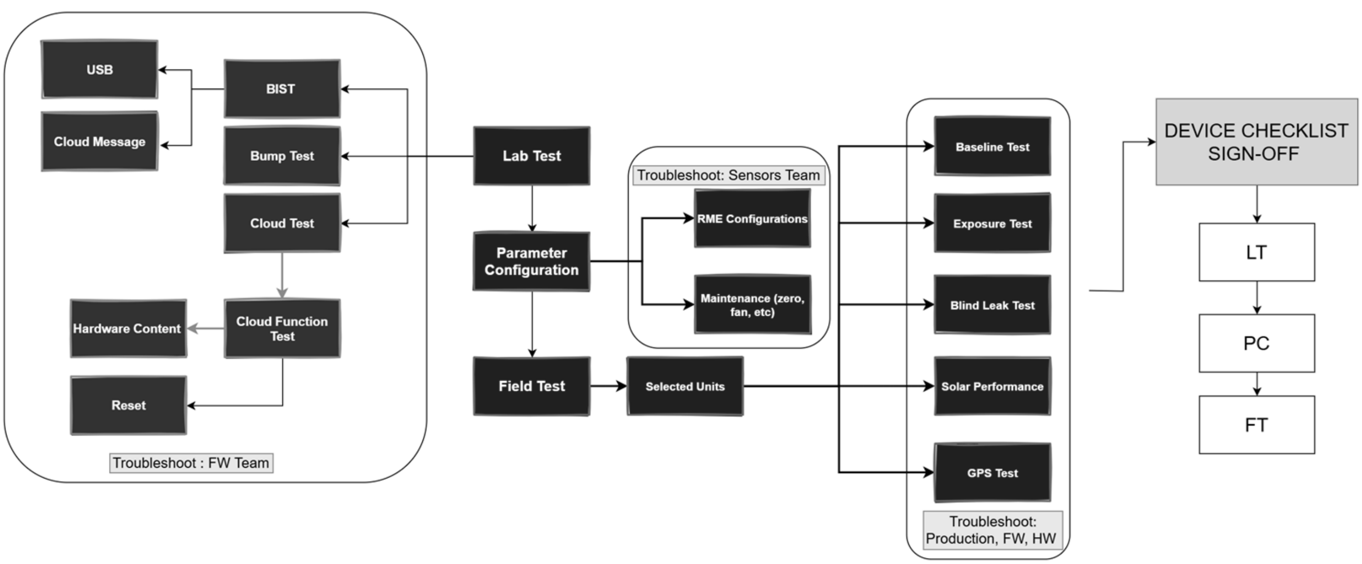

Figure 4: Qube's Manufacturing Quality Control Process

10.3 Field calibration after deployment

10.3.1 Qube sensors use a patent-pending (Reference 9 in Section 16) method to continuously verify sensor outputs against the environmental gas background at the deployment location and re-calibrate themselves as needed upon detecting a drift from the baseline. This process runs continuously and autonomously on the device

10.3.2 Qube's MOS sensors utilize calibration curves in conjunction with lab-calculated sensor-specific coefficients. A subset of these coefficients is used for correcting drift, by autonomously adjusting these coefficients in response to changes in performance due to age and exposure.

10.3.3 Qube's auto-baseline works by continuously calculating the background concentration of methane being measured by the device (excluding spikes as these correspond to actual measurements of methane above background). An auto-baseline is performed according to the procedures in Section 10.3.3.1

10.3.3.1 The device then determines if drift has occurred by comparing the calculated background concentration against the sensor's programmed background.

10.3.3.2 If drift is detected, the device triggers an auto-baseline event where the subset of coefficients responsible for correcting drift are recomputed such that the calculated background concentration matches the programmed background.

10.3.3.3 The number and frequency of auto-baseline processes a sensor undergoes is autonomously tracked. When a sensor exhibits excessive repeated auto-baselines (e.g., every day vs. every few months) then it will be flagged through Qube's anomaly detection and scheduled for replacement by Qube's support triage team.

11. Analytical Procedures

[Reserved]

12. Detecting and Alerting

The Qube platform continuously monitors methane gas concentrations and environmental data at each device, collecting measurements during a periodic screening survey. Qube utilizes the collected wind speed and wind direction data to estimate the trajectory of transported gas and identify potential source(s) of emissions. Inversion modeling is employed to support the estimation of emission rates, with real-time data analysis and processing occurring in the Qube platform. Estimated emission rates are used to determine exceedances during periodic screening surveys, with automated reporting of results sent to operators. Details of this process are provided in the following subsections.

12.1 Conversion of methane concentration measurement to mass emission rate

Three main data processing steps are utilized to convert methane concentration data to mass emission rates: (i) detection, (ii) localization, and (iii) quantification.

12.1.1 Detection

12.1.1.1 Qube's platform determines each sensor's baseline methane concentration from the rolling minimum concentration readings (on a per device basis) using each device's previous 3 hours of concentration readings. This baseline is representative of readings when no methane concentration spikes are observed.

12.1.1.2 The sensor baseline determined in 12.1.1.1 is subtracted from each device's concentration time series to obtain methane concentrations over the background.

12.1.1.3 If methane concentrations over background clear the Qube platform's threshold, this data proceeds to the localization and quantification steps outlined in the following sections.

12.1.2 Localization

Qube's platform collects wind speed and wind direction data from each device's anemometer to assist with determining the potential emission source(s).

12.1.2.1 Qube's platform transforms the collected wind speed and wind direction data from each device into wind vectors. Where data is missing or invalid, the average wind vectors from each device across the site are used.

12.1.2.2 Potential emission source(s) are identified by tracing adjoint plumes along the upwind paths from the sensor locations which is shown to be equivalent to forward dispersion in the following equations.

Advection-diffusion equation:

$$\frac{\partial \mathrm{C}}{\partial \mathrm{t}} + \nabla \cdot (\mathrm{C}\mathbf{u} - \mathrm{D}\nabla \mathrm{C}) = \mathrm{S}$$

Advection-diffusion adjoint:

$$\frac{\partial \lambda}{\partial \mathrm{t}} + \nabla \cdot \left(-\lambda\mathbf{u} - \mathrm{D}^{\mathrm{T}}\nabla \lambda\right) = \mathrm{F}$$

Where:

$\mathbf{u}$ = velocity

D = diffusivity

S = source term

t = time

λ = adjoint variable

F = adjoint source term

12.1.2.3 Qube's platform corrects for distance from sources using Gaussian plume modeling principles.

12.1.2.4 Qube's platform determines the correlation between concentration readings and potential emission sources located upwind of the sensor measuring emissions. These correlations are converted to determine the probability that each potential source was responsible for the detected emissions. The Pearson correlation coefficient (which measures the linear correlation between two data sets) is computed between the upwind mapping and the sensor readings for each potential emission source. The source with the highest correlation is assumed to be the most likely source of emissions.

12.1.2.5 Qube's platform compensates for potential offsite sources of emissions with offsite direction filtering and estimation of elevated concentrations from offsite sources. The relative positions of Qube IIoT devices and emission sources are known, and gas concentration measurements are associated with wind arrival angles from the anemometer data collected by each device, allowing for directional filtering of data to determine if emissions are from an offsite source. If there is a possibility that readings are related to an onsite emission source, then the readings are included for quantification.

12.1.3 Quantification

Qube's platform utilizes a model following the steps outlined in this subsection to quantify methane mass emission rates.

12.1.3.1 Qube's model uses wind speed, wind direction, and methane concentration measurements to estimate a concentration distribution over an area and estimate the rate of emissions leaving the facility.

12.1.3.2 The model assumes that gas releases mix quickly with the surrounding air and that movement of the plumes is primarily driven by the wind. The model also assumes that a single emission dominates at a particular time.

12.1.3.3 Qube's model performs an inversion using processed and filtered device measurements to infer the release rate based on readings from each device and their assumed position within the plume.

$$C(x, y, z) = \frac{Q}{2\pi\bar{u}\sigma_y\sigma_z}\left[\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\right]\left[\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right]$$

where:

C = concentration
x = distance downwind
y = horizontal distance from the plume centerline
z = vertical distance from the ground
H = height of the plume centerline (aka. effective stack height)
Q = emission rate
$\bar{u}$ = mean wind velocity in the x direction in the downstream direction along the plume centerline
σ_y = lateral dispersion coefficient (standard deviation of Gaussian distribution in y)
σ_z = vertical dispersion coefficient (standard deviation of Gaussian distribution in z)

12.1.3.4 This model has the following assumptions:

12.1.3.4.1 No initial concentration is included (plume will be in addition to ignored background)

12.1.3.4.2 Constant source rate is assumed

12.1.3.4.3 No absorption or generation by the ground

12.1.3.4.4 Constant wind in the horizontal direction (x as defined in the above equation)

12.1.3.4.5 Inversion layers are ignored in the simple equation above

12.1.3.4.6 Diffusivities vary only with downwind distance

12.1.3.4.7 Negligible diffusion in flow direction compared with mean transport

12.1.3.5 Qube's platform post-processes individual sensor estimates, and downweighs or removes sensors with a weak signal-to-noise ratio.

12.1.3.6 Qube's platform uses the weighted average to consolidate estimated rates from individual sensor data and return a consolidated value.

12.1.3.7 Qube's platform time bounds the raw estimates of site-level emission rates and averages these values into a single emission event with a constant rate.

12.2 Alerting

12.2.1 Determining exceedances

The emission rates calculated in the prior section are used to determine threshold exceedances during periodic screening surveys. Figure 5 below illustrates this workflow. The process begins by starting the screening period, which commences on the 1st day of the screening period or on a day of the operator's choosing within the required screening period. During this period, which lasts for 7 calendar days, data is collected through Qube's continuous monitoring system, producing quantification readings in kg/hr. After the 7-day screening survey period, a block average is calculated based on the valid quantified readings. This block average is then compared against a 90% Probability of Detection (PoD) threshold (e.g., 5 kg/hr). If the block average does not exceed the threshold, no remedial actions are required until the next screening survey. However, if the block average exceeds the threshold, a site-wide follow-up must be conducted as required in 40 CFR §60.5398b(b)(5).

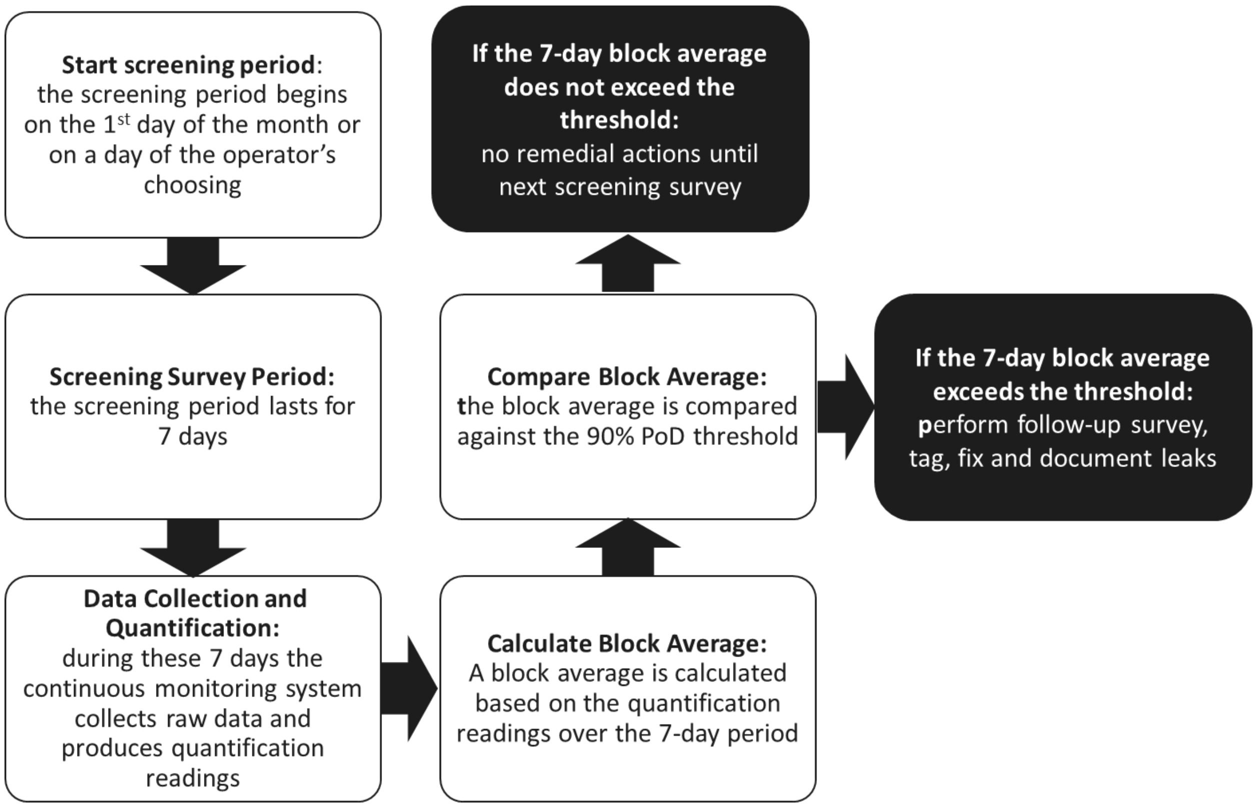

Figure 5: Investigative analysis workflow

12.2.1 Reporting periodic exceedances

Each periodic screening's results are automatically provided to the operator in a report, which is generated within 72 hours of the screening. This report is sent via email and is also available for download on the Qube platform. The report includes the following details for each site: site information (name, location, lat/long coordinates), screening period (start time, end time, duration), and screening results (number of emissions exceeding the threshold, timing and duration of each exceedance, inferred location of each exceedance, average emission rate for each exceedance, and the emission identification number for each exceedance).

13. Method Performance

13.1 Validation of method envelope of operation

Section 13.1 summarizes the operational ranges required for the Qube system. Supporting details on these ranges are covered in the following subsections.

13.1.1 Power

The maximum battery life in the absence of solar radiation is based on the battery capacity, power consumption of each component in the Qube device, and intelligent firmware that engages escalating power-saving modes as the state of charge decreases. Qube has conducted internal testing to validate battery discharge and recharge under varying environmental conditions, along with ongoing QA/QC checks on battery capacity.

13.1.2 Temperature

The operating temperature range is based on both individual hardware components and sensor accuracy. Electronic components within the Qube device are rated from -40°C to +85°C. Two different MOS sensors (standard and high-temperature) can be used depending on the expected climate in the deployment region. Standard sensor temperature range is -40°C to +50°C, while the high-temperature sensor range is -10°C to 70°C. Qube devices have successfully been deployed in regions at both ends of the operating temperature range (e.g., New Mexico, California, Kuwait, Saudi Arabia, Northern Canada, etc.).

13.1.3 Relative humidity

The relative humidity (RH) range is based on ensuring the MOS sensors can reliably maintain their accuracy and precision. Standard sensor range is 10-90% RH, while the high-temperature sensor range is 10-100% RH. Field deployments in low-humidity regions such as the Permian basin in Texas and the DJ basin in Colorado have demonstrated successful operation with relative humidity reaching the 10% minimum.

13.1.4 Wind speed

The upper bound of 150 km/hr is based on the specifications provided by the anemometer manufacturer. While this upper limit has not been reached in the field, Qube devices have been successfully deployed in regions with wind speeds exceeding 50-60 km/hr.

13.2 Aggregate detection threshold

The aggregate detection threshold of this method is 1.5 kg/hr from distances ranging from 75 to 100m at a 90% probability of detection. These values were determined through independent third-party controlled releases found in references 2 and 3 in Section 16 and described in further detail in the following sections.

13.2.1 Methane Emissions Technology Evaluation Center (METEC)

Qube participated in METEC's Advanced Development of Emissions Detection (ADED) protocol during a three-month period in 2022. METEC conducted a total of 353 experiments with 593 controlled releases where emission rates ranged from 9.89 to 173.0 SLPM whole gas (0.4 - 7 kg/hr). Qube demonstrated a 90% PoD at 1.5 kg/hr, shown by Figure 6 below.

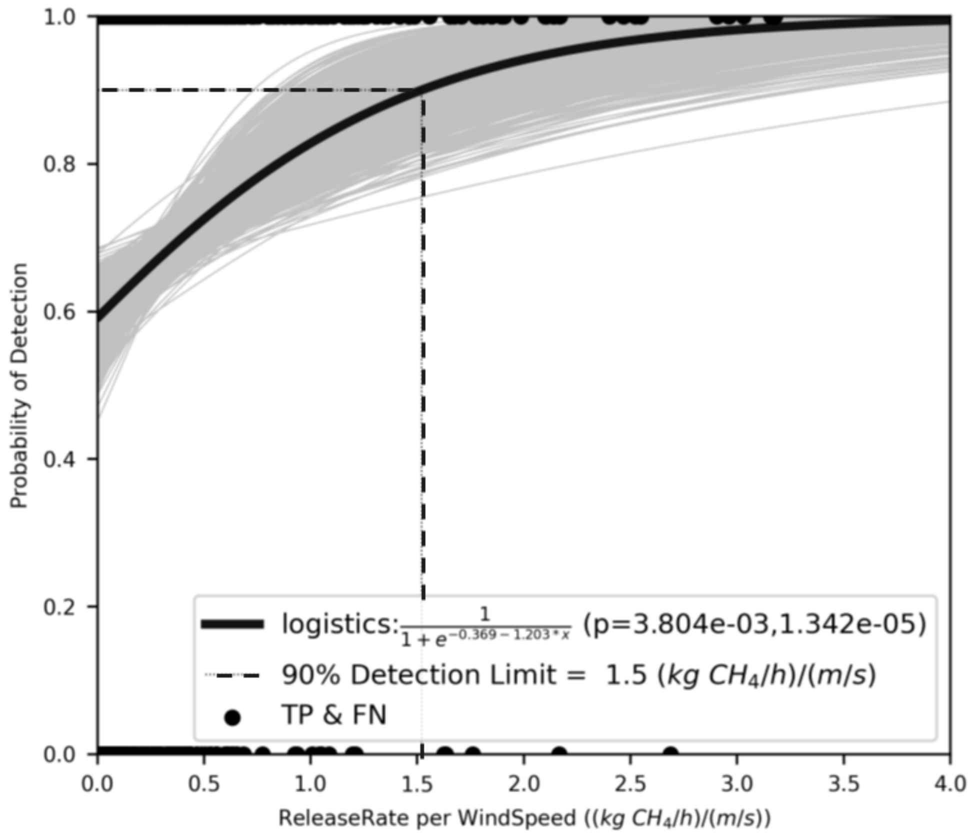

Figure 6: Probability of detection versus wind-normalized emission rate

13.2.2 Highwood Emissions Management

In 2022, Qube's continuous monitoring system performance was evaluated by Highwood Emissions Management (Highwood) in a single-blinded study performed at Qube's Controlled Release Testing Facility (CRTF).

Testing protocols were developed to guarantee that release occurrence, timing, emission rate, and environmental conditions were only known by Highwood and not by Qube Technologies staff. Highwood remotely activated all controlled releases.

The probability of detection was calculated as a function of emission rate, distance from source to sensor, wind speed, and wind direction. Emission rates ranged from 0.10 kg/hr up to 1.38 kg/hr, and each release consisted of 40 minutes of steady-state methane discharge fixed at the release rate being tested, followed by 20 minutes of "non-release" to ensure the air was clear for the following release. Wind speeds ranged from 1 to 19 m/s, and ambient temperature ranged from -14 to 13°C. A detection at any point within the release window was considered a true positive.

Results show that under average wind conditions (wind index of 0.4 and wind speed of 6 m/s), the PoD of a 1.0 kg/hr release rate for the Qube Solution is approximately 37% at 100m, 58% at 75m, and 78% at 50m for a 40-minute release window. At 75m, the Qube Solution has a 90% PoD for a 1.5 kg/hr emission, shown in Figure 7 below.

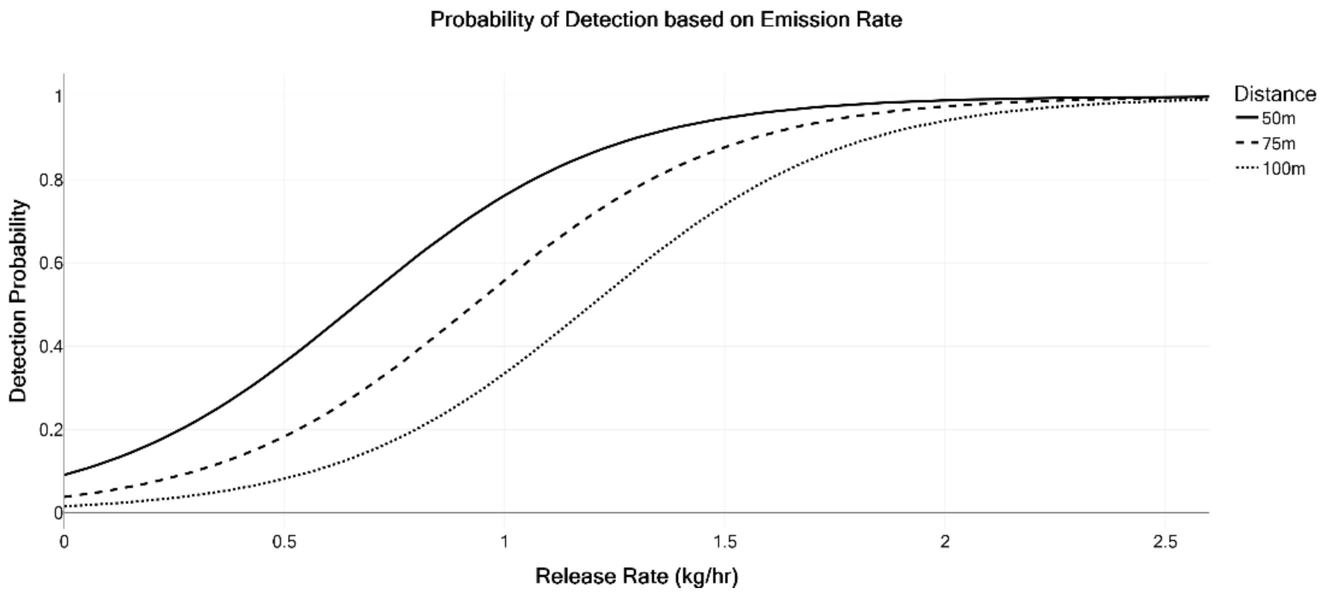

Figure 7: PoD at variable distance based on emission rate and assuming favorable wind conditions

14. Pollution Prevention

[Reserved]

15. Data Management and Recordkeeping

15.1 Data Storage

15.1.1 Device data is ingested by the cloud-based Qube Platform and is stored in a secure time-series database. All data is encrypted in transit and at rest.

15.2 Data Reporting Procedure

The results of each periodic screening are provided to the operator in a report, generated automatically within 72 hours of the screening. The report is sent via email and available for download on the Qube platform. It includes the following information for each site:

15.2.1 Site information: name, location, lat/long coordinates

15.2.2 Screening period: start time, end time, duration

15.2.3 Screening results: number of emissions exceeding the threshold, timing and duration of each exceedance, inferred location of each exceedance, average emission rate of each exceedance, emission identification number for each exceedance.

15.3 Recordkeeping Procedure

This section defines which records are maintained by Qube and the operator related to the periodic screening conducted using this test method. Additional records that are required by the work practice specified in the applicable subparts, such as records related to OGI surveys and repairs are not specific to this test method and are defined within the applicable subparts.

15.3.1 The following records are maintained within the Qube platform and accessible to operators via dashboards.

15.3.1.1 Name of screening operator (i.e., Qube)

15.3.1.2 Lat/long location of each Qube device on the site

15.3.1.3 Date of each periodic screening survey (i.e., 7-day period used for screening survey)

15.3.1.4 Date that results of periodic screening are sent to the operator

15.3.1.5 Aggregate detection threshold used for the screening survey and spatial resolution (i.e., facility-level)

15.3.1.6 Records of calibrations used during the screening if needed, including information in Section 7 and Section 10

15.3.1.7 Results from periodic screening

15.3.2 The following records are maintained by the operator. The operator may choose to maintain these records within the Qube platform or separately. The operator is responsible for collecting this information and maintaining each record for compliance.

Records of follow-up inspections from confirmed detections of emissions during periodic screening:

15.3.2.1 Date of the inspection of fugitive emissions components and inspection of covers and closed vent systems

15.3.2.2 Name of operator(s) performing the survey or inspection

15.3.2.3 Identification of the monitoring instrument(s) used for surveys and instrument inspections

15.3.2.4 Records of calibrations for the instrument(s) used during the survey or instrument inspection, as applicable

15.3.2.5 Records of each fugitive emission from a fugitive emissions component affected facility and each leak or defect for each cover and closed vent system inspection as specified in 40 CFR 60.5424b(c)(6)(v)(A) through (F)

15.3.2.6 Date when an investigative analysis is initiated, and the result of the investigative analysis in accordance with 40 CFR 60.5398b(b)(5)(vi) and (vii)

15.3.2.7 Dates of implementation and completion of action(s) taken as a result of the investigative analysis and a description of the action(s) taken according to 40 CFR 60.5398b(b)(5)(vi) and (vii)

15.3.2.8 Records of each OGI survey conducted as specified in 40 CFR 50.5424b(c)(9)(i) through (vii)

15.3.2.9 Deviations from the monitoring plan or a statement that there were no deviations from the monitoring plan

15.4 Continuous improvement

Throughout device production, data quality is closely tracked and analyzed. Any nonconformities or customer issues are thoroughly investigated using root cause analysis. Corrective and preventive actions are then implemented to continuously improve the QA/QC system and prevent recurrence of problems.

16. References

1. M. Yadav, M. Kumar, S. Chaudhary, K. Yadav and A. Sharma, "A Review on Chemiresistive Hybrid Zinc Oxide and Nanocomposites for Gas Sensing," Industrial & Engineering Chemistry Research, vol. 62, no. 29, pp. 11259-11278, 2023.
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9. Adrian Dumitru, inventor; Qube Technologies Inc, assignee; System and Method to Auto Calibrate and Auto Baseline a Pollutant Gas Detector. International patent application PCT/CA2024/050275. March 6, 2024
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17. Tables, Diagrams, Flowcharts and Validation Data

[Reserved]

Appendices

Appendix A: Device Installation and Registration

A.1. Pre-Installation

A.1.1. Each MOS sensor must be calibrated following the procedures specified in Section 10.1 prior to deployment in the field.

A.1.2. Each Qube device must be installed and mounted according to the steps outlined in this section.

A.2. Unpacking

A.2.1. Remove the device and anemometer box from the main box. Inspect for damage.

A.2.2. Open the anemometer box and check contents. Contents should include the anemometer, the inlet vent piece, 4x self-tapping metal screws for securing the main bracket to the mounting pole, and 4x 10-32 machine screws for attaching the anemometer to the top of the main bracket.

A.3. Installation of Anemometer and Solar Panel

A.3.1. Slide the main bracket over the 2” outer diameter (OD) mounting pole. The mounting pole can be attached to fence posts using stainless steel worm gear hose clamps or T-bolt clamps. For sites without fencing, piles or stands can be used. Qube recommends a height of 5 to 8 feet for most applications.

A.3.2. Remove the anemometer set screw, insert the mounting shaft into the body of the anemometer, and reinsert and tighten the set screw. Note: Insert the anemometer mounting shaft straight into the body of the anemometer. Do not twist or rotate.

A.3.3. With the body of the anemometer positioned over the grey device enclosure, attach the anemometer to the main bracket, using the 4x 10-32 machine screws.

A.3.4. Thread on the inlet vent piece (hand-tighten).

A.3.5. Push-connect the color-coded anemometer and solar panel barrel connectors, aligning the red dots.

A.3.6. In temperate climates, adjust the solar panel tilt angle by changing the lower solar bracket bolt position. There are three available positions. The solar panel may be left in the default vertical position in climates with heavy snowfall.

A.3.7. Ensure that the outlet vent piece is tightly sealed against the side of the enclosure (hand-tighten).

A.4. Device Mounting and Startup

A.4.1. Ensure that the device is oriented with the solar panel and the anemometer’s south “S” indicator facing due South using a digital or physical compass. Orientation of the anemometer and solar panel will need to be verified by using a digital or physical map and selecting an object of reference that is directly due south of the device’s position.

A.4.2. With the device correctly oriented, drill the self-tapping metal screws through the main bracket and into the mounting pole to prevent rotation. Ensure that the base of the pole is also secured to prevent rotation.

A.4.3. Remove the front cover panel by loosening the four Phillips head screws.

A.4.4. Locate the power jumper in the upper-left portion of the circuit board and pull it off the two pins. The power jumper can be inserted onto one of the two pins for storage.

A.4.5. Monitor the status indicator LED below the Particle Boron cellular modem. During this startup procedure it will cycle through several states. A slow teal “breathing” pulse indicates that the device is in its operational state. Prior states may include flashing green (searching for signal), and periodically blinking purple (firmware update in progress).

A.4.6. Replace the front cover. Note the device number located on the label on the side of the device.

A.5. **Device Registration**

A.6. Each Qube device must be registered following installation to allow for data transmission following the registration procedures outlined in this section. Registration can be completed via mobile device.

A.6.1. Scan the QR code on the label on the side of the device

A.6.2. Log in to the client-specific Qube account.

A.6.3. Verify that the device number is correct and click “Next”.

A.6.4. Allow use of location devices when prompted. This is vital in order to accurately record the device coordinates, ensuring accurate localization results.

A.6.5. Select the correct site on which the device is installed. The closest available site will be selected by default. Note: sites must be pre-configured by Qube during the Qube deployment evaluation.

A.6.6. Wait approximately 15 seconds for the mobile device GPS coordinates to stabilize, then click “Use My Location”.

A.6.7. Verify that the device location is correct on the map and matches the location specified in the deployment plan. Manually adjust on the map as necessary.

A.6.8. Review the installation details. Click “Save” to complete the registration process.

A.7. Optionally, view live data and click “Done”.

Appendix B: Bump Testing Procedures

This is an optional procedure to empirically check the measured values of a Qube monitoring device. This procedure is prescriptive in nature and must be conducted by trained personnel to ensure accurate sample delivery.

B.1 Calibration Gases

Calibration gases are available in a variety of compositions but are typically dry with 0% humidity. Qube's MOS methane sensors require >10% humidity to detect calibration gases. It is therefore required that any bump tests using calibration gas in the field or in the lab follow these conditions:

B.1.1 The gas must contain a methane concentration of less than 2,500 ppm (100 ppm is recommended and widely available)

B.1.2 The gas must be a "balanced air" gas, i.e., the blend must contain air and methane (rather than an inert gas and methane). Qube's sensors require the presence of oxygen to function. Therefore, any calibration gas used must contain oxygen

B.1.3 The gas must be hydrated. Calibration gases are typically dry, meaning that the partial pressure of H2O in the air constituent of the gas is zero. This places the relative humidity of the gas outside Qube's calibrated range

B.2 Sampling Equipment

B.2.1 A special apparatus was designed and constructed for testing with calibration gases. Calibration gas is first supplied through a variable-rate regulator to a brass 1/2" NPT manifold via 1/8" ID PVC tubing.

B.2.2 Wetted 30-micron water filter for hydration. Downstream of the filter outlet, the gas passes through a gate valve and enters the Qube monitoring device inlet vent via a direct-threaded connection to the daughter card enclosure. A second gate valve is also included to create a purge loop for clearing the daughter card enclosure after the test is complete.

B.2.3 A choke is installed on the Qube monitoring device outlet vent via a direct-threaded connection (3/4" NPT), with a reduction to a 1/8" ID tubing whip.

Note: The choke is necessary due to the low flow rate of calibration gas (0.1 L/min.) required to properly hydrate the gas. Without the choke, there is a risk of dilution of the calibration gas in the daughter card enclosure via the outlet vent due to turbulent flow across the outlet fan.

Figure 8 provides an example where 100-ppm methane-air balance calibration gas was to bump test Qube's sensor. The gas was supplied by NorLAB of Boise, Idaho, in a 103-litre (1.52-litre compressed) steel cylinder at 1,000 psi, with a variable flow-rate regulator capable of delivering between 0.1 and 7.0 litres per minute.

B.3 Procedure

Using the apparatus and procedure described here, the Qube continuous monitoring device produced methane concentration readings of 100 ppm (+/- approximately 1ppm) during a 12-minute test, with a calibration gas flow rate of 0.1 L/minute, as shown in Figure 9.

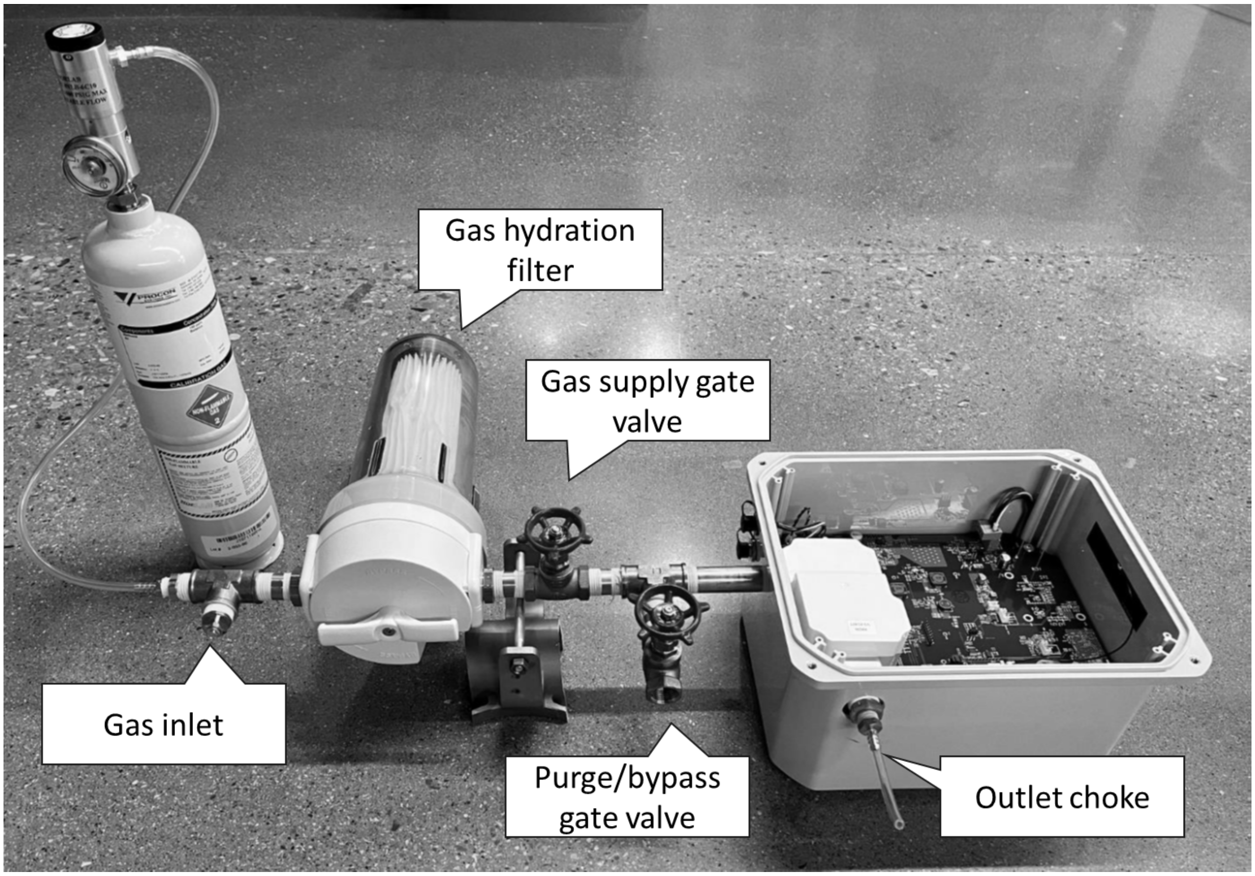

Figure 8: Qube continuous monitoring device lab-based testing apparatus

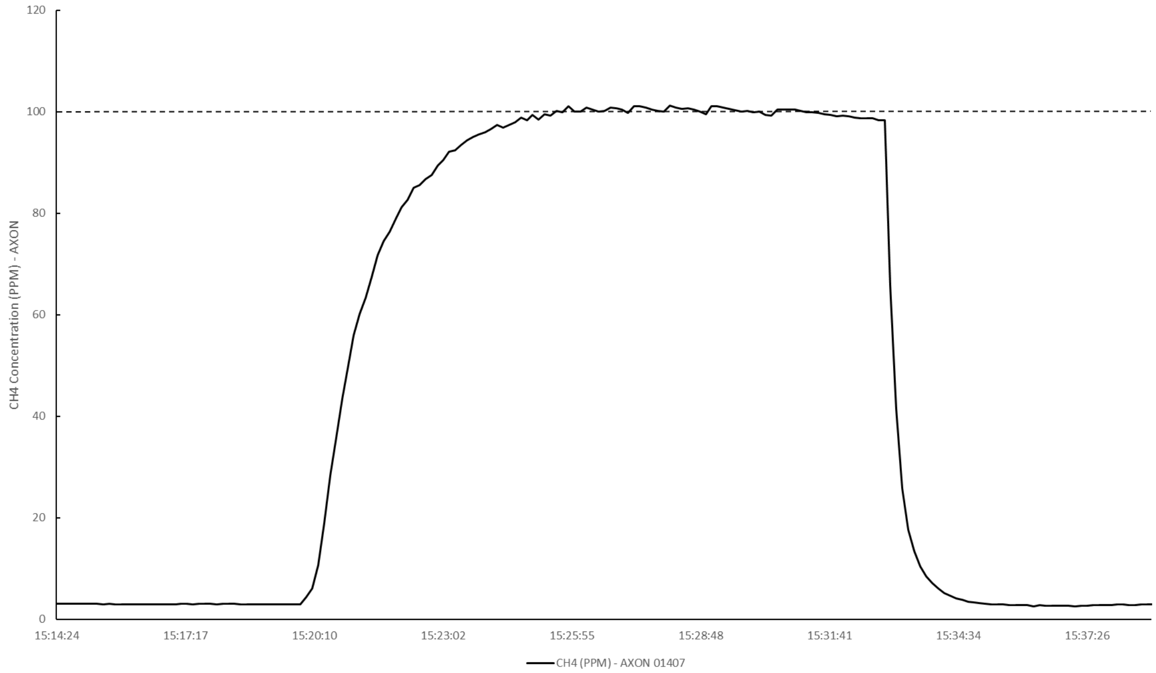

Figure 9: Bump testing results of the Qube continuous monitoring device. The Qube continuous monitoring device could detect methane concentrations of 100 PPM.

The methane concentration of the calibration gas was verified using a Los Gatos GGA-30p Off-Axis ICOS analyzer (LGA). The GGA-30p also produced readings of 100ppm (Figure 10). The verification test must be run separately from the Qube test. Concurrent testing is not feasible because the GGA-30p's compressor produces a gas flow rate exceeding the effective flow capacity of the hydration filter.

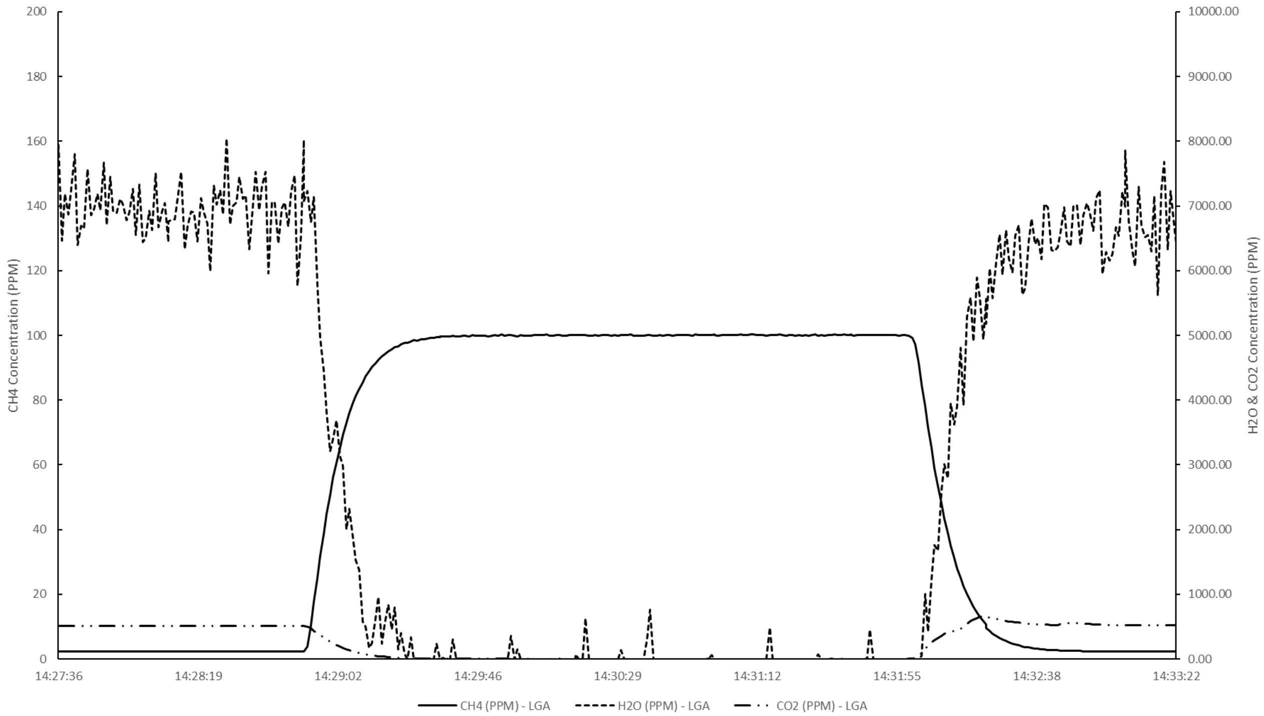

Figure 10: OA ICOS Analyzer Verification of methane concentrations registered by the Qube continuous monitoring device