Design Philosophy of Reliable - Quantitative Optical Gas Imaging camera GMP03 for Achieving Reliable Quantification in the Field

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Fig. 0 QOGI camera GMP03

About QOGI camera GMP03

The GMP03 is Konica Minolta’s handheld Quantitative Optical Gas Imaging (QOGI, hereafter referred to as QOGI) camera, built for methane detection and field-based emission quantification. Building on the foundation of conventional Optical Gas Imaging (OGI, hereafter referred to as OGI) cameras, GMP03 unifies leak visualization and quantification within a single device and introduces the Reliable Quantitative Optical Gas Imaging (R-QOGI, hereafter referred to as R-QOGI) framework—a design that couples representative emission quantification values with an intuitive reliability indicator.

This approach enables field operators to not only determine how much gas is being emitted, but to understand the reliability of each quantified result under variable environmental conditions such as wind, background complexity, and sensitivity fluctuations.

Abstract

This white paper presents the design philosophy for achieving reliable, decision-ready quantification using the R-QOGI camera GMP03 under real-world field conditions. While OGI cameras have become widely adopted for rapid leak detection, effective methane-mitigation efforts and regulatory reporting increasingly

require identifying leaks and quantifying emission rates. Direct-contact methods, such as high-volume sampling, or bagging techniques, are often impractical in hazardous, hard-to-reach, or structurally complex facilities, reinforcing the need for a robust non-contact alternative.

However, field-based QOGI faces inherent fundamental challenges. Outdoor airflow is rarely stable, and wind-driven plume deformation introduces significant temporal variability. As a result, measurement sequences often contain transient segments that are unsuitable for quantification, leading to unstable results and a high dependence on operator interpretation.

To address these challenges, the R-QOGI camera GMP03 reframes quantification as a time-series evaluation problem. It analyzes plume dynamics and environmental stability over time, automatically selects only data segments suitable for quantification, and generates a single representative emission value.
In addition, the R-QOGI camera GMP03 provides an intuitive reliability indicator derived from cumulative imagery and environmental metrics, enabling users to assess the reliability of each result on site while reducing reliance on operator judgment.

Finally, this paper outlines how QOGI cameras are evolving beyond fugitive-emissions to address higher-rate events—such as vents, blowdowns, and episodic releases—that are required to be quantified under recent regulatory and reporting frameworks. These advancements include large-scale calibration, enhanced background reconstruction.

1.The Role and Limitations of Conventional OGI cameras

OGI cameras have become a widely adopted method for leak detection, leveraging the infrared absorption and emission characteristics unique to specific gases. By visualizing otherwise invisible plumes, OGI cameras have played a central role in enabling rapid localization and early repair of gas leaks—initially as a tool for plant safety, and increasingly as a key technology for methane-reduction efforts. As the development of oil and gas wells has accelerated, methane emissions from production, gathering, and transmission infrastructure have gained global attention, driving greater reliance on OGI cameras for environmental compliance and mitigation.

However, effective methane-emission mitigation requires not only detecting and repairing leaks but also accurately understanding the amount of methane being released. Traditional quantification methods, such as high-volume samplers or bagging techniques are direct-contact approaches and often impractical in hazardous, hard-to-reach, or structurally complex facilities, leaving critical gaps in emissions reporting.

The OGI cameras offer a non-contact alternative capable of visualizing both small leaks and large releases, with each pixel capturing a measurable signal intensity. This capability laid the foundation for the development of QOGI, which seeks to derive emission rates directly from infrared imagery.

From the earliest stage of development, Konica Minolta pursued a different approach: generating stable, high contrast, high dynamic range gas flow imagery through proprietary image processing technologies. This foundation enabled the creation of the first commercially practical QOGI camera system, the GMP02, which was adopted by leading OGMP 2.0 member companies and contributed to early achievements of OGMP 2.0 Level 5.

2. Understanding the Challenges of QOGI in Field Use

QOGI derives flow-rate estimates optically rather than through direct-contact measurement, making the technique inherently susceptible to environmental variation. In outdoor field settings, stable airflow is rare; wind direction and speed fluctuate continuously, causing gas plumes to deform rapidly and unpredictably.

Wind-driven variability is the primary source of temporal instability in the plume signal (see Figure 1). Even moderate gusts can cause the plume to thin, fold, or break apart intermittently, producing transient segments that are unsuitable for quantification.

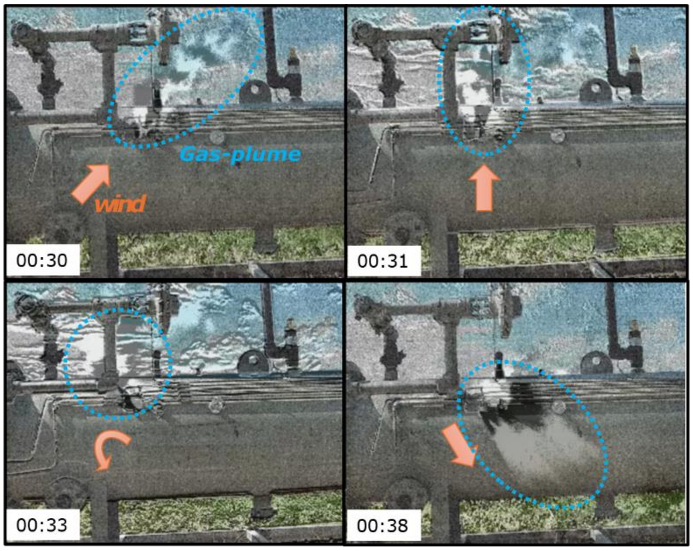

Figure 1. Wind-Induced Variability in Methane Plume Behavior.

Four consecutive still images show how gusts can transiently invalidate frames for quantification; GMP03 addresses this by evaluating plume behavior, selecting only segments suitable for analysis, and generating a single representative value accompanied by a reliability indicator.

Because neither the camera nor the operator can control these situational dynamics, GMP02 intentionally performs quantification over short time intervals, allowing operators to review multiple candidate values and choose the most representative result based on plume behavior.
Skilled inspectors were able to achieve reliable results with this method; however, as adoption expanded, differences in operator experience led to variability in interpretation.

3. R-QOGI camera GMP03: Solving the Fundamental Challenges

The new GMP03 directly addresses these fundamental challenges. It introduces an automated capability to evaluate temporal fluctuations in plume shape, motion, and environmental conditions, extracting only the segments deemed suitable for quantification and generating a single representative value. In addition, GMP03 provides an intuitive reliability indicator based on cumulative imagery and environmental metrics, giving users a clear understanding of the reliability of each result.

The following sections explain the technical foundations that enable these advancements and how the R-QOGI camera GMP03 delivers decision-ready quantification to the field—without requiring expert interpretation.

A Shift in Design Philosophy: From "Correct Values" to "Trustworthy Decisions"

In GMP03, a mechanism was introduced to automatically evaluate the temporal variation in gas plume behavior and extract only information suitable for quantitative analysis.

However, further advances in algorithmic sophistication alone do not ensure that highly accurate flow-rate values can always be calculated under all real-world field conditions.
Flow rate estimation using QOGI cameras is strongly influenced by gas detection sensitivity at the time of imaging and by surrounding environmental noise. When sensitivity is degraded or when noise levels are high, the algorithm cannot acquire sufficient information, making it inherently difficult to estimate highly accurate flow-rate values.

For example, a clear sky background without clouds often provides a large delta T (difference in temperature between the gas and the image background), leading to strong gas to be captured with high detectability and is therefore well suited for quantification. However, sensitivity varies depending on factors such as altitude, time of day, and relative position of the sun. In addition, the presence of clouds may reduce sensitivity or act as a source of noise.

In GMP02, a sensitivity map function was provided to help users assess gas sensitivity. By checking gas-enhanced images, users can determine whether clouds or other factors are likely to act as sources of noise.

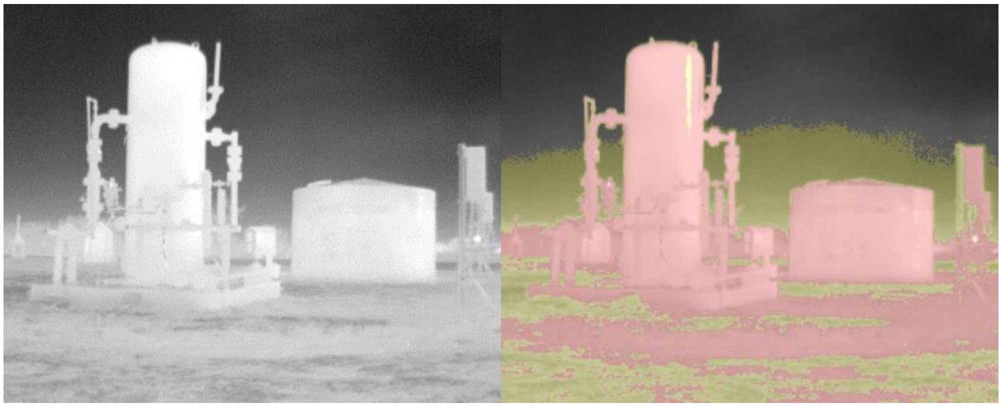

Fig. 2 Sensitivity map OFF (left) / ON (right).

The sensitivity map shows areas of poor gas detection sensitivity in red, areas of slightly reduced sensitivity in yellow, and areas of good sensitivity in the original image.

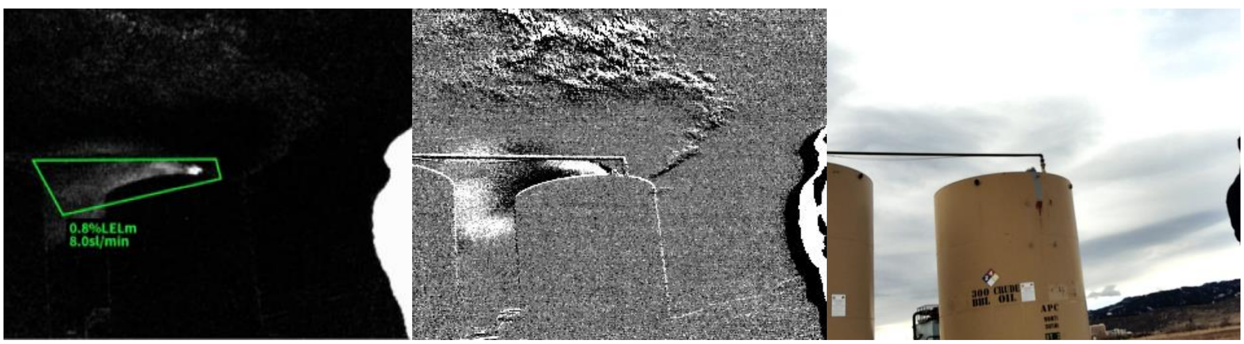

Fig. 3 Case where clouds do not turn into noise.

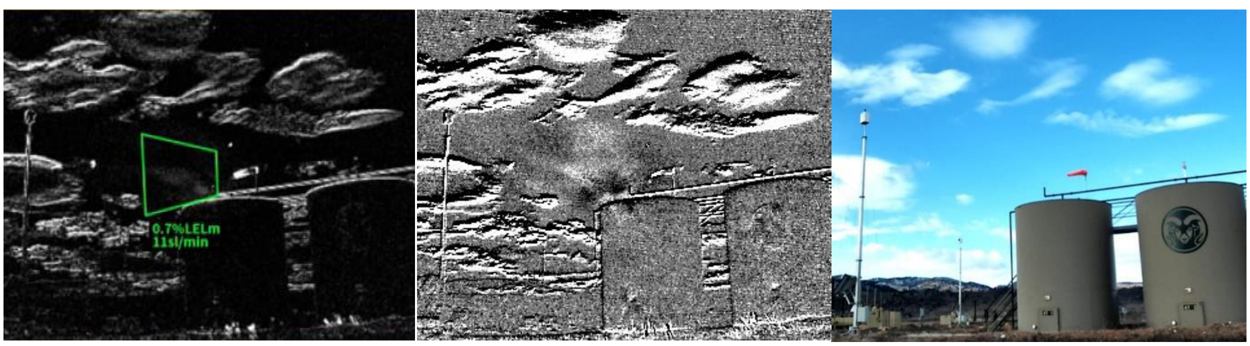

Fig. 4 Case where clouds turn into noise.
Gas-enhanced image (left) / High sensitivity image (center) / Visual image (right)

At the same time, there are many cases in which estimation accuracy can be improved by changing the shooting scene or timing and re-performing the estimation under more favorable conditions. This is because factors such as cloud cover and wind conditions change over time.

In GMP03, in addition to assistive functions such as the sensitivity map introduced in GMP02, the core design philosophy was redefined. Rather than focusing on "always producing correct numerical values," GMP03 places emphasis on "enabling users to judge whether a result should be adopted."

To achieve this, GMP03 combines aggregation of estimation results using representative values with visualization of their reliability. This approach provides a mechanism that allows users to immediately determine on-site whether re-shooting is necessary or whether the estimation result can be accepted.

4.Core Strengths of the R-QOGI camera GMP03: Representative Values and Reliability Indicators

The core strength of the R-QOGI camera GMP03 lies not merely in presenting a single numerical value as the estimated flow rate, but in its ability to show the conditions under which that value was obtained and to what extent it can be trusted.

To realize this, two key features were introduced: representative values and reliability indicators.

4.1 Concept of Representative Values

In flow rate estimation, the amount of gas passing through a user-specified area per unit time is calculated. For this reason, estimation accuracy tends to be higher under conditions in which gas flows stably in a single direction.

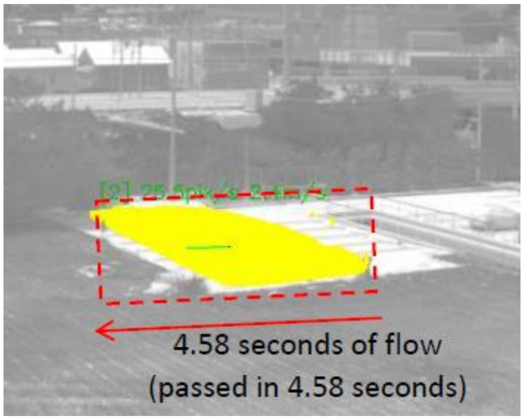

Fig. 5 Gas quantification technology.

Specifically, more accurate flow rate estimation is generally possible when wind flows steadily in a single direction, compared with periods of turbulent or swirling airflow.

In addition to the influence of wind, estimation errors may occur under these imaging conditions:

- When the temperature of the observed object is close to the gas temperature, detection sensitivity decreases and the flow rate tends to be underestimated.
- In environments with significant noise, noise may be misidentified as gas, leading to overestimation of the flow rate.

The R-QOGI camera GMP03 automates this experiential skill and generates a representative value by extracting and integrating only the flow-rate estimates that are assessed to be most consistent and reliable.

As a result, compared with simple averaging, representative values are less affected by variations in imaging conditions and external disturbances, enabling more accurate and stable flow rate estimation.

4.2 Role of Reliability Indicators

The reliability indicator shows the credibility of the calculated representative value using three levels.

This reliability is determined through a comprehensive evaluation of factors such as imaging sensitivity, noise level, and wind conditions.

Flow-rate estimation inherently becomes more difficult as imaging conditions deteriorate, making it increasingly challenging for the algorithm to produce highly accurate values.

Nevertheless, in many cases, estimation accuracy can still be improved by adjusting the shooting angle or timing of the plume movement and performing the quantification again with improved inputs.
Based on this characteristic, the R-QOGI camera GMP03 places strong emphasis on enabling users to determine for themselves whether a representative value should be accepted.
The reliability indicator serves as a guideline to help users determine whether the representative value can be used as is, or whether re-shooting is advisable.

In particular, when sensitivity is low or noise levels are high, the system explicitly indicates the difficulty of achieving high-precision estimate through the reliability indicator, thereby encouraging re-shooting whenever possible.

4.3 Differences from Other Approaches

As described above, the R-QOGI camera GMP03 is designed with the understanding that plume behavior and imaging conditions vary over time, and it places strong emphasis on enabling users to assess the validity of the results.

In contrast, many conventional QOGI camera approaches present only the estimated flow rate value without providing indication of the conditions under which the value was obtained or how reliable it is. Consequently, decisions on whether to accept the estimated value inevitably depend on the operator's experience and subjective judgment.

By presenting representative values together with reliability indicators, the R-QOGI camera GMP03 provides users not only with the estimated value itself, but also with guidance on whether that result should be used, or if the accuracy could be improved. This is the fundamental difference between the R-QOGI camera GMP03 and conventional QOGI camera approaches that display estimated values alone.

5.Accuracy

The representative values introduced in the R-QOGI camera GMP03 are designed to help users obtain more reliable flow rate estimates in field environments where imaging conditions and plume behavior vary significantly. To verify their effectiveness, validation was conducted using quantitative evaluation data acquired with GMP02 at the Colorado State University METEC facility during two campaigns (December 12–15, 2022, and July 17–21, 2023).

Using the raw data collected during these campaigns, flow rate estimates calculated by simple averaging were compared with representative values calculated based on the R-QOGI concept. The proportion of estimates falling within a factor-of-two range (50%–200%) relative to the true flow rate was as follows:

Simple averaging: 54%
Representative values: 61%

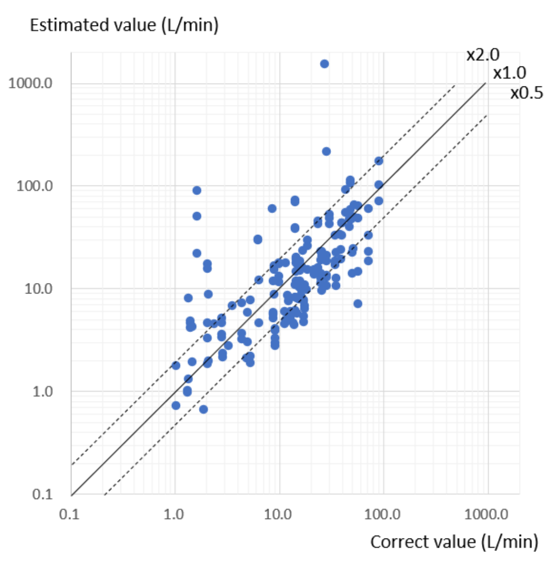

Fig. 6 Simple averaging

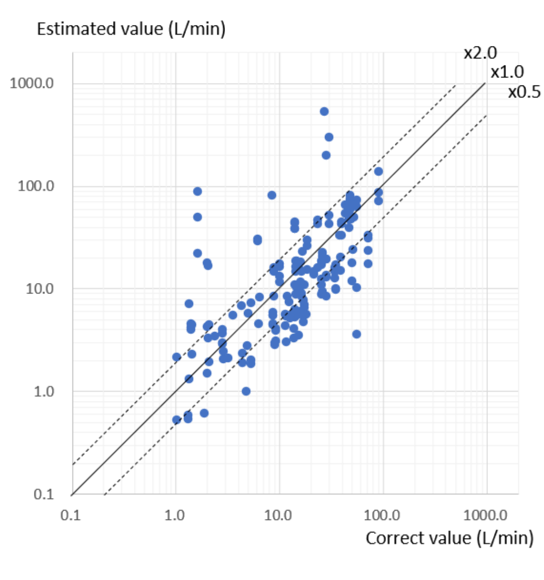

Fig. 7 Representative values

These results confirm that estimation accuracy improves when representative values are used. In real-world environments, where plume behavior and imaging conditions vary continuously, the use of representative values—derived by evaluating conditions and selectively extracting and integrating estimates—provides more reliable flow-rate estimation than simple averaging.

By combining representative values with reliability indicators, the R-QOGI camera GMP03 establishes a framework that not only enhances estimation accuracy but also enables users to assess each result.

6.Future Technical Directions

QOGI technologies have traditionally focused on the detection and quantification of fugitive quantification—relatively small, unintentional leaks typically below a few kilograms per hour. While this capability remains essential for LDAR (Leak Detection and Repair) programs globally, the regulatory and industrial landscape is rapidly shifting. Under frameworks such as OGMP 2.0 Level 4/5, operators are now expected to quantify not only fugitive emissions but also intentional releases, including vents, blowdowns, and other large episodic events. Although these high-rate emissions occur less frequently, they account for a disproportionate share of total methane emissions and therefore require accurate and dependable quantification methodologies. Recent developments have thus focused on extending the effective range of QOGI quantification to encompass these high-rate release events.

A primary challenge in extending quantification beyond fugitive emissions is the fundamentally different behavior of large gas plumes. Field evaluations at METEC and Stanford have demonstrated that traditional concentration-pathlength (ppm-m) estimation methods—optimized for small leaks—can significantly under-estimate emissions in the 20–1000 kg/hr range, particularly in situations where gas retention prevents accurate background determination.

To extend QOGI capabilities into higher emission-rate regimes, development efforts have focused on addressing the fundamental behavioral differences between small leaks and large gas plumes. Dense cloud formations generated during high-rate releases can obscure backgrounds or exhibit dynamics that limit the effectiveness of conventional estimation approaches. To improve performance under these conditions, the following enhancements have been implemented:

- **Expansion of the concentration–pathlength lookup table (development of a measurement system capable of handling higher concentration ranges)**
  The quantification range has been expanded through the introduction of a high-concentration measurement framework, enabling reliable estimation in dense plume conditions.

- **Mitigation of challenges specific to large leaks (e.g., gas retention)**
  Measures have been implemented to address issues such as gas accumulation that may hinder stable background determination, thereby improving robustness during large‑release events.

Taken together, these developments represent a significant expansion of OGI-based quantification capabilities. With planned product releases for vent and blowdown quantification in 2026 and super-emitter quantification in 2027, QOGI systems are evolving into comprehensive emission measurement platforms capable of supporting regulatory reporting, carbon accounting, and operational decision-making. As global methane reduction initiatives accelerate, these innovations will play a vital role in enabling operators to understand their full emission profiles and to take informed, data-driven action.

7. Conclusion: R-QOGI as a Framework for Achieving Reliable, Decision-Ready Quantification

The core advancement of the R-QOGI camera GMP03 lies in its ability to transfer the critical act of judgment from human operators to an algorithmic framework specifically designed for field conditions. Conventional QOGI cameras have long faced a structural limitation: because plume behavior and environmental factors such as wind are inherently uncontrollable, the validity of quantitative results depended heavily on operator experience and subjective interpretation. Consequently, quantitative outputs were often treated as indicative rather than truly decision-ready.

GMP03 fundamentally addresses this limitation by redefining QOGI quantification as a time-series evaluation problem. Rather than requiring skilled operators to identify favorable moments for measurement, the R-QOGI camera GMP03 continually analyzes plume morphology, motion, background stability, and environmental conditions over time. Segments deemed unsuitable for quantification are automatically excluded, and a single representative value is generated from the remaining valid data. Each output is paired with an intuitive reliability indicator derived from cumulative imagery and environmental metrics, enabling users to understand the reliability of each result directly onsite without relying on expert judgment.

This shift transforms the QOGI camera from a visualization-assisted estimation tool into a measurement technology capable of supporting operational decision-making. By transferring judgment from individuals to algorithms, the R-QOGI camera GMP03 delivers consistency, reproducibility, and explainability—attributes essential for regulatory reporting, emissions accounting, and operational methane reduction strategies. Equally important, this approach enables quantification performance to scale across users, facilities, and regions without depending on a limited pool of highly experienced inspectors.

Beyond fugitive emissions, R-QOGI is evolving to address the full range of methane sources required under advanced regulatory and reporting frameworks, including vents, blowdowns, and large episodic releases. Advances in large-scale correction, background reconstruction, and total mass estimation further extend the applicability of OGI based quantification to high-rate and long-range scenarios. Together, these developments position QOGI as a comprehensive emissions measurement platform rather than a niche inspection tool.

In essence, the R-QOGI camera GMP03 shifts the fundamental question for QOGI camera from "Can it be measured?" to "Can it be trusted and used for decisions?" By embedding judgment directly into the quantification process, the R-QOGI camera GMP03 transforms field measurements into standardized, reproducible procedures rather than subjective evaluations. As global methane reduction initiatives accelerate, this paradigm shift will be essential in enabling operators to reliably understand their emissions, report them reliably, and take informed, data driven action.

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