Alternative Testing Procedure: Determination of Methane Emissions from Stationary Sources

October 11, 2024

Submitted to:

The Environmental Protection Agency Emission Measurement Center

https://www.epa.gov/emc/oil-and-gas-alternative-test-methods

Prepared by:

Exploration Robotics Technologies Inc.

https://www.xplorobot.com

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1. Scope and Application

1.1 Scope

This method is applicable for demonstrating compliance with the procedures in 40 CFR §60.5398b 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 monitoring per 40 CFR §60.5398b(b).

1.2 Application

1.2.1 The application of this technology is per the Environmental Protection Agency's 40 CFR part 60 Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review.

1.2.2 The test method is applicable to methane emissions from oil and gas infrastructure. This method can be used as defined in §60.5398b(b) in lieu of the required fugitive monitoring and inspection and monitoring of covers and closed vent systems under 40 CFR part 60 subparts OOOOa, OOOOb and OOOOc to identify emissions.

1.2.3 This method is used as an alternative to the Best System of Emissions Reduction (BSER), which is quarterly OGI surveys.

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

1.2.5 Applicable sites include single wellhead sites, small well sites, multi-wellhead sites, well sites with major production and processing equipment, centralized production facilities, and compressor stations.

1.3 Analytes

Compound Name	CAS No.
Methane	74-82-8

1.4 Method Range and Sensitivity

Xplorobot Laser OGI range is 50 meters based on the TDLAS sensor specifications. Xplorobot Laser OGI detects thief hatch emissions from the ground and fugitive emission sources inside oil and gas facilities from positions outside of the facilities' boundaries.

For component-level inspections where emission quantification is required, the distance of the inspection must not exceed 7 meters based on the demonstrated accuracy of the emission quantification by Xplorobot Inspector software algorithms.

Xplorobot Laser OGI sensor sensitivity is 1 gram per hour as demonstrated in controlled release and field experiments. In blind testing at the Methane Emissions Technology Evaluation Center, Xplorobot Laser OGI demonstrated a 90% probability detection level of 156 grams per hour. The 90% confidence level of detection is a combination of the device sensitivity (1 gram per hour for Xplorobot Laser OGI), the time spent scanning and the skill level of the inspectors using the device.

The detection threshold for emission reporting for Xplorobot Laser OGI device is 500 ppm-m based on the correspondence between Xplorobot Laser OGI and Methos 21 measurements established in control-rate experiments (see **Section 2** for details).

1.5 Component-level Spatial Resolution

Xplorobot Laser OGI is a Component-Level Alternative Test Method per 40 CFR §60.5398b. Xplorobot Laser OGI spatial resolution is 0.4 cm at 1 meter distance and 20 cm at 50 meter distance based on the laser aperture and the accuracy of the emission localization of the computer vision software in the device.

2. Summary of Method

The LDAR inspector uses Xplorobot Laser OGI to systematically scan equipment components - such as valves and flanges - by walking around the equipment and using a green laser to track inspection of each component. When a reportable emission is detected (defined as an emission with maximum column-integrated concentration at or above 500 ppm-m), the inspector records a Digital Emission Tag for that emission source. The Digital Emission Tag is synced to the inspector's smartphone via a Bluetooth link and then uploaded to the cloud-based Xplorobot Compliance Database for immediate operator notification.

Inspection data - methane concentration, visualization, GPS coordinates and meteorological data - is uploaded to the Xplorobot Compliance Database. Within the Database, each component inspected is automatically identified by a computer vision algorithm and Digital Compliance Records are created for all components that were found to either (i) not emit methane or (ii) emit methane within allowable limits.

Upon completion of the repairs, per the requirement of 40 CFR § 60.5398b(b)(5)(v), Xplorobot Laser OGI is used to verify the absence of the emission and to create Digital Compliance Records for the repaired component.

Digital Emission Tags and Digital Compliance Records for all components inspected are stored in the Xplorobot Compliance Database in satisfaction of the recordkeeping requirements of 40 CFR § 60.5420b(c) and 40 CFR § 60.5424b(c).

3. Definitions of Method

(a) Digital Compliance Record: a digital record for a specific component stored in the Xplorobot Compliance Database that certifies zero emission for that component on a specific date at a specific time, thereby supporting regulatory compliance and auditing per 40 CFR § 60.5424b.

(b) Digital Emission Tag: a digital record for a specific component integral to the functionality of Xplorobot Laser OGI and stored in the Xplorobot Compliance Database that certifies presence of methane emission from that component on a specific day at a specific time, thereby supporting regulatory compliance and auditing per 40 CFR § 60.5424b.

(c) Xplorobot App: Software on the LDAR inspector smartphone used to provide site, equipment and component information for scans and Digital Emission Tags for immediate cloud upload and operator notification.

(d) Xplorobot Compliance Database: Secure digital storage containing all compliance-related data, including Digital Emission Tags and Digital Compliance Records, for each facility, site, equipment and component inspected using Xplorobot Laser OGI. This database provides accessible historical emissions information and compliance reporting to facility operators and regulatory authorities per 40 CFR § 60.5424b.

(e) Xplorobot Inspector Software: Proprietary software designed to complement, and integral to the functionality of, the Xplorobot Laser OGI device by analyzing inspection data to localize and quantify methane emissions.

(f) Xplorobot Laser OGI: The Xplorobot Laser OGI is an Active Optical Gas Imaging device that detects methane emissions at a component level and visualizes methane emissions otherwise not visible to the naked eye.

4. Interferences

The main limitation of Xplorobot Laser OGI is the necessity of a reflection point to return the laser beam back to the device. Detection of methane emission, or certifying zero emission, is performed by pointing the laser beam directly at the component being inspected and reflecting the laser beam from that component. In the case of open vents and flares, detection of methane emission may not be possible if (1) open vent or flare is observed against an open sky and does not have any reflection points behind it and/or (2) the methane plume is rising vertically up and does not extend below the edge of the vent or flare. Detection of emission from open vents or flares should be done either by reflecting Xplorobot Laser OGI from equipment directly behind the opening of the vent or flare or by installing a reflection point (a small metal plate welded above the vent or flare). Alternatively, other methane emission detection solutions can be used for those emissions point per the LDAR plan adopted by the facility operator.

5. Safety

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

Emissions detected by this Alternative Test Method may contain compounds that are irritating or corrosive to tissues (e.g., heptane) or may be toxic (e.g., benzene, methyl alcohol). Nearly all are fire hazards. Compounds in emissions should be determined through familiarity with the source. Appropriate precautions can be found in reference documents, such as reference No. 3 in **Section 16**.

Operation of Xplorobot Laser OGI in an oil and gas facility requires compliance with Hot Work Permit and other safety standards as defined by the facility operator.

6. Equipment and Supplies

Xplorobot Laser OGI and its embedded software is purposely integrated to meet the requirements of 40 CFR §60.5398b for component-level inspection. The main components of Xplorobot Laser OGI device are (1) a Tunable Diode Laser Absorption Spectroscopy (TDLAS) sensor that has a green visible laser and an infrared measurement laser, (2) a high-resolution visual camera, (3) a GPS, (4) an anemometer and (5) a thermometer. **Figure 1** shows the Xplorobot Laser OGI and its main components. Local wind and temperature data is recorded to meet the requirements of 40 CFR §60.5398b(d)(3)(iv)(E). The TDLAS sensor emits a laser beam with the wavelength of 1653 nanometers that is absorbed by methane molecules, thus enabling determination of methane in the air column between the sensor and the point which reflects the infrared laser beam back to the device. The TDLAS sensor determines the column-integrated methane concentration by comparing the energy loss for the 1653 wavelength to the energy loss in the adjacent wavelength in the laser spectrum. To visualize the reflection point of the infrared laser, the TDLAS sensor uses a visible green laser that is aligned with the infrared measurement laser.

Figure 1. Xplorobot Laser Optical Gas Imaging Device.

7. Reagents and Standards

Xplorobot Laser OGI does not use reagents.

8. Sample Collection, Prevention, and Storage

8.1 Calibration check

Calibration check must be performed before the first deployment of Xplorobot Laser OGI and monthly thereafter to ensure proper functioning of the device.

8.2 Site and equipment scanning plan

For each site, the LDAR inspector establishes a plan for scanning each piece of equipment (and its components) and piping between the equipment. The site inspection plan must ensure that all equipment, components and piping segments are scanned by Xplorobot Laser OGI to satisfy the requirements of 40 CFR 60.

8.3 Individual equipment and component scanning

To turn on the Xplorobot Laser OGI, the LDAR inspector pushes the power button on the device. Upon loading the operating system, the screen displays the safety message advising the LDAR inspector of the laser safety measures, tripping and slipping hazards and methane emission safety rules. The LDAR inspector must read and acknowledge the safety message before scanning.

To start scanning, the LDAR inspector presses the “Start” button on the Xplorobot Laser OGI touchscreen and waits for the green indicating laser to turn on. The LDAR inspector uses Xplorobot Laser OGI device to systematically scan equipment components - such as valves and flanges - by walking around the equipment and using a green laser to track inspection of each component. While scanning, Xplorobot Laser OGI continuously records column-integrated methane concentration in PPM-m, visual images (used for visualization of emissions otherwise not visible by a naked eye), GPS data, wind speed, and ambient temperature.

The dwell time for each component is one second.

8.4 Emission point tagging

When Xplorobot Laser OGI records a column-integrated methane concentration measurement of 5ppm-m (but less than 500ppm-m), the device emits a beeping noise and the display color changes from green to yellow, indicating presence of the emission source in the vicinity. The inspector then uses the green location laser to investigate the area of possible emission and locate the emission source. When Xplorobot Laser OGI records a column-integrated methane concentration measurement at or above 500ppm-m, the display color changes from yellow to red, indicating detection of a reportable emission.

Upon identification of a reportable emission with column-integrated concentration at or above 500 ppm-m, the inspector localizes the emission point (the component upon which the highest concentration is recorded), then presses the "Digital Emission Tag" button on the touch screen to visualize the methane emission otherwise not visible to the naked eye in real-time on the screen of Xplorobot Laser OGI.

Figure 2. Detection of the emission (concentration above 500ppm-m) and visualization of the emission otherwise not visible to the naked eye by the Xplorobot Laser OGI device.

Pressing the "Digital Emission Tag" button automatically creates a Digital Emission Tag that is stored in the memory of Xplorobot Laser OGI, synced to the inspector’s smartphone via a

Bluetooth link, and consists of the following information.

- Visualization of the emission otherwise not visible to the naked eye that localizes it to a specific component.
- Maximum column-integrated methane concentration at the emission source in ppm-m.
- Estimate of the emission rate in grams per hour
- GPS location of the recorded emission source (the sensor position during the scan).
- Date and time of the detection of the emission source.
- Wind speed and ambient temperature at the emission source location.

- *Figure 3. Visualization of emission is otherwise not visible to the naked eye, attributing the emission to the specific components (bolt, thief hatch) and detection of emission from an underground pipe.*

The real-time visualization of the emission is based on high-resolution photographs to provide localization of the emission source to a specific component. By recording all information required for emissions reporting and creating a visualization of the methane emission, Xplorobot Laser OGI digitally captures all the information required for emissions reporting per 40 CFR 60.5420b(b) and 40 CFR 60.5424b.

8.5 Scan completeness check

Upon completing the equipment scan, the LDAR inspector presses “Stop” button. A summary of the scan is displayed on the screen of Xplorobot Laser OGI, including all the Digital Emission Tags recorded by the LDAR inspector.

8.6 Xplorobot App cloud upload

The Xplorobot Laser OGI is paired with the inspector’s smartphone running Xplorobot App that is used to upload Digital Emission Tags to Xplorobot Compliance Database for immediate notification to the oil and gas facility operator about the emission source identified during the inspection. Email notifications are automatically sent to the stakeholders per operator’s specifications.

8.7 Digital data upload and storage

Upon inspection completion, all visual, methane, GPS, and meteorological data captured by Xplorobot Laser OGI is securely uploaded to the cloud-based Xplorobot Compliance Database. In addition, each Digital Emissions Tag is supplemented with information on the specific site, equipment, and component (using GPS information to link with the site and equipment/component database or manual input). Each Digital Emissions Tag is classified as a fugitive emission, malfunctioning component, as-designed emission, or allowable emission.

Xplorobot data flow, record keeping and reporting

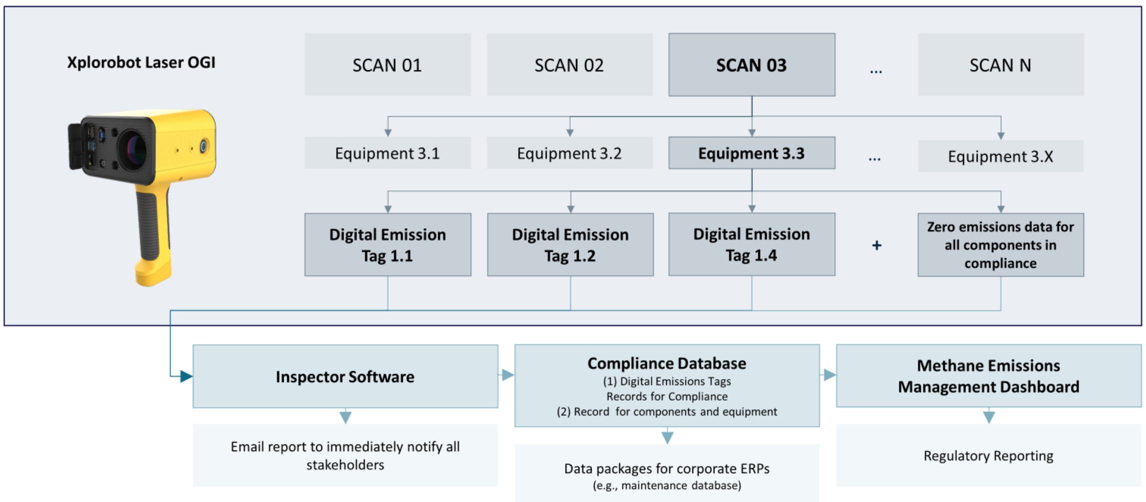

Figure 4. Data flow, recordkeeping and reporting for the proposed Alternative Test Method to satisfy the requirements of 40 CFR § 60.5420b(c) and 40 CFR § 60.5424b(c).

Xplorobot Compliance Database automatically notifies (by email) all stakeholders involved in reporting, repairing, and mitigating the emissions per Operator's requirements.

8.8 Component-level Digital Compliance Record cataloguing

During component-level facilities inspection, Xplorobot Laser OGI continuously records methane, visual, GPS and meteorological data for all components inspected. When uploaded to the Xplorobot Compliance Database, Xplorobot Inspector software automatically identifies each component inspected and creates Digital Compliance Records for those components that do not emit methane (concentration detected is zero or below emission detection threshold). Each Digital Compliance Record consists of the following information.

- Digital map of methane concentration measured on the component (zero concentration or concentration below the reporting threshold).
- Maximum column-integrated methane concentration at the component in ppm-m.
- Estimate of the emission rate (based on Xplorobot proprietary physics + neural network-model) in grams per hour.
- GPS location of the recorded emission (the sensor position during the scan).
- Date and time of the compliance certification.
- Wind speed and ambient temperature at the emission source location.

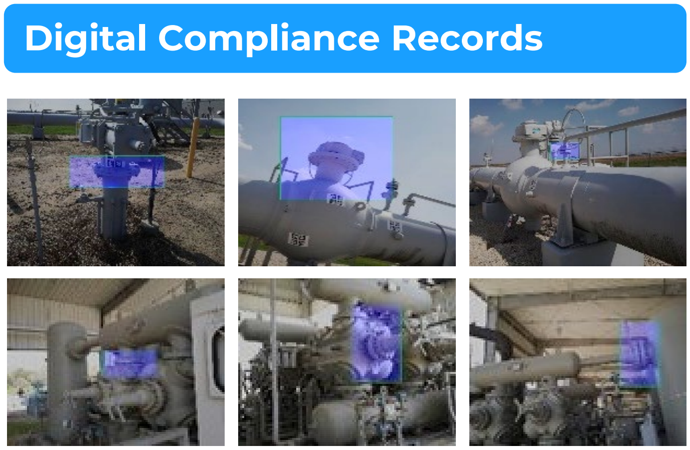

Figure 5. Digital Compliance Records in the form of 2D methane concentration maps for equipment and components

All Digital Emissions Tags and Digital Compliance Records are stored in the Xplorobot Compliance Database in satisfaction of the recordkeeping requirements of 40 CFR § 60.5420b(c) and 40 CFR § 60.5424b(c).

8.9 Inspection completeness and dwell time review

Upon upload of the scan data to Xplorobot Compliance Database and creating all Digital Compliance Records for all the components on all equipment on the site, the completeness of the inspection is checked by comparing the list of equipment scanned against the known equipment count for each site inspected. Further, for each equipment, the count of the components is compared against the standard equipment count for that equipment or the equipment count from the baseline Xplorobot Laser OGI survey.

The dwell time for each component is verified automatically by counting the number of methane data points that correspond to that component.

8.10 Repair work order issue

For each fugitive emission or malfunctioning component, a repair work order is issued within the Xplorobot Compliance Database. The status of the work order is tracked until the repair is complete.

8.11 Repair verification

Upon completion of the repairs, per the requirement of 40 CFR § 60.5398b(b)(5)(v), Xplorobot Laser OGI is used to verify the absence of the emission and to create Digital Compliance Records for the component repaired that is stored in the Xplorobot Compliance Database per 40 CFR 60.5420b(c) for recordkeeping and per 40 CFR 60.5424b for reporting.

9. Quality Control

Section	Quality Control Measure	Effect
8.1	Calibration Check	Ensure proper functioning of Xplorobot

		Laser OGI
8.6	Scan Completeness Check	Ensure that all emission sources are documented
8.10	Inspection Completeness Review	Ensure that all equipment and all components are inspected
8.10	The dwell time verification	Ensure that proper time is spend inspecting each component
10	Calibration and Standardization	

Xplorobot Laser OGI can be used to detect emissions from a distance up to 50 meters. For quantification, Xplorobot Laser OGI should be deployed at a distance between 1 and 7 meters.

Xplorobot Laser OGI should be utilized in wind conditions of less than 25 miles per hour and temperatures from -12 F to + 108F based on the tests performed to-date.

10. Calibration and Standardization

A calibration check of the TDLAS sensor is performed monthly using a methane sample vial (provided by Xplorobot). When pointing the laser at the vial from a 2 meters distance, the reading of the device should be in the range between 2,000 ppm-m and 3,000 ppm-m. No daily calibration checks are required.

11. Analytical Procedures

Reserved

12. Data Analysis and Calculations

Data collected by Xplorobot Laser OGI is used to estimate the emissions rate by utilizing physical modeling of the methane plume dynamic. The behavior of the methane plume in the vicinity of the source is driven by a combination of three factors: (1) wind dispersion, (2) buoyancy and (3) jet flow of methane out of an emission point. The relative contributions of these three regimes depend strongly on the wind conditions and the pressure differential between the gas inside the equipment and the atmospheric pressure. In enclosed spaces (such as inside compressor stations), ventilation plays the role like that of wind outdoors.

Xplorobot Laser OGI records real-time wind speed at the emission location with methane concentration measurements. The Xplorobot Inspector software maps the emission concentration at and around the emission point in 3D. A combination of the plume's geometric extent, the spatial distribution of concentration recorded (the concentration measurement as a function of angle and as a function of the distance from the emission source), and the wind speed is used in the Xplorobot proprietary algorithm to calculate the emissions flow rate in grams per hour or standard cubic feet per hour.

Xplorobot Inspector proprietary algorithm incorporates the dynamics of three flow regimes (wind dispersion, buoyancy and jet) and uses machine learning to interpolate between them. Figure 6 provides the results of Xplorobot emission rate algorithm calibration in 437 controlled rate experiments. 349 of these were used to train the neural network and calibrate the physics formulas and 88 were used for testing the accuracy of the predictions. **Figure 7** provides an example of Xplorobot emission rate prediction for 40 emission sources in real field conditions compared to Hi Flow emission rate measurements for those emission sources.

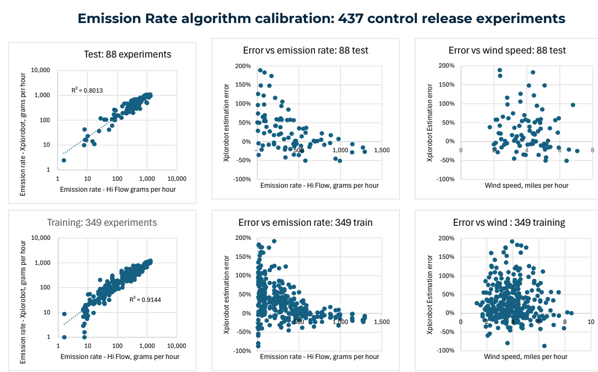

Figure 6. Xplorobot proprietary physics-neural-network algorithm calibration in 437 control release experiments

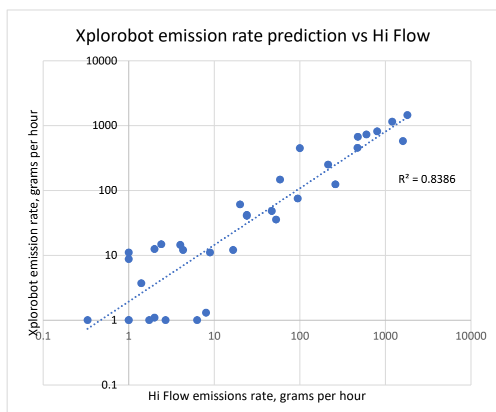

Figure 7. Xplorobot emission rate prediction for 40 emission sources in real field conditions compared with Hi Flow measurements

13. Method Performance

13.1 Accuracy of emission detection and localization

In an orphan well campaign led by the US Forest Service near Marietta, OH, Xplorobot Laser OGI detected multiple emissions sources that were quantified to be below 1 gram per hour by a Hi Flow device (see **Figure 8**). Xplorobot Laser OGI is designed for 1 gram per hour sensitivity through the design of the device, selection of the characteristics of individual sensors and performance of the embedded software.

Campaign Results: Marietta, Ohio

Work Completed:

Scope: 21 wells scanned in 3 days

Results: Xplorobot sensor detected 100% emissions (including 5 emission sources of ~1gph that an infrared OGI camera did not detect)

Emission Rates: Ranged from less than 1 gph to 1,600 gph

Average Rate: 225 gph per source

Observations for Xplorobot Results:

Easy to deploy in the field (4.5 lb. sensor in a shoulder bag)

Time-efficient detection/quantification/certification–2 min set-up and 3 min measurement per well

Accurate emissions estimates achieved in the range from 10 to 1,6000 gph

Well Name	Rate, g/hr	FLIR Detection	Xplorobot Detection
Porter Run 2	Zero Emission	Zero Emission	Zero Emission
Private #7	<1.0	No detection	Detection
Private #2	<1.0	Not tested	Detection
Rutherford Nancy 2	1.0	No detection	Detection
USA Joy 1	1.0	No detection	Detection
Edward Wiles #3	1.4	Not tested	Detection
USA #19	2.0	Not tested	Detection
Martin James #1	2.0	No detection	Detection
Edward Wiles #3	2.4	Not tested	Detection
Private #3	4.0	Not tested	Detection
Rutherford Nancy 3	8.0	No detection	Detection
Private #1	20.0	Not tested	Detection
Holiday Rueben #6	24.0	No detection	Detection
Zwick Bros #3	24.0	Not tested	Detection
Grace Joy 1	52.7	Detection	Detection
Undocumented 1	58.5	Detection	Detection
Private #5	100	Detection	Detection
Private 8	600	Detection	Detection
Charles Hall #6	800	Detection	Detection
Westbrook WM B	1,200	Detection	Detection
Private #9	1,600	Not tested	Detection

Figure 8. Emissions detection in an orphan well field campaign led by US Forest Service near Marietta, OH.

In blind testing at the Methane Emissions Technology Evaluation Center Xplorobot Laser OGI demonstrated a 90% probability detection level of 156 grams per hour, or 4 standard liters per minute, that is in the range of the 90% probability detection level between 2.6 standard liters per minute and 7.7 standard liters per minute for infrared OGI cameras operated by highly experienced LDAR inspectors (Zimmerle et al, 2020). It is important to emphasize that, according to the findings of Zimmerle et al (2020), the 90% confidence level of detection is a combination of the sensitivity of the device (1 gram per hour for Xplorobot Laser OGI) and the skill level of the inspectors using the device.

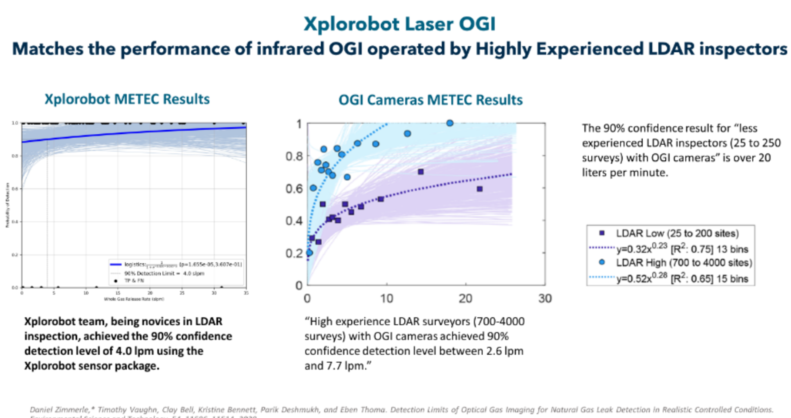

Figure 9. Results of blind tests at METEC for Xplorobot Laser OGI and for infrared OGI cameras (Zimmerle et al, 2020).

Xplorobot Laser OGI can detect emissions that typically challenge detection by infrared OGI cameras due to the absence of thermal contrast between the gas and the background. Xplorobot Laser OGI detects emission from under wraps and emissions from buried pipes. **Figure 10** and **Figure 11**, respectively, provide examples of such emission detections.

Figure 10. Emissions were detected under a bubble wrap, and the recording on the regulator after the wrap was removed.

Figure 11. Emission detected under gravel and recorded on tubing after gravel was removed.

13.2 Accuracy of conversion to Method 21 Equivalent Concentration

To compare the detection accuracy of Xplorobot Laser OGI and Method 21 devices, we performed a set of controlled release experiments with emission rates ranging between 0.4 grams per hour and 574 grams per hour as validated by a Hi Flow device. The exact quantitative correspondence between a local concentration measurement and a column-integrated concentration measurement cannot be established, as the column-integrated measurement is impacted not only by the distribution of the methane in the path of the laser but also by the aperture of the laser beam which varies between TDLAS sensors from different manufacturers. However, the control rate experiments demonstrate that the Xplorobot Laser OGI measurement of 500 ppm-m corresponds to 500 ppm measurements by a Method 21 device (Figure 12).

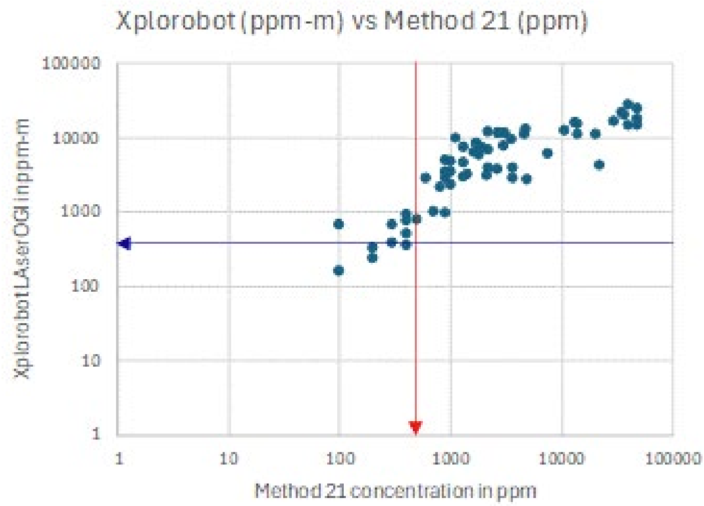

*Figure 12. Comparison between **Xplorobot Laser OGI** and Method 21 device measurements.*

14. Pollution Prevention

Pollution is not created by this Alternative Test Method.

15. Waste Management

Waste and physical samples are not produced or collected with this Alternative Test Method.

16. References

1. Daniel Zimmerle, Timothy Vaughn, Clay Bell, Kristine Bennett, Parik Deshmukh, and Eben Thoma. Detection Limits of Optical Gas Imaging for Natural Gas Leak Detection in Realistic Controlled Conditions. Environmental Science and Technology, 54, 11506−11514, 2020.
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3. Handbook of Hazardous Materials: Fire, Safety, Health. Alliance of American Insurers. Schaumberg, IL. 1983.