REQUEST ID: ALTTECH-20

Alternative Testing Procedure: Determination of Methane Emissions from Stationary Sources

June 28, 2024

Submitted to:

The Environmental Protection Agency Emission Measurement Center

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

Prepared by:

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This document does not contain Confidential Business Information.

Preface: Application Requirements Compliance

Submitting Entity Qualifications

Exploration Robotics Technologies Inc. (“Xplorobot") is a qualified applicant as required by 40 CFR §60.5398b, as indicated below.

Code Reference	Summary of Requirement	How Compliance is Achieved
§60.5398b(d)(2)(i)	The submitting entity must be an organization located in or that has representation in the United States.	Xplorobot is a US corporation headquartered in Houston, Texas.
§60.5398b(d)(2)(ii)	If the submitting entity is not considered an owner or operator of a regulated facility under subpart OOOOa or OOOOc, the provisions (d)(2)(ii)(A) and (d)(2)(ii)(B) must be satisfied.	Xplorobot is not an owner or operator of an affected facility.
(A)	The submitting entity must directly represent the provider of the measurement system.	Xplorobot is the manufacturer and provider of Xplorobot Laser OGI devices.
(B)	The measurement system must have been applied to methane measurements domestically or internationally.	Xplorobot Laser OGI has been deployed in 6 countries (including US) on 3 continents
§60.5398b(d)(2)(iii)	The applicant technology must be readily available for use and satisfy either (A) or (B) below.	Xplorobot Laser OGI was commercialized in 2023 and deployed commercially in Texas, New Mexico, Oklahoma, Colorado, Pennsylvania, West Virginnia, Ohio, Colorado and Wyoming.

(A)	The technology has been sold, leased, or licensed, or offered for sale, lease, or license to the general public.	Xplorobot leased and/or offered for lease Xplorobot Laser OGI system products to oil and gas operators representing all segments of the natural gas supply chain.
(B)	The technology was developed by an owner or operator for internal use and/or use by external partners.	Not applicable.
§60.5398b(d)(2)(iv)	The submitting entity must be able to provide an application with the information required in paragraph (d)(3).	An index detailing the application sections that satisfy each requirement is provided in the following section.

Index of Required Information

This Alternative Test Method application satisfies the requirements defined in in 40 CFR §60.5398b(d)(3). The following index details each regulatory requirement and references the application section(s) that satisfy each requirement, with a brief description of how each requirement is satisfied.

Code Reference	**Summary of Requirement**	**How and Where Compliance is Achieved**
§60.5398b(d)(3)(i)	Include the submitter's name and contact information in the application.	Company information and contact details are included on the cover page.
§60.5398b(d)(3)(ii)	Specify the desired applicability of the technology.	Xplorobot Laser OGI is broadly applicable for use throughout the oil and natural gas sector, which is detailed in Section 1.2 (Application).
§60.5398b(d)(3)(iii)	Provide a description of the measurement technology. The description must contain the information requested in paragraphs (A) through (D).	The description of the measurement technology is provided separately in the Description of Technology document included in the application package.
§60.5398b(d)(3)(iv)	Provide a description of how the measurement technology is converted to a methane mass emission rate. The description must contain the information requested in paragraphs (A) through (F).	The method procedures are described concisely in Section 2 (Summary of Method). This application includes further details on the physical and neural network models used to convert the measurement to an emission rate in Section 12 (Data Analysis and Calculations).

(A)	Provide a detailed workflow demonstrating the steps from measurement technology signal output to final emission rate. Workflows must include a description of how data is handled and stored. The workflow must also identify: a. any raw data processing procedures b. if processing steps are manual or automated c. when and what quality assurance checks are made to the data.	See Section 2 (Summary of Method) for an encapsulated description of the workflow. This section must be understood in the context of this complete application and makes reference to other key sections including Section 9 (Quality Control) and Section 12 (Data Analysis and Calculations). A discussion regarding how data is handled and stored can be found in Section 2.4 (Data flow, recordkeeping and reporting) with additional detail provided in Section 8 (Sample Collection, Preservation, and Storage). See the following sections for the specific information requested: a. Section 2 (Summary of Method) and Section 12 (Data Analysis and Calculations) b. Section 2 (Summary of Method) and Section 12 (Data Analysis and Calculations) c. Section 9 (Quality Control)
(B)	Include a description of how any meteorological data used are collected, sourced, or used.	Local wind and ambient temperature are recorded during the inspection as described in Section 2 (Summary of Method). Utilization of Wind Data for emission rate quantification is described in Section 2.3 (Emission Rate Estimation).
(C)	Include a description of any models used, including how inputs are derived.	A description of models used is provided in Section 2 (Summary of Method). Additional model details are provided in Section 12 (Data Analysis and Calculations).

(D)	Include a description of all calculations used, including defined variables.	The calculations used in the subject method are described in Section 12 (Data Analysis and Calculations).
(E)	Include a description of a-priori methods and datasets used.	A-priori identification of the target components to which the subject method is applied is used to inform scan coverage as described in Section 2 (Summary of Method).
(F)	Include a description of algorithms/machine learning procedures used in the data processing.	The algorithms used in the subject method are described in Section 2 (Summary of Method). Additional details are provided in Section 12 (Data Analysis and Calculations).
§60.5398b(d)(3)(v)	Provide a description of how data is handled and stored. The description must contain the information requested in paragraphs (A) through (C).	Details regarding how data is handled and stored can be found in two locations in this application: • Section 8 (Sample Collection, Preservation, and Storage). • Section 2 (Summary of Method). • See responses below for more specificity.
(A)	Describe how the data, including metadata, are collected, maintained, and stored.	All the types of data collected, and the recordkeeping procedures are provided in Section 2 (Summary of Method).
(B)	Include a description of how raw data streams are processed and manipulated, including how the resultant data processing is documented and how version controlled is maintained.	Descriptions of the data processing, manipulation, storage, and recordkeeping are provided in Section 2 (Summary of Method) and Section 8 (Sample Collection, Preservation, and Storage).

(C)	Include a description of how and what data are provided to the end-user.	Data Deliverables (Digital Emission Tags and Digital Compliance Records) and their communication to the end-user are described in Section 2 (Summary of Method).
§60.5398b(d)(3)(vi)	Provide information verifying that the technology meets the aggregate detection threshold(s) defined in paragraphs §60.5398b(b), including supporting data verifying field performance and how probability of detection is determined. The explanation must contain the information requested in paragraphs (A) through (D).	Xplorobot Laser OGI performance metrics and their field validation are described in Section 1 (Scope and Application). Xplorobot Laser OGI detection sensitivity field performance has been rigorously tested and supporting information in the form of scientific studies describing these test results is provided in Section 1 (Scope and Application).
(A)	Cite independently evaluated published reports that assess the applicant technology. Reports must identify a site-level detection threshold with sufficient supporting data to evaluate if data was collected consistent with the metrics specified in paragraph (d)(3)(vi)(C) and if these metrics are adequate.	A selection of third-party independent studies that evaluate Xplorobot Laser OGI capabilities are cited and discussed in Section 13 (Method Performance) and elsewhere.

	(B)	Specify standard operating procedures including safety considerations, measurement limitations, personnel qualification and responsibilities, equipment and supplies, data and record management, and quality assurance/quality control.	This application contains a discussion of the standard operating procedures as required. See specifically: • Safety considerations are detailed in Section 5 (Safety). • Measurement limitations are described in Section 4 (Interferences). • Personnel responsibilities and qualifications are described in Section 2 (Summary of Method). • Required equipment and supplies is listed in Section 6 (Equipment and Supplies). • Data and record management is detailed in Section 8 (Sample Collection, Preservation and Storage). • QA/QC procedures are included in Section 9 (Quality Control).
	(C)	Include a description of the alternative testing procedure in the format described in Guideline Document 45 on the Emission Measurement Center's website. The description must include objectives to ensure the required detection threshold is maintained.	This application is in the format specified by Guideline Document 45. See Section 1 (Scope and Application) for a description of the objectives used to ensure the specified detection threshold is maintained.
	(D)	Include any documents provided to end-users of the data generated by the measurement system.	End-user deliverables are covered in Section 2 (Summary of Method).

§60.5398b(d)(3)(vii)	Submit supporting information verifying the spatial resolution of technology meets the following criteria: (C) Component-level spatial resolution means a technology with the ability to identify emissions within a radius of 0.5 meter of the emission source.	The spatial resolution of the subject method meets the requirements detailed in paragraph (C), "Component Level". See Section 1.5 for the details on spatial resolution.

Table of Contents

1. Scope and Application

1.1 Scope

This application presents is an Alternative Test Method for determining 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).

The proposed Alternative Test Method is a component-level method utilizing the **Xplorobot Laser OGI** hand-held device that measures column-integrated methane concentration with a Tunable Diode Laser Absorption Spectroscopy (TDLAS) sensor. During an inspection, **Xplorobot Laser OGI** simultaneously records methane concentration and high-resolution images of components inspected and uses a computer vision algorithm to create real-time visualization of emissions otherwise not visible to the naked eye. **Xplorobot Laser OGI** also records simultaneously the local wind speed with an integrated anemometer and uses a proprietary algorithm to estimate the methane emission rate in grams per hour.

The operator creates **Xplorobot Laser OGI's Digital Emission Tag** for each emission source identified in the inspection. The **Digital Emission Tag** includes the date, time, site, equipment, component, concentration detected, emission rate estimate, wind speed measured, and the GPS location of the source. Furthermore, upon upload of the data collected by **Xplorobot Laser OGI** into a component-level **Xplorobot Compliance Database**, our software automatically creates **Digital Compliance Records** for each component that was found either not emitting methane or emitting methane within allowable limits per EPA regulations or manufacturers specifications. **Digital Emission Tags** and **Digital Compliance Records** create an auditable trail for each inspection. They can also be used for calculations of fugitive emissions per 40 CFR 98 Subpart W on a leak/no leak basis.

Xplorobot Laser OGI 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 (4 standard liters per minute) that is in the range of the 90% probability detection level for infrared OGI cameras operated by highly experienced LDAR inspectors (Zimmerle et al, 2020). (Note: the 90% probability detection level reflects both the device sensitivity and the human inspector performance). Therefore, our Alternative Test Method application proposes to use **Xplorobot Laser OGI** in the exact same manner and frequency as the requirements for OGI surveys established by 40 CFR 60 subparts OOOOa, OOOOb and OOOOc for periodic inspections of oil and gas facilities.

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 only well sites, small well sites, multi-wellhead only well 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. We confirmed in field campaigns the ability of **Xplorobot Laser OGI** to detect thief hatch emissions from the ground and detection of fugitive emission sources inside oil and gas facilities from positions outside of the facilities' boundaries.

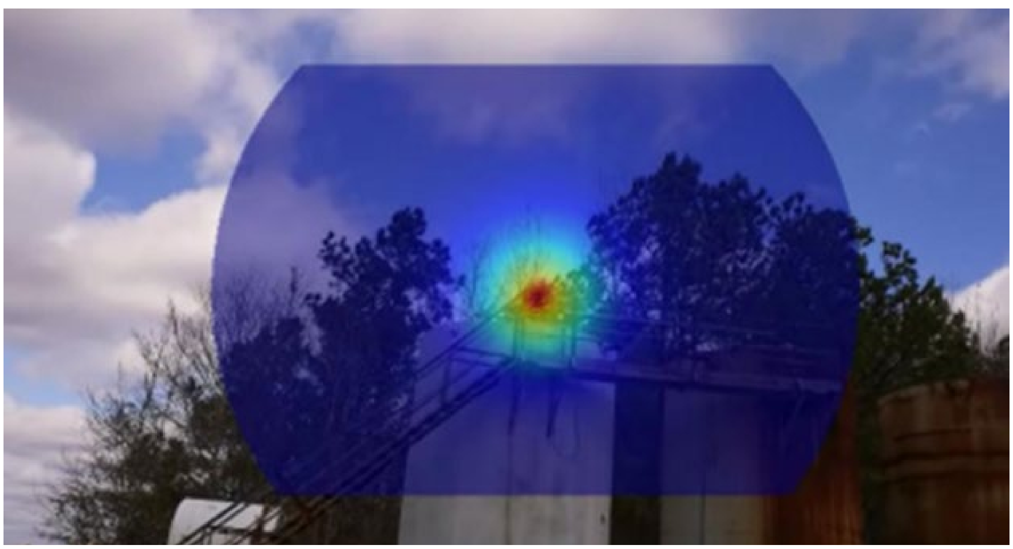

Figure 1. Detection of fugitive emission on a thief hatch vent.

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

Xplorobot Laser OGI sensitivity is 1 gram per hour as demonstrated in controlled release and field experiments. For example, 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 2). It is important to emphasize that 1 gram per hour is the device sensitivity for **Xplorobot Laser OGI** and that it is the result of 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 2. 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 3).

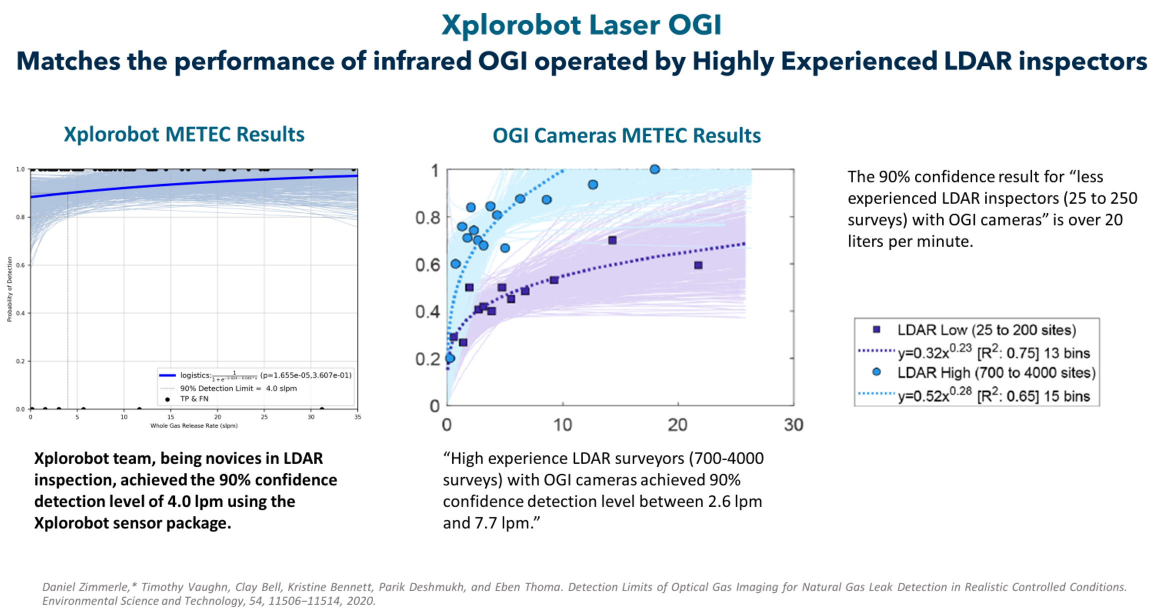

*Figure 3. Results of blind tests at METEC for **Xplorobot Laser OGI** and for infrared OGI cameras (Zimmerle et al, 2020).*

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, our control rate experiments suggest that the **Xplorobot Laser OGI** measurement of 500 ppm-m corresponds to 500 ppm measurements by a Method 21 device (Figure 4).

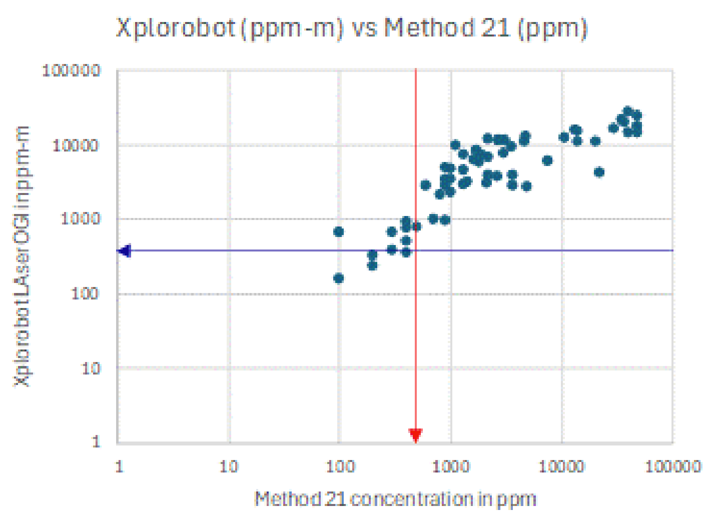

*Figure 4. Comparison between **Xplorobot Laser OGI** and Method 21 device measurements.*

Xplorobot Laser OGI can detect emissions that are typically challenging to be detected by infrared OGI cameras due to the absence of thermal contrast between the gas and the surrounding media, such as emissions from under wraps and emissions from buried components. Figures 5 and 6 provide examples of such emission detections.

Figure 5. Emissions were detected under a bubble wrap, and the recording on the regulator after the wrap was removed.

Figure 6. Emission detected under gravel and recorded on tubing after gravel was removed.

1.5 Component-level Spatial Resolution

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 of the Original Equipment Manufacturer and the accuracy of the emission localization of the computer vision software in the device. Figure 7 presents examples of the spatial resolution of the emission detection. This spatial resolution makes **Xplorobot Laser OGI** into the Component-Level Alternative Test Method per 40 CFR §60.5398b.

Figure 7. Examples of component-level emission source detection in oil and gas facilities recorded from distances of 3 meters and 1 meter.

2. Summary of Method

2.1. Xplorobot Laser OGI Device and Digital Emission Tags

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 8 shows the **Xplorobot Laser OGI** and its main elements. 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. 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.

Under the proposed Alternative Test Method, LDAR surveys are conducted using the **Xplorobot Laser OGI** device. Inspectors systematically scan equipment components—such as valves and flanges—by walking around the equipment, using a green laser to track inspection of each component (Figure 9). 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.

Figure 8. Xplorobot Laser Optical Gas Imaging Device.

Figure 9. Scanning equipment and components with Xplorobot Laser OGI device.

When Xplorobot Laser OGI records a column-integrated methane concentration measurement of 50ppm-m, the device emits a beeping noise and changes the color of display 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 above 500ppm-m, the device display changes the color to red, indicating that the inspector is nearing the emission source location. Upon locating the emission point (the component on which the highest concentration is recorded), the Operator presses the "**Digital Emission Tag**" button on the device 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 10 shows the methane concentration and emission visualization on the screen of **Xplorobot Laser OGI**.

*Figure 10. 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** and consists of the following information.

- Visualization of the emission otherwise not visible to the naked eye that attributes it to a specific component (see Figure 11 for examples).
- Maximum column-integrated methane concentration at the emission source in pp-m.
- Estimate of the emission rate (based on Xplorobot proprietary physics-based model) 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.

The real-time visualization of the emission is based on high-resolution photographs to provide localization of the emission source to a specific component. Similarly, visualization of the emission on 3D models of the component (created based on the photographs) is used to precisely locate the emission source on the equipment. 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.

For immediate notification of the oil and gas facility operator about the emission source identified during the inspection, the **Xplorobot Laser OGI** can be paired with the inspector's smartphone running **Xplorobot App**. The Xplorobot App uploads the **Digital Emission Tag** to the **Xplorobot Compliance Database** and email notifications are sent automatically to the stakeholders per operator's specifications.

Figure 11. 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.

2.2. Digital Compliance Records and Xplorobot Compliance Database

Upon inspection completion, all visual, methane, GPS, and meteorological data captured by **Xplorobot Laser OGI** are securely transferred to the cloud-based **Xplorobot Compliance Database**. The transfer is done by connecting **Xplorobot Laser OGI** device to the inspector's computer running Xplorobot App. Upon the upload, 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, as-designed emission, and allowable emission. Other classifications can be added per operator's requirements.

During component-level facilities inspection, **Xplorobot Laser OGI** records continuously methane, visual, GPS and meteorological data for all components inspected. Upon the upload to the cloud, 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.

i. Digital map of methane concentration measured on the component (zero concentration or concentration below the reporting threshold).

ii. Maximum column-integrated methane concentration at the component (zero or above zero, as detected in the field).

iii. Estimate of the emission rate (based on Xplorobot proprietary physics + neural network-based model) in grams per hour.

iv. GPS location of the recorded emission (the sensor position during the scan).

v. Date and time of the recorded emission.

vi. Wind speed and temperature at the emission source location.

vii. Time and date of the recording, the digital map of methane concentration measured on the component.

Xplorobot Inspector software can create **Digital Compliance Records** in the form of 2D concentration maps (usually appropriate for individual components such as flanges or valves) or 3D concentration maps on 3D equipment models (usually suitable for large and complex equipment, such as compressors, which contain a considerable number of potential emission sources in close proximity). Figure 12 provides examples of **Digital Compliance Records**.

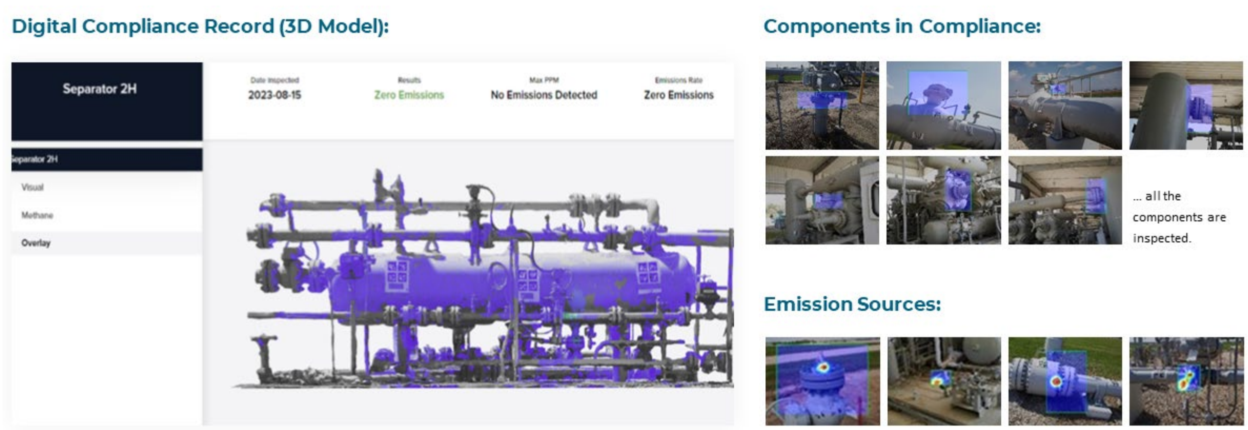

Figure 12. Digital Compliance Records include 3D and 2D methane concentration maps for equipment and components

All **Digital Emissions Tags** and **Digital Compliance Records** are uploaded to the Xplorobot Compliance Database to meet the recordkeeping 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. 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 a **Digital Compliance Records** for the component repaired that is stored in the **Xplorobot Compliance Database** per 40 CFR 60.5420b(c) for recordkeeping and 40 CFR 60.5424b for reporting.

2.3. Emission Rate Estimation

Data collected by **Xplorobot Laser OGI** is used to estimate the emissions rate by utilizing physical modeling of the methane plume dynamic. Based on **Xplorobot Laser OGI** field campaign experience, 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 creates a 3D model of the emission location and 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 13 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 14 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.

Emission Rate algorithm calibration: 437 control release experiments

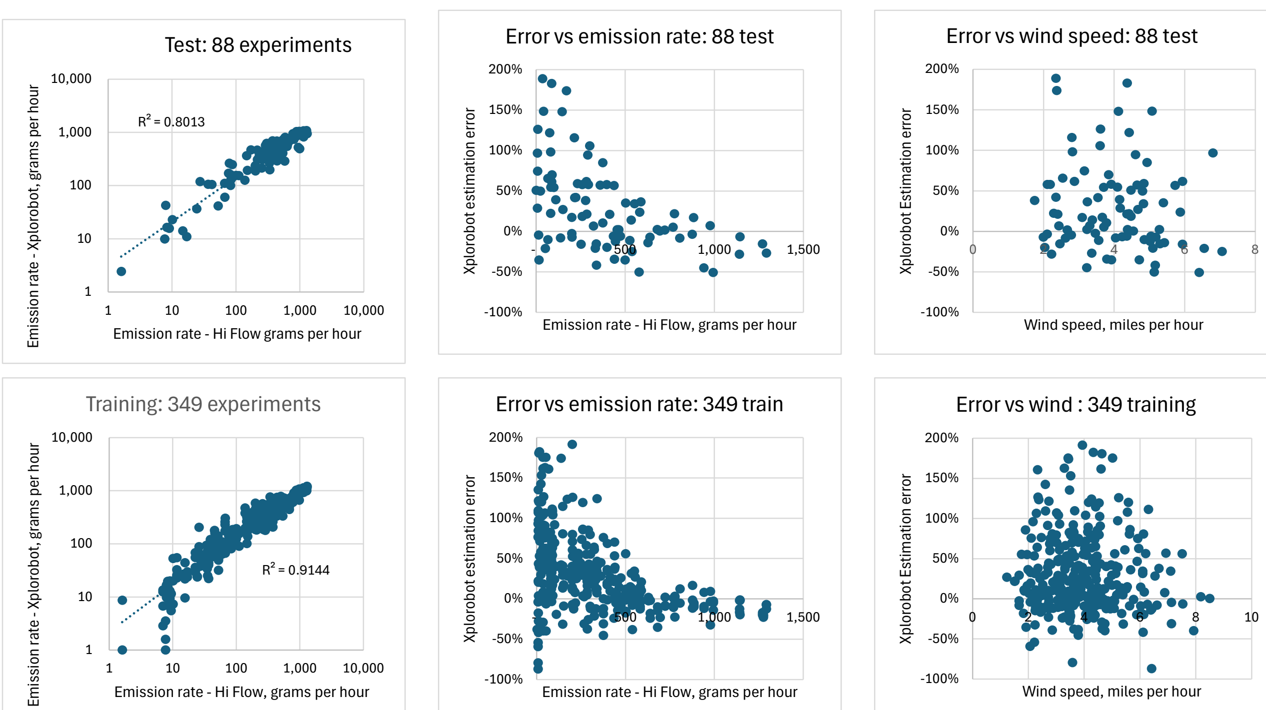

Figure 13. Xplorobot proprietary physics-neural-network algorithm calibration in 437 control release experiments.

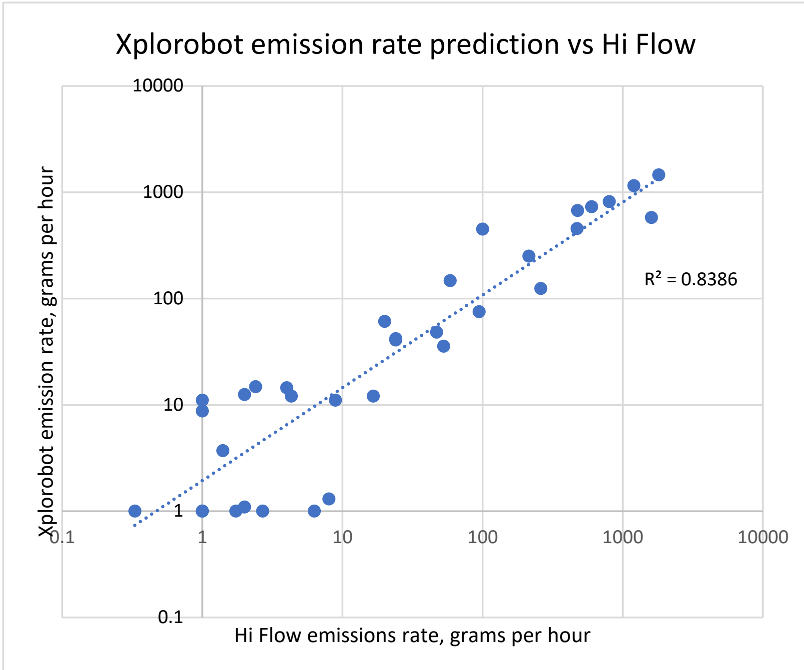

Figure 14. Xplorobot emission rate prediction for 40 emission sources in real field conditions compared with Hi Flow measurements

Currently, the Xplorobot physics-neural-network algorithm provides predictions within +/- 30% in for emission rates above 500 grams per hour and +/- 50% for emission rates between 100 grams per hour and 500 grams per hour. We are continuing to acquire additional control release and field data to further improve the accuracy of our emission rate predictions, especially at lower emission rates.

2.4. Data Flow, Recordkeeping, and Reporting

All raw data acquired by **Xplorobot Laser OGI** is transferred to and stored in the **Xplorobot Compliance Database** and is available for auditing and quality control purposes. **Digital Emissions Tags** (complete with the emission rate estimates) are used by facility operators to plan and execute emission mitigation efforts. **Digital Compliance Records** are created for components that do not emit methane and for components where emissions were mitigated. Facility operators can access **Digital Emission Tags** and **Digital Compliance Records** on **Methane Emission Management Dashboard** that tracks execution of LDAR programs adopted by operators, tracks the emissions sources from identification to repair to post-repair certification, and tracks cumulative emission volumes for the year per recordkeeping, reporting and repair verification requirements of 40 CFR §60.5398b(d)(3), §60.5420b(c), and §60.5424b(c). Figure 15 provides a diagram of the data flow, recordkeeping and reporting under the proposed Alternative Test Method.

Xplorobot data flow, record keeping and reporting

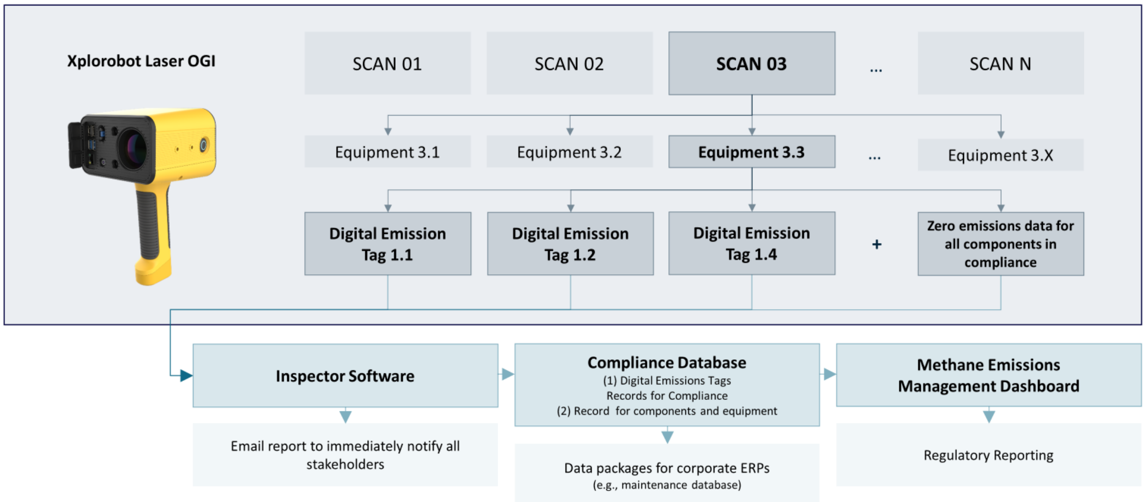

Figure 15. Data flow, recordkeeping and reporting for the proposed Alternative Test Method.

Xplorobot Compliance Database can be used for accurate reporting of fugitive emissions under 40 CFR 98 Subpart W. Emission rates estimates provided as part of **Digital Emission Tags** can be used to create specific emission factors for each component type. The count of **Digital Emission Tags** and **Digital Compliance Records** for each component type can be used for Leak/No leak fugitive emission calculations. Importantly, the ability to access historical **Digital Compliance Records** for components found to be emitting methane in subsequent inspections allows facility operators to define the duration of each emission source to estimate the emissions volume for reporting under 40 CFR 98 Subpart W.

Xplorobot Compliance Database provides auditable records of emission sources and zero emissions on a component level to enable quality control of the LDAR programs and component-level (bottoms-up) to site level (top-down) reconciliations.

3. Definitions of Method

(a) **Xplorobot Laser OGI**: The **Xplorobot Laser OGI** is a quantitative and commercially available device that detects methane emissions at a component level and visualizes methane emissions otherwise not visible to the naked eye. **Xplorobot Laser OGI** falls into the category of Active Optical Gas Imaging.

(b) **Xplorobot Inspector Software**: Proprietary software designed to complement the **Xplorobot Laser OGI** device by analyzing inspection data to pinpoint and quantify methane emissions. This software aids in decision-making by enabling prompt response and corrective measures.

(c) **Digital Emission Tag**: a digital record for a specific component 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.

(d) **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.

(e) **Xplorobot Compliance Database**: A 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.

4. Interferences

(a) The main limitation of **Xplorobot Laser OGI** is the requirement to have 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 (2) methane plume is raising vertically up and does not extent below the edge of the vent or flare. We recommend installing a reflection point (a small metal plate welded above the vent or flare) to use **Xplorobot Laser OGI** for open vents or flares. Alternatively, other methane emission detection solutions can be used for those emissions point per LDAR plan adopted by the facility operator.

(b) In field deployments and control release tests, the 1653 nm wavelength sensor did not generate false positive signals in the presence of water vapor, CO_2 or other hydrocarbon gases.

(c) Inspection can be conducted in light rain or snow conditions as sparse rain drops or snowflakes do not interfere with the laser. Inspection in heavy rain or snow is not recommended due to safety considerations (slips and falls).

(d) There is no known impact of the ambient temperature or wind on the accuracy of detection. However, we recommend using **Xplorobot Laser OGI** in wind conditions of less than 25 miles per hour and temperatures from -12 F to + 108F based on the tests performed to-date.

5. Safety

Operation **Xplorobot Laser OGI** requires compliance with Hot Work Permit and other safety standards as defined by Operators.

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.

7. Reagents and Standards

Xplorobot Laser OGI does not use reagents.

8. Sample Collection, Prevention, and Storage

All data recorded by **Xplorobot Laser OGI** during inspections are transferred to a cloud-based database and are stored per facility operators' and regulatory requirements for record retention.

9. Quality Control

Digital Emission Tags and **Digital Compliance Records** stored in **Xplorobot Compliance Database** can be reviewed by third party auditors to ensure completeness and accuracy of LDAR programs per regulatory requirements.

Completeness of the site coverage and equipment coverage is evaluated using the GPS data collected by **Xplorobot Laser OGI**. Viewing GPS coordinates of the inspector path informs of the completeness of the inspection coverage.

Completeness of component-level coverage is evaluated by comparing the count of **Digital Emission Tags** and **Digital Compliance Records** against the known or estimated component count for the specific equipment or site. Typically, the first inspection at the site establishes the component count that all the follow-up inspections are compared against.

Adherence to the dwell time requirements for each component is evaluated by counting the number of methane concentration measurements collected for that component as part of a Digital Emission Tag or Digital Compliance Record.

10. Calibration and Standardization

A calibration check of the TDLAS sensor is performed on a monthly basis using a methane sample vial (provided by Xplorobot)

11. Analytical Procedures

All raw data, the **Digital Emission Tags** and **Digital Compliance Records** are stored in **Xplorobot Compliance Database** and are used to create reports per 40 CFR § 60.5424b and 40 CFR 90 Subpart W.

Digital Emission Tags are attributed to specific components and completed with the information listed in Section 2.1 and stored in the **Xplorobot Compliance Database**. Specific emission factors can be calculated for each equipment and component type based on all of the Digital Emission Tags for each individual operator, across multiple operators, for individual regions or types of sites.

Digital Emission Tags and **Digital Compliance Records** can be used to establish accurate component counts and create detailed emission reports on a component level.

Frequency of emission and their estimated rates for each component type can be used to identify root causes and optimize mitigation plans. For example, emissions on the same equipment from different vendors type can be compared to identify best-in-class vendors. The effectiveness of emission mitigation can be compared between different maintenance vendors or for different maintenance frequencies.

12. Data Analysis and Calculations

Data collected by **Xplorobot Laser OGI** includes column-integrated methane concentration, high resolution images, GPA data, wind speed data and ambient temperature. Data acquired is used to create **Digital Emission Tags, Digital Compliance Records** and emission rates estimates as discussed by Section 2.

Xplorobot Inspector software algorithm uses data recorded as part of the Digital Emission Tag to estimate the emission rate in grams per hour.

13. Method Performance

Xplorobot Laser OGI was used to-date to detect methane emissions at 308 facilities of 42 operators in 6 countries on 3 continents. We catalogued 1,068 **Digital Emission Tags** in Xplorobot **Compliance Database**. Additionally, **Xplorobot Laser OGI** was deployed on landfills and in orphaned wells campaigns, demonstrating the ability to detect methane emissions from the buried underground pipes.

In a blind trial with one of the largest United States pipeline operators, Xplorobot team with **Xplorobot Laser OGI** devices worked concurrently (but not side-by-side) with the operator's in-house LDAR team with infrared OGI devices. In the first compressor station **Xplorobot Laser OGI** devices identified 20 emission sources while infrared OGI devices identified 5. In the second compressor station, **Xplorobot Laser OGI** devices identified 11 emission sources while infrared OGI devices identified 6. Most of the additional emission sources identified by **Xplorobot Laser OGI** were in the category of low contrast between the temperature of gas versus the temperature of background media, wind conditions, and small emission rates.

Xplorobot enabled methane emissions inspection by regular operators with no LDAR certification in client operations in New Mexico, Texas, Louisiana and Wyoming as well as in Europe and Australia. We have been able to deliver training for the use of **Xplorobot Laser OGI** cameras over Zoom.

*Figure 16. Example of **Xplorobot Laser OGI** successful operation by a 9-year-old child.*

14. Pollution Prevention

A discussion of pollution prevention issues is not relevant, as no physical samples are collected under this method.

15. Waste Management

Waste and physical samples are not produced or collected with this method.

16. References

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.

Methane Emissions Technology Evaluation Center. Survey Emission Detection and Quantification Final Report for Xplorobot Laser OGI, October 2023.