XPLOROBOT LASER GAS IMAGER: COMPONENT-LEVEL FUGITIVE METHANE EMISSION MONITORING

1. Scope and Application

1.1. Scope

1.1.1. This method is applicable for the determination of methane leaks from process equipment and for demonstrating compliance with the procedures outlined in 40 CFR §60.5398b for fugitive emissions components at affected facilities. It also ensures compliance with periodic inspection and monitoring requirements for covers and closed vent systems, specifically through periodic screening, as approved, per 40 CFR §60.5398b(b). Applicable sites could include but are not limited to, single-wellhead sites, small well sites, multi-wellhead sites, well sites with major production and processing equipment, centralized production facilities, and compressor stations.

1.2. Application

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

1.2.2. The test method is applicable to methane (CAS No. 74-82-9) emissions from oil and gas infrastructure. This method can be used, as approved by the Administrator, in lieu of the applicable fugitive monitoring requirements in either §60.5397a or §60.5397b and inspection and monitoring of covers and closed vent systems in either §60.5416a or §60.5416b.

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

1.3. Method Range and Sensitivity

1.3.1. Xplorobot Laser Gas Imager's range is 50 m based on the Tunable Diode Laser Absorption Spectroscopy (TDLAS) sensor specifications.

1.3.2. Xplorobot Laser Gas Imager's 90% confidence level of detection is 156 g/hr. The 90% confidence level of detection is determined by a combination of the device sensitivity, dwell time per component, and the skill level of the inspectors operating the device. Xplorobot Laser Gas Imager achieves a hardware-only sensitivity of 1 g/hr, based on the sensitivity of the TDLAS sensor.

1.3.3. The detection threshold for emission reporting with the Xplorobot Laser Gas Imager is 500 ppm-m, as established through the correspondence between the Xplorobot Laser Gas Imager and Method 21 measurements in control-release experiments (see Section 2 for details).

1.3.4. Xplorobot Laser Gas Imager is a Component-Level Alternative Test Method per 40 CFR §60.5398b(3)(vii)(C) with a spatial resolution of < 0.5 m Xplorobot Laser Gas Imager's spatial resolution is 0.4 cm at 1 m distance and 20 cm at 50 m distance, based on the computer vision software settings. This spatial resolution (aperture) is larger than the aperture of the infrared laser of the TDLAS sensor used in the Xplorobot Laser Imager (provided under CBI).

1.4. Data Quality Objectives

1.4.1. Adherence to the requirements of this method ensures that the data supporting the technology's objective is accurate and of high quality. The technology's objective is to detect fugitive emissions during Leak Detection and Repair (LDAR) inspections at Well Sites (Single Wellhead Only, Multi-wellhead and Well Sites with Major Production, and Processing Equipment), Centralized Production Facilities and Compressor Stations, as defined by 40 CFR § 60. This includes detecting emissions above the 500 ppm-m reporting threshold at the required time intervals (quarterly, semi-annually, or annually) and certifying repairs of fugitive emission sources.

2. Summary of Method

2.1 The LDAR inspector uses the Xplorobot Laser Gas Imager to systematically scan equipment components—such as valves and flanges—by walking around the equipment and utilizing a green laser to track the 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) and confirmed, the inspector records a Digital Emission Tag for the emission source. The Digital Emission Tag is then transferred to the inspector's Integrated Communication Device via a Bluetooth connection and then uploaded to the cloud-based Xplorobot Compliance Database, enabling immediate operator notification.

2.2 Inspection data (methane concentration, visualization, GPS coordinates, and meteorological data) is uploaded to the Xplorobot Compliance Database. Within the Xplorobot Compliance 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.

2.3 Upon completion of the repairs, per the requirement of 40 CFR § 60.5398b(b)(5)(v), Xplorobot Laser Gas Imager is used to conduct repair verification and to create Digital Compliance Records for the repaired component(s).

2.4 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).

2.5 Conducting LDAR inspections with the Xplorobot Laser Gas Imager requires one hour of operational training and signing into the Xplorobot App. Additionally, a two-hour oil and gas facility training session is required to learn equipment tracing (using the visualization laser), adherence to dwell time, tag emissions tagging, and proper information entry in the Xplorobot App.

3. Definitions and Abbreviations of Method

3.1 Definitions

3.1.1 *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.

3.1.2 *Digital Emission Tag*: A digital record for a specific component and stored in the Xplorobot Compliance Database that certifies presence of methane emission from that component on a specific day at a specific time.

3.1.3 *Integrated Communication Device*: The LDAR inspector's device which runs the Xplorobot App and serves as the communication interface for Xplorobot Laser Gas Imager.

3.1.4 *Xplorobot App*: Software on the LDAR inspector's Integrated Communication Device used to provide site, equipment, and component information for scans—facilitating the creation of Digital Emission Tags for immediate cloud upload and operator notification.

3.1.5 *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 Gas Imager. This database provides accessible historical emissions information and compliance reporting to facility operators and regulatory authorities per 40 CFR § 60.5424b.

3.1.6 *Xplorobot Inspector Software*: Proprietary software integral to the functionality of the Xplorobot Laser Gas Imager device by analyzing inspection data to localize methane emissions.

3.1.7 *Xplorobot Laser Gas Imager:* Fully integrated hardware-software system designed to detect and localize methane emissions at a component level. The Xplorobot Laser Gas Imager combines in a single hand-held device:

a) A tunable diode laser absorption spectroscopy (TDLAS) module, equipped with a red or green pointing laser, an open-path tunable infrared measurement laser, a photodetector to capture reflected infrared light, and electronics for wavelength sweeping and signal processing to calculate methane content in ppm-m.

b) A high-resolution visual camera for component detection and emission localization.

c) GPS for location tracking.

d) Thermometer for temperature monitoring.

e) Data processing hardware and software that generate real-time visualizations of methane emissions.

3.2 Abbreviations

3.2.1 *3D*: Three-dimensional

3.2.2 *CFR*: Code of Federal Regulations

3.2.3 *EG*: Environmental Protection Agency's 40 CFR part 60 Emissions Guidelines: Subpart OOOOc

3.2.4 *g/hr*: Grams per Hour

3.2.5 *GPS*: Global Positioning System

3.2.6 *LDAR*: Leak Detection and Repair

3.2.7 *mph*: miles per hour

3.2.8 *nm*: nanometer

3.2.9 *NSPS*: Environmental Protection Agency's 40 CFR part 60 New Source Performance Standards: Subparts OOOO, OOOOa, and OOOOb

3.2.10 *ppm*: Parts per Million

3.2.11 *ppm-m*: Parts per Million-Meter

3.2.12 *scfh*: Standard Cubic Feet per Hour

3.2.13 SIM: Subscriber Identity Module

3.2.14 *slpm*: Standard Liters per Minute

3.2.15 SMS: Short Message Service

3.2.16 *TDLAS*: Tunable Diode Laser Absorption Spectroscopy

3.2.17 *WiFi:* Wireless Fidelity

3.2.18 *°F:* Degrees Fahrenheit

4. Interferences and Envelope of Operation

4.1 The Xplorobot Laser Gas Imager requires a reflection point to return the laser beam back to the device. Detection of methane emissions, or certifying zero emissions, 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 emissions may not be possible if (1) the 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.

4.2 Detection of emissions from open vents or flares should be done either by reflecting the Xplorobot Laser Gas Imager 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 points per the LDAR plan adopted by the facility operator.

4.3 Upwind emissions from significant methane sources may generate trace methane concentrations in the vicinity of components that do not emit methane. Locating the component with the maximum methane concentration and confirming it as the primary source of the emission is necessary prior to determining the presence of any secondary sources in the vicinity.

4.4 High winds cause rapid dispersion of methane in the atmosphere and complicate emission detection. Xplorobot Laser Gas Imager shall not be used in sustained winds above 20 mph.

4.5 The Xplorobot Laser Gas Imager has been deployed in light rain and snow conditions in the field without any deterioration in detection performance. Scattered rain drops and snowflakes did not create interference with the laser beam. However, deployment in heavy rain or snow is not recommended.

4.6 Due to the ambient light requirement for recording visual images, the Xplorobot Laser Gas Imager shall not be used at night without sufficient background lighting.

Title	Summary	Mitigation

Reflection Point	Method requires infrared laser reflection points for emission detection	Equipment without reflection points cannot be covered using this method. Reflection points can be added above open vents or stacks for emission detection from the ground.
Interference from Upwind Emissions	Methane plume from upwind emissions may create reading above 500 ppm-m on components downstream	Emissions downstream from significant emission sources that can create TDLAS reading of 500 ppm-m should be inspected after the upwind emission is repaired or during periods of low wind.
Wind	Emission plume dispersion in high wind conditions	The Xplorobot Laser Gas Imager shall not be used in sustained winds above 20mph. In high winds the optimal position to detect emission from a component is downwind from that component.
Heavy Snow or Rain	Execution safety	The Xplorobot Laser Gas Imager shall not be used in heavy rain or snow.
Lighting	Ambient lighting is required for collecting visual images	The Xplorobot Laser Gas Imager shall not be used at night without sufficient background lighting.

5. Safety

5.1 This Alternative Test Method may not cover all potential safety scenarios associated with its use. Users of this test method are responsible for establishing appropriate safety and health practices and determining the applicability of regulatory limitations prior to performing this test method.

5.2 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.

5.3 Although the radiation level of the Xplorobot Laser Gas Imager is not harmful for human eyes, the LDAR inspector should avoid shining the laser towards other people or in their own eyes.

5.4 Currently, the Xplorobot Laser Gas Imager is not classified as an intrinsically safe device. Therefore, we recommend operating the Xplorobot Laser Gas Imager in oil and gas facilities under a Hot Work Permit.

6. Equipment and Supplies

6.1 The Xplorobot Laser Gas Imager and its embedded software are fully integrated to meet the requirements of 40 CFR §60.5398b for component-level inspection. The Xplorobot Laser Gas Imager combines in a single hand-held device: (a) a tunable diode laser absorption spectroscopy (TDLAS) module equipped with a red or green pointing laser, an open-path tunable infrared

measurement laser, a photodetector to capture reflected infrared light, and electronics for wavelength sweeping and signal processing to calculate methane content in ppm-m (b) a high-resolution visual camera for component detection and emission localization, (c) a GPS for location tracking, (d) a thermometer for temperature monitoring and (e) data processing hardware and software that generate real-time visualizations of methane emissions.

6.2 The Xplorobot App requires the LDAR inspector to carry an Integrated Communication Device equipped with a SIM card and Bluetooth receiver to facilitate emission source notifications and data synchronization.

6.3 Daily calibration checks require the use of a methane vial provided with the Xplorobot Laser Gas Imager.

6.3 Data upload to the cloud-based Xplorobot Compliance Database requires a Wi-Fi connection to the Xplorobot Laser Gas Imager

7. Reagents and Standards

7.1 Xplorobot Laser Gas Imager uses a vial defined in Appendix 3 with 90% methane (± 10%) for monthly calibration checks. The vial is replaced annually or upon breaking or loss by Xplorobot.

8. Data Collection

8.1 Calibration check

8.1.1 Calibration check for Xplorobot Laser Gas Imager must be performed daily to ensure proper functioning of the device.

8.1.2 The daily calibration check is performed using a methane sample vial (provided by Xplorobot and described in Appendix 4). When pointing the laser at the vial from a 2-m distance, the device reading should be above 2,000 ppm-m. If the reading is below 2,000 ppm-m, the LDAR inspector should contact Xplorobot personnel and perform a supervised calibration check. If the supervised calibration check fails, the device should be returned to Xplorobot for diagnostic and repair.

8.2 Site and equipment scanning plan

8.2.1 For each site, the LDAR inspector establishes a site inspection 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 the Xplorobot Laser Gas Imager to satisfy the requirements of 40 CFR 60.5397a(b).

8.2.2 For each site, the LDAR inspector must identify all components, such as open vents with no covers, that lack a reflection point for the laser beam and determine alternate emission monitoring technologies to inspect those components.

8.3 Individual equipment and component scanning

8.3.1 To turn on the Xplorobot Laser Gas Imager, the LDAR inspector presses the power button on the device. Once the operating system loads, the screen displays a safety message advising the LDAR

inspector of laser safety measures, tripping and slipping hazards, and methane emission safety protocols. The LDAR inspector must read and acknowledge this safety message before beginning any scanning.

8.3.2 To start scanning, the LDAR inspector presses the “Start” button on the Xplorobot Laser Gas Imager touchscreen and waits for the green indicating laser to turn on. The LDAR inspector uses the Xplorobot Laser Gas Imager device to systematically scan equipment components—such as valves and flanges—by walking around the equipment and using the green laser to track the inspection of each component. While scanning, the Xplorobot Laser Gas Imager 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.

8.3.3 The dwell time for each component is two seconds.

8.4 Detection of Emission

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

8.5 Monitoring Survey Upon Confirmed Detection of Emission and Emission Point Tagging

8.5.1 The Xplorobot Laser Gas Imager is used according to the procedure in Appendix 1 per 40 CFR 60.8b(3) to conduct Monitoring Survey upon confirmed detection of emission.

8.5.2 When a reportable emission is observed as indicted by the Xplorobot Laser Gas Imager, the LDAR Inspector must use the Xplorobot Laser Gas Imager to conduct a methane survey in accordance with the procedure in Appendix 1 to localize the emission point (the component upon which the highest concentration is recorded) and must record the leak by pressing the "Digital Emission Tag" button on the touch screen, which will visualize the methane emission.

8.5.3 Once the methane emission is visualized and its source identified, the inspector must create the Digital Emission Tag by pressing the "Digital Emission Tag" button. The Digital Emission Tag is stored in the memory of the Xplorobot Laser Gas Imager, transferred to the LDAR inspector’s Integrated Communication Device via Bluetooth, and includes the following information:

a. Visualization of the emission that localizes it to a specific component.

b. Maximum column-integrated methane concentration at the emission source in ppm-m.

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

d. Date and time of the detection of the emission source.

e. Wind speed and ambient temperature at the emission source location.

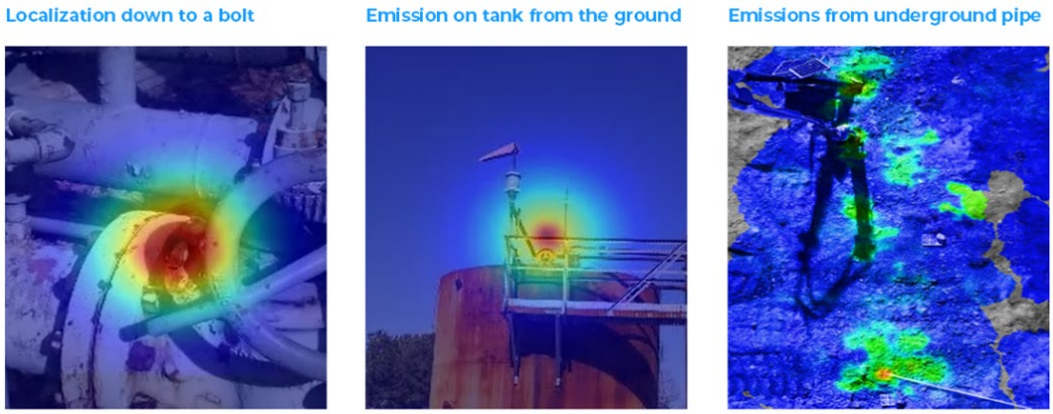

Figure 1. Examples of methane emission visualization using Xplorobot Laser Gas Imager. On the left is methane emission visualization for a leak from a bolt on a flange. In the center is methane emission visualization for leak from a thief hatch on a tank. On the right is methane emission visualization for leak from an underground pipeline.

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

8.6 Scan completeness check

8.6.1 Upon completing the LDAR inspection of all fugitive components, covers, and closed vent systems, as applicable, the LDAR inspector presses the “Stop” button. A summary of the scan is displayed on the screen of the Xplorobot Laser Gas Imager, including all the Digital Emission Tags recorded by the LDAR inspector for that component.

8.7 Xplorobot App cloud upload

8.7.1 The Xplorobot Laser Gas Imager is paired with the LDAR inspector’s Integrated Communication Device running the Xplorobot App, which is used to upload Digital Emission Tags to the Xplorobot Compliance Database. Notifications regarding the identified emission source are sent to the oil and gas facility operator immediately (or within 24 hours if the LDAR inspector is in an area without cellular coverage). Email notifications are automatically sent to stakeholders according to the owner or operator’s specifications.

8.8 Digital data upload and storage

8.8.1 Upon completing the inspection, all visual, methane, GPS, and meteorological data captured by the Xplorobot Laser Gas Imager is securely uploaded to the cloud-based Xplorobot Compliance Database. In addition, each Digital Emissions Tag is checked for completeness by the LDAR inspector and 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 fugitive emission, malfunctioning component, or as-designed emission.

8.8.2 The Xplorobot Compliance Database automatically sends email notification to all stakeholders

responsible for reporting, repairing, and mitigating emissions, as specified by the owner or operator's requirements.

8.9 Inspection completeness and dwell time review

8.9.1 Upon uploading the scan data to the Xplorobot Compliance Database and creating Digital Compliance Records for all the components on all equipment on the site, the completeness of the inspection is automatically checked by the Xplorobot software, comparing the list of equipment scanned against the known equipment count for each site inspected. Additionally, for each equipment, the component count is compared against the standard component count for that equipment or the count from the baseline Xplorobot Laser Gas Imager survey. The results of the completeness check are then communicated to the facility operator.

8.9.2 The dwell time for each component is automatically verified by the Xplorobot software by counting the number of methane data points (20 per component, acquired at a rate of 10 per second) that correspond to that component. The results of the dwell time verification are communicated to the facility operator.

8.10 Repair verification

8.10.1 Upon completion of the repairs, as required by 40 CFR § 60.5398b(b)(5)(v), the Xplorobot Laser Gas Imager is used according to the procedure in Appendix 1 per 40 CFR 60.8b(3) to verify the absence of emissions and to create Digital Compliance Records for the component repaired, which 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

Table 9-1. Quality Assurance/Quality Control Criteria

Instrument / Procedure	Measurement	Acceptance Criteria	Frequency Checked / performed	Corrective Action
Sensor Calibration Check	Calibration check with a vial	Concentration measured over 2,000 ppm-m	Daily	Sensor returned to Xplorobot for repair
Scan Completeness Check	Number of emission points	Every emission point is documented in the database	Every inspection	Re-tag the emissions points missed and submit to database
Inspection Completeness Review	Equipment and component count	All equipment is scanned, all components are scanned	Every inspection	Conduct re-inspection of equipment or components missed
Dwell Time Verification	Number of methane points per component	20 (equivalent to 2-s dwell time)	Every inspection	Conduct re-inspection of components missed

Meteorological Conditions	Wind speed and temperature measured by the Xplorobot Laser Gas Imager	Temperature between -12 °F to 108 °F, sustained wind below 20 mph	Every inspection	Re-schedule inspection for the day when the meteorological conditions are within the range
Annual Calibration and Standardization	Controlled concentration measurements	Concentration measured is within 10% of the actual for three controlled concentration gases (e.g. 20 ppm, 200 ppm and 2000 ppm)	Annually by Xplorobot employees	Sensor is repaired by Xplorobot before shipping it back to the operator

10. Calibration and Standardization

10.1 Daliy Calibration Check: A calibration check of the TDLAS sensor is performed daily using a methane sample vial (provided by Xplorobot). When pointing the laser at the vial from a 2-m distance, the reading of the device should be above 2,000 ppm-m.

10.2 Annual Calibration: Calibration is performed annually by Xplorobot. The Annual Calibration includes performing column-integrated methane concentration measurements with each Xplorobot Laser Gas Imager in three calibrated methane concentration (e.g. 20 ppm, 200 ppm and 2,000 ppm provided by the United States National Institute of Standards and Technology) in a chamber of known length with two glass windows on both sides of the chamber. The reading of the Xplorobot Laser Gas Imager is recorded for each concentration. Sensors that record a deviation of more than 10% are repaired or re-calibrated by Xplorobot before returning the Xplorobot Laser Gas Imager to the operator.

10.3 Equipment and Component Count Verification: Operator performance checks are conducted daily by comparing the equipment count and the component counts established for the oil and gas facility against the equipment and component counts identified and catalogued in the Xplorobot Compliance Database.

10.4 Dwell Time: LDAR inspector adherence to the dwell time is checked daily by the Xplorobot Compliance Database software by counting the number of data points for each component (must be 20 to meet the 2-s dwell time requirement).

10.5 Standardization: Conducting LDAR inspections using the Xplorobot Laser Gas Imager requires one hour of training on operating the device and signing into the Xplorobot App. Additionally, a two-hour training session at an oil and gas facility is required to learn how to trace equipment using the visualization laser, adhere to dwell time, tag emissions, and provide the required information in the Xplorobot App.

11. Analytical Procedures

11.1 [Reserved]

12. Detection and Alerting

12.1 Detection: When Xplorobot Laser Gas Imager records a column-integrated methane concentration measurement of more than 5 ppm-m, but less than 500 ppm-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.

12.2 Alerting: Upon detection, the LDAR inspector performs the Monitoring Survey procedure in Appendix 1 per 40 CFR 60.8(b) to localize the emission to a specific component. The LDAR inspector uses the green location laser to investigate the area of possible emission and locate the emission source. When the Xplorobot Laser Gas Imager records a column-integrated methane concentration measurement at or above 500 ppm-m, the display color changes from yellow to red, indicating detection of a reportable emission. The LDAR inspector is required to create a Digital Emission Tag using the Xplorobot Laser Gas Imager, including displaying the emission visualization on the Xplorobot Laser Gas Imager screen and recording the emission visualization as part of the Digital Emission Tag. Upon completing the inspection, the Digital Emission Tag is automatically transferred to the LDAR inspector's Integrated Communication Device. The LDAR inspector adds information on the component type and the Digital Emission Tag is transferred to the Xplorobot Compliance Database via cellular network connection of the Integrated Communication Device. The Xplorobot Compliance Database creates immediate notifications (by email, SMS, or other preferred means) to the facility operator.

13. Method Performance

13.1 Accuracy of emission detection and localization

13.1.1 In an orphan-well campaign led by the US Forest Service near Marietta, OH, the Xplorobot Laser Gas Imager detected multiple emissions sources that were quantified to be below 1 g/hr by a Hi Flow device. The Xplorobot Laser Gas Imager has a laser specifically designed to detect 1 g/hr

13.1.2 In blind testing at the Methane Emissions Technology Evaluation Center, the Xplorobot Laser Gas Imager demonstrated a 90% probability detection level of 156 g/hr, or 4 slpm. This falls within the 90% probability detection range between 2.6 slpm and 7.7 slpm observed for Infrared OGI cameras operated by highly experienced LDAR inspectors (Zimmerle et al, 2020). According to Zimmerle et al. (2020), the 90% confidence level of detection is a combination of the device's technological sensitivity and the skill level of the inspectors using the device.

13.1.3 The Xplorobot Laser Gas Imager is capable of detecting emissions that are challenging for infrared Gas Imager cameras due to the absence of thermal contrast between the gas and the background. The Xplorobot Laser Gas Imager detects emissions from under wraps and emissions from buried pipes. Figure 2 and Figure 3 provide examples of these types of emission detections.

Figure 2. Examples of emission detection from a regulator under bubble wrap. On the left, methane emission visualization shows emission coming from under bubble wrap. On the right, a Digital Emission Tag for the regulator is created once the bubble wrap is removed. Removing bubble wrap is required to localize the emission to the specific component under the wrap.

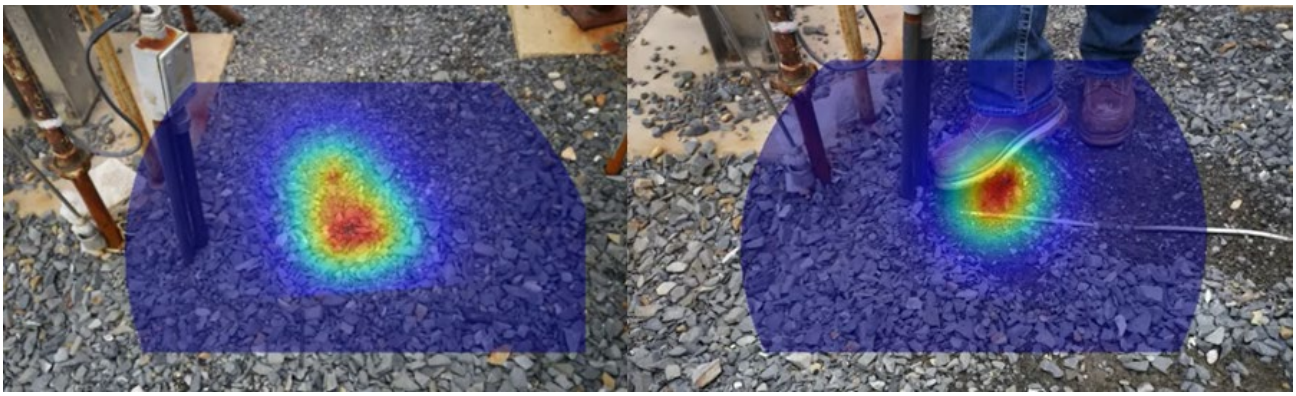

Figure 3. Example of emission detection from a buried tubing connector. On the left, methane emission visualization shows methane emission coming from the ground. On the right, a Digital Emission Tag for a connector on buried tubing is created once the gravel is removed.

13.2 Accuracy of conversion to Method 21 Equivalent Concentration

13.2.1 To compare the detection accuracy of the Xplorobot Laser Gas Imager and Method 21 devices, a set of controlled release experiments were performed with emission rates ranging between 0.4 g/hr and 574 g/hr, as validated by a Hi Flow device. A Method 21 device was deployed at the emission source (closer than 1 m in distance) and the Xplorobot Laser Gas Imager was deployed from a distance ranging from 1 m to 5 m. 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 Gas Imager measurement of 500 ppm-m corresponds to 500-ppm measurements by a Method 21 device (Figure 4).

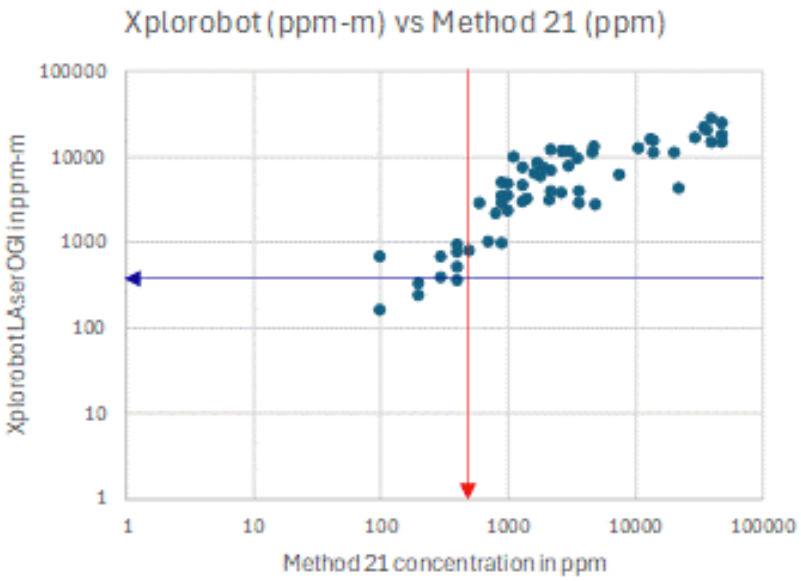

*Figure 4. Comparison between Xplorobot **Laser Gas Imager** and Method 21 device measurements. In controlled rate experiments the 500 ppm measurement on a Methd 21 device (closer than 1 m in distance) corresponded to a 500ppm-m measurement of Xplorobot Lasegr Gas Imager (from distances between 1 and 5 meters).*

14. Pollution Prevention

14.1 [Reserved]

15. Records and Data Management

15.1 During component-level facilities inspection, the Xplorobot Laser Gas Imager continuously records methane, visual, GPS, and meteorological data for all components inspected. This data is uploaded to the cloud-based Xplorobot Compliance Database via a Wi-Fi connection in the inspector office, hotel, or home. Mobile internet devices with satellite connectivity can be provided for data upload from oil and gas facilities.

15.2 When uploaded to the Xplorobot Compliance Database, the Xplorobot Inspector software uses visual data to automatically identify each component inspected and create Digital Compliance Records for those components that do not emit methane (concentration detected is zero or below the 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). See Figure 5.
- Maximum column-integrated methane concentration at the component in ppm-m.
- 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.

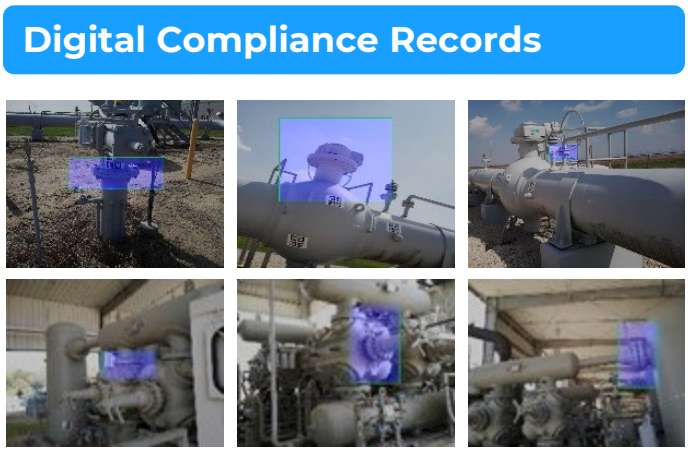

Figure 5. Digital Compliance Records in the form of 2D methane concentration maps for equipment and components. Upon upload of the component-level data to the Xplorobot compliance database, Xplorobot Inspector Software generates a 2D map of methane concentration for each component with concentration. Blue color indicates zero concentration or absence of emission.

15.3 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).

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.

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

3. Handbook of Hazardous Materials: Fire, Safety, Health. Alliance of American Insurers. Schaumberg, IL. 1983.

Appendix 1: Monitoring Survey Upon Confirmed Detection of Emission using Xplorobot Laser Gas Imager

A1.1. Scope:

A1.1.1 This Appendix 1 is attached to the Xplorobot Laser Gas Imager Component-Level Fugitive Emission Monitoring Alternative Test Method Application for monitoring survey per 40 CFR 60.5398(b)(2)(vi) of process equipment after identification of methane emissions.

A1.2. Monitoring Survey Upon Confirmed Detection of Emission

A1.2.1 Upon confirmed detection of an emission (the Xplorobot Laser Gas Imager column-integrated concentration reading of 500 ppm-m), per requirements of 40 CFR 60.5398(b)(5)(iv)(A), the LDAR inspector conducts a monitoring survey of all fugitive emissions components located within a 1-meter radius of the confirmed emission detection. The survey is performed following the procedure below.

A1.2.2 Scan all components within a 1-meter radius of the confirmed emission detection, monitoring the maximum column-integrated concentration of methane displayed on the Xplorobot Laser Gas Imager screen. The Xplorobot Laser Gas Imager displays both the maximum concentration recorded in the vicinity of the confirmed emission and the current sensor reading.

A1.2.3 If the current reading of the column-integrated methane concentration and the maximum detected reading is increasing, the LDAR inspector is moving towards the source of the confirmed emission. If the current reading of column-integrated concentration is decreasing and the maximum reading stays the same, then the LDAR inspector is moving away from the confirmed emission source.

A1.2.4 Once the component that corresponds to the maximum column-integrated concentration is detected, it is deemed to be the emission source. The LDAR inspector presses the “Record Digital Emission Tag” button on the screen of the Xplorobot Laser Gas Imager to tag the emission source.

A1.2.5 The LDAR inspector dwells on the emission source for 10 to 15 s (timed by the Xplorobot Laser Gas Imager) to accumulate at least 100 methane readings at and around the emission source. This process validates the emission source location and generates a visualization of the methane emission.

A1.3. Equivalency

A1.3.1 The equivalency to the reference methods, required to establish the adequacy of using the Xplorobot Laser Gas Imager for Methane Surveys Upon Confirmed Emission Detection, is provided in Section 13.

Appendix 2: Post-Repair Verification Using Xplorobot Laser Gas Imager

A2.1. Scope:

A2.1.1 This Appendix 2 is attached to the Xplorobot Laser Gas Imager Component-Level Fugitive Emission Monitoring Alternative Test Method Application for completion of re-inspection and monitoring of process equipment after identification of methane leaks from, and repair of, process equipment.

A2.2. Repair and Post-Repair Verification Procedure

A2.2.1 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 completed.

A2.2.2 Upon completion of the repairs, per the requirement of 40 CFR § 60.5398b(b)(5)(v), the Xplorobot Laser Gas Imager is used to verify the absence of emissions on the component that was previously identified to emit methane during the prior inspection, following the procedure outlined below.

A2.2.3 The LDAR inspector uses the Digital Emission Tag on his Integrated Communication Device to verify the component that requires post-repair inspection.

A2.2.4 The LDAR inspector turns on the Xplorobot Gas Imager and initiates inspection.

A2.2.5 The LDAR inspector points the Xplorobot Laser Imager at the component that requires post-repair verification and investigates that component for a 10-s dwell time.

A2.2.2.5 If emission is detected on that component (column-integrated concentration is measured to be above 500ppm-m), the LDAR inspector creates a Digital Emission Tag for that component and submits it to the Xplorobot Compliance Database for additional repair to be scheduled and completed.

A2.2.2.7 If no reportable emission is detected (column-integrated methane concentration of zero or below 500 ppm-m), the LDAR inspector saves the inspection result and provides the information on the site, equipment, and component for upload to the Xplorobot Compliance Database.

A2.2.2.8 Upon receipt of the re-inspection data in the Xplorobot Compliance Database, a Digital Compliance Record is created for the repaired component and stored in the Xplorobot Compliance Database per 40 CFR 60.5420b(c) for recordkeeping and per 40 CFR 60.5424b for reporting.

A2.3. Equivalency

A2.3.1 The equivalency to the reference methods required to establish the adequacy of using the Xplorobot Laser Gas Imager for Post-Repair Verification is provided in Section 13.

Appendix 3: Monitoring Plan Template

A3.1 Monitoring Plan Requirements

A3.1.1 Per 40 CFR 60.5398(b)(2), to perform component-level periodic screening of oil and gas facilities using the Xplorobot Laser Gas imager, the facility operator is required to develop a Site Monitoring Plan that covers a collection of fugitive emission components, covers and closed vent systems at each site where the Xplorobot Laser Gas Imager will be used. The Site Monitoring Plan is required to contain information specified in 40 CFR 60.5398(b)(2)(i) through (ix).

A3.1.2 The template below is developed by Xplorobot to capture all the information required for the Site Monitoring Plan by 40 CFR 60.53.98(b)(2).

Facility/Site Name	[Facility/Site name]
Facility/Site Location	[City, State]
Facility/Site GPS Coordinates	[Latitude, -Longitude]
Alternative Test Method	(1) Xplorobot Laser Gas Imager for all components that have a laser beam reflection point. (2) Alternate technology such as OGI for components that do not have reflection points (e.g. open vents or stacks).
Inspection resolution	Component-level
Xplorobot Laser Gas Imager Inspection Frequency	Quarterly per 40 CFR 60.5398(b)(1) for ATM with detection threshold below 1 kg/hr with no OGI inspection required
LDAR Inspection Company	[Company name]
LDAR Inspection Company phone number	[Company phone number]
LDAR inspector name	[Inspector name]
LDAR inspector email	[Inspector email]
Monitoring Survey	Use the Xplorobot Laser Gas Imager to localize the emission to the specific component per 40 CFR 60.8(b)(3).
Procedure for identifying and repairing fugitive emission components, vents, closed vent systems	Use the Xplorobot Laser Gas Imager to localize emission(s) to a specific component(s) per 40 CFR 60.8(b)(3)
Procedure for verifying repairs	Use the Xplorobot Laser Gas Imager to verify repairs of specific component(s) per 40 CFR 60.8(b)(3)
Records to be kept	Digital Emission Tags and Digital Compliance Records for each component on each equipment stored in the Xplorobot Compliance Database.

Appendix 4: Methane Vial for Calibration Check

Style	A
Capacity	
fl. oz.	0.67
ml	20
Diameter	1 1/8”
Height	2 1/4”
Mouth	
OD	15/16”
Graduated	No
Material	Borosilicate Glass
Color	Clear
Clarity	Clear
Lid	
Type	Threaded
Material	Melamine Plastic
Color	Green
Seal Material	PTFE Plastic
Autoclavable	No
Maximum Temperature	Not Rated
Includes	Lid
RoHS	Not Compliant
REACH	Not Compliant
DFARS	Specialty Metals COTS-Exempt
Country of Origin	United States
USMCA Qualifying	No
Schedule B	701090.0540
ECCN	EAR99