	Department of Administration Purchasing Division 2019 Washington Street East Post Office Box 50130 Charleston, WV 25305-0130	**State of West Virginia** **Centralized Request for Proposals** **Service - Prof**

Proc Folder: 1465803

Doc Description: DEP OOG - Methane Emission Quantification

Proc Type: Central Master Agreement

Reason for Modification:

Date Issued	Solicitation Closes	Solicitation No	Version
2024-07-25	2024-08-20 13:30	CRFP 0313 DEP2500000001	1

BID RECEIVING LOCATION

BID CLERK
DEPARTMENT OF ADMINISTRATION
PURCHASING DIVISION
2019 WASHINGTON ST E
CHARLESTON WV 25305
US

RECEIVED
2024 AUG 27 PM 1:12
WV PURCHASING DIVISION

VENDOR

Vendor Customer Code:

Vendor Name : NEXT LVL ENERGY LLC

Address : 1600 CORPORATE DRIVE

Street :

City : BIRMINGHAM

State : AL **Country :** USA **Zip :** 35242

Principal Contact : CHRIS VEAZEY

Vendor Contact Phone: (304)590-7107 **Extension:** N/A

FOR INFORMATION CONTACT THE BUYER
Joseph E Hager III
(304) 558-2306
joseph.e.hageriii@wv.gov

Vendor Signature X [signature] **FEIN#** 46-5279721 **DATE** 08/27/24

All offers subject to all terms and conditions contained in this solicitation

ADDITIONAL INFORMATION

he West Virginia Department of Administration, Purchasing Division (hereinafter referred to as the "Purchasing Division") is issuing iis solicitation as a request for proposal ("RFP"), as authorized by W. Va. Code 5A-3-10b, for the West Virginia Department of nvironmental Protection (hereinafter referred to as the "Agency") to provide methane emission quantification ("MEQ") services for elected oil and natural gas wells per the attached specifications and terms and conditions.

*Online responses have been prohibited for this solicitation, if you have questions contact the Buyer - Josh Hager - oseph.E.HagerIII@wv.gov

NVOICE TO	SHIP TO
ENVIRONMENTAL PROTECTION REAP OFFICE 601 57TH ST SE CHARLESTON WV 25304 US	STATE OF WEST VIRGINIA VARIOUS LOCATIONS AS INDICATED BY ORDER No City WV 99999 US

Line	Comm Ln Desc	Qty	Unit of Measure	Unit Price	Total Price
	4.2.1.1 Measure pre-plugging methane emissions	200.00000	EA		

Comm Code	Manufacturer	Specification	Model #
7121506			

Extended Description:
.2.1.1 Measure pre-plugging methane emissions

NVOICE TO	SHIP TO
ENVIRONMENTAL PROTECTION REAP OFFICE 601 57TH ST SE CHARLESTON WV 25304 US	STATE OF WEST VIRGINIA VARIOUS LOCATIONS AS INDICATED BY ORDER No City WV 99999 US

Line	Comm Ln Desc	Qty	Unit of Measure	Unit Price	Total Price
	4.2.1.2 Measure post-plugging methane emissions	200.00000	EA		

Comm Code	Manufacturer	Specification	Model #
7121506			

Extended Description:
.2.1.2 Measure post-plugging methane emissions

INVOICE TO	SHIP TO
ENVIRONMENTAL PROTECTION REAP OFFICE 601 57TH ST SE CHARLESTON WV 25304 US	STATE OF WEST VIRGINIA VARIOUS LOCATIONS AS INDICATED BY ORDER No City WV 99999 US

Line	Comm Ln Desc	Qty	Unit of Measure	Unit Price	Total Price
3	4.2.1.3 Screen wells for methane emissions	200.00000	EA		

Comm Code	Manufacturer	Specification	Model #
77121506			

Extended Description:
4.2.1.3 Screen wells for methane emissions

SCHEDULE OF EVENTS		
Line	Event	Event Date

DIVERSIFIED
energy

August 27, 2024

BID CLERK
WEST VIRGINIA DEPARTMENT OF ADMINISTRATION
PURCHASING DIVISION
2019 WASHINGTON ST E
CHARLESTON, WV 25305-0130

Doc Description: DEP OOG - Methane Emission Quantification
Solicitation No. CRFP 0313 DEP2500000001

To Whom It May Concern:

Please see attached our comprehensive methane emission rate quantification solution to satisfy the Agency's goals and objectives that is fully compliant with BIL guidelines. Next LVL proposes to provide measurements of pre- and post-plugging methane emission rates from wells selected by the Agency, by using the Xplorobot TDLAS technology to quantify and document emissions. The equipment we will use is described fully in the attached documentation. Xplorobot has a proven track record in meeting BIL guidelines (1 gram per hour) from recent work performed for the U.S. Department of Interior in the Osage Nation of Oklahoma (see attached detailed summary illustrating performance). For wells not initially appearing to be leaking, wells can be re-visited and re-scanned using Xplorobot technology to verify no emissions are present. In addition, For purposes of screen wells for emissions, Next LVL has access to other complimentary traditional technology such as the Teledyne Flir GT-44 gas detector (compliant with EPA Method 21) which, upon Department request can be used to add further verification.

Next LVL will employ experienced and qualified Leak Detection and Repair (LDAR) Technicians who are well-experienced in the use of Xplorobot and other complimentary gas detection technologies. These technicians will have access to our LDAR experts, Oleg Mikhailov and Paul Espenan (see attached resumes)

Prior success using this technology has been proven as documented in the attached technical support. Numerous oil and gas operating companies, including Diversified Energy, the parent company of Next LVL have been using Xplorobot successfully to meet various LDAR obligations under EPA Subpart W and the Oil and Gas Methane Partnership 2.0. Again, we refer you to the supplemental information provided which provides details of the approvals obtained for this technology by the State of Colorado, and efforts underway for additional approvals from the US EPA.

Our proposal includes our approach and methodology to providing the service or solving the problem described by the goals/objectives of the request.

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energy

Also included are previous demonstrated successes using equipment to acquire methane emission rate quantification for wells and/or related oil and gas infrastructure.

In short, we believe that the combination of Xplorobot and Next LVL is an efficient and effective partnership that will exceed all goals of the project.

TABLE OF CONTENTS

Chris Veazey

Chris Veazey
Director of Administration
Next LVL Energy
Diversified Energy Company
414 Summers St.
Charleston, WV 25301
(304) 590-7707
Email: cveazey@dgoc.com

COVER

VENDOR NAME: NEXT LVL ENERGY LLC
BUYER: Josh Hager
SOLICITATION NO.: CRFP 0313 DEP2500000001
BID OPENING DATE: 08/27/2024 @ 1:30 PM ET
BID OPENING TIME: 08/27/2024 @ 1:30 PM ET

DESIGNATED CONTACT: Vendor appoints the individual identified in this Section as the Contract Administrator and the initial point of contact for matters relating to this Contract.

(Printed Name and Title) CHRIS VEAZEY, DIRECTOR OF ADMINISTRATION

(Address) 414 Summers Street Suite 200 Charleston, WV 25301

(Phone Number) / (Fax Number) (304) 590-7707

(email address) CVEAZEY@DGOC.COM

CERTIFICATION AND SIGNATURE: By signing below, or submitting documentation through *wv*OASIS, I certify that: I have reviewed this Solicitation/Contract in its entirety; that I understand the requirements, terms and conditions, and other information contained herein; that this bid, offer or proposal constitutes an offer to the State that cannot be unilaterally withdrawn; that the product or service proposed meets the mandatory requirements contained in the Solicitation/Contract for that product or service, unless otherwise stated herein; that the Vendor accepts the terms and conditions contained in the Solicitation, unless otherwise stated herein; that I am submitting this bid, offer or proposal for review and consideration; that this bid or offer was made without prior understanding, agreement, or connection with any entity submitting a bid or offer for the same material, supplies, equipment or services; that this bid or offer is in all respects fair and without collusion or fraud; that this Contract is accepted or entered into without any prior understanding, agreement, or connection to any other entity that could be considered a violation of law; that I am authorized by the Vendor to execute and submit this bid, offer, or proposal, or any documents related thereto on Vendor's behalf; that I am authorized to bind the vendor in a contractual relationship; and that to the best of my knowledge, the vendor has properly registered with any State agency that may require registration.

By signing below, I further certify that I understand this Contract is subject to the provisions of West Virginia Code § 5A-3-62, which automatically voids certain contract clauses that violate State law; and that pursuant to W. Va. Code 5A-3-63, the entity entering into this contract is prohibited from engaging in a boycott against Israel.

NEXT LVL ENERGY LLC

(Company)

(Signature of Authorized Representative)

Chris Veazey

(Printed Name and Title of Authorized Representative) (Date)

CHRIS VEAZEY

(Phone Number) (Fax Number)

CVEAZEY@DGOC.COM

(Email Address)

DIVERSIFIED
energy

Also included are previous demonstrated successes using equipment to acquire methane emission rate quantification for wells and/or related oil and gas infrastructure.

In short, we believe that the combination of Xplorobot and Next LVL is an efficient and effective partnership that will exceed all goals of project.

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(304) 590-7707
Email: cveazey@dgoc.com

ADDENDUM ACKNOWLEDGEMENT FORM
SOLICITATION NO.: CRFP 0313 DEP2500000001

Instructions: Please acknowledge receipt of all addenda issued with this solicitation by completing this addendum acknowledgment form. Check the box next to each addendum received and sign below. Failure to acknowledge addenda may result in bid disqualification.

Acknowledgment: I hereby acknowledge receipt of the following addenda and have made the necessary revisions to my proposal, plans and/or specification, etc.

Addendum Numbers Received:
(Check the box next to each addendum received)

☑ Addendum No. 1	☐ Addendum No. 6
☐ Addendum No. 2	☐ Addendum No. 7
☐ Addendum No. 3	☐ Addendum No. 8
☐ Addendum No. 4	☐ Addendum No. 9
☐ Addendum No. 5	☐ Addendum No. 10

I understand that failure to confirm the receipt of addenda may be cause for rejection of this bid. I further understand that any verbal representation made or assumed to be made during any oral discussion held between Vendor's representatives and any state personnel is not binding. Only the information issued in writing and added to the specifications by an official addendum is binding.

NEXT LVL ENERGY LLC
Company

Chris Veazey
Authorized Signature

08/27/2024
Date

NOTE: This addendum acknowledgement should be submitted with the bid to expedite document processing.

Proposal 1: Step 1 – $1,000,000 / $1,000,000 = Cost Score Percentage of 1 (100%)
Step 2 – 1 X 30 = Total Cost Score of 30

Proposal 2: Step 1– $1,000,000 / $1,100,000 = Cost Score Percentage of 0.909091 (90.9091%)
Step 2 – 0.909091 X 30 = Total Cost Score of 27.27273

6.8. Availability of Information: Proposal submissions become public and are available for review immediately after opening pursuant to West Virginia Code §5A-3-11(h). All other information associated with the RFP, including but not limited to, technical scores and reasons for disqualification, will not be available until after the contract has been awarded pursuant to West Virginia Code of State Rules §148-1-6.3.d.

By signing below, I certify that I have reviewed this Request for Proposal in its entirety; understand the requirements, terms and conditions, and other information contained herein; that I am submitting this proposal for review and consideration; that I am authorized by the bidder to execute this bid or any documents related thereto on bidder's behalf; that I am authorized to bind the bidder in a contractual relationship; and that, to the best of my knowledge, the bidder has properly registered with any State agency that may require registration.

NEXT LVL ENERGY LLC
(Company)

CHRIS VERZEY, DIRECTOR OF ADMINISTRATION
(Representative Name, Title)

(804) 590-7707
(Contact Phone/Fax Number)

08/27/2024
(Date)

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:

Exploration Robotics Technologies Inc.

https://www.xplorobot.com

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.

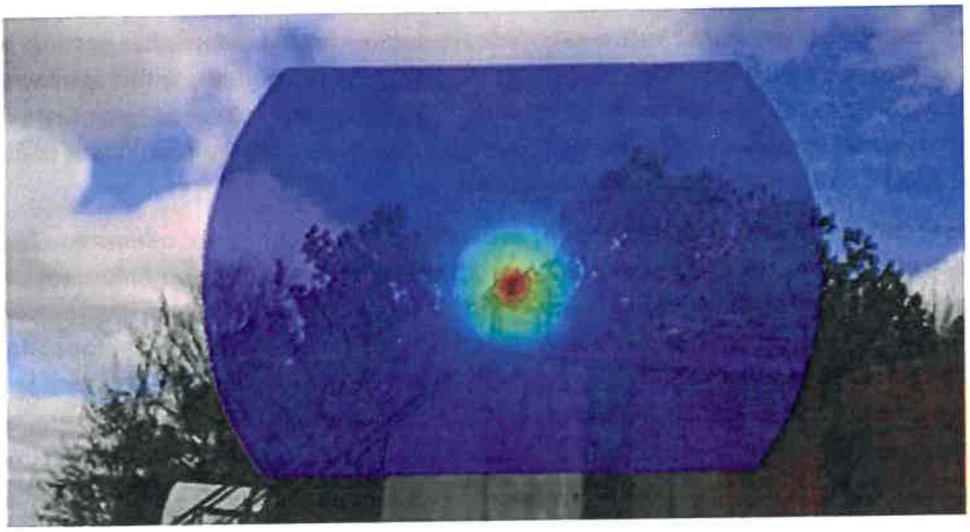


Figure 1. Detection of fugitive emission on a thief hatch vent.

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

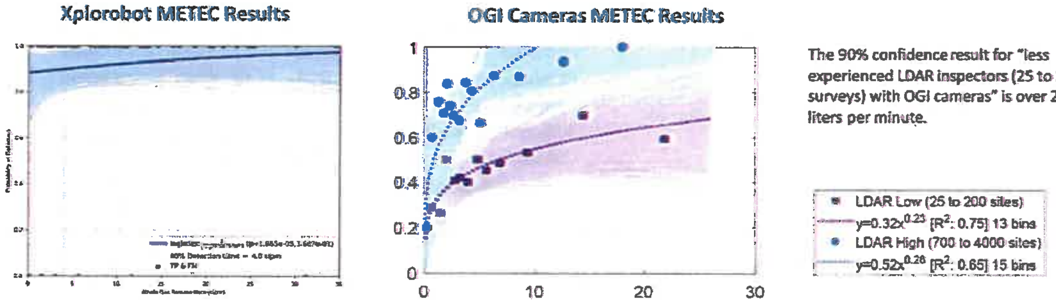
Well Name	Rate, g/hr	FLIR Detection	Xplorobot Detection
Porter Run 2	Zero Emission	Zero Emission	Zero Emission
Private #7	<1.0	No detection	Detection
Private #2	<1.0	Not tested	Detection
Rutherford Nancy 2	1.0	No detection	Detection
USA Joy 1	1.0	No detection	Detection
Edward Wiles #3	1.4	Not tested	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).

Xplorobot Laser OGI

Matches the performance of infrared OGI operated by Highly Experienced LDAR inspectors



The 90% confidence result for "less experienced LDAR inspectors (25 to 250 surveys) with OGI cameras" is over 20 liters per minute.

Xplorobot team, being novices in LDAR inspection, achieved the 90% confidence detection level of 4.0 lpm using the Xplorobot sensor package.

"High experience LDAR surveyors (700-4000 surveys) with OGI cameras achieved 90% confidence detection level between 2.6 lpm and 7.7 lpm."

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.*

*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).

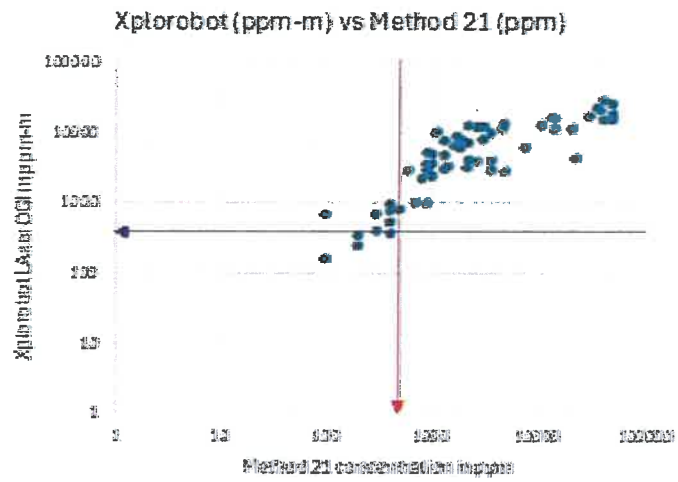


*Figure 4. Comparison between **Xplorobot Laser OGI** and Method 21 device measurements.*

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.

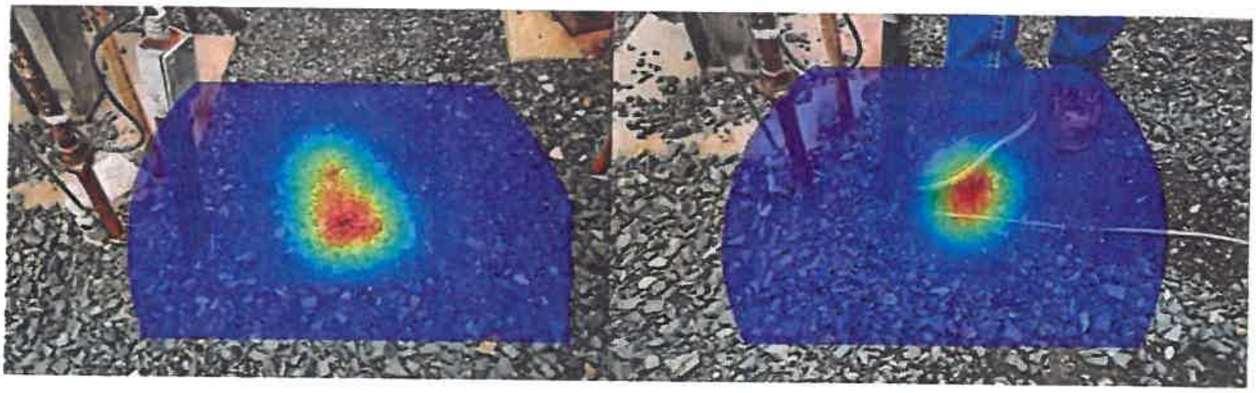


Figure 6. Emission detected under gravel and recorded on tubing after gravel was removed.

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.

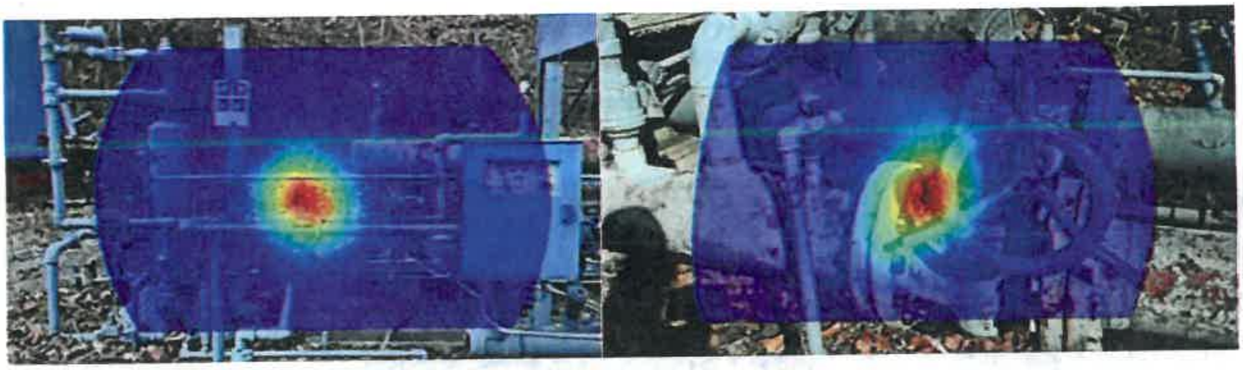


Figure 7. Examples of component-level emission source detection in oil and gas facilities recorded from distances of 3 meters and 1 meter.

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.

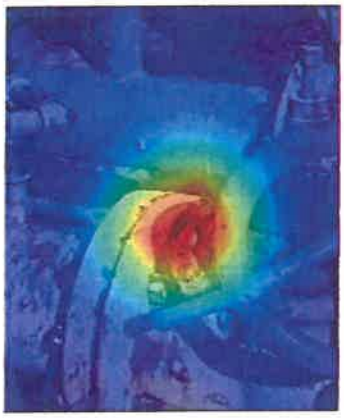
- Visualization of the emission otherwise not visible to the naked eye that attributes it to a specific component (see Figure 11 for examples).
- Maximum column-integrated methane concentration at the emission source in pp-m.
- Estimate of the emission rate (based on Xplorobot proprietary physics-based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

Xplorobot Laser OGI Digital Emission Tag Examples

Localization down to a bolt:



Emission on tank from ground:

Emissions not visible by OGI:

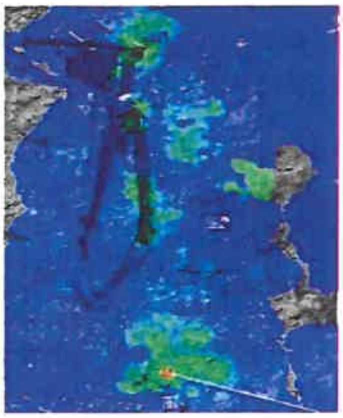


Figure 11. Visualization of emission is otherwise not visible to the naked eye, attributing the emission to the specific components (bolt, thief hatch) and detection of emission from an underground pipe.

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**.

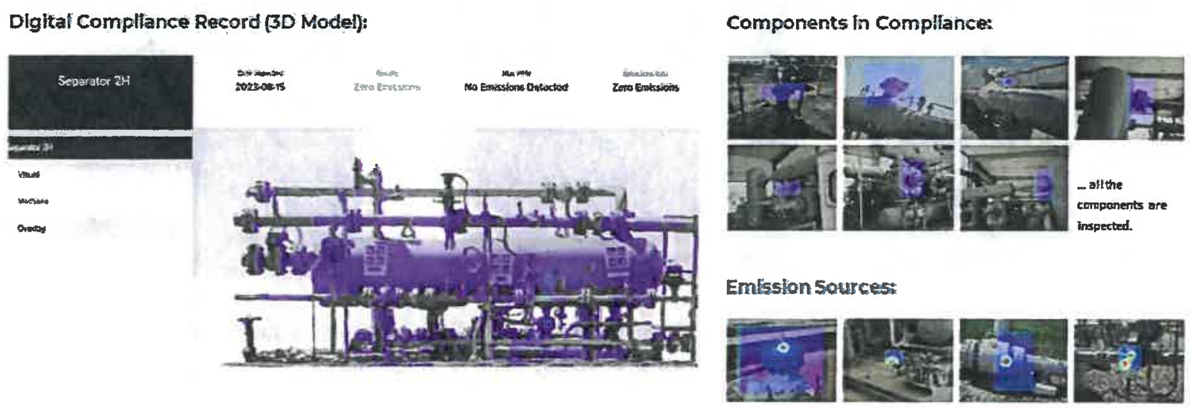


Figure 12. Digital Compliance Records include 3D and 2D methane concentration maps for equipment and components

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.

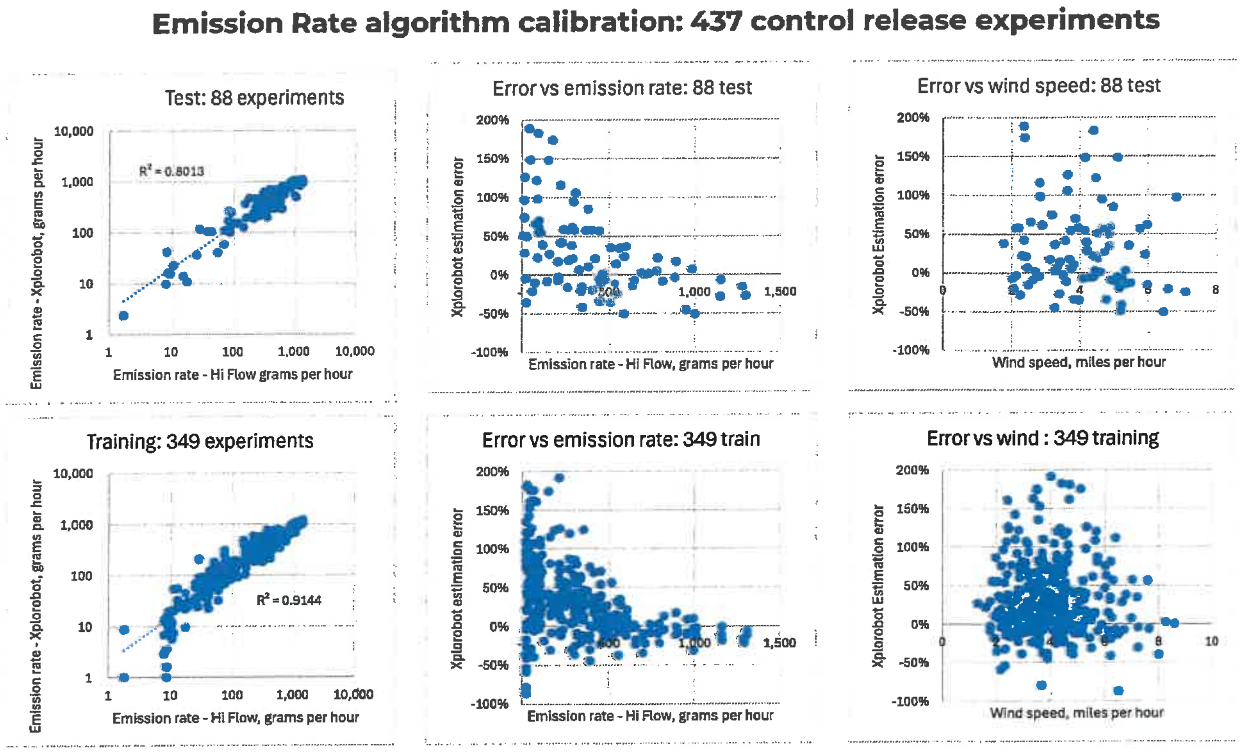


Figure 13. Xplorobot proprietary physics-neural-network algorithm calibration in 437 control release experiments.

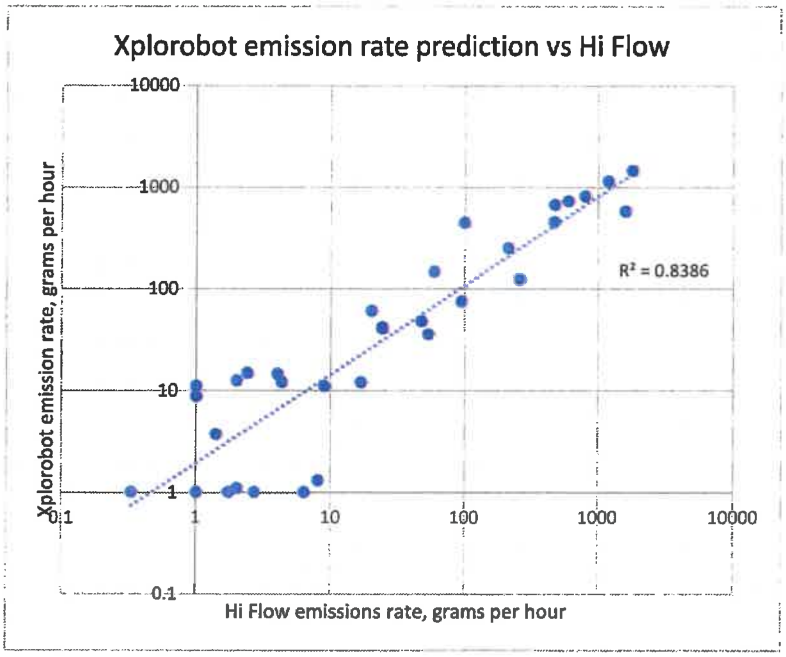


Figure 14. Xplorobot emission rate prediction for 40 emission sources in real field conditions compared with Hi Flow measurements

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.

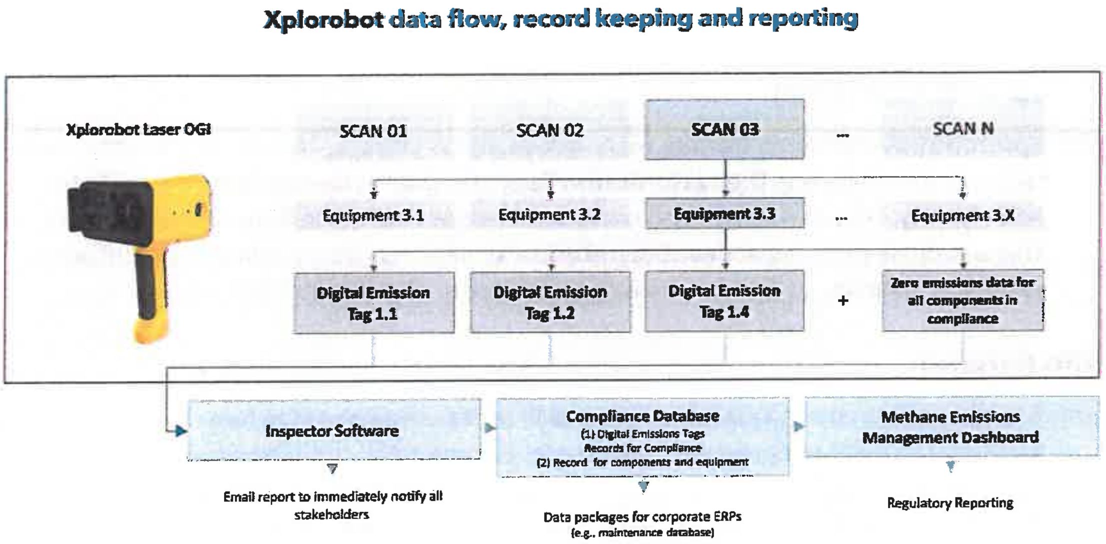


Figure 15. Data flow, recordkeeping and reporting for the proposed Alternative Test Method.

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, CO2 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.

REQUEST ID: 20

Description of Technology

Request for Alternative Test Method

Methane Detection Technology

§60.5398b(b) Periodic Screening

The Environmental Protection Agency Emission Measurement Center

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

Exploration Robotics Technologies, Inc.

https://www.xplorobot.com

This document does not contain Confidential Business Information.

Contents

This document provides technical details for the proposed Alternative Test Method for methane detection and quantification. We cover the details of the Xplorobot Laser OGI sensor, the technique for data acquisition, the steps in data processing, analysis and reporting.

1. Definitions for the Alternative Test Method.

1.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. The United States Environmental Protection Agency defines an Optical Gas Imaging Device (OGI) as a "device that visualizes emissions otherwise not visible to the naked eye" (Appendix K to Part 60, Title 40).

1.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.

1.d. Digital Emission Tag

Digital Record for a specific component stored in the **Xplorobot Compliance Database** that certifies presence of methane emission from that component, thereby supporting regulatory compliance and auditing per 40 CFR § 60.5424b.

1.e. Digital Compliance Record

Digital Record for a specific component stored in the **Xplorobot Compliance Database** that certifies zero emission for that component, thereby supporting regulatory compliance and auditing per 40 CFR § 60.5424b.

1.f. 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.

2. Description of Measurement Technology

2.a. General technology description

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 and the ambient temperature at the site and uses a proprietary algorithm to estimate the methane emission rate in grams per hour.

Xplorobot Laser OGI creates a **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, Xplorobot Inspector** 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 experiments at the Lawrence Berkeley National Laboratory (Figure 23) and field deployment with oil and gas clients (Figure 27) and confirmed with Semtec Hi Flow device. 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.

In blind testing at the Methane Emissions Technology Evaluation Center ("METEC") **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). It is important to emphasize that the 90% probability detection level reflects both the device sensitivity and the human inspector performance.

Xplorobot 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. emission rate in grams per hour.

2.b. Xplorobot Laser OGI and its elements

Xplorobot Laser OGI device, presented in **Figure 1** below, consists of the following elements:

Figure 1. Xplorobot Laser OGI device and its elements

Tunable Diode Laser Absorption Spectroscopy (TDLAS)

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.

High-Resolution Visual Camera

A high-resolution visual camera is employed to capture images during inspections. These images are used to visualize methane emissions that are otherwise not visible to the naked eye and to create **Digital Emissions Tags** and **Digital Compliance Records.** The proprietary Xplorobot computer vision software utilizes these images to precisely locate the sensor within 1 inch spatially and 0.5 degrees directionally, offering far greater accuracy than GPS, which suffers from drift and is typically only accurate to several meters.

Computer

An onboard computer serves as the main processing unit for the **Xplorobot Laser OGI.** It interfaces with all sensors, initiates the device, manages data acquisition, stores recorded information, and provides an inspection summary either through the device's screen or via a wired connection to an on-site computer. The computer runs the algorithm that visualizes methane emissions otherwise not visible to the naked eye and the algorithm that provides the initial emission rate estimate based on Xplorobot proprietary physics-based model.

Anemometer

An anemometer records local wind speed data, which is crucial for methane flow rate estimations and improves dispersion modeling. Accurate local wind measurements, time-synced with methane concentration measurements, are essential due to the highly variable nature of wind both spatially and temporally.

Thermometer (part of the Anemometer)

A thermometer records the ambient temperature at the inspection location.

GPS

A GPS unit records the approximate position of the inspection. This information is cross-referenced with a database of the Operator's site and equipment locations. If the coordinates match a known location, the site is automatically assigned to the inspection, reducing user data entry and minimizing errors.

Bluetooth/Wi-Fi/4G LTE

Xplorobot Laser OGI incorporates a Bluetooth device that connects it to the inspector's smartphone to transmit **Digital Emissions Tags** to a cloud-based Xplorobot Compliance Database for immediate automatic notifications of the facility operator of the emission sources identified. Upon completion of the inspection, Wi-Fi or an ethernet cable is used to download the inspection data (all the methane measurements, visual images, wind and temperature readings and GPS coordinates) to a laptop or desktop computer for further upload to the cloud-based **Xplorobot Compliance Database.**

Xplorobot team is now working on adding a 4G LTE card to **Xplorobot Laser OGI** to provide additional options for the device connectivity to the cloud.

Touch Screen Display

The touchscreen display is the main interface of the Xplorobot Laser OGI device. It provides a user interface for performing the following tasks:

- Initiating the scan.
- Displaying column-integrated methane concentration (ppm-m) and wind speed readings at the laser's current location
- Visualizing methane emissions otherwise invisible to the naked eye for each emission point identified during the inspection.
- Creating **Digital Emission Tags** for each emission point identified during the inspection.
- Finishing the scan.
- Reviewing a summary of the scan, complete with information for each **Digital Emission Tag**.
- Saving the data acquired during the scan.

Figure 2 provides an example of the User Interface of the **Xplorobot Laser OGI.**

Figure 2. User interface of Xplorobot Laser OGI.

Battery

A Lithium-Ion battery is enclosed in the handle. The battery life of the device is approximately 4 hours of continuous scanning.

Miscellaneous

Other miscellaneous components in the device include the following:

- A Buzzer that serves as an aid during scanning. If the ppm-m level exceeds a predetermined threshold, the buzzer sounds to notify the person conducting the inspection of a potential methane emission location.
- A Real Time Clock (RTC) ensures accurate time measurements on the device. The time zone is automatically adjusted based on the device's location. The clock provides timestamps for all measurements and ensures post-inspection quality control by

verifying that the dwell (stare) time requirements are met.

2.c. Xplorobot Laser OGI 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.

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.

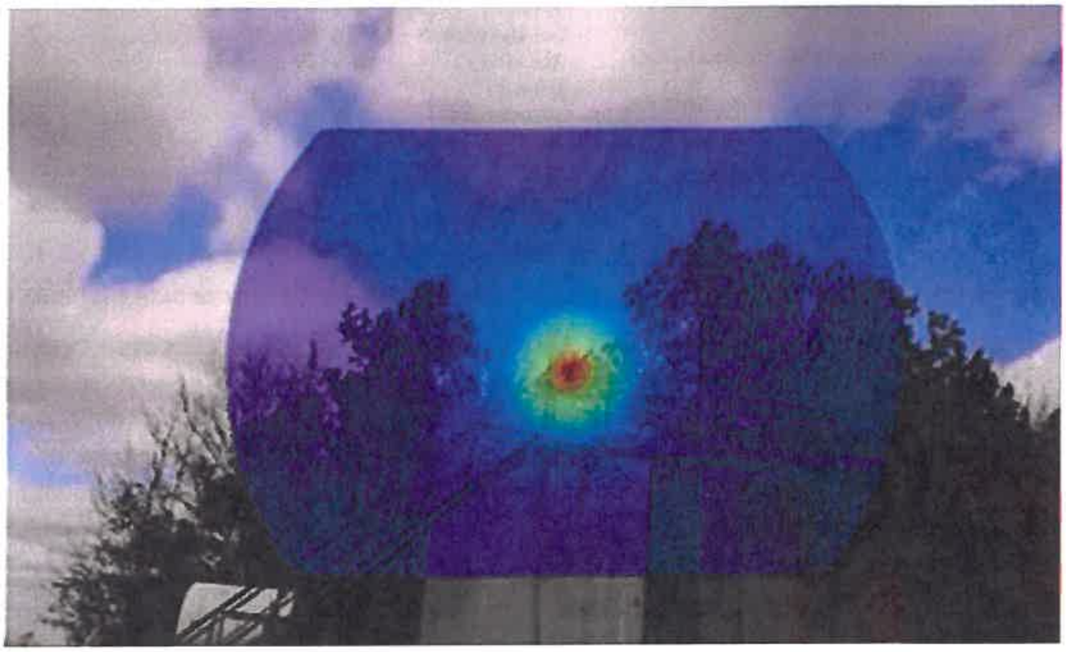


Figure 3. Detection of fugitive emission on a thief hatch vent.

Xplorobot Laser OGI sensitivity is 1 gram per hour as demonstrated in controlled release and field experiments. For example, in an orphan wells 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 4)

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 4. 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 (METEC) **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). Note 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 5).

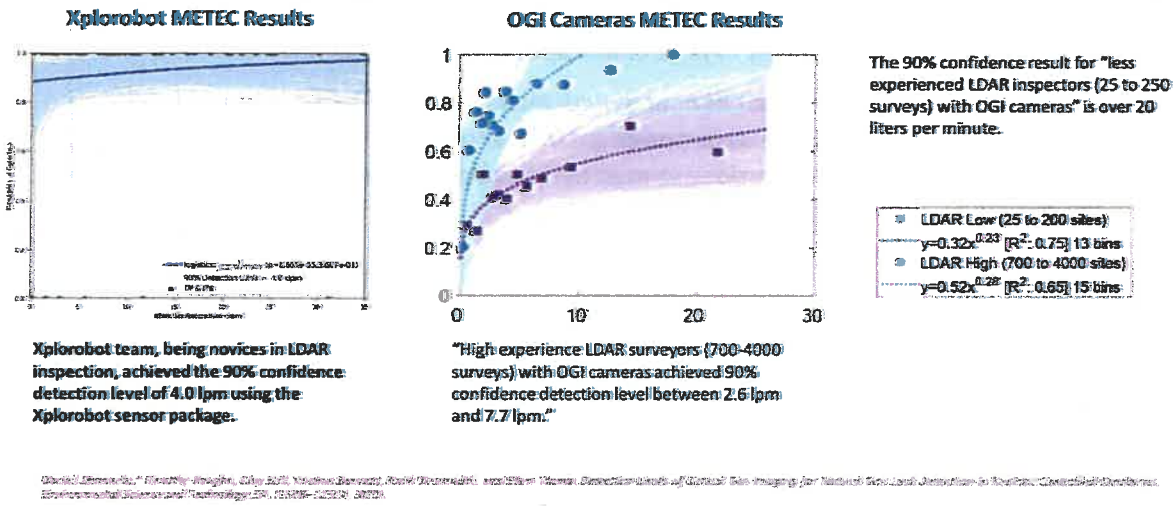


Figure 5. Results of blind tests at METEC for Xplorobot Laser OGI and for infrared OGI cameras (Zimmerle et al, 2020).

To compare the accuracy of detection between Xplorobot Laser OGI and Method 21, we performed a set of controlled release experiments with emission rates ranging between 0.4 grams per hour and 787 grams per hour as validated by a Hi Flow device. The exact comparison 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 experiments suggest that the Xplorobot Laser OGI measurement of 500 ppm-m corresponds to 500 ppm or lower measurements by a Method 21 device (Figure 6).

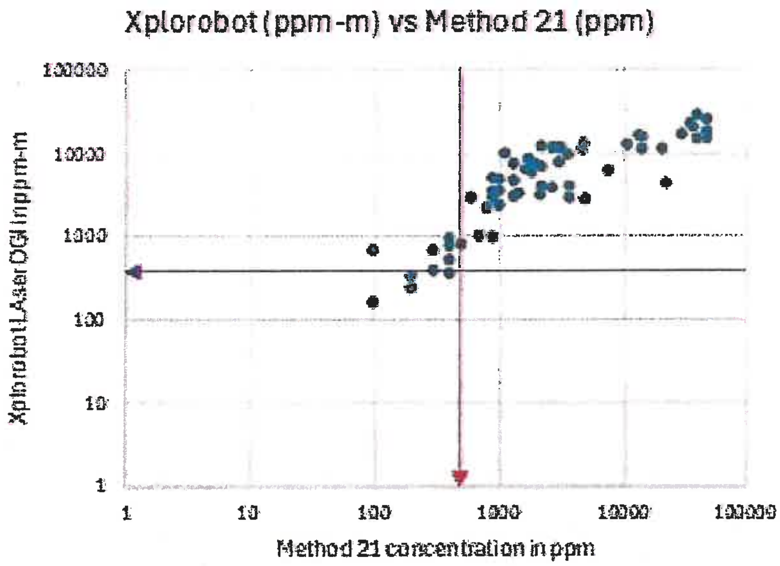


Figure 6. Equivalence between Xplorobot Laser OGI and Method 21.

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 7 and 8 provide examples of such emission detections.

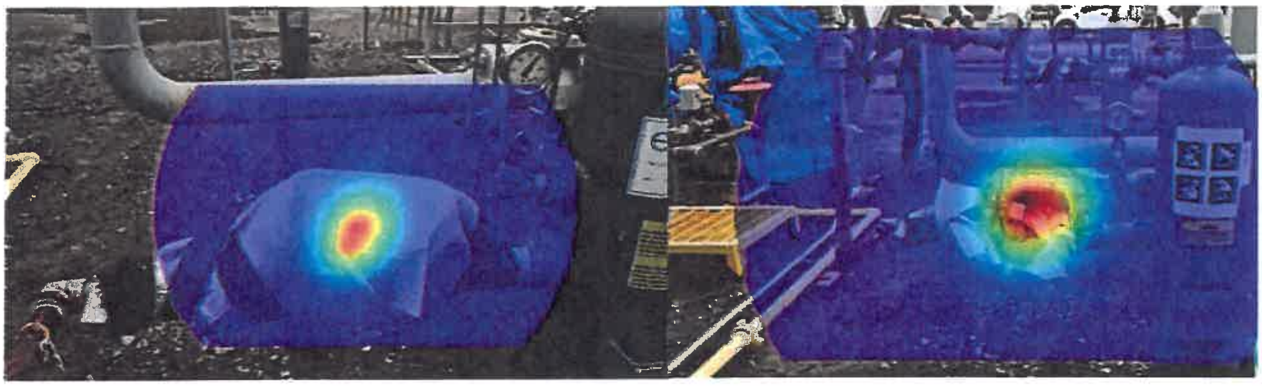


Figure 7. Emissions were detected under a bubble wrap, and the recording on the regulator after the wrap was removed.

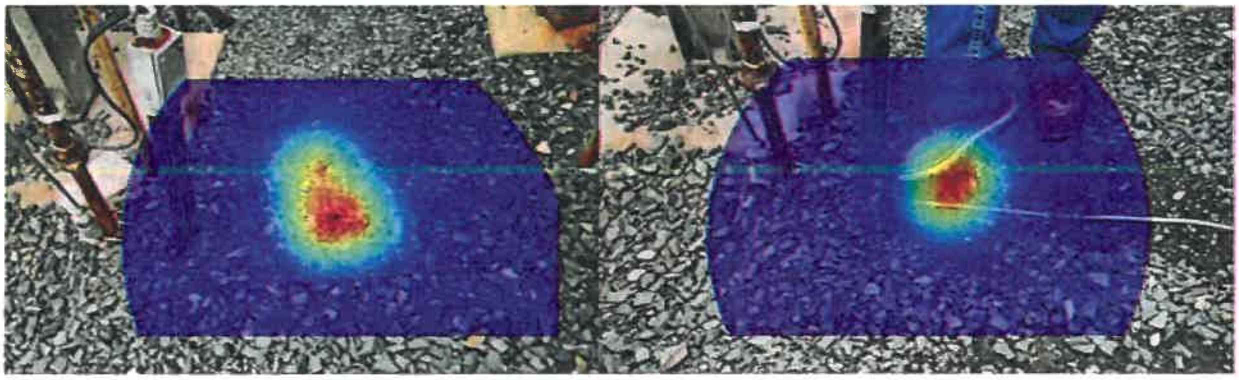


Figure 8. Emission detected under gravel and recorded on tubing after gravel was removed.

2.d. Temporal and spatial scale.

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 9 presents examples of the spatial resolution of the emission detection. This spatial resolution makes **Xplorobot Laser OGI** a Component-Level Alternative Test Method per 40CFR §60.5398b.

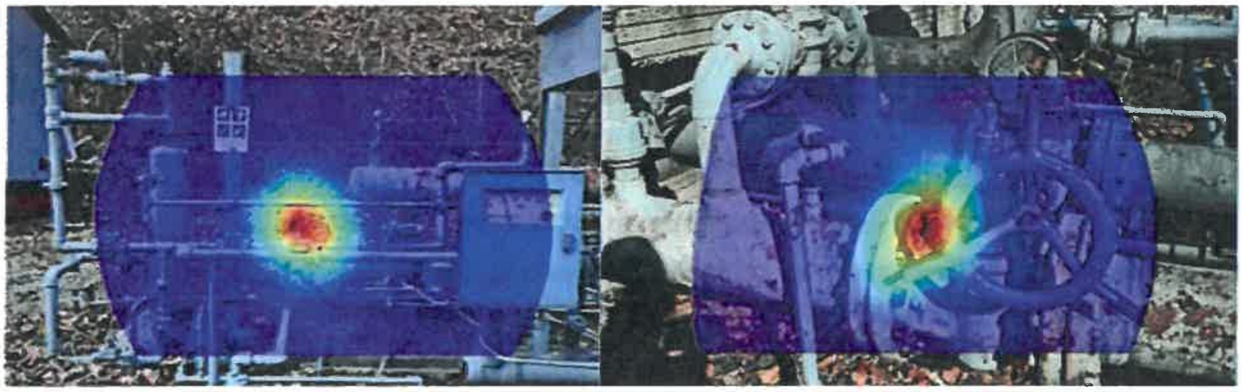


Figure 9. Examples of component-level emission source detection in oil and gas facilities recorded from distances of 3 meters and 1 meter.

2.e. Inspection procedure and recording a Digital Emission Tag.

Under the proposed ATM, 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. 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 10 illustrates the typical procedure for employing the **Xplorobot Laser OGI** in LDAR surveys.

*Figure 10. Scanning equipment and components with **Xplorobot Laser OGI** device.*

Xplorobot Laser OGI displays column-integrated methane concentration measurements by the TDLAS sensor on the device screen. The **Xplorobot Laser OGI alert** threshold for methane emissions alert is set at a column-integrated concentration of 50 ppm-m. When the concentration measured exceeds 50 ppm-m, the device emits a beeping noise, alerting the person conducting the inspection of an emission source presence. The concentration display turns yellow for values between 50 ppm-m and 500 ppm-m and red for values above 500 ppm-m.

When an inspector identifies a potential emission point at the 500 ppm-m threshold, they use the green location laser to investigate the area of possible emission and locate the point of emission. Upon locating the emission point, 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 **Xplorobot Laser OGI** screen. **Figure 11** shows an example of emission visualization on the screen of **Xplorobot Laser OGI**.

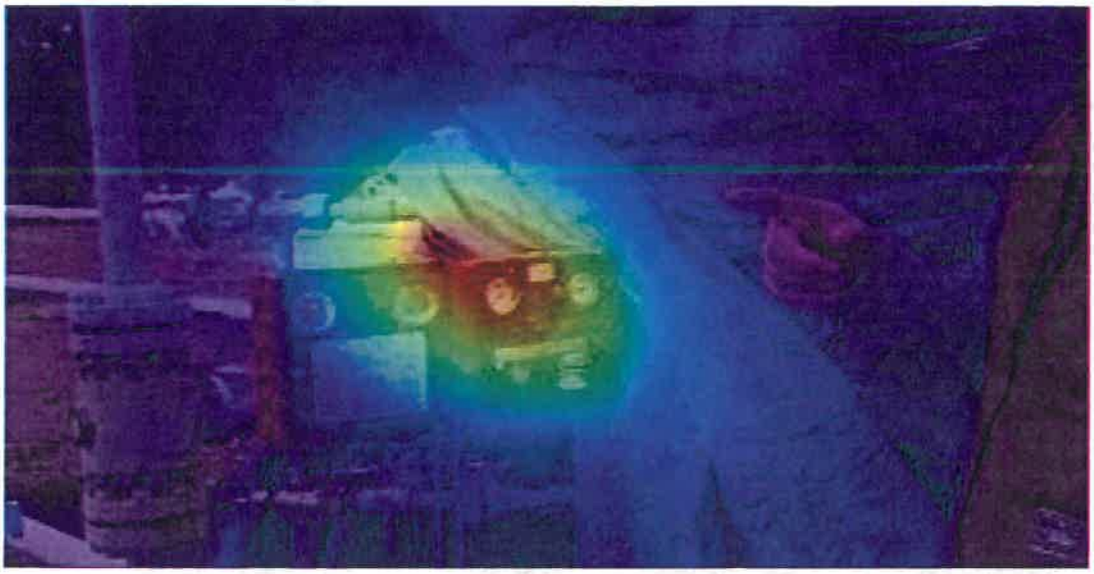


Figure 11. Detection of the emission (column-integrated concentration above 500ppm-m) and visualization of the emission otherwise not visible to the naked eye by the Xplorobot Laser OGI device.

Pressing the "**Digital Emission Tag**" button automatically creates a **Digital Emission Tag** that consists of the following information:

(i) Visualization of the emission.

(ii) Column-integrated methane concentration (in ppm-m) at and in the vicinity of the emission point.

(iii) Estimate of the emission rate 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 location.

The real-time visualization of the emission is based on high-resolution photographs to provide attribution of the emission to a specific component. The same high-resolution photograph or 3D model 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 required information for emissions reporting per the requirements of 40 CFR § 60.5424b.

Digital Emission Tags can be uploaded directly into the cloud-based Xplorobot Compliance Database via a Bluetooth connection on an inspector smartphone running Xplorobot App. Upon the Digital Emission Tag upload, Xplorobot Compliance Database generates an email alert to all stakeholders involved in the emission mitigation process.

2.f. Xplorobot Inspector Software and Digital Compliance Records

Upon inspection completion, all visual, methane, GPS, and meteorological data captured by **Xplorobot Laser OGI** is securely transferred via an ethernet cable or WiFi connection to a computer running proprietary **Xplorobot Inspector** software that includes an oil and gas operations database of sites, equipment, and components. 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.

In the course of an inspection, **Xplorobot Laser OGI** records methane, visual, GPS and meteorological data to document compliance for components and equipment that do not emit methane or emit methane within design or allowable limits. As equipment and components are scanned, **Xplorobot Laser OGI** accumulates records of methane concentrations that are zero or below the proposed Detection Threshold for Xplorobot Laser OGI at 500 ppm-m. All records of methane column concentration are downloaded into **Xplorobot Inspector** upon completion of the inspection. **Xplorobot Inspector** processes these records and creates **Digital Compliance Records** for components or equipment that do not emit methane or that emit methane within design limits.

Xplorobot Inspector 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 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**.

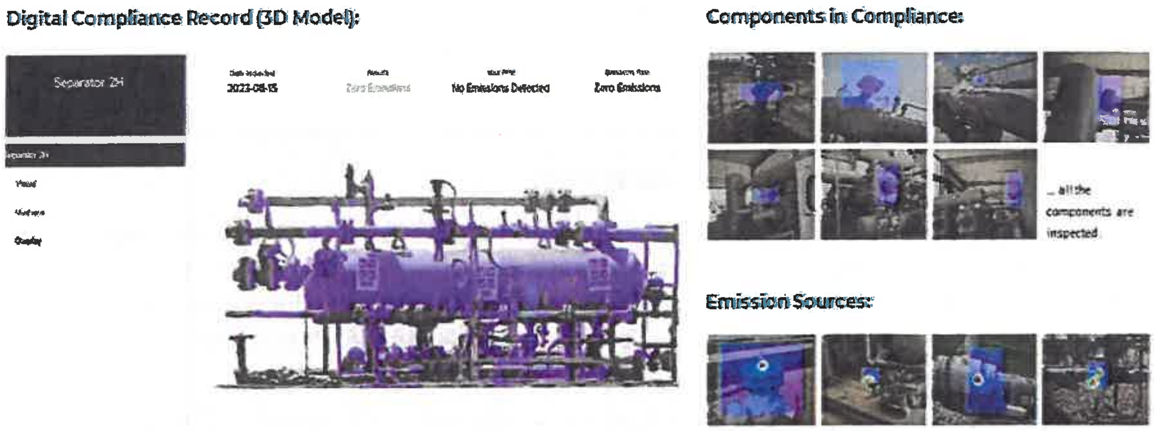


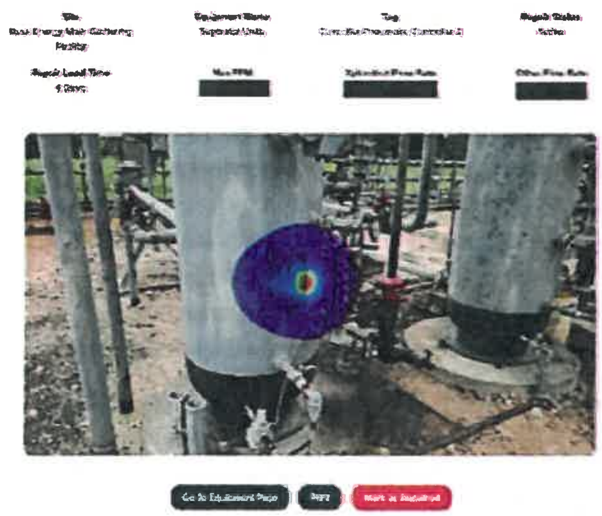
Figure 12. Digital Compliance Records include 3D and 2D methane concentration maps for equipment and components.

2.g. Compliance Database and Operator Notification

All **Digital Emissions Tags** are uploaded to the **Xplorobot Compliance Database** for recordkeeping per 40 CFR 60.5420b(c) and 60.5424b(c).

Upon upload of a **Digital Emissions Tag, Xplorobot Compliance Database** automatically notifies (by email or other means of electronic communication) all stakeholders in reporting, repairing, and mitigating the emissions (see Figure 13). When repairs are completed, **Xplorobot Laser OGI** is used to verify the repair and **Digital Records of Compliance** are then created and documented in the **Xplorobot Compliance Database**.

Visualization and Information on the Dashboard:



Compliance Database Entries

- **Date:** 2024-06-12
- **Time:** 13:26
- **Operator:** Rusk Energy
- **Site:** Main Gathering Facility
- **Equipment:** Separator X
- **Component:** Pneumatic Controller X
- **Maximum Concentration:** XXX
- **Emission Rate Estimate:** XXX
- **Emission Rate Confirmation:** XXX
- **GPS Coordinates:** 29.746 -96.574
- **Wind Speed:** 6.7 mph
- **Atmospheric Pressure:** 101.62 kPa

- **Repair Status:** Active
- **Repair Lead Time:** 6 days

Figure 13. Example of a Digital Emission Tag notification.

Digital Compliance Records stored in the **Xplorobot Compliance Database** provide auditable records of zero emissions to enable quality control of the LDAR programs and component-level (bottoms-up) to site level (top-down) reconciliations. Importantly, the ability to access historical **Digital Compliance Records** for components found to be emitting methane in subsequent inspections allows the Operator to define the duration of the emissions to estimate the emissions volume for reporting under 40 CFR 98 Subpart W.

2.h. Methane Emissions Management Dashboard

Xplorobot facilitates access to all data in the **Xplorobot Compliance Database** utilizing a map- based **Methane Emissions Management Dashboard** that provides an "operations view" (Figure 14) of all the sites and equipment with all emission sources. The Dashboard provides access to all the **Digital Emissions Tags** and **Digital Compliance Records** stored in the **Xplorobot Compliance Database**. It allows tracking of repairs and post-repair verifications.

The **Methane Emissions Management Dashboard** also provides an "analytics view" (Figure 15) of the emissions source counts and volumes on regional, site, and equipment levels. The Dashboard provides functionality for emissions analytics, site, equipment, component-level compliance, and historical inspection records. The Dashboard autonomously generates all fugitive emissions reports required per 40 CFR § 60.5424b.

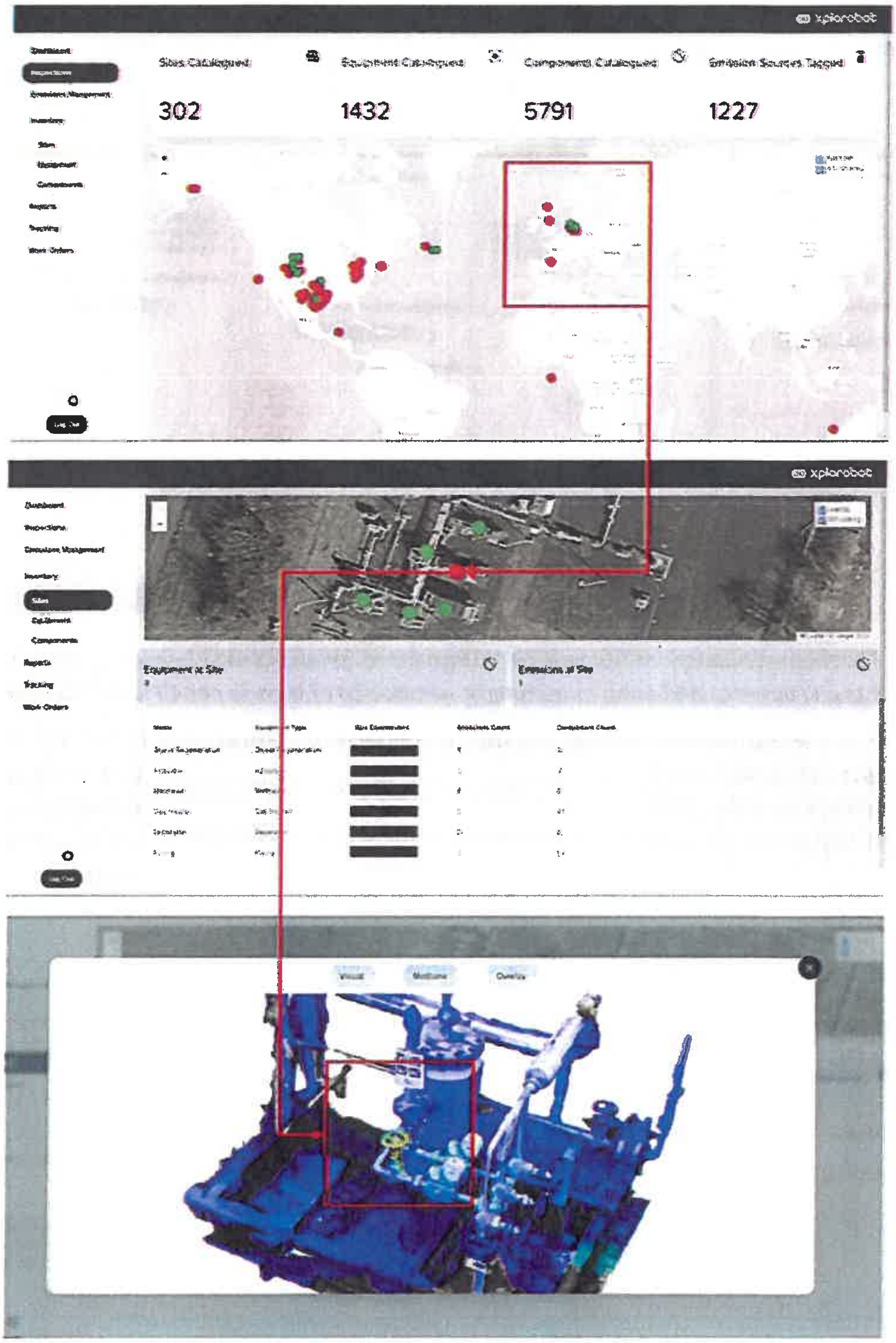


Figure 14. The Methane Emissions Management Dashboard "operations view" provides access to information for specific sites, equipment, and components as well as all the inspection results through a map-based interface.

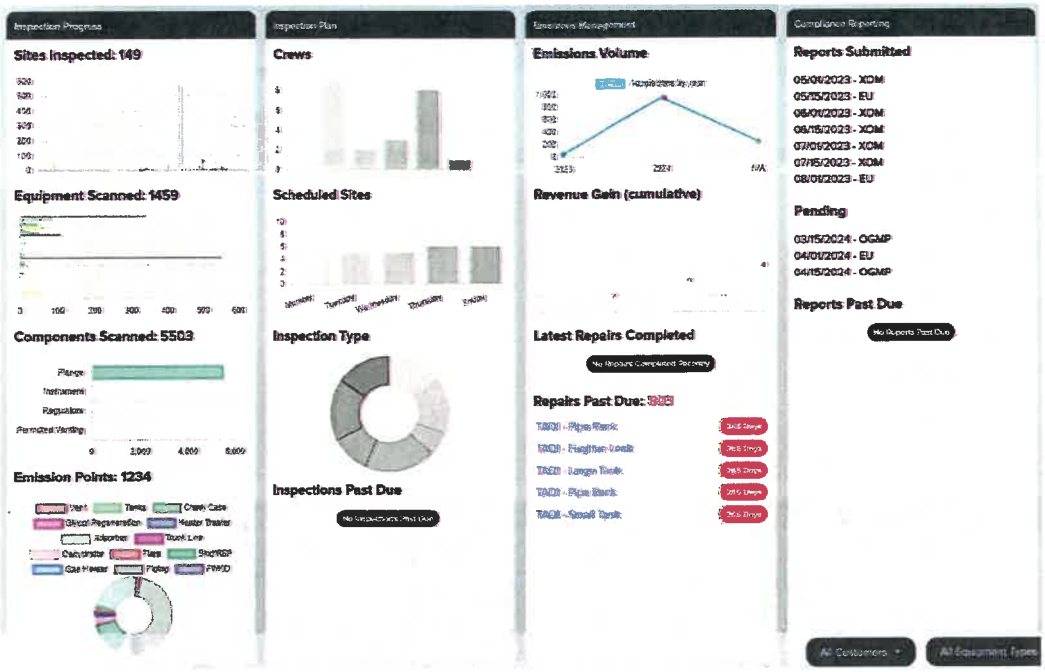


Figure 15. The Methane Emissions Management Dashboard "analytics view" provides emission sources counts and volumes and enables automatic generation of reports per 40 CFR § 60.5424b

Together, all the **Digital Emission Tags** and **Digital Compliance Records** stored in the **Xplorobot Compliance Database** and accesses through the **Methane Emission Management Dashboard** create a full digital track record of all inspections conducted with **Xplorobot Laser OGI** devices and facilitate emissions mitigation, regulatory reporting and auditing of the LDAR program efficiency and accuracy. Figure 16 provides a diagram of data flow in the proposed Alternative Test Method.

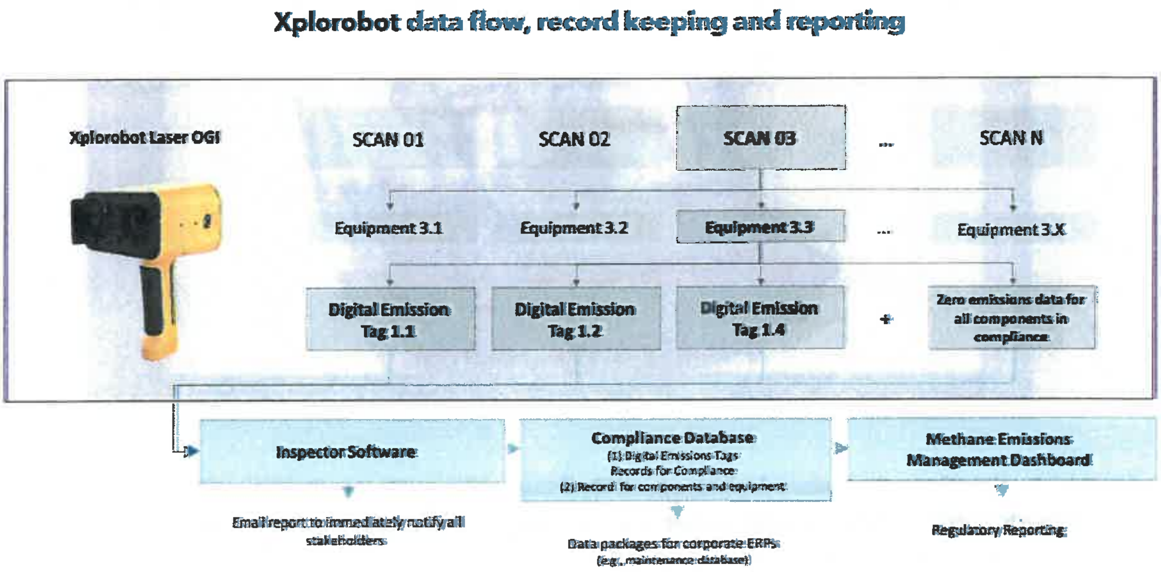


Figure 16. Data flow, recordkeeping and reporting for the proposed Alternative Test Method.

2.i. Description of the real-time Visualization Algorithm

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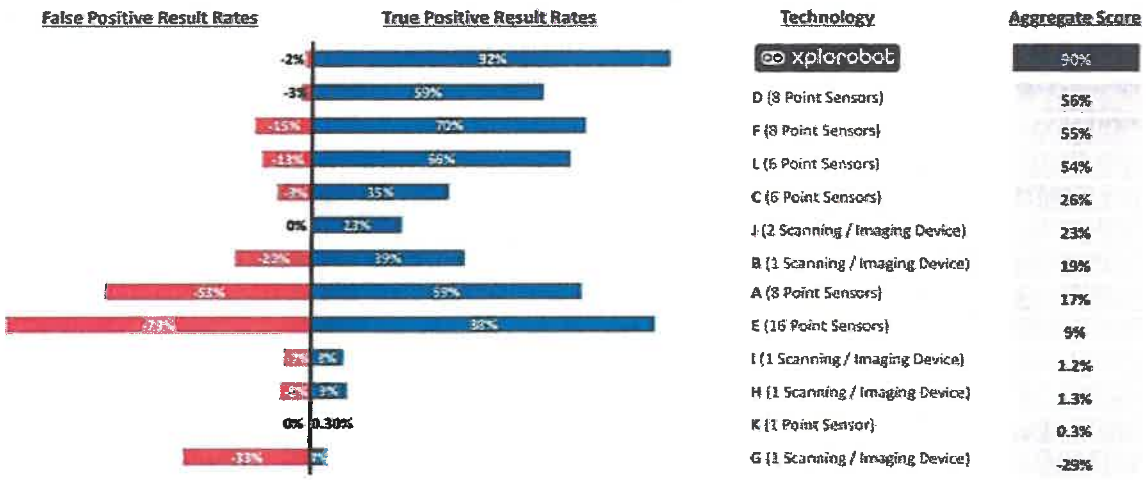
3. Technology Accuracy Validation and equivalence to Infrared Optical Gas Imaging

The **Xplorobot Laser OGI** device was tested alongside other technologies over a 4-day period under the Advancing Development of Emissions Detection (ADED) protocol. The goal of the experiments was to identify emissions points throughout the facility. The team was not briefed on the number of emission point(s), if any, present in each experiment, the location of the emission point(s), or the emission rate.

The Xplorobot team consisted of Xplorobot employees with no formal training in LDAR inspection or experience working in oil and gas or oilfield services companies. METEC results demonstrate that using **Xplorobot Laser OGI** does not require significant expertise or training to achieve high-accuracy results.

In ADED testing, **Xplorobot Laser OGI** demonstrated a 91.4% true positive rate and 2% false positive rate. Figure 17 below provides a comparison of **Xplorobot Laser OGI** results with the published results from other technology providers (Clay et al., 2023).



* METEC is the Methane Emissions Technology Evaluation Center at the Colorado State University sponsored by the US Department of Energy. METEC provides independent blind testing for all methane detection technologies for the US market.

Figure 17. Comparison of the single-blind test results for Xplorobot Laser OGI against other technologies tested at METEC.

At the request of Xplorobot, the blind testing at METEC focused primarily on emissions below 10 liters a minute to define the 90% confidence detection limit for **Xplorobot Laser OGI**. Figure 18 presents the distribution of the flow rates in the blind testing experiments.

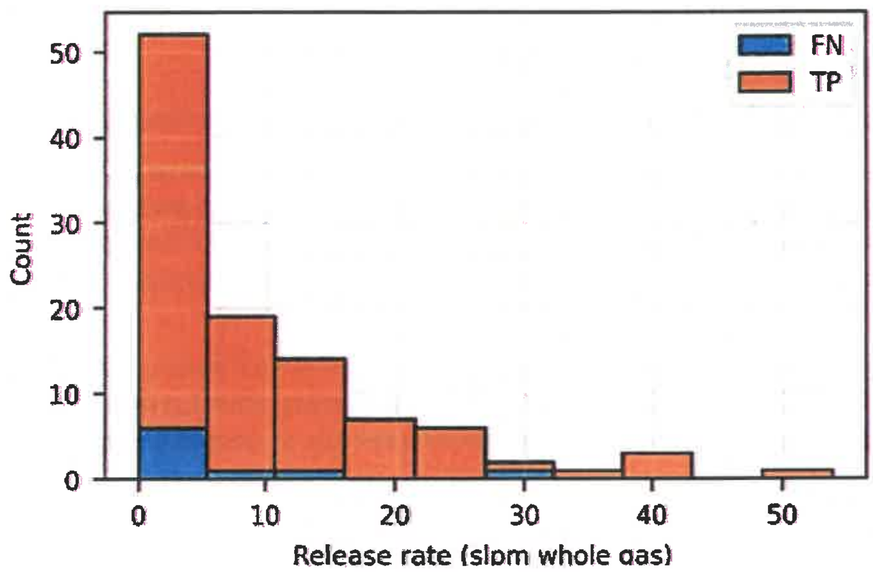


Figure 18. Emissions rate distribution in the METEC blind tests for Xplorobot Laser OGI, focused on emissions below 10 liters per minute.

Xplorobot Laser OGI achieved the 90% detection limit of 157 grams per hour or 4 standard liters per minute. Figure 19 presents the probability of the detection curve for **Xplorobot Laser OGI** achieved at METEC.

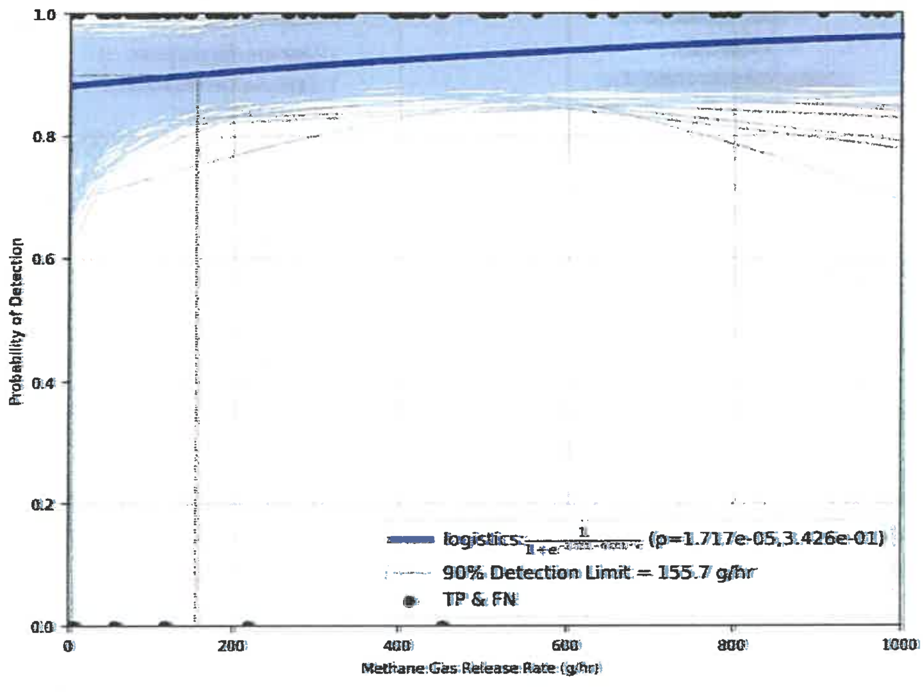


Figure 19. Probability of detection curve for Xplorobot Laser OGI achieved at METEC.

The results of the blind testing for **Xplorobot Laser OGI** allow a direct comparison with the results of Infrared Optical Gas Imaging Cameras at the same facility. Zimmerle et al. (2020) presented the results of blind tests of Infrared OGI cameras at METEC in which the inspectors performing the tests were separated into two groups: "Less experienced LDAR inspectors" and "Highly experienced inspectors."

The less experienced group performed 20 - 250 LDAR surveys prior to the testing, while the highly experienced inspectors performed 700 - 4000 LDAR surveys. The highly experienced LDAR group achieved a 90% confidence detection level between 2.6 - 7.7 standard liters per minute, while the less experienced group's 90% confidence of detection was over 20 standard liters per minute. Figure 20 presents the results of 90% confidence levels for Infrared Optical Gas Imaging operated by Less Experienced LDAR Inspectors and High Experience LDAR Inspectors from Zimmerle et al. (2023) with an overlay of the probability of detection curve for **Xplorobot Laser OGI**.

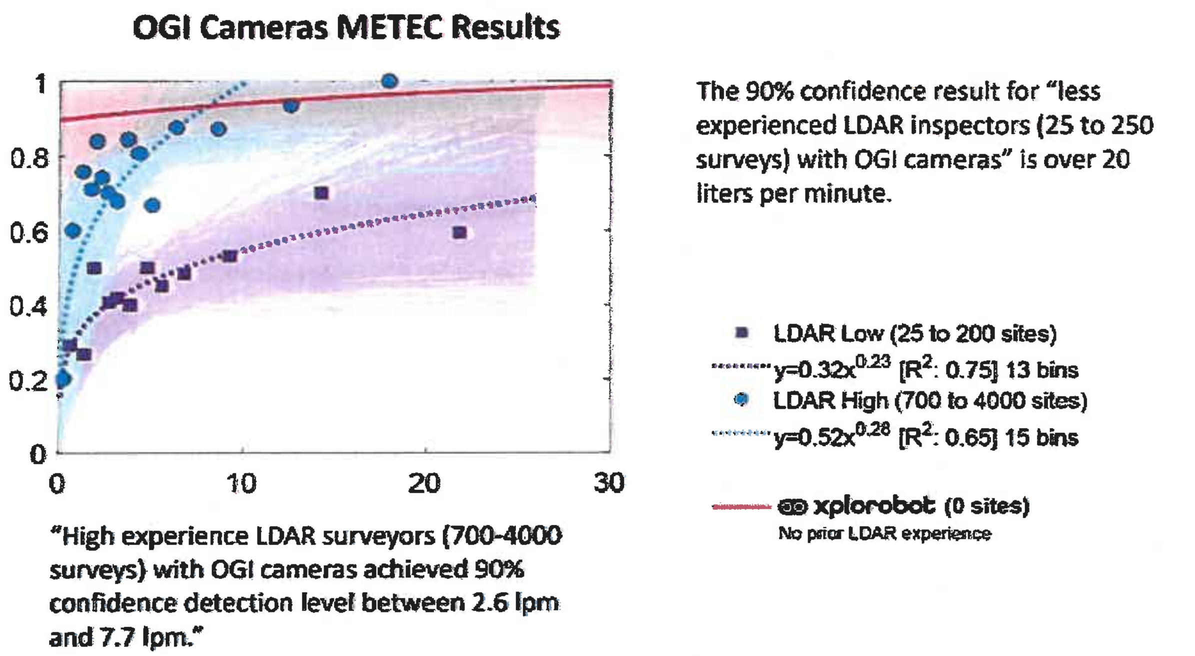


*Figure 20. Probability of detection for Infrared OGI cameras operated by High Experience LDAR Inspectors and by Low Experience LDAR inspectors from Zimmerle at al. (2020) with an overlaid probability of detection curve for **Xplorobot Laser OGI***

The 90% confidence level results for **Xplorobot Laser OGI** (157 grams per hour or 4 liters per minute) fall in the range of the results for Infrared Optical Gas Imaging operated by High Experience LDAR inspectors (between 2.6 and 7.7 liters per minute). Thus, the METEC blind testing results for **Xplorobot Laser OGI** matched the detection accuracy of Infrared Optical Gas Imaging cameras operated by Highly Experienced LDAR inspectors (between 700 and 4000 LDAR surveys).

Numerous additional field deployments demonstrated the accuracy of **Xplorobot Laser OGI** as compared to to Infrared Optical Gas Imaging. 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 Laser OGI detected methane emissions in field conditions with temperatures ranging from minus 20 Celsius (minus 4 F) in field data acquisition for Carbon Creek Energy in February of 2023 to plus 44 Celsius (110 F) in field data acquisition for Diversified Energy in Ft. Worth, TX in April and in wind conditions up to 25 mph.

4. Additional control release and field testing

4.a. Lawrence Berkeley National Laboratory tests in the 1 gram per-hour to 20 grams per-hour range

To define the detection limits for **Xplorobot Laser OGI**, we performed controlled release experiments at the Lawrence Berkeley National Laboratory in September 2023 and February 2024. We used gas with a 5% methane concentration and varied the emissions rate from 0.5 liter per minute (approximately 1 gram per hour of methane) to 20 liters per minute (approximately 40 grams per hour of methane). Xplorobot Laser OGI detected emissions of 1 gram per hour and above at LBNL.

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Figure 21. Experimental setup at the Lawrence Berkeley National Laboratory.

Xplorobot Laser OGI detected emissions for all the experiments at the Laboratory. Figure 22 presents the results of the maximum concentration detected for each emissions rate in the experiments.

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Figure 22. Methane concentration in ppm-m recorded by the Xplorobot Laser OGI device at the Lawrence Berkeley National Laboratory.

4.b. Alberta Methane Emissions Program (AMEP) tests range from 3 to 1200 grams per hour.

Xplorobot performed controlled release experiments at the Alberta Methane Emissions Program (AMEP) in March and October 2023. The emissions rates in the controlled rate experiments ranged from 3 grams per hour to 1200 grams per hour. **Xplorobot Laser OGI** detected the emissions in all the experiments at the site. The temperatures at the site ranged from minus 10 Celsius to plus 5 Celsius, and the wind speeds ranged from 1 mile to 12 miles per hour. Figure 23 presents an example of the detection results at AMEP.

AMEP Well Head - control rate experiment

Experiment	Known flow rate	Max concentration measured	Result
1	0.1 m3/day	2,052	Detection
2	1 m3/day	9,040	Detection
3	10 m3/day	11,300	Detection
4	20 m3/day	12,416	Detection
5	40 m3/day	13,798	Detection

Key observations:

- Emissions of 0.1m3/day (~3 grams/hour) and above are clearly detected
- Wind speed range during the experiment was between 0.5 miler per hour and 7.5 miles per hour

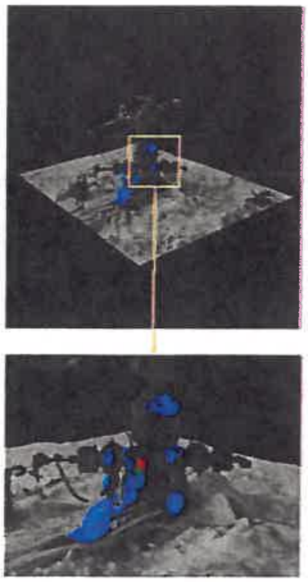

Figure 23. Example of controlled rate release experiments at the Alberta Methane Emissions Program.

4.c. Confirmation of the 1 gram per hour detection limit in field conditions by oil and gas operators

From September 2023 to June 2024, **Xplorobot Laser OGI** was used at multiple client facilities in Colorado, Texas, Louisiana, Pennsylvania, Ohio, West Virginia, Germany, Australia, The United Kingdom, and France. When possible, we used the Semtec High Flow device to record the emissions rates detected by **Xplorobot Laser OGI** and establish the lower detection limit in real field deployment conditions. We recorded emissions rates at client sites ranging from 0.3 to 10,000 grams per hour. Figure 24 provides an example of **Xplorobot Laser OGI** detecting emission below 1 gram per hour at a client site as validated by the High Flow device.

Figure 24. Xplorobot Laser OGI detection of emission below 1 gram per hour in field conditions.

4.d. Confirmation of the 1 gram per hour detection limit in Orphan Wells campaigns

In May of 2024, Xplorobot team worked on an orphaned wells campaign in the Osage Nation in Oklahoma led by the Lawrence Berkeley National Laboratory. Figure 25 presents the results of emission detection in the range from 1.7 grams per hour to 1,450 grams per hour as confirmed by Semtec Hi Flow Device.

Campaign Results: Osage Nation

Work Completed:

Scope: 57 wells scanned in 3 days

Results: Emissions quantified on 16 wells (14 – single source, 2 – double sources)

Emission Rates: Ranged from 1.7 gph to 1,118 gph

Average Rate: 184 gph per source, 52 gph per orphaned well

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

More neural network training is required for rates below 10 gph

Site	Well	Hi-Flow Emission rate gph	Xplorobot Maximum ppm-m	Max Wind mph
BallRanch	5	1.7	750	4.5
MaryWyrick	5	2.7	700	4.2
BallRanch	3	4.3	100,000	2.6
BallRanch	12	6.3	1,466	1.8
BallRanch	19	8.9	5,976	2.4
MaryWyrick	2	16.6	5,031	3.2
MaryWyrick	10	46.9	18,537	4.7
MaryWyrick	4	94.4	50,000	3.1
Terhune	818	213	23,922	12.2
29N9E27	OR01	230	30,708	19.1
Enru Chuck	02a	260	10,158	10.3
BallRanch	7	471	19,389	3.0
BallRanch	15	475	32,196	6.0
MaryWyrick	6	1118	48,372	6.3
Lucy	1	1450	50,870	11.0

Figure 25. Xplorobot Laser OGI detection of emission at 1.7 grams per hour in field conditions.

In May of 2024, Xplorobot team worked on an orphaned wells campaign near Marietta, OH led by the US Forest Service. Figure 26 presents the results of emission detection in the range from below 1 gram per hour to 1,600 grams per hour as confirmed by Semtec Hi Flow Device.

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 26. Xplorobot Laser OGI detection of emission at and below 1 gram per hour in field conditions

5. **Case study – field deployment by an oil and gas operator in West Texas.**

In November of 2023, **Xplorobot Laser OGI** was used at a site in West Texas to successfully identify emissions that were not identified by previous surveys with infrared OGI cameras. Figure 27 below provides a case study by the operator as published in their annual ESG report.

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Figure 27. Case study of the Xplorobot Laser OGI deployment published by a client.

6. **Technology Limitations**

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.

When inspecting a storage tank thief hatch or pressure relief valve (PRV) from ground level, the laser should be aimed to reflect off the thief hatch or PRV. If necessary, the inspector should step back to a position where they can achieve this reflection. Figure 28 provides an example of detecting emissions from a thief hatch at ground level.

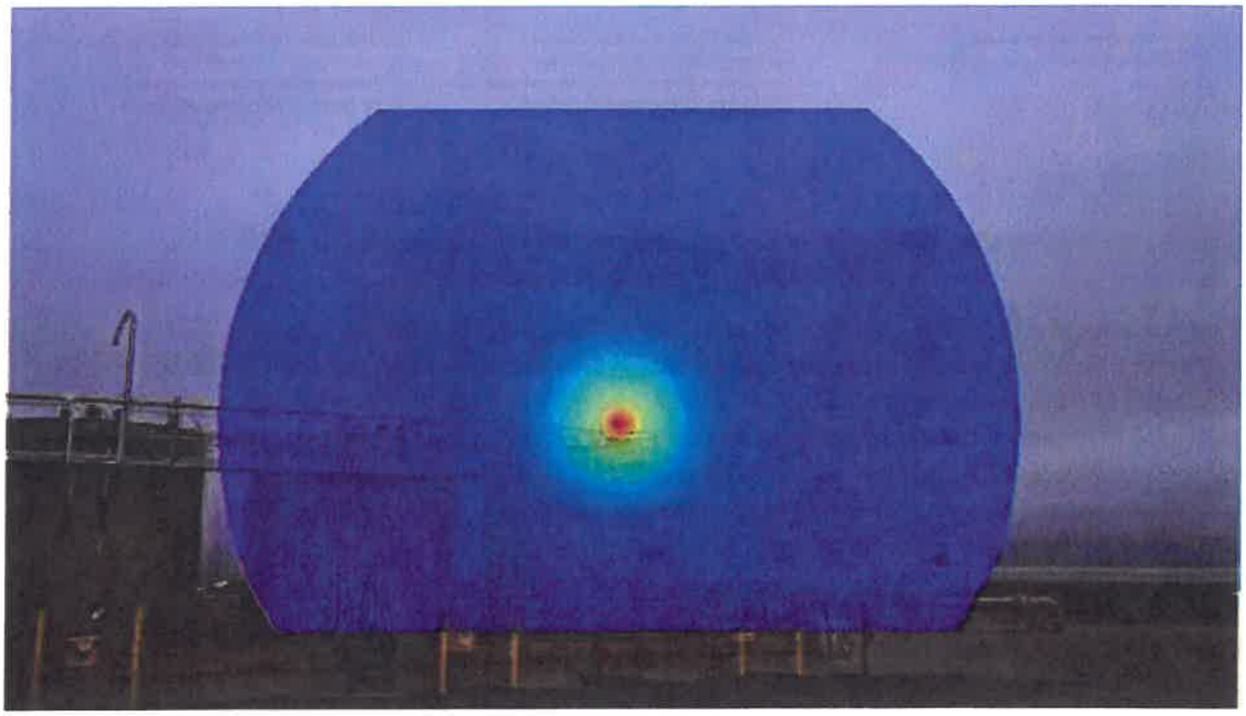

Figure 28. Emission detection from the ground with the laser reflected from the thief hatch.

7. Quantification of the emission rate

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. Figure 29 provides examples of the three factors that we identified in field experiments.

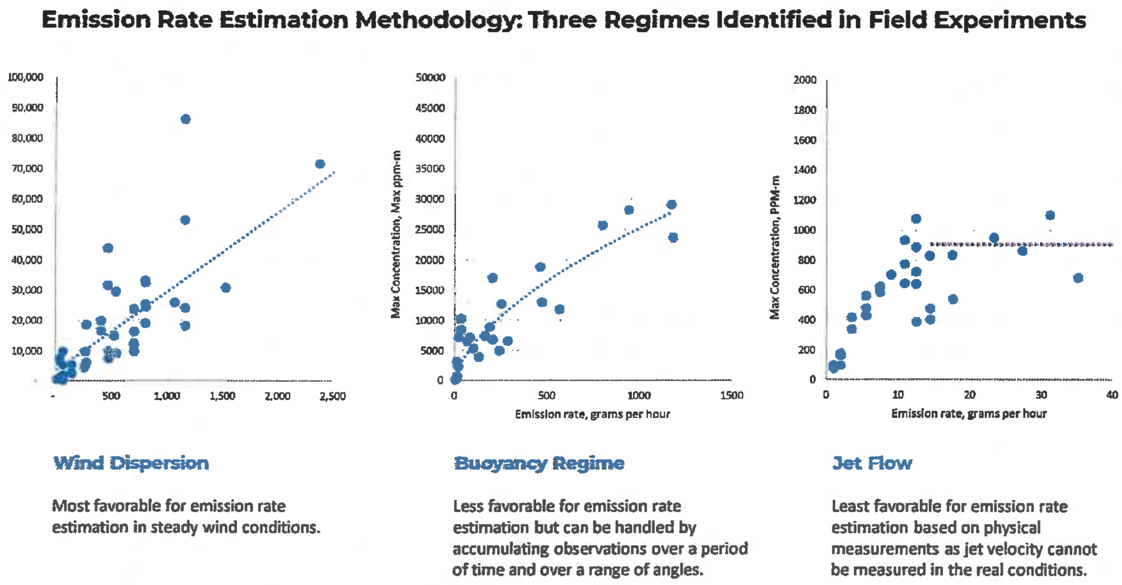

Figure 29. Three factors present in near-field emission detection result is significantly different behavior than that expected from wind dispersion models.

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 30 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 31 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.

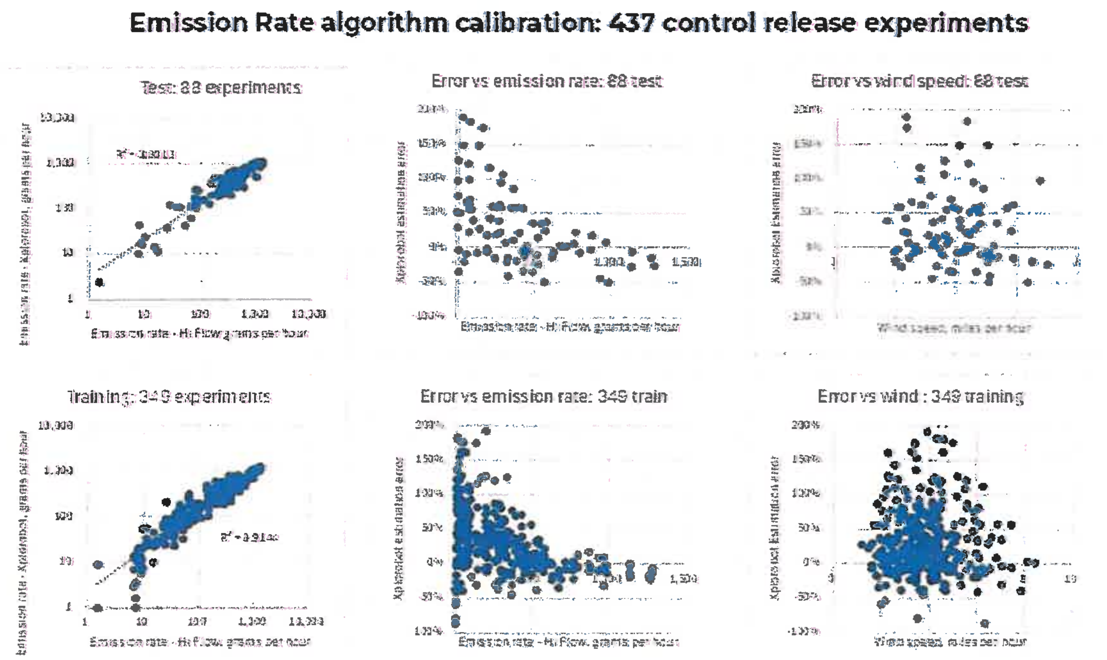

Figure 30. Example of Xplorobot methane emission rate prediction for a set of 437 controlled experiments in Denver, CO

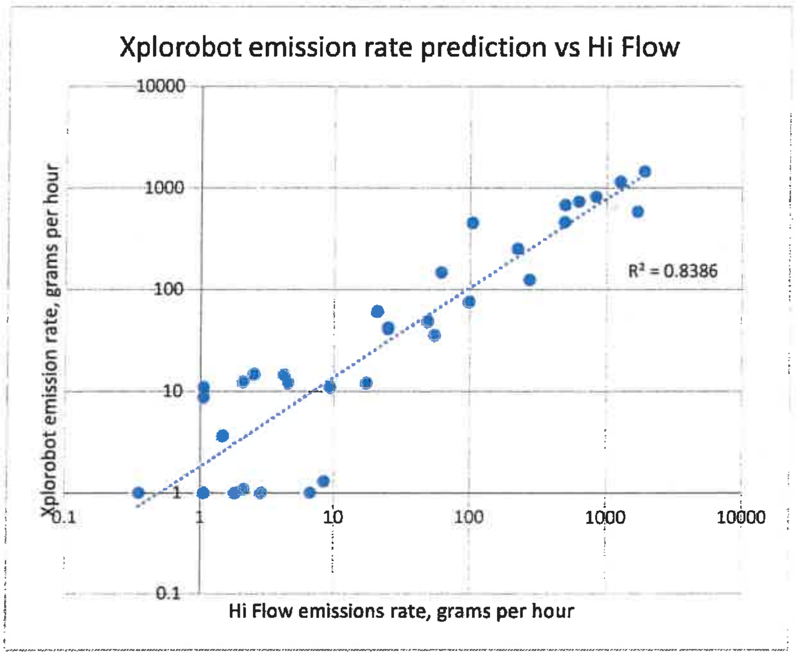

Figure 31. Xplorobot emission rate prediction for 40 emission sources in real field conditions compared with Hi Flow measurements

Currently, the Xplorobot physics-neural-network algorithm provides predictions within +/- 30% 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.

8. Description of alternative technology analytics

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 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.

9. Quality control of input data

[Content reserved for Confidential Business Information]

10. Quality Control of output results

[Content reserved for Confidential Business Information]

11. References

Clay Bell, Chiemezie Ilonze, Aidan Duggan, and Daniel Zimmerle, Performance of Continuous Emission Monitoring Solutions under a Single-Blind Controlled Testing Protocol. Environmental Science and Technology, 57, 5794–5805, 2023.

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.

Daniel Zimmerle, Wendy Hartzell, Ethan Emerson, David Allen, Arvind Ravikumar, and Kathleen Smits. Advancing Development of Emissions Detection. Energy Institute, Colorado State University, July 2023.

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

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Additional Information

Alternative Approved Instrument Monitoring Method

(AAIMM) Application

Exploration Robotics Technologies, Inc.

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Executive Summary

The purpose of this document is the presentation by Exploration Robotics Technologies Inc. ("Xplorobot") of a proposed Alternative Approved Instrument Monitoring Method for detecting methane emissions in oil and gas operations using the **Xplorobot Laser OGI** hand-held device and integrated software that creates **Digital Emission Tags** and **Digital Compliance Records** that are stored in a component-level **Xplorobot Compliance Database** and are used for communication, mitigation planning and certification and regulatory reporting.

The Colorado Department of Public Health & Environment defines detailed Leak Detection and Repair requirements in Air Quality Control Commission (AQCC) Regulation 7, Part B, Sections I.L. and II.E. The Alternative AIMM proposed by Xplorobot and detailed in this application follows exactly the scope and frequencies defined in LDAR programs per AQCC Regulation 7, Part B, Sections I.L. and II.E while using the **Xplorobot Laser OGI** device as the instrument monitoring method. Blind testing at the Methane Emissions Technology Evaluation Center demonstrated that **Xplorobot Laser OGI** achieves detection results equivalent to IR OGI cameras. Therefore, we respectfully request that the Colorado Department of Public Health and Environment approve the use of **Xplorobot Laser OGI** as an instrument monitoring method in satisfaction of the requirements for LDAR programs defined by AQCC Regulation 7, Part B, Sections I.L. and II.E.

Xplorobot Laser OGI facilitates digital capture, communication, and reporting of information about emission sources identified during inspections. For each methane emission source detected, **Xplorobot Laser OGI** creates a **Digital Emission Tag** that consists of an emission visualization video, methane concentration at the source, the GPS location, wind speed at the location at the time of the measurement, an estimate of the emission rate in grams per hour, and a date/timestamp of the recording along with the site, equipment, and component corresponding to that source.

All **Digital Emission Tags** are uploaded to **Xplorobot Compliance Database** upon completion of the inspection, and all stakeholders are immediately notified (by email, or any other preferred means of electronic communication) about emission sources requiring mitigation. The **Digital Emission Tags** can be accessed on the **Methane Emissions Management Dashboard** and compiled autonomously into reports per Regulation 7 requirements.

In addition to detecting emission sources, **Xplorobot Laser OGI** enables digital capture of zero emissions data, creating **Digital Compliance Records** for specific components or equipment. Additionally, upon successful mitigation of the emission source identified during the inspection, **Digital Compliance Records** are created for those sources to establish a digital track record of the repairs and to provide a transparent, auditable trail of emissions mitigation. All **Digital Compliance Records** are uploaded to the **Xplorobot Compliance Database** where, together with the **Digital Emission Tags**, a comprehensive, auditable digital record of each inspection is maintained.

Any operator or maintenance technician can deploy **Xplorobot Laser OGI**—it does not require any certification. As a result, the detection of an emission source, mitigation of that emission, and certification of the effectiveness of the mitigation can be done by the same person during the same visit to a pad or a facility, significantly reducing the cycle time for mitigation, along with the cost and labor burden of methane emission mitigation.

The **Digital Emission Tags** and **Digital Compliance Records** stored in the component-level **Xplorobot Compliance Database** provide operators and regulators with auditable information—at the equipment/component level—for each site inspected. Third parties can audit **Digital Emission Tags** and **Digital Compliance Records** to confirm inspection process quality, adherence to the LDAR program scope, and cadence specified in Regulation 7. We trust that if adopted as an Alternative Instrument Measurement Method, our solution will significantly enhance the operators' ability to detect and mitigate emissions in a timely manner, contributing to the protection of Public Health and Environment per the goals of the State of Colorado.

Glossary

In this document, we utilize definitions consistent with those presented in Fox et al. (2019), crucial for the interpretation of our content, outlined as follows:

Technology: Defined as any equipment used for sensing emissions, which may include supplementary platforms or tools (for example, positioning systems or weather measurement devices) to enable comprehensive data collection on emissions.

Work Practice: Describes the application methods of technology in emissions detection, covering operational protocols (such as the distance from the emission source and the duration of measurements) and any limitations on use (like specific environmental conditions or operational sectors).

Method: Represents the combination of technology, work practices, and analytical processes within a Leak Detection and Repair (LDAR) framework. A mix of methods is often employed; for example, broad area screening (using drones) may precede targeted leak confirmation and analysis using a direct measurement tool (such as a portable OGI device).

LDAR Program: The structured deployment of various methods across an array of assets, detailing the approaches adopted for each facility, including survey frequencies, repair timelines, and reporting obligations. The program aims to reduce emissions on a collective scale beyond individual methodologies.

Xplorobot Laser OGI Device: 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 on the device's screen. The United States Environmental Protection Agency defines an Optical Gas Imaging Device (OGI) as a "device that visualizes emissions otherwise not visible to the naked eye" (40 CFR Part 60).

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

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, thereby supporting regulatory compliance and auditing per Colorado Air Quality Control Commission Regulation 7.

Digital Compliance Record: a digital record for a specific component stored in the **Xplorobot Compliance Database** that certifies presence of methane emission from that component, thereby supporting regulatory compliance and auditing per Colorado Air Quality Control Commission Regulation 7.

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 with **Xplorobot Laser OGI**. This database provides accessible historical emissions information and compliance reporting per Colorado Air Quality Control Commission Regulation 7.

Methane Emissions Management Dashboard: An interface offering immediate insight into emissions management operations. This dashboard accesses all data in **Xplorobot Compliance Database** and displays current emission levels, emission source, status of mitigation activities and any system notifications to facilitate informed management decisions and compiling reports per regulatory requirement.

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Table of Contents

1. Proposal description

1.1. Overview

Exploration Robotics Technologies, Inc. (Xplorobot), in partnership with Utah Gas Corp. (UGC), is proposing to the Colorado Department of Public Health and Environment (CDPHE) an Alternative Approved Instrument Monitoring Method (AAIMM) Application.

CDPHE Regulation 7 defines the information that must be submitted as part of the approval process for the AAIMM. Summarized below is the required information, with references to the sections of this document that provide detailed information for each requirement.

I.L.8.a.(ii)(A): The proposed Alternative Approved Instrument Monitoring Method utilizes a quantitative measurement system: **Xplorobot Active Laser Optical Gas Imaging (Xplorobot Laser OGI)**. The Tunable Diode Laser Absorption Spectroscopy Sensor (TDLAS) estimates the average methane concentration in the column of air between the sensor and the reflection point of the laser on the specific component that is being inspected. **Xplorobot Inspector** software uses the plume's aerial extent, methane concentration around the emissions point, and wind speed recorded during the inspection of the specific component to estimate the methane emissions rate. (See Section 7 for details of the emissions quantification procedure).

I.L.8.a.(ii)(B): **Xplorobot Laser OGI** and **Xplorobot Inspector** software are available commercially and are used by multiple oil and gas operators in the United States and abroad as part of their LDAR programs. (AIMM Application form, Section 1)

I.L.8.a.(ii)(C): Usage of the TDLAS (as part of the general category of Infrared Laser Beam Illuminated Instrument) is approved by the United States Environmental Protection Agency for monitoring methane emissions under 40 CFR Part 98 Subpart W. (AIMM Application form, Section 2)

I.L.8.a.(ii)(D): Leak detection capabilities of the **Xplorobot Laser OGI** have been tested at the Methane Emissions Technology Evaluation Center (METEC), the Alberta Methane Emissions Program (AMEP) and at the Lawrence Berkeley National Laboratory (LBNL). The 90% confidence detection limit of 4.0 standard liters per minute demonstrated at METEC falls in the 90% confidence limit range for Infrared OGI cameras operated by most experienced LDAR inspectors (between 2.6 standard liters per minute and 7.7 standard liters per minute). (See Section 4 and Section 5 for control rate and blind testing of the **Xplorobot Laser OGI**). (See Section 3 for discussion and data supporting the reliability and limitations of **Xplorobot Laser OGI**, including the ability to identify specific leaks, locations, and detection limits). Furthermore, in METEC blind testing, **Xplorobot Laser OGI** demonstrated detection probability above 80% in the range from 1 standard liter per minute to 4 standard liters per minute.

At the Lawrence Berkeley National Laboratory controlled release tests and in field conditions at sites managed by the United States Forest Service, **Xplorobot Laser OGI** demonstrated the ability to detect emissions at 0.025 standard liters per minute or 1 gram per hour in field conditions as verified by a Semtec Hi Flow device.

I.L.8.a.(ii)(E): The frequency of measurements for **Xplorobot Laser OGI** are proposed to mirror the frequencies defined in the LDAR programs per Sections I.L. and II.E of Regulation 7. **Xplorobot Laser OGI** and **Xplorobot Inspector** software create **Digital Emission Tags** and **Digital Compliance Records** stored in the **Compliance Database** (See Section 2 and Section 7.

I.L.8.a.(ii)(F): Precision and bias data quality indicators for **Xplorobot Laser OGI** are provided in Section 3.

I.L.8.a.(ii)(G): Quality control and quality assurance procedures necessary to ensure proper operation of **Xplorobot Laser OGI** are outlined in the Operating Procedure (see Section 7).

I.L.8.a.(ii)(H): **Xplorobot Laser OGI** is proposed as a monitoring instrument method at the frequencies specified by Regulation 7 Sections I.L. and II.E for Approved Instrument Monitoring Methods.

I.L.8.a.(ii)(I): **Xplorobot Laser OGI** achieves emission reductions that are at least as effective as the emission reductions achieved by the leak detection and repair provisions in Section I.L. because **Xplorobot Laser OGI** provides the 90% confidence detection limit equivalent to the Infrared Optical Gas Imaging cameras that are currently approved to meet the requirements of LDAR inspections specified by Sections I.L. and II.E of AQCC Regulation 7 Part B. Section 4 details the 90% detection limit per blind testing at METEC.

1.2. Applicant Team

1.2.1. List all applicants and contact information

Applicant	Company	Role	Email
Oleg Mikhailov	Exploration Robotics Technologies, Inc.	CEO	oleg@xplorobot.com
J. Wayne Ballew, Jr.	Exploration Robotics Technologies, Inc.	COO and General Counsel	jwayne.ballew@xplorobot.com
Taryn Weiner	Utah Gas Corp	Manager, Air and Sustainability	tweiner@utahgascorp.com
Adam Hayman	Alberta Methane Emissions Project	Director	adam.hayman@amep.ca

Doug Benevento	Holland and Hart	Partner	dhbenevento@hollandhart.com
Anne Austin	Austin Legal & Public Affairs PLLC	Partner	anne@austin-legal.com

Table 1 Program participants, their organizations, roles, and contact information.

1.3. Program Scope

1.3.1. Facilities, companies, production types, and value chain segments

The scope of this proposed AAIMM is all regulated facilities that require a leak detection and repair (LDAR) program under the Department of Public Health and Environment, Air Quality Control Commission, Regulation 7, including Storage Tank Emission Management (Regulation 7, Part B, II.C.2)

Regulation 7 has separate rules for facilities inside and outside the 8-hour Ozone Control Area; regardless of facility jurisdiction, the facility types requiring mandatory LDAR are well-production facilities and natural gas compressor stations. All natural gas compressor stations require an LDAR program, regardless of jurisdiction. Whether a well production facility requires an LDAR program is based on a facility's yearly total volatile organic compound (VOC) emissions on a 12-month rolling total. The specifics of required LDAR programs for well production facilities that require one are based on the facility's VOC emissions, proximity to occupied areas, and, beginning January 1, 2023, if the facility resides in a disproportionately impacted (DI) community.

The scope of this application encompasses the monitoring requirements of all facility types that require LDAR and all components that require monitoring with an approved instrument monitoring method (AIMM) under the Colorado Department of Health and Environment, Regulation 7.

The U.S. Energy Information Administration indicates that in 2020, there were 37,833 producing wells in Colorado. *Figure 1* shows the locations of active wells in Colorado. If approved, Operators can choose to build an LDAR program based on the technology described in this AAIMM or construct an LDAR program based on an existing AIMM.

1.3.2. Geographical coverage

Colorado accounts for just over 4% of total U.S. petroleum production and has the 7th largest gas reserves of any state. Most hydrocarbon production stems from the Denver-Julesburg (D.J.) Basin in northeastern Colorado and the Piceance Basin in western Colorado (*Figure 1*). Within the D.J. basin, the largest producing field is the Wattenburg Field, which accounts for 9 out of every 10 barrels of crude oil produced in Colorado.

Natural gas production has recently migrated away from dry natural gas production in the Piceance basin to the liquid natural gas exploration and production of the D.J. basin.

Hydrocarbon-bearing shale reservoirs have become exploitable with the advent and widespread adoption of horizontal drilling and hydraulic fracturing. As a result, the Niobrara Shale Formation is Colorado's most productive formation.

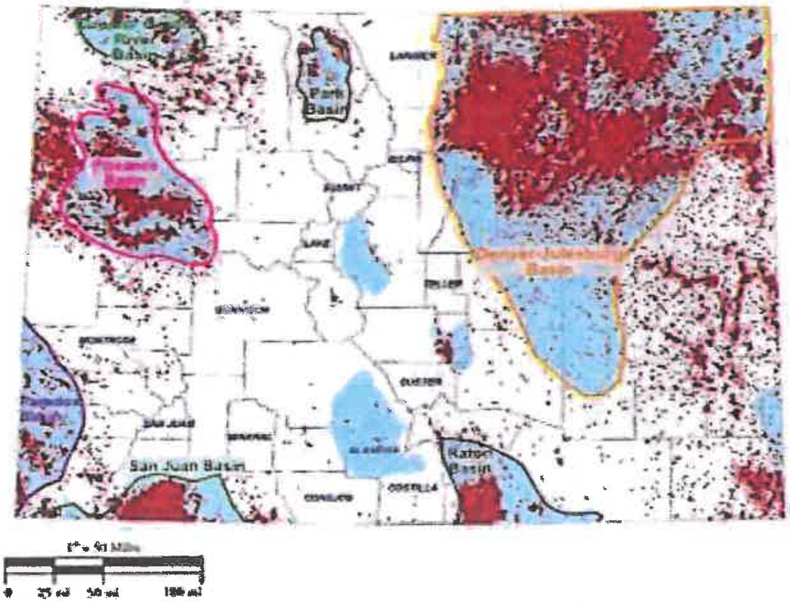


Figure 1. Colorado facilities requiring LDAR.

2. Description of the Alternative LDAR program

2.1. Summary of the Alternative LDAR program

The proposed alternative LDAR program utilizes the hand-held **Xplorobot Active Laser Optical Gas Imaging (Xplorobot Laser OGI)** device to inspect equipment and components at oil and gas facilities. All data acquired by **Xplorobot Laser OGI** is processed by **Xplorobot Inspector** software. **Xplorobot Compliance Database** and **Methane Emissions Management Dashboard** for oil and gas operations.

Xplorobot Laser OGI is designed for use in the LDAR programs defined in Sections I.L and II.E of AQCC Regulation 7, Part B, without modification to the scope or frequency thereof. **Xplorobot Inspector** software automates the recording, communication, storage, and reporting of methane emissions per the requirements of Regulation 7. For each emissions point identified during the inspection, **Xplorobot Inspector software** creates a **Digital Emission Tag** and sends notifications to all stakeholders involved in the emissions tracking and mitigation. For components and equipment not emitting methane (or within allowable limits), **Xplorobot Inspector Software** creates **Digital Compliance Records** in the form of methane concentration maps overlaid on 2D images or 3D models of that equipment or components. All **Digital Emissions Tags** and **Digital Compliance Records** are stored in the integrated **Compliance Database** for the oil and gas Operator. The Operator's personnel can access the information stored in the **Compliance Database** through a map-based **Methane Emissions Management Dashboard**. The information maintained in the **Compliance Database** is used to compile and submit annual reports to the CDPHE per Regulation 7. It retains all the LDAR inspection data per the Regulation 7 record keeping requirements.

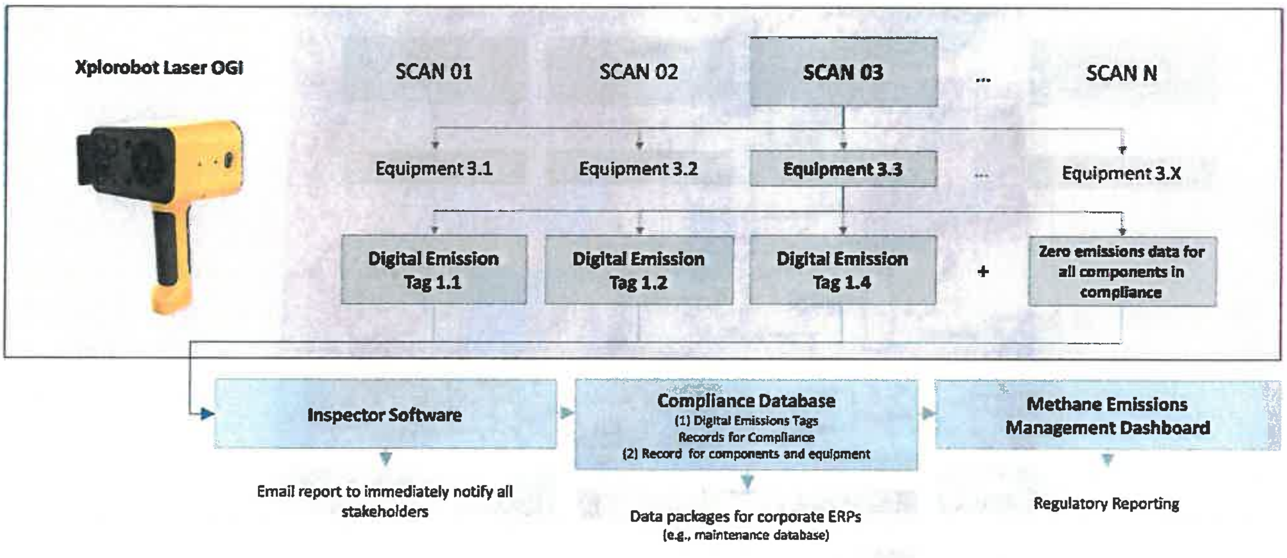


Figure 2. Xplorobot data flow, recordkeeping and reporting.

2.2. Roles and Responsibilities

The parties with responsibilities in the proposed alternative AIMM are Xplorobot and the Operator (this may be an oil and gas operator for well production facilities or the company that owns/operates a natural gas compressor station). The roles and responsibilities of each party are as follows:

1. Xplorobot:

a. Provide **Xplorobot Laser OGI** to the Operator and conduct on-site training for using the device.

b. Consult the Operator on the efficient design of the inspection scope and routes to meet the requirements of Regulation 7.

c. Install **Xplorobot Inspector** software on the purpose-specific computers or servers utilized by the Operator to (i) process data acquired by the **Xplorobot Laser OGI** device and (ii) maintain the **Xplorobot Compliance Database** that documents **Digital Emissions Tags** and **Digital Compliance Records**.

d. Ensure that all the relevant information required for proper documentation of **Digital Emissions Tags** and **Digital Compliance Records** are maintained in the **Xplorobot Compliance Database**.

e. Implement electronic notification of relevant emissions information to the Operator's stakeholders per the Operator's standard operating procedures.

f. Design and deploy the **Methane Emissions Management Dashboard** to (i) facilitate communication of information to all stakeholders and (ii) compile annual reports per Regulation 7.

g. Provide the Operator with the link between the **Xplorobot Compliance Database** and the Operator's corporate databases (e.g., Maintenance Database) for complete and timely transmission of the data required for emissions mitigation to those databases.

h. Conduct routine quality assurance and quality control reviews of data gathered.

i. Perform planned and periodized inspections of system components to guarantee functionality.

2. Operator:

a. Work collaboratively with Xplorobot to identify the inspection scope and frequency necessary to ensure compliance with Regulation 7.

b. Assign Operator personnel or third-party contractors to perform Regulation 7 inspections using **Xplorobot Laser OGI**. Ensure these personnel receive training from Xplorobot.

c. Enact Xplorobot as the responsible party for 3rd party inspections.

d. Provide computers to install **Xplorobot Inspector** software to process data acquired during inspections.

e. Provide Xplorobot with the list of sites, equipment, and component types for setting up the **Compliance Database** and the Methane Emissions Management Dashboard.

f. Perform scans of equipment and components per the requirements of Sections I.L. and II.E of AQCC Regulation 7, Part B, using **Xplorobot Laser OGI**, following the standard operating procedure detailed in Section 7.

g. Record emission points identified during inspections using the "**Digital Emissions Tag**" functionality of the **Xplorobot Laser OGI** to create Digital Emission Tags for each.

h. Download the data acquired during inspection to the **Xplorobot Inspector** software and ensure that proper site, equipment, and component information is added to the Digital Emission Tags for submission to the Xplorobot **Compliance Database**.

i. Classify the Digital Emission Tags as "fugitive emissions," "as-designed emissions," or "permitted emissions" for proper follow-up and mitigation measures upon submission to the Xplorobot

Compliance Database.

j. Reference historical **Digital Compliance Records** for components where emissions were identified to establish emissions duration.

k. Utilize the Xplorobot **Compliance Database** to plan follow-up and mitigation actions.

l. Perform verification inspection of the fugitive emissions points post-repair to ensure proper documentation and reporting per Regulation 7 and create **Digital Compliance Records** for the repaired components.

m. Submit an annual report of all LDAR details to the CPDHE as per AQCC Regulation 7, Part B, Sections I.L.7, and II.E.9, and in regard to reporting of pneumatics, Part B, Section III.F.5 (CDPHE Instructions).

2.3. Description of Each Method Used in the AAIMM LDAR Program

2.3.1. Xplorobot Laser OGI device and Digital Inspection Tags

The main components of **Xplorobot Laser OGI** 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. The TDLAS sensor emits a laser beam with the wavelength of 1653 nanometers that is absorbed by methane molecules, thus enabling determination of the column-concentrated methane concentration in the air column between the sensor and the point which reflects the infrared laser beam back to the device. 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 3* below shows the **Xplorobot Laser OGI** and its elements.

Under the proposed AIMM, 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. 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. **Xplorobot Laser OGI** captures methane concentration data at a rate of ten readings per second and visual information at a rate of 5 images per second. *Figure 4* illustrates the typical procedure for employing the **Xplorobot Laser OGI** in LDAR surveys.

Xplorobot Laser OGI uses a TDLAS sensor with a methane detection range of 50 meters. From ground level, the device has demonstrated the ability to detect emissions from overhead flanges, vents, and thief hatches at heights over 2 meters above ground. Therefore, the **Xplorobot Laser OGI** significantly reduces the number of Components deemed unsafe to inspect under Regulation 7, Part B, Sections I.L.3 and II.E.5.

Figure 3. Xplorobot Laser Optical Gas Imaging Device and its elements.

Figure 4. Scanning equipment and components with Xplorobot Laser OGI device.

Xplorobot Laser OGI displays TDLAS sensor measurements on the device screen. The **Xplorobot Laser OGI** threshold for methane emissions alert is set at a column-integrated concentration of 50 ppm-m. When the concentration measured exceeds 50 ppm-m, the device emits a beeping noise, alerting the person conducting the methane inspection to identify a potential emission point. The concentration display turns yellow for values between 50 ppm-m and 500 ppm-m and red for values above 500 ppm-m.

To establish the equivalency between **Xplorobot Laser OGI** and Method 21, we ran as set of controlled release experiments (verified by a Semtec Hi Flow device in the range of emissions rates between 0.01 standard liters per minute (0.4 grams per hour) to 18.2 standard liters per minute (787 grams per hour). The cross-plot of the Method 21 measurements to **Xplorobot Laser OGI** measurements is shown in *Figure 5*. In practice, there is no exact way to establish the equivalency between a local concentration measurement with a Method 21 device and a column-integrated concentration measurement with a TDLAS laser because the distribution of methane in 3D space and the concentration profile for an emission source are determined not only by the emission rate but also by the wind distribution, by the velocity with which gas is escaping from the emission point, the geometry of the equipment and other factors. In the controlled rate experiments, for all emissions rates where the Method 21 device read values above 500 ppm, the **Xplorobot Laser OGI** read values over 500 ppm-m. We, therefore, propose to establish the Detection Threshold for **Xplorobot Laser OGI** at 500 ppm-m as an equivalency threshold to 500 ppm for Method 21.

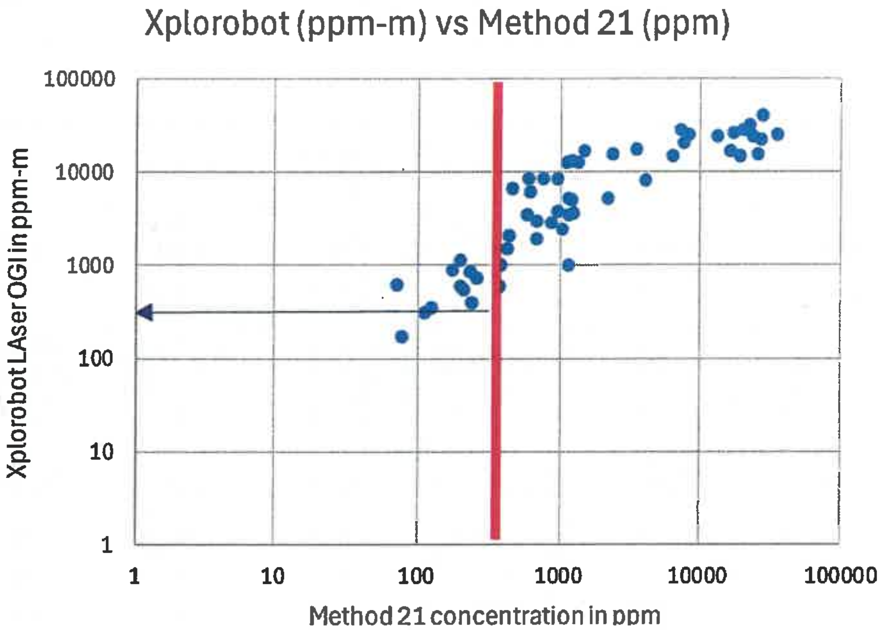


Figure 5. Equivalency between Xplorobot Laser OGI and Method 21 sniffer suggesting the 500ppm-m as the Detection Threshold for Regulation 7.

During inspection of equipment other than Storage Tanks, when an inspector identifies a potential emission point at the 500 ppm-m threshold, they use the green location laser to investigate the area of possible emission and locate the point of emission. Upon locating the emission point, 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 **Xplorobot Laser OGI** screen. *Figure 6* shows the methane concentration and emission visualization on the screen of **Xplorobot Laser OGI**. *Figure 7* provides an example of the visualization of methane emission otherwise not visible by the naked eye using **Xplorobot Laser OGI**.

During inspection of Storage Tanks (including, without limitation, thief hatches, PRVs and/or other access points to the tank), when an inspector identifies column-integrated concentration above zero, they record a Digital Emission Tag for that emission. Per the Storage Tank Emission Management requirements of AQCC Regulation 7, any concentration above zero is required to be recorded as an emission source. Please refer to the **Xplorobot Laser OGI** operating manual for specific instructions on Storage Tank inspection.

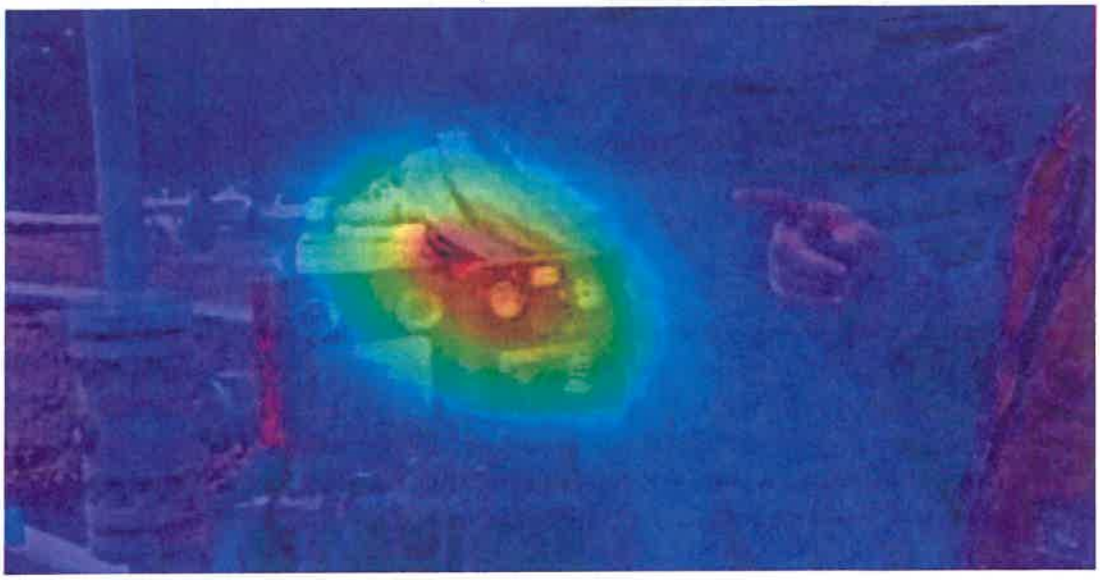


Figure 6. Detection of the emission (column-integrated concentration above 500ppm-m) and visualization of the emission otherwise not visible to the naked eye by the Xplorobot Laser OGI device.

Pressing the "**Digital Emission Tag**" button automatically creates a **Digital Emission Tag** that consists of:

(i) Digital photo and visualization of the emission in a form of a map of methane concentration measured at and around the emission point displayed in a color scale from blue (zero) to red (maximum ppm-m detected).

(ii) Maximum column-integrated methane concentration at and in the vicinity of the emission point.

(iii) Estimate of the emission rate in intervals "<1g/hr.", "1-15 g/hr.", "15-50 g/hr.", "50-150 g/hr.", "150-500 g/hr." and ">500g/hr."

(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 location.

Figure 7. Visualization of methane emission is otherwise not visible to the naked eye, attributing the emission to the specific component (flange).

The real-time visualization of the emission is based on high-resolution photographs to provide attribution of the emission to a specific component. The same high-resolution photograph or 3D model 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 required information for emissions reporting per AQCC Regulation 7.

2.3.2. Xplorobot Inspector Software and Digital Compliance Records

Upon inspection completion, all visual, methane, GPS, and meteorological data captured by **Xplorobot Laser OGI** is securely transferred via an ethernet cable or Wi-Fi connection to a computer running proprietary **Xplorobot Inspector** software that includes an oil and gas operations database of sites, equipment, and components. 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 from equipment or components, emissions requiring follow-up investigation (emissions from storage tanks) and as-designed emission (e.g. pneumatic devices). Other classifications can be added per operator's requirements.

In the course of an inspection, **Xplorobot Laser OGI** records methane, visual, GPS and meteorological data to document compliance for components and equipment that do not emit methane or are within allowable limits. As equipment and components are scanned, **Xplorobot Laser OGI** accumulates records of methane concentrations that are zero or below the threshold defined by AQCC Regulation 7 at 500 ppm for Method 21 and the proposed Detection Threshold for **Xplorobot Laser OGI** at 500 ppm-m. All records of methane column concentration are downloaded into **Xplorobot Inspector** upon completion of the inspection. **Xplorobot Inspector** processes these records and creates **Digital Compliance Records** for components or equipment that do not emit methane or that emit methane within allowable limits.

Xplorobot Inspector 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 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 8* provides examples of **Digital Compliance Records.**

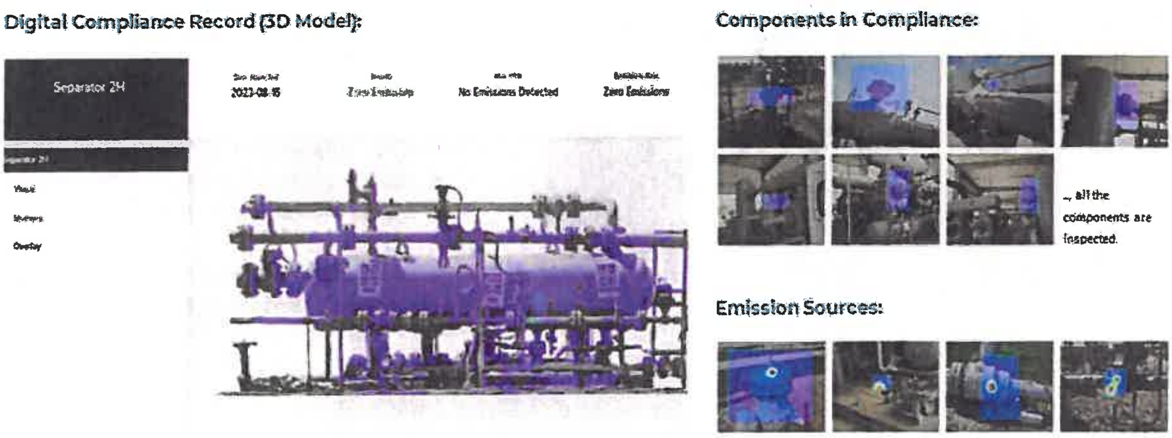


Figure 8. Digital Compliance Records include 3D and 2D methane concentration maps for equipment and components.

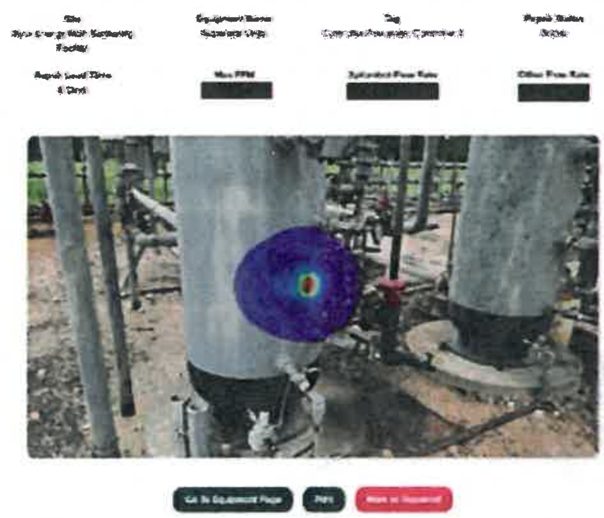
2.3.3. Compliance Database and Operator Notification

All **Digital Emissions Tags** are uploaded to the **Xplorobot Compliance Database** and the **Methane Emissions Management Dashboard** for access by stakeholders in the LDAR program. The **Compliance Database** is then used to report the emissions per the requirements of AQCC Regulation 7.

Upon entering the **Digital Emissions Tags** into the **Compliance Database, Xplorobot Compliance Database** automatically notifies (by email or other means of electronic communication) all stakeholders in reporting, repairing, and mitigating the emissions. Repairs will be conducted on tagged emissions along the timelines outlined in Regulation 7 Part B, Sections I.L.5. and II.E.7 (and for pneumatic controllers, III.F.2). When repairs are completed, **Xplorobot Laser OGI** is used to verify the repair and **Digital Compliance Records** are then created and documented in the **Compliance Database**.

Digital Compliance Records stored in the **Xplorobot Compliance Database** provide auditable records of zero emissions to enable quality control of the LDAR programs and component-level (bottoms-up) to site level (top-down) reconciliations. Importantly, the ability to access historical **Digital Compliance Records** for components found to be emitting methane in subsequent inspections allows the Operator to define the duration of the emissions to estimate the emissions volume for reporting under 40 CFR 98 Subpart W or Colorado AQCC Regulation 7.

Visualization and Information on the Dashboard:



Compliance Database Entries

- **Date:** 2024-06-12
- **Time:** 13:26
- **Operator:** Rusk Energy
- **Site:** Main Gathering Facility
- **Equipment:** Separator X
- **Component:** Pneumatic Controller X
- **Maximum Concentration:** XXX
- **Emission Rate Estimate:** XXX
- **Emission Rate Confirmation:** XXX
- **GPS Coordinates:** 29.746 -96.574
- **Wind Speed:** 6.7 mph
- **Atmospheric Pressure:** 101.62 kPa

- **Repair Status:** Active
- **Repair Lead Time:** 6 days

Figure 9. Notification based on a Digital Emission Tag.

2.3.4. Methane Emissions Management Dashboard

Xplorobot facilitates access to all data in the **Xplorobot Compliance Database** utilizing a map- based **Methane Emissions Management Dashboard** that provides an "operations view" (*Figure 10a*) of all the sites and equipment with all emission sources. The Dashboard provides access to all the **Digital Emissions Tags** and **Digital Compliance Records** stored in the **Xplorobot Compliance Database**. It allows tracking of repairs and post-repair verifications.

The **Methane Emissions Management Dashboard** also provides an "analytics view" (*Figure 10b*) of the emissions source counts and volumes on regional, site, and equipment levels. The Dashboard provides functionality for emissions analytics, site, equipment, component-level compliance, and historical inspection records. The Dashboard autonomously generates all fugitive emissions reports required per AQCC Regulation 7.

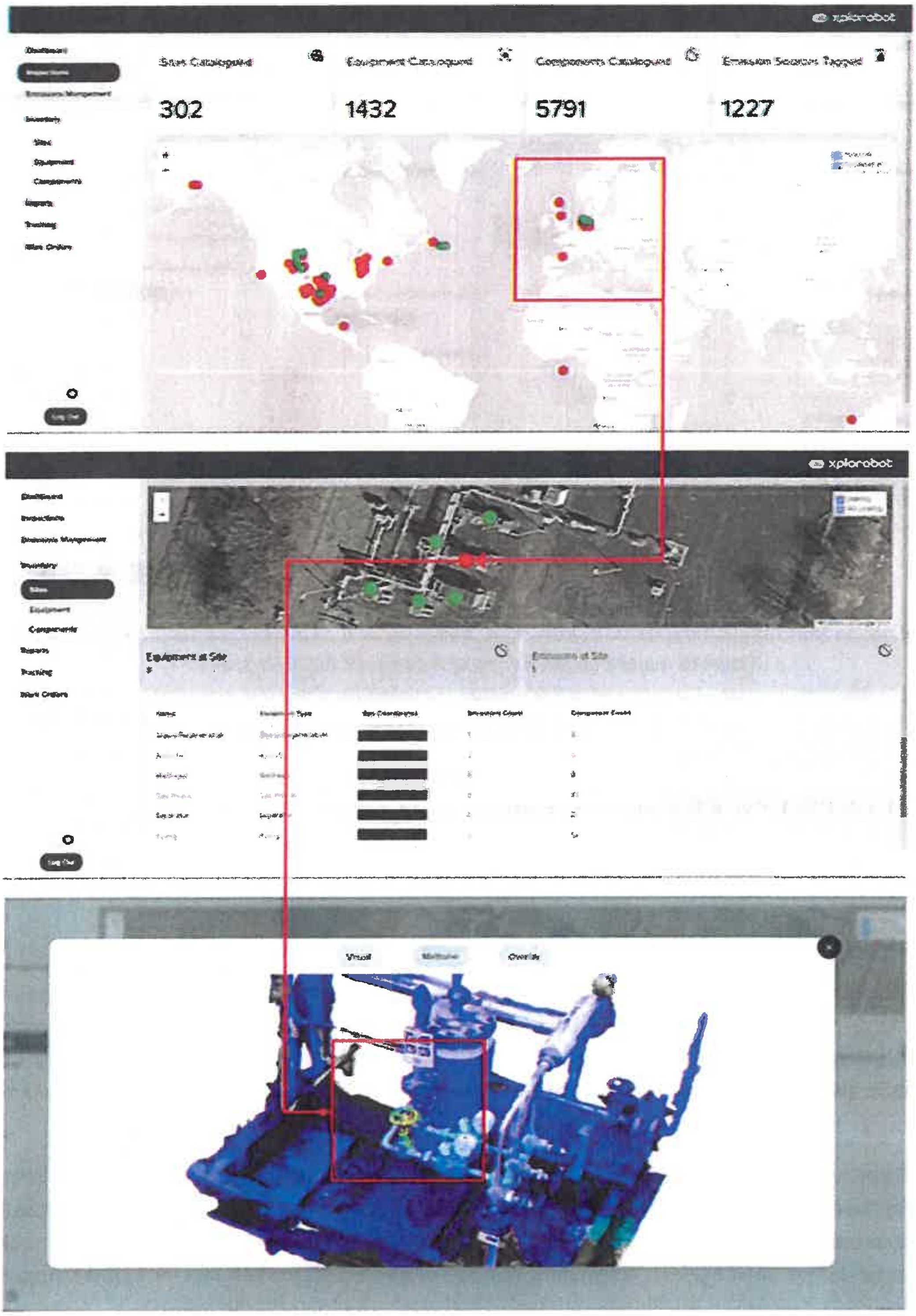


Figure 10a. The Methane Emissions Management Dashboard "operations view" provides access to information for specific sites, equipment, and components as well as all the inspection results through a map=based interface.

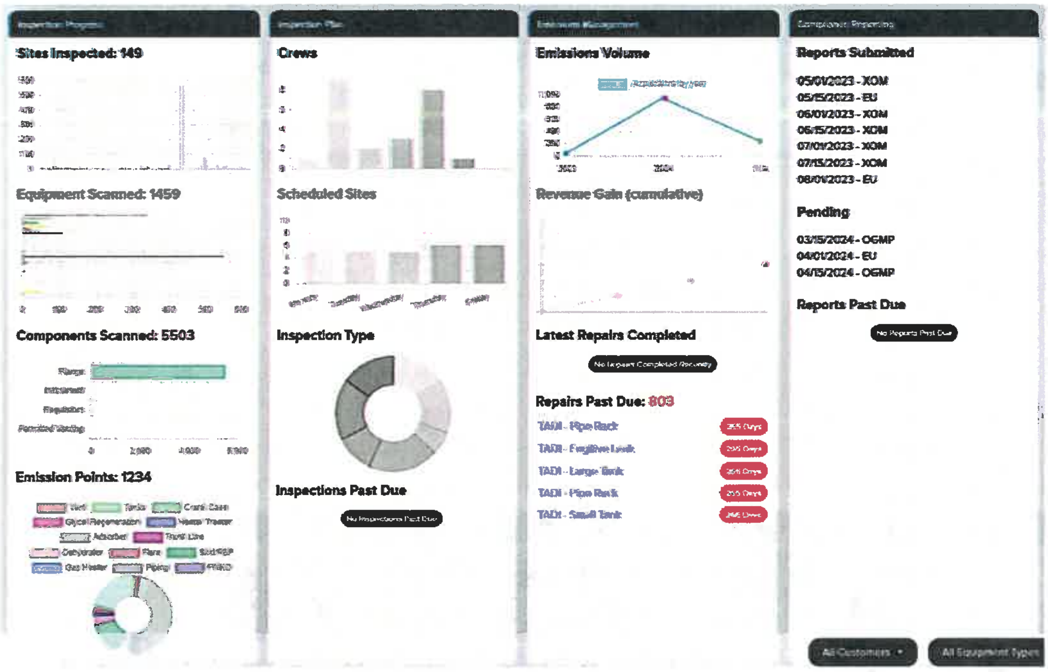


Figure 10b. The Methane Emissions Management Dashboard "analytics view" provides emission sources counts and volumes and enables automatic generation of reports per AQCC Regulation 7.

3. Xplorobot Laser OGI Device Detailed Overview

3.1. Description of Technology Used in Xplorobot Laser OGI

3.1.1. General technology description

Xplorobot Laser OGI is an integrated device that consists of multiple sensors, including a Tunable Diode Laser Absorption Spectrometry (TDLAS) sensor for measuring methane concentration, a computer that controls the acquisition of data by multiple sensors, and a touchscreen display that provides a User Interface. The display shows recorded methane concentration and visualizes methane emissions that are otherwise not visible to the naked eye.

The TDLAS sensor used by Xplorobot falls into the general category of "Infrared Laser Illuminated Devices" defined in the United States EPA 40 CFR Part 98 Subpart W and, therefore, is acceptable for methane emissions monitoring as defined in Subpart W. **Xplorobot Laser OGI** is integrated such that it meets the definition of Optical Gas Imaging device per United States EPA 40 CFR Part 60, Appendix K as a device that visualizes methane emissions otherwise not visible to the naked eye.

Xplorobot Laser OGI software creates **Digital Emissions Tags** for all identified emission points, complete with the visualization video of methane emissions otherwise not visible to the naked eye, GPS location of the emission recording, wind and temperature data, and time stamp. Upon uploading data to the **Xplorobot Inspector** software, the site, equipment, and component information is added to the **Digital Emission Tag**. The Tag provides localization of the emission source based on high-resolution photographs or 3D models created using these photographs. Therefore, the **Digital Emission Tag** provides localization within a fraction of an inch, pinpointing the source of the emissions to a specific component or even a bolt on that component.

Additionally, **Xplorobot Laser OGI** records methane concentration data for all components, including those in compliance. Based on the data, **Xplorobot Inspector** creates **Digital Compliance Records** for equipment and components that do not emit methane, components for which methane concentration is measured below the detection threshold of 500 ppm-m.

3.1.2. Xplorobot Laser OGI Components

Xplorobot Laser OGI, presented in *Figure 11* below, consists of the following components.

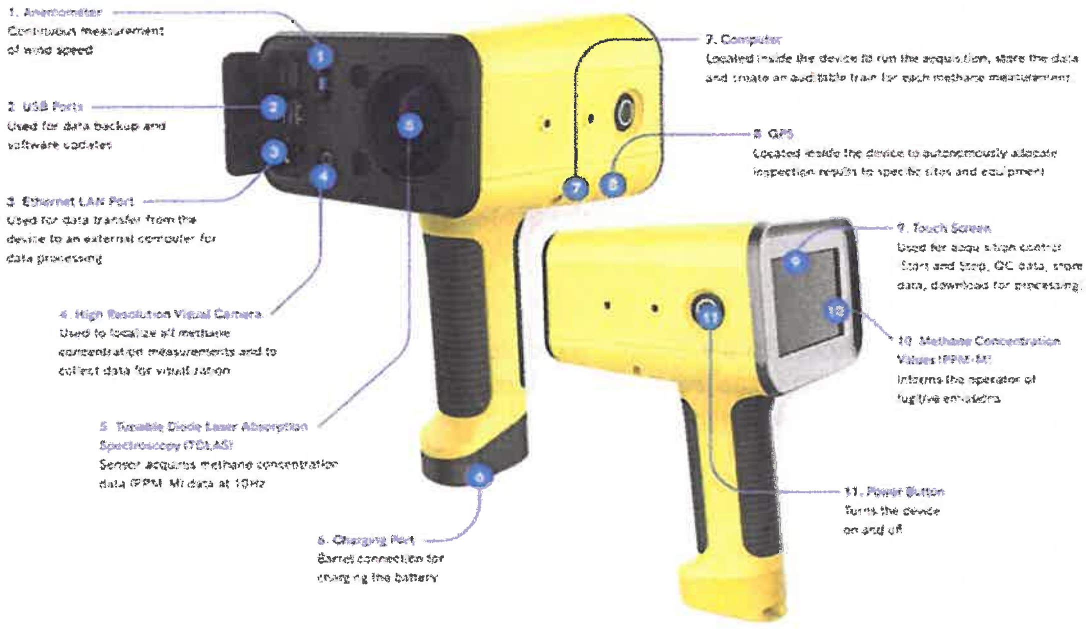


Figure 11. Xplorobot Laser OGI

a) Tunable Diode Laser Absorption Spectroscopy (TDLAS):

Xplorobot Laser OGI measures column-integrated methane concentration using a TDLAS sensor. 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.

b) High-Resolution Visual Camera:

A high-resolution visual camera is used to capture images during the performance of an inspection. 3MP images are recorded at a frequency of 5 Hz. The recorded images are used to visualize the methane emissions otherwise not visible to the naked eye and to create **Digital Emissions Tags** and **Digital Compliance Records.**

c) Computer

An onboard computer is the main processing unit for **Xplorobot Laser OGI**. All information gathered from the sensors interface with this computer, which initiates the device, runs the data acquisition, stores the recorded information, and provides an inspection summary through the device screen or a wired connection to the on-site computer.

d) Anemometer

An anemometer records wind speed data at 5 Hz. It is used during methane flow rate estimations to improve dispersion modeling.

e) Thermometer (part of the anemometer)

A thermometer is used to record the temperature at the inspection location.

f) GPS

A GPS unit records the approximate position of the inspection. This information is then cross-referenced to a database of the Operator's site locations. If the coordinates match a known location, the site is automatically assigned to the inspection.

g) Touch Screen Display

The touch screen is the main interface of the device. The screen provides a User Interface for the device to perform the following tasks:

- Initiating the scan.
- Displaying methane concentration (ppm·m) and wind speed readings at the laser's current location
- Visualizing methane emissions otherwise invisible to the naked eye for each emission source identified during the inspection.
- Creating **Digital Emission Tags** for each emission source identified during the inspection.
- Finishing the scan.
- Reviewing a summary of the scan, complete with information for each.
- Saving the data acquired during the scan.

Figure 12 provides an example of the User Interface of **Xplorobot Laser OGI**.

Figure 12. User interface of Xplorobot Laser OGI.

h) Battery A Lithium-Ion battery is enclosed in the handle. The battery life of the device is approximately 4 hours of continuous scanning.

i) Miscellaneous Other miscellaneous components in the device include the following:

- A buzzer is used as an aid while scanning. If the measured column-integrated concentration exceeds the 50 ppm-m value, the buzzer sounds to notify the person conducting the methane inspection of the presence of an emissions source in the area of inspection.
- **Xplorobot Laser OGI** screen displays the maximum methane column-integrated concentration detected during the scan since the last Digital Emission Tag has been recorded. In inspections of Storage Tanks, the maximum column-integrated concentration indicator is used to confirm whether any measurements above Zero have been recorded to ensure compliance with the AQCC Regulation 7 requirements for Storage Tanks inspection. In case the inspector did not record the Digital Emission Tag for that emission, pressing on the maximum column-integrated concentration indicator brings out the visual photograph corresponding to this measurement, enabling the inspector to review the location where the detection occurred and return to that location to record the Digital Emission Tag.
- A Real Time Clock (RTC) is used to keep an accurate time measurement on the device. The time zone is automatically set to the location where the device is being used. The clock provides timestamps for all measurements and post-inspection quality control that the dwell (stare) time requirements are met.

3.1.3. Manufacturer information

Xplorobot Laser OGI is manufactured by **Exploration Robotics Technologies Inc.**, a corporation organized under the laws of Delaware in August 2019 and headquartered in Houston, Texas.

3.1.4. Technology maturity

The **Xplorobot Laser OGI** is at technology readiness level (TRL) 9, corresponding to fully mature technology that has been successfully deployed in its intended operational environment. **Xplorobot Laser OGI** has been deployed in 308 facilities operated by 42 operators in 6 countries on 3 continents.

3.1.5. Commercial availability

Xplorobot Laser OGI and **Xplorobot Inspector** are commercially available worldwide. They have been deployed in the United States, Canada, The United Kingdom, France, Germany, and Australia.

3.1.6. Temporal and spatial scale

Temporal Scale:

Xplorobot Laser OGI inspection is proposed to be used annually, semi-annually, and/or quarterly, as prescribed by Regulation 7, Part B, Sections I.L. and II.E for each site, equipment, and/or component.

Xplorobot Laser OGI records methane concentration measurements ten times per second, providing the Operator with a time-efficient method for documenting compliance. Xplorobot recommends (i) a 1-second dwell time for each stand-alone component not emitting methane to document compliance and (ii) a 10-second interval for recording concentration at and around each emission point to create a detailed **Digital Emissions Tag**. The recommended Operating Practices for **Xplorobot Laser OGI** are detailed in **Section 7**.

Spatial scale:

The spatial resolution of **Xplorobot Laser OGI** is 0.4 centimeter at a measurement distance of 1 meter and 20 centimeters at a distance of 50 meters. At low emissions rates (e.g., 1 gram per hour), **Xplorobot Laser OGI** can distinguish between emissions on adjacent bolts on a flange. At high emissions rates (e.g., over 1 kg per hour), **Xplorobot Laser OGI** uses the concentration distribution to localize the emissions location to within 5 centimeters. In a typical inspection, a combination of the **Xplorobot Laser OGI** localization accuracy, the ability to visualize the emissions on the screen of the device, and the Operator's knowledge of the equipment are used in concert to attribute the emission to the specific component (e.g., rod packing vent, flange, gauge, or vent). Based on the laser aperture, the spatial resolution of **Xplorobot Laser OGI** increases to approximately 20 centimeters at 50 m distance.

3.2. Technology Limitations

The main limitation of the TDLAS sensor is the necessity of a reflection point for the laser behind the methane plume being characterized. This limitation is not typically encountered when inspecting well heads, separators, vessels, compressors, or piping racks, as the laser is reflected off the specific component inspected.

When inspecting a storage tank thief hatch or pressure relief valve (PRV) from ground level, the laser should be pointed such that it reflects from the thief hatch or PRV. If necessary, the person conducting the methane inspection should step back from a tank to a position where they can reflect the laser off the thief hatch or PRV. ***Figure 13*** provides an example of a thief hatch emission detection from ground level.

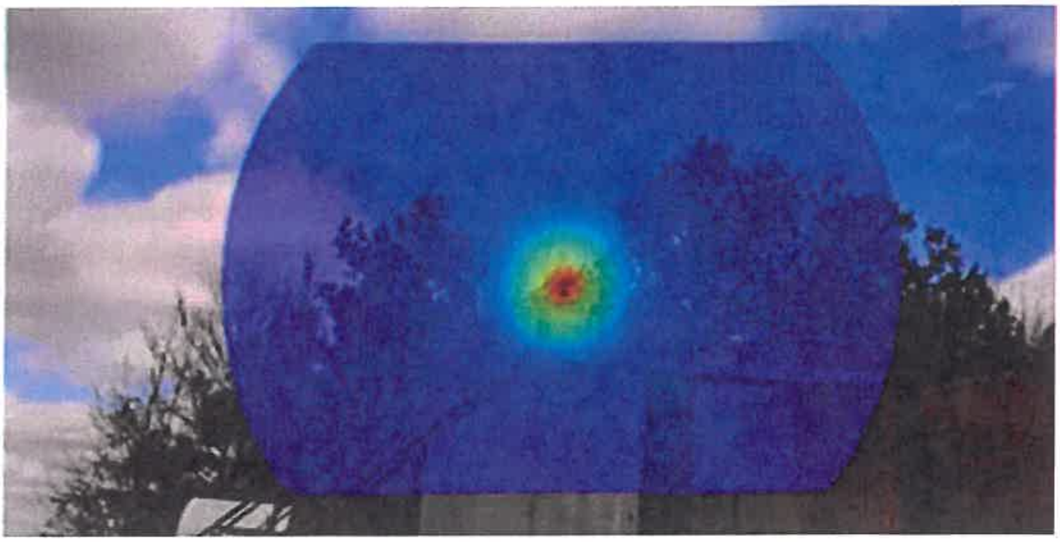


Figure 13. Thief hatch emission detection from the ground.

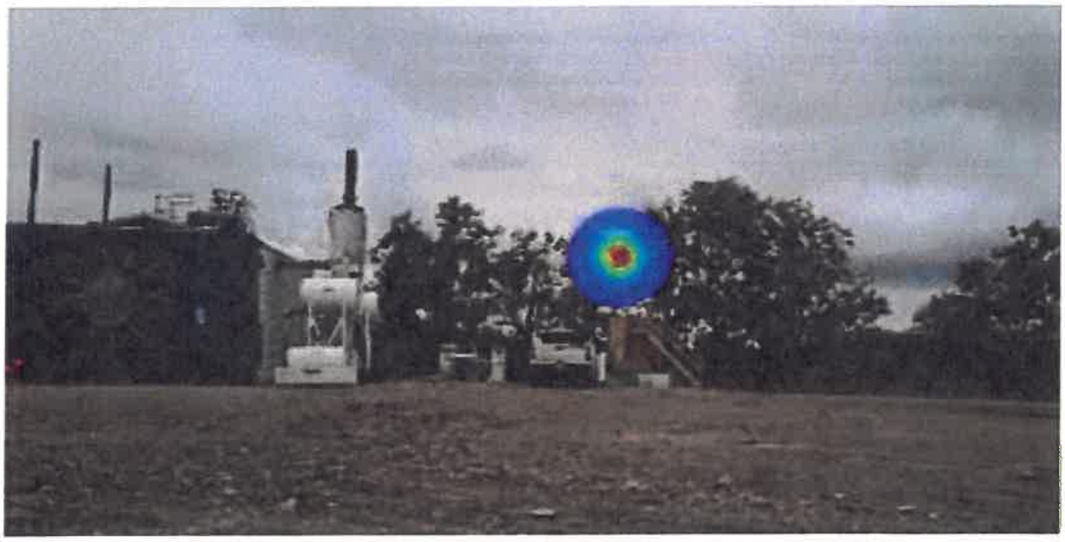


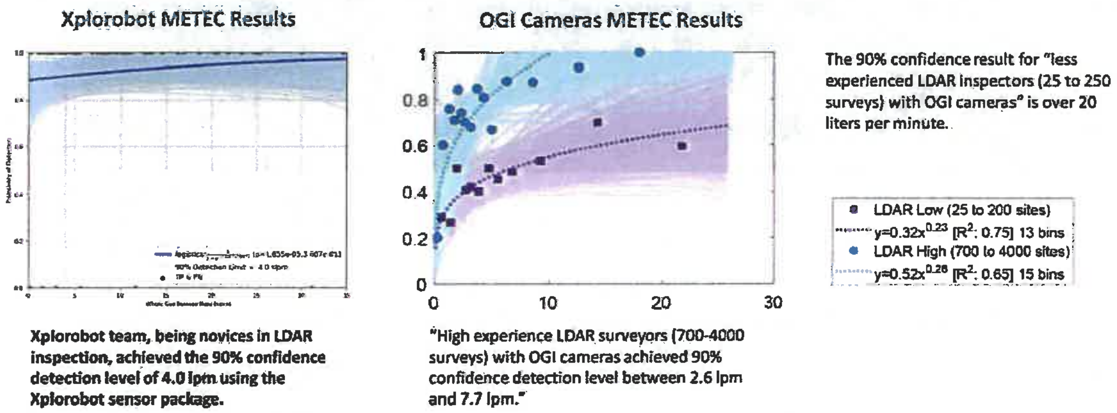
Figure 14. Detection of an open vent emission utilizing the tree behind the vent to reflect the laser.

Detection of emissions from a PRV or open vents may not be possible if no reflection point exists behind the PRV or vent. In some cases, emissions can be detected if the plume extends below the vent's rim and the laser can be reflected from the rim (or if the vent has a rain cover, it can be used as a reflection point). In other cases, objects behind the vent (e.g., a tree) can be used as a reflection point. One of Xplorobot customers recommended that a small metal triangle be fixed at the top of the vent to facilitate emission detection using **Xplorobot Laser OGI**. Operators well-receive this simple and economical modification to existing equipment/components, given the overall cost savings and operational efficiency provided by **Xplorobot Laser OGI**.

3.3. Quality Control

3.3.1. Indications of precision and bias

Blind testing at the Methane Emissions Technology Evaluation Center indicated a 90% detection confidence level of 4 liters per minute, matching the performance of the Infrared Optical Gas Imaging cameras in the hands of most experienced LDAR inspectors (Zimmerle et al., 2020). Please see Section 4 for more details.



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.*

Figure 15a. Comparison of the Xplorobot Laser OGI sensitivity to the sensitivity of infrared OGI cameras.

In an orphan wells campaign near Marietta, OH, led by the US Forestry Service, **Xplorobot Laser OGI** demonstrated the ability to detect emissions as low as 1 gram per hour in field conditions.

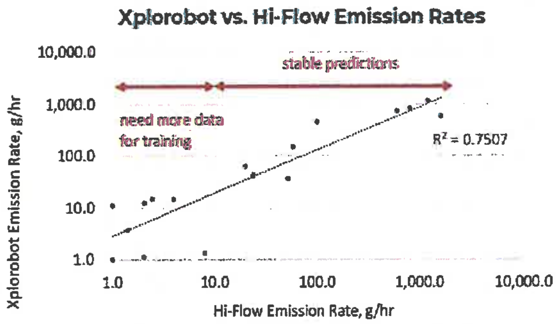
Field tests at oil and gas sites indicate that **Xplorobot Laser OGI** can detect emissions as low as 0.4 grams per hour (as verified by Hi-Flow device measurements of the emissions rates) with an Xplorobot columnated concentration of 269 ppm-m (this would not exceed the 500 ppm-m leak threshold per this application).

Campaign Results: Marietta, Ohio

Scope: 21 wells scanned in 3 days

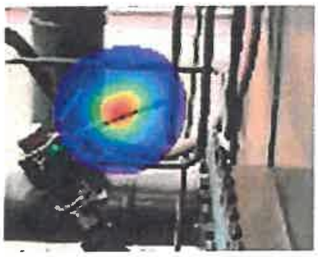
Emission Rates: Ranged from less than 1 gph to 1,600 gph

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



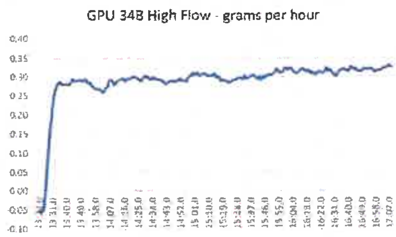
Well Name	Rate, g/hr	FLIR Detection	Xplorobot Detection
Porter Run 2	Zero Emission	Zero Emission	Zero Emission
Private #7	<1.0	No detection	Detection
Private #2	<1.0	Not tested	Detection
Rutherford Nancy 2	1.0	No detection	Detection
USA Joy 1	1.0	No detection	Detection
Edward Wiles #3	1.4	Not tested	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 15b. Comparison of the Xplorobot Laser OGI sensitivity to the sensitivity of infrared OGI cameras.



Emissions visualization on the sensor screen

3D Analysis of Methane Concentration
Max concentration: 269 ppm-m
Emissions rate estimate: 0.8 grams per hour



Validation Using Semtec High Flow Device
Emissions rate: 0.3 grams per hour

Xplorobot conducted multiple field and controlled trials confirming 1 gram per hour sensitivity

Figure 16. ***Xplorobot Laser OGI*** *detection of emission below 1 gram per hour in field conditions.*

3.3.2. Calibration check and maintenance requirements

Field experiments performed by Longpath Technologies suggest that performance of methane-sensing infrared lasers does not deteriorate over several years (Longpath Technologies, 2024). Nevertheless, we recommend performing a calibration check of the column concentration measurement on **Xplorobot Laser OGIs** once a month using a methane sample in a glass vial provided by Xplorobot with the device. To perform the calibration check of **Xplorobot Laser OGI**, position a sample vial at 1 meter from the device, initiate the recording, and direct the device's green laser pointer at the vial. The device will emit a beeping noise, indicating the detection of methane. Press the "**Digital Emission Tag**" button and record the methane concentration at and around the vial. The device should register zero concentration when the green laser is pointed away from the vial and concentration values up to 3000 ppm-m when pointing at the vial. The real-time visualization should display the methane hot spot at the vial. Afterward, stop the recording and review the inspection summary on the device screen. The visualization picture should provide a methane hot spot on the vial, and the maximum concentration recorded should range from 2,700 ppm-m to 3,300 ppm-m.

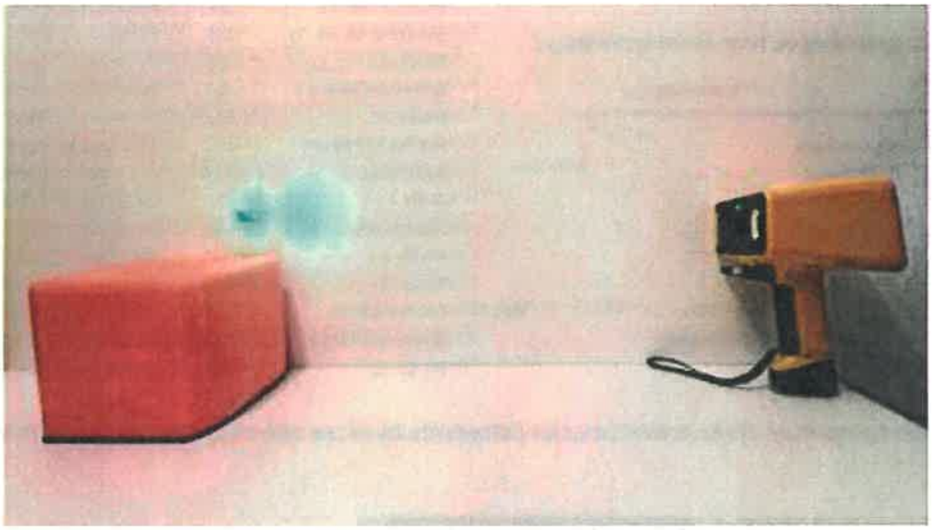


Figure 17. Example of monthly calibration of the Xplorobot Laser OGI device with the methane sample in a glass vial.

If the calibration check fails, the person conducting the methane inspection should repeat the calibration steps above. If the calibration fails again, the person conducting the methane inspection is instructed to contact Xplorobot to service the device.

To calibrate the accuracy of the device for estimation of the emission rate, we recommend conducting an annual calibration. Xplorobot team will conduct the emission rate calibration at Xplorobot test center in Denver for all devices deployed in Colorado.

3.3.3. Training, quality indicators, and operator competence

Xplorobot provides on-site or remote training for Operators to properly use the **Xplorobot Laser OGI**. The typical training is approximately 1-hour and focuses on methodology for collecting data with the device and recording **Digital Emissions Tags**.

Because **Xplorobot Laser OGI** records and stores all inspection data, which is then used to create both **Digital Emissions Tags** and **Digital Compliance Records**, Xplorobot can provide Operators with feedback on the quality and comprehensiveness of the inspection after data is downloaded and processed by **Xplorobot Inspector**. For example, a review of a 3D methane map on a 3D model of a separator can indicate which flanges or connections were missed during the inspection if no methane data was recorded for these components. Similarly, a review of a **Digital Emissions Tag** and the associated methane concentration map may indicate that the person conducting the methane inspection missed the center of the leak and did not record the maximum concentration of the emission.

Typically, Xplorobot provides a one-hour initial training session and 3 to 4 reviews of the inspection quality, which is sufficient to provide an Operator with the skills required to collect high-quality data.

3.4. Additional Functionality and Features

Data collected by **Xplorobot Laser OGI** can be used to estimate the emissions rate by utilizing physical modeling of the methane plume dynamic. Based on Xplorobot field measurements, 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 a role similar to 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, 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.

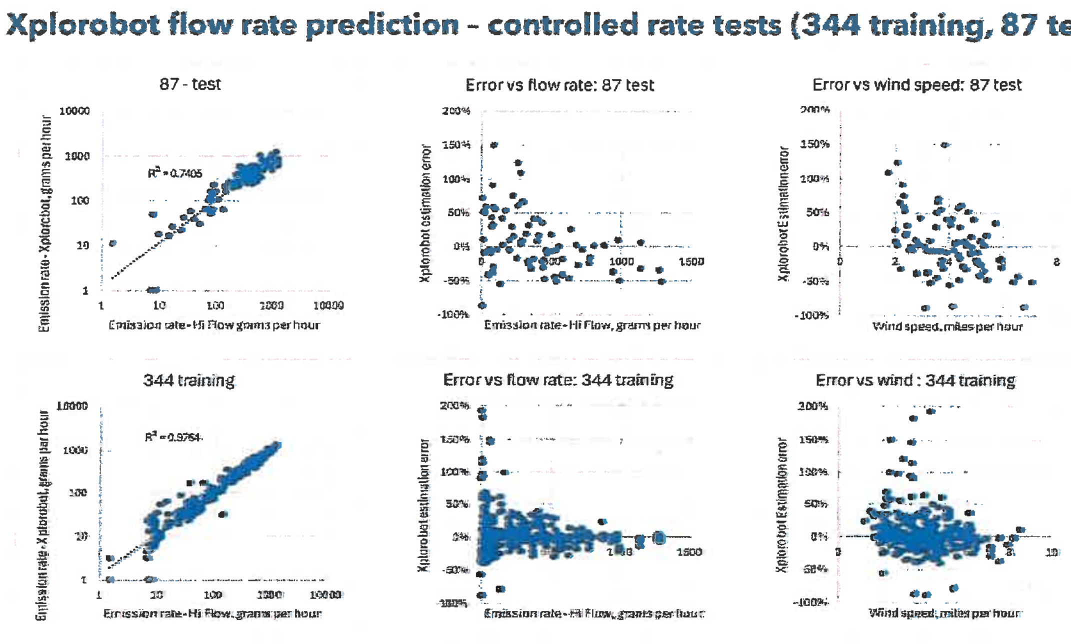


Figure 18. Example of Xplorobot methane emission rate prediction for a set of 431 controlled experiments in Denver, CO.

Xplorobot's proprietary algorithm incorporates both the dynamics of three flow regimes (wind dispersion, buoyancy and jet) and uses machine learning to interpolate between them.

Currently the algorithm provides predictions within +/- 50% for emissions rates above 200 grams per hour or 8 standard liters per minute. The Xplorobot team is continuing to work on improving the accuracy of emission rate predictions for emissions below 200 grams per hour or 8 standard liters per minute by acquiring additional data and improving physics-based data representations for neural network estimations.

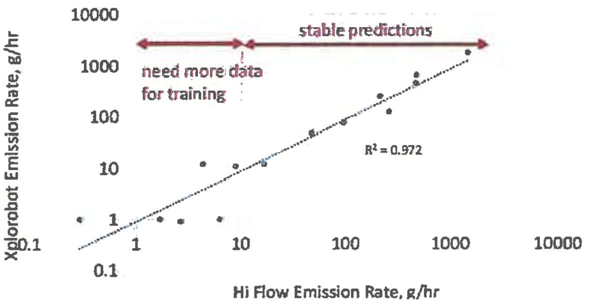
Campaign Results: Osage Nation

Scope: 57 wells scanned in 3 days

Emission Rates: Ranged from 1.7 gph to 1,118 gph

Results: Emissions quantified on 16 wells (14 – single source, 2 – double sources)

Xplorobot vs. Hi-Flow Emission Rates



Site	Well	Hi-Flow Emission rate gph	Xplorobot Maximum ppm-m	Max Wind mph
Ball Ranch	5	1.7	750	4.5
Mary Wyrick	5	2.7	700	4.2
Ball Ranch	3	4.3	100,000	2.6
Ball Ranch	12	6.3	1,466	1.8
BallRanch	19	8.9	5.976	2.4
Mary Wyrick	2	16.6	5,031	3.2
Mary Wyrick	10	46.9	18.537	4.7
Mary Wyrick	4	94.4	50,000	3.1
Terhune	81B	213	23,922	12.2
29N9E27	OR01	230	30,708	19.1
Enru Chuck	02a	260	10,158	10.3
Ball Ranch	7	471	19,389	3.0
Ball Ranch	15	475	32,196	6.0
Mary Wyrick	6	1,118	48,372	6.3
Lucy	1	1,450	50,870	11.0

Figure 19. Example of Xplorobot methane emission rate prediction in an orphan wells campaign in Osage Nation, OK.

3.5. Description of Alternative Technology Analytics

3.5.1 Definition of a detection event

Based on the equivalency to Method 21 established in controlled rate experiments (*Figure 5*), we propose to use 500 ppm-m as the emission detection threshold. The software in **Xplorobot Laser OGI** is set up such that when **Xplorobot Laser OGI** records values at or above 50 ppm-m alert threshold, the device emits a beeping noise, and the concentration indicator turns yellow. When the device detects values at or above 500 ppm-m (the proposed Detection Threshold), the concentration indicator turns red, indicating that a reportable emission has been detected. An Operator is required to localize the emission by exploring the vicinity of the area where the emission was recorded to find the location of maximum concentration measurement and press the **"Digital Emissions Tag"** button to create a comprehensive record of the emission.

For emission detection from Storage Tanks the detection **Xplorobot Laser OGI** threshold is any column-integrated concentration above zero per AQCC Regulation 7, so the person conducting inspection must record Digital Emission Tags for any measurable emission on Storage Tanks, localizing the emission to the specific thief hatch (if detected from the ground level) or to a specific component on the thief hatch (if detected from the distance of less than 2 meters on an elevated walkway)

In some cases, **Xplorobot Laser OGI** indicates the presence of emission below a tarp, cover, gravel, or soil. Xplorobot's operating procedure requires unwrapping the tarp or cover or removing the gravel or soil to expose the emission component for proper quantification and documentation. Examples of such detection are shown in *Figures 17* and *18*.

Figure 20. Emissions were detected under a bubble wrap, and the recording on the regulator after the wrap was removed.

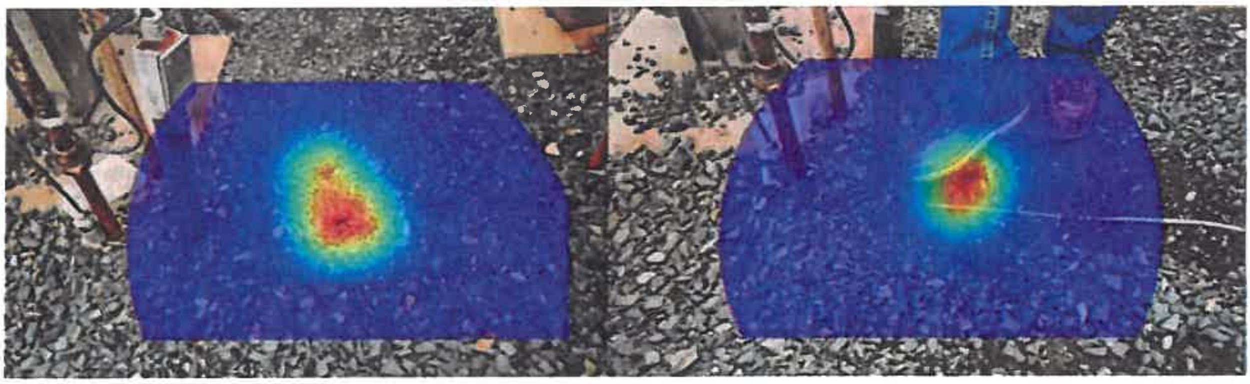


Figure 21. Emission detected under gravel and recorded on tubing after gravel was removed.

3.5.2. Localization method

Emissions are localized to the specific component by scanning the emissions area and monitoring the location where the maximum concentration is recorded. The resolution of **Xplorobot Laser OGI** is 0.4 (cross sectional diameter) at a distance of 1 meter and 20 (cross sectional diameter) centimeters from a distance of 50 meters. The emissions visualization software used in **Xplorobot Laser OGI** automatically scales the image of the plume to guide the person conducting methane inspection to the point of maximum concentration (i.e., areas of lower concentration will fade once higher concentrations are recorded in adjacent areas). **Xplorobot Laser OGI** demonstrated the ability to localize emissions not just to a flange but also to a specific bolt on a flange.

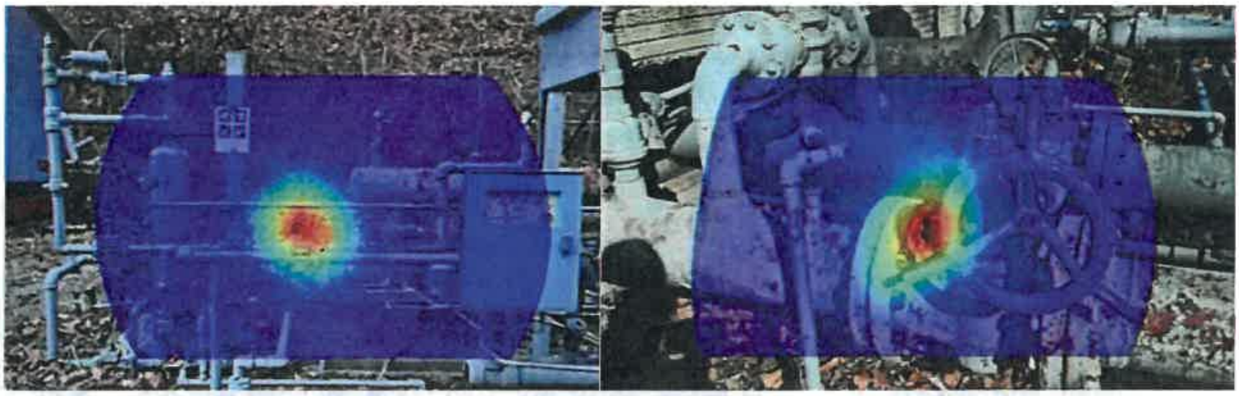


Figure 22. Examples of plume visualization that localizes emissions to a component and a bolt.

4. Equivalence to Infrared Optical Gas Imaging Device and Blind Testing at METEC.

4.1. Methodology

The **Xplorobot Laser OGI** device was tested alongside other technologies over a 4-day period under the Advancing Development of Emissions Detection (ADED) protocol. The goal of the experiments was to identify emissions points throughout the facility. The team was not briefed on the number of emission point(s), if any, present in each experiment, the location of the emission point(s), or the emission rate.

During the testing period, the Xplorobot team saw experiments with varying numbers of emissions points and emissions rates to quantify the technology's detection threshold. The team also saw a variation in the type of equipment surveyed to fully evaluate the technology's capabilities.

The task was to localize the emission(s) to specific equipment on equipment at the site without knowing which equipment and components would be the emission source. The team reported each of the emissions points we detected during the survey.

The Xplorobot team consisted of 4 Xplorobot employees with no formal training in LDAR inspection or experience working in oil and gas or oilfield services companies. METEC results demonstrate that using **Xplorobot Laser OGI** does not require significant expertise or training to achieve high-accuracy results.

4.2. Detection Accuracy Results

In the ADED testing, **Xplorobot Laser OGI** technology demonstrated a 91.4% true positive rate and a 2% false positive rate. This detection rate is the best compared to the technologies tested as part of the ADED program. *Figure 23* below provides a comparison of **Xplorobot Laser OGI** results with the published results from other vendors (Clay et al., 2023).

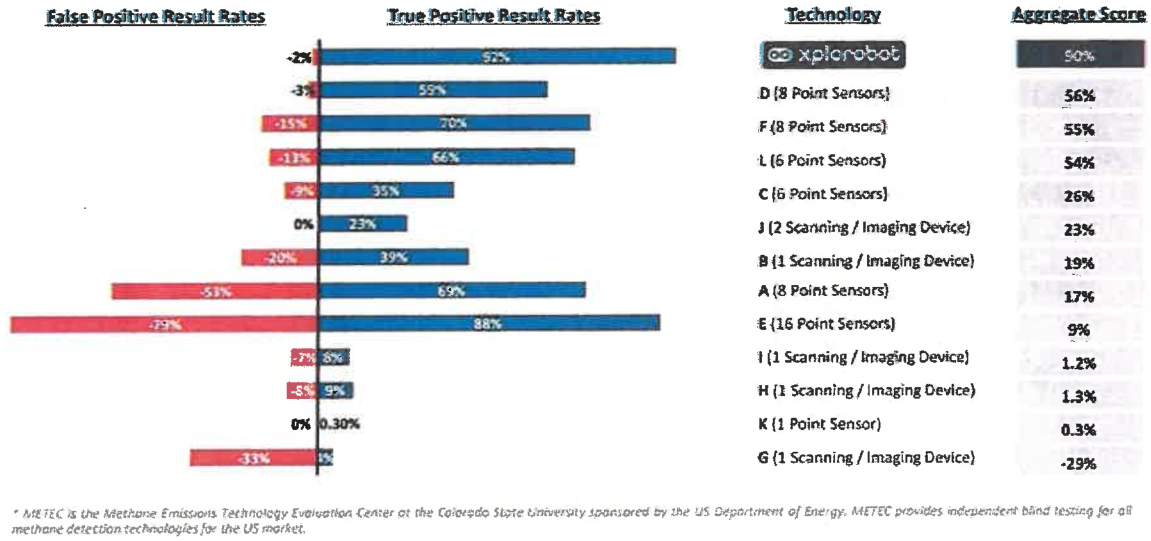


Figure 23. Comparison of the single-blind test results for Xplorobot Laser OGI against other technologies tested at METEC.

4.3. 90% Detection Confidence and Infrared OGI Camera Comparison

At the request of Xplorobot, the blind testing at METEC focused primarily on emissions below 10 liters a minute to define the 90% confidence detection limit for **Xplorobot Laser OGI**. *Figure 24* presents the distribution of the flow rates in the blind testing experiments.

Xplorobot Laser OGI achieved the 90% detection limit of 155.7 grams per hour or 4 standard liters per minute. *Figure 25* presents the probability of the detection curve for **Xplorobot Laser OGI** achieved at METEC.

The results of the blind testing for **Xplorobot Laser OGI** allow a direct comparison with the results of Infrared Optical Gas Imaging Cameras at the same facility. Zimmerle et al. (2020) presented the results of blind tests of Infrared OGI cameras at METEC in which the inspectors performing the tests were separated into two groups: "Less experienced LDAR inspectors" and "Highly experienced inspectors."

The less experienced group performed 20 - 250 LDAR surveys prior to the testing, while the highly experienced inspectors performed 700 - 4000 LDAR surveys. The highly experienced LDAR group achieved a 90% confidence detection level between 2.6 - 7.7 standard liters per minute, while the less experienced group's 90% confidence of detection was over 20 standard liters per minute. *Figure 26* presents the results of 90% confidence levels for Infrared Optical Gas Imaging operated by Less Experienced LDAR Inspectors and High Experience LDAR Inspectors from Zimmerle et al. (2023) with an overlay of the probability of detection curve for **Xplorobot Laser OGI**.

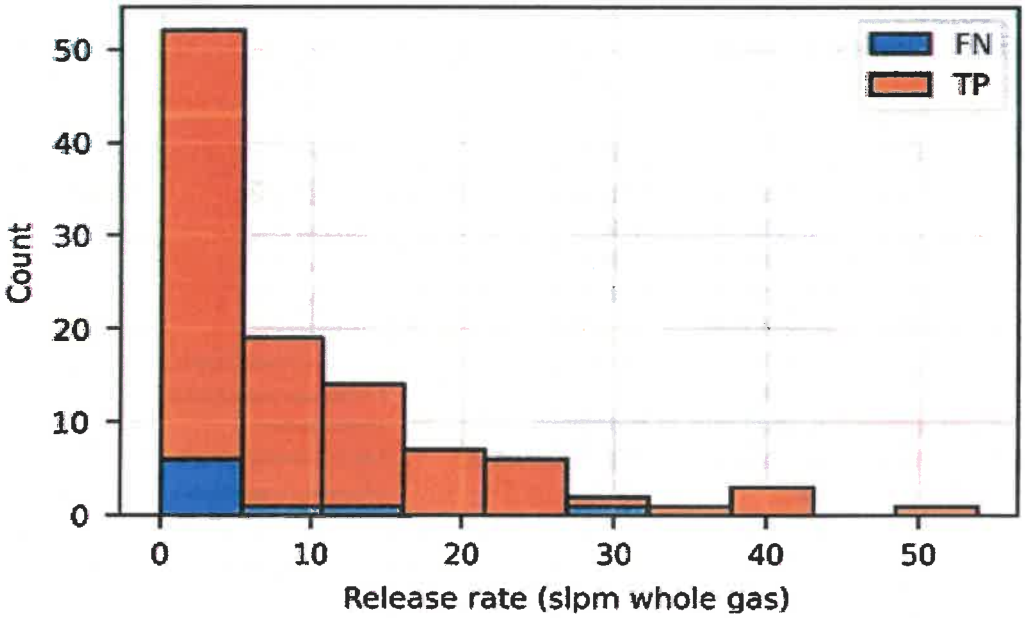


Figure 24. Emissions rate distribution in the METEC blind tests for Xplorobot Laser OGI, focused on emissions below 10 liters per minute.

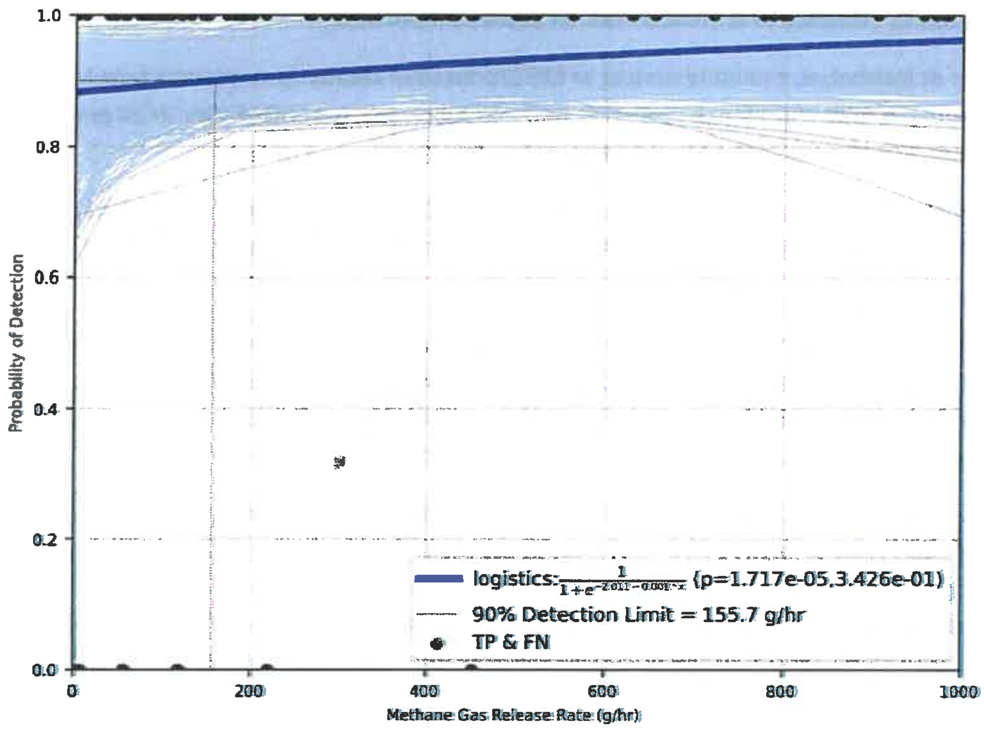


Figure 25. Probability of detection curve for Xplorobot Laser OGI achieved at METEC.

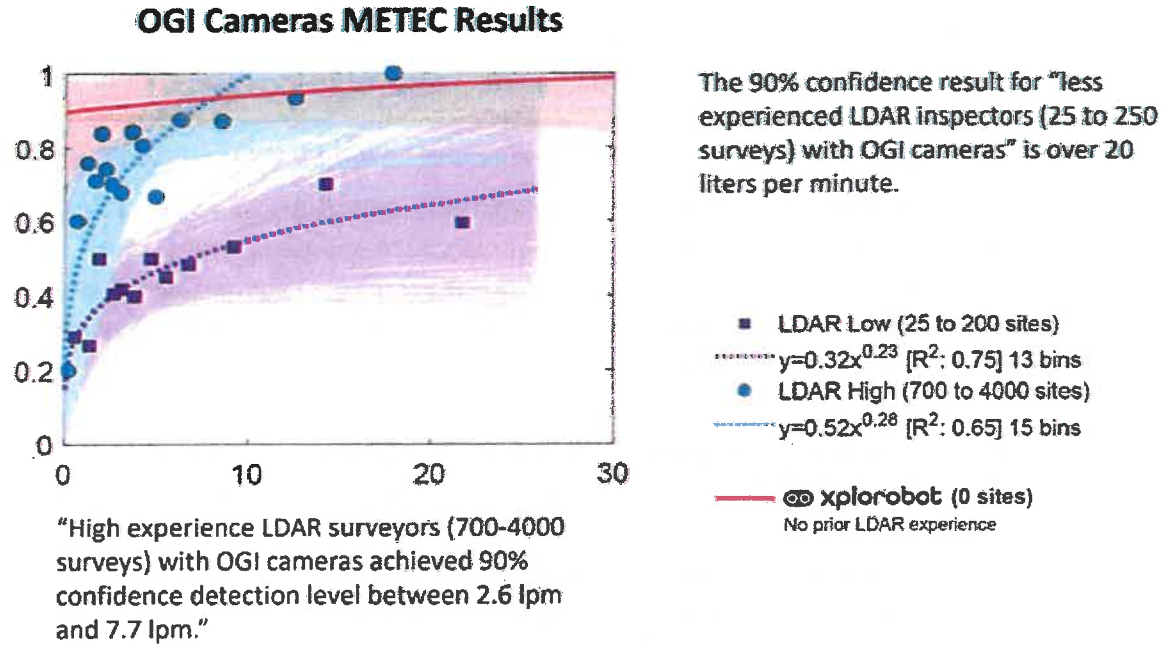


Figure 26. (Zimmerle et al, 2023) Probability of detection for Infrared OGI cameras operated by High Experience LDAR Inspectors and by Low Experience LDAR inspectors with an overlay of the probability of detection curve for Xplorobot Laser OGI.

The 90% confidence level results for **Xplorobot Laser OGI** (4 liters per minute) fall in the range of the results for Infrared Optical Gas Imaging operated by High Experience LDAR inspectors (between 2.6 and 7.7 liters per minute). Thus, the METEC blind testing results demonstrate that **Xplorobot Laser OGI** results are matching the detection accuracy of Infrared Optical Gas Imaging cameras operated by Highly Experienced LDAR inspectors (between 700 and 4000 LDAR surveys). Importantly, **Xplorobot Laser OGI** was achieved by Xplorobot employees without formal LDAR training or certification, with two of the four employees performing methane emission inspection for the first time in their life and being trained as part of the METEC trial.

Numerous field campaigns demonstrated the equivalence of **Xplorobot Laser OGI** results to Infrared Optical Gas Imaging results. For example, 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 (of which all were above 500 ppm-m) while infrared OGI devices identified 5. In the second compressor station, **Xplorobot Laser OGI** devices identified 11 emission sources (of which 9 were above 500 ppm-m) 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 Laser OGI detected methane emissions in field conditions with temperatures ranging from minus 20 Celsius (minus 4 F) in field data acquisition for Carbon Creek Energy in February of 2023 to plus 44 Celsius (110 F) in field data acquisition for Diversified Energy in Ft. Worth, TX in August 2023 and in wind conditions up to 25 mph.

5. Additional Controlled Release Testing at LBNL and AMEP and Field Tests by Oil and Gas Operators and in Orphaned Wells Campaign to Confirm 1 gram-per-hour Detection Limit

5.1. Lawrence Berkeley National Laboratory Tests in the 1 gram-per-hour to 20 grams-per-hour Range

To define the detection limits for **Xplorobot Laser OGI**, we performed controlled release experiments at the Lawrence Berkeley Laboratory in September 2023 and February 2024. We used gas with a 5% methane concentration and varied the emissions rate from 0.5 liter per minute (approximately 1 gram per hour of methane) to 20 liters per minute (approximately 40 grams per hour of methane). *Figure 27* demonstrates the experimental setup at the Lawrence Berkeley National Laboratory.

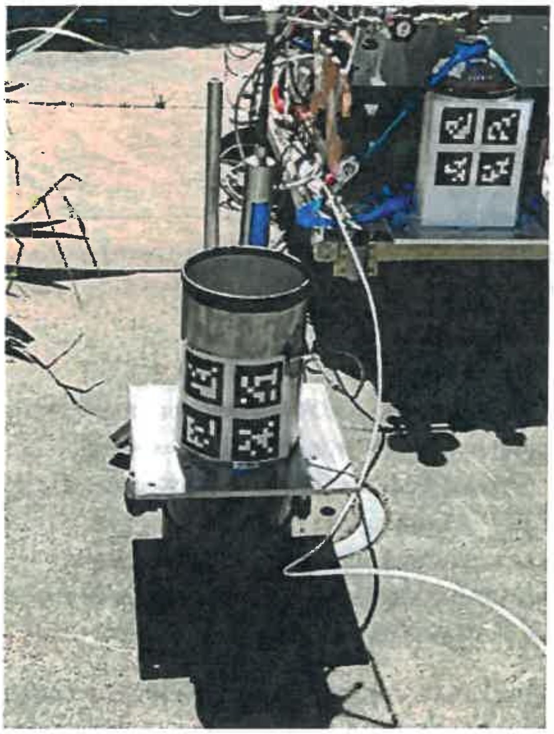


Figure 27. Experimental setup at the Lawrence Berkeley National Laboratory.

Xplorobot Laser OGI detected emissions for all the experiments at the Laboratory. *Figure 28* presents the results of the maximum concentration detected for each emissions rate in the experiments. The maximum concentration recorded for the emission rate of 1 gram per hour ranged between 80 and 120 ppm-m.

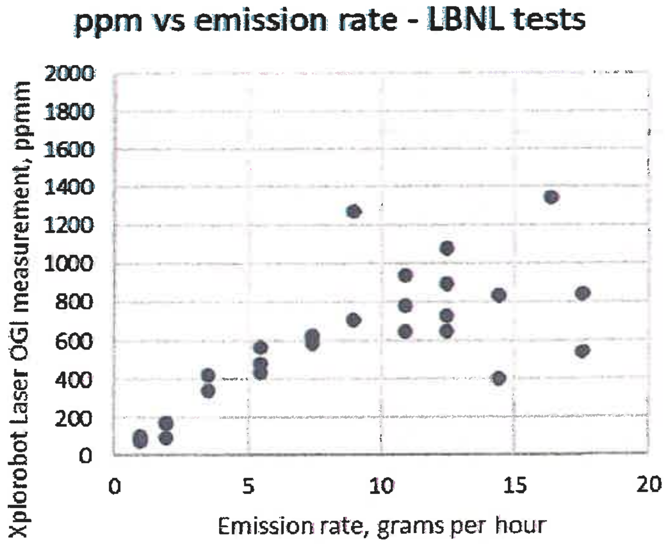


Figure 28. Methane concentration in ppm-m recorded by the Xplorobot Laser OGI device at the Lawrence Berkeley National Laboratory.

5.2. Alberta Methane Emissions Program (AMEP) Tests Range from 3 to 1200 grams-per-hour

Xplorobot performed controlled release experiments at the Alberta Methane Emissions Program (AMEP) in March and October 2023. The emissions rates in the controlled rate experiments ranged from 3 grams per hour to 1200 grams per hour. **Xplorobot Laser OGI** detected the emissions in all the experiments at the site. The temperatures at the site ranged from minus 10 Celsius to plus 5 Celsius, and the wind speeds ranged from 1 mile to 12 miles per hour. *Figure 29* presents an example of the detection results.

AMEP Well Head - control rate experiment

Experiment	Known flow rate	Max concentration measured	Result
1	0.1 m3/day	2,052	Detection
2	1 m3/day	9,040	Detection
3	10 m3/day	11,300	Detection
4	20 m3/day	12,416	Detection
5	40 m3/day	13,798	Detection

Key observations:

- Emissions of 0.1m3/day (~3 grams/hour) and above are clearly detected
- Wind speed range during the experiment was between 0.5 miler per hour and 7.5 miles per hour

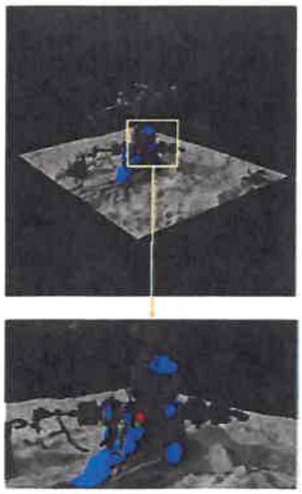


Figure 29. Example of controlled rate release experiments at the Alberta Methane Emissions Program.

5.3. Confirmation of the 1 gram-per-hour Detection Limit in Field Conditions by Oil and Gas Operators

From September 2023 to January 2024, **Xplorobot Laser OGI** was used at multiple client facilities in Colorado, Texas, Louisiana, Pennsylvania, Ohio, West Virginia, Germany, Australia, The United Kingdom, and France. When possible, we used the Semtec High Flow device to record the emissions rates detected by **Xplorobot Laser OGI** and establish the lower detection limit in real field deployment conditions. We recorded emissions rates at client sites ranging from 0.3 to 10,000 grams per hour. *Figure 30* provides an example of **Xplorobot Laser OGI** detecting emission below 1 gram per hour at a client site as validated by the High Flow device.

Emissions visualization on the sensor screen

3D Analysis of Methane Concentration
Max concentration: 269 ppm-m
Emissions rate estimate: 0.8 grams per hour

Validation Using Semtec High Flow Device
Emissions rate: 0.3 grams per hour

Xplorobot conducted multiple field and controlled trials confirming 1 gram per hour sensitivity

Figure 30. Xplorobot Laser OGI detection of emission below 1 gram per hour in field conditions.

5.4. Confirmation of the 1 gram-per-hour Detection Limit in Orphan Wells Campaigns

In May of 2024, Xplorobot team worked on an orphaned wells campaign in the Osage Nation in Oklahoma under the leadership of the Lawrence Berkeley National Laboratory. *Figure 31* presents the results of emission detection in the range from 1.7 grams per hour to 1,450 grams per hour as confirmed by Semtec Hi Flow Device.

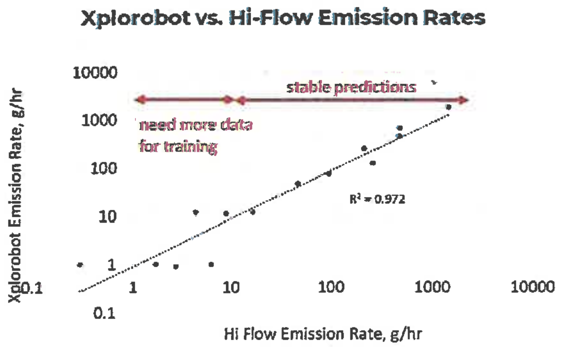
xplorobot

Campaign Results: Osage Nation

Scope: 57 wells scanned in 3 days

Emission Rates: Ranged from 1.7 gph to 1,118 gph

Results: Emissions quantified on 16 wells (14 – single source, 2 – double sources)



Site	Well	Hi-Flow Emission rate gph	Xplorobot Maximum ppm-m	Max Wind mph
Ball Ranch	5	1.7	750	4.5
Mary Wyrick	5	2.7	700	4.2
Ball Ranch	3	4.3	100,000	2.6
Ball Ranch	12	6.3	1,466	1.8
BallRanch	19	8.9	5.976	2.4
Mary Wyrick	2	16.6	5,031	3.2
Mary Wyrick	10	46.9	18.537	4.7
Mary Wyrick	4	94.4	50,000	3.1
Terhune	81B	213	23,922	12.2
29N9E27	OR01	230	30,708	19.1
Enru Chuck	02a	260	10,158	10.3
Ball Ranch	7	471	19,389	3.0
Ball Ranch	15	475	32,196	6.0
Mary Wyrick	6	1,118	48,372	6.3
Lucy	1	1,450	50,870	11.0

Figure 31. Xplorobot Laser OGI detection of emission at 1.7 grams per hour in field conditions.

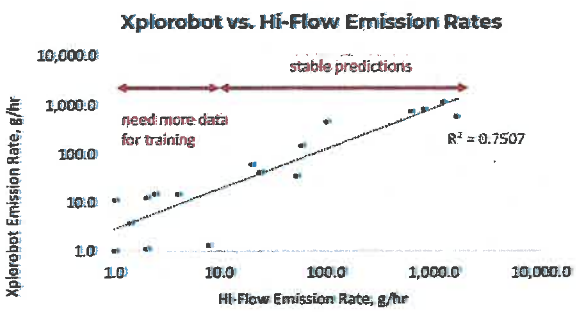
In May of 2024, Xplorobot team worked on an orphaned wells campaign near Marietta, OH under the leadership of the Lawrence Berkeley National Laboratory. *Figure 32* presents the results of emission detection in the range from below 1 gram per hour to 1,600 grams per hour as confirmed by Semtec Hi Flow Device.

Campaign Results: Marietta, Ohio

Scope: 21 wells scanned in 3 days

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

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



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 32. Xplorobot Laser OGI detection of emission at and below 1 gram per hour in field conditions.

6. Field Deployments with Utah Gas Company and Other Oil and Gas Companies in the United States

6.1. Deployment Case Studies

Through field deployments, **Xplorobot Laser OGI** has proven effective at detecting emissions, localizing their sources, and enabling operators to react quickly and remedy the cause of the emissions.

The following case studies detail typical Xplorobot deployment scenarios. In each case study, the **Xplorobot Laser OGI** efficiently detected an emission, identified the source, and alerted the Operator, who resolved the issue. Due to non-disclosure agreements, specific details, such as facility type, are unspecified.

6.1.1. Case Study 1: Utah Gas in Colorado

In August and September 2023, **Xplorobot Laser OGI** was used at Utah Gas Company's Dragon Trail plant. Inspections were performed on gas processing equipment and compressors. Inspections with **Xplorobot Laser OGI** cameras detected all the emissions flagged by the LDAR inspectors using Infrared Optical Gas imaging cameras and identified two additional emission points.

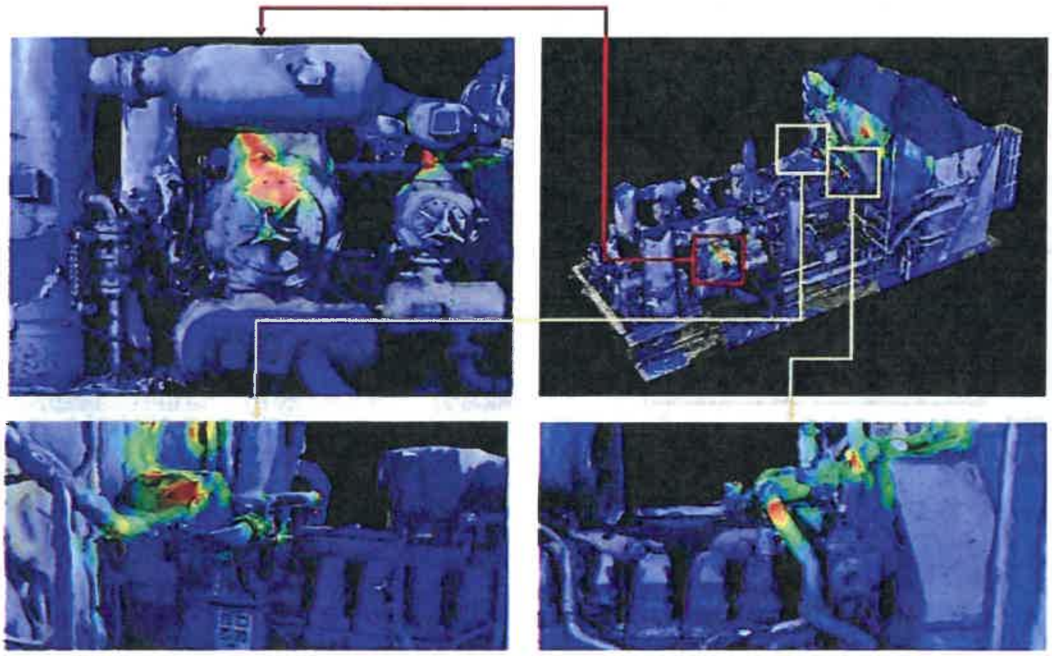


Figure 33. Example of emissions identification on an Ariel Compressor.

Based on the inspection results, a **Methane Emissions Management Dashboard** was integrated for Utah Gas Corp. *Figure 34* presents a snapshot of the Dashboard.

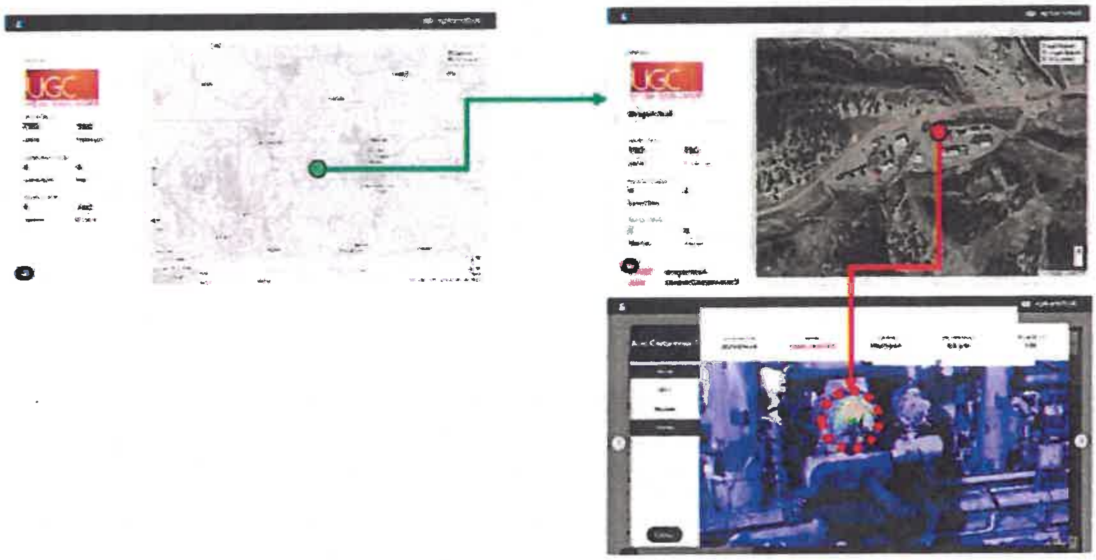


Figure 34. Methane Emissions Management Dashboard for Utah Gas Corp Dragon Trail Plant.

6.1.2. Case Study 2: Client site in Louisiana

In January 2024, **Xplorobot Laser OGI** was used to perform a side-by-side comparison with an Infrared Optical Gas Imaging Device on eight pads. Of the 50 emissions points at the site, **Xplorobot Laser OGI** was able to identify 48, while Infrared Optical Gas Imaging was able to identify 42. Infrared Optical Gas Imaging identified two emission sources that **Xplorobot Laser OGI** missed, while **Xplorobot Laser OGI** identified 10 points that an Infrared Optical Gas Imaging camera did not detect. Of note was the detection of emissions under tarps, bubble wrap, and gravel that were not visible by the infrared OGI cameras. *Figures 35 and 36* present the results of such emissions.

For some of the larger emissions (over 1 kg per hour as measured by Semtec Hi Flow device), **Xplorobot Laser OGI** was able to detect them from a significant distance, including outside the plant gate and across the road. *Figure 37* presents an example of the detection of larger emissions from distances of up to 50 m.

Figure 35. Emissions detected under a bubble wrap and the recording on the regulator after the wrap was removed.

Figure 36. Emission detected under gravel and recorded on a tubing after removing gravel.

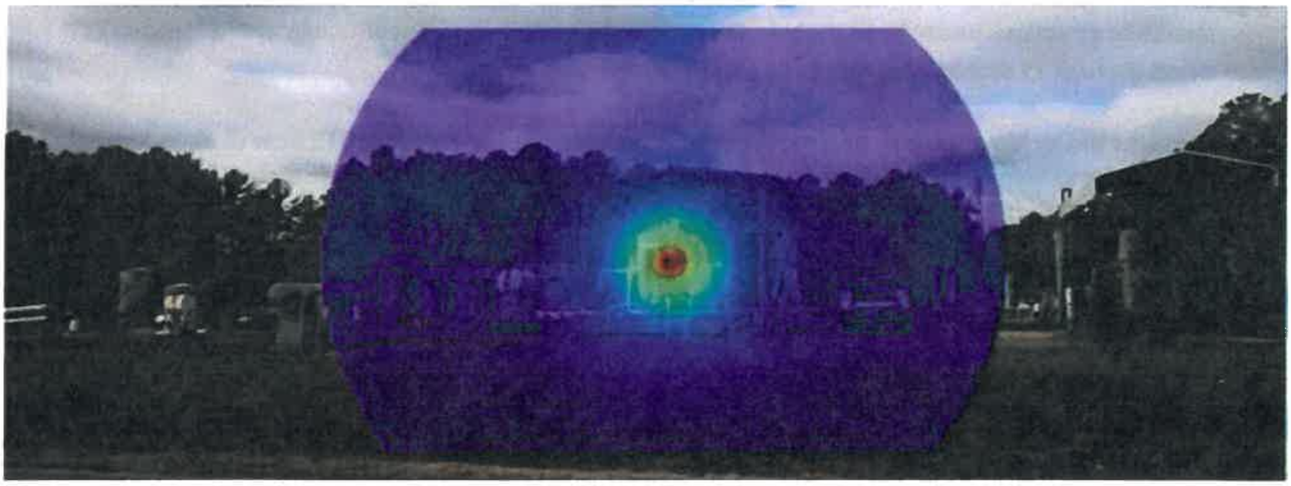


Figure 37. Emissions detection from outside the plant gates across the road.

6.1.3. Case Study 3: Client site in West Texas

In December of 2023, **Xplorobot Laser OGI** was used at a site in Texas to successfully identify emissions that were not identified by previous surveys with infrared OGI cameras. *Figure 38* below provides a case study by the operator as published in their annual ESG report.

Handheld laser OGI technology

Throughout 2023, NGP worked with upstream and midstream portfolio companies to evaluate their options for detecting, measuring and monitoring emissions in their operations. Due to NGP's unique strengths in both oil and gas and emerging energy technologies, the Energy Transition team conducted a benchmarking study of more than 15 emissions monitoring companies. This research was shared with the upstream and midstream portfolio companies as a reference point while evaluating their own program needs. Conversely, the Energy Transition deal team solicited views on the methane monitoring industry from NGP flagship portfolio companies, providing an operator's insight.

CASE STUDY: Greenlake Energy Operating Methane Emissions Detection Technology Pilot

Situation:
A production facility site was chosen due to suspected emissions leak that was causing costly facility shut-ins due to high oxygen levels. LDAR conducted ~30 days prior with particular emphasis attempting to identify suspected leak on VRU equipment. OGI technician was unable to identify a leak. Three Lease Operators were given handheld cameras with no training along with vendor founder and technician. LO's were asked to walk the facility and attempt to identify emissions leaks.

Approach Objectives:

- Leak identification: identify and digitally map equipment and emissions.
- Zero emissions certification: demonstrate 3D mapping capabilities (future requirement)

Result:
Intermittent VRU compressor leak identified on adjoining flange (included overflow intermittent exhaust) and additional leak on VRU compressor head gasket area. This was the suspected source of oxygen issue that LDAR survey was unable to identify. Onsite video visualization and recording confirmed the source and a digital 3D model processed and provided of equipment allowing for methane overlay and quantification.

greenlake ENERGY

Strategic Goal:
Minimize emissions risk/penalty via early identification and resolution with strong documentation.

- Improve recordkeeping and documentation
- Prepare for new regulations
- Streamline reporting

Digital imaging of emissions sources

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Figure 38. Case study of a field deployment of Xplorobot Laser OGI published by a client.

7. Proposed Work Practices

7.1. Requirements of Use

<u>**Facility Type:**</u> A hand-held **Xplorobot Laser OGI** can detect and report methane emissions from any oil or natural gas production facility or compressor station in Colorado that requires LDAR inspections per Regulation 7, Part B, Sections I.L and II.E. **Xplorobot Laser OGI** can be used at both outdoor and indoor facilities.

<u>**Number of Devices and Coverage:**</u> **Xplorobot Laser OGI** can be used by any operator or mechanic, and initial training is provided by Xplorobot personnel. To effectively mitigate methane emissions, **Xplorobot Laser OGIs** can be used on multiple sites on a given day. We estimate that one **Xplorobot Laser OGI** can cover between 300 and 400 well pads annually or between 80 and 120 compressor stations yearly for quarterly

inspections.

<u>Data storage:</u> **Xplorobot Laser OGI** data storage is 250 GB, allowing storage of approximately 1 month of inspection data. Xplorobot software monitors the storage use and regularly purges data (bi-weekly) from the device once data is uploaded into **Xplorobot Compliance Database.**

<u>Connectivity:</u> The **Xplorobot Laser OGI** device does not require internet connectivity during inspections as it stores all data in the internal computer memory until uploaded. There is sufficient storage space on the device for approximately 1 month of inspections. Upon completing the inspection, data is downloaded by the person conducting the methane inspection to a laptop or desktop computer running **Xplorobot Inspector** software. The computer running **Xplorobot Inspector** software connects to the internet through the network in the Operator's field office or through the dedicated internet connectivity device (MiFi) attached to the computer. Data processed by **Xplorobot Inspector** software, including **Digital Emission Tags** and **Digital Compliance Records,** is uploaded to the remote server running the **Xplorobot Compliance Database** and the **Methane Emissions Management Dashboard**. Depending on the Operator's preferences, the server can be at the Operator's or Xplorobot premises.

<u>Detection distance:</u> **Xplorobot Laser OGI** can be used for detection of emission at distances up to 50 m.

<u>Quantification distance</u>: **Xplorobot Laser OGI** can be used for emission quantification at distances up to 7 meters.

<u>Wind speed and direction:</u> **Xplorobot Laser OGI** was successfully used in field deployments to detect methane emissions in wind conditions of up to 25 miles per hour. There is no restriction on wind speed in the device's design. Given that we have not tested the accuracy of **Xplorobot Laser OGI** detection in winds above 25 miles per hour, we recommend to not use **Xplorobot Laser OGI** if the sustained wind exceeds over 25 miles per hour

<u>Ambient temperature:</u> **Xplorobot Laser OGI** was successfully used in field deployments to detect methane emissions from 0 degrees Fahrenheit (near Calgary, AB, Canada) to 110 degrees Fahrenheit (near Dallas, TX, USA). There is no restriction on the temperature for the TDLAS sensor to detect methane. However, the overall temperature restriction on the operation of the **Xplorobot Laser OGI** is 120 degrees Fahrenheit (set as a limit for efficient cooling of the sensor electronics by its cooling system).

<u>Ambient lighting:</u> **Xplorobot Laser OGI** uses an infrared laser to illuminate the equipment and components being inspected. Methane emissions can be detected in the dark; however, visualization of methane emissions on the sensor screen requires normal lighting conditions for the device camera to record visual images. Using **Xplorobot Laser OGI** outdoors after sunset, without additional illumination, is not recommended.

<u>Weather conditions</u>: **Xplorobot Laser OGI** was deployed in light rain and snow conditions in the field and demonstrated no deterioration of detection performance. Scattered rain drops and snowflakes did not

create interference with the laser beam. We do not recommend deploying **Xplorobot Laser OGI** in heavy rain or snow conditions due to safety concerns for slips and trips for the inspector.

7.2. Operating Procedure

This proposed AAIMM is applicable to all facilities that are required to conduct component-level LDAR inspection per Regulation 7, Part B, Sections I.L and II.E. The frequency and scope of the inspections are the same as prescribed by Regulation 7 for the Approved Instrument Measurement Methods. **Xplorobot Laser OGI** records data that is required to create **Digital Emissions Tags** for the sources of emission discovered during the inspections, as well as data that is required to generate **Digital Compliance Records** for equipment and components that do not emit methane or that emit methane within allowable limits.

7.2.1. Xplorobot Laser OGI operating procedure and recording of Digital Emissions Tags

To acquire comprehensive methane emissions data for a site that requires LDAR inspection per Regulation 7, Part B, Sections I.L and II.E, a person conducting methane inspection must follow the Xplorobot Operating Procedure, which consists of the following steps.

1. **Step 1: Defining the Scope and the walking route**

- Defining the scope encompasses the Operator's identification of equipment and components to be inspected, the sequence of inspections, and the scope of each scan.
- Identify the quantity and location of the equipment in the inspection scope (e.g., the number of wellheads, separators, tanks, piping strings, manifolds, compressors, etc., at the site).
- If facility modification was done since the last inspection, identify the list of new or modified equipment and components that need to be inspected and cataloged in the **Xplorobot Compliance Database**.
- Define the sequence of the scans. Xplorobot recommends following the path of hydrocarbon flow. For example, for a well pad, start with wellheads, then piping to separators, then separators, then any scrubbers or absorbers, then export compression (if any), then liquid lines to tanks, then tanks, etc.
- Define the scope of each scan. Scan each wellhead, separator, scrubber, compressor, etc., separately to facilitate the attribution of each emission point to a single piece of equipment.
- Define any obstacles for accessing the equipment or walking hazards on the route. **Xplorobot Laser OGI** has a detection range of 50 meters. Therefore, the person conducting methane inspection does not need to climb over or under equipment or climb to heights above ground level to conduct scans. Most components, even on tops of tanks, separators, and columns, can be scanned from the ground level if a proper position for scanning is identified. However, it is recommended to complete inspections from no more than 4 meters away from components or equipment for quantification accuracy and localization

precision. For components or equipment that are difficult to monitor, a further distance not to exceed 50 meters may be used.

- Document any potential emission sources that do not have any reflection points behind them for the TDLAS laser to be reflected from to perform the measurement (e.g. open vents above equipment). If possible, use a removable reflecting point (e.g. a small flat piece of plastic on an extendable pole).

If a facility operator intends to use **Xplorobot Laser OGI** for regular inspection of open vents, the operator must install reflection points in a form of small metal plates above the vent (approximately 4" above the vent or flare, and no less than 4" in diameter) such that the TDLAS laser can be reflected from such a plate when shining across the vertical column of air immediately above the vent. The placement of the plate should be at least 4 inches above the vent to ensure that the laser beam crosses the path of the plume.

When inspecting Storage Tanks, the person conducting the methane inspection must identify a position on a pad from which they can see the thief hatches and vents on top of tanks and can reflect the TDLAS laser from those thief hatches. Thief hatches can be inspected from the ground by reflecting the laser from the cap of the hatch. Open vents require a reflection point above them. If no such reflection points exist for positions on the ground, the inspection must be conducted from the walkway at the top of the tank.

2. **Step 2: Scanning Equipment**

Once the scanning sequence and the walking path have been determined, the person conducting the methane inspection can perform the methane scan with **Xplorobot Laser OGI**. Starting at the defined starting/stopping point of the walking route, start the scanning process on the device using the "**START**" button on the User Interface (UI). Once scanning has started, a green laser will shine out of the front of the **Xplorobot Laser OGI**. This laser is used to visualize the point at which the infrared methane sensing laser shines. The UI will display the methane concentration values measured by the TDLAS sensor and the wind speed values recorded by the anemometer.

The person conducting methane inspection follows the predetermined route around the equipment to ensure that every component (e.g., flange, valve, vent, etc.) is properly scanned. Per requirements of NSPS 60 Appendix K, a two second dwell is required for each component. The adherence of the operator to the 2 seconds requirement is confirmed upon data processing as part of creating the Digital Compliance Record for each component.

Xplorobot Laser OGI leak detection threshold for fugitive emissions on equipment and components other than Storage Tanks is 500 ppm-m based on the equivalency between **Xplorobot Laser OGI** and Method 21 measurements *(Figure 5)*. **Xplorobot Laser OGI** alert threshold is set at 50 ppm-m. If the column-integrated concentration measurement exceeds the alert threshold of 50 ppm-m, the **Xplorobot Laser OGI** will emit a beeping noise, alerting the person conducting the methane inspection of a potential emission source. Upon receiving the alert, the person conducting the methane inspection uses the green visualization laser to scan around the possible emission source to locate the highest concentration corresponding to the emission point. The localization accuracy of the **Xplorobot Laser OGI** at a distance of 1 meter is about 0.4 centimeter. This localization accuracy allows the person to locate the emission point (e.g., flange) and localize the emissions to the specific bolt on the flange when inspection is conducted at a close range.

At distances of 50 meters, the localization accuracy of **Xplorobot Laser OGI** is 20 centimeters. This allows detection of emissions from open vents (provided that a reflection point above it) or thief hatches, pressure relief devices, and other access points on Storage Tanks. If an emission is detected from a distance between 4 meters and 50 meters, the inspector must come to the safest allowable distance to the emission source to record a Digital Emission Tag to achieve the best localization accuracy and the best emission rate estimation.

The procedure to locate the point of highest concentration involves scanning the component in the areas of typical emission source locations as follows.

I. For flanges - the circumference of the flange connection and the bolts

II. For valves - the circumference of three flanges and the valve stem

III. For connections - the circumference of the connection on both sides

IV. For pneumatic controllers - top of the controller, arras around the stem, flange connections

V. For level controllers - all connections and the bleed pint inside the controller box

VI. For gauges - the circumference of the connection on the stem

VII. For open vents - the opening of the vent and circumference of any caps placed on them

VIII. For thief hatches on top of tanks - the circumference of the thief hatch

IX. For cooler boxes on compressors bolt connections outside the box, area of the vent opening

X. For compressor ends - all connections and caps, vents and pressure relief points

XI. For natural gas engines - piping and flanges of the gas supply system, crank case vents

Once the emissions point is localized and the maximum emission rate is obtained, the person conducting the methane inspection presses the **"Digital Emission Tag"** button on the device's touch screen to initiate a comprehensive recording of the emission point. Once the button is pressed, a window with a real-time visualization of the methane emissions otherwise not visible to the naked eye comes up on the device screen. The person continues to scan the emissions source and the area around the emission source (we recommend scanning an area 10 inches in diameter) to acquire methane measurements to fully visualize the emissions. In case of scanning emissions from tops of tanks from distances exceeding 10 meters, we recommend to scan an area of approximately 1 ft in diameter. Once sufficient data is acquired (in approximately 10 to 20 seconds), the emissions visualization window is closed, indicating that a **Digital Emission Tag** recording is complete. The person conducting the methane inspection can scan the rest of the components or equipment along the predetermined route.

Based on the equivalency between Method 21 and **Xplorobot Laser OGI**, Digital Emission Tags must be recorded for all emissions at or above 500 ppm-m on equipment and components that are not Storage Tanks as required by AQCC Regulation 7.

During inspection of Storage Tanks (including, without limitation, thief hatches, PRVs and/or other access points to the tank), Digital Emission Tags must be recorded for all emissions above zero ppm-m measured by **Xplorobot Laser OGI** as required by AQCC Regulation 7. After completing the inspection of each Storage Tank, the inspector must review the maximum column-integrated concentration recorded during the inspection. If no Digital Emission Tags were recorded, but the maximum recorded column-integrated concentration is above Zero ppm-m, the inspector must press on the maximum column-integrated concentration display bring up the photo of the location where that non-Zero value was recorded and must return to that location to re-inspect the area and record the Digital Emission Tag. If the inspection was conducted from the ground level and there is safe access to the top of the tank from an elevated walkway, the inspector must investigate the area where emission was recorded from that walkway. All emissions recorded on Storage Tanks must be labeled as requiring further investigation upon upload of those Digital Emission Tags into Xplorobot **Compliance Database.**

Figure 39. A person without LDAR certification or any special training successfully operating Xplorobot Laser OGI scanning a separator in METEC, Fort Collins, Colorado.

Once all equipment and components defined in the scope are scanned, the person conducting the methane inspection can stop the scan using the **Xplorobot Laser OGI** User Interface. Once the scan is stopped, the summary is presented on the screen. The summary consists of all **Digital Emissions Tags** recorded during the scan. Once the summary is reviewed, the person conducting the methane inspection can save or not save the data for the scan. If the "Yes" button is pressed on the screen, the scan will be saved for post processing. If the "No" button is pressed, then the data from the scan will not be recorded.

7.2.2. Xplorobot Inspector Software operating procedure

The **Xplorobot Inspector** software is designed to require minimal human intervention in the data flow from **Xplorobot Laser OGI** to the **Compliance Database**. This provides an auditable digital-trail and reduces the risk of error in data assignment.

Along with **Xplorobot Laser OGI**, an edge computer and software are provided to the Operator for data transfer and post-acquisition processing. When the **Xplorobot Laser OGI** is connected to the edge computer via an ethernet cable, the software automatically detects the connection, and the person performing methane inspection is prompted if they would like to download the data from **Xplorobot Laser OGI** to the computer.

Data from all scans on the sensor is then downloaded. This process takes a few minutes, and a progress bar showing the percentage completed will appear. The sensor not only sends the file but also calculates a checksum hash. The software on the edge computer saves the file and calculates a checksum hash. It then compares the two hashes to ensure the file was not corrupted during the download process. A message is sent to the sensor to notify it that the file download was successfully completed.

The file server on the sensor keeps track of which files have been successfully downloaded. Once all files for an inspection have been downloaded, the data for that inspection is archived on the sensor and will be deleted only if additional disk space is required for further scans later. Currently, the data storage on the sensor package allows for approximately one month of inspections. Thus, a backup of the raw inspection data is kept on the sensor for about one month after the inspection is performed.

The **Xplorobot Inspector** software then displays summary information about each scan (*Figure 40, below*). The person performing the methane inspection is asked to provide further information regarding the location and equipment/components scanned so that the inspection results are correctly classified and stored in the database. The software checks that the fields have been completed and only allows the person to submit the inspection for processing once all required fields have been entered. The red cross next to the date and time of the inspection indicates that some fields are missing. Once all fields have been entered, the red cross is replaced with a green check mark indicating that the inspection data is ready for processing.

To minimize data entry errors, the sites are pre-populated in the database along with their GPS coordinates. The software uses the GPS coordinates recorded by the sensor to select the correct site automatically. Similarly, GPS coordinates are stored for each equipment and the software will automatically select the equipment based on the average GPS coordinates from the sensor during the inspection. Instead of typing site and equipment names, the person only needs to verify that the correct menu entries were selected. This verification is needed because GPS accuracy is typically about 10 meters, and some equipment may be closer together.

Figure 40. Image of the software on the edge computer.

To minimize data entry errors, the sites are pre-populated in the database along with their GPS coordinates. The software uses the GPS coordinates recorded by the sensor to select the correct site automatically. Similarly, GPS coordinates are stored for each equipment and the software will automatically select the equipment based on the average GPS coordinates from the sensor during the inspection. Instead of typing site and equipment names, the person only needs to verify that the correct menu entries were selected. This verification is needed because GPS accuracy is typically about 10 meters, and some equipment may be closer together.

The person performing methane inspection is also asked to define and label the emission based on the plume visualization on a photo (bottom right of *Figure 40*, above) and enter any field notes. Duplicate scans may also be discarded at this time. Apart from specifying the site, equipment, and component for each scan and the **Digital Emission Tag**, the person has the option to characterize each **Digital Emission Tag** as "fugitive emission," "as designed emission," or "permitted emission." **Xplorobot Inspector** software separates the **Digital Emissions Tags** by category of the mitigation actions required by Regulation 7.

Finally, the person performing methane inspection must specify whether the **Digital Compliance Records** should be created as 2D or 3D methane maps. Then, the inspection data is ready to be submitted for processing. All inspections go into a queue and are processed on the edge computer. Another tab shows the status of the processing for each inspection.

An alternative procedure is to upload inspection data into a remote computer with high CPU and GPU capabilities for faster parallel processing of the inspection data.

The processing workflow creates the following deliverables:

- Visualization of methane emissions otherwise not visible to the naked eye for each **Digital Emission Tag**.

- Email report for the **Digital Emissions Tags**.

- **Digital Compliance Records** in the form of 2D methane concentration maps per component or a 3D methane concentration map for complex equipment (e.g., compressors).

- Estimation of emissions rates for each emissions source recorded as **Digital Emission Tags.**

- Upload **Digital Emission Tags** and **Digital Compliance Records** to the **Compliance Database** and the **Methane Emissions Management Dashboard**.

The timeline for data processing is approximately 1 hour per scan after data is uploaded to the cloud-based **Xplorobot Compliance Database**. Datasets are processed in parallel, so the time from upload to receiving reports is approximately 1 hour for all inspections.

7.2.3. Visualization of methane emissions otherwise not visible to the naked eye for each Digital Emission Tag

Xplorobot Laser OGI and **Xplorobot Inspector** software utilize advanced Computer Vision to locate the position of each methane measurement (acquired at 10Hz frequency) in space relative to the emission source point identified by the **Digital Emission Tag**. **Xplorobot Inspector** combines all the methane data points in 3D to compile a 3D model of the plume. It then creates a projection video for all the data points acquired for the **Digital Emission Tag**.

7.2.4. Email notification of the emissions detected

An initial report summarizing the inspections is generated and emailed to stakeholders. This report contains a list of the sites inspected with the results and serves as a rapid notification for the case where immediate action may be required. It is a digital record of the emission point that can be provided to the repair crew. If any emissions were detected, then it contains an initial estimate of the flow rates and the 2D images visualizing the plumes, otherwise it just indicates that no emissions were detected.

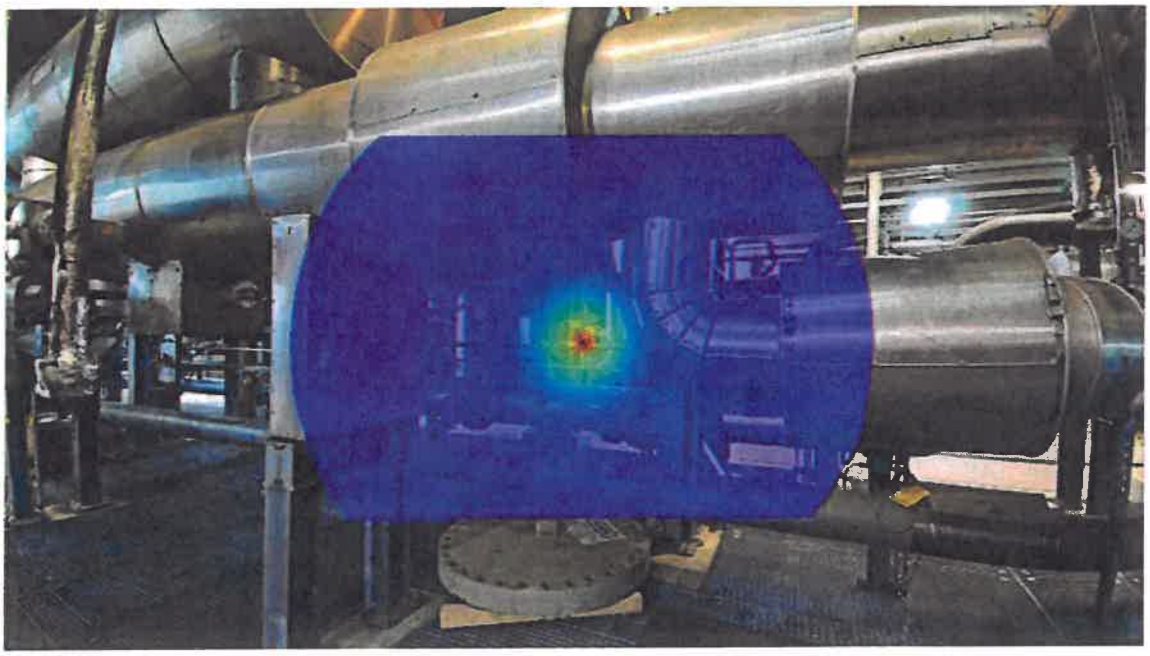

Figure 41. Detection clip from a video of 2D visualization of an emission point.

Figure 42. Example of two pages from a PDF email report with the initial inspection summary.

7.2.5. Digital Compliance Records

Xplorobot utilizes advanced Machine Learning and Artificial Intelligence algorithms to identify each component scanned by the Operator during each scan. **Xplorobot Inspector** extracts methane points recorded for each of these components and creates a 2D concentration map using the same Computer Vision-based approach used for real-time visualization of methane emission on the screen of **the Xplorobot Laser OGI** device. *Figure 43* presents a set of **Digital Compliance Records** for flanges at an inspection site.

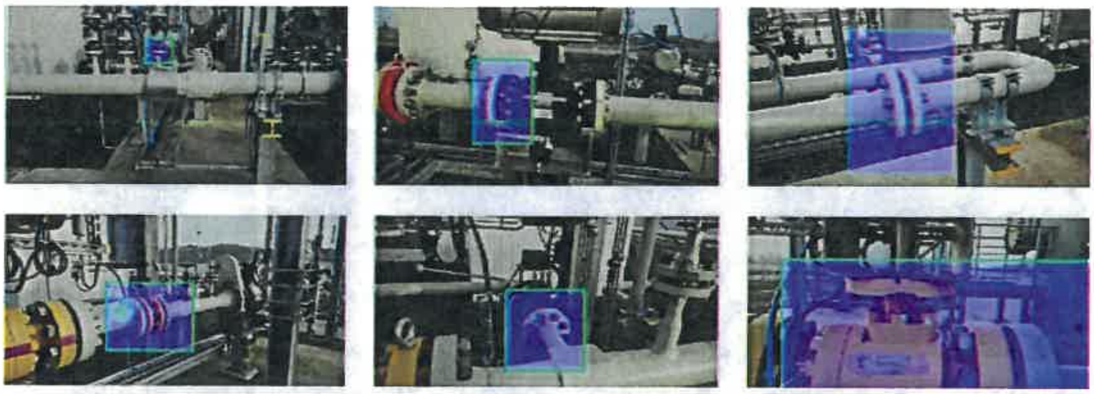

Figure 43. Digital Compliance Records for flanges at an inspection site.

For complex equipment, **Xplorobot Inspector** software offers an option of creating a 3D model and documenting the **Digital Record of Compliance** as a 3D methane concentration map on this model. Xplorobot utilizes the visual information recorded during the inspection to create the 3D model. We typically request the person performing methane inspection to conduct scans at three different levels (waist, chest, and head level) and point **Xplorobot Laser OGI** up, straight, and down during scans at this level to collect visual data coverage required for creating a 3D model. We then use Xplorobot's proprietary computer vision algorithms to define the location of each methane measurement to create the 3D map. *Figure 44* presents an example of **Digital Compliance Certification** for a separator at an inspection site.

Figure 44. 3D model of a horizontal separator with a 3D map of methane concentration based on Xplorobot Laser OGI inspection.

7.2.6. Compliance Database operating procedure

Upon completing the analysis, the **Xplorobot Inspector** Software autonomously submits all the **Digital Emission Tags** and all the **Digital Compliance Records** to the **Compliance Database** for the Operator. The **Compliance Database** is used to compile reports required by Regulation 7 and submit the information required to create work tickets for emission mitigation per Regulation 7's repair requirements. *Figure 45* provides a diagram of the **Compliance Database** architecture.

Figure 45. The architecture of the Compliance Database.

The **Compliance Database** serves as a tool for conducting process audits and ensuring transparency and accountability in emissions management. The comprehensive digital archive also equips operators with a resource to assess and optimize their operations.

7.2.7. Methane Emissions Management Dashboard operating procedure

All **Digital Emissions Tags** and **Digital Compliance Records** are presented to the Operator in the **Methane Emissions Management Dashboard** through 3D models and video visualizations of emissions points. The interface of the Dashboard includes methane intensity metrics with the following information:

- Gas Production (Current and Year-to-Date Average)
- Equipment Surveyed (Current Month and Year-to-Date)
- Emissions Points (Found and Repaired)
- Alerts

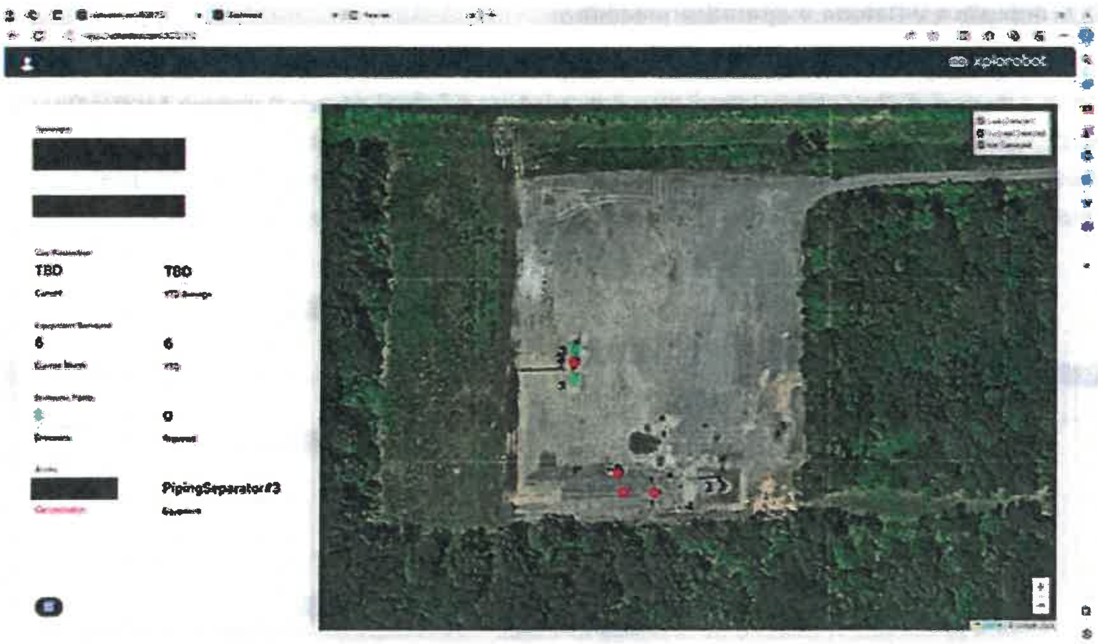

Figure 46. The Methane Emissions Management Dashboard at the map/facility level showing an inspected site.

The Dashboard integrates all the Operator's assets from the regional to the site/facility to the component level. The assets are visualized in a map highlighting the sites, facilities, and equipment inspected. In the map, green icons indicate zero emissions, red icons indicate fugitive emissions, and gray icons indicate all other assets that need to be inspected. Upon selecting the icons at the site/facility level, a window appears with the inspection results of the selected component in an intuitive visual form (3D model, videos, and images) along with the following information:

- Name of the Equipment
- Date of Inspection
- Results (Emissions Detected or Zero Emissions)
- Maximum Concentration
- Emissions Rate
- Repair Status

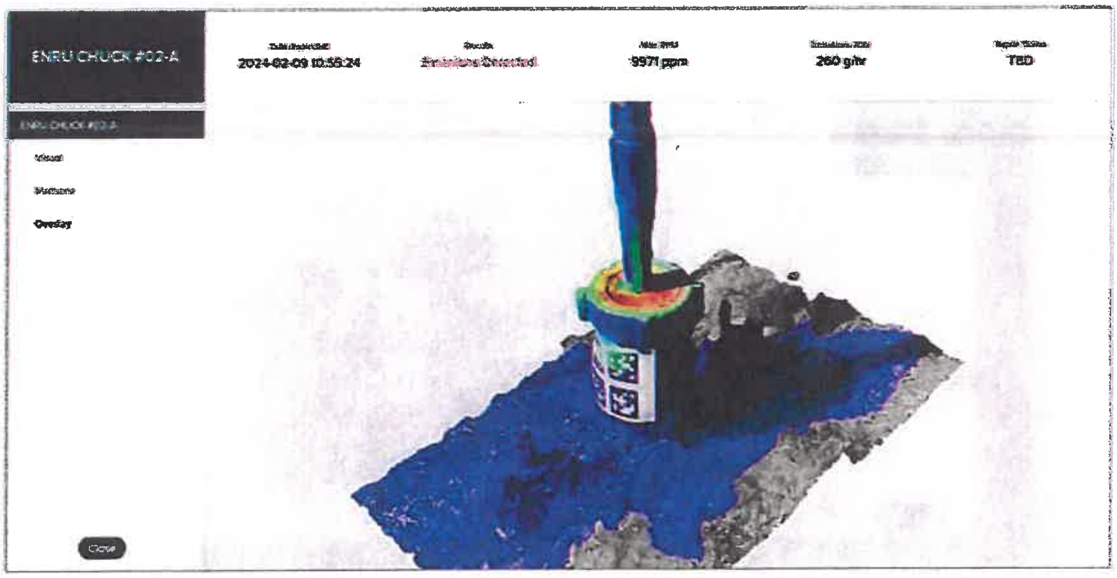

Figure 47. Methane Emissions Management Dashboard at the component level showing inspected equipment with inspection results on the upper horizontal row.

For component-level results, the Dashboard offers two types of displays based on equipment type and processing workflow:

7.2.8. Component-level results

The Dashboard has two ways to display inspection results for components based on the equipment type and processing workflow:

1. <u>Model-based workflow results:</u>

   For complex equipment (i.e., compressors, separators, wellheads, etc.), emissions points are visually represented in 3D models. In the Dashboard, each model includes three textures—a visual texture representing the equipment as-is, a methane texture translating the methane data in the 3D model, and an overlay texture showing the visual and the methane textures together. Video recordings of leaks captured in the field are also available for all the components where emissions have been detected.

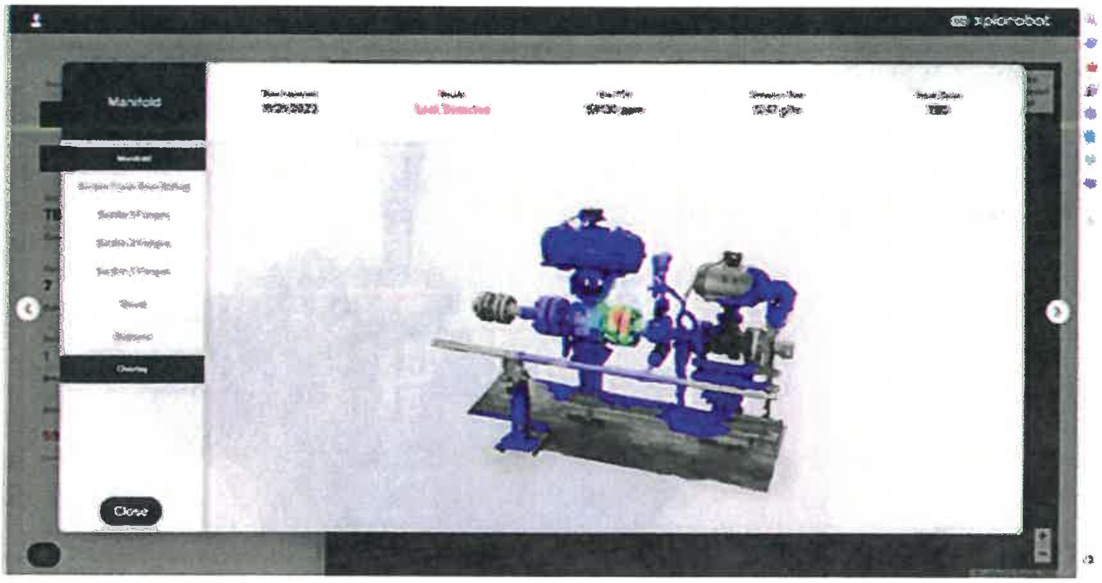

Figure 48. Methane Emissions Management Dashboard at the component level showing 3D model-based workflow results.

2. Computer vision workflow results:

For piping and simpler equipment, emissions points are identified and cataloged using an advanced AI algorithm applied to high-resolution images acquired in the field. The raw data is then translated visually to these images as methane maps. In the Dashboard, the analyzed images with the methane maps are displayed. As with the model-based results, video recordings of leaks captured in the field are also available for all the components where emissions have been detected.

In addition to the map view, results can be accessed from a list format that displays all assets and equipment names with alerts for those components with emissions.

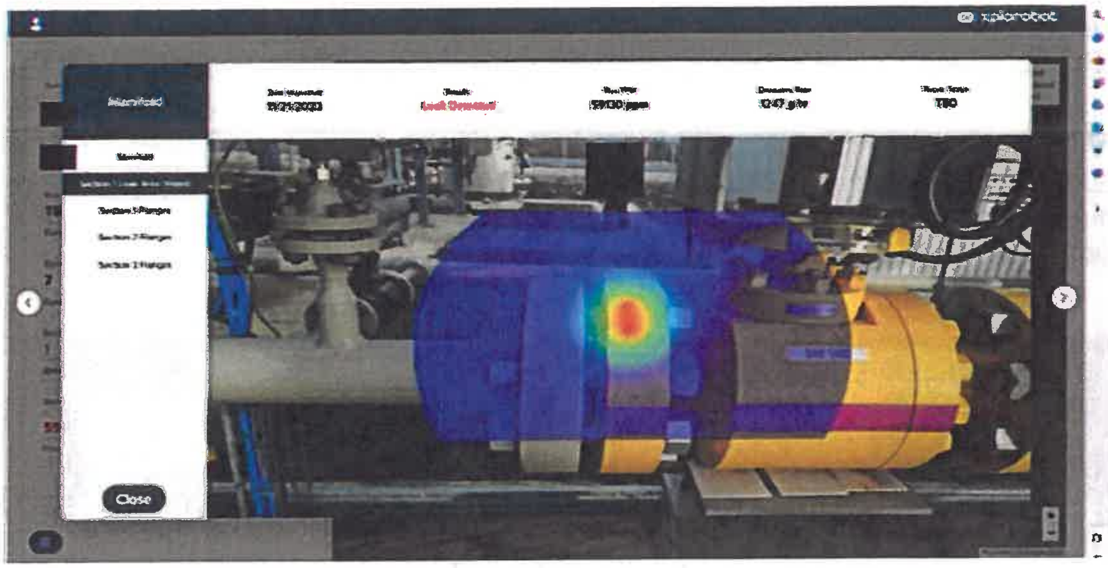

Figure 49. Methane Emission Management Dashboard at the component level showing computer vision workflow results.

7.2.9. Verification of repairs and completion of Digital Compliance Records post-repair

After the identification of a leak, the repair process commences. The repair procedures and timelines outlined in Regulation 7 will be adhered to in the implementation of this proposed AAIMM. In accordance with Regulation 7, the timelines for repairing leaks differ based on jurisdiction, and reasonable delays in repair, as deemed justifiable, are acceptable.

7.3. Source Tracking for Repair

Xplorobot Laser OGI was developed so that any operator or mechanic can use it in the field. Thus, in many cases, an operator or mechanic that identified an emission source using **Xplorobot Laser OGI** can conduct the repairs immediately if the right tools are available. Certification of the successful repair can be done using **Xplorobot Laser OGI** immediately upon completion. Enabling the detect-repair-certify activity in one field visit considerably reduces the turn-around time for emissions mitigation and reporting. The **Digital Emission Tag** and the Digital Compliance Record created per- and post-repair, can be uploaded into the **Compliance Database** and the **Methane Emissions Management Dashboard** by the Operator or mechanic upon returning to the field office.

In cases when an immediate repair cannot be conducted upon the detection of the emission in the field, a **Digital Emission Tag** is created, and an email notification about the emission is issued by the **Xplorobot Inspector** software upon data download. The email notification is directed to all the relevant stakeholders in the organization who are responsible for tracking the emissions and conducting repairs and mitigation activities. The **Digital Emission Tag** is uploaded into the **Compliance Database** and is available for review by all relevant stakeholders in the **Methane Emissions Management Dashboard**. The information on the site, equipment, and components captured in the **Digital Emission Tag** is used to create a work order for repair or mitigation activity.

The **Digital Emission Tag** localizes the emission source with an accuracy of 1 centimeter when **Xplorobot Laser OGI** is deployed from a distance between 1 and 2 meters from the source. A combination of a narrow aperture laser beam, high-resolution images, digital recording of all data, and the proprietary Xplorobot computer-vision based algorithm allows localization of the emission source not just to a flange but often to a specific bolt. *Figure 50* provides an example of a bolt-level accuracy of emission source localization. This accuracy enables capturing, storing, and communicating accurate information for the emission source location required for conducting repairs and mitigation activities.

Figure 50. Example of emission source localization to a specific bolt on a flange by Xplorobot Laser OGI.

Once the repairs or mitigation are complete, **Xplorobot Laser OGI** is used to document the absence of emission and a Digital Compliance Record is created and stored in the **Compliance Database**, documenting the successful mitigation of the emission.

7.4. Program-Level Data Collection, Analysis, Storage, and Interpretation.

For the proposed AAIMM, the two parties will be responsible for record-keeping and communication of LDAR program-level data. All records will be securely stored on cloud-based servers for at least five years, and the party accountable for these records will provide access to the Division upon request. The record-keeping requirements align with those outlined in Regulation 7, Part B, specifically Sections II.E.8 (statewide) and I.L.6 (8-hour Ozone Control Area). Regulation 7 stipulates a consistent approach to record-keeping in both jurisdictions. The duties of the two parties and their respective record-keeping responsibilities are as follows:

1. **Xplorobot**:

    a. Establish the **Compliance Database** for the Operator to hold all **Digital Emissions Tags** and all **Digital Compliance Records** created from **Xplorobot Laser OGI** inspections of the Operator's facilities, equipment, and components.

b. Provide access to all the information stored in the Digital **Compliance Database** through an integrated **Methane Emissions Management Dashboard** for the Operator.

c. Establish reporting and communication templates for the Operator.

2. Operators of facilities using the Xplorobot Laser OGI:

a. Conduct regular component-level inspections using **Xplorobot Laser OGI** data.

b. Create **Digital Emissions Tags** for every emission source identified during inspections.

c. Download all the inspection data into **Xplorobot Inspector** software and provide additional data required to complete **Digital Emissions Tags** and to create **Digital Compliance Records** for equipment and sites in the **Compliance Database**.

d. Conduct repairs and mitigation activities for emissions sources and use **Xplorobot Laser OGI** or any other approved device to certify repair and mitigation success.

e. Submit reports to the regulating authorities utilizing data from the **Compliance Database**.

7.5. Program Reporting Plan

7.5.1. Reporting amongst program participants

The proposed AAIMM promotes a transparent and efficient flow of information among LDAR participants, facilitated by granting access to cloud-based databases. The primary communication will be between Xplorobot and the Operator (s). The operators' continuous uploads of data to the cloud platform ensure that both the Operator and Xplorobot have constant access to the system's gathered measurements. To interact with Xplorobot measurements, the Operator will utilize an interactive dashboard through access provided by Xplorobot.

The process is clear and well-defined. By establishing a protocol for information exchange, the proposed AAIMM ensures a structured data flow between Xplorobot and the Operator. The raw emission data is stored locally with the Operator. Should Xplorobot need additional data from the Operator regarding details of detection events (for example, distinguishing between a confirmed leak and a routine emission event), they can request it from the Operator. This process supports effective collaboration by allowing Xplorobot to access and analyze follow-up information on detection events as it refines the distinction between confirmed leaks and routine emissions.

The responsibility is assigned to Xplorobot to maintain its database of **Xplorobot Laser OGI** footage that aligns with efficient record-keeping practices. The reciprocal access provision, allowing the Operator to request information for internal reviews or regulatory reporting, enhances collaboration while maintaining a secure framework.

The emphasis on limiting information sharing to the participants of the unified LDAR program underscores the importance of confidentiality and data integrity. This ensures that sensitive data, such as Xplorobot inspection details, remains within the defined boundaries of the participating entities, preventing unauthorized access and promoting a focused and controlled information exchange.

7.5.2. Reporting to the regulator

In accordance with Regulation 7, Part B, Sections II.E.9 (statewide), I.L.7 (8-hour Control Area), and III.F.5 (statewide pneumatic controller program), an annual report is required for submission to the relevant regulatory body. All records that fall under the responsibility of the Operator to collect (as outlined in **Section 2.2** of this proposal) will be furnished to the regulator. The ultimate responsibility for submitting yearly reports rests with the Operator. Given that this program captures more information than an approved instrument monitoring method, any additional reporting standards required by the Air Pollution Control Division can be established in collaboration with Xplorobot.

Section 8 of this application provides an illustrative example of the tabular time series of monitoring system data. The Operator will receive and submit this information to the regulator within the timelines specified in Regulation 7.

7.6. Auditability of the Proposed Program

All pertinent program data, including information captured by **Xplorobot Laser OGI**, will be stored in cloud-based databases. Additionally, the platform will house leak repair data, enabling regulators to verify the proper and timely repair of identified leaks. Regulators can request access to the cloud-based server through established data request channels.

8. Recordkeeping and Reporting Format

As part of the proposed Alternative AIMM, Xplorobot will establish a **Compliance Database** for each Operator participating in the program. The **Compliance Database** will be populated with **Digital Emission Tags** created for each emission source identified in the inspections conducted by the Operator personnel of contractors using **Xplorobot Laser OGI**. The structure of the data flow from the in-field inspection to the **Compliance Database** and to Regulatory reporting is presented in *Figure 51.*

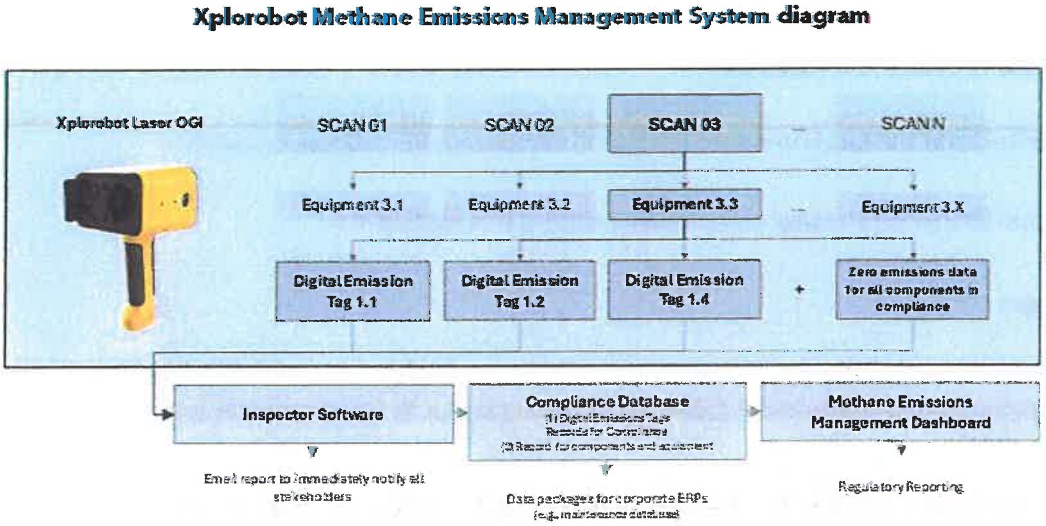

Figure 51. Diagram of data flow from Xplorobot Laser OGI inspections to Compliance Database to Regulatory Reporting.

Each **Digital Emission Tag** stored in the **Compliance Database** contains the following information.

1. Site, equipment, and component that is emitting methane.
2. Visualization of the methane emission otherwise not visible to the naked eye, which localizes the emission source to a specific component.
3. Methane concentration at and around the emission source.
4. Wind speed and temperature at the emission source.
5. GPS coordinates for the location where the emission source was recorded.
6. Estimate of the emission rate in grams per hour or standard cubic feet per minute.
7. Date and time when the emission source was detected.

Each **Digital Compliance Record** stored in the **Compliance Database** contains the following information.

1. Site, equipment, and component in compliance.
2. 2D or 3D methane concentration map certifying the absence of methane emission.

3. Wind speed and temperature at the equipment/component location at the time when the Digital Compliance Record was established.

4. GPS location for the location where the Digital Compliance Record was established.

5. Data and time when the Digital Compliance Record was established.

9. References

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Methane Emissions Technology Evaluation Center. Survey Emission Detection and Quantification Final Report , performer - XPLOROBOT, October 11, 2023.

Thomas A Fox, Thomas E Barchyn, David Risk, Arvind P Ravikumar and Chris H Hugenholtz. A review of close-range and screening technologies for mitigating fugitive methane emissions in upstream oil and gas. Environmental Research Letters, 14(5), April 2019.

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Survey Emission Detection and Quantification Final Report

METEC
METHANE EMISSIONS TECHNOLOGY EVALUATION CENTER

Performer: Xplorobot
Report Generated: October 11, 2023

1 Experiment Summary

Testing included a total of 36 experiments performed between 2023/09/24 23:59 and 2023/09/27 23:59. A total of 105 controlled releases were performed during these experiments. Individual experiments included between 1 and 6 controlled releases, with an average of 2.92 controlled releases per experiment. Figure 1 shows the distribution of number of controlled releases per experiment. Figure 2 shows the distribution of emission rate of controlled releases during experiments. Emission rates ranged from 0.0 and 2090.0 gCH_4/h. Figure 3 summarizes the location of controlled releases by equipment unit.

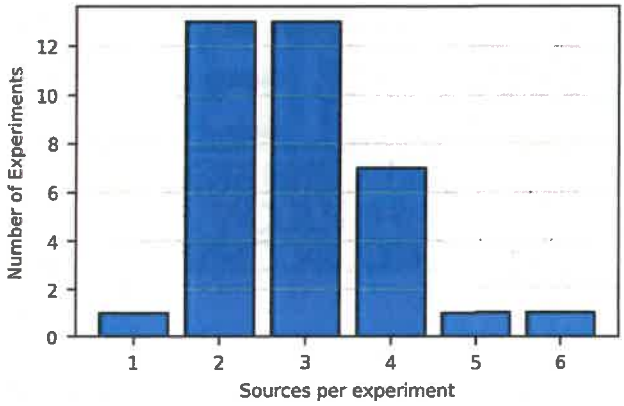

Figure 1: Histogram of number of controlled releases included in each experiment

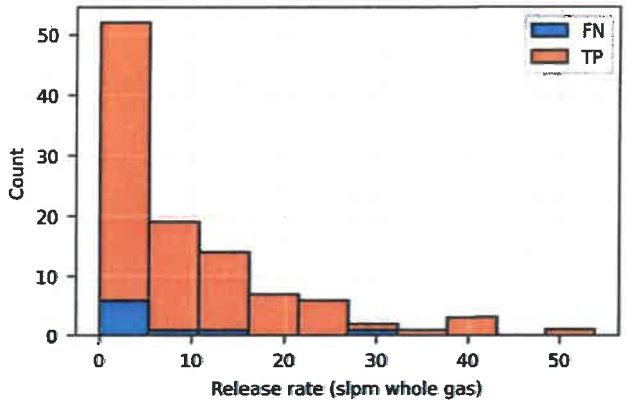

Figure 2: Histogram of metered emission rate (slpm whole gas) for all controlled releases performed during experiments

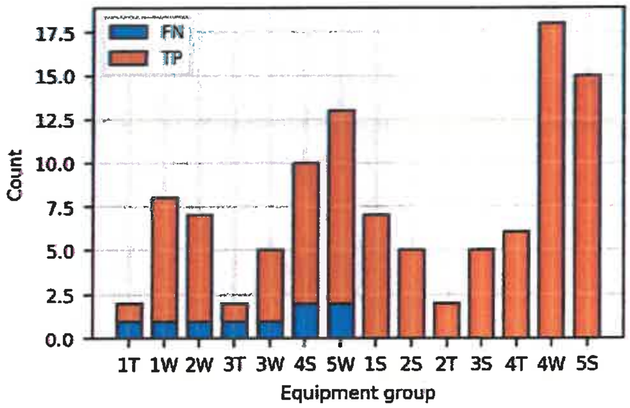

Figure 3: Distribution of controlled releases across equipment groups

Figure 4 shows the average ambient temperature during each experiment. Temperature ranged from 18.3 ^{o}C to 27.7 ^{o}C, with a mean of 24.2 ^{o}C.

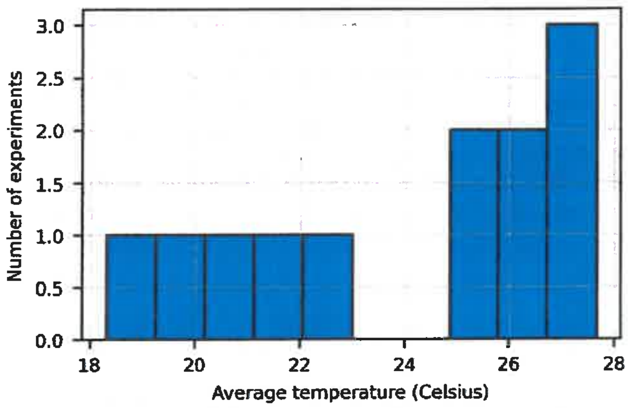

Figure 4: Histogram of average temperature (^{o}C) during each experiment

Figure 5 shows the average wind speed of each experiment. Wind speed ranged from 1.27 m/s to 2.78 m/s, with a mean of 2.02 m/s.

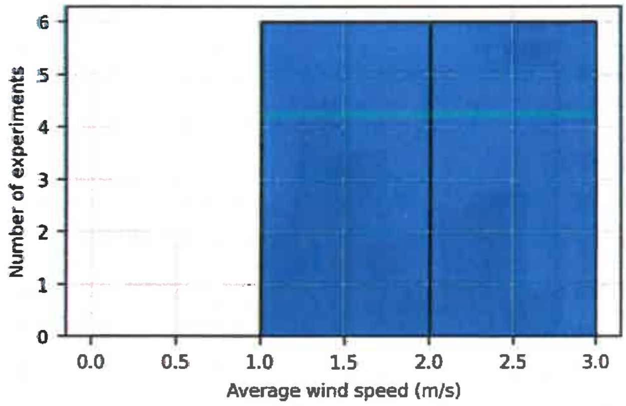

Figure 5: Histogram of average wind speed (m/s) during each experiment

2 Performance Metrics

Metrics as described in section 6 in the protocol are reported in this section. Primary metrics are reported for all performers. Secondary metrics are reported only if the performer detection reports included the required data for their calculation.

2.1 Classification of Detections

Xplorobot reported a total of 98 detection reports. Detection reports were matched to controlled releases following the method outlined in the test protocol to identify true positives, false positives, and false negatives. The classification of controlled releases and detections is shown in Table 1. The classification of individual detections and controlled releases can be found in the accompanying data files.

Table 1: Classification of controlled releases and detection reports.

Level	True Positive	False Negative	False Positive	Excluded from Analysis	Total
Controlled Releases	96	9	-	0	105
Detection Reports	96	-	2	0	98

2.2 Probability of Detection

The probability of detection (POD) curves derived from the classified detection and controlled release records are illustrated in figures 6 through 10. Figures 6 and 7 shows the POD calculated using a variable width bin. In this approach the number of data points within each bin, and therefore the statistical significance of each bin, is approximately equal.

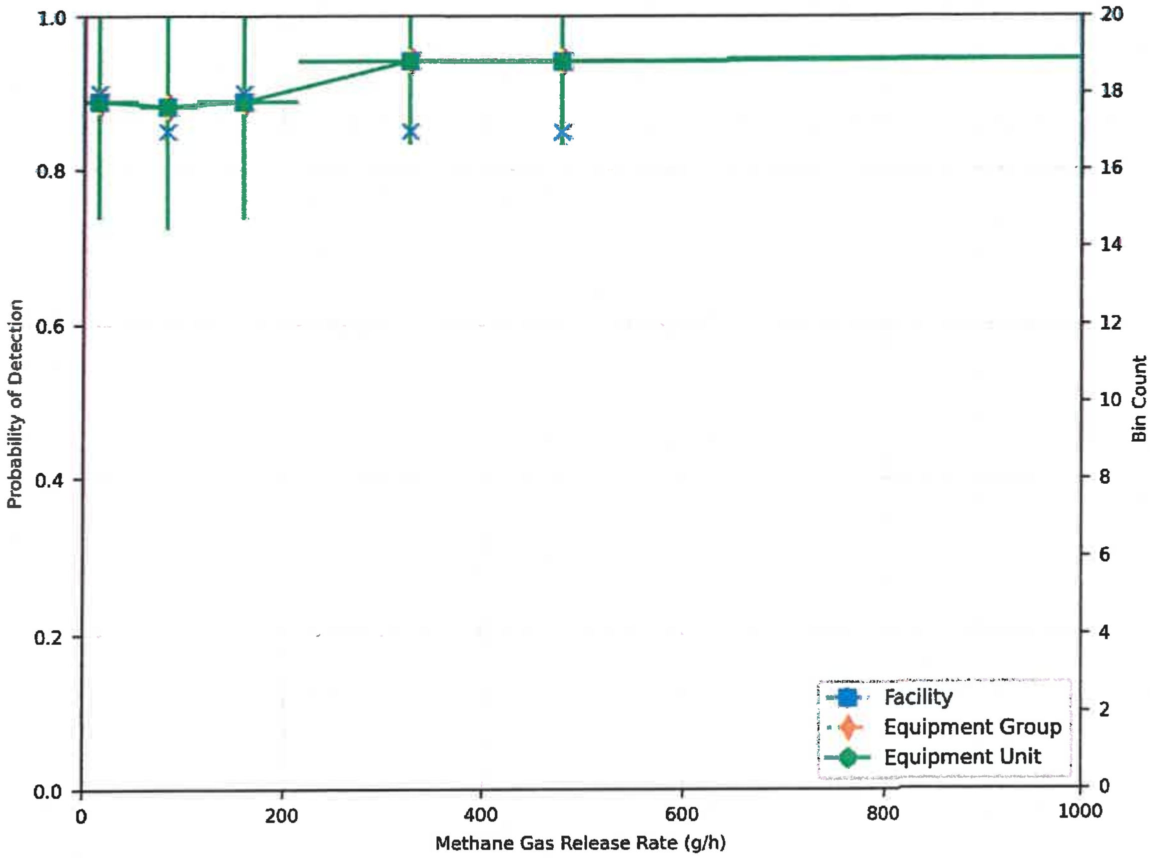

Figure 6: Probability of detection vs emission rate (g CH_4/hr) with even data count per bin. POD includes all true positives at equipment unit, equipment group, and facility levels. Markers represent mean emission rate and observed POD. X whiskers indicate maximum and minimum emission rate in bin. Y whiskers indicate maximum and minimum POD when empirical data is bootstrapped. Number of data points within each bin is plotted on right hand axis.

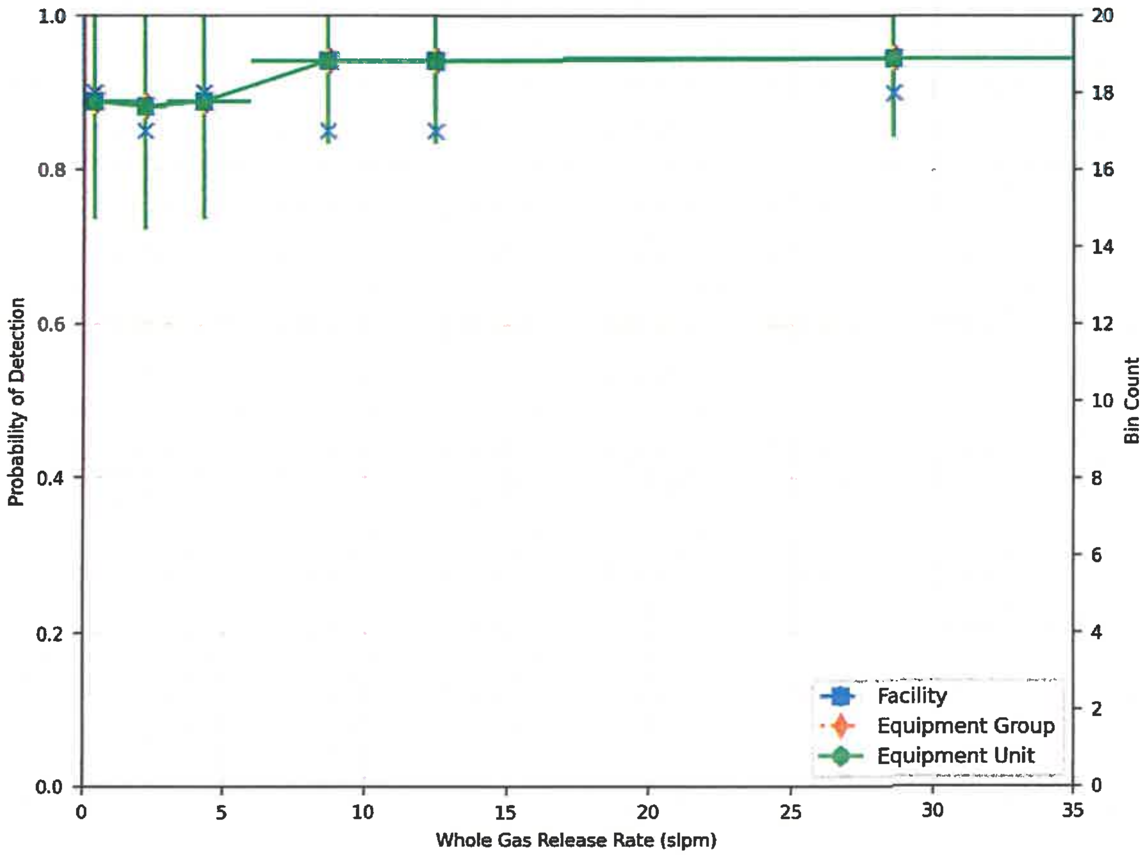

Figure 7: Probability of detection vs emission rate (slpm whole gas) with even data count per bin. POD includes all true positives at equipment unit, equipment group, and facility levels. Markers represent mean emission rate and observed POD. X whiskers indicate maximum and minimum emission rate in bin. Y whiskers indicate maximum and minimum POD when empirical data is bootstrapped. Number of data points within each bin is plotted on right hand axis.

Figures 8 and 9 shows the POD calculated using a fixed bin width. In this approach the number of data points within each bin, and therefore the statistical significance of each bin, varies according to the distribution of controlled releases included during the testing. Beware using this form of the curve, as the statistical significance of some bins may be very low.

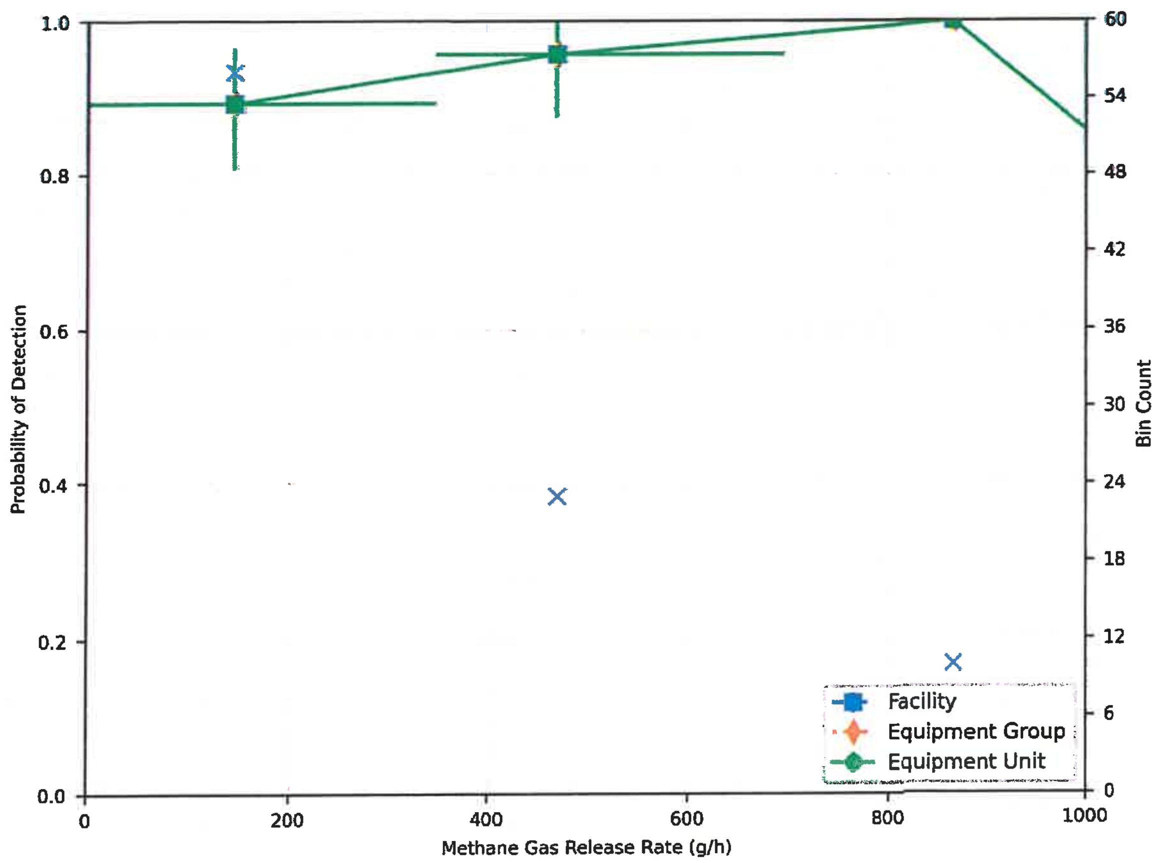

Figure 8: Probability of detection vs emission rate (g CH_4/hr) with even bin widths. POD includes all true positives at equipment unit, equipment group, and facility levels. Markers represent mean emission rate and observed POD. X whiskers indicate maximum and minimum emission rate in bin. Y whiskers indicate maximum and minimum POD when empirical data is bootstrapped. Number of data points within each bin is plotted on right hand axis.

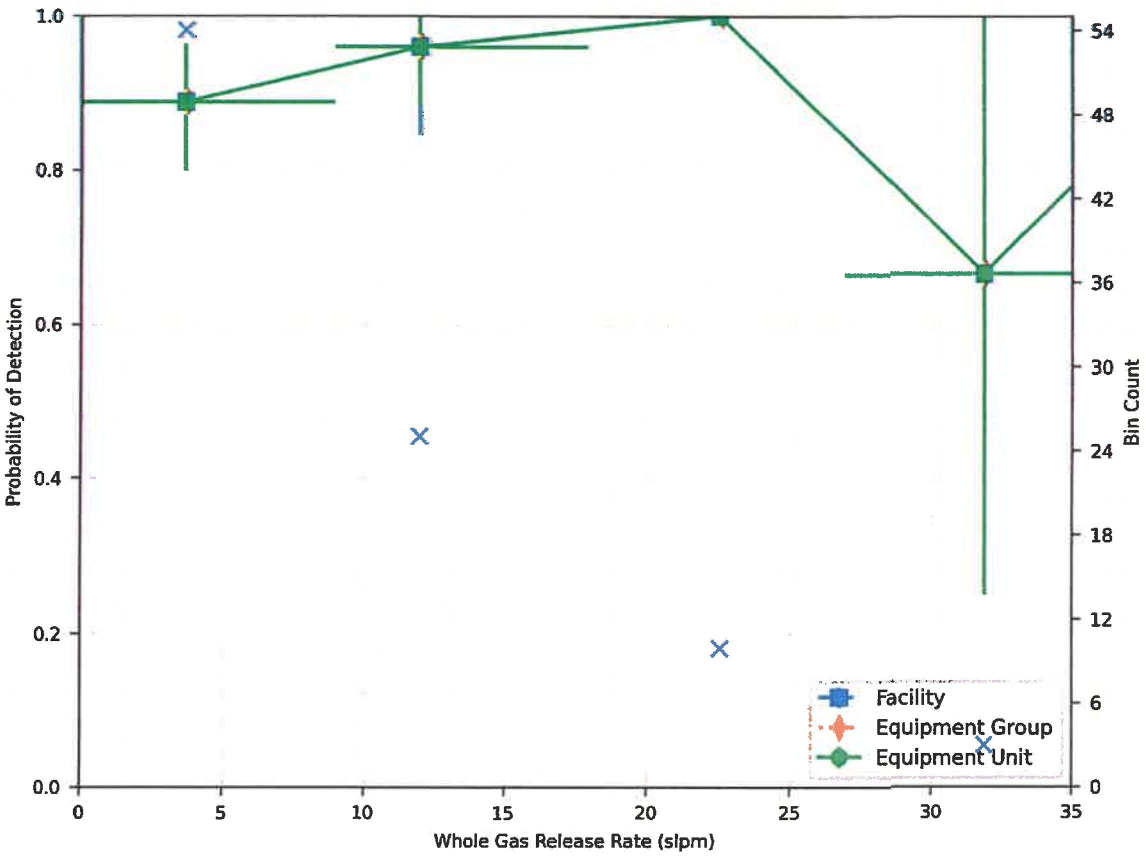

Figure 9: Probability of detection vs emission rate (slpm whole gas) with even bin widths. POD includes all true positives at equipment unit, equipment group, and facility levels. Markers represent mean emission rate and observed POD. X whiskers indicate maximum and minimum emission rate in bin. Y whiskers indicate maximum and minimum POD when empirical data is bootstrapped. Number of data points within each bin is plotted on right hand axis.

Figures 10 shows a logistic regression performed against the true positive and false negative results.

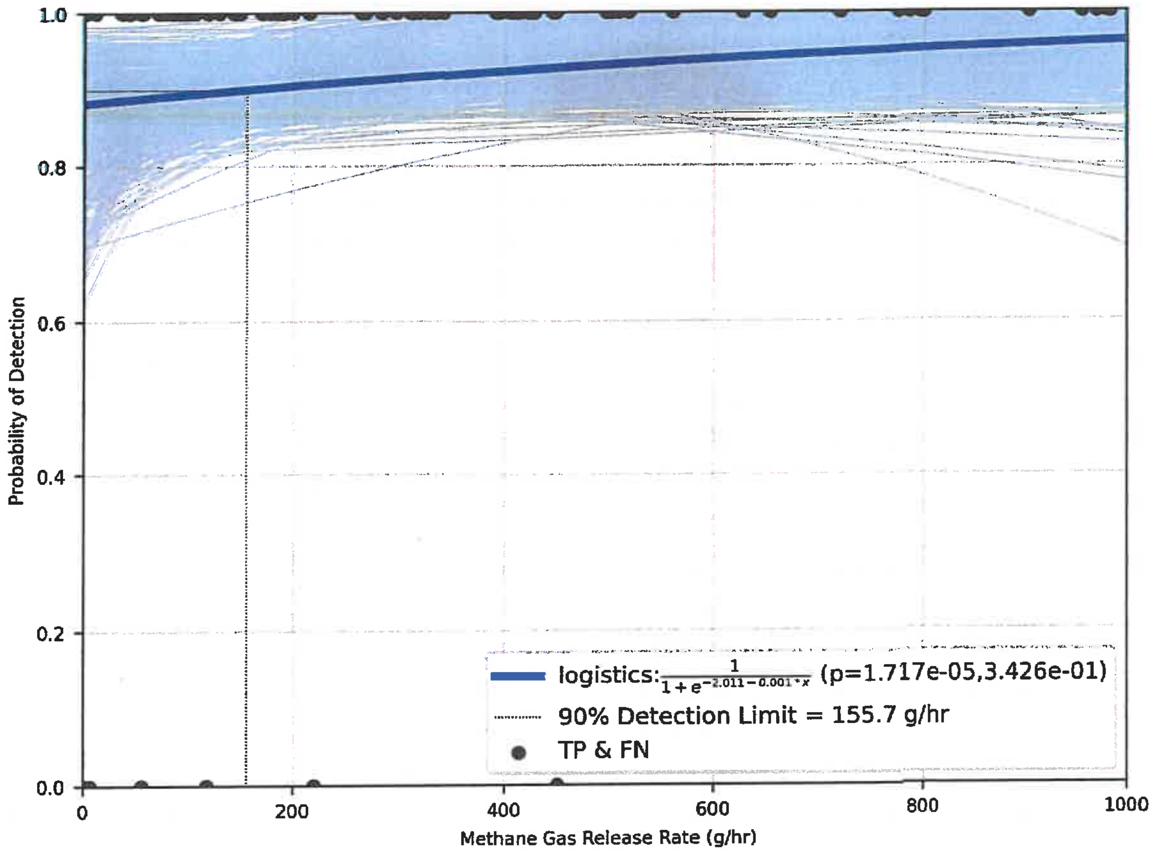

Figure 10: Probability of detection versus emission rate. The probability of detection vs emission rate (g CH_4/h) assessed with logistic regression including all true positives (equipment unit-, equipment group-, and facility-levels). True positive and false negative detections are shown with markers at y = 1 and y = 0 respectively. The regression is performed on bootstrapped results to show a cloud of curves to illustrate uncertainty in the result.

2.3 False Positive Fraction

The false positive fraction ($N_{FP}/(N_{FP} + N_{TP})$) derived from all detections was 0.0204.

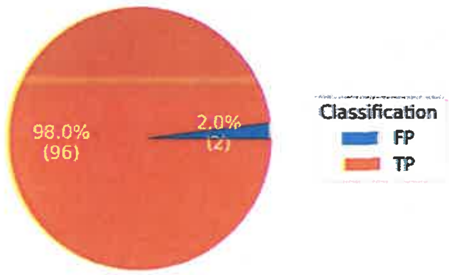

Figure 11: Classification of performer detection alerts. True Positive (TP) alerts were paired with a controlled release at the test center. False Positive (FP) alerts were unpaired.

2.4 False Negative Fraction

The false negative fraction ($N_{FN}/(N_{FN} + N_{TP})$) derived from all controlled releases was 0.0857.

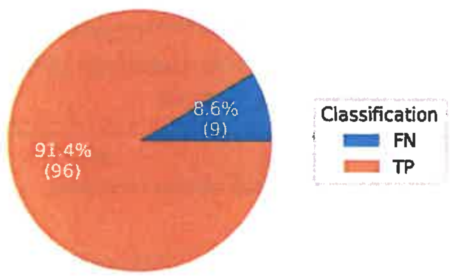

Figure 12: Classification of controlled releases. True Positive (TP) releases were paired with a detection reported by the performer. False Negative (FN) releases were unpaired.

2.5 Survey Time

The survey time of individual detections is illustrated in figure 13. The average time on each equipment group normalized by the count of equipment units is shown in figure 14. The minimum survey time was 13.0 minutes. The maximum survey time was 41.0 minutes. The mean survey time was 26.489795918367346 minutes.

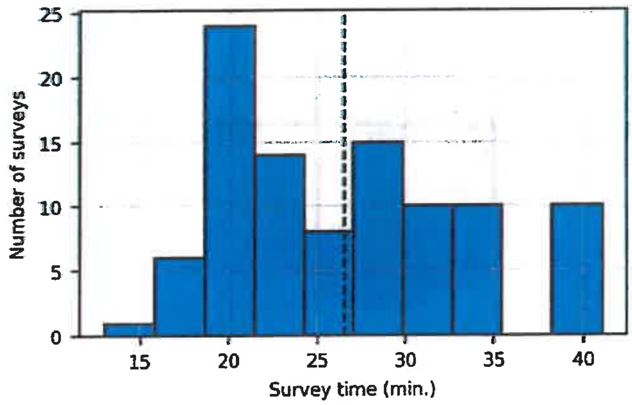

Figure 13: Histogram of survey time per experiment.

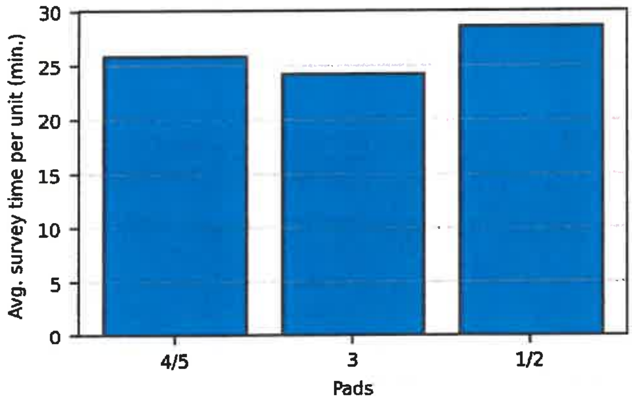

Figure 14: Average survey time per equipment unit by facility.

2.6 Localization Precision (Equipment Unit)

Table 2 lists the number of true positives at the equipment unit, equipment group, and facility-level.

Table 2: Localization Precision (Equipment Unit)

Level	True Positive Count
Equipment Unit	96
Equipment Group	0
Facility	0

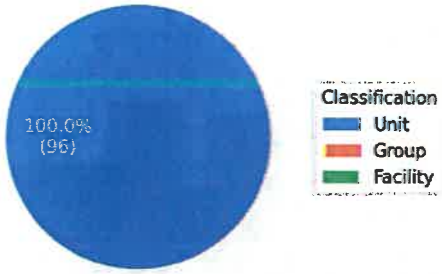

Figure 15: Categorizing True Positive detections by localization precision levels. The localization precision levels include the Equipment unit level, Equipment group level, and the Facility level.

2.7 Localization Accuracy (Equipment Unit)

Table 3 lists the localization accuracy (the fraction of reports identified as true positive) at the equipment unit, equipment group, and facility-level . The fraction of reports identified as false positive is also included in the table.

Table 3: Localization Accuracy (Equipment Unit)

Level	Localization Accuracy
Equipment Unit	0.98
Equipment Group	0.98
Facility	0.98
False Positive Fraction	0.0204

2.8 Quantification Accuracy (Absolute)

Xplorobot did not report data required to compute this metric.

2.9 Quantification Accuracy (Relative)

Xplorobot did not report data required to compute this metric.

2.10 Quantification Precision (Absolute)

Xplorobot did not report data required to compute this metric.

2.11 Quantification Precision (Relative)

Xplorobot did not report data required to compute this metric.

2.12 Localization Accuracy (Single Coordinate)

Xplorobot did not report data required to compute this metric.

2.13 Localization Accuracy (Bounding Box)

Xplorobot did not report data required to compute this metric.

2.14 Bounding Box Accuracy

Xplorobot did not report data required to compute this metric.

2.15 Localization Precision (Bounding Box)

Xplorobot did not report data required to compute this metric.

3 Documentation of Test Protocol

A copy of the test protocol is provided in Survey Protocol R0.0.pdf in the zip folder with this report.

4 Documentation of System Under Test

Table 4 lists the documentation from Xplorobot while survey testing. Data left empty was reported as N/A.

Table 4: Performer Information

Field	Data
(1) Please provide a detailed description of system configuration and primary components including the sensor and deployment platform. Additionally, the location (latitude, longitude, height) of auxiliary components such as meteorological station or any other equipment installed at or near the Test Center must be recorded.	nan
(2) Please record the model number of each primary component in (1)	nan
(3) Please record the software revision installed on the components in (1), including performer-specific software components, revisions, or customizations	nan
(4) Please record the revision number of any software analytics installed offsite. For example software to convert concentration maps to mass emission quantification estimates during the experiments.	nan
(5) Please provide a detailed description of the methodology used during emission detection/quantification surveys.	nan
(6) Please provide the confidence level at which emission detection data are reported.	nan
(7) Please record the number of personnel participating in the surveys and their roles. Any remote personnel participating in the survey in any fashion should be documented as part of the survey team in this section. Names of individual personnel are not required.	nan

5 Controlled Release and Detection Data

Controlled release and classification data are provided in classifiedReports.csv in the zip folder with this report. The raw data reported by the performer is provided in rawPerformerData.xlsx in the zip folder with this report.

6 Flow Meter Calibrations

Meter calibrations are available from the test center by request.

Oleg Mikhailov

oleg.mikhailov@gmail.com 415-535-7555

Education

University of California at Berkeley, MBA 2004
Massachusetts Institute of Technology, Ph.D., Geophysics 1998
Moscow Institute of Physics and Technology, Diploma, Physics 1993

Experience

Xplorobot (Exploration Robotics Technologies Inc.)
Co-founder and CEO 2019-present

- Lead development of a methane emissions detection and quantification solution for Energy Industry clients (including ExxonMobil, EOG Resources, Carbon Creek Energy, CENOVUS)
- Deployed autonomous robotics solutions in on-shore and offs-shore oil and gas facilities
- Xplorobot technology was recognized by the 2022 World Oil Technology Awards in the Sustainability category and two awards in Newfoundland and Labrador Technology Show

AlixPartners
Managing Director 2020-2021

- Led turn-around and performance improvement projects for oilfield service companies

The Boston Consulting Group
Managing Director and Partner 2015-2019

- Led 30+ cases in oil and gas operations, including performance improvement for all product lines of the Leading Global Oilfield Services Company in North America ($9B in revenues, $300M EBITDA improvement), $2B growth strategy for a Global Engineering and Construction Company, and operations performance improvement programs for international oil and gas companies in North America, Canada, UK, Russia, Indonesia, Argentina and Thailand

Bashneft 2013 – 2014
Corporate Officer and Vice President for Operations

- Responsible for oil and gas production (400mboed, $1.5B annual operating budget) and annual capital program (over $500M) for drilling, workovers and facilities maintenance
- During tenure, production grew by 15%, meters drilled and hydraulic fracturing count doubled from 2013 to 2014

TNK-BP (Russian JV of British Petroleum)
Vice President, Operations and Asset Management 2012 – 2013
Vice President, Western Siberia Division 2011 – 2012

- Responsible for 1 million barrels a day operations, $1.5B annual capital and $3B annual operating budgets
- Developed & Managed Operations Efficiency Improvement Program to enhance cash flows by $300M over three years.
- Implemented risk-sharing agreements with Schlumberger and Halliburton that enabled new technology deployment for economic development of “challenged reserves”

Chevron Corporation

Operations Manager, Western Gulf of Mexico 2010 – 2011

- Responsible for Chevron-operated oil and gas fields in the Western Area of Gulf of Mexico with operated production over 120M BOED, 450 operations personnel on 130 production platforms

Deputy Asset Manager, Thailand 2008 – 2009

- Responsible for Satun and Funan gas fields off-shore Gulf of Thailand with production capacity over 600M MCFD of natural gas and 20M BOED of condensate

Business Development Manager, Thailand and China 2006 – 2008

- Led gas price negotiations for the U123 gas-to-power sales agreement in Thailand (deal closed with significant price improvement on $30B in gas sales)
- Led fiscal terms negotiations for U123 concession extension in Thailand ($750M bonus negotiated)
- Managed commercial bid submission and gas sales agreement negotiations for Chuandongbei gas field in Sichuan basin (5TCF in recoverable reserves)
- Received two Chevron Chairman's Awards for successful negotiations outcomes

Technical and Commercial assignments in various Chevron Businesses 1998 - 2005

PAUL M. ESPENAN, CSP

832.494.8794 | pmespenan@gmail.com | https://www.linkedin.com/in/paul-espenan/

Trusted leader accomplished in emission reduction strategy and implementation. Reduced methane emissions intensity of >60,000 marginal wells / gathering and compression by 50% in three years. Deep energy production and services industry experience. Practiced in strategic delivery of credible business-focused Environmental, Health, Safety (EHS), Regulatory and ESG / Sustainability systems. Accomplished with integration of efficient EHS/ESG processes and systems. Described by CEO as exceptional leader. Sought out mediator, investigator and counselor. Successful in transformational performance and culture leadership through re-alignment of EHS Team into engaged high-performance family. Polished, inspirational speaker. Effective emissions reduction trainer.

COMPETENCIES

Positive Cultural Change | Integration | Performance Improvement | Air Emissions | Contractor Safety Programs
Construction | Incident Investigation & Learning | Systems, Programs, Process Safety | Regulatory Requirements
Compliance Auditing | Risk Management | Environmental, Social, and Corporate Governance

PROFESSIONAL EXPERIENCE

Diversified Energy Company **1/2020 to present**

Rapidly growing ESG and sustainability-focused independent natural gas company with in-house service capabilities operating in Appalachia, Louisiana, Texas and Oklahoma with substantial midstream and delivery operations; traded on the New York and London Stock Exchanges.

Vice President / Senior Vice President Environmental, Health, Safety and Regulatory

Advanced emission reduction projects from pilots to implementation. Sourced advanced technology and built business partnerships. Working-leader willing to do any job, building relationships and connecting at all levels without regard to titles. Leadership instructor and coach to senior leadership and VP's. Transformed siloed, stagnant 26-member Environmental, Health, Safety and Regulatory organization to fully engaged, cross-functional service-oriented 43-member family. Consolidated multiple heritage company procedures into new efficient programs. Reduced safety incident rates by 50% and GHG reported emissions by 50% in successive years. Created carbon economy revenue streams > $10MM/yr, implemented revenue generating emission reduction practices. Established framework to attain carbon neutrality, built Maximum Abatement Cost Curve project list. Established program to generate certified carbon credits and significantly reduce plugging costs, with projected benefit of $39MM. Prepared production facilities to sell Responsibly Produced Gas with annual benefit of >$5MM. Screened new assets for carbon intensity / cost of carbon with strategy to reduce intensity. Integrated new assets. Leader of water management operations including disposal, flowback, and sales. Interact with BOD on monthly basis. Deliver presentations to investors. Significant contributor to annual Sustainability Reporting efforts. Strong knowledge of international ESG reporting protocols (IPCC, TCFD, SASB, GRI) and ESG scorecard review organizations.

Inspiritus Group, LLC **2018 to present**

EHS Management Consulting Company serving the oil & gas, financial and real estate sectors.

Provided environmental expertise to emerging environmental businesses. Supported real estate transactions. Provided program leadership to a large independent energy company: developed strategic initiatives to address operational needs, program gaps, and transformational performance. Using transformational leadership methods, working with executive leadership, developed metrics and tactics to achieve short and long-term goals. For an energy-focused capital management company, supported EHS program reviews. For a Commercial Real Estate Company, provided property development strategy, consulting, and guidance. Provided keynote speaking events: Key Energy; American Society of Safety Professionals; Human Performance, Root Cause and Trending Association (Incident Investigation).

LINN ENERGY, LLC, Houston, TX **2007 to 2018**
Independent oil and gas company focused on long-life PDP properties, substantial midstream operations, peak market cap of $6.5B, operations in 13 states, 1,900 employees.

Vice President, Environmental, Health & Safety, 2016 to 2018
Led a high-performance organization focused on operational support, influence, people, and results. Created and executed strategic vision and delivery of EHS efforts, growth, and development of 31-member team. Trusted by senior leadership as having the pulse of the organization. Manage budget of $6MM, AFE Projects to $9MM. Communicated quarterly with Board of Directors. Inspired organization through regular messaging and meetings.

- Developed Field Operations Guide with area-specific seamless approach to field guidance and translated EHS actions. Guides became greasy from actual use.
- During rapid company growth, attained top quartile EHS performance in peer benchmarking, favorable board annual ratings. Met all company scorecard and milestone stretch goals for multiple years.
- Utilized transformational leadership methods (3 laws of Human Performance) to form and direct spill reduction teams and achieve breakthrough performance. Reduced annual spill frequency by 20% (2X), annual spill cost by 69%.
- Effectively used incident investigations, cultural assessments, cultural corrective action, alignment and branding to improve safety performance in worst assets to zero incidents for 2 plus years and reduce unplanned outages at Jayhawk gas plant by 100% for multiple years, breaking all prior uptime performance records.
- Led successful two-year company-wide Talent Management strategic initiative team. Delivered company-wide leadership workshops improving performance, resilience, and morale during downturn as measured by surveys and supervisor feedback.
- Created a strong reporting culture of improvement and learning through "Good Catch" recognition and rewards efforts, safety leadership training, and safety maturity development.

Manager, Director of Environmental, Health & Safety, 2007 – 2016
Steady advancement by high performance in a rapidly growing organization based on strong relationships built with operations leaders, high performance, influence, and results. Performed all requirements for organizational success. Designed and implemented all policies, programs and guidance systems for a new company.

- Integrated over 60 new properties, systems, and associated staff. Attained consistent EHS performance, verified by audits.
- Created "For What Matters Most" branding for EHS communication and focus. Brand and message became a unifying force for EHS performance.
- Established and increased engagement, maturity, responsibility, and performance of local EHS committees and emerging talent. Mentored emerging potentials to fortify succession planning. ~80% promoted.
- Delivered safety meetings and training so good people would pay to come.
- Reduced enterprise risk through contractor screening, emergency response, crisis management team leadership, business continuity planning, legislative emerging issues log. 100% of mitigations completed within one year.
- Designed and delivered successful gas plant, production, midstream, water management, DOT pipeline and truck fleet EHS programs. Achieved multiple no finding audits in DOT and Process Safety (PSM).
- Delivered efficient, sustainable, data systems and advanced analytics for incidents and GHG tracking including: P2 Merrick eVin, Carte, WellView, SiteView, Spotfire. GHG and emission inventory reporting fully automated.
- Gained operating experience in PA, WV, KY, MI, IL, LA, OK, KS, TX, NM, WY, CO, CA.

BURLINGTON RESOURCES / CONOCOPHILLIPS, Houston, TX **1998 to 2007**
A large independent oil and gas company with international operations, acquired by ConocoPhillips.

Environmental, Health & Safety Representative, Advisor
Gained practical knowledge of domestic and international (Canada, UK, Algeria, Ecuador, China) land-based and offshore (including floating and deepwater) oil and gas drilling, production and gas processing. Reported to drilling for 2 years. Strong hands-on experience in air permitting and emissions calculation. Emphasis in drilling safety, audits, investigations and contractor performance. Gained trust of operations through responsive, reliable service. Engaged regulatory agencies frequently. International (East Irish Sea) experience.

- Built and implemented worldwide EHS management systems, improving consistency and performance.
- Built Top 8 audit methodology recognized by drilling organization as a best practice.
- Designed inexpensive method for effective lightning strike and static elimination systems for produced water tanks. Reduced losses in field to zero for multiple years with annual savings of ~$600K/year

BROWN & ROOT / HALLIBURTON **1990 to 1998**
An engineering, procurement, construction, military support, and maintenance company owned by Halliburton.

Specialist, Environmental Manager
Supported environmental aspects of company operated facilities and plants, industrial services, industrial maintenance and operation, engineering, construction, and military base support. Significant experience in compliance for large design-build projects. Unique operational experience as Environmental Manager of Base Operations Support at Johnson Space Center. Experienced in certification of two sites for ISO 9000 and 14001.

Previous professional experience included:
Environmental Specialist, JONES & NEUSE, Houston, TX (Environmental Consulting)
Legal Assistant in Environmental and Occupational Law, THOMPSON & KNIGHT, Dallas, TX (Law Firm)

EDUCATION & CERTIFICATIONS

Master of Science, Environmental Science, University of Texas at Dallas
Bachelor of Science, Environmental Health, Louisiana State University
Certified Safety Professional, Board of Certified Safety Professionals, #16430, 2000

CHRIS VEAZEY, CSP

(304) 590-7707
cveazey@dgoc.com

EDUCATION:

M.B.A.
University of Charleston, Charleston, WV

M.S., Safety Management,
West Virginia University, Morgantown, WV

B.S., Industrial and Civil Engineering Technology,
West Virginia Institute of Technology, Montgomery, WV

CERTIFICATION:

Certified Safety Professional, Board of Certified Safety Professionals

ACTIVITIES:

President of the Board of Directors for the Camp Billo Foundation youth camp
Advisory Board Member and former Adjunct Instructor of Safety Management at Marshall University
Active member of Ohio, PA, and WV Oil & Gas Association's Environmental & Safety Committees
Former Board member of Pennsylvania Independent Oil & Gas Association
Charter Member of Buckeye STEPS safety organization
Managed underground pipeline construction, The Fishel Company

EXPERIENCE:

Diversified/Next Level Energy Company, Director of Administration, 2023 – Present

Managed asset retirement operations by collaborating with Production, Regulatory, Land Administration, and Construction departments to develop well plugging schedules and ensure plugging operations are outfitted with proper permits and access.

Collaborated with Diversified and Next Level Energy leadership teams to secure third-party plugging agreements and reported performance data to allocate resources efficiently.

Implemented technology solutions to enhance administrative and reporting processes and optimize resource utilization.

Managed the administrative budget and expenditure approvals based on internal and external plugging responsibilities, ensuring financial responsibility and cost-effectiveness.

Supported plugging operations by consolidating permitting processes from Land Administration and Production Operations to build an inventory of approved and permitted wells.

Managed landowner relations throughout the permitting, construction, plugging and reclamation process of external well operators, federal orphaned well programs and Diversified Energy in four states.

Coordinated with the Diversified Energy Company Environmental, Health and Safety Department on permit compliance issues, environmental abatement and implemented a water sampling program.

IMS, LLC, Owner - Health, Safety and Environmental Consulting, 2019 – Present

Managed the HSE program of a midstream services company that provides disposal and recycling services. Maintained DOT, EPA SPCC and WV DEP compliance.

Conducted assessments, training, and investigations. Provided contractor ISN and PEC compliance services per customer requirements.

Implemented Hours-of-Service tracking software and cameras integrated with commercial vehicles. Reviewed plans and permits with emergency and regulatory officials.

Revised company training program including FMCSA inspections and created orientation training videos. Participated with industry associations and presented at industry seminars and conferences.

Enervest Operating & OWS Energy, HSE Manager, 2010 – 2022

Directed policy and implementation of the safety, health, and environmental management system of production facilities, regulated pipelines, and process safety compliance. Managed training, permitting, and compliance reporting for all assets across the country. Conducted audits of regulated facilities and represented the company in regulatory audits.

Implemented new facility standards for fire and pollution prevention devices. Conducted hazard assessments, approved engineering designs and proposals and managed facility construction. Conducted informational meetings with landowners, stakeholders and emergency officials concerning hydraulic fracturing and pipeline damage prevention public awareness.

Chesapeake Midstream Partners; EHS Specialist Central Region, 2009 –2010

Managed the EHS program for the midstream group in the Appalachian Basin. Conducted training, inspected compressor facilities, updated prevention plans, and inspected pipeline construction activities. Implemented an environmental waste management plan, conducted investigations of compressor facility incidents, and implemented corrective action plans. Monitored production facility maintenance, treatment facility construction, pipeline construction and lease reclamation.

CDX Gas; EHS Coordinator East Region, 2005 –2009

Managed the EHS program including planning, air quality permitting, water discharge permitting and monitoring reports. Represented the company through ISO 14000 certification and acted on its behalf in industry associations and in regulatory meetings. Worked with WVDEP completing the CBM Water Discharge General Permit revision. Established hydrogen sulfide monitoring and respiratory protection programs.

Key Energy Services; Eastern Division EHS Director, 2002 –2004

Directed the safety department covering seven facilities in six states and Ontario, Canada. Assisted in establishing a corporate environmental management system. Trained and evaluated new Safety Representatives from field positions. Managed liability and workers' compensation claims and represented the company in organizational meetings and regulatory audits.

Nicholas L. Bumgardner M.S., CSP.

Cell: 304-545-4848
Bum8221@gmail.com

Summary

Dedicated professional with over 10 years' experience in the natural gas industry focusing on natural gas project related permitting within the Appalachian Region. Expert level knowledge of permitting, environmental, health, and safety in the manufacturing, natural gas production, and construction industries. Exceptionally knowledgeable in OSHA, ANSI, NIOSH, WVDEP, ODNR, PADEP, KYDOG, WVDNR, & WVDOH regulations and standards.

Skills and Courses

- Smartsheet
- GoFormz
- SharePoint
- AutoCAD
- Adobe
- Microsoft Office Suite
- ESRI ArcView
- OSHA 10 Construction
- OSHA 10 General
- Red Cross CPR First Aid/AED Trainer
- USAF Veteran

Education/Professional Development

Certified Safety Professional (CSP-38936)
M.S. Safety Management, West Virginia University, Morgantown, WV May 2014
B.S. Landscape Architecture, West Virginia University, Morgantown, WV May 2009

Professional Summary

Permitting Specialist - Permitting Supervisor – Diversified Energy Bridgeport, WV March 2023 – Present

- Lead permitting department in the execution of strategic initiatives to meet commitments for all DEC, 3rd party, Federal and State plugging objectives.
- Coordinate with Oil and Gas regulators across the multi-state Appalachian Region on all aspects of plugging permits to ensure timely review and issue of plugging permits to meet plugging schedule requirements.
- Utilize technology to streamline permitting process with state agencies across Appalachian region.
- Integrate with NLE staff to focus on development of the plugging schedule by completing desktop and field review of prospect wells to include legacy, COA, Federal, and 3rd party wells.
- Coordinate with NLE staff to group prospect wells to minimize mobilization costs between locations.
- Assist customers with issues surrounding all aspects of the permit application and permitting process, plugging, and reclamation phases of well plugging.
- Integrate plugging forms and letters into Smartsheet to eliminate repetitive data entry tasks.
- Developed training aids for core permitting processes across the operational region.

EHS Leader- Novelis Aluminum Buckhannon, WV April 2019 – Present

- Provided leadership, mentorship, and served as a subject matter expert for Novelis personnel to implement environmental, health, safety, and loss prevention programs.
- Supported regulatory compliance efforts through self-assessments, inspections, audits, laboratory testing, and standards benchmarking to ensure facilities comply to the highest standards.
- Led safety and environmental incident investigations, Root Cause Analysis Teams, EHS Committees, steering committee, and MOC initiatives.
- Revamped and streamlined both web based and classroom training to include mission critical safety and environmental awareness, EHS policies and directives, new hire orientation, contractor safety onboarding, and visitor safety awareness.
- Provided EHS leadership that resulted in a reduction of IRR by 40% and DAWR by 19% over a 2-year period.

Nicholas L. Bumgardner M.S., CSP.

Cell: 304-545-4848
Bum8221@gmail.com

Safety Specialist - MEC Construction Mt. Morris, PA March 2019 – April 2019

- Provided site safety analysis, hazard recognition & mitigation, and daily safety briefings on multi-million-dollar projects.
- Provided safety support to multiple job locations across a 3-state operating area.

Landman I, II, III - EQT Production Co. Bridgeport, WV August 2011 – January 2019

- Coordinate production related projects with focus on permitting, site design, construction, drilling, water operations, and compliance related activities to meet regulatory requirements while aligning with drill/frack schedules.
- Effectively manage contractor workflow with focus on environmental projects from initial field review through final permit application submittal of Army Corps of Engineers (NWP 3,12,14, & 39), US Fish and Wildlife Consultations, WVSHPO Consultation, WVDEP Stormwater, and Floodplain Activity Permitting
- Facilitate both desktop and field level reviews to ensure designs and as built plans meet all regulatory specifications of federal, state, and local agencies.

WVANG/USAF Utilities Systems Specialist – February 2001 – February 2009

- Installs, inspects, maintains, troubleshoots, modifies, repairs, and manages plumbing, water distribution, wastewater collection systems, water and wastewater treatment systems, fire suppression, backflow prevention systems, natural gas distribution systems, liquid fuel storage, distribution, and dispensing systems.

Jeff Gach
Field Specialist

Work History

1999-2004 Roustabout
Doing well setups and repairs as needed.

2004-2007 Wellsite and pipeline coordinator
Supervised well-site survey operations along with laying out roads and pipelines. Utilizing fieldwork and mapping software systems.

2007-2011 Drilling and completion manager
Supervise the drilling rigs, logging, long string cementing, and completion activities in my project area.

2011-2016 Production Supervisor
Managed 6 employees and 550 wells, being responsible for day-to-day repairs and troubleshooting production issues.

2016-2022 Production Forman
Managed 14 employees and 1,800 wells over an 8-county area. Responsible for daily production maintenance and dealing with utility customers off our operated systems. Also, oversaw utilization of methane emissions detection equipment and well-site inspections by my employees on my part of the assets.

2022-present Field Specialist
Evaluating sites for plugging consideration and conducting site inspections pre and post plugging. Conducting methane emissions testing on over 400 wells during this time as part of my inspection process using RMLD and other measurement devices to document levels.
Locating pre-permit and incorrectly mapped sites utilizing mapping and field work, then collecting submeter accuracy GPS equipment to correctly spot these sites.
Laying out construction and plugging plans based on routing and construction needs.

Kevin J. Cook
Next LVL Energy

41 years of gas field experience (March 1983 — Current)

Jobs Held and Duties Performed:

- Rig Hand
- Rig Operator
- Well Operator
- Lead Well Operator
- CDL Truck Driver
- Production Specialist
- Field Specialist — Plugging (Current), including:
  - Working with Land Department and landowners
  - Working with WVDEP Field Inspectors
  - Completing GPS Surveys for well locations and access roads
  - Assessing construction feasibilities for rig/equipment access
  - Assessing wellhead and tubular conditions
  - Assessing WVDEP requirements for reclamations/monuments

Certifications and Skills:

- Driscoll School of Plastic Pipe Fusion
- Hobert's Seminar of Welding Inspection
- Clearwater Seminar of Well Production
- SWVCC Computer Skills Seminar
- Pump Jack Operation Seminar
- H2S Safety Course
- Echo-meter Seminars
- Operation of swab rigs
- Supervision of swab rigs and service rigs
- Proficient in daily rig reporting
- Proficient in Total Well Management Well Analyzer Operation
- Proficient in well production and optimization
- Proficient in plunger lift installation, operation, and repairs
- Proficient in Geotech 7 Trimble GPS Operation
- Proficient in WVDEP Well Finder App
- Proficient in operation of RMLD detection equipment
- Proficient in reading drilling and completion reports