Methane Alternative Test Method 13: SLB Periodic Screening System for Fugitive Methane Emission Monitoring

1 Scope and Application

1.1 Scope

This method is applicable for demonstrating compliance with the procedures in 40 CFR §60.5398b for fugitive emissions components in affected facilities and compliance with periodic inspection and monitoring requirements for covers and closed vent systems, specifically demonstrating compliance through periodic screening in §60.5398b(b), as approved, per §60.5398b(d). Affected facilities could include, but are not limited to, single wellhead only sites, small well sites, multi-wellhead sites, well sites with major production and processing equipment, centralized production facilities, and compressor stations. This method outlines the procedures and information necessary to implement, operate, and use SLB's **S**ystematic **O**bservation **o**f **F**acility **I**ntermittent **E**missions (herein referred to as SOOFIE) emissions monitoring system for periodic screening in accordance with the requirements of §60.5398b(b) and §60.5398b(d).

1.2 Application

1.2.1 The application of SLB's SOOFIE emissions monitoring system is per the Environmental Protection Agency's 40 CFR part 60 New Source Performance Standards (NSPS): Subparts OOOO, OOOOa, and OOOOb, and Emissions Guidelines (EG): OOOOc, for the Oil and Natural Gas Source Category.

1.2.2 This test method is applicable for periodic screening of methane (CH_4, CAS #: 74-82-9) emissions from oil and gas facilities. It can be used, as approved by the Administrator, in lieu of the applicable fugitive monitoring requirements in either §60.5397a or §60.5397b and inspection and monitoring of covers and closed vent systems in either §60.5416a or §60.5416b. This test method may be used for fugitive monitoring requirements specified in §60.5397c and monitoring of covers and closed vent systems under §60.5416c when a state, local, or tribal authority incorporates the model rule (i.e., OOOOc) for the emission guidelines as part of their State Implementation Plan (SIP) or elsewhere, approved as applicable.

1.2.3 This test method is a performance-based method to determine whether facility-level emissions remain below prescribed thresholds.

1.3 Method Sensitivity

The sensitivity of this method is a 5, 10, or 15 kg/hr alerting threshold. A SOOFIE device's Minimum Detection Limit is 0.6 kg/hr at a 90% probability of detection (POD). Operators will select the alerting threshold based on their specific site characteristics and operator practices and will define the appropriate threshold in their monitoring plan.

1.4 Data Quality Objectives

Adherence to the requirements of this method will ensure that the data supporting the technology's objective will be accurate and of quality. The technology's objective is to screen for fugitive emissions at or above detection thresholds of 5 kg/hr, 10 kg/hr, or 15 kg/hr. Screening frequency is defined based on the facility type and applicable detection threshold (Tables 1 and 2). Alerts of emissions at or above the detection threshold will prompt operator response, including follow-up surveys and leak repair.

Table 1. *Method detection limits and minimum screening frequencies for multi-wellhead oil and gas sites, sites with major projection and processing equipment, centralized production facilities, as well as compressor stations.*

Method Detection Limit	Minimum Screening Frequency
5 kg/hr	Monthly
10 kg/hr	Bi-monthly + OGI Inspection
15 kg/hr	Monthly + OGI Inspection

Table 2. *Method detection limits and minimum screening frequencies for single wellhead oil and gas sites, as well as small well sites.*

Method Detection Limit	Minimum Screening Frequency
5 kg/hr	Quarterly
10 kg/hr	Tri-annually + OGI Inspection
15 kg/hr	Bi-monthly or Quarterly + OGI Inspection

2 Summary of Method

2.1 Description of Technology

The SOOFIE emissions monitoring system is a network of SOOFIE devices that incorporate environmental data (i.e., temperature, pressure, and wind conditions) and methane concentration measurements at various sampling points with site information (i.e., potential sources and site layout) to detect and quantify methane emissions. Methane is measured at each SOOFIE device using a highly sensitive metal-oxide semiconductor (MOS) sensor. Through a hybrid quantification approach that applies a physics-based atmospheric model to a machine learning algorithm, the SOOFIE emissions monitoring system determines facility-level emissions that can be applied for periodic screening alerting purposes.

2.2 General Method Overview

A general overview of the method is covered below, which encompasses data collection, reporting, and performance metrics that satisfy the data quality objectives. A more detailed overview and validation of the method is presented in Sections 8-14.

2.2.1 Initial siting and sensor installation procedures are conducted once at the time of initial site setup. Sensors are generally located around the site perimeter but can be placed internally as well at the discretion of the owner/operator.

2.2.2 Each SOOFIE device measures methane concentration using a MOS sensor, in addition to environmental variables including temperature, pressure, and relative humidity.

2.2.3 At least one SOOFIE device in the SOOFIE emissions monitoring system at a site is equipped with a two-dimensional sonic anemometer to measure wind conditions.

2.2.4 Methane concentration data is used to distinguish between periods of emission events from non-emission periods.

2.2.5 For each emission event, methane concentration and wind values are used to identify the most likely source and perform event-based quantification using a hybrid machine learning and physics-based model.

2.2.6 For non-emission periods, each 5-min packet of data is evaluated for coverage of a defined probable source, to ensure that the data represents on-site measurements. Only non-emission data with confirmed coverage is used for quantification.

2.2.7 To perform periodic screening, SOOFIE devices transmit data digitally to the cloud.

2.2.8 Cloud-based analytics and Quality Assurance / Quality Control (QAQC) procedures ensure that all data used for quantification comes from operating devices.

2.2.9 Site coverage and QAQC requirements must be met for the periodic screening to be considered 'valid'.

2.2.10 If all quality checks are passed, the Site Average Emission Rate Estimate is calculated for the periodic screening period.

2.2.11 An alert is generated if the facility-wide Site Average Emission Rate Estimate is above the applicable alerting threshold (Tables 1 and 2).

2.2.12 In case of an alert, the owner/operator must conduct a facility-wide follow-up survey using Optical Gas Imaging (OGI) or Method 21.

3 Definitions and Abbreviations

3.1 Definitions

3.1.1 ***Customer Service Representative***: An SLB employee who will assist in ensuring that the periodic screening has been completed properly including: running the Siting Tool to determine recommended SOOFIE device placement, perform Root Cause Analysis (RCA), ensure proper site setup, and contacting the owner/operator if devices require replacement.

3.1.2 ***Dashboard:*** A web application interface for the SOOFIE emissions monitoring system provided to the Operator by SLB. This application is one way to access 1-min resolution readings from individual SOOFIE devices.

3.1.3 ***Detection Above Reporting Limit:*** Used in the context of the periodic screening evaluation to describe a case where the Site Average Emission Rate Estimate for the Screening period is above the appropriate alerting threshold.

3.1.4 ***Detection Below Reporting Limit:*** Used in the context of the periodic screening evaluation to describe a case where the Site Average Emission Rate Estimate for the Screening Period is below the appropriate alerting threshold.

3.1.5 ***Environmental Probability of Detection:*** The likelihood or capability of a device to detect a methane emission for any wind condition that is seen at the site. This value is based on site-specific information, including probable source location, quantity of devices, and device location. This value is artificially lowered by the 'environmental uptime' requirements (e.g., under what conditions the plume is calculated). The Siting Tool assumes complete instrumental detection within 100 m of a probable source and seeks to maximize the environmental POD through recommending the quantity and location of devices.

3.1.6 ***False Negative***: A confirmed controlled release event that did not produce a detection by the SOOFIE emissions monitoring system.

3.1.7 ***Invalid Data:*** Data is assessed as 'valid' or 'invalid' in 5-min increments. For times outside of emission events, data that does not cover on-site probable sources are considered 'invalid'. For times within emission events, data is 'invalid' if an emission rate could not successfully be calculated. An unsuccessful calculation occurs when, after data pre-processing, there are fewer than three, 5-min data points per emission event.

3.1.8 ***Instrumental Probability of Detection:*** The likelihood for a device to detect a methane emission at a given rate, given that the plume is flowing over the device. This value is determined through The Methane Emissions Technology Evaluation Center's (METEC) Advanced Development of Emissions Detection (ADED) campaign at 90% POD and continued controlled release experiments.

3.1.9 ***Minimum Detection Limit*****:** The emission rate at which the SOOFIE emissions monitoring system achieves a 90% POD, as determined through controlled release testing.

3.1.10 ***Operator:*** The end-user and recipient of the SOOFIE emissions monitoring system periodic screening report.

3.1.11 ***Placement Algorithm*****:** Also referred to as the 'Siting Tool', it is a proprietary algorithm developed by SLB and used by the SLB Customer Service Representatives to determine the recommended quantity of SOOFIE devices and their placement locations at a site. If site coverage requirements are not met for a periodic screening, an RCA may determine that this tool must be re-run with updated wind data.

3.1.12 ***Plume*****:** A trail or cloud of gas which can be dispersed by the wind from an emission source.

3.1.13 ***Probability of Detection:*** The probability that any on-site leak will be detected by the SOOFIE emissions monitoring system at the site across an extended period. The site-wide POD is influenced by the site-specific wind conditions, sensor location, and equipment performance. In lieu of fully verified leak location and rate data across one year, the site-wide POD of the technology can be evaluated by its two main components: Environmental POD (wind conditions and device location) and Instrumental POD (equipment performance).

3.1.14 ***Root Cause Analysis*****:** A procedure that is conducted when the site coverage metrics are not met, in which a Customer Service Representative identifies the underlying reason for this failure. Results from this analysis will determine the appropriate mitigation steps including re-siting, restart of a periodic screening, or equipment replacement.

3.1.15 ***Screening Period*****:** Defined by a period of at least 48 hours of valid emission rates. This period may be extended up to 7 days of measurements to ensure periodic screening source coverage requirements are met.

3.1.16 ***Site Average Emission Rate Estimate***: The single data point resulting from the periodic screening evaluation on a facility-wide basis. This rate is defined as the total kilograms of methane released across 'valid' emission rates used in the periodic screening, divided by the length of time covered by the 'valid' emission rates used.

3.1.17 ***Site Coverage Requirements***: For a successful periodic screening, each identified probable source must have temporal coverage of at least 30 minutes of 'valid' data.

3.1.18 ***Sonic Anemometer***: A device that uses ultrasonic soundwaves to measure wind speed and wind direction. SLB's SOOFIE emissions monitoring system uses a two-dimensional sonic anemometer.

3.1.19 ***SOOFIE Device***: A device produced and distributed by SLB that, at a minimum, includes temperature, humidity, pressure and methane (MOS) sensors, and can connect to a sonic anemometer (as needed). A SOOFIE device is often referred to as a *point-sensor* due to its data output reflecting measurements at one location per device.

3.1.20 ***SOOFIE Emissions Monitoring System:*** A network of SOOFIE devices used to detect and quantify fugitive facility-level emissions.

3.1.21 ***True Positive:*** A confirmed detection by the SOOFIE emissions monitoring system that aligns with a controlled release event.

3.1.22 ***Valid Data***: Data is assessed as 'valid' or 'invalid' in 5-min increments. For times outside of emission events, data must cover an on-site probable source to be considered 'valid'. For times within emission events, data is 'valid' if an emission rate was successfully calculated. For successful calculation, data after pre-processing must include at least three, 5-min data points per emission event, ensuring both emission accuracy and adequate instrumental uptime.

3.2 Abbreviations

3.2.1 ***MOS***: Metal-oxide semiconductor

3.2.2 ***OGI:*** Optical Gas Imaging

3.2.3 ***POD***: Probability of Detection

3.2.4 ***QA:*** Quality Assurance

3.2.5 ***QC:*** Quality Control

3.2.6 ***RCA:*** Root Cause Analysis

3.2.7 ***SOOFIE:*** Systematic Observation of Facility Intermittent Emissions

4 Method Interferences and Envelope of Operation

4.1 Impact of Local Weather Conditions

This periodic screening method is designed to operate within specific environmental conditions to ensure accurate methane detection and quantification. Surveys must be conducted during suitable weather conditions, as adverse factors such as strong winds, rain, and fog can interfere with the performance of the MOS sensors. Because stable plumes are difficult to predict during low wind or highly variable wind conditions, the following conditions must be met for a given 5-min period quantification:

- The average wind speed must be between 0.4-7 m/s.
- Humidity levels must be between 2-100%.
- Temperatures must be between -20-70 °C.
- Pressure must reflect a value that can be found on the Earth's surface (i.e., between 800-1,200 mbar).
- The presence of around 21% oxygen.

The method's operational envelope is summarized in **Table 3**, and the operational conditions of individual sensors within a SOOFIE device are presented in Table 4.

Table 3. *Summary of the SOOFIE emissions monitoring system method interferences and envelopes of operation.*

Condition	**Summary**	**Mitigation**
Solar irradiance	The method requires enough sunlight in the preceding days to power the SOOFIE system.	SOOFIE device's battery backup ensures continued operation during low sunlight periods. If solar charging is insufficient for over a week, surveys must be postponed until sufficient power is available.
Wind Speed	Wind is the primary mechanism of transporting a particle from source to sensor. Wind speed must be between 0.4-7 m/s for accurate detection and quantification.	Data collected outside of these wind conditions will not be used for the periodic test.
Wind Direction Variability	High variability (i.e., above 45° standard deviation in wind direction) of wind direction will negatively impact the ability to predict source location and accurately quantify methane emissions.	Data collected during wind conditions with a standard deviation above 45° will not be used for the periodic test.
Temperature	Temperatures must be between -20 °C and 70 °C.	Data collected outside of these temperature conditions will not be used for the periodic test.
Relative Humidity	Humidity must be above 2% and below 100% RH.	Data collected outside of the humidity envelope will not be used for the periodic test.
Sensor Connectivity	LTE, 2G/3G, or on-site WiFi connectivity is required to transmit data from sensors to the cloud for data processing.	In case of a loss of cellular communication, local sensors can store up to eight hours of data. Periods with lost data due to extended device connectivity issues will not be used for the periodic test.
Hazardous zones	The methane sensors in the SOOFIE devices are not rated for use in hazardous zones.	As outlined in Section 5.3, during the siting process both the Customer Service Representative and client need to verify that sensors are not placed within hazardous zones.
Sensor placement and source coverage	Sensors must ensure adequate coverage of all identified potential emissions sources during the periodic screening.	Siting must follow the SLB siting protocol, as described in Section 8 and Appendix B to provide the operator with recommended sensor placement. An operator may choose whether they would like to place sensors according to the SLB siting protocol. No matter the placement, a 'valid' periodic screening calculation must ensure a minimum of 30 minutes of spatial coverage for each potential emissions source.

Table 4. *Sensor-specific operational conditions, based on manufacturer specifications.*

Sensor Name	Upper and Lower Sensing Range
Methane Sensor	0 ppm to 2,500 ppm
Temperature Sensor	–40 °C to 125 °C
Humidity Sensor	0% RH to 100% RH
Pressure Sensor	10 mbar to 2,000 mbar
Sonic Anemometer (Wind Speed)	0 m/s to 60 m/s
Sonic Anemometer (Wind Direction)	0° to 360°
GPS	N/A
Accelerometer	–2g to +2g

5 Safety

5.1 Disclaimer

This method may involve hazardous materials, operations, and equipment. This alternative test method may not address all the safety problems associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to performing this alternative test method.

5.2 Hazardous Pollutants

Methane leaks may be determined by this method, and other compounds commonly found in the crude oil and natural gas sector may be irritating, corrosive, or toxic to biological tissues. Nearly all pose fire hazards. Compounds in emissions should be determined through familiarity with the source. Appropriate precautions can be found in reference documents, such as reference No. 4 in Section 16 of EPA Method 21.

5.3 Sensor placement

The SOOFIE devices are not intended to be used in hazardous areas. They have a general safety rating (see Section 5.4 on the SOOFIE device's general safety certifications and ratings) and must be kept away from hazardous locations, and at least 1 m away from on-site sources. As a general guideline, however, SOOFIE devices are placed at a distance of at least 1.5 times the source height away from each probable source. SOOFIE devices are not intrinsically safe and do not carry any certifications for use when an explosive atmosphere may be present; such as ATEX, IECEx, Class/Div.

5.4 Product Safety

SOOFIE V1 has the following safety tests:

- UL/IEC 61010 tested (safety requirement for electrical equipment for measurement control and laboratory use)

SOOFIE V2 has the following safety certifications:

- UL 62368-1 (safety standard that classifies energy sources, prescribes safeguards against those energy sources, and guides the application of, and requirements for, that safeguard)
- UL 61010-1
- CSA C22.2 No.62368-1
- CSA C22.2 No.61010-1-12

6 Equipment and Supplies

SLB's SOOFIE emissions monitoring system is supplied with all necessary components for accurate real-time methane emissions detection. The system communicates via cellular networks or on-site Wi-Fi to facilitate data transmission, alerting, and analysis. A SOOFIE device is composed of several components:

6.1 Sonic Anemometer

A SOOFIE emissions monitoring system uses at least one, two-dimensional sonic anemometer to determine wind direction, wind variability, and wind speed at a site. The sensor provides a wind direction resolution of 1° with an accuracy of ± 2°, and a wind speed resolution of 0.01 m/s with a ± 2% accuracy. Sonic anemometers are designed to work at temperatures -35-70 °C. Each wind sensor must be installed 1.5-2.5 m above ground level. Wind speeds must be greater than or equal to 0.4 m/s and below 7 m/s, and wind direction variability (quantified as the wind direction standard deviation) must be below 45 degrees for data from the SOOFIE emissions monitoring system to be used.

6.2 MOS Sensor

The MOS sensor is used to measure methane in the air at the sensor's location. Operating conditions of the MOS sensors fall between -40-70 °C and 2-99% RH. SLB-based laboratory testing has determined that the MOS instrumental has a resolution of < 85 ppb, accuracy of ± 0.79 ppm, and a signal drift of < 1%/year, SLB's proprietary calibration and QAQC methods verify sensor performance throughout the Screening Period.

6.3 Temperature, Pressure, and Humidity Sensors

The temperature, pressure, and humidity sensors operate within a temperature range of -40-85 °C, and relative humidity between 0-100% RH. The temperature sensor reports temperature at a resolution of 0.01 °C at an accuracy of ± 5 °C. The humidity sensor reports relative humidity at a resolution of 0.1% at an accuracy of ± 5% RH. The pressure sensor reports pressure at a resolution of 0.13 mbar at an accuracy of ± 2.5 mbar.

6.4 Printed Circuit Boards

A SOOFIE device is outfitted with two printed circuit boards and several microchips mounted on them, including a telecommunications chip, accelerometer (SOOFIE V2), GNSS (Global Navigation Satellite Sensor) sensor (SOOFIE V2), power supply, and sealed switch. The MOS sensor and antenna used for SOOFIE devices are also connected to this printed circuit board.

6.5 Solar Panel

The solar panel provides power to the SOOFIE device without being connected to the grid. It is attached to the mounting pole through a support bracket. 30-watts is the minimum power rating used for one SOOFIE device; 65-watts is the maximum power rating compatible with system.

6.6 Battery

The SOOFIE device's battery stores power during low solar irradiance at night or during extended periods of heavy overcast weather.

6.7 Antenna

The antenna enables SOOFIE devices to communicate with the SLB servers through cell towers or local Wi-Fi networks.

6.8 Housing

The housing of SOOFIE devices protects sensitive electronics and equipment from the environment. A proprietary adsorbent filter material is used in its housing to eliminate the influence of interference gases (e.g., alcohols), resulting in a highly selective response to methane.

6.9 Mounting Pole and Stand

SLB provides the customer with a variety of stand options based on the application of the SOOFIE emissions monitoring system and site uses. A mounting pole with a height of approximately 1.5-2 m is fastened to the stand. The SOOFIE device and solar panel are attached to the pole through a custom mounting bracket.

6.10 Clamps, brackets, and other support equipment

SOOFIE devices require several clamps and other equipment to be installed on a vertical post. The brackets holding the SOOFIE device and the solar panel are corrosion resistant.

6.11 Installation Tools

The installation of the SOOFIE emissions monitoring system is designed to be straightforward and efficient, utilizing standard tools that ensure precise assembly and secure mounting of all system components. Depending on the specific SOOFIE device version, operators may need to use a variety of tools as detailed in the installation guidelines. These tools are critical for achieving a proper setup and maintaining the integrity of the system during operation. Key tools typically required include:

- **Screwdriver:** Essential for fastening and loosening screws throughout the assembly process.
- **Wrench:** Used to tighten bolts and secure components, ensuring stable installation.

- **Sockets:** Facilitate the efficient handling of various fasteners that hold the system components together.
- **Hex Key:** Required for specific fasteners provided in the installation kit, allowing for accurate adjustments and secure connections.

6.12 Compass

A compass that reliably points to true north is required to properly orient the sonic anemometer(s). This can be achieved using a traditional compass or a modern cellphone application, ensuring that the system is correctly aligned for optimal performance.

6.13 Tablet/Phone

During installation, operators must have access to either the SOOFIE app or document the precise source and sensor locations to a SLB Customer Service Representative. Coordinates are within 2.5 m of actual location (CEP-50 with 24-hr static condition and open sky) and reported to nine decimal points.

7 Reagents and Standards

[Reserved]

8 Data Collection and Method Input Sourcing

8.1 Pre-Screening Site Setup

8.1.1 Pre-Deployment Initial Siting

SLB requires at least three SOOFIE devices per site. The actual number of devices required can significantly differ based on site-specific wind characteristics, road layouts, property boundaries, equipment locations, etc. Because of this, SLB uses its proprietary Siting Tool before site installation. This interactive code incorporates site-specific information and atmospheric data to provide the owner/operator with a customized recommendation for the quantity and placement of SOOFIE devices and ensures that the required detection capabilities for periodic screening at the site are met. Using results from the Siting Tool, the operator can choose how many SOOFIE devices they would like to deploy.

At most sites, the point-sensor network and anemometer(s) are positioned at the fenceline around the site but can also be positioned within the site (at the owner/operator’s discretion and depending on site configuration) to maximize detection capabilities. Siting Tool inputs are described in Table 5 below, and the general workflow is presented in Appendix B. The owner/operator is required to inform SLB of the movement, addition, or removal of any potential on- and off-site sources at the facility.

Table 5. Summary of user inputs for running the Siting Tool.

Instrument/Source	Variables	Use
Operator	Site Name	A unique name for which to identify the site
Operator	Operator	Identify name of operator
Operator	Site Perimeter	Identify the potential area where devices can be placed
Operator	Site Coordinates	Identify the central location of the site, for document of general site location and to aid in georeferencing of imagery
Operator	Emission Source Information	Identify location, type of equipment, and potential source height of the emission.
Operator	Potential Off-Site Sources	Identify the location and height (if possible) of potential off-site sources to be monitored to distinguish between on-and off-site emissions.
Operator	Roads, buildings or obstructions, and zones to avoid sensor placement	Identify areas where devices cannot be placed or buildings/objects that may impact plume movement.
Operator	Device connectivity	Determine whether device connectivity should be arranged via cellular reception or Wi-Fi.
Operator	Define range of devices interested in placing (optional)	Provide a ballpark range of the number of devices the client would like to place. If not chosen, SLB will evaluate a placement of up to 20 devices at a site.
SLB	Distance to Detection	The distance to detect a leak of a given magnitude. For the Periodic Screening application, this value is set to a distance of 100 m between source and sensor.
Variable (see below)	Wind Data	Select one of the three options of obtaining wind data below:
1. Operator	On-site or nearby wind data (optional)	Used if new site far from existing SOOFIE emissions monitoring systems
2. Public Weather Station	Historical wind data (optional)	Used if new site far from existing SOOFIE emissions monitoring systems
3. SLB	Anonymized nearby wind data (optional)	Used if new site near and likely has similar wind conditions to existing SOOFIE emissions monitoring systems

8.1.2 Initial Installation

For the initial installation of a SOOFIE emissions monitoring system, the installer and Customer Service Representative perform the following steps:

8.1.2.1 Installer: Mounts the SOOFIE device 1.5-2 m above the ground surface. If a given SOOFIE device will be recording wind data, a wind anemometer is installed at the top of the pole. The installer must ensure that the instrument's North Arrow is aligned towards true north (within a minimum of 5° accuracy) using a compass. After equipment installation, the installer will scan the code on the side of the SOOFIE device using the SOOFIE app. This will automatically gather and document the GPS coordinates of that SOOFIE device's location and confirm its on-site location. If the installer cannot access or chooses not to use the SOOFIE app, they can record the equipment ID and GPS coordinates (to four decimal degrees) of each SOOFIE device.

8.1.2.2 Installer or Customer Service Representative: Mark the location of potential sources on the site. This can either be completed visually by a Customer Service Representative using satellite imagery or can be documented on the SOOFIE app by the installer.

8.1.2.3 Installer: Once SOOFIE device locations and sources have been documented, the SOOFIE app will transform the facility information into a single JSON file that will be sent to a Customer Service Representative for integration into the dashboard. If the SOOFIE app is not used for installation, the installer can send the documented source and sensor locations to a Customer Service Representative.

8.1.2.4 Customer Service Representative: The site information (either as a JSON or documented coordinates) is uploaded into the dashboard. A Customer Service Representative confirms appropriate cellular connectivity and sensor operation.

8.1.2.5 Customer Service Representative: Two and five days after installation of the SOOFIE emissions monitoring system, a Customer Service Representative confirms appropriate operation of the devices (e.g., providing acceptable readings, adequate connection and battery power).

8.1.2.6 The owner/operator will need to ensure that each SOOFIE device is turned 'on' for at least 48 hours (allowing time for the sensor to settle) before using any readings or calculation from that respective sensor.

8.1.3 Data Inputs

Below (Table 6), we present a summary of the data collected for the SOOFIE emissions monitoring system.

Table 66*. A summary of the input variables that SLB uses for source localization and quantification.*

Instrument/Source	Variables	Use
2-D Sonic Anemometer	Wind Speed (m/s), Wind Direction (degrees), Wind Direction Variability (degrees)	Wind data gathered from at least one device, used to localize and quantify methane sources when emissions are detected. Wind data is also used to aid in QAQC validation of on-site vs. off-site events and site coverage assessment.
Methane Sensor	Methane concentration (ppm)	Device-level concentration data is used to detect emissions by assessing methane concentrations and the change in concentrations at a single point.
Humidity Sensor	Relative humidity (%)	Device-level ambient humidity is used to calibrate the MOS output into a methane concentration value.
Pressure Sensor	Atmospheric pressure at the device (mbar)	Device-level atmospheric pressure is used to calibrate the MOS output into a methane concentration value.
Temperature Sensor	Ambient temperature at the device (°C)	Device-level ambient temperature is used to calibrate the MOS output into a methane concentration value.
Device Coordinates	Longitude/Latitude (decimal degrees)	Provides an understanding of the location of individual devices in relation to potential sources and wind direction to aid in plume quantification.
Potential Emission Source Coordinates	Longitude/Latitude (decimal degrees)	Provides an understanding of the location of potential sources in relation to SOOFIE devices and wind direction to aid in plume quantification.

8.2 Periodic Screening Workflow

The generalized periodic screening procedure is detailed below, from the collection of samples through to the final report received by the operator. The workflow can be broken down into five major steps (**Figure** 1), as is outlined below:

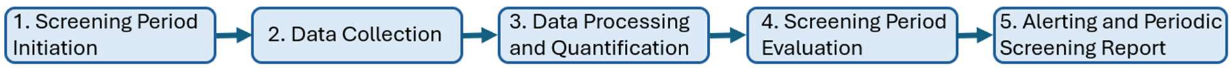


***Figure** 1. A general workflow of the steps taken in each periodic screening evaluation.*

8.2.1 Screening Period Initiation

The periodic screening will begin either on the first day of the month for the appropriate screening frequency or can alternatively be defined by the owner/operator. The latter approach allows for the flexibility of the operator to choose a period when no maintenance events are anticipated. Before initiating SOOFIE periodic screening, operators are responsible for conducting a preliminary site check to ensure that ongoing emissions are addressed. It is the responsibility of the owner/operator to notify SLB about any changes to the prior agreed-upon start of a screening period.

8.2.2 Data Collection and Initial Processing

Throughout the periodic Screening Period, raw data will be collected at all SOOFIE devices at 1-min increments and transmitted wirelessly via a data connection to a cloud-based database owned and operated by SLB. Each SOOFIE device is equipped with a MOS sensor that provides methane concentration data. Additional details on the detection capabilities, calibration, and precision of the MOS sensor are detailed in Sections 6.2 and 10. In addition, each point sensor measures temperature, humidity, and pressure. Depending on the SOOFIE device version, additional data may be collected for device health monitoring, which can include but is not limited to GNSS (Global Navigation Satellite System) location, battery voltage, and data from a three-axis accelerometer to alert customer service if or when a sensor has tipped.

Each installed SOOFIE emissions monitoring system requires at least one point sensor at a site to be equipped with a two-dimensional sonic anemometer.

Every 15 minutes, all raw measurements undergo a QC check, and the raw MOS sensor output is converted to 1-min resolution methane concentration (ppm) measurements using SLB's proprietary calibration model. Sensor-specific QAQC checks as described in Section 9.29.2. All QC'ed 1-min data used for quantification is accessible by the owner/operator through a Dashboard or API (Application Programming Interface).

8.2.3 Data Processing and Quantification

Once at least 48 hours of data have been collected, the data processing procedure can begin (**Figure 2**). As a first step, the complete 1-min resolution data from all devices is ingested into our proprietary AI event detection algorithm, and the beginning and end of all emission events that have taken place during the screening period are documented. In the case that an emission event is ongoing at the end of seven days of data collection is reached, the event will be terminated for processing. Building from this initial step, the facility-level methane emissions are quantified as follows:

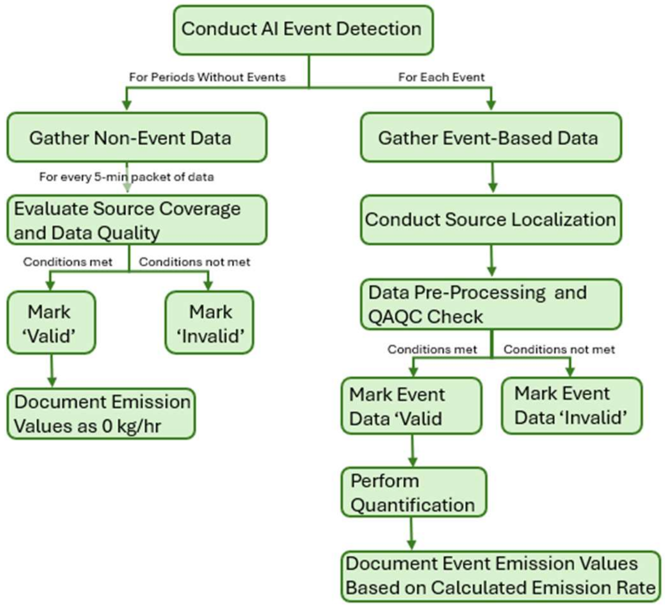


Figure 2. *A diagram showing the general data processing and quantification workflow. As shown above, quantification is performed at an event-scale across the screening period and undergoes data quality validation.*

8.2.3.1 Identified Emission Events

For each identified event, the start and stop times of the event are noted, and all 1-min data that was collected during this period is gathered and processed into 5-minute averages. Next, all data from the event is utilized to delineate the most probable emission source.

Next, a series of data pre-processing procedures are performed to ensure that the quantification algorithm is only provided with quality data inputs. First, noisy data is eliminated by extracting only signals with a change of at least 0.5 ppm in methane concentration. Next, data is filtered for data that is collected within the envelope of operation (Section 4). Further, all data that is not downwind of a probable source at the time of measurement is removed, thus eliminating the incorporation of off-site emissions. Lastly, the data remaining after this pre-processing process is verified to confirm it temporally covers at least three 5-min data points per emission event, ensuring both emission accuracy and adequate instrumental uptime. If data from the event does not pass the temporal coverage check, data collected during the period of this emission event is marked as 'invalid'. If data does pass the temporal coverage check, it is implemented into SLB's proprietary quantification algorithm, a hybrid machine learning and Gaussian plume model, to determine the event's emission rates. Currently, SLB's model assumes one continuous source for each event, with the intent to extend to multiple sources in future algorithm updates. Validation of model performance is demonstrated in Section 13. Since a continuous emission rate is assumed throughout the emission event, all data that falls within the event's period is marked as 'valid' and characterized by the event emission rate.

8.2.3.2 Identified Non-Event Data

For each 5-min period outside of emission events, a series of data validation procedures are performed. First, each period without a notable methane detection is verified to be sampling from a probable source on the site. Areas upwind of every sensor are spatially analyzed and only a 5-min time period is marked as a ‘valid’ zero kg/hr emission rate if at least one sensor is covering a probable source. If no devices are covering a probable source in a 5-min time period, that period will be marked as ‘invalid’. This step ensures that all non-emission readings reflect data from the site.

At the end of the data processing and quantification step, all data collected during the Screening Period is processed in 5-min increments and evaluated by quality (marked as ‘valid’ or ‘invalid’). All ‘valid’ data is associated with a quantified emission value.

8.2.4 Screening Period Evaluation

The Screening Period Evaluation assures that the overall quantification criteria of the periodic screening are met. Both internal and external evaluations of point sensors have demonstrated better quantification on longer (over several hours) time periods, which allows data signals to be assessed from multiple devices and across dynamic wind conditions (Daniels et al., 2025). At the same time, the importance of identifying leaks in a timely manner is recognized. It is because of these reasons that SLB’s method quantifies facility-wide emissions across 48 valid hours with the potential to extend the screening time to 7 days, if required for spatial coverage. This process is detailed below (**Figure** 3).

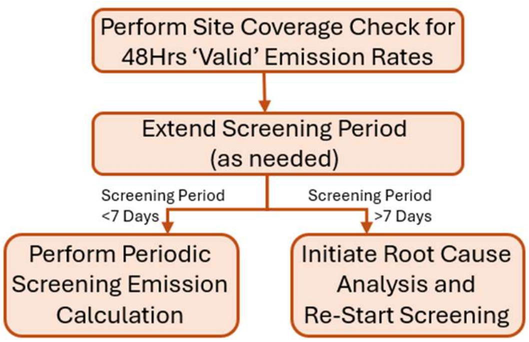


***Figure** 3. An overview of the Screening Period evaluation conducted after data has been processed. At least 48 hours of ‘valid’ emission rates are required in each screening period.*

The first step of the Screening Period evaluation is to assess whether the first 48 hours of valid emission rates meet site coverage requirements. This coverage check utilizes data from all SOOFIE devices and evaluates whether the network has at least 30 minutes of coverage of each probable source within the periodic screening. If coverage requirements are initially not met, the Screening Period is extended until each probable source has coverage of at least 30 minutes. If the Screening Period falls within 7 days, the screening coverage check is passed, and the Site Average Emission Rate Estimate is calculated. If the Screening Period needs to be extended beyond 7 days to reach site coverage, an RCA (Section 9.3) is initiated, and the periodic Screening Period is re-started.

The Site Average Emission Rate Estimate is calculated through determining the sum of emissions (in kg) across the Screening Period and dividing this value by the length of time (in hours) of the Screening Period. The resulting Site Average Emission Rate Estimate (in kg/hr) is then compared to the applicable alerting threshold (Section 12.2).

8.2.5 Alerting and Periodic Screening Report

An alert is generated if the periodic screening emission rate is above the applicable alerting threshold (as detailed in Section 12.2). In case of an alert, the owner or operator must conduct a facility-wide follow-up survey using OGI or Method 21.

9 Quality Control

9.1 Quality Control for Hardware

Prior to field deployment, all hardware undergoes inspection, as outlined in Table 7. Devices with any hardware or physical defects are not deployed into the field. All electrical connections, including battery, solar charge controller, power cables, and signal cables for SOOFIE devices, are checked for proper placement and secure attachment. Proper installation of electrical protection devices is also confirmed. A test antenna and anemometer are connected to verify system functions. Before equipment is shipped to the field for installation, the SOOFIE app is used to check sensor readings. If incorrect values appear, connections are rechecked. Equipment is only shipped if all hardware quality control criteria are met.

Table 7**7**. *Quality Control for Hardware of SOOFIE devices.*

Component Category	QA/QC Test or Specification	Acceptance Criteria	Frequency	Corrective Action
Enclosure & Hardware	Visual Inspection	All required hardware is present and torqued correctly	Each unit	Replace the enclosure if damage is shown. Otherwise verify correctly torqued hardware
Electrical Connections	Connection Verification	All connections are correct and tight	Each unit	Replace and recheck connections
Solar Panel System	Electrical Testing	Solar input resistance < 1 Ω	Each unit	Replace and recheck
Charge Controller	Firmware Update & Configuration	Firmware is updated, and configuration is correct	Each unit	Replace and recheck
Sensors & Wiring	Power & Sensor Function Test	Sensors provide valid readings in SOOFIE app	Each unit	Replace and recheck connections
Configuration Software	Build Configuration Validation	All form entries are correct and submitted	Each unit	Do not deploy—reboot software or replace board as needed
Enclosure Sealing	O-Ring Inspection	O-ring is present, undamaged, and seated properly	Each unit	Replace and recheck
Final Assembly	Final Enclosure Check	Screws are torqued correctly, labels correctly applied	Each unit	Do not deploy—replace individual parts as needed and recheck

9.2 Quality Control for Sensors

Sensor quality checks are conducted during and after installation of each SOOFIE device. Any sensors reporting values outside of the sensor-specific operating range are flagged and tracked by SLB daily. In addition, the sonic anemometer reports an ‘error’ code when the anemometer provides an error, allowing for fast error detection. If analysis of sensor errors conclude that sensors are reporting faulty values, SLB will contact the owner/operator within 1 business day of receiving a flag. A summary of the QAQC metrics for each sensor is provided in Table 8.

***Table 8**8. An overview of the QAQC metrics and acceptance criteria used throughout the periodic screening process, as well as the corrective actions that are taken when the acceptance criteria are not met.*

Instrument/ System	QC Procedure	Acceptance Criteria	Frequency of QC Procedure	Corrective Action

Wind Sensor	Wind Speed Accuracy	± 2%	Verified at time of manufacturing by the supplier; no additional checks performed	N/A
Wind Sensor	Wind Direction Accuracy	± 2%	Verified at time of manufacturing by the supplier; no additional checks performed	N/A
Wind Sensor	Wind Speed Bounds	0 – 60 m/s	1-min	Measurements outside of bounds are not used, trigger RCA for potential anemometer replacement
Wind Sensor	Error Check	Value, no error	Daily	Replace anemometer
Methane (MOS) Sensor	Reserved	Reserved	1-min	Measurements outside of bounds are not used, trigger RCA for potential MOS replacement
Methane (MOS) Sensor	Concentration Accuracy	± 12%	Verified at time of manufacturing	N/A
Methane (MOS) Sensor	Sensor time since first deployment	< 10 years (Figaro Engineering, 2000)	Every periodic screening	Replace sensor or unit
Relative Humidity Sensor	Relative humidity accuracy	± 1% RH	Verified at time of manufacturing by the supplier; no additional checks performed	N/A
Relative Humidity Sensor	Expected humidity bounds	2% - 99%	1-min	Measurements outside of bounds are not used, trigger RCA for potential sensor replacement
Temperature Sensor	Temperature Accuracy	± 1 °C	Verified at time of manufacturing by the supplier; no additional checks performed	N/A
Temperature Sensor	Expected temperature bounds	-20 – 70 °C	1-min	Measurements outside of bounds are not used, trigger RCA for potential sensor replacement
Pressure Sensor	Pressure Accuracy	± 2.5 mbar	Verified at time of manufacturing by the supplier; no additional checks performed	N/A
Pressure Sensor	Expected Pressure bounds	400 – 1,200 mbar	1-min	Measurements outside of bounds are not used, trigger RCA for potential sensor replacement
Operating Window	Wind Speed	> 0.4 – 7 m/s	1-min	Filter measurement

Operating Window	Wind Direction Standard Deviation	< 45°	1-min	Filter measurement
Operating Window	Relative Humidity	2% - 99%	1-min	Filter measurement
Site Coverage Assessment	Site Coverage	Minimum of 30 minutes of valid data within periodic screening for all potential emission sources	Every periodic screening	Trigger RCA and potential re-siting
Screening Period Evaluation	Temporal Coverage	48 hours – 7 days	Every periodic screening	Trigger RCA and potential re-siting

9.3 Root Cause Analysis and Re-Siting Evaluation

The RCA process begins as soon as the Site Coverage Assessment is not met. Potential reasons for an RCA could be:

- Inadequate instrumental uptime causes a large portion of 'invalid' data, leading to a failure in the Site Coverage Assessment
- Too few SOOFIE devices deployed, leading to a failure in the Site Coverage Assessment
- Anomalous wind conditions (e.g., a hurricane, multi-day rain event) cause significant loss in instrumental uptime, leading to a failure in the Site Coverage Assessment

In these cases, a SLB Customer Service Representative will analyze the failure of the Site Coverage Assessment by:

- Analyzing wind conditions during the periodic screening to determine if the *Operational Window* (Section 4) prevented adequate data collection. If this is the case, the periodic screening will restart.
- Analyzing data transmission during the periodic screening. If one or more SOOFIE devices are providing 'invalid' data readings due to a failure in sensor QAQC checks, SLB will reach out to the owner/operator to replace faulty sensors and equipment. Once the equipment is replaced, the Customer Service Representative will contact the owner/operator to discuss whether there is sufficient spatial and temporal coverage for a 'valid' periodic screening, the periodic screening should be restarted, or if an OGI survey is required to replace the periodic screening for the given time period.
- Comparing wind data over the last periodic screening to the annual wind data applied in the Siting Tool. If the wind data is substantially different, the Customer Service Representative will re-run the Siting Tool.
- Comparing SLB's recommended quantity of devices as well as their locations. If significantly different and site coverage requirements are not met, the Customer Service Representative will reach out to the owner/operator about either adding more SOOFIE devices to the existing SOOFIE emissions monitoring system or moving devices to locations with better source coverage.

10 Calibration and Standardization

10.1 Calibration Procedures

Sensors installed in the SOOFIE device have been pre-calibrated by the manufacturer prior to assembly. Prior to shipment to the field and immediately following installation, the SOOFIE app is used to verify that the sensors are producing raw readings within the acceptance criteria outlined in Table 8. After deployment at the site, the MOS sensor within each SOOFIE device is automatically calibrated remotely (Section 10.1.1). As described in Section 9.2, the SLB checks daily for any flagged sensors, ensuring normal operation across the SOOFIE emissions monitoring system. In addition, individual 1-min methane values are verified as part of the data quality control procedures to be used for quantification. Although a bump test is optional and not required, procedures (Appendix A) can be used both in a field and lab setting to verify sensor performance. The specific steps taken for calibrating individual MOS sensors are outlined below:

10.1.1 Metal Oxide Semiconductor Calibration

Each MOS sensor is calibrated individually to ensure accurate methane concentration readings. To handle the large number of sensors, the calibration process is automated to standardize the performance of all sensors and ensure reliable methane measurements across different locations.

The Digital Automated MOS Synchronization System (DAMOSS), SLB's proprietary technique, frequently checks and adjusts the sensors based on temperature and humidity changes, minimizing the impact of environmental factors on sensor performance. After calibration, the methane concentration (in ppm) is derived from the sensor output and environmental parameters (i.e., temperature, relative humidity, and specific humidity) using a proprietary empirical model.

DAMOSS automatically identifies, assesses, and corrects drift-related issues in the MOS sensors in the following process:

a. Regular Checks: The algorithm checks the entire fleet of SOOFIE devices for drift and fluctuations every three hours.
b. Issue Identification: If a drift-related issue is detected, DAMOSS activates within the next minute.
c. Data Assessment: The algorithm assesses recent data and quantifies the MOS sensor drift.
d. Digital Re-calibration: The system automatically re-calibrates the MOS sensor based on expected performance under current conditions.

11 Analytical Procedures

[Reserved]

12 Detection and Alerting

12.1 Detection

Here we define an 'event detection' as the identification of an emission event using the AI event detection algorithm, with each detection associated with a documented start and end time. As described in Section 8.2, all sensor data collected during each detected event are analyzed to define the most likely source and associated emission rate of the detected emission. Once the screening process is complete and all quality checks are satisfied, the Site Average Emission Rate Estimate is determined for the respective periodic screening survey according to the procedures outlined in Section 8.2.4. If the Periodic Screening is 'valid' and the Site Average Emission Rate Estimate is above the applicable alerting threshold, we identify it as a 'detection'.

12.2 Alerting

Once QC checks have determined that the Periodic Screening is 'valid' and the Site Average Emission Rate Estimate for the Periodic Screening is calculated, the Site Average Emission Rate Estimate is compared to the applicable alerting threshold (as chosen by the owner/operator and shown in Tables 1 and 2). If the Site Average Emission Rate Estimate is above this threshold, it is considered a Detection Above Reporting Limit and triggers an 'alert' to the owner/operator. If the Site Average Emission Rate Estimate is below the threshold, it is considered a Detection Below Reporting Limit, and the owner/operator does not receive an 'alert'. If an 'alert' is issued, it is the responsibility of the operator to conduct a facility-wide follow-up inspection as required in 40 CFR §60.5398b(b).

SLB will send a periodic screening report to the operator in the format of a .pdf or .xls file (as preferred by the operator) within one week of the end of the assessment. These results are provided with a facility-level spatial resolution. Information contained in the report includes:

- Name of the owner/operator or recipient of report
- Alternative test method and technology used for periodic screening
- Spatial resolution (e.g., facility-level) of the technology used
- Detection threshold of the technology used for periodic screening
- Date that the periodic screening report was created and processed
- Date that the periodic screening report was issued to the owner/operator
- Alerting threshold used for periodic screening assessment
- Periodic Screening Site-Specific Information
    - Name of site analyzed for the report
    - Site type
    - Site location
    - Time period of periodic screening
    - Unique periodic screening report identifier
- Periodic Screening Results:
    - Assessment of 'alert' or 'no alert'
    - Calculated Site Average Emission Rate Estimate

13 Method Performance

The SOOFIE emissions monitoring system has been extensively evaluated in performance across multiple controlled releases. Specifically, it has been applied across three testing campaigns:

1. METEC 2024 ADED: METEC conducted a series of tests from February through April 2024 in an emissions testing campaign known as ADED. Tests ranged in duration from 0.3 to 8 hours, with 1-5 simultaneous sources in an emission event. Total methane rates per source ranged from 0.08 to 6.71 kg/hr, and total facility emissions ranged from 0.2 to 9.4 kg/hr.
2. Desert Release: SLB conducted a series of 16 controlled releases with emission rates between 0.5 and 2.3 kg/hr at an anonymized site in a desert environment. The releases took place on May 27-29, 2025. Temperatures during releases ranged from 27.8 °C to 54.4°C, and winds varied from 0.19 m/s to 10.91 m/s.
3. Permian Release: SLB conducted a controlled release at a Permian facility on May 30, 2024. The 1-hr release of 1.27 kg/hr at brisk wind speeds from 4.1 m/s to 6.4 m/s.

Data from these controlled release campaigns is applied below to evaluate and validate SLB quantification method.

13.1 Validation of Method Sensitivity

Data from all three release campaigns were used to evaluate the methane sensitivity of the SOOFIE devices. From this analysis, the Instrumental Percent of Detection can be demonstrated. To isolate the instrumental detection capabilities, first, plume coverage of the SOOFIE emissions monitoring system is ensured. For each release, it was confirmed that the plume dispersed over at least one sensor in the sensor network and detection capabilities were only evaluated if this condition was met. Next, events where the event-wide average wind speed was above 7 m/s (e.g., our operating conditions) were removed. Lastly, whether the SOOFIE network detected an emission (e.g., False Negative or True Positive) was labeled and compared to the total facility-wide release rate.

For this analysis, a logistic regression model was fitted to the data, where $y = 1$ represents a True Positive, and $y = 0$ indicates a False Negative. To quantify model uncertainty, 200 bootstrap resamples of all controlled release results (344 events) were performed, each generating a logistic model. These bootstrapped fits provide a visual and statistical representation of prediction variability. Based on the fitted model, a 90% POD threshold was identified at approximately 0.6 kg/hr, which is below the reference detection limit of 5 kg/hr (**Figure** 4).

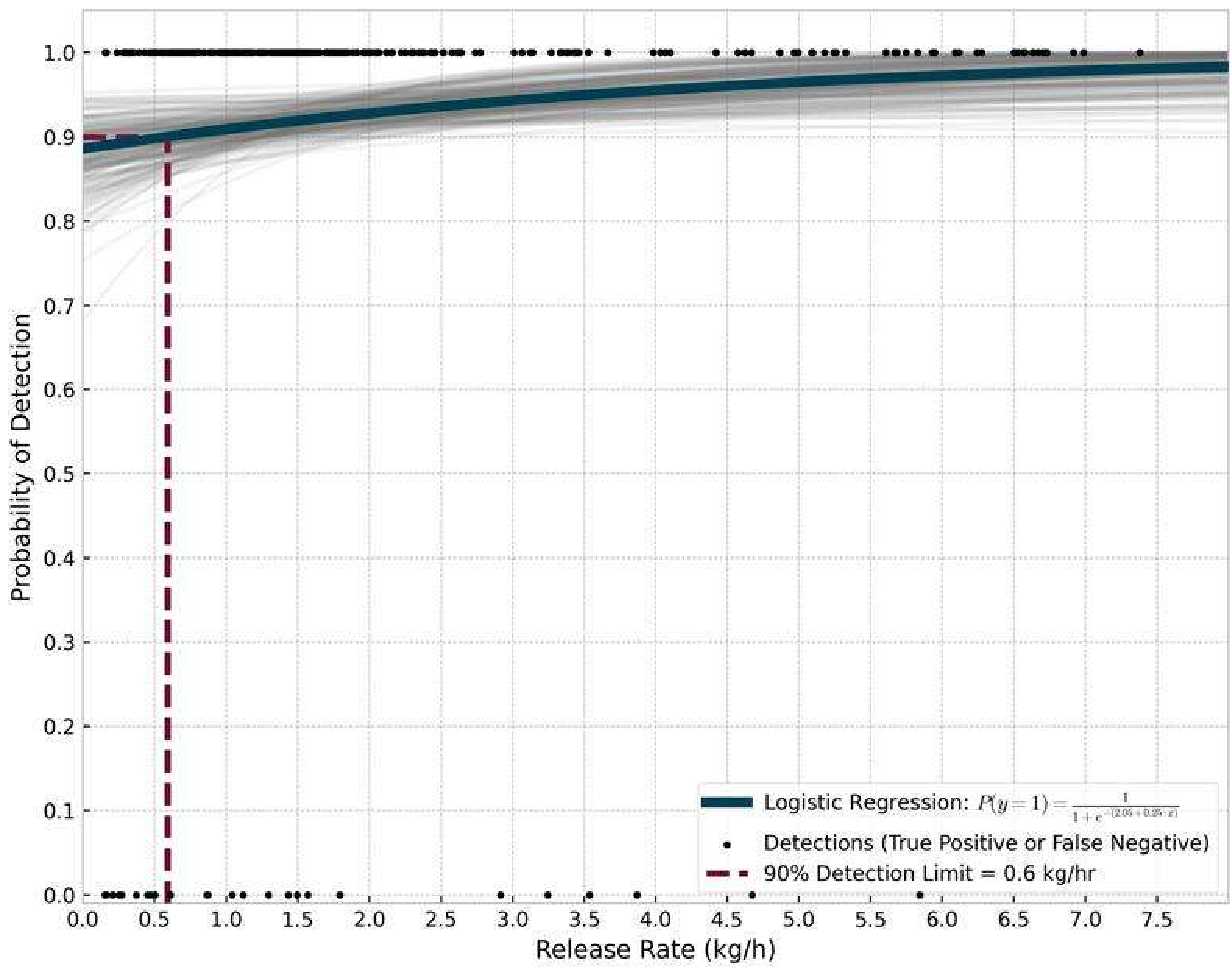
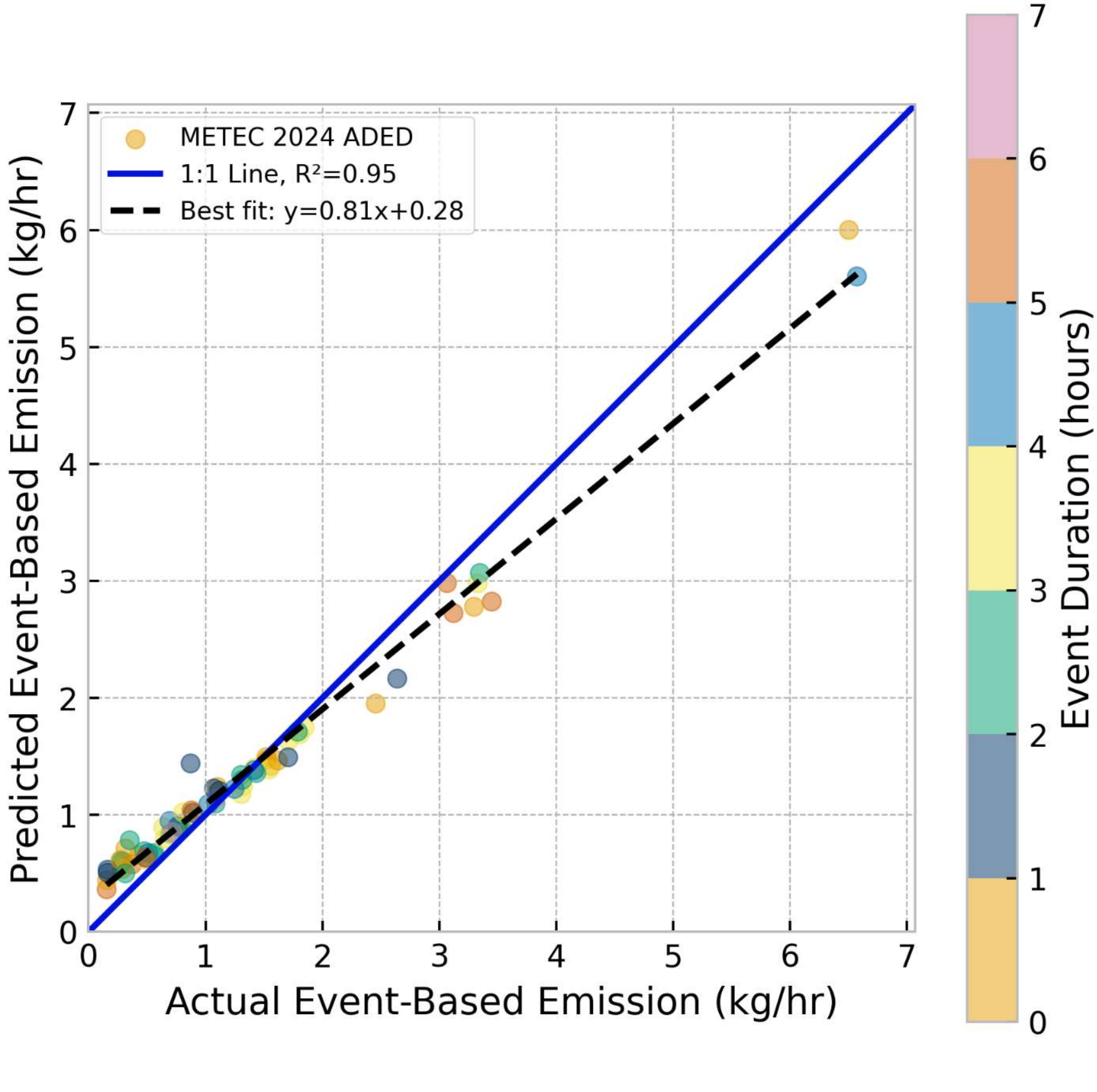


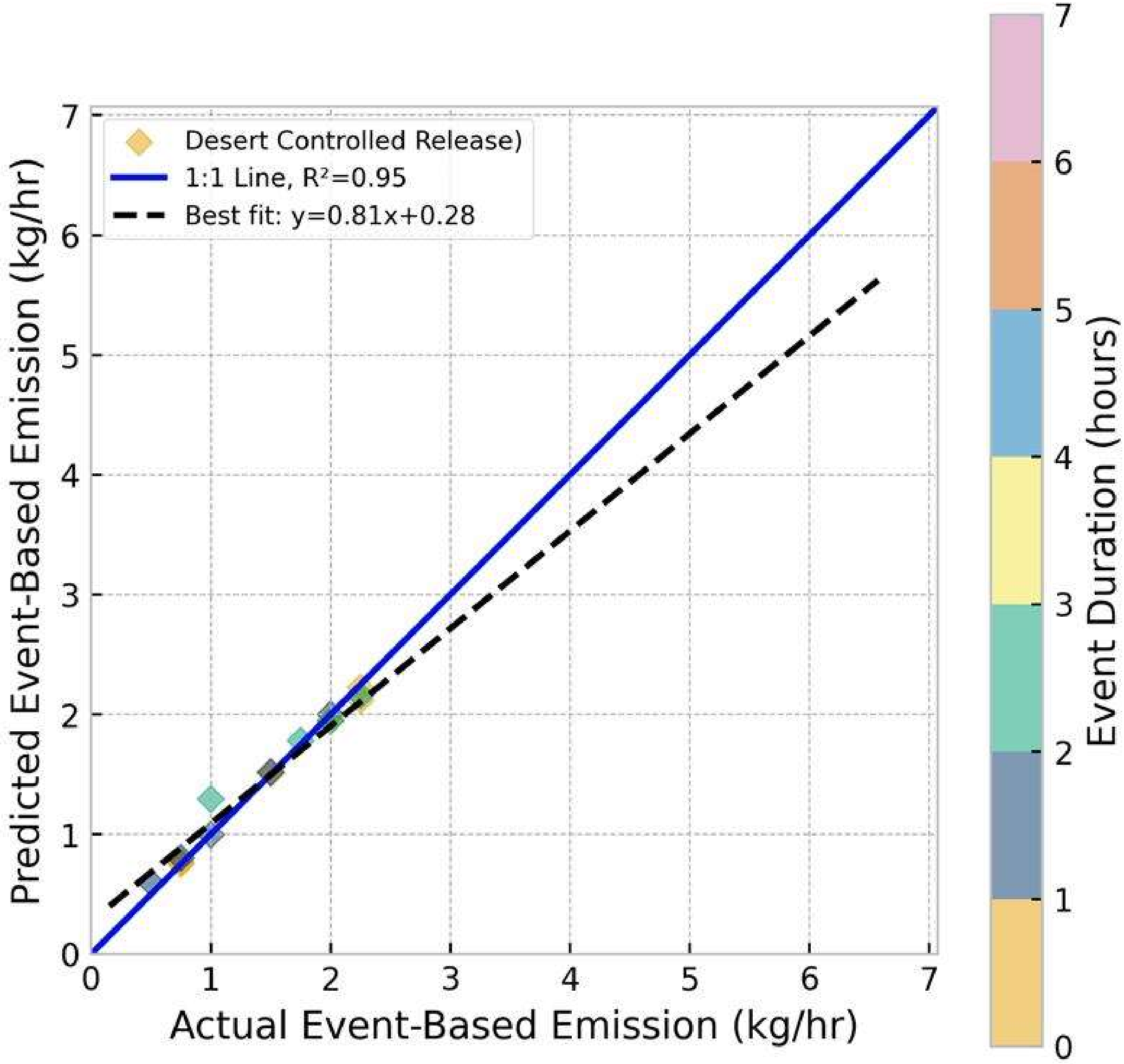
***Figure** 4. A comparison of the release rate to the 90% POD. The gray lines show the 500 bootstrapped simulations, and the small black dots represent the raw (True Positive / False Negative) values, where a True Positive is represented by y = 1, and a False Negative is shown by y = 0.*

13.2 Evaluation of Method Quantification

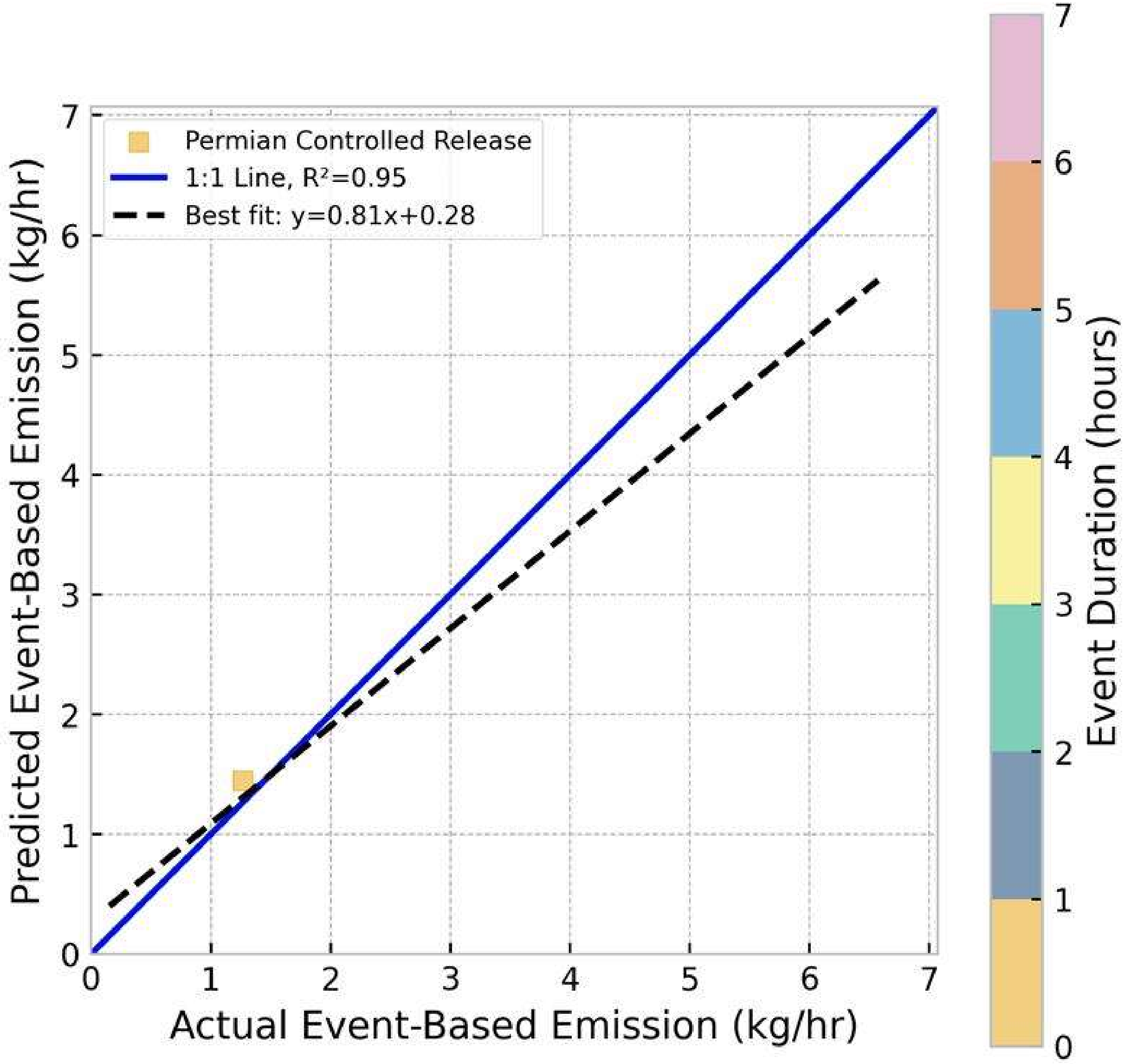
To validate the hybrid machine learning and physics-based model, the predicted emission estimates were compared to the actual controlled release rates. A high correlation coefficient (R^2= 0.95) of a direct comparison of the two values shows that the model is effective at predicting release rates on a per-event basis (Figure 5). The coefficients of the line of best fit show that, in general, SOOFIE devices tend to slightly overestimate emissions at low (< 1.5 kg/hr) release rates and marginally underestimate at higher (> 2 kg/hr) emission rates. These findings are further illustrated in an assessment of the absolute quantification with release rate (Figure 6). Figures 5 and 6 demonstrate that, at emission rates < 3 kg/hr, the event duration improves accuracy, whereas duration does not appear to be tied with increased accuracy at higher emission rates. Lastly, the comparison between estimated and actual emission rates on a log-log scale highlights the strong performance of the model.

As shown in Figure 7, 89% of data fell within a quantification accuracy within a factor of two, with only the low-magnitude (< 0.4 kg/hr) emission rates falling outside of the range. This result is highly significant, as achieving agreement within a factor of two is broadly recognized in the atmospheric sciences and environmental engineering literature as a stringent criterion for model-data congruence. This highlights stable model performance, even in the presence of confounding variables such as plume intermittency, meteorological variability, and sensor limitations. The slight divergence at low emission rates is consistent with the signal-to-noise challenges that often constrain precise quantification at the lower bounds of detection.





Desert Controlled Release)
1:1 Line, R²=0.95
Best fit: y=0.81x+0.28
Predicted Event-Based Emission (kg/hr)
Actual Event-Based Emission (kg/hr)
Event Duration (hours)
0
1
2
3
4
5
6
7



Permian Controlled Release
1:1 Line, R²=0.95
Best fit: y=0.81x+0.28
Predicted Event-Based Emission (kg/hr)
Actual Event-Based Emission (kg/hr)
Event Duration (hours)
0
1
2
3
4
5
6
7

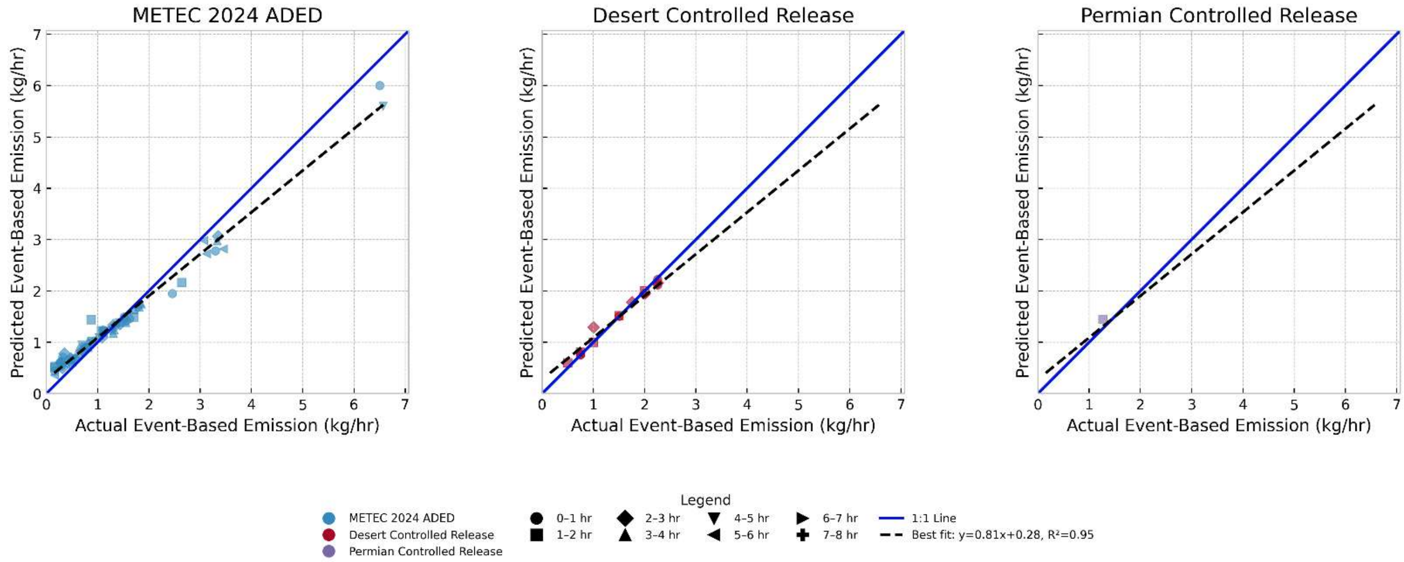


Figure 5. *A direct comparison of the actual event-based emission rates and predicted emission rates from the model. Data from all controlled releases are incorporated into this evaluation.*

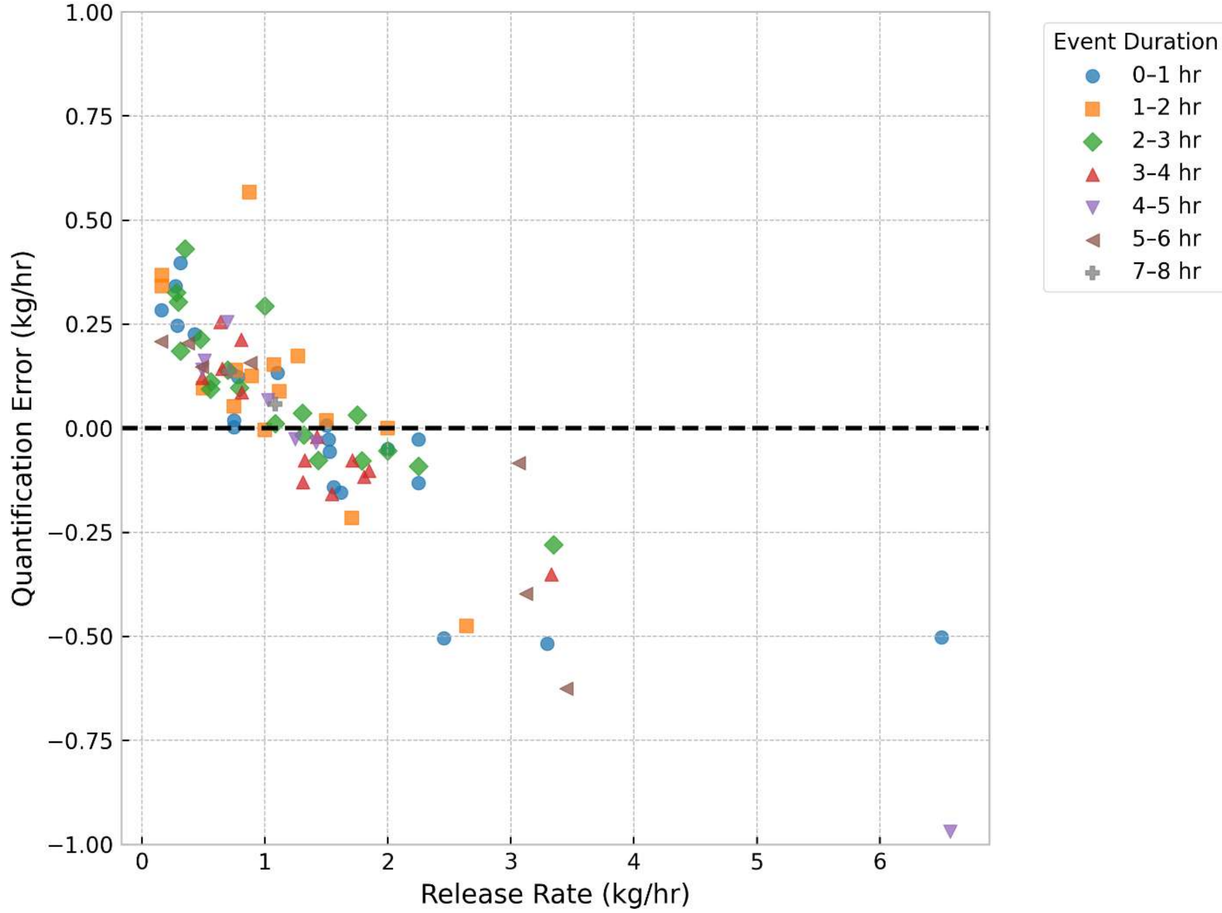


Figure 6. *A comparison of the quantification error with the release rate.*

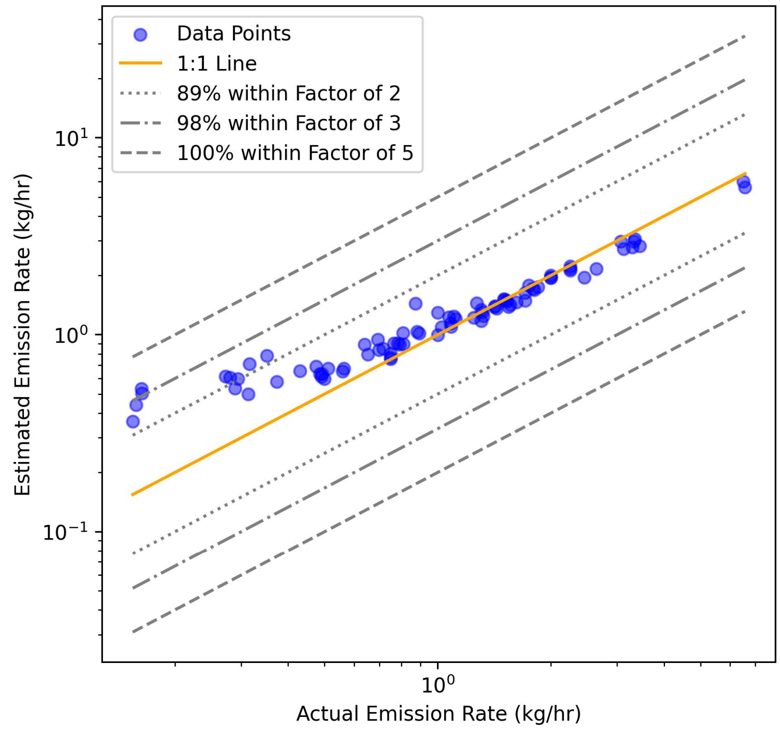


Figure 7. *A direct comparison of the estimated and actual emission rates on a log-log scale.*

14 Pollution Prevention

In a typical OGI survey, individual equipment is surveyed for 2 to 10 seconds. If leaks are found during an OGI survey, these emissions represent a short (2 to 10-s) period of survey. In contrast, this method ensures that each probable source is covered for at least 30 minutes. It follows that a periodic screening survey performed by SLB through the SOOFIE emissions monitoring system has a higher temporal coverage and understanding of a given site. Although periodic screening alerts are generally triggered for persistent leaks, access to the SOOFIE Dashboard still allows the owner/operator to identify the intermittent leaks that may occur at the site.

In addition to pollution prevention, a SOOFIE emissions monitoring system does not require systematic maintenance and can operate autonomously. Because of this feature, operators can minimize the time and cost of dispatching LDAR crews for extensive on-ground inspections. In addition, SOOFIE device site setup involves vertical posts that do not require ground penetration, construction, or alteration of the environment; thus, limiting physical site impacts and allowing for sensor movement if required by re-siting methods.

15 Data Management and Recordkeeping

Figure 8 illustrates the details, data path, and security built into the SOOFIE platform. SOOFIE data are collected and encrypted at the local device. Each encrypted data packet is transmitted to cloud-based servers via mobile virtual network operator. Data packets are unencrypted in the cloud, and then re-encrypted for transmission to Enterprise, where they are verified and routed according to type and content of packet. These raw packets are processed with the Gaussian plume model, and the results are available to the customer via browser-based dashboard, API, or other customer data delivery solutions.

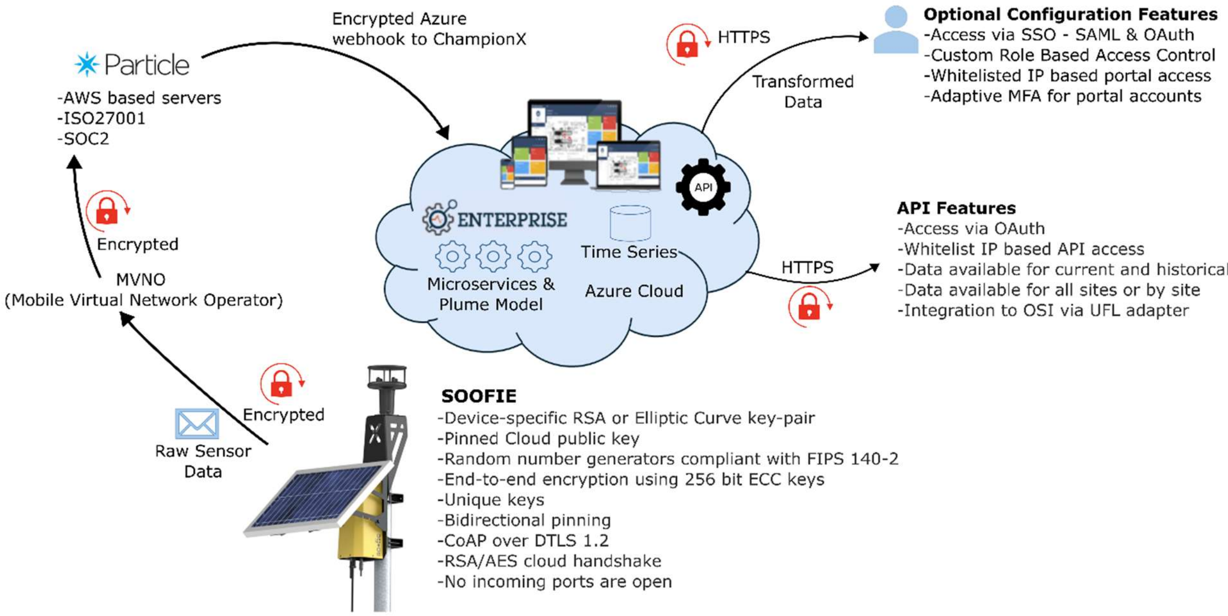


Figure 8*. Workflow of data management and recordkeeping of SOOFIE devices.*

16 References

Daniels, W. S., Kidd, S. G., Yang, S. L., Stokes, S., Ravikumar, A. P., & Hammerling, D. M. (2025). Intercomparison of three continuous monitoring systems on operating oil and gas sites. ACS EST Air, 2(5), 564–577. https://doi.org/10.1021/acsestair.4c00298

Figaro Engineering Inc., *MTTF Values for TGS2611* (document dated May 19, 2000), personal communication to the author, April 17,

Appendices

Appendix A: Bump Test Procedures

A bump test is an optional procedure for verifying the measured values of individual SOOFIE devices. This procedure shall be conducted by a trained personnel member to ensure accurate performance of the reference sensor, comparable sample delivery across both the SOOFIE device and reference sensors, and safe handling of methane gas. Below, we describe how SOOFIE sensors are validated internally in the lab, and how field-based procedures can also be used to verify the quality of individual SOOFIE device data.

A.1. Lab and Assembly-Based Verification

SLB verifies the manufacturer specified performance and operation of a representative population of the MOS sensors used in SOOFIE devices. This verification is completed in a research grade environmental chamber to control temperature and relative humidity levels throughout the test. Data is collected from SOOFIE device's MOS sensors throughout the ranges of operational temperatures and humidities but without methane, the output is compared against collocated reference sensors (Aeris Pico, Aeris Strato, Picarro) sampling from the same air volume as the SOOFIE device. The MOS sensors are verified to be accurate within 1 ppm or 1% of the measurement, whichever is larger. SLB creates a known baseline, all SOOFIE devices are compared against this to verify basic sensor element and heater plate electrical operation. The SOOFIE device and reference sensors must be sampling for a minimum of three minutes continuously, ideally five minutes. Data sampling method must match between SOOFIE device and reference sensor(s), i.e., if the SOOFIE device performs 1-min averaging, the reference sensor data must average over the same time period.

Figure A-1. *An image of the chamber and sampling setup or the lab-based verification.*

A.2. Field-Based Verification

A.2.1 Prerequisites

A.2.1.1 Device Conditioning

Ensure the SOOFIE device has been powered continuously for at least 48 hours. The SOOFIE device must also operate within its environmental operational window during this period.

A.2.1.2 Calibration Gas Requirements

Calibration gas must be methane (± 3.0%) balanced in air without exceeding 100 ppm, contain a minimum of 21% oxygen, hydrated to a minimum of 30% relative humidity. Gas must be delivered to the sensor using direct tubing that eliminates outside interference or mixing from ambient air.

A.2.2 Equipment and Materials

- SOOFIE device with MOS sensor
- Calibration gas cylinder meeting specifications in Section A.2.1.2
- Reference sensor, defined here as a Laser Absorption Spectroscopy (LAS) sensor with an accuracy of at least 5% at 100 ppm. Sensors that meet these criteria include but are not limited to ones produced by Aeris, Los Gatos, Quanta3 and Axetris.
- Tubing and fittings for gas delivery
- Data acquisition system for both SOOFIE and reference sensors

A.2.3 Procedure

1. Position the SOOFIE device and reference sensor in a stable, interference-free environment. Ensure both devices are sampling air from the same location.
2. Ensure the gas flow/hydration apparatus is configured to avoid influencing the MOS sensor (e.g., no abnormal airflow or thermal disruption).
3. Confirm that both sensors are operational and logging data. Ensure sampling intervals match between the SOOFIE device and the reference sensor. Example: If SOOFIE uses 1-min averaging, configure the reference sensor to average over one minute as well
4. Begin gas flow to the SOOFIE device and reference sensor and wait one minute before starting to record data.
5. Maintain continuous exposure for five minutes, monitoring for consistent gas delivery and environmental stability. Check that you are recording data from both sensors during the entire gas exposure period.
6. After five minutes of data recording has elapsed, turn off the gas flow and stop recording data.
7. Calculate the 5-min average for each sensor using the 1-min average values recorded.
8. Repeat steps 3-7, five times for each set of validation measurement. Wait five minutes between each replicate reading.

A.2.4 Validation and Comparison

After the test, compare the SOOFIE MOS sensor readings against the reference sensor data. The SOOFIE will have passed the test if the average of the five measurements (obtained in Step 8 of Section A.2.3) is within 25% of that of the reference sensor.

A.2.5 Safety and Compliance

- Handle calibration gases in accordance with local safety regulations.
- Use appropriate PPE when working with pressurized gas systems.
- Ensure all equipment is certified and maintained per manufacturer guidelines

A.2.6 Documentation

Record the following in the test log:

- SOOFIE Device ID and location
- Calibration gas specifications (manufacturer, accuracy, methane concentration, tank pressure at start of experiment)
- Gas flow rate set point
- Duration of exposure
- Environmental conditions (temperature, humidity, pressure, ambient wind speed)
- Reference sensor used (manufacturer, model, last calibration date, expected accuracy)
- Data sampling intervals
- Observations and anomalies
- Calculated 5-min average per device (SOOFIE and reference sensor)

Appendix B: Siting Information

SLB's Siting Tool provides the recommended quantity of SOOFIE devices, as well as their suggested placement. This algorithm incorporates site-specific information with wind data (wind speed and variability) to maximize leak detection across space and time.

The general workflow of the Siting Tool is described below:

1) *Site/File Setup and Site Image Upload:* The user enters the site name and the site operator name. The algorithm also asks the user to upload a georectified site image of the site.

2) *Draw Site Boundary:* The user is asked to interactively draw the site boundaries of the site to aid the algorithm in identifying the areas where sensors can potentially be placed.

3) *Incorporate Site Equipment Information:* The user is asked to draw the site equipment on the site imagery and include site-specific information (i.e., site perimeter, geographic site location, source locations, and placement of roads and buildings). This aids the algorithm to identify potential sources and the height of the potential leak.

4) *Bring in Wind Data:* The user is requested to either upload their own wind data or to search for nearby data. If the user selects the latter option, the algorithm will automatically search data from open-source weather stations or anonymously use data from a nearby SOOFIE Emissions Monitoring System. A minimum of one year's worth of data is required, so that the placement algorithm incorporates seasonal and monthly wind variability.

5) *Run Simulations*: After incorporating numerous site-specific information (i.e., wind data, component location, and leak likelihood), the client can choose between fenceline or internal site placement. Next, simulations are run to determine the 'Probability of Detection' of any on-site releases at identified sources.

6) *Process Placement to Maximize Source Coverage:* The algorithm incorporates the results from the previous step to determine the optimal placement and amount of SOOFIE devices needed to obtain at least 90% POD across the site.

7) *Export Results and Recommended Placements:* The user is informed how the quantity and location of sensor placement can impact site-wide sensor performance. We recognize that the 'Probability of Detection' is a function of both the length of the emission as well as the wind variability with time. As a result, the output of the Siting Tool is an estimated 'Probability of Detection' across a given user-defined time frame (1-hr, 4-hr, 12-hr, etc.) (Figure B-1). Unless a user-selected range of devices are considered, the Siting Tool will also provide the operator with the recommended number of devices for a given site and time to detection.

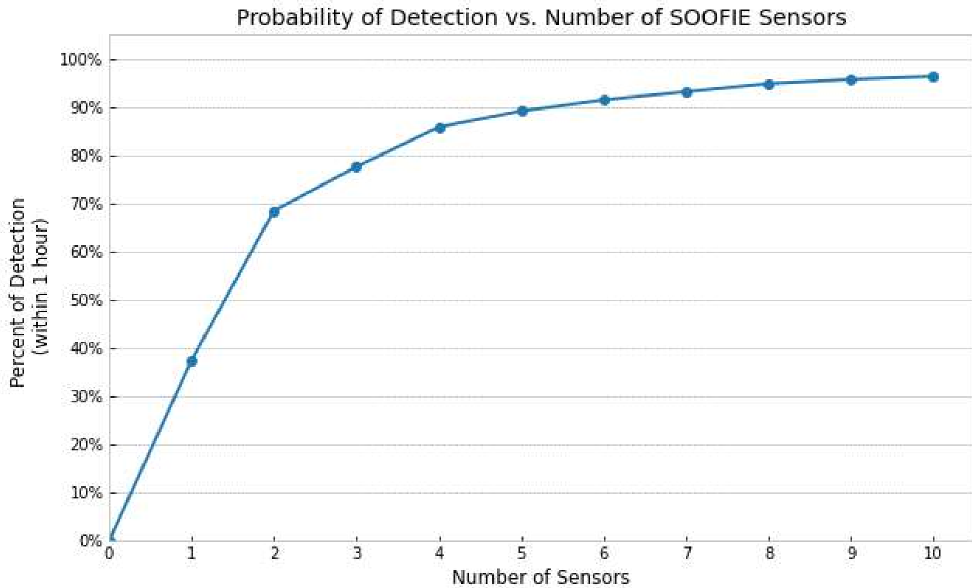


Figure B-1. *An example output to the siting algorithm (results vary based on site), showing the expected performance of the SOOFIE emissions monitoring system in relation to the quantity of SOOFIE devices deployed at a given site. These results can be used to decide on the number of devices needed at a given site to ensure adequate site coverage.*

Evaluation of the Siting Tool using METEC ADED controlled release data showed strong performance of the Siting Tool. As shown in Figure B-2, the Siting Tool's predicted Percent of Detection consistently fell within 10% of the actual results, and, at ≥ three SOOFIE devices, had an average error of 7%. Despite its good performance, it is the operator's choice whether to place devices as recommended by SLB, with the risk of failing site coverage requirements (Section 8.2.4) within a given periodic screening.

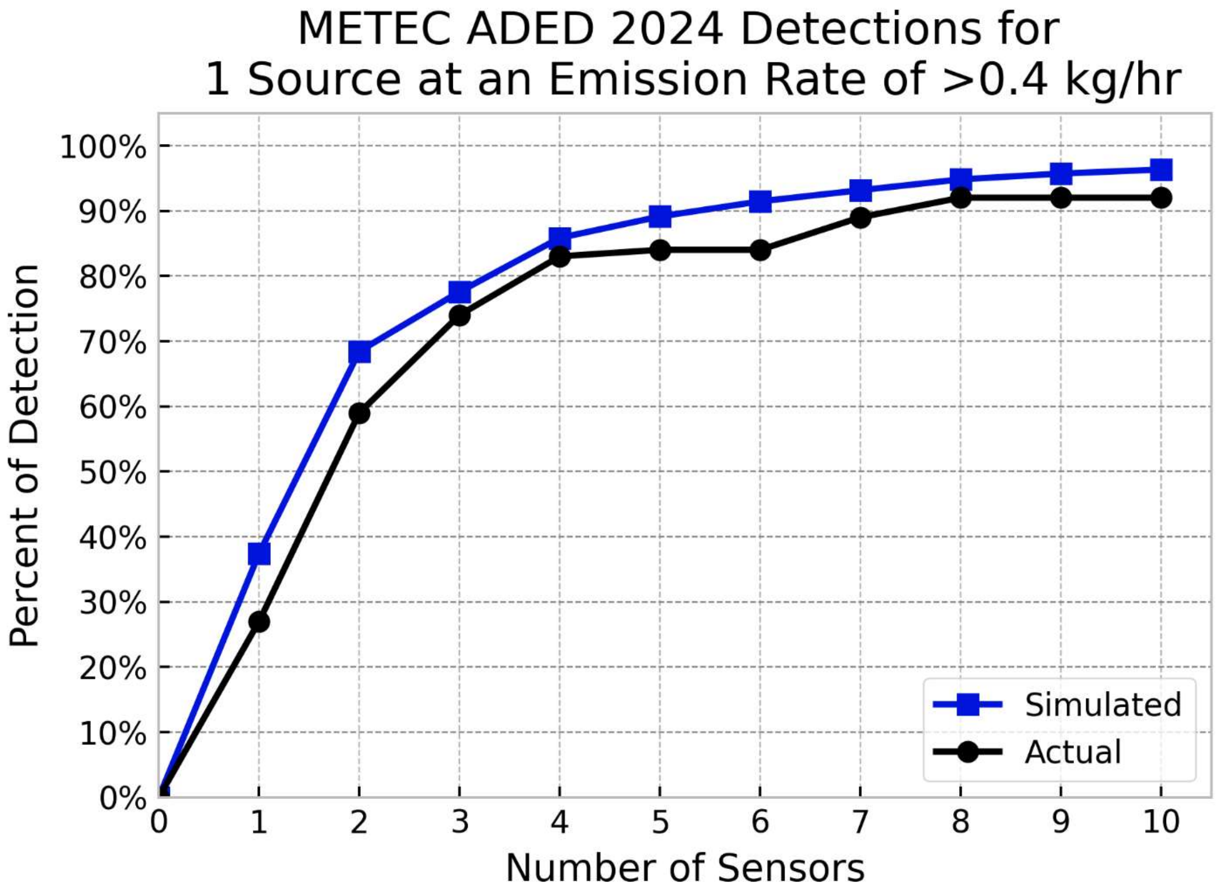


Figure B-2. *A comparison of simulated sensor placement performance versus the actual on-site detection capabilities at METEC ADED during two months of controlled releases.*

The Siting Tool is generally used in two instances: 1) It will be run by SLB's Customer Service Representatives prior to initial site setup, and 2) if required for the RCA when the QAQC screening period evaluation fails and there appears to be insufficient site coverage. The algorithm will be revisited as part of the RCA to inform the operator on additional sensor placements (Section 8.2.4). When applicable, the algorithm can be re-run to incorporate recent wind data and ensure spatial coverage requirements are met.

Appendix C: Site Monitoring Plan

Table C-1 provides a summary of the information required to be included in a Site Monitoring Plan, as prescribed by 40 CFR §60.5398b(b)(2). It is the responsibility of the operator to develop and maintain the Monitoring Plan while using this ATM. Importantly, if an OGI survey is required under this ATM or utilized to replace a periodic screening, a Fugitive Emissions Monitoring Plan is required, per 40 CFR §60.5397b(b). Tables C-2 and C-3 summarize the Monitoring Plan requirements applicable to a facility when monitoring surveys are conducted to investigate confirmed detections by this ATM.

Table C-1. A summary of Site Monitoring Plan requirements.

Requirement	Description	Citation
Facility Name	Name of the facility	
Facility Coordinates	Latitude and longitude coordinates of the site in decimal degrees to an accuracy and precision of at least four decimals of a degree using the North American Datum of 1983.	40 CFR §60.5398b(b)(2)(i)
Facility Type	(i.e., single wellhead only site, small site, multi-wellhead only site, well site with major production and processing equipment, centralized production facility)	
Alternative Test Method	SLB SOOFIE Emissions Monitoring System	40 CFR §60.5398b(b)(2)(ii)
Spatial Resolution	Facility-Level	40 CFR §60.5398b(b)(2)(ii)
Surveyor	SLB SOOFIE Emissions Monitoring System	40 CFR §60.5398b(b)(2)(iii)
Applicable Detection Threshold	5 kg/hr, 10 kg/hr, or 15 kg/hr	
Frequency of Periodic Screenings	Dependent on site type and applicable detection threshold, as shown in Tables 1 and 2	40 CFR §60.5398b(b)(2)(iv)
Is an annual OGI survey required as part of this ATM work practice, prescribed by 40 CFR §60.5398b(b)(1)(i) or (ii)?	Yes or no, dependent on site type and applicable detection threshold as shown in Tables 1 and 2	40 CFR §60.5398b(b)(2)(v)
Will an OGI survey be utilized to replace a periodic screening survey with this alternative test method?	Yes or no. If 'Yes' follow requirements of Tables C-2 and C-3.	40 CFR §60.5398b(b)(2)(v)
Procedures and timeframes for identifying and repairing fugitive emissions components, covers, and closed vent systems with confirmed detections		40 CFR §60.5398b(b)(2)(vii)
Procedures and timeframes for verifying repairs for fugitive emissions components, covers, and closed vent systems		40 CFR §60.5398b(b)(2)(viii)
Records that will be kept and the length of time records will be kept		40 CFR §60.5398b(b)(2)(ix)

Table C-2. A summary of Monitoring Plan information required if confirmed detections are investigated using the Optical Gas Imaging monitoring survey.

Requirement	Description	Citation
Technique for determining fugitive emissions	Optical Gas Imaging	40 CFR §60.5397b(c)(2)
Manufacturer of detection equipment		40 CFR §60.5397b(c)(3)
Model number of detection equipment		40 CFR §60.5397b(c)(3)
Verification of OGI specifications, as prescribed by 40 CFR §60.5397b(c)(7)(i)(A) and (B)		40 CFR §60.5397b(c)(7)(i)(A) 40 CFR §60.5397b(c)(7)(i)(B)
Procedure for daily verification check		40 CFR §60.5397b(c)(7)(ii)
Maximum viewing distance		
Procedure for determining maximum viewing distance		40 CFR §60.5397b(c)(7)(iii)
Maximum wind speed		
Procedure for determining maximum wind speed		40 CFR §60.5397b(c)(7)(iv)
Procedures for how the operator will ensure adequate thermal background		40 CFR §60.5397b(c)(7)(v)(A)
Procedures for how the operator will deal with adverse monitoring conditions (e.g., wind)		40 CFR §60.5397b(c)(7)(v)(B)
Procedures for how the operator will deal with interferences (e.g., steam)		40 CFR §60.5397b(c)(7)(v)(C)
Required training and experience		40 CFR §60.5397b(c)(7)(vi)
Procedures for calibration and maintenance		40 CFR §60.5397b(c)(7)(vii)

Table C-3. A summary of Monitoring Plan information required if confirmed detections are investigated using the Method 21 monitoring survey.

Requirement	Description	Citation
Technique for determining fugitive emissions	Method 21	40 CFR §60.5397b(c)(2)
Manufacturer of detection equipment		40 CFR §60.5397b(c)(3)
Model number of detection equipment		40 CFR §60.5397b(c)(3)
Verification of M21 specifications		40 CFR §60.5397b(c)(8)(i)
Procedures for conducting surveys		40 CFR §60.5397b(c)(8)(ii)
Procedures for calibration, in alignment with 40 CFR §60.5397b(c)(8)(iii)(A), (B), and (C)		40 CFR §60.5397b(c)(8)(iii)
Procedures for monitoring yard piping		40 CFR §60.5397b(c)(8)(iv)
A list of fugitive emissions components to be monitored and the method for determining the location of fugitive emissions components		40 CFR §60.5397b(d)(2)
Plan for each difficult-to-monitor fugitive emissions component		40 CFR §60.5397b(d)(2)
Plan for each unsafe-to-monitor fugitive emissions component		40 CFR §60.5397b(d)(2)

Appendix D: Periodic Screening Surveys for Special Instances

D.1. In alignment with the *Pollution Prevention* objectives of this alternative technology, the owner or operator is permitted to identify and repair any leaks detected during a periodic screening. The owner/operator is also responsible for documenting and notifying SLB of any on-site activities that could impact emission estimates or screening outcomes during the Screening Period. By default, SLB will not alter the periodic screening timeframe due to such activities. However, if the operator chooses and informs SLB accordingly, the screening may be restarted once the leak has been properly resolved. If the restarted Screening Period falls outside of the required screening frequency, an OGI survey may be required as a substitute.

D.2. In the event of unforeseen maintenance activities occurring during a Periodic Screening, the owner or operator reserves the right to restart the Screening Period. In such instances, it is the responsibility of the owner/operator to document all relevant on-site activities and notify SLB, including coordinating the timing of the restart. Should the new Screening Period extend beyond the prescribed screening frequency, an OGI survey may be required as a substitute.