ChampionX Aerial Optical Gas Imaging Method

In Support of the ChampionX Alternative Test Method for the New Source Performance Standards and Emission Guidelines for Oil and Natural Gas Operations

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CHAMPIONX

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1 Scope and Application

1.1 Applicability

Aerial OGI (AOGI) is a methane monitoring method for detecting methane emissions from stationary sources. This method is primarily used in oil and gas operations and designed for operators to find leaks on their sites efficiently. The target analyte is methane (CH_4, CAS number: 74-82-8), and AOGI detects methane leaks from stationary sources with mass emissions equal to or higher than 0.281 kg/hr with over 91% probability of detection, qualifying for periodic emissions monitoring as prescribed under §60.5398b(b) and Tables 1 and 2.

1.2 Scope

This method outlines procedures for detecting methane emissions using AOGI, a helicopter equipped with an OGI camera on a targeting gimbal. AOGI is designed to identify methane leaks from stationary sources in oil and gas operations. The method leverages advanced thermography principles, allowing the OGI camera to capture high-resolution images and enabling operators to efficiently locate and document leaks. The helicopter's mobility ensures rapid and comprehensive site coverage, including hard-to-reach areas, enhancing overall inspection effectiveness. The system is calibrated to detect methane emissions with high accuracy, identifying leaks with emissions equal to or less than 1 kg/hr, and significantly improving the ability to monitor and manage methane emissions. This method supports compliance with environmental regulations – as an alternative to OOOOb and OOOOc regulations -- and contributes to safety and environmental stewardship by facilitating prompt leak detection and repair.

2 Summary of Method

This method employs AOGI to detect methane emissions from fugitive emission sources, components located at well sites, centralized production facilities, and compressor stations, including covers and closed vent systems. AOGI utilizes a helicopter equipped with a high-resolution – a minimum of 640 x 512 with a telephoto lens size 50mm OGI camera mounted on a targeting gimbal. This method closely resembles the methodology found in EPA-designated OGI screening processes, using standard thermography principles and techniques to find emission sources.[1,2]

The process includes the following key steps:

[1] §60.18(g) Alternative work practice for monitoring equipment for leaks
[2] §60.5397a What fugitive emissions GHG and VOC standards apply to the affected facility which is the collection of fugitive emissions components at a well site and the affected facility which is the collection of fugitive emissions components at a compressor station?

2.1 Pre-Flight Planning

Technicians consult with facility operators to plan the inspection route, considering site-specific factors such as topography and weather conditions. Pre-flight planning ensures that the helicopter can safely and effectively cover all areas of interest.

2.2 Equipment Checks and Calibration

Before each flight, all equipment, including the helicopter, OGI camera, and gimbal, undergoes thorough checks and calibration to ensure optimal performance. The OGI camera is calibrated using sample gases to ensure accurate detection in accordance with the alternative work practice calibration distances.[3] Each calibration check is stored and associated to each survey and leak for recordkeeping purposes.

2.3 Flight Operations

During the flight, the helicopter follows the planned route while the OGI camera captures thermal images to identify methane leaks. The gimbal allows for precise targeting and stabilization, ensuring clear imagery. The OGI camera operates using standard thermography principles, enabling operators to detect and locate methane emissions efficiently and rapidly. This approach closely resembles EPA-designated OGI screening processes as described in NSPS OOOOa,[4] NSPS OOOOb,[5] and NSPS OOOOc.[6]

2.4 Detection and Documentation

Methane emissions are detected in real-time using thermographic imaging. Detected leaks are recorded and processed, providing detailed information such as GPS coordinates and visual footage. In the report is a digital map showing the flight path of the helicopter for each day's survey. This data allows facility owners and operators to begin the appropriate leak repair processes quickly and provides documentation that the survey was completed in accordance with regulatory deadlines. If a major release is found (i.e., liquids spill, large leak estimated to be >30 kg/hr or anything posing a health and safety concern, the camera tech will notify the operator immediately using communications channels.

2.5 Post-Flight Data Processing

After the flight, the recorded data is analyzed to verify leak locations and compile a comprehensive report. The report includes all necessary details for operators to initiate leak repairs promptly. All information required to maintain compliance is provided immediately or

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3 §60.18(i)(2) Daily Instrument Check
4 §60.5397a(d)(1)
5 §60.5397b(d)(1)
6 §60.5397c(d)(1)

within 48 Hours, ensuring all information necessary for the operator to maintain compliance is provided within five days as prescribed in (§60.5398b(b)(5)(i).

2.6 Compliance and Reporting

Within five days, operators receive a detailed final report, this report will also be a conclusion of the daily reports sent out within 48 hours of leak detection and supports compliance with environmental regulations and facilitates timely corrective actions. The report provides all necessary information for operators for all leaks, to maintain compliance and to begin the appropriate leak repair processes.

By following these steps, AOGI provides an efficient, reliable, and auditable method for detecting methane emissions from fugitive sources, enhancing operational safety and environmental protection. The method's ability to quickly locate and document leaks allows for prompt repair actions, minimizing environmental impact and supporting regulatory compliance.

3 Definitions

AOGI – Aerial Optical Gas Imaging

EPA – Environmental Protection Agency

SOP – Standard Operating Procedure

GPS – Global Positioning System

FAA – Federal Aviation Administration

Shogun – High-resolution optical gas imaging device designed to detect methane leaks using advanced thermography principles. It provides precise targeting and stabilization for clear and accurate leak detection during aerial inspections

4 Interferences

4.1 Local weather conditions

AOGI cannot be used in conditions deemed unsafe by the trained and FAA licensed helicopter pilot. Adverse weather conditions, including strong winds, rain, fog, and poor visibility, can impede the performance of the OGI camera and the safety of the helicopter operation. The method must be performed during daylight hours.

4.2 Density Altitude

Density altitude cannot go beyond the safe operating levels of the selected helicopter during summer months. It does not affect images from AOGI, so in high density altitude conditions, a different type of helicopter will be used.

4.3 Topography

The site must be suitable for the helicopter to monitor, with enough perimeter space to allow the helicopter to circle the facility.

5 Safety Considerations

5.1 Pre-Flight Equipment Checks

Before each flight, conduct a thorough inspection of all equipment, including a pre-flight inspection of the helicopter, OGI camera, and other detection or recording devices. Verify that all components are functioning correctly and securely mounted. Check for any signs of wear or damage and confirm that all software systems are updated and operational. Perform systems check to ensure that all electronic and mechanical parts are in good working order.

5.2 Crew Safety Briefings

Hold comprehensive safety briefings for all crew members before each flight. These briefings should cover emergency procedures, the specific flight and operational plans for the day, and any potential risks identified during the planning phase. Include a review of the safety protocols, roles, and responsibilities of each crew member. Ensure all crew members understand the actions to take in case of an emergency and are familiar with the location and use of safety equipment.

5.3 Regular Communication

Maintain regular communication between the flight crew and ground control throughout the operation if needed. If survey includes controlled airspace, pilot will maintain communications with appropriate towers. Communication with the office team happens after data uploads to ensure information and data is properly noted and data transfers secured.

5.4 Weather Monitoring

Continuously monitor weather conditions before and during flights. Utilize reliable weather forecasting tools and services to stay updated on current and projected weather conditions. Adjust flight plans based on weather updates to avoid hazardous conditions like strong winds, turbulence, or poor visibility, which can significantly impact flight safety and data quality. Establish a decision-making process for weather-related adjustments and cancellations.

5.5 Flight Data Recording

Ensure all flight data is continuously recorded according to SOP guidelines. This includes logging GPS coordinates, altitude, airspeed, and camera settings. Data recording supports the mission's goals and provides critical information for reviewing flight safety and effectiveness post-operation. Use robust data recording systems to capture high-quality data and ensure that backup systems are in place in case of primary system failure. Conduct regular audits of recorded data to verify accuracy and completeness.

6 Equipment & Supplies

The following equipment is essential for conducting AOGI operations:

6.1 Helicopter

The helicopter must comply with FAA guidelines and maintain appropriate altitudes for both safety and effective inspection. It should be equipped for stable flight and capable of operating within the specified environmental conditions. Example of helicopters previously flown:

- Robinson 44
- Jet Ranger Bell 206

6.2 Gimbal & OGI Camera

The gimbal and OGI camera must feature four-axis stabilization to ensure stable imagery. The camera should be high-resolution (640 X 512) to accurately detect methane leaks. The system should also allow for precise targeting and movement to capture comprehensive data.

6.3 Control Board for OGI Camera

A control board is necessary for operating the OGI camera. It should facilitate easy adjustments and fine-tuning of the camera settings during flight to ensure optimal performance.

6.4 Data Transfer Device

A reliable data transfer device is required for securely transmitting data from the OGI camera to ground-based systems. This device should support rapid data transfer to minimize downtime and ensure efficient processing.

6.5 Computer with Monitor

A computer with a high-resolution monitor is needed for sending, receiving, and analyzing data. The computer must be capable of playing back video recordings to confirm detections and non-detections. It should have sufficient processing power and storage capacity to handle large volumes of data.

6.5.1 Video Playback Capability

The computer must support video playback to review and verify recorded footage. This ensures that detected leaks are accurately identified and documented for further action.

7 Reagents & Standards

To ensure the accuracy and reliability of the OGI camera, it is essential to obtain high-quality sample gas specifically for calibration purposes. This sample gas must be of a known concentration and purity, suitable for calibrating the OGI camera to detect methane emissions accurately. Proper verification with these sample gases ensures that the equipment can consistently detect and measure methane leaks, thereby supporting the validity of the monitoring process and compliance with environmental regulations.

7.1 Verification Gases

7.1.1 Methane Verification Gas

Gas containing methane (CH_4) of a known concentration is used to verify the operation of the OGI camera. This ensures the camera's detection accuracy for methane emissions. The gas should be certified and traceable to national standards.

7.1.1.1 Handling and Storage

Verification gases must be handled carefully and stored in appropriate containers to maintain integrity. Containers should be labeled with the gas type, concentration, and expiration date.

7.2 Standards

7.2.1 Reference Standards

Utilize reference standards provided by recognized bodies such as the National Institute of Standards and Technology (NIST) to ensure that verification procedures are accurate and reliable.

7.2.1.1 Verification Protocols

Follow established verification protocols to verify that the OGI camera is performing correctly.[7] This includes regular calibration checks before and after flights to maintain measurement accuracy.

8 Sample Collection, Preservation & Storage

In the AOGI method, no physical samples are collected during the detection of methane emissions. The process relies solely on the real-time data captured by the OGI camera mounted on the helicopter. As a result, there are no requirements for collecting, preserving, or storing physical samples. All methane emission detections are documented through digital recordings and data logs, which are then analyzed and processed to generate comprehensive reports. This approach ensures that the method is efficient and focused on immediate data capture and analysis, without the need for handling physical samples.

9 Quality Control

9.1 Gimbal Inspection

- Visually inspect the gimbal mechanism to ensure it is free from any visible damage, corrosion, or mechanical issues.
- Check all moving parts, including motors, bearings, and hinges, for smooth operation and proper alignment.
- Verify that the gimbal is securely attached to the helicopter's exterior and that all fasteners and connections are tightened to the manufacturer's specifications.
- Test the gimbal's range of motion to ensure it can pan, tilt, and rotate smoothly without binding or resistance.
- Confirm that the gimbal's stabilization system functions correctly to ensure steady footage even during helicopter movements.

9.2 OGI Camera Inspection

- Perform a thorough visual inspection of the OGI camera for any signs of damage, lens obstructions, or wear.
- Clean the camera lens to ensure optimal image quality and unobstructed gas detection capabilities.
- Test the camera's calibration settings and adjust as necessary to ensure accurate methane detection.

[7] §60.18(i)(2) Daily Instrument Check

9.3 Electrical Connections & Power Supply

- Inspect all electrical connections and cables associated with the OGI camera, gimbal, and onboard power supply.
- Ensure that connectors are securely seated and free from damage or corrosion.
- Test the camera's power supply to verify it receives sufficient voltage and current for normal operation.
- Confirm that backup power sources, such as batteries or generators, are available in case of any electrical failures during the flight.

9.4 Communication & Control Systems

- Check the communication links and control systems between the OGI camera, gimbal, and helicopter cockpit.
- Verify that the pilot and camera operator can communicate effectively and control the gimbal's movement as needed during the inspection.
- Test remote control functions, such as pan and tilt commands, to ensure they are responsive and accurate.

9.5 Environmental Considerations

- Assess environmental factors affecting the OGI camera's performance, such as temperature extremes, humidity, and precipitation.
- If necessary, take precautions to protect the camera and gimbal from adverse weather conditions, such as covering them with protective enclosures or shields.

10 Calibration & Standardization

10.1 Gas Verification

See section *7. Reagents & Standards*

10.2 Camera Alignment & Calibration

- Ensure the OGI camera is securely mounted within the gimbal and properly aligned for optimal field of view.
- Check the camera's focus and zoom settings to calibrate appropriately for the intended inspection objectives and operating conditions.
- Verify that the camera's lens is clean and free from any obstructions or debris that could affect image quality or gas detection capabilities.
- If applicable, test the camera's thermal imaging capabilities to ensure accurate detection and visualization of gas emissions.

10.3 Gimbal Calibration

- Calibrate the gimbal's range of motion to ensure it can pan, tilt, and rotate smoothly. Perform these checks regularly to detect any mechanical issues.
- Verify the gimbal's stabilization system to ensure it functions correctly, providing steady footage even during helicopter movements. Adjust calibration settings as needed to maintain stability.

10.4 SOPs

- Maintain detailed documentation of all calibration procedures and results. This ensures traceability and allows for continuous improvement of the calibration process.
- Develop and follow standardized protocols for calibration and testing. These protocols should be based on industry best practices and regulatory requirements.

10.5 Calibration Frequency

- Schedule routine calibration of all equipment at regular intervals, not just before and after flights. This ensures long-term accuracy and reliability.
- Conduct additional calibration checks after any significant repairs, software updates, or if any discrepancies are noted during regular operation.

11 Procedures

Throughout this method document, various procedures are referenced to ensure compliance and operational efficiency. Detailed descriptions and specific protocols for these procedures are maintained in the Confidential Business Information (CBI) section of our documentation. Access to this information is restricted to authorized personnel to protect proprietary and sensitive business information.

For specific procedural details, please refer to the corresponding sections within the CBI documentation.

11.1 Start-Up

- Following engine start, while the pilot conducts further system checks, the camera operator should perform the following steps:
  - Secure the seat belt, ensuring that any wiring is positioned under the seat belt to keep it restrained and clear of flight controls.
  - Initiate tracker time coinciding with the engine start.
- After the pilot completes the start checks and confirms readiness, proceed with the following:
  - Power up the camera monitor, camera, and gimbal systems.
  - Begin operations using natural light before switching to thermal imaging.

  - Allow the thermal system a few minutes to cool down to operating temperature.
  - Once the thermal system is ready, select a target and verify its clarity and contrast to ensure proper functioning.
  - Maneuver the gimbal through a full 360-degree rotation and a 180-degree vertical movement to check for any binding or restrictions in motion.
  - If any checks are unsuccessful, the flight will be aborted to resolve any issues with the helicopter off and the camera hooked up to another power source.

11.2 In-Flight Procedures

- When approaching a target, execute the following steps in sequence:
  - Confirm the PIN or name with the pilot.
  - Record the following details in the notebook:
    - PIN
    - Time on target
    - Tank quantity
    - Flare quantity
    - Presence of Soofie devices, if applicable
    - Locate the target using the camera.
- Switch to thermal imaging mode:
- Be mindful of light angles and intensity, as they can affect the quality of the image. Continue to focus on the target and view each part of the site from various angles for comprehensive coverage.
- Initiate the survey and complete up to 4 sweeps by circling the complete pad up to 3 times (an example survey flight path is shown in Figure 1 and 2). Be sure that the helicopter stays on the perimeter of the target area.
  - If the pad is large, divide the pad into sections and sweep the divided areas up to 3 times.
- If you detect a leak, notify the pilot and switch to natural light. Then, look outside to locate a site sign.
- Upon identifying a site sign, communicate its location to the pilot. Then, follow these steps:
  - Once properly positioned, zoom in on the sign and begin recording.
  - Pan out to capture a comprehensive video of the site in natural light.
  - Switch back to thermal imaging to document the leak.
  - Do not start recording the leak unless the helicopter is in an optimal position. If unsure, consult with the pilot. Typically, a good position mirrors the approach direction, moving into the wind with the site directly ahead.
  - Recording duration in thermal mode should be adjusted based on company standards or the visibility of the leak, generally between 15 and 20 seconds of targeted footage.
- After recording, complete the following site documentation tasks:

- Place an additional PIN for the site and record this PIN in your notes.
- Document the type and location of the leak in your notes.

11.3 Post-Flight Procedures

- After the flying day, transmit all collected data to the home office through the shared drive. This includes:
  - Videos and notes
    - Ensure written notes are sent for integration into the spreadsheet.
  - Send in maps and application information.
  - Record and include details such as flight time, miles traveled, surveys completed, and all inspected targets.
  - Confirm the accuracy and inspection of all targets.

12 Data Analysis & Calculations

12.1 OGI Detection of Methane

This method provides a minimum detection level of ≤1 kg/hr methane for the operation of AOGI. The AOGI platform does not offer quantified leak rate data to the operator. Instead, the operator is notified of all detected leaks.

12.2 Detection Limit of Methane

12.2.1 Operating Envelope

The AOGI platform's operating envelope is defined by the maximum allowable operating altitude to guarantee the minimum detection limit and the maximum distance from the site.

12.2.2 Calibration for Precision

The gimbal and OGI camera are calibrated and verified to ensure precise detection capabilities. Verification involves using known concentration gases, and calibration involves adjusting the camera settings accordingly.

12.3 Pre-Flight Planning

Site configurations are considered during pre-flight planning to optimize detection efficiency. This includes assessing topography, potential obstacles, and environmental conditions.

12.3.1 Flight Plan Development

Flight plans are created to meet minimum detection levels while preventing plume disruptions from the helicopter's downwash. The plans ensure comprehensive coverage of the target area, considering safety and operational efficiency.

12.4 Data Processing & Validation

12.4.1 Data Extraction

Extract relevant data from the recorded images and video footage, identifying frames where methane emissions are visible.

12.4.2 Image & Video Analysis

Utilize specialized software to analyze thermal images and video footage for methane leak detection. This includes enhancing image quality and identifying gas plumes.

12.4.3 Data Integrity Checks

Ensure the integrity of the collected data by verifying completeness and checking for any signs of corruption.

12.5 Data Interpretation

12.5.1 Leak Characterization

Use the data to characterize detected leaks, including their size, location, and potential impact on the environment.

12.5.2 Compliance Evaluation

Compare the results against regulatory standards to determine compliance. Provide detailed reports to facility operators with all necessary information for regulatory adherence.

12.6 Reporting Results

12.6.1 Report Preparation

Compile comprehensive reports detailing detected leaks, including visual evidence, GPS coordinates, and any relevant observations.

12.6.2 Timely Reporting

Ensure that all information required for maintaining compliance is provided to operators within five days of detection.

12.7 Continuous Improvement

Regularly review data analysis methods and incorporate feedback to improve accuracy and efficiency. Update analysis methods and tools as necessary to ensure ongoing improvement and adaptation to new standards or technologies.

13 Method Performance

13.1 Validation Results

After a video has been captured and transmitted to the office a second person views the image assuring that all leaks are located on the site.

13.1.1 Detection Accuracy

The probability of detection for the AOGI method for leaks >0.281 kg/hr was 91% for in air detection and 94% after in-office validation based on in-field experiments. No false positives were found.

13.1.2 Sensitivity and Specificity

Given that the AOGI uses an OGI camera, the same specificity to gas is expected and seen for this method. AOGI can see leaks as low as 28 g/hr. The AOGI platform did not result in false positive detections in each study.

13.1.3 Spatial Resolution Limits of AOGI Platform

The AOGI platform has a component-level spatial resolution and can identify emissions within a radius of 0.5 meters of the emission source.

13.2 Detection Limits

13.2.1 Minimum Detection Level

The minimum detection level of the AOGI method is 0.281 kg/hr with a 91% probability of detection for in-field detection by a trained AOGI operator. This minimum detection level is enhanced with in-office verification, where the probability of detection is 94% at 0.5 kg/hr.

13.3 Continuous Monitoring of Performance

13.3.1 Ongoing Assessments

This method is continually monitored and assessed to maintain and improve performance. This includes periodic performance reviews and equipment and procedure updates based on technological updates and findings.

14 Pollution Preventions

14.1 Efficient Periodic Inspections

The AOGI platform is an efficient method for conducting periodic inspections of methane emissions. By utilizing a helicopter equipped with an OGI camera, flight plans can take direct routes and efficiently scan a site in a few minutes, significantly reducing the need for extensive on-ground inspections. Ground OGI crews typically can survey four to five sites a day whereas the AOGI can survey up to 100 sites.

14.2 Reduction of Vehicle Emissions

The helicopter-based AOGI method can reduce the total fuel consumption and emissions compared to traditional ground-based inspection methods. While helicopters do consume fuel, their efficiency allows a single flight to cover a vast area that would otherwise require multiple vehicles and extensive driving over several days.

Ground-based inspections typically involve multiple vehicles traveling long distances, especially in remote or extensive oil and gas fields, leading to increased overall fuel consumption and emissions. Helicopters can quickly access remote and widespread locations without extensive road travel, reducing cumulative emissions from multiple vehicles.

For example, the Robinson-44 burns approximately 90 gallons of aviation gas a day and can cover 150 sites, leading to 0.6 gallons of gas per site for AOGI. The gas used by the Robinson-44 is equivalent to 5 kg CO_2 per site. A truck and crew can cover 5 sites a day and burn approximately 15 gallons each day, leading to 3 gallons of gas per site or 24.3 kg CO_2 per site.[8]

Furthermore, the helicopter's ability to take direct flight paths minimizes travel distances compared to the indirect routes that vehicles often take due to terrain and infrastructure limitations.

14.3 Minimizing Environmental Disturbance

Aerial inspections minimize the physical impact on the environment compared to ground-based methods. Helicopters can cover large areas without disturbing the site’s natural habitat, reducing the method’s ecological footprint.

14.4 Early Leak Detection and Mitigation

By providing rapid and accurate detection of methane leaks, the AOGI platform enables operators to address and mitigate leaks more quickly. Early detection and repair of leaks

[8] CO_2 emissions coefficients taken from https://www.eia.gov/environment/emissions/co2_vol_mass.php

prevent prolonged methane emissions, reducing the overall release of harmful greenhouse gases into the atmosphere.

14.5 Compliance with Environmental Regulations

The AOGI platform helps ensure compliance with environmental regulations by providing precise and timely data on methane emissions. This aids operators in maintaining adherence to regulatory standards, avoiding potential fines, and contributing to overall environmental protection efforts.

14.6 Data-Driven Decision Making

The comprehensive data collected by the AOGI system supports data-driven decision-making for emissions management. Operators can use the detailed reports to prioritize leak repairs, optimize maintenance schedules, and implement more effective emissions control strategies.

14.7 Sustainable Operational Practices

By integrating the AOGI platform into their operations, companies can demonstrate their commitment to sustainable practices. The use of advanced technology for emissions monitoring aligns with corporate sustainability goals and enhances ChampionX's environmental stewardship.

15 Waste Management

15.1 Minimization of Waste

Practices are in place to minimize waste generation by optimizing the use of materials and resources during AOGI operations. This includes careful pre-flight planning and efficient use of fuel, calibration gases, and other consumables to reduce unnecessary waste.

15.2 Disposal of Consumables

- Verification gas cylinders are disposed of or recycled properly in accordance with local regulations and environmental guidelines. Safe handling procedures are followed to prevent leaks or accidents.
- Dispose of cleaning materials, such as wipes and solvents used for maintaining the OGI camera and gimbal, in accordance with hazardous waste disposal regulations. Use environmentally friendly cleaning products whenever possible to minimize environmental impact.

15.3 Electronic Waste

- Electronic waste generated from the maintenance and replacement of equipment, such as the OGI camera, data transfer devices, and computers, is managed responsibly. Electronic components are recycled or disposed of through certified e-waste recycling programs to minimize environmental impact, ensuring compliance with all relevant environmental regulations.

15.4 Continuous Improvement

- Opportunities to reduce waste through improved processes, technology upgrades, and employee training are continuously sought. A culture of sustainability is promoted within ChampionX by encouraging best practices in waste management and recognizing efforts to minimize waste.

16 References

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- Zimmerle, D., *et. al.* "Detection Limits of Optical Gas Imaging for Natural Gas Leak Detection in Realistic Controlled Conditions." *Environ. Sci. Technol.* (2020), 54, 18, 11506–11514.

17 Tables and Diagrams

Figure 1. Example flight path with multiple sites close together.

Figure 2. Example flight path with 3 sweeps.