Alternative Test Method (MATM-006)

February 21, 2025

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 affected facilities and compliance with periodic inspection and monitoring requirements for covers and closed vent systems, specifically demonstrating compliance through periodic screening in 40 CFR 60.5398b(b), as approved, per 40 CFR §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.

1.2 Application

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

1.2.2. The test method is applicable to methane (CH_4, CAS No. 74-82-9) emissions from stationary sources in the upstream and midstream oil and gas sector and designed for operators to survey for leaks on sites such as but not limited to production sites, gather and boosting stations, processing plants, transmission and storage facilities, distributions systems for stationary sources in upstream, midstream and downstream oil and gas facilities. This method can be used, as approved by the Administrator, in lieu of the applicable fugitive monitoring requirements in either §60.5397a or §60.5397b and inspection and monitoring of covers and closed vent systems in either §60.5416a or §60.5416b. This test method may be used for fugitive monitoring requirements 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.

Note: While the target pollutant is methane, AOGI uses a cooled Mid-Wave Infrared (MWIR) camera that can also detect methane leaks and VOCs such as ethane (74-84-0), propane (74-98-6), propylene (105-07-1), 1-pentene (109-67-1), butane (106-97-8), ethyl benzene (100-41-4), heptane (142-82-5), hexane (110-54-3), isoprene (78-79-5) and octane (11-65-9).

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

1.3 Method Sensitivity

This sensitivity of the outlined method is below 1 kg/hr as applied to Tables 1 and 2 Subpart OOOOb of Part 60, Title 40. The method can confirm the detection of fugitive emissions at a component-level spatial resolution (§60.5398b(b)(5)(iv)) and provides real imagery and video of the leak point so that an operator can visually define the problem source. This method's sensitivity from fugitive sources is 0.28 kg/hr with over 90% probability of detection (POD), qualifying for periodic emissions monitoring as prescribed under §60.5398b(b) and Tables 1 and 2.

1.4 Data Quality Objectives

Adherence to the test method outlined in this document will ensure the fugitive leak data will be accurate and of quality. The technology's objective is to screen for fugitive emissions that are equal and/or exceed 1 kg/hr on oil and gas sites, such as well-pads, compressor stations and other sites with fugitive emission sources, on a quarterly frequency. This method will provide images, geolocation data, and videos within an alert, triggering a leak detection and survey response for the operator.

2. Summary of Method

2.1 AOGI Method

This method employs AOGI to detect methane emissions from fugitive emission sources, components located at well sites, centralized production facilities, gathering and boosting stations, processing plants, transmission and storage facilities, meter and valve stations, and distribution stations, including covers and closed vent systems. AOGI utilizes a helicopter equipped with a high-resolution – a minimum of 640 x 512 OGI camera mounted on a targeting gimbal and a ChampionX trained AOGI thermographer. This method closely resembles the methodology found in §60.5397a, §60.5397b, and 40 CFR Part 60, Appendix K, for OGI in leak detection. The process includes the following key steps:

2.1.1 *Pre-Flight Planning:* Technicians consult with facility owner or operators to plan the inspection route, review plot plans and assess list of facilities to plan approach and site identification activities pre-flight. Also, technicians consider site-specific factors such as topography and prevalent weather conditions. Pre-flight planning ensures that the helicopter can safely and effectively cover all areas of interest.

2.1.2 *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 (§60.18(i)(2) Daily Instrument Check). Each calibration check is stored and associated to each survey and leak for recordkeeping purposes.

2.1.3 *Flight Operations:* During the flight, the helicopter follows the planned route while the OGI camera captures thermal images to screen and 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, NSPS OOOOb, and EG OOOOc.

2.1.4 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 and provides documentation that the survey was completed in accordance with regulatory deadlines.

Note: If a release is observed which could pose a health or safety concern, the owner or operator of the affected facility should be immediately contacted.

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

2.3 Compliance and Reporting

As identified in the applicable regulations, operators receive a detailed final report, this report will support compliance with applicable 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.

3. Definitions of Method

3.1. Definitions

3.1.1 AOGI technician means a trained thermographer that has completed the ChampionX AOGI training plan.

3.1.2 Approach means the path the helicopter takes when arriving to the site, to set up for efficient inspection.

3.1.3 Gimbal means a pivoted support system that stabilizes a camera along different axes to enable smooth image and video capture.

3.1.4 OGI camera means specialized infrared camera that is tuned to visually monitor gas emissions.

3.1.5 Survey means a single site inspection for the AOGI method, comprised of multiple sweeps.

3.1.6 Sweep means the helicopter's flight path that covers one full circle of the equipment or site being monitored.

Thermal imaging mode means the operating mode of the camera that uses the mid-wave infrared detector which is used to capture and create images and videos of gas leaks using infrared radiation.

3.2 Abbreviations

AOGI – Aerial Optical Gas Imaging

Deg – degrees

FAA – Federal Aviation Administration

GPS – Global Positioning System

MDL – Minimum Detection Level

MWIR – Mid Wave Infrared

OGI – Optical Gas Imaging

POD – Probability of Detection

SOP – Standard Operating Procedure

4. Method Interferences and Envelope of Operation

4.1 Local Weather Conditions

AOGI cannot be used in conditions considered unsafe by the trained and Federal Aviation Agency (FAA) licensed helicopter pilot. Adverse weather conditions, including strong winds, rain, fog, and poor visibility, can impede the OGI camera's performance and the helicopter operation's safety. This method may be performed at different density altitudes if the operating conditions are suitable for the aircraft used during the execution of this test method. The method's envelope of operation is summarized in Table 1. The operating envelope of this method must adhere to any manufacturer guidelines for the equipment being used.

Table 1. Method interferences to this method's operating envelope

Condition	Summary	Mitigation
Solar illumination	The method requires sunlight for robust detection	Schedule flights to meet required illumination constraints
Solar Glare	This method is affected by direct sun into the camera and strong glares	This method can be performed during periods of low sun angles (< 30 deg to the horizon). During periods with low sun angles, the OGI technician and pilot must ensure camera angles and approaches do not include solar glare that obscures the view of the camera. To ensure there is no solar glare, the approach angle must be changed. If the sun is close to the horizon, the camera angle must be more vertical to avoid the sun in frame. QC flag for excessive glare.
Fog, steam, and particulate matter	This method requires meteorological visibility of 400 ft to be two times the operating envelope's viewing distance.	Schedule flights to avoid low visibility conditions. Modify flight plan to visit sites when fog, steam, or particulate matter dissipates.
Clouds	Dense low, clouds with a ceiling less than 300 ft can obscure facilities from view, impacting detection and/or quantification	Schedule flights for conditions with better than broken sky cover; use cloud gaps and repeat overflights to image priority facilities; QC flag for obscured objects
High wind speed	Wind speeds more than 30 mph dilute CH_4 concentration, unsafe flying conditions	Schedule flights to avoid high wind conditions. QC flag in analysis workflow for high winds reported in reanalysis product.
Precipitation	This method must not be performed during precipitation	Schedule flights to avoid precipitation conditions. QC flag for unexpected conditions.
Unsuitable terrain for flight path (Topography)	The site must be suitable for the helicopter to monitor, with over 100 to 150 ft of space around the site to allow the aircraft to circle the facility within the operating envelope's distance and altitude.	Adjust altitude when possible. Pre-flight planning is needed to avoid unsuitable sites for the survey.

5. Safety

5.1 Equipment Inspection

Before each flight, this method requires a thorough inspection of all equipment, including a pre-flight inspection of the helicopter, OGI camera, and other detection or recording devices. AOGI technicians and pilot must verify that all components are functioning correctly and securely mounted. Technicians must check for any signs of wear or damage and confirm that all software systems are updated and operational. The pilot and AOGI technician must perform systems check to ensure that all electronic and mechanical parts are in good working order.

5.2 Safety Briefings

This method requires 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. This briefing must Include a review of the safety protocols, roles, and responsibilities of each crew member, first responder contacts and procedures, and the closest hospitals during the flight. All crew members must understand the actions to take in case of an emergency and are familiar with the location and use of safety equipment.

5.3 Communication

The AOGI crew must maintain regular communication between the flight crew and local air traffic 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. Data is duplicated from the hard drive and transmitted to ChampionX servers. The hard drive copy is retained for three months while the server copy is retained for 5 years.

5.4 Weather Conditions

The AOGI crew must continuously monitor weather conditions before and during flights. Weather must be reevaluated every 3 hours, or when weather conditions change during flight. This method requires the AOGI crew to utilize reliable weather forecasting tools and services to stay updated on current and projected weather conditions. The noted weather conditions must come from the closest available meteorological station. The AOGI crew must adjust flight plans based on weather updates to avoid hazardous conditions like strong winds, turbulence, or poor visibility, which can significantly impact flight safety, data quality, and operating envelope.

5.5 Data Recording

This method requires all flight and survey data is continuously recorded according to regulatory 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. This method requires the use robust data recording systems to capture high-quality data and ensure that backup systems are in place in case of primary system failure.

5.6 Audits

ChampionX will conduct quarterly audits of safety protocol, equipment health, adherence to method, and quality assurance of recorded data to verify accuracy and completeness. Audits occur every 200 flight hours. The records of the audits are retained for 5 years.

6. Equipment and Supplies

The following equipment is essential for conducting AOGI operations:

6.1 Helicopter

The helicopter must comply with FAA guidelines and maintain conditions safely for the operating envelope of this method. A trained ChampionX pilot will determine if an aircraft is suitable for this test method by determining if the specifications and ability of the aircraft can safely meet the required operating envelope for the method. The helicopter must be able to support equipment weight, have attachment requirements and authorization, and mounting locations to allow for appropriate viewing perspectives.

6.2 OGI Camera

The OGI camera in use must be high resolution (minimum 640 x 512 pixels) with a MWIR detector tuned for the target emission gas. The camera must have up to digital 8x zoom. The operating temperature of the camera must be between -5 to 45 ^{o}C.

6.3 Daylight Camera

The visible light camera must be of HD quality (minimum 1280 x 720 pixels) to accurately identify site signage and for use in the localization of leaks.

6.4 Gimbal

The gimbal must feature five-axis stabilization to ensure stable imagery. The system must also allow for precise targeting and movement to capture comprehensive data while flying at 120 knots. The gimbal must have 6 axes of movement in a 5-axis gimbal that is gyro-stabilized. The azimuth must be 360 deg continuous. The elevation must be 35 to -205 deg from horizontal. The roll must be ± 90 deg. The slew rate must be 0-130 deg/second.

6.5 Control board for gimbal and camera

6.5.1 A control board is necessary for operating the OGI camera. It should facilitate easy adjustments and fine-tuning of the camera settings such as focus, contrast and brightness during flight to ensure the method stays within the operating envelope.

6.5.2 The board must allow the operator to adjust camera settings such as brightness, contrast, zoom, and focus. These settings must be adjusted based on the current weather and flight conditions, to ensure the visibility of leaks.

6.5.3 The AOGI technician must be able to control the gimbal directly to focus and target fugitive emission sources appropriately.

6.6 Data Transfer Device

A reliable data transfer device is required for securely transmitting data from the OGI camera to ground-based systems. The system must support the transfer and processing of file sizes over 10 GB.

6.7 Computer with Monitor

6.7.1 A computer with a high-resolution monitor (1920 x 1080 pixels) is needed for sending, receiving, and analyzing data during the post-flight process.

6.7.2 The computer must be capable of playing back video recordings to confirm detections and non-detections. Minimum specifications for computer:

a) CPU: Minimum 3.0 GHz core clock speed, quad-core.
b) GPU: Minimum 4 GB of VRAM, base clock of 1700 MHz.
c) Minimum memory: 32 GB of RAM.

7. Reagents and Standards

A verification gas containing the target gas or similar analog like a butane source (e.g., lighter) or propane cylinder. This gas must be used to verify the that the OGI camera is working properly during pre-inspection testing. A live IR image using this test gas must be produced to confirm the OGI camera is working for daily checks.

8. Data Collection and Method Input Sourcing

Throughout this test method, various procedures are referenced to ensure compliance and operational efficiency. Some of the descriptions and standard operating procedures in this section of the method are considered proprietary and not included in this document. Access to this information is restricted to authorized personnel to protect proprietary and sensitive business information.

Table 2. Data inputs collected for this method

Instrument/Source	Variables	Use
US National Weather Service HRRR 3 km 60 m Forecast	Wind Speed (m/s), Wind direction (degrees)	Preliminary meteorological data. Forecast data used for flight planning and initial data work up for emission rates and plume characterizations.
Site plan	Site dimensions, equipment configuration, and equipment height	Preliminary determination of site approach and flight planning.
Survey Site List	Geolocation data (Latitude, Longitude)	Determination of efficient flight planning to minimize flight time and fuel use.
HD Visual Camera	Site name	Confirmation of site being inspected.
OGI Camera clock	Time on site	Confirmation of site being inspected and time spent on survey.
AOGI Technician	Visual site configuration	Confirmation of site being inspected and communication of leaks found in survey.
OGI Camera	Survey video	Primary source of leak information of this method. Provided to operator for leak repair.
Helicopter Geolocation Systems	Latitude and Longitude	Leak location information used for reporting and identifying leak source.
AOGI Technician	Narrative leak identification information	Complimentary information for reporting and identifying leak source.
Helicopter Geolocation System	Latitude and longitude of flight path	Exact flight path data to determine the efficiency of route, confirmation of surveys completed.

8.1 Pre-flight activities

8.1.1 AOGI technicians must consult with facility operators to plan the inspection route and approach. This involves reviewing plot plans of the assets being inspected and incorporated into flight plans, which are captured during pre-flight activities and notated via .kml files with geolocation data.

8.1.2 AOGI technicians must incorporate individual site configurations and equipment installations to ensure the survey stays within this method's operating envelope. Tall installations such as flares and prevailing weather patterns (specifically wind) must be considered.

8.1.3 AOGI technicians must review the client's leak naming conventions for ease of identification and LDAR response.

8.1.4 AOGI technicians must assess whether a site is large enough to be split into two surveys. When a site is found to be large enough to require multiple surveys, the AOGI technician must assess the sites configuration to determine the best approach and flight plan to access and survey the site. The flight plan must allow for complete views of monitored equipment and be within the operating envelope of this method.

8.1.5 This method’s pre-flight planning must list all sites being surveyed in one flight. The flight plan is constructed from the list of sites being surveyed. This flight plan must consider the efficiency of the route and the approach necessary for each site.

8.2 Flight Checks

8.2.1 The method requires a power check on the camera monitor, camera, and gimbal systems. If any of the following checks identified in Section 8.2.1.1 through 8.2.1.5 fails, refer to Section 9.

8.2.1.1 Visually inspect the gimbal mechanism to ensure it is free from any visible damage, corrosion, or mechanical issues.

8.2.1.2 Check all moving parts, including motors, bearings, and hinges, for smooth operation and proper alignment. Ensure there is no pinching or restriction of camera movement by cables.

8.2.1.3 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.

8.2.1.4 Test the gimbal's range of motion to ensure it can pan, tilt, and rotate smoothly without binding or resistance.

8.2.1.5 To test a range of motion, lay four targets on the ground, and move the camera to the furthest top left, mark on a ground target, move to further bottom left, then top right, bottom right. The technician must measure for squareness of box and targets, and the distance to demonstrate freedom of movement for full control and are the distances aligning to height of camera and expected angles.

8.2.2 The method requires confirmation of clear images when operating the visible light camera. A clear image must be in focus, enough to read large text (such as text and numbers from a speed limit sign) from 250 ft.

8.2.3 Power on OGI camera and once the OGI camera has cooled to operating temperature, use standard gas to verify it can image target gas. Image must show gas emanating from the source and be clearly defined by the operating technician.

8.3 In-Flight Procedures

8.3.1 When approaching a target, the OGI technician must confirm the site location with the pilot. Locate site signage identifying the site and record an image or video of the sign.

8.3.2 Screen the site on approach, identify the site's boundaries for inspection, and adjust pre-flight plans if necessary to accommodate for unforeseen circumstances such as temporary equipment installations or on-site personnel. AOGI technician must monitor any changes to the survey do not significantly impact the operating envelope or data quality indicators.

8.4 Flight Documentation

8.4.1 Record the following details either electronically or in writing. Store the information safely for report.

a) Site identifier.
b) Time on target.
c) Broad equipment groups and fugitive emission sources including but not limited to: Tank batteries and the tank quantity, flare quantity and general location, compressor stations, and the site size to maintain this method's viewing distance.

8.4.2 Locate target groupings to begin OGI inspection and switch to thermal imaging mode. Initiate the survey and complete a minimum of 2 sweeps by circling the site (an example survey flight path is shown in Figures 1 and 2 – Section 17). The AOGI technician must monitor the helicopter stays on the perimeter of the target area. If there is a deviation from the operating envelope during a sweep or data was not captured, the AOGI technician must inform the pilot to conduct another sweep of the site.

8.4.3 If the pad is large where it is impossible to stay on the perimeter of the site and maintain a lateral viewing distance of 200 ft, the AOGI technician must instruct the pilot to divide the pad into section and survey the divided areas.

8.4.4 The AOGI technician will record the local date and time of recording for the site survey. Time is recorded using UTC offsets based on the local time zone and as HH:MM AM/PM. The date is recorded in MM/DD/YYYY.

8.4.5 As video is being recorded, the operator must maintain video quality, adjusting the brightness, contrast, and zoom to maintain clear images according to ChampionX training standards.

8.4.6 If a clear image or video cannot be maintained due to low sun angles or glare, the AOGI technician must instruct the pilot to adjust the flight path to remove the interference from the camera view. The AOGI technician can provide feedback to pilot for specific flight settings of speed, altitude steadiness for image and video capture.

8.4.7 If a leak is detected: record the video in thermal imaging mode based on the standards required by 60.5398b. Record the location of the leak by recording the latitude and longitude, any identifying details of the site, equipment type, equipment location, time of survey, number of leaks, approximate size of leak and other narrative notes electronically or written to aid in the follow up survey and repair.

8.4.8 Upon identifying a site sign or site identifier if available or seen, communicate its location to the pilot. Record an image or video for the site sign for recordkeeping and the final report. If the site identifier is missing, the AOGI technician must use the geolocation coordinates to identify the site in the final report.

8.5 Post-Flight Procedures

After the surveys are complete, this method requires the AOGI technician to transmit all collected (electronic or written) data to a secure server. This includes:

a) Videos and notes.
b) Ensuring written notes are sent for integration into the spreadsheet.
c) Sending in maps and application information.
d) Recording, including details such as flight time, miles traveled, surveys completed, and all inspected facilities.
e) Confirming all sites surveys were performed, and data uncorrupted. Check the data logs and flight maps to confirm coverage.

8.6 Secondary Inspection Protocol

8.6.1 All written data and notes from the previous flights' surveys are recorded in a spreadsheet or table. Data includes:

a) Company
b) Site identifier
c) Time of detection
d) Number of leaks
e) Equipment type and leak notes
f) Approximate leak size based AOGI technician discretion
g) Video number
h) GPS Pin number
i) Other notes

8.6.2 The videos are downloaded from the secure server and verified the data is uncorrupted.

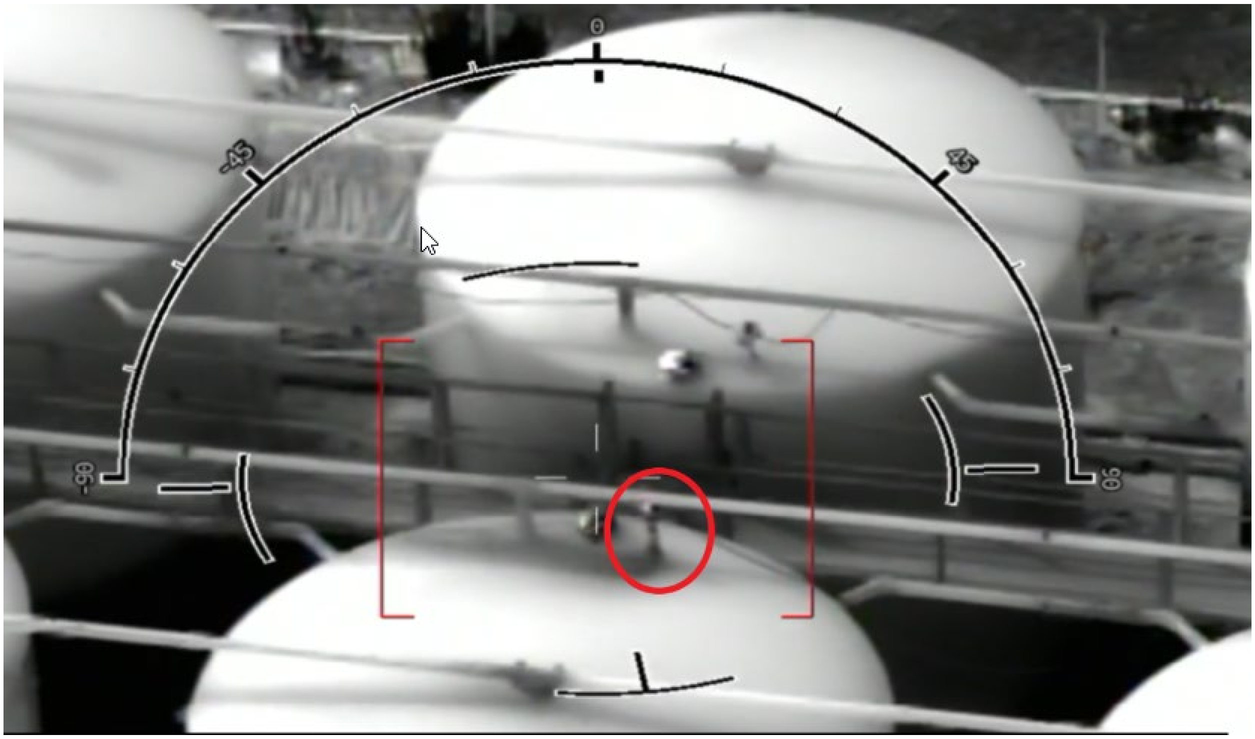
8.6.3 The number of leaks and the leak location for each survey are confirmed by review of the survey videos and data. Additional leaks must be documented and reported if found.

8.6.4 The videos may be edited in the following ways to maximize visibility and utility for the operator:

a) Brightness levels
b) Speed of video
c) Contrast levels
d) Digital zoom levels

8.6.5 While the full, unedited video of surveys is retained, small video clips of leaks ranging in length of 10-60 seconds are generated from the original survey video for the final report to aid the operator in diagnosing and respond to leaks. Images that point out the leaks are generated for the report. See Figure 1 as an example.

Figure 1: Inspection image



8.6.6 The processed videos are uploaded to a secure server. All unedited videos, edited videos, clips, images, note, and data generated are stored for 5 years.

8.7 Final Report

8.7.1 The final report is generated when all videos are processed and uploaded a secure server. The final report is generated either as an .csv, .xslx, or .pdf file. The final report includes:

- *a) Site identifier*
- *b) Latitude and longitude*
- *c) Survey date*
- *d) Survey time*
- *e) Number of leaks found on site*
- *f) Description of leaks on site*
- *g) Link to image of leak with leak circled*
- *h) Video clip of link*

8.7.2 The final report is then emailed to the operator. The operators can choose to download and store their data from the secure server. The final report and associated data are retained for 5 years.

9. Quality Control

Table 3. Quality control acceptance criteria and corrective actions for this method

QA/QC Test or Specification	Acceptance Criteria	Frequency	Corrective Action, if not met
Gimbal freedom of movement	Full range of movement	Daily	If not met, restart the system. If gimbal has limited range of movement that can be compensated by flight adjustments, continue to fly until repair can be performed.
Visual of gas	Visual of test gas with high resolution	Daily	Gas must be seen in daily verification test. If not seen, adjust camera settings like brightness or contrast. If no visual confirmation of gas can be confirmed, restart the camera. If unable to visualize after, camera should be fixed before operation.
Gimbal lock-on operation	Lock on capabilities fully operational	Daily	During first survey pass, confirm lock-on capabilities of gimbal are fully operational. If no leak is spotted on first survey, the operator should target a stationary equipment piece to confirm capabilities.
Visible light camera	Clear visual	Daily	If not met, the operator should check the lens is not obscured and then restart the camera.
Zoom function	The zoom functionality should be operational for all zoom levels	Daily	Zoom levels must provide clear images. To address zoom issues, operator should restart the camera. If zoom functionality still does not work, the survey may still be completed but adjustments made to flight course to ensure image quality.
Data recording	Data is actively recording while in flight	Continuous	Operator must ensure throughout the flight that flight data, videos and images are recorded. If recording is stopped, the operator should restart the recording and check where in the flight plan the recording stopped. If recording functionality is impaired, the data recording systems and instruments should be restarted. If recording cannot be reinstated during flight, surveys cannot continue until the data recording is fully restored.
Data integrity	Data is fully viewable and uncorrupted	Daily	Data must be confirmed to be uploaded to ChampionX servers at the end of day. Data must be spot checked for integrity and that the files are not corrupted during transfer.
Secure equipment	Equipment is secure and there is no movement at connection points.	Daily	If there is movement, check the torque of the connections and ensure they are to manufacturer standards.
Lens inspection	Lens has no blemish or scratches	Daily	Images must be clear. If images are not clear, clean lens and check for scratches.

QA/QC Test or Specification	Acceptance Criteria	Frequency	Corrective Action, if not met
AOGI Technician Training	Training complete	Monthly	AOGI technicians must confirm they have completed their training and retain their ability to perform OGI inspections on the ground as well as AOGI ChampionX training. AOGI technicians may still be in training when performing a survey; however, the technician must be supervised by a trained AOGI technician. Otherwise, if training is not complete, the technician must complete training, or surveys must not begin.
Survey Completion Check	All required equipment has been inspected	Each survey	The AOGI technician must confirm each survey is completed including the required number of sweeps and required equipment groups. If equipment groups were excluded, an additional sweep must be added to the survey.
Pre-flight documentation check	Flight plan includes all facilities for inspection	Daily	The AOGI technician must confirm the facility list for the upcoming flight surveys. If list is incomplete, the flight may begin as the list is updated.
Post-flight documentation	All notes (written or electronic) are uploaded and uncorrupted	Daily	The AOGI technician must confirm any notes (written or electronic) are uploaded and uncorrupted. If notes are missing or incomplete, the AOGI technician must inform the office, and the secondary detection protocol will generate notes from the video and metadata to include on the final report.
Post-Processing Data Review	All data is uncorrupted	Daily	The secondary review protocol must confirm survey data is uncorrupted. The survey must be repeated if the video data is corrupted and unretrievable.
Secondary Inspection Review	All surveys contain the appropriate number of sweeps and equipment groups	Daily	The secondary review protocol must ensure each survey contains the appropriate number of sweeps and all affected equipment groups. If a video of a single survey is missing an equipment group, the affected equipment group must be inspected in a follow-up or the survey repeated. If a survey is found to be missing an adequate number of sweeps, the survey must be repeated with the correct number of sweeps.

10. Calibration and Standardization

10.1 Calibration procedures

10.1.1 The OGI camera must be inspected monthly or when redeployed onto the aircraft and verify calibration is to manufacturer standards, you must inspect and verify calibration of the elements identified in section 10.1.1.1 – 10.1.1.5.

10.1.1.1 Ensure the OGI camera is securely mounted within the gimbal and properly aligned for optimal field of view.
10.1.1.2 Check the camera's focus and zoom settings to calibrate appropriately for the intended inspection objectives and operating conditions.
10.1.1.3 Verify that the camera's lens is clean and free from any obstructions or debris that could affect image quality or gas detection capabilities.
10.1.1.4 If applicable, test the camera's thermal imaging capabilities to ensure accurate detection and visualization of gas emissions.
10.1.1.5 Record calibration data, store data on ChampionX servers, and ensure the calibration falls within manufacturer's specifications.

10.1.2 The gimbal must be inspected monthly or redeployed onto the aircraft and must be verified that calibration is to manufacturer standards, you must inspect and verify calibration of the elements identified in section 10.1.2.1 – 10.1.2.3.

10.1.2.1 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.
10.1.2.2 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.
10.1.2.3 Record calibration data, store data on ChampionX servers and ensure the calibration falls within manufacturer’s specifications.

10.1.3 *Calibration Frequency*: Routine calibration checks must be performed monthly, and at manufacturer’s recommended cadence. This ensures long-term accuracy and reliability. Additional calibration checks must be performed after any significant repairs, software updates, or if any discrepancies are noted during regular operation.

10.2 Standardization: Training Requirements

10.2.1 ChampionX trained AOGI technicians must be a trained thermographer with over 2000 hours of ground OGI survey experience. ChampionX trained AOGI technicians must also be fully trained to perform Appendix K surveys.

10.2.2 The AOGI technician requires over 400 hours of additional flight training, including ground and air training.

10.2.3 The AOGI technician must complete a ChampionX performance review from a trained AOGI technician.

10.2.4 Section 15.3 includes additional information on AOGI technician training and records management.

11. Analytical Procedure

[Reserved]

12. Detection and Alerting

12.1 Detection

12.1.1 *Initial detection:* The detection protocol for this method requires the assessment of a trained AOGI technician to target and video a leak in flight.

12.1.2 *Secondary detection:* The detection protocol for this method requires the follow-up assessment of all videos to confirm any leaks from the initial detection or report any leaks missed by the initial detection protocol. The secondary detection protocol will generate the report providing the following data:

- *a) Site identifier*
- *b) Latitude and longitude*
- *c) Survey date*
- *d) Survey time*
- *e) Number of leaks found on site*
- *f) Description of leaks on site*
- *g) Link to image of leak with leak circled*
- *h) Video clip of link*

12.2 Alerting

12.2.1 The minimum detection limit of this test method is 0.28 kg/hr with a 91% POD rate by the AOGI technician and an increased POD with the secondary detection protocol. The detection limit for this method is valid when operating the AOGI platform at an altitude of 100-250 ft. A valid survey must maintain an altitude between 100-250 ft with no compromising interferences, as outlined in Section 4.

12.2.2 The operating envelope was determined via controlled releases on multiple sites in different environmental conditions, using a third-party entity to evaluate the AOGI platform. The experiment included multiples types of tests: a lower limit “step-down” test to validate the minimum detection threshold for the AOGI based on actual field conditions; a release point test randomly varied the leak rate and location between multiple separate release points to validate the ability to find and determine leaks; a release point test randomly varied the leaks' location between multiple separate release points while the leak rate was held constant to validate the ability to find and determine leaks. No false positives were found.

13. Method Performance

13.1 Testing

13.1.1 This method was evaluated via controlled releases on multiple sites in different environmental conditions, using a third-party entity to evaluate the AOGI platform. The experiment included multiple types of tests detailed in Sections 13.1.1.1 through 13.1.1.3.

> 13.1.1.1 A lower limit “step-down” test to validate the minimum detection threshold for the AOGI based on actual field conditions.

13.1.1.2 A release point test randomly varied the leak rate and location between multiple separate release points to validate the ability to find and determine leaks.

13.1.13. A release point test randomly varied the leaks' location between multiple separate release points while the leak rate was held constant to validate the ability to find and determine leaks.

13.1.2 Each test comprised a series of surveys with the AOGI. This study defines a survey as a leak detection attempt with the AOGI at set release conditions (i.e., leak rate and location). A survey typically included a minimum of two sweeps over the site, per the procedures outlined in this method.

13.1.3 No false positives were found. Over 120 controlled releases with blank testing across multiple days with various gas sources were performed to validate this method’s performance.

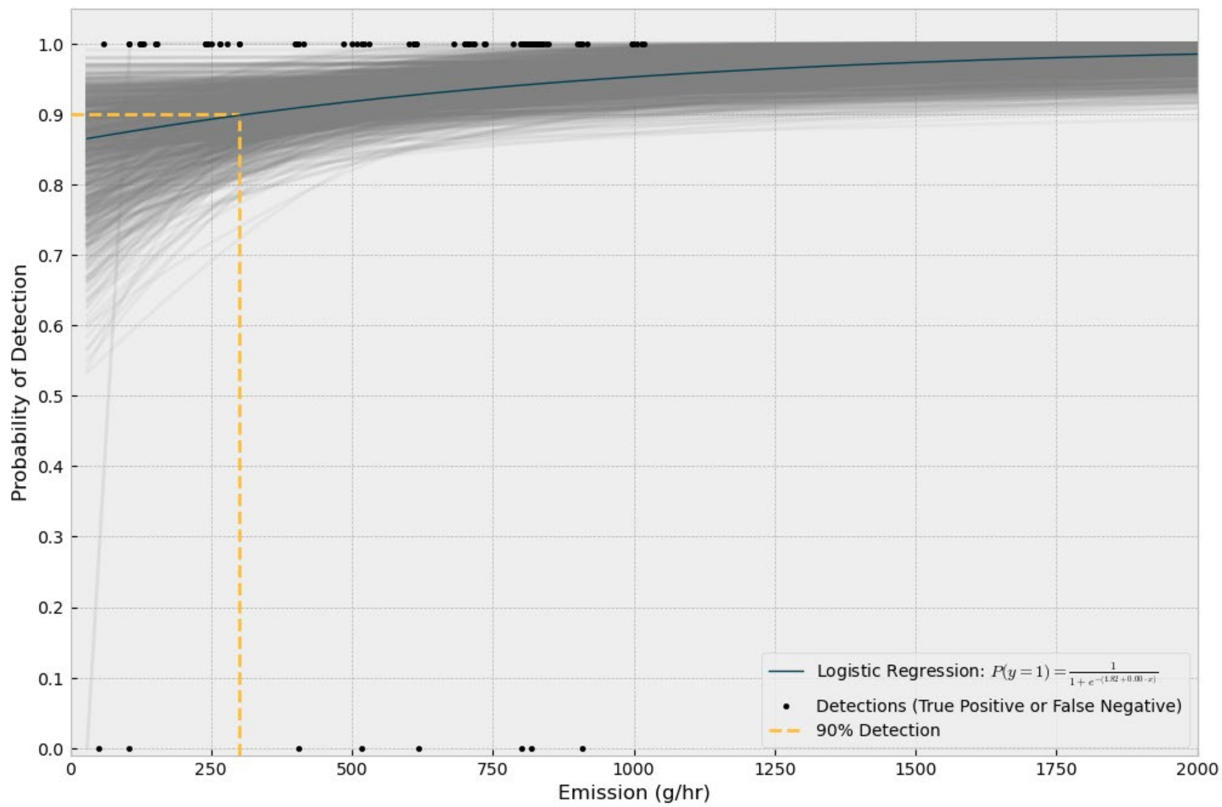
13.1.4 Testing personnel did not have direct communication with the helicopter crew; therefore, confirmation of in-air detections was performed following the test program.

13.1.5 The sites included in the field program were multiple active production facilities and are representative of other production facilities in the region with background emissions and intermittent leaks from facility components. This sites also had other operator's equipment nearby not included in the study. An inventory of the major operational components at the facilities is provided below.

a) Horizontal separators
b) Vertical separators
c) Heater treaters
d) Meter runs
e) Tank batteries comprised of more than 6 tanks
f) Flares
g) Gas lifts

13.1.6 This method’s sensitivity was evaluated to have a 91% POD for leaks at 0.28 kg/hr, 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. See Figure 2 below displaying the POD curve found for the controlled release study that demonstrates the robust and repeatable nature of this method.

Figure 2: POD curve for the controlled release study using this method. A bootstrap logistic regression l method using over 120 data points was used. The lines represent the 500 bootstrap calculations performed. The blue line represents the average of those individual calculations. The yellow dotted lines display the intercept of the 90% POD of the averaged line logistic regression.



13.1.7 Sensitivity can be affected by altitude and meteorological conditions. When performed within the operating envelope, this method will maintain sensitivity requirements needed to perform well below the 1 kg/hr limit as specified by regulation.

13.1.8 Through over 120 controlled release trials, we determined a POD of 91% at the minimum detection limit of 0.28 kg/hr. Repeat measurements showed consistent performance, proving highly robust detection capabilities and performance.

13.1.9 There is minimal systematic bias in this method that is accounted for and significantly reduced through the secondary detection protocol. Given that this method's minimum detection limit of 0.28 kg/hr is well below the strictest regulatory levels, we can conclude systematic bias does not significantly affect this test method.

13.2 Spatial Resolution of Method

The AOGI platform has a component-level spatial resolution and can identify emissions within a radius of 0.5 m of the emission source. The video and following report visual pinpoints the source of the leak from fugitive emission components. The AOGI system provides leak source geolocation data to also pinpoint leaks.

13.3 Detection Limits

The minimum detection level of the AOGI method is 0.28 kg/hr with a 91% POD for in-field detection by a trained AOGI technician. This minimum detection level is enhanced with in-office verification.

13.4 Continuous Monitoring of Performance

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 Prevention

14.1 Helicopter-based

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.

14.2 Ground-based

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 of site supervision, orientations and additional personnel that may need to be on site. 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.[1]

14.3 Aerial inspections

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.

15. Data Management and Recordkeeping

15.1 Inspection Data

The workflow of the inspection data discussed in sections 15.1.1-15.1.5 is summarized in Figure 3.

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

15.1.1 Data is generated by the OGI camera, gimbal and GPS systems and includes geolocation data, helicopter orientation data, camera orientation data, and videos and images produced by the OGI and HD cameras. Data is stored locally on hard disks on the helicopter during the survey. Data includes:

a) Daily verification checks.
b) Identification of the sites surveyed and the survey date.
c) Name of pilot and AOGI technician on flight.
d) Weather conditions every 2 hours including cloud coverage, temperature, and wind speed.
e) Geolocation data for the route taken.
f) Orientation data of helicopter.
g) Orientation data of gimbal.
h) OGI video and images of leaks detected or footage of entire survey.
i) HD video and images.

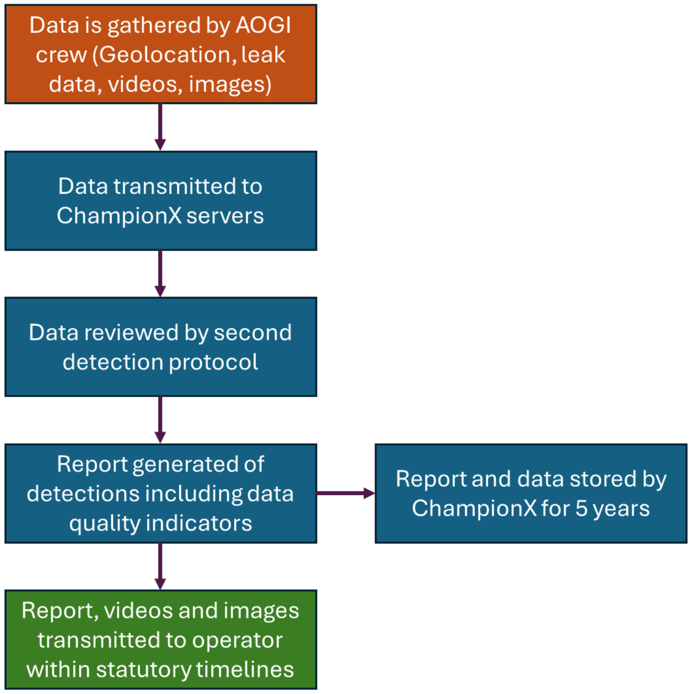
15.1.2 Once the flight is complete, data is transmitted to secure servers. This data is used to generate LDAR reports. Original hard disks are stored for 3 months. Data is checked for corruption after transfer. If data is corrupted, a second upload from the original hard disks must be initiated.

15.1.3 Data is then reviewed during the second detection protocol.

15.1.4 Data is then used to generate a report of detections, and includes data quality indicators such as flight data, geolocation data, video and images of leaks. Data is then moved to long term storage on ChampionX storage as required in §60.5420b(c).

15.1.5 Report, video and images are then transmitted to the operator within statutory timelines.

Figure 3:Inspection data workflow



15.2 Calibration data

15.2.1 Calibration data must be stored in long term storage as required in §60.5420b(c).

15.2.2 The records must be accessible to all AOGI trained technicians.

15.2.3 Records must also be easily accessible for review by the Administrator if requested.

15.3 AOGI technician training data

15.3.1 The training plan for AOGI technicians must be retained for as long as those AOGI technicians are performing surveys, plus 5 years.

15.3.2 Training plans must be easily accessible by AOGI technicians.

15.3.3 Training plans must be easily accessible for review by the Administrator if requested.

15.4 AOGI technician data

15.4.1 The date of completion of initial thermography courses.

15.4.2 The log of ground OGI inspection hours.

15.4.3 The log of AOGI training hours.

15.4.4 The completion data of AOGI training course.

15.4.5 The number and date of all flights where surveys are performed.

15.4.6 The date and results of semiannual audits as required by Appendix K.

15.4.7 The date of the biennial classroom training refresher as required by Appendix K.

16. References

1. Footer, T. U. “Technical Support Document: Optical Gas Imaging Protocol,” 40 CFR Part 60, Appendix K, Revision 5, (2015).

2. Hodgkinson, J. and Tatam, R. “Optical Gas Sensing: A Review”. (2013) Meas. Sci. Technol. 24 012004.

3. U.S. EPA. “Alternative Work Practice to Detect Leaks from Equipment.” 40 CFR Part 60, (2006).

4. U.S. EPA. “Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources Reconsideration.” 2018, 40 CFR Part 60, (2018).

5. 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.

6. “Third Party Validation of an Airborne OGI Camera Pursuant to the EPA Alternative Test Method Rule,” submitted to EPA under CBI, (2024).

17. Tables, Diagrams, and Flow Charts

Figure 4: Example flight path with multiple sites close together.

Figure 5: Example flight path with 3 sweeps.

Appendix

ChampionX AOGI Site Monitoring Plan

Site Name	
Site Coordinates (4 decimals)	
Site Surveyor	**ChampionX**
Site Survey Contact Information	
Alternative Method Being Used	**ChampionX Aerial OGI**
Leak Detection Threshold	**1 kg/hr**
Required frequency	**Quarterly**
Spatial Resolution	**Component-level**
Serial number of equipment used	**Gimbal:** **OGI Camera:** **Helicopter:**
AOGI Pilot	
AOGI Technician	
AOGI Alternative Test Method Procedure Verification	
AOGI Daily Calibrations Verification	
Timeframe for alert (max 5 days)	

If Leak Found and using OGI as Follow up

Follow-up method used	OGI
Manufacturer and model#	
Verification of OGI specifications *(40 CFR 60.5397b(c)(7)(i)(A) & 40 CFR 60.5397b(c)(7)(i)(B)*	
Daily verification check	
Maximum viewing distance	
Maximum wind speed	
Procedure discussion (*including thermal background, how to deal with adverse monitoring conditions*)	
OGI technician	
Manufacturer calibration and maintenance followed	
Fugitive emission components monitored	
Components to be repaired	
Repair date of components *Repair and verification must be completed within 30 days of receiving alert	
Verification of repair *Repair and verification must be completed within 30 days of receiving alert	

If Leak Found and using Method 21 as Follow up

Follow-up method used	Method 21
Manufacturer and model #	
Verification of method 21 equipment specifications *(40 CFR 60.5397b(c)(8)(i))*	
Procedures for calibration reviewed 40 CFR 60.5397b(c)(8)(iii)	
Instrument check (40 CFR 60.5397b(c)(8)(iii)(A))	
Drift assessment (40 CFR 60.5397b(c)(8)(iii)(B))	
Procedure discussion (*including calibration, how survey was conducted, procedure if monitoring yard pipeline*)	
Method 21 technician	
Manufacturer calibration and maintenance followed:	
Fugitive emission components monitored:	
Components to be repaired	
Repair Date of components *Repair and verification must be completed within 30 days of receiving alert	
Verification of repair date *Repair and verification must be completed within 30 days of receiving alert	