Determination of Volatile Organic Compound and Greenhouse Gas Leaks Using Optical Gas Imaging

1.0 Scope and Application

1.1 Analytes.

Analytes	CAS No.
Volatile Organic Compounds (VOCs)	No CAS number assigned.
Methane	74-82-8
Ethane	74-84-0

1.1.1 This protocol is applicable to the detection of VOCs, including hazardous air pollutants (HAPs), and hydrocarbons, such as methane and ethane.

1.2 Scope. This protocol covers surveys of process equipment using Optical Gas Imaging (OGI) cameras in oil and gas upstream and downstream sectors (from production to refining to distribution). The specific component focus for the surveys is determined by the applicable subpart, and can include, but is not limited to, valves, flanges, connectors, pumps, compressors, open-ended lines, pressure relief devices, and seal systems.

1.3 Applicability. This protocol is applicable to all facility types from the upstream and downstream oil and gas sectors and may apply to well heads, compressor stations, boosting stations, petroleum refineries, gas processing plants, and gasoline distribution facilities when referenced by an applicable subpart. This protocol is not applicable to chemical plants or other facility types outside of the oil and gas upstream and downstream sectors. This protocol is intended to help determine the presence and location of leaks and is not currently applicable for use in direct emission rate measurements from sources.

2.0 Summary

2.1 A hand-held, field portable infrared (IR) camera capable of imaging the target gas species is employed to survey process equipment and locate fugitive or leaking gas emissions. By restricting the amount of incoming thermal radiation to a small bandwidth corresponding to a region of interaction for the gas species of interest, the camera provides an image of an invisible gas to the camera operator. The camera type and manufacturer are not stated in this protocol, but the camera used must meet the specifications and performance criteria presented in Section 6. The keys to becoming proficient and maintaining leak detection proficiency using OGI cameras are proper camera operator training with sufficient field experience and conducting OGI surveys frequently throughout the year.

3.0 Definitions

Ambient air temperature means the air temperature in the general location where the OGI survey is being performed.

Applicable subpart means a subpart in 40 CFR part 60, 61, 63, or 65 that requires the monitoring of regulated equipment for fugitive emissions or leaks, for which this protocol is referenced.

Camera Configuration means different ways of setting up an OGI camera that affect the detection capability. Examples of camera configurations that can be changed include the operating mode (*e.g.,* standard versus high sensitivity or enhanced), the lens, the portability (*e.g.,* handheld versus tripod), and the viewer (*e.g.,* OGI camera screen versus an external device like a tablet).

Delta temperature (delta-T or ΔT) means the difference in temperature between the emitted process gas temperature and the surrounding background temperature. It is an acceptable practice in the field to assume that the emitted process gas temperature is equal to the ambient air temperature.

Dwell time means the time required to survey a manageable subsection of a scene in order to provide adequate probability of leak detection. The dwell time is the active time the operator is looking for potential leaks and does not begin until the scene is in focus and steady.

Fugitive emission or leak means any emissions observed using OGI.

Imaging is the process of producing a visual representation of emissions that may otherwise be invisible to the naked eye.

Operating envelope means the range of conditions (*i.e.,* wind speed, delta-T, viewing distance) within which a survey must be conducted to achieve the quality objective.

Optical gas imaging camera means any hand-held, field portable instrumentation that makes visible emissions that may otherwise be invisible to the naked eye.

Persistent leak is any leak that is not intermittent in nature.

Repair means that a component is adjusted, or otherwise altered, to eliminate a leak.

Response factor means the OGI camera's response to a compound of interest relative to a reference compound at a concentration path-length of 10,000 part per million-meter. Response factors can be obtained from peer reviewed articles or may be developed according to procedures approved by the Administrator.

Senior OGI camera operator is a camera operator who has conducted OGI surveys at a minimum of 500 sites over the entirety of their career, including at least 20 sites in the past 12 months, and has completed or developed the classroom camera operator training as defined in Section 10.2.1.

4.0 Interferences

4.1 Interferences from atmospheric conditions can impact the operator's ability to detect gas leaks. It is recommended that conditions involving steam, fog, mist, rain, solar glint, high particulate matter concentrations, and extremely hot backgrounds are avoided for a survey of acceptable quality.

5.0 Safety

5.1 Site Hazards. Prior to applying this protocol in the field, the potential hazards at the survey site should be considered; advance coordination with the site is critical to understand the conditions and applicable safety policies. This protocol does not address all of the safety concerns associated with its use. It is the responsibility of the user of this protocol to establish appropriate health and safety practices and determine the applicability of regulatory limitations prior to implementing this protocol.

5.2 Hazardous Pollutants. Several of the compounds encountered over the course of this protocol may be irritating or corrosive to tissues (*e.g.*, heptane) or may be toxic (*e.g.*, benzene, methyl alcohol). Nearly all are fire hazards. Chemical compounds in gaseous emissions should be determined from process knowledge of the source. Appropriate precautions can be found in reference documents, such as reference 13.1.

6.0 Equipment and Supplies

6.1 An OGI camera meeting the following specifications is required:

6.1.1 The spectral range of infrared radiation measured by the OGI camera must overlap with a major absorption peak for the chemical target of interest, meaning the OGI camera must be sensitive with a response factor of at least 0.25 when compared to the response factor of propane for the majority of constituents (>75 percent) of the expected gaseous emissions composition.

6.1.2 The OGI camera must be capable of detecting (or producing a detectable image of) methane emissions of 17 grams per hour (g/hr) and butane emissions of 18.5 g/hr at a viewing distance of 2 meters and a delta-T of 5 °Celsius (C) in an environment of calm wind conditions around 1 meter per second (m/s) or less.

6.2 The following items are needed for the initial performance verification of the OGI camera:

6.2.1 Methane test gas, chemically pure grade (99.5%) or higher.

6.2.2 Butane test gas, chemically pure grade (99%) or higher.

6.2.3 Release orifice, ¼ inch in diameter.

6.2.4 Mass flow controller or rotameter, capable of controlling the gas emission rate within NIST traceable accuracy of 5 percent.

6.2.5 An industrial fan, capable of adjusting the sustained nominal wind speeds at regular intervals up to 15 m/s, with the ability to maintain a set speed within 20 percent of the target wind speed.

6.2.6 A meteorological station within 1 mile of the location of the testing capable of providing representative data meeting the following minimum specifications at least once every hour:

6.2.6.1 Ambient temperature readings accurate to at least 0.5 °C, with a resolution of 0.1 °C or less, and a minimum range of -20 to 70 °C.

6.2.6.2 Ambient pressure readings accurate to at least 1.5 millibar (mbar), with a resolution of 0.1 mbar or less, and a minimum range of 700 to 1100 mbar.

6.2.6.3 Wind speed readings accurate to at least 0.1 m/s, with a resolution of 0.1 m/s or less, and a minimum range of 0.1 to 20 m/s.

6.2.6.4 Wind direction readings accurate to at least 5 °C, with a resolution of 1 °C or less.

6.2.6.5 Relative humidity readings accurate to at least 2 percent, with a resolution of 0.1 percent or less, and a minimum range of 10 to 90 percent noncondensing.

6.2.7 A temperature-controlled background large enough for viewing the emissions plume and capable of maintaining a uniform temperature. Uniform is defined as all points on the background deviating no more than 1 °C from the average temperature of the background.

6.2.8 T-type probe thermocouple and readout, accurate to at 1 °C, for measuring the test gas at the point of release.

6.2.9 T-type surface skin thermocouple and readout, accurate to at 1 °C, for measuring the background immediately behind the test gas.

6.2.10 Device to measure the distance between the OGI camera and the release point (*e.g.*, tape measure, laser measurement tool), accurate to at least 2 centimeters (cm), with a resolution of at least 1 cm.

7.0 Camera Calibration and Maintenance

7.1 The camera does not require routine calibration for purposes of gas leak detection but may require calibration if it is used for thermography (such as with ΔT determination features).

8.0 Initial Performance Verification and Development of the Operating Envelope

8.1 Determine that the OGI camera meets the specification in Section 6.1. A document demonstrating compliance with this requirement must be retained with other OGI records.

8.2 Field conditions such as the viewing distance to the component to be monitored, wind speed, ambient air temperature, and the background temperature all have the potential to impact the ability of the OGI camera operator to detect the leak. It is important that the OGI camera has been tested under the full range of expected field conditions in which the OGI camera will be used.

8.3 An operating envelope must be established for field use of the OGI camera. The operating envelope must be confirmed for all potential configurations, such as high sensitivity modes, available lenses, and handheld versus tripod. Conversely, separate operating envelopes may be developed for different configurations. If, in addition to or in lieu of the display on the camera itself, an external device (*e.g.*, laptop, tablet) is intended to be used to visualize the leak in the field, the operating envelope must be developed while using the external device. If the external device will not be used at all times, use of the external device is considered a separate configuration, and the operating envelope testing must be performed for both configurations. Imaging must not be performed when the conditions are outside of the developed operating envelope.

8.4 Development of the operating envelope is to be performed using the test gas composition, flow rate, and orifice diameter described in Section 6.1.2, and must include the following variables:

8.4.1 Delta-T, regulated through the use of a temperature-controlled background encompassing approximately 50 percent of the field of view, with no potential for solar interference;

8.4.2 Viewing distance from the OGI camera to the component being imaged; and

8.4.3 Wind speed, controlled through the use of an industrial fan.

8.5 Determine the operating envelope using the following procedure:

8.5.1 Set up the methane test gas at a flow rate of 17 g/hr.

8.5.2 For this flow rate, the ability of the OGI camera to produce an observable image is challenged by ranges of the variables in Sections 8.4.1 through 8.4.3.

8.5.3 A panel of no less than 4 observers who have been trained using the OGI camera and who have a demonstrated capability of detecting gaseous leaks will observe the test gas release for each combination of delta-T, distance, and wind speed. A test emission is determined to be observed when at least 75 percent of the observers (*i.e.*, 3 of the 4 observers) see the image.

8.5.4 Repeat the procedures in Sections 8.5.2 and 8.5.3 using the butane test gas at a flow rate of 18.5 g/hr.

8.5.5 The operating envelope to be used in the field for each OGI camera configuration tested is the more restrictive operating envelope developed between the two test gases.

8.5.6 Repeat the procedures in Sections 8.5.1-8.5.5 for each camera configuration that will be used to conduct surveys in the field.

8.6 The results of the testing to establish the operating envelope, including supporting videos, must be documented and kept with other OGI records.

9.0 Conducting the Monitoring Survey

Each site must have a monitoring plan that describes the procedures for conducting a monitoring survey. At a minimum, the monitoring plan must include the following:

9.1 Prior to imaging, the operator must perform a daily verification check to confirm that the camera is operating properly. This verification must consist of the following at a minimum:

9.1.1 Confirm that the OGI camera software loads successfully and does not display any error messages upon startup;

9.1.2 Confirm that the OGI camera focuses properly at the shortest and longest distances that will be imaged;

9.1.3 Confirm that the OGI camera produces a live IR image using a known emissions source, such as a butane lighter or a propane cylinder;

9.1.4 Confirm that the OGI camera can record data and/or leak footage properly by using the check in Section 9.1.3 as a test run and saving the resulting file with the survey record; and

9.1.5 Confirm that the OGI camera can perform the delta-T check function as expected, if this function will be used meet the requirement in Section 9.2.3.

9.2 The site must develop a procedure for ensuring that the monitoring survey is performed only when conditions in the field are within the operating envelope established in Section 8. This procedure must include the following:

9.2.1 Determination of the camera operator's maximum viewing distance from the surveyed components, based upon wind speed and expected delta-T at the monitoring site. This determination must be made each day a survey is conducted.

9.2.2. Description of how the viewing distance from the surveyed components, the wind speed, and the delta-T will be monitored to ensure that the monitoring survey is conducted within the limits of the operating envelope;

9.2.3 Description of how the operator will ensure an adequate delta-T is present in order to view potential gaseous emissions, *e.g.*, using a delta-T check function built into the features of the OGI camera or using a background temperature reading in the OGI camera field of view;

9.2.4 Description of how the operator will recognize the presence of and deal with potential interferences and/or adverse monitoring conditions, such as steam, fog, mist, rain, solar glint, extremely high concentrations of particulate matter, and hot temperature backgrounds;

9.2.5 Description of how the operator will deal with changes in site conditions during the survey, especially as it relates to the camera operator's maximum viewing distance.

9.3 The site must conduct monitoring surveys using a methodology that ensures that all the regulated components within the unit or area are monitored. This must be achieved using one of the following three approaches. The approach chosen and how the approach will be implemented must be described in the monitoring plan. The use of a component database can help make the survey process more efficient, but, the component database is not a substitute for the approaches described below.

9.3.1 Use of a route map or a map with designated observation locations. The map must be included as part of the monitoring plan, with a predetermined sequence of process unit monitoring (such as directional arrows along the monitoring path) depicted or designated observation locations clearly marked.

9.3.2 Use of visual cues. The facility must develop visual cues (*e.g.*, tags, streamers, or color-coded pipes) to ensure that all regulated components were monitored. The monitoring plan must describe what visual cue method is used and how it will be used to ensure all components are monitored during the survey.

9.3.3 Use of global positioning system (GPS) route tracing. The facility must document the path taken during the survey by capturing GPS coordinates along the survey path, along with date and time stamps. GPS coordinates must be recorded frequently enough to document that all regulated components were monitored. The monitoring plan must describe how often GPS coordinates will be recorded and how the route tracing will ensure all regulated components are monitored.

9.4 The site must develop a procedure that describes how components will be viewed with the OGI camera. In general, a component should be imaged from at least two different angles, and the operator must dwell on each angle for a minimum of 5 seconds before changing the angle, distance, or focus and dwelling again. For a complex scene of components, the operator must divide the scene into manageable subsections and dwell on each angle for a minimum of 5 seconds per component in the field of view (e.g., for a subsection with 5 components, the minimum dwell time would be 25 seconds). The operator may reduce the dwell time for complex scenes based on the monitoring area and number of components in the subsection as prescribed in Table 14-1, provided the manageable subsection for the angle fills greater than half of the field of view of the camera. The procedure must discuss changes, if necessary, to the imaging mode of the OGI camera that are appropriate to ensure that leaks from all regulated components can be imaged.

9.5 The site must have a plan for avoiding camera operator fatigue, as physical, mental, and eye fatigue are concerns with continuous field operation of OGI cameras. The OGI camera operator should not survey continuously for a period of more than 20 minutes without taking a rest break. Taking a rest break between surveys of process units may satisfy this requirement; however, for process units or complex scenes requiring continuous survey periods of more than 20 minutes, the operator must take a break of at least 5 minutes after every 20 minutes of surveying.

Note: If continuous surveying is desired for extended time periods, two camera operators can alternate between surveying and taking breaks.

9.6 The site must have a procedure for documenting monitoring surveys.

9.6.1 For each monitoring survey, record the date and approximate start and end times.

9.6.2 At the start of the survey, when transitioning to the next major process area, and at the end of the survey, record the weather conditions, including ambient temperature, wind speed, relative humidity, and sky conditions.

9.7 The site must have a procedure for documenting fugitive emissions or leaks found during the monitoring survey.

9.7.1 If a leak is found, at a minimum capture a 10-second video clip of the leaking component and keep the video clip with the rest of the OGI survey documentation. The leaking component must be tagged for repair, and the date, time, and location of the leak must be recorded and stored with the OGI survey records. This information can be used to visually assist the operator with locating components that need repair.

9.7.2 If no emissions are found, no recorded footage is required to demonstrate that the component was not leaking.

9.7.3 At least once each monitoring day, each operator must record a quality assurance (QA) verification video that is a minimum of 5 minutes long. The video must document the procedures the operator uses to survey *(e.g.*, dwell times, angles, distances, backgrounds) and the camera configuration.

9.8 The site's monitoring plan must describe the process that will be used to ensure the validity of the monitoring data as detailed in Section 11.

10.0 Camera Operator Training

10.1 The facility or company performing the OGI surveys must have a training plan which ensures and monitors the proficiency of the camera operators. Training should include classroom instruction and field training on the OGI camera and external devices, monitoring techniques, best practices, process knowledge, and other regulatory requirements related to leak detection that are relevant to the facility's OGI monitoring efforts. If the facility does not perform its own OGI monitoring, the facility must ensure that the training plan for the company performing the OGI surveys adheres to this requirement.

10.2 Prior to conducting monitoring surveys, camera operators must complete initial training and demonstrate proficiency with the OGI camera and any external devices to be utilized for detecting a potential leak.

10.2.1 At a minimum, the training plan must include the following classroom training elements as part of the initial training:

10.2.1.1 Key fundamental concepts of the OGI camera technology, such as the types of images the camera is capable of visualizing and the technology basis (theory) behind this capability.

10.2.1.2 Parameters that can affect image detection (*e.g.*, wind speed, temperature, distance, background, and potential interferences).

10.2.1.3 Description of the components to be surveyed and example imagery of the various types of leaks that can be expected.

10.2.1.4 Calibration, operating, and maintenance instructions for the OGI camera used at the facility.

10.2.1.5 Procedures for performing the monitoring survey according to the site monitoring plan, including the daily verification check; how to ensure the monitoring survey is performed only when the conditions in the field are within the established operating envelope; the number of angles a component or set of components should be imaged from; how long to dwell on the scene before changing the angle, distance, and/or focus; how to improve the background visualization; the procedure for ensuring that all regulated components are visualized; required rest breaks; and documenting surveys.

10.2.1.6 Recordkeeping requirements.

10.2.1.7 Common mistakes and best practices.

10.2.1.8 Discussion on the regulatory requirements related to leak detection that are relevant to the facility's OGI monitoring efforts.

10.2.2 At a minimum, the training plan must include the following field training elements as part of the initial training:

10.2.2.1 A minimum of 10 site surveys with OGI where the trainee is observing the techniques and methods of a senior OGI camera operator (see definition in Section 3.0) who reinforces the classroom training elements.

10.2.2.2 A minimum of 40 site surveys with OGI where the trainee performs the initial OGI survey with a senior OGI camera operator verifying the results by conducting a side-by-side comparative survey and provides instruction/correction where necessary.

10.2.2.3 A minimum of 50 site surveys with OGI where the trainee performs the survey independently with the senior OGI camera operator trainer present and the senior OGI camera operator provides oversight and instruction/correction to the trainee where necessary.

10.2.2.4 A final site survey test where the trainee conducts the OGI survey and a senior OGI camera operator follows behind with a second camera to confirm the OGI survey results. The trainee must achieve zero missed persistent leaks relative to the senior OGI camera operator to be considered authorized for independent survey execution.

10.3 All OGI camera operators must attend an annual classroom training refresher. This refresher can be shorter in duration than the initial classroom training but must cover all the salient points necessary to operate the camera (*e.g.*, performing surveys according to the monitoring plan, best practices, discussion of lessons learned throughout the year).

10.4 Performance audits for all OGI camera operators must occur on a quarterly basis with at least one month between two consecutive audits. Performance audits must be conducted according to one of the following procedures:

10.4.1 Performance audit by comparative monitoring. Comparative monitoring in near real-time is where a senior OGI camera operator reviews the performance of the employee being audited by performing an independent monitoring survey.

10.4.1.1 Following the survey conducted by the camera operator being audited, the senior OGI camera operator will conduct a survey of at least 4-hours to ensure that no persistent leaks were missed.

10.4.1.2 If a persistent leak is missed by the camera operator being audited, then the camera operator being audited will need to retrain following the field portion of the initial training outlined in Section 10.2.2. For the retraining, the required number of site surveys with OGI is reduced to 5 full side-by-side comparative surveys in Section 10.2.2.2 and 10 supervised surveys in Section 10.2.2.3 before the audited camera operator must achieve zero missed persistent leaks on the final survey test to be recertified.

10.4.2 Performance audit by video review. The camera operator being audited must submit unedited and uncut video footage of their OGI survey technique to a senior OGI camera operator for review.

10.4.2.1 The videos must contain at least 4 hours of survey footage. If a single survey is less than 4 hours, footage from multiple surveys may be submitted; however, all videos necessary to cover a 4-hour period must be recorded and submitted for review. The senior OGI camera operator will review the survey technique of the camera operator being audited, as well as look for any missed leaks.

10.4.2.3 If the senior OGI camera operator finds any leaks missed by the camera operator being audited or finds that the survey techniques during the video review do not match the monitoring plan required by Section 9, then the camera operator being audited will need to retrain the field portion of the initial training outlined in Section 10.2.2. For retraining, the required number of site surveys with OGI is reduced to 5 full side-by-side comparative surveys in Section 10.2.2.2 and 10 supervised surveys in Section 10.2.2.3 before the audited camera operator must achieve zero missed persistent leaks on the final survey test to be recertified.

10.4.3 If a camera operator is not scheduled to perform an OGI survey during a quarter, then the audit must occur with the next scheduled monitoring survey.

10.5 If an OGI camera operator has not conducted a monitoring survey in over 12 months, then they must repeat the initial training requirements in Section 10.2.

11.0 Quality Assurance and Quality Control

11.1 As part of the facility's monitoring plan, the facility must have a process which ensures the validity of the monitoring data. Examples may include routine review and sign-off of the monitoring data by the camera operator's supervisor, periodic comparative monitoring using a different camera operator as part of a continuing training verification plan described in Section 10, or other due-diligence procedures.

11.2 Daily OGI camera verification must be performed and a brief (5-10 second) video recorded as described in Section 9.1. Additionally, the daily QA verification video for each operator must be recorded as described in Section 9.7.3.

11.3 The following table is a summary of the mandatory QA and quality control (QC) measures in this protocol with the associated frequency and acceptance criteria. All of the QA/QC data must be documented and kept with other OGI records.

Summary Table of QA/QC

Parameter	**QA/QC Specification**	**Acceptance Criteria**	**Frequency**
OGI Camera Design	Spectral bandpass range	Must overlap with major absorption peak of the compound(s) of interest.	Once prior to conducting surveys and any time the compound of interest is expected to change due to process changes.
OGI Camera Design	Initial camera performance verification	Must be capable of detecting (or producing a detectable image of) methane emissions of 17 g/hr and butane emission of 18.5 g/hr at a viewing distance of 2 meters and a delta-T of 5 °C in an environment of calm wind conditions around 1 m/s or less.	Once prior to conducting surveys.

Parameter	QA/QC Specification	Acceptance Criteria	Frequency
Developing the Operating Envelope	Observation confirmation	Leak is observed by 3 out of 4 panel observers for specific combinations of delta-T, distance, and wind speed.	Once prior to conducting surveys and prior to using a new camera configuration.
OGI Camera Functionality	Verification Check	Meet the requirements of Section 9.1 to confirm that the OGI camera software loads successfully and that the camera focuses properly, produces a live IR image, records, and, as applicable, performs the delta-T check function.	Each monitoring day, prior to conducting a survey.
Camera Operator Training	Classroom training	Meet the requirements of Sections 10.2.1 and 10.3 with the issuing of a certificate or record of attendance kept in the employee or OGI records file.	Prior to conducting surveys, with an annual refresher, and after prolonged periods (greater than 12 months) of not performing OGI surveys.
Camera Operator Training	Field training	Meet the requirements of Section 10.2.2 while maintaining the records of facilities visited by the trainee in the employee or OGI records file along with a certificate or record of completion issued upon the achievement of zero missed persistent leaks with the date of the survey recorded.	Prior to conducting surveys and after prolonged periods (greater than 12 months) of not performing OGI surveys.
OGI Camera Operator Performance	QA verification video	Record a video that is a minimum of 5 minutes long that documents the procedures the operator uses to survey *(e.g.*, dwell times, angles, distances, backgrounds) and the camera configuration.	Each monitoring day.
OGI Camera Operator Performance	Quarterly performance audits	Comparative monitoring: No missed persistent leaks over a 4-hour survey as determined by senior OGI camera operator's survey. OR Video review: No missed leaks as determined by senior OGI camera operator and OGI survey technique in submitted videos matches the requirements in Section 9.	Every 3 months, with at least 1 month between consecutive audits.

12.0 Recordkeeping

12.1 The facility must keep the records required by this protocol for a period of 5 years, unless otherwise specified in an applicable subpart.

12.2 The facility must maintain the following records in a manner that is easily accessible to all OGI camera operators:

12.2.1 Complete site monitoring plan with all the required elements;

12.2.2 Initial OGI camera performance verifications;

12.2.3 Camera maintenance and calibration records over the lifetime of the OGI camera; and

12.2.4 The OGI camera operating envelope limitations.

12.3 All data supporting development of the operating envelope.

12.4 The training plan, and for each OGI camera operator, the following records. These may be kept in a separate location for privacy but must be easily accessible to program administrators and available for review if requested by the Administrator:

12.4.1 The date of completion of initial OGI camera operator classroom training;

12.4.2 The date of the passed final site survey test following the initial OGI camera operator field training;

12.4.3 The number and date of all surveys performed, and if the survey is part of initial field training or retraining, notation of whether the survey was performed by observing a senior OGI camera operator, side-by-side with a senior OGI camera operator, or with oversight from a senior OGI camera operator;

12.4.4 The date and results of quarterly performance audits; and

12.4.5 The date of the annual classroom training refresher.

12.5 Monitoring survey results shall be kept in a manner that is accessible to those technicians executing repairs and at a minimum must contain the following:

12.5.1 Daily verification check;

12.5.2 Camera operator's maximum viewing distance for the day, based upon wind speed and expected delta-T at the monitoring site.

12.5.3 Identification of the site surveyed and the survey date and start and end times;

12.5.4 Name of the OGI camera operator performing the survey and identification of the OGI camera used to conduct the survey. The identification of the OGI camera can be the serial number or an assigned name/number labeled on the camera, but it must allow an operator or inspector to tie the camera back to the records associated with the camera (*e.g.*, maintenance, initial performance verification);

12.5.5 Weather conditions, including the ambient temperature, wind speed, relative humidity, and sky conditions, at the start of the survey, when transitioning to the next major process area, and at the end of the survey;

12.5.6 Video footage of any leak detected along with the date, time, and component location;

12.5.7 The daily QA verification video for each operator; and

12.5.8 GPS coordinates for the route taken, if Section 9.3.3 is used to ensure all regulated components are monitored.

13.0 References

13.1 U.S. Department of Health and Human Services. (2010). NIOSH Pocket Guide to Chemical Hazards. NIOSH Publication No. 2010-168c. Also available from https://www.cdc.gov/niosh/docs/2010-168c/default.html.

13.2 U.S. Environmental Protection Agency. (2021). Technical Support Document: Optical Gas Imaging Protocol (40 CFR Part 60, Appendix K).

13.3 U.S. Environmental Protection Agency. (2020). Optical Gas Imaging Stakeholder Input Workshop Presentations and Discussion; Summary Letter Report.

13.4 Zeng, Y., J. Morris, A. Sanders, S. Mutyala, and C. Zeng. (2017). Methods to Determine Response Factors for Infrared Imagers used as Quantitative Measurement Devices. *Journal of the Air & Waste Management Association*, *67*(11), 1180-1191. DOI: 10.1080/10962247.2016.1244130. Available online at: https://doi.org/10.1080/10962247.2016.1244130.

13.5 Zimmerle, D., T. Vaughn, C. Bell, K. Bennett, P. Deshmukh, and E. Thoma. (2020). Detection Limits of Optical Gas Imaging for Natural Gas Leak Detection in Realistic Controlled Conditions. *Environmental Science & Technology*, *54*(18), 11506-11514. DOI: 10.1021/acs.est.0c01285.

14.0 Tables, Diagrams, and Flow Charts

Table 14-1. Dwell Time (in seconds) by Subsection Area and Scene Complexity

	Components in Subsection				
Monitoring Area (m^2)	**2-3**	**4-5**	**5-10**	**10-20**	**>20**
0.125	5	10	15	20	25
0.25	5	15	20	25	30
0.50	10	15	25	30	*
1.0	10	20	30	*	*
>1.0	*	*	*	*	*

* The camera operator must either reduce the subsection volume, the scene complexity, or both by moving closer to the components or changing the viewing angle.

The operator must divide the scene into manageable subsections and image each subsection from at least two different angles. The dwell time for each angle must be a minimum of 5 seconds per component in the field of view. The operator may reduce the dwell time based on the monitoring area and number of components as described in this table, provided the manageable subsection for the angle fills greater than half of the field of view of the camera. The depth of components within the monitoring area must be less than 0.5 meters.