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4 Technology

4.1 Introduction

Methane detection and quantification technologies have been rapidly evolving in recent years. This section describes some of that evolution in a brief historical review of methane detection and quantification, including recent developments and a template against which future developments can be evaluated. Additionally, this section addresses performance criteria of methane detectors, which may be relevant for different applications, and can be used to characterize the accepted and emerging methane detection and quantification technologies according to their capabilities, limitations, costs, and uncertainties.

4.1.1 Brief History of Methane Detection and Quantification Devices

Methane leak detection has been performed since natural gas was first captured and transported by pipelines to customers.

Originally gas was seen only as a byproduct of producing oil in the 19th century, and gas was burned off at the oil field production site. As markets developed for gas, the gas was captured and moved to customers. As a result, keeping the gas in the production system became important since gas was then a saleable product. The original leak detection methods applied were simple “audio, visual, and olfactory” (AVO) techniques, wherein a natural gas systems operator would detect a leak by human observation. In certain conditions, and for certain leak sizes, a person can detect the sound of a leak, the smell of emitted gas, or other visual signals, such as darker deposits left on the equipment near a leak source where heavier condensing components in the gas stream drop out. As pipeline systems grew, AVO techniques were also applied to leak detection for natural gas transmission pipeline routes, where the operator would walk, drive, or fly over the buried pipeline route looking for signs such as dead vegetation or small openings in the ground surface that may indicate a leak area. AVO techniques are still used today, though emission detection devices now are far superior at detecting leaks both for above ground and buried pipeline equipment.

Using AVO for leak or source detection is advantageous since it involves using “tools” readily available at all times; however, there are disadvantages as well. AVO inspection uses human senses as a primary form of detection and identification – audio involves listening for abnormal sounds; visual involves close inspection of components for cracks, deterioration, discoloration, obvious signs of wear, etc.; and olfactory uses sense of smell to identify areas of irregular or strong odors in the process area. The aforementioned detection methods can help with general leak detection but are dependent on other factors such as required training, sensitivity to odor and audible thresholds, and appropriate staffing. AVO is an important component of routine inspections, but there are limitations to using it as a sole method of identification.

Soap bubble identification has also long been used to identify a specific leak location, but is primarily used in conjunction with other methods for leak identification. The soap bubble method is not practical to use in large scale leak surveys as it requires applying a soap bubble solution to a specific location to either confirm or further narrow the identity of a leak. Additionally, this technique requires direct access to the component. As the natural gas systems and pipeline networks grew, so did best practices among natural gas pipeline operators. Often these were then codified by regulatory bodies, so that routine leak detection became a requirement for local distribution systems and transmission pipelines.

Also, after the passage of the Clean Air Act in 1970, emissions from other industries that handle more toxic chemicals became a national focus, leading to the development of fugitive detection techniques, such as USEPA’s Method 21, which defined a technique that identifies all potential leaking components and uses a flame ionization detector (FID) to find hydrocarbons in air around any leaking industry equipment. Though Method 21 was not intended originally for natural gas systems, it did become the standard for leak detection on above ground equipment in other industries and defined a rigorous fugitive emission measurement technique.

USEPA Method 21 was originally developed for the determination of volatile organic compound (VOC) leaks from process equipment using a portable instrument appropriate for the target gas of the process (USEPA 2017b). This method intends to locate and classify leaks only and is not to be used as a direct measure of mass emission rate from individual sources.

Generally, a calibration gas mixture of the target VOC is used to calibrate the instrument for both precision and accuracy of the target gas. An individual then inspects all components (e.g., piping, valves, flanges, pumps, etc.) of the process using the instrument to identify leak sources. Generally, a detected concentration above a certain minimal level defines when a leak requires further mitigation steps. The method provides a quantifiable concentration for a leak source, but is not able provide emission rates, or specifically identify which VOCs are emitting from the leak.

Local distribution companies (LDCs) that bring natural gas to consumer's businesses and households have always had a high need for leak detection simply because of the proximity to the public, and the larger consequences of a leak. They have long used a routine leak detection walk with a sniffer device like an FID to detect any leaks in the buried distribution pipeline system. Today, a much wider variety of detection options are already deployed by LDCs.

Similarly, transmission and storage companies have deployed a variety of detection techniques that have been added to their routine pipeline right of way surveys using AVO. Some of these include cameras that can detect increased methane concentrations from aircraft flyovers. In above ground facilities, such as compressor stations, other leak detection tools have been applied in recent years, such as Optical Gas Imaging (OGI) cameras, a requirement under the 2008 Greenhouse Gas Reporting Program (USEPA 2009).

The upstream was the last segment of the natural gas supply chain to apply leak detection devices. In the past decade, some upstream companies have implemented voluntary leak detection programs using handheld OGI cameras and handheld Tunable Diode Laser Absorption Spectroscopy (TDLAS) devices. In a few states, leak detection and repair programs are now required.

Research advancements led to new detection developments that can be applied to the whole supply chain. Starting in the early 1990s, the importance of greenhouse gas impacts from leaks was given additional political consideration. It became necessary to determine the amount of gas leaked by the natural gas supply chain, which led to the development of national system estimates (i.e., emission inventories), and emissions field measurements. In fact, new measurement techniques were developed, such as the high volume dilution sampler, because of these efforts. The high volume dilution samplers were designed to quantify, rather than just detect, a leak rate. The high volume dilution sampler became a commercial product in the 1990s and remains one of the only devices to directly quantify the rate of a found leak.

Commercial enterprises have also produced new detection techniques, such as the OGI cameras commercially offered beginning in the early 2000s. These handheld cameras provide on-screen visualization of a gas plume that is otherwise invisible to the naked eye. Other commercial products from a variety of sources use multispectral and hyperspectral cameras for plume detection. For ambient air samples, many developments have been made in the past 10 years that have increased the determination's accuracy of the fraction of in-air methane. One example is the cavity ring down system, which has been deployed in many vehicle-based downwind or ambient air studies.

In more recent years, the Obama Administration issued its Climate Change Action Plan and Methane Action Plan, thus adding political goals for methane detection and emission reduction along the entire natural gas supply chain. The industry has also had other motivations as well to show that only a small fraction of gas is emitted so that natural gas would remain the preferred fuel for expansion when considering global warming and greenhouse gas impacts. Research projects were created to develop new detection and quantification techniques, such as the ongoing Methane Observation Networks with Innovative Technology to Obtain Reductions (MONITOR) by the U.S. Department of Energy's Advanced Research Projects Agency – Energy (DOE ARPA-E), and the Methane Detectors Challenge by the Environmental Defense Fund. Both of these efforts had specific goals to produce new technologies that were much less expensive and that could perform continuous monitoring. In addition to sponsored research efforts, development of independent commercial technologies for methane detection and quantification continues by academics and the private sector.

In future years, these research efforts, and the development efforts of independent commercial enterprises, are expected to produce new detection devices and offerings.

4.1.2 Classification Scheme

The classification approach used in this document compares the technologies by primary data type, result type, detection range, specificity to methane/ interference, other benefits, measurement temporal resolution, size, typical deployment method, environmental limitations, calibration procedures, maturity, and miscellaneous. This approach allows existing, commercially-offered technologies to be compared to technologies that are currently being developed, or those that may emerge in the future. These comparison categories are described briefly below.

Primary Data Type and Result Type. Different systems may present data in various formats. Quantitative systems will produce a numerical value such as parts per million (ppm) or a leak rate of grams per hour (g/hr). Qualitative systems may provide data in different formats, such as a video image or a processed image from an OGI camera.

It is important to note that certain methods may use simple quantitative (concentration) data from detectors to calculate or estimate a quantitative (emission) rate. Examples of these are:

- Using simplified inverse dispersion modelling to estimate an emission rate when only quantitative (concentration) data is gathered. The quantitative (concentration) data may be from a single source sample or a distributed network of detectors.
- Using box models over large areas, with measured inlet concentrations into the box and measured outlet concentrations from the box, in order to perform a mass balance, and then calculate the net emission rate inside the box. This is commonly used in some aircraft-based approaches deployed over single sites or much larger geographic areas.
- Measuring downwind concentrations of the gas species being emitted as well as a known release rate of a tracer gas, and then assuming equal dispersion, calculating the estimated release rate of the emitted gas by simple ratio to the tracer gas.

Since this section evaluates the detector, and not the platform, only the result type from the detector will be classified.

Detection Range. Listed from low to high, this represents the typical sensitivity of the technology.

Specificity to Methane and Interference. Discusses whether the detection of methane is focused only on methane or whether it will also produce a result that includes other hydrocarbons (specific vs. non- specific). Additionally, interference by other substances is characterized from high to low.

Other Benefits. Items that might be of interest to the user including whether the technology can detect a large variety of other compounds, distinguish between thermogenic and biogenic, determine requirements for lower power and voltage, and determine high reliability and durability.

Measurement Temporal Resolution. A set time interval during which a detector may produce a discreet result that is, or can be, repeated. Better resolution would mean more frequent readings, whereas poorer temporal resolution would mean less frequent readings. Temporal resolution may not be important for all measurements, especially those that only require a single sample.

Size. Refers to the device size, which has some implications for how it can be deployed. Some of the size categories are: 1) “small” (e.g., small distributed printed card detectors); 2) “handheld,” which would apply to equipment portable by one person, such as the high volume dilution sampler backpack, some of the OGI cameras, or a TDLAS remote methane leak detector (RMLD); and 3) “large,” which would include devices that have to be “vehicle-based” such as some of the larger equipment driven in ground vehicles or airplanes (e.g., the Picarro cavity ring down system).

Typical Deployment Method. Describes the normal means of deployment for the system. Some systems may be deployed in downwind ambient air measurements only, while some may be applied directly at the emission location. Some systems may be deployable in multiple methods. We classify deployment methods in three categories: 1) “walking” for handheld devices; 2) “vehicle path” for satellite, airplane, unmanned aerial vehicle (drone), or vehicle-based systems; or 3) “fixed location”.

Environmental Limitations. Any known limitations for the method listed in text format. This includes atmospheric delta temperature limitations for the OGI camera (i.e., not all days nor all times of day are suitable for measurement) or the need for stable winds to transport plumes to the measurement point.

Calibration Procedures. The required calibrations, the duration, and level of effort required for said calibrations.

Maturity. Technology classification defined as developing, newly available, or mature. Developing is for technology that has undergone testing in the laboratory environment. Newly available is for technology that has undergone field testing and is considered a viable technology for regulatory or industrial use. Mature is technology that is commercial available.

Miscellaneous. Includes notes that may differentiate a system, such as frequent calibration requirements or known high or low service factors for particular systems.

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