



***A Publication for AGA Members***

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# **Considerations for Eliminating Hazardous Leaks and Minimizing Releases of Natural Gas**

**Authored by AGA's Operations Section Regulatory Action Committee  
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## **Background**

On December 27, 2020, the PIPES Act of 2020 was signed into law by President Trump. This bipartisan law is intended to enhance pipeline safety, increase transparency, and refine the existing Pipeline and Hazardous Material Safety Administration (PHMSA) rulemaking process. Among the new requirements and mandates for natural gas pipeline operators included in the PIPES Act is Section 114, which requires natural gas operators to evaluate and update their existing inspection and maintenance plans by December 27, 2021, taking into consideration measures that will eliminate hazardous leaks and minimize releases of natural gas from pipeline facilities<sup>1</sup>. Specifically, Section 114 requires operators to address in their plans:

*... “(D)(ii) eliminating hazardous leaks and minimizing releases of natural gas from pipeline facilities; and “(E) the extent to which the plan addresses the replacement or remediation of pipelines that are known to leak based on the material (including cast iron, unprotected steel, wrought iron, and historic plastics with known issues), design, or past operating and maintenance history of the pipeline.”*

Additionally, an operator’s plan “*must meet the requirements of any regulations promulgated under section 60102(q)*”, which includes a congressional mandate for PHMSA to focus on the use of advanced leak detection strategies in order to further reduce methane emissions<sup>2</sup>. PHMSA has recently begun the process of developing a rulemaking to meet the Congressional mandate contained in Section 113 of the PIPES Act and held a public workshop in May 5-6, 2021. PHMSA currently expects to release a Notice of Proposed Rulemaking by May 2022. Once any rulemaking implementing Section 113 of the PIPES Act is complete, operators will be required to update their plans to meet the new regulatory requirements.

## **Overview**

This paper is intended to serve two purposes. First, it will provide guidance for operators as they review and update as applicable their existing inspection and maintenance plans in accordance with Section 114 of the PIPES Act.

1. **Updating Existing Plans**: outlines considerations and existing procedures or standards that operators may want to update and clarifies existing requirements that eliminate hazards and minimize releases of natural gas.

Second, this paper outlines several leading practices and considerations that may be helpful to operators as they review, and if needed, further develop their Leak Detection and Repair (LDAR) programs in preparation for PHMSA’s pending rulemaking which addresses the requirements within Section 113 of the PIPES Act. It should be noted that while reviewing existing LDAR programs can help identify areas where additional technologies or practices may help minimize the release of gas to the atmosphere, the use of specific technologies or implementation of specific practices is not currently within the scope of Section 114. This paper may be revisited and updated once PHMSA publishes its final rule on Section 113 and provides additional guidance to operators.

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<sup>1</sup> “*Protecting our Infrastructure of Pipelines and Enhancing Safety (PIPES Act) of 2020*”, Division R, SEC. 114. LEAK DETECTION AND REPAIR, Page 2687).

<sup>2</sup> “*Protecting our Infrastructure of Pipelines and Enhancing Safety (PIPES Act) of 2020*”, Division R, SEC. 113. LEAK DETECTION AND REPAIR, Page 2682).

The strategies outlined within this paper are intended to serve as guidance, rather than a comprehensive listing of strategies that an operator should include in their operations and maintenance plans or LDAR programs. Operators may elect to implement all, some, or none of these recommendations based on their own unique system, leak history, and existing requirements already in place in company procedures or state and federal regulations. This paper is not intended to supersede or expand any existing statutory or regulatory requirements, but rather to provide guidance for operators as they review and, as necessary, enhance their existing LDAR programs.

For the purposes of this paper, advanced leak detection technologies are defined as practices or commercially available technologies which expedite leak survey, expedite leak repair, enhance leak detection, quantify methane emissions (either as a flow rate or in rough categories of small, medium and large), accelerate pipeline replacement or repair programs, or otherwise positively impact the LDAR programs. Essentially, this would include any strategies, practices, or commercially available technologies that meet or exceed existing state and federal minimum regulatory requirements and associated guidance. LDAR programs may include advanced leak detection technologies as well as incremental practices an operator may implement such as accelerated pipeline replacement, expedited leak repair, etc.

2. Evaluating supplemental leak detection programs: This will help operators identify within their existing LDAR programs areas where additional measures may be implemented to expand their LDAR program, including considerations for:
  - A. Confirming a comprehensive leak data set.
  - B. Performing a current leak detection technology review.
  - C. Reviewing the quality of data capture.
  - D. Tracking *below ground* leaks and associated repairs.
  - E. Tracking *above ground* leaks and associated repairs.
  - F. Trending leak repair and leak inventories.
  - G. Identifying existing initiatives related to environmental goals
  
3. Evaluating repair and replacement timeframes for leaks which may pose a greater risk to public safety or the environment: Once an operator has reviewed their existing LDAR program, operators should identify what practices and strategies can be enhanced or what new practices and strategies may be implemented including:
  - A. Modifying the frequency of leak survey repairs based on a leak being hazardous to public safety or the environment.
  - B. Performing above-ground non-hazardous leak repairs.
  - C. Continuing to Focus on Damage Prevention and Public Awareness Programs
  - D. Work efficiencies/coordinate work on system to minimize release
  - E. Additional considerations

4. Considerations for using Commercially Available Advanced Leak Detection Technology (ALDT): Operators typically utilize traditional hand-held or vehicle mounted leak detection technologies, in addition to visual vegetation inspections, to perform leak surveys. This paper provides a snapshot of some of the most common commercially available advanced leak technologies. The list is not intended to be a comprehensive list, and provides guidance and considerations for:
  - A. Evaluating conventional and advanced leak detection technologies based on an operator's system and environment
  - B. Evaluating the use and applicability of commercially available leak detection technology
  
5. Continuous Improvement: Operators should periodically review their LDAR programs and strategies and make any necessary updates or adjustments. This paper will discuss how an operator may:
  - A. Review Implemented LDAR Strategies
  - B. Manage and Communicate Changes
  - C. Validate Data Accuracy and Trends

## **1. Updating Existing Plans**

Section 114 (a) and (b) of the PIPES Act of 2020 requires each pipeline operator update their inspection and maintenance plans to contribute to eliminating hazardous leaks and minimizing releases of natural gas from pipeline facilities and that PHMSA and its state partners inspect these plans. Additionally, there are several existing regulatory requirements including: performing periodic leak surveys, implementing corrosion control programs, managing effective damage prevention program, and maintaining gas distribution and transmission system integrity, all of which focus not only on enhancing public safety and reliability, but proactively seeks to prevent leaks from occurring, thereby helping to minimize the release of natural gas into the atmosphere. Furthermore, several operators are proactively participating in voluntary programs such as the EPA Gold STAR Methane Challenge and One Future to minimize emissions (which are addressed later in this document). These other, existing efforts should also be considered and accounted for when operators are evaluating how to comply with the new requirements of Section 114.

On June 10, 2021, PHMSA published Advisory Bulletin ADB-2021-01<sup>3</sup>, outlining its intention to begin performing inspections in 2022 on the adequacy of operators updated plans to meet the intent of Section 114. In the ADB, PHMSA noted that they expect updates to procedures to be detailed and unique to each operator's system.

PHMSA also notes that updates to plans should address the replacement of leak prone pipelines. In 2011, following a string of major natural gas pipeline incidents, DOT, PHMSA, and the States issued a Call to Action<sup>4</sup> to accelerate the repair, rehabilitation, and replacement of the highest-risk pipeline infrastructure. Among other factors PHMSA identified pipeline age and material as significant risk indicators. Pipelines constructed of cast and wrought iron and bare steel, are among those materials that pose the highest risk. In fact, a review of PHMSA's distribution annual report data found that just 21% of distribution operators have cast iron and/or bare steel and that these operators account for a majority of repaired leaks<sup>5</sup>.

Replacing these known leak prone pipelines is not only an effective strategy to reduce the overall system risk but it reduces emissions from a source with a higher potential for leaks.

Natural gas pipeline operators may want to consider the following as they seek to implement the requirements of Section 114:

- *Ensure that your existing inspection and maintenance plan (or equivalent) places an emphasis on minimizing releases of natural gas **and** clarifies that safety is a top priority*
- *Ensure that your existing inspection and maintenance plan (or equivalent) places an emphasis on eliminating hazardous leaks as quickly and as safely as possible*
- *Ensure that your existing emergency response plan (or equivalent) places an emphasis on eliminating hazardous leaks **and** clarifies that safety is a top priority*

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<sup>3</sup> Pipeline Safety: Statutory Mandate To Update Inspection and Maintenance Plans To Address Eliminating Hazardous Leaks and Minimizing Releases of Natural Gas From Pipeline Facilities. 86 Fed. Reg 31002 (June 10, 2021)

<sup>4</sup> [PHMSA Call to Action](#)

<sup>5</sup> Accounts for 95% of corrosion leaks on mains, 92% of natural force leaks on mains, 91% of pipe/weld/joint failure leaks; 97% "other cause" leaks on mains; and 76% of all known leaks.

- *Operators are generally considering the replacement of vintage pipelines as part of their integrity management programs. Operators are encouraged to include leak prone pipelines and review their risk ranking.*

Natural gas pipeline operators may want to consider the following as they seek to implement leak prone pipeline replacement projects:

- *Do factors such as past leak repairs, pipe vintage, pipe material, existing cathodic protection, cold weather, flooding, known incidents, and safety-related conditions or abnormal operating conditions exist? And, if so, do these increase the risk of leak prone pipelines?*
- *Do opportunities exist to leverage regulatory requirements to achieve rate-making commission approval for accelerated pipeline replacement?*
- *Do operators consider strategies to lower pipe replacement costs such as insertion, trenchless construction, expanding higher pressure systems into low pressure areas to reduce pipe size, optimizing project size to achieve economies of scale and lower unit replacement costs (thereby increasing the amount of pipe replaced for a given budget)?*

## **2. Evaluating supplemental leak detection programs**

A review of an operator’s existing LDAR program may be useful in identifying potential opportunities to revise, or expand, their existing LDAR program to address environmental impacts. For example, an operator may identify that above and below ground leaks are tracked or reviewed differently within the company, and operators may consider modifications to comprehensively review all leaks within their system.

Operators are not required to consider all aspects of their LDAR program, nor is the list of considerations below intended to be comprehensive. However, the questions below may be useful for an operator to understand as they are developing supplemental leak detection programs:

- *How are leaks currently identified?*
- *How is leak data captured?*
- *How are leaks currently reported?*
- *How are leaks graded for safety and environmental impacts; and*
- *How is leak monitoring and repair currently trended and tracked?*

Operators are encouraged to document and address any gaps identified through this process prior to considering additional leak repair and detection strategies.

### **A. Confirming a comprehensive leak database.**

Generally, operators have processes to perform scheduled leak surveys and to respond to customer or 3<sup>rd</sup> party leak calls. However, operators may benefit from reviewing their existing documentation processes to ensure that other system leaks, such as those identified during routine work activities, are considered, and reported within a company’s overall LDAR program.

### **B. Performing a Current Leak Detection Technology Review.**

Operators should consider reviewing if leak detection tools are available to all appropriate staff, and if these tools are appropriate for the facilities being inspected, as well as the unique

environment and location of the facility. Additional considerations related to tool selection are provided below in section 4.

**C. Reviewing the Quality of Data Capture.**

Operators should also consider reviewing what type of data they are capturing as part of routine leak surveys, when responding to customer or 3<sup>rd</sup> party leak calls, during routine operations, or when responding to an emergency or incident. The data captured, and potentially the forms and systems where this information is documented, will vary based on operator or system. The main consideration for operators is to ensure that all appropriate data is being captured and reviewed, and that this data is useful in helping an operator drive decisions for enhancing public safety and minimizing the impact of emissions from leaks to the environment.

**D. Tracking below ground leaks and associated repairs.**

Operators are encouraged to better understand their leak profile and use this information to help determine which LDAR strategy or combination of strategies (discussed in section 3 below) may be most effective for an operator to implement. Understanding how quickly leaks are currently repaired, and the feasibility/resource constraints associated with the potential repair of non-hazardous leaks is needed prior to developing and implementing an effective strategy to minimize leaks. Below are some, but not all, questions that an operator may want to consider:

- *Average leak repair timeframes for below ground grade 2 and grade 3 leaks?*
- *How many leaks are repaired vs. reported each year by grade?*
- *How many unrepaired leaks vs reported exist at the end of each year by grade?*
- *What is the level of upcoming replacement of leak prone pipe and how will it impact the existing trend? Are leak repair volumes, backlogs, and reported leaks trending upward or downward<sup>6</sup>?*
- *What is the planned replacement rate of leak prone pipe and how will pipe replacement impact the existing leak per mile trend?*

**E. Tracking above ground leaks and associated repairs.**

Operators are also encouraged to perform a similar review of their existing above ground leaks. In addition to determining average leak repair timeframes based on leak grade, a company may want to consider a review of existing work practices around pairing of leak repairs with other scheduled work.

*Example: If an operator is performing a turn-on order or any other type of work at a customer premise, providing any open leaks that may be mitigated on the meter set (if an employee or contractor is qualified to perform that work) would allow for synergies.*

**F. Trending leak repair and leak Inventories.**

For operators to identify and demonstrate that their current leak repair programs are minimizing leaks, it is important for operators to accurately track current leak metrics. The principal question to consider here is the quality of current tracking mechanisms within the company and understand how frequently this information is gathered and reviewed. Examples

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<sup>6</sup> Note that advanced leak technology may result in an increase of reported leaks.

of information that operators may want to consider reviewing to help identify potential trends include:

- *Number of repaired leaks*
- *Estimated volume of natural gas savings from repairing leaks*
- *Number of unrepaired leaks*
- *Estimated volume of natural gas released from unrepaired leaks*
- *Location of leaks*
- *Reported leaks*
- *Aging of leaks*

Once this data is collected, operators may consider validating if these reports include all leaks identified and repaired. Lastly, while not related directly to trending leaks, increased visibility from senior leadership could help promote better tracking and provide an urgency to ensure leaks are being repaired quickly. Some operators may also opt to implement targets and goals around the closeout of open leaks.

#### **G. Identifying Existing Initiatives Related to Environmental Goals**

It is also important to note that several AGA member companies actively participate in the Environmental Protection Agency's (EPA) Methane Challenge program and the One Future program. These voluntary programs provide an opportunity for operators to commit to implementing Best Management Practices identified by the EPA to reduce methane emissions. In addition to these voluntary programs, operators are encouraged to communicate and document enhancements to their LDAR programs which may already be in place or underway as part of the EPA or other voluntary emission reduction programs.<sup>7</sup>

### **3. Evaluating repair and replacement timeframes for leaks which may pose a greater risk to public safety and the environment**

Having a greater understanding of its own leak profile allows an operator to better identify which LDAR strategy or strategies are best suited to meet the intent of Section 113 to further reduce methane emissions on their systems.

Of note, some of these strategies may already be part of an operator's existing LDAR program and may be captured as part of other ongoing initiatives.

Operators may want to consider one or more of the following strategies to enhance their LDAR program. In determining which strategies are most effective, operators should:

- *Ensure public and operator personnel safety remains a top priority<sup>8</sup>;*
- *Focus on known contributors to emissions or leaks within an operator's system;*

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<sup>7</sup> [EPA's Voluntary Methane Programs for the Oil and Natural Gas Industry](#)

<sup>8</sup> Maintaining public and pipeline safety should always be a top priority. Consideration of environmental impacts, while also of utmost importance, should never trump public and pipeline safety. In many cases the two may be able to be addressed hand in hand. However, a release of natural gas may be necessary to quickly mitigate an immediate hazard. Examples include having to allow relief valves to blow during regulator failures or allowing damaged pipelines to safely vent to atmosphere following an excavation damage.

- Consider existing environmental or regional constraints which may reduce the efficacy of a strategy, technology, or method;
- Evaluate the impact to existing resources and staffing; and
- Consider impact to current rates and/or rate base

**A. Modifying the frequency of leak survey or repairs based on a leak being hazardous to public safety or the environment.**

The principal benefit of this strategy is that it decreases how long a leak releases natural gas to the atmosphere before being detected or repaired. This could include, as appropriate:

- I. Performing more frequent leak surveys to potentially help detect leaks earlier.
- II. Performing supplemental leak surveys of pipelines with a higher potential to leak.
- III. Accelerating repair timeframes for leaks which are not hazardous to pipeline safety (i.e., Grade 2 and Grade 3 leaks), but, based on the estimated volume of natural gas released to the atmosphere over a period of time, may be hazardous to the environment. In an attempt to prioritize repair of environmentally hazardous leaks, operators should consider implementing a method, as defined by operator, for estimating the flow rate of each leak, and help to correctly identify which leaks result in larger emissions.
- IV. Utilizing recently developed leak detection technologies that would potentially help improve an operator's ability to quickly gather larger leak indication data. These technologies, and others under development, may provide more accurate measurements of the concentration of natural gas released from leaks. Some of these technologies are outlined below (section 4). The potential limitations for new technologies should also be considered.
- V. Utilizing enhanced leak repair technologies to help offset the incremental cost of repairing additional leak categories. This might include:
  1. Pipe lining methods
  2. Keyhole repair methods
  3. Robotic tools to facilitate a repair from within a pipeline

*Potential Considerations:*

- Can changes, to leak repair and survey frequencies or other mitigation activities, be implemented in higher-risk locations, as determined by an operator's existing Risk Model?
- Can field personnel who are already performing other tasks also perform leak mitigation activities or gather leak data? Considerations to how training and availability of resources may impact changing roles should be reviewed.
- Review of pipeline and appurtenances to identify where robotic tools can facilitate repairs.
- Can alternate technologies provide indications for larger emitters within the pipeline system?
- Can data be gathered to develop a system-specific analysis of emissions?

**B. Performing Above-ground repairs.**

Repairing above ground facilities by tightening threaded joints or lubricating seals, such as service cocks, valves, compressor seals and flanges, can provide an effective means to help quickly eliminate certain leaks. Typically, these repairs do not interrupt gas service or require extensive excavation and can be an effective strategy to help reduce system emissions. Facilities with above ground components include, but are not limited to:

- I. Regulating stations;
- II. Compressor stations;
- III. Valve assemblies; and
- IV. Customer meter/regulator sets.

*Potential Considerations:*

- *How close is the equipment or the leak to structures?*
- *Is the equipment or leak located inside?*
- *Has your system identified certain components as likely to leak? If so, where are those components in your system, and how frequently are they being surveyed for leaks?*
- *Can field personnel who are already performing alternate work activities also perform leak mitigation activities or gather leak data?*
- *Can work be performed without interrupting service?*
- *How complex is the repair or mitigation?*

**C. Continuing to focus on Damage Prevention and Public Awareness Programs**

Excavation damages continue to be a leading cause of pipeline incidents and are a significant contributing factor for natural gas incidents<sup>9</sup>. It should be noted that in addition to potentially strengthening targeted outreach, operators also need help from state authorities to actively enforce One Call Laws on excavators who fail to notify 811 or fail to follow safe excavation practices, such as hand-digging around underground utilities.

*Potential Considerations*

- *Review number of incorrect locates and consider performing an analysis to revise errors.*
- *Review locating procedures to see if any revisions are needed to the existing procedure or process*
- *Review mapping errors and identify if additional resources are needed to update the accuracy of maps*
- *Review excavation damage and discuss if additional pipeline and facilities marking is needed*
- *Review excavation damage trends and discuss if additional outreach needs to be broadened to include additional stakeholders*
- *Review excavation damage and discuss if additional training of personnel or contractors is needed*
- *Review and as needed update messaging*
- *Review how information is being communicated (mail, electronic, bill inserts, radio, etc) and expand if needed*

**D. Work efficiencies/coordinate work on system to minimize release**

Operators are encouraged to review upcoming routine or planned work activities performed by others to identify if there are existing non-hazardous leak repairs or pipeline replacement which may be included in the work plan. In addition to reducing the time that a leak remains open,

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<sup>9</sup> [PHMSA's National Pipeline Performance Measures. Excavation Damage Data – Incidents, Leaks, and Damages Caused by Excavation Damage](#)

other work efficiencies include reducing system outage times to perform work, reducing cost to perform an open trench excavation, and enhancing the overall integrity of the pipeline.

*Considerations:*

*-Existing programs or planned work activities? Including meter replacement programs, retrofits for inline inspection, corrosion remediation projects, station maintenance, or other proactive maintenance measures, etc.*

*-Is there planned work by the city, state, or other utilities?*

**E. Additional considerations**

When pipelines are replaced or work requires a cut out, consideration should also be made regarding intentional vented emissions from pipeline facilities upon blowing down and returning a pipeline to service<sup>10</sup>. Also, reducing of intentional release of gas should focus on releases that do not compromise safety.

Operators may consider accelerating their current infrastructure replacement programs and remediation work to both eliminate pipeline safety hazards and help minimize environmental impacts due to releases of natural gas into the atmosphere. Operators are strongly encouraged to discuss leak repair and pipeline replacement programs with their respective state regulating agency, as applicable, to ensure operators' programs align with state emissions goals and targets and expectations for cost recovery if state agencies have such goals and targets.

*Potential Considerations:*

*-Utilizing blowdown compressors*

*-Flaring gas to reduce CO<sub>2</sub>e emissions*

*-Re-routing the gas within the system before blowdown or capturing vented gas and putting it back into the pipeline, while considering safety and operational feasibility.*

*-Drawing down pressure into an adjacent lower-pressure system through a permanent or temporary regulator station.*

*- Adding valves or stopple fittings to reduce the volume of venting for future repairs*

*-Lower operating pressure to reduce leakage rates until repair or replacement can be completed. The reduction of operating pressure should be balanced with seasonal demand.*

*-Using a CGI to check natural gas concentrations when purging natural gas into new lines to limit natural gas release while still obtaining 100% gas in air mixture within the pipe*

**4. Considerations for using Commercially Available Advanced Leak Detection Technology (ALDT):**

**A. Evaluating conventional and advanced leak detection technologies based on an operator's system and environment**

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<sup>10</sup> AGA Technical White Paper ["Blowdown Emission Reduction White Paper"](#)

There are multiple factors such as leak source, surrounding environment, and available information that could influence the selection of leak detection technology.<sup>11</sup>

Vehicle-mounted and aerial technologies offer high area coverage and can be used to generate localized maps of source locations. The aerial methods especially have the advantage of surveying areas that might be difficult for land vehicles or on-foot, and these advantages should be considered by operators as they assess the efficacy of ALDT's. Any leak indications must be verified using a traditional walking survey.

#### **B. Evaluating the Use and Applicability of Commercially Available Leak Detection Technology**

Detection and sensor technologies leverage unique chemical and physical properties to quantify the chemical organic compound of interest. Examples of sensor types include catalytic, thermal, electrochemical, and optical - each having associated advantages and disadvantages. Methane sensors for the gas industry have seen a directed growth towards optical sensors due to their reliability and flexibility in open and closed path applications. These optical methods utilize methane's ability to absorb a specific band of infrared light to detect or quantify the concentration of methane in a sample. These can further be distinguished by their detection methodology. The most prevalent infrared-optical detection methods for methane are Tunable Diode Laser Absorption Spectroscopy (TDLAS), Interference Polarization Spectroscopy, Cavity Ring Down Spectroscopy (CRDS), and Differential Absorption LiDAR (DIAL).

The table below summarizes some potential advantages and disadvantages of different technologies. The table is not intended to be a comprehensive list of all commercially available technologies but is rather intended to provide an overview of some technologies and some of the considerations an operator may take into account. AGA does not endorse any specific technology, or technology provider.

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<sup>11</sup> PHMSA Pipeline Leak Detection, Leak Repair, and Methane Emission Reductions Public Meeting. May 5, 2021. Transcript. Pg. 304-305. Dr. Smits "...key for leak detection is understanding the environmental conditions in which the leak detection is being performed. And I've done quite a bit of research on this and demonstrated how emissions are widely affected by both above and below ground conditions. And these effects should be incorporated into the deployment method. And by not including such information, it can potentially lead to misclassification of leaks.

Technology	Detection Method	Open/ Closed Path	Current Application
Tunable Diode Laser Absorption Spectroscopy (TDLAS)	A tunable laser diode is set to the methane absorption wavelength. The light sensor measures the reduction in light intensity to correlate methane concentration. <sup>12</sup>	Open	Handheld detectors, stationary detectors, drone-mounted aerial surveys <sup>13</sup>
Interference Polarization Spectroscopy	A tunable interference polarization filter splits a single laser beam into two polarized beams. These create an interference fringe pattern on the sensor surface. The presence of gaseous species introduces a birefringence to the signal. The signal is analyzed to determine the concentration of gaseous medium. <sup>14</sup>	Closed	Handheld pumped-based detector, road vehicle-mounted <sup>15</sup>
Cavity Ring Down Spectroscopy (CRDS)/ Off-Axis Integrated Cavity Output (OA-ICOS)	An infrared diode laser set to the methane absorption wavelength is reflected within a mirror detection chamber to increase the laser's effective path length. The amount of time (ringdown time) for the laser to dissipate is used to determine the concentration of the gaseous medium. <sup>16</sup> Off-Axis Integrated Cavity Output (OA-ICOS) utilizes a similar detection method as does CRDS but uses a different alignment of the optics within the instrument. <sup>17</sup>	Closed	Vehicle-mounted CRDS Systems, UAV, aircraft-mounted <sup>18, 19, 20</sup>
Differential Absorption LiDAR (DIAL)	A tunable laser diode emits two wavelengths: one centered on the methane absorption band and another in a low absorption band. The DIAL system compares the absorption of the two wavelengths to correlate methane concentration. <sup>21, 22</sup>	Open	Helicopter-mounted systems <sup>23</sup>

## 5. Continuous Improvement

### A. Review Implemented LDAR Strategies

Operators should consider periodically reviewing the effectiveness of their LDAR programs and consider making changes, where needed, to keep pace with new technologies or work practices,

<sup>12</sup> [2020 Natural Gas Leak Abatement Plan, SoCalGas, September 2020 \(Amended\)](#)

<sup>13</sup> [Aerial-based gas tomography – from single beams to complex gas distributions](#), European Journal of Remote Sensing, Volume 52, 2019

<sup>14</sup> [Mid-Infrared Polarization Spectroscopy Measurements of Species Concentrations and Temperature in a Low-Pressure Flame](#), Applied Spectroscopy, 2019, Vol. 73(6) 653-664

<sup>15</sup> [Leak Detection Body of Knowledge – Recommended Practice](#), Gas Technology Institute, January 29, 2021

<sup>16</sup> [Infrared Spectroscopy with a Cavity Ring-Down Spectrometer](#), Army Research Laboratory, August 2014 (available at: <https://apps.dtic.mil/dtic/tr/fulltext/u2/a608710.pdf>)

<sup>17</sup> [Enhancing off-axis integrated cavity output spectroscopy \(OA-ICOS\) with radio frequency white noise for gas sensing](#), OSA Publishing, Optics Express, Volume 27, Issue 21, Page 30517, OSA, 2019

<sup>18</sup> [Cavity Ring-Down Methane Sensor for Small Unmanned Aerial Systems](#), Sensors for Unmanned Aircraft Systems and Related Technologies, MDPI, January 14, 2020

<sup>19</sup> [Open-path cavity ring-down methane sensor for mobile monitoring of natural gas emissions](#), Optics Express, Vol. 27, Issue 14, pp. 20084-20097, OSA, 2019

<sup>20</sup> [Sampling of Methane Emissions Detection Technologies and Practices for Natural Gas Distribution Infrastructure](#), NARUC,

<sup>21</sup> [Methane Abatement Best Practices Compliance Plan](#), PG&E Presentation, April 19, 2018

<sup>22</sup> [Differential absorption LIDAR for the detection and quantification of greenhouse gases](#), NIST, April 2021

<sup>23</sup> [Performance evaluation of a 1.6- \$\mu\$ m methane DIAL system from ground, aircraft and UAV platforms](#), Optics Express, Vol. 25, Issue 25, pp. 30415-30432, OSA, 2013

improved equipment, revised internal procedures, or conditions that would affect a given LDAR technology or process.

Factors an operator may want to consider as part of reviewing their LDAR program include:

1. Effectiveness of an operator's leak-prone pipe and fitting replacement program. This would include reviewing leak trends and leak-prone pipe inventory.
2. Effectiveness and sensitivity of the equipment and tools used to detect leaks on both an LEL and PPM of methane basis.
3. Potential use of enhanced technology to target larger emissions along their pipeline systems.
4. Lessons learned from external events relating to leak detection and repair.
5. New regulations, orders, or advisories related to LDAR programs.

#### **B. Manage and Communicate Change**

Program changes should be incorporated into LDAR procedures and communicated internally to affected parts of the organization using a management of change process. External communications on measures to enhance an operators LDAR program to reduce natural gas emissions and protect the environment should also be considered, where appropriate. As part of their management of change processes, operators are encouraged to think about how to communicate (customer bill inserts, social media, website, internal documents, etc.) and whom to communicate with (regulators, local officials, customers, employees, etc.). Communications may include parties such as pipeline safety regulators, customers, and any relevant governing agencies, as defined by the operator.

Significant decisions, as defined by the operator, to modify an operator's current LDAR program should be documented and readily accessible to be available for review by regulators. Some details to consider within this documentation would include the reason for the change, expected benefits, effective dates, and timelines. These changes should be documented and communicated in a manner which is consistent with an operator's existing pipeline safety management system, or management of change process.

#### **C. Validate Data Accuracy and Trends**

Once final, PHMSA's pending regulations are anticipated to provide guidance on tools, technologies, and methods to minimize releases of natural gas. Although releases are reported using industry approved emission factors, calculations and methods, new data, the use of more accurate technologies, or industry benchmarking may affect or impact the validity of previous emissions calculations. Operators are encouraged to review system specific data and raise any gaps or discrepancies with the industry, as well as state and federal regulators.