METHANE
GUIDING
PRINCIPLES

REDUCING METHANE EMISSIONS

Best Practice Guide: Equipment Leaks

January 2024

Contents:

Disclaimer

This document has been developed by the Methane Guiding Principles partnership. The Guide provides a summary of current known mitigations, costs, and available technologies as at the date of publication, but these may change or improve over time. The information included is accurate to the best of the authors' knowledge, but does not necessarily reflect the views or positions of all Signatories to or Supporting Organisations of the Methane Guiding Principles partnership, and readers will need to make their own evaluation of the information provided. No warranty is given to readers concerning the completeness or accuracy of the information included in this Guide by SLR International Corporation and its contractors, the Methane Guiding Principles partnership or its Signatories or Supporting Organisations.

This Guide describes actions that an organisation can take to help manage methane emissions. Any actions or recommendations are not mandatory; they are simply one effective way to help manage methane emissions. Other approaches might be as effective, or more effective in a particular situation. What readers choose to do will often depend on the circumstances, the specific risks under management and the applicable legal regime.

Summary

This guide covers unintentional leaks from pressurized equipment used in the oil and gas industry. This document refers to these leaks as 'fugitive leaks'. Other emissions from equipment designed to vent are covered in the best-practice document 4 'Reducing methane emissions from venting'.

Fugitive emissions are usually caused by imperfections or ordinary wear in sealed joints such as flange gaskets, screwed connections, valve-stem packing, or by poorly seated valves. Improper installation can cause leaks, but leaks most commonly result from ordinary wear or stress that damages the sealed surface over time. Leaks can also come from the wall of a pressurized vessel or pipeline, as a result of corrosion or damage.

This guide addresses the sources of leaks and the mitigation strategies that can be used to detect and repair leaks, so reducing emissions from fugitive leaks. The general mitigation strategies are listed below.

It is important to note that best practice to minimize fugitive leaks is covered by several best-practice guides. Leaks can be minimized:

- by design and operation (see Design guide);
- by detecting leaks (as covered in this guide);
- through repairs (as covered by this guide and the Operational Repairs guide); and
- through management systems (see the Continual Improvement guide).

Best practice for reducing methane emissions from fugitive leaks

Keep an accurate inventory of emissions from equipment leaks

Complete Preventative Maintenance to prevent equipment leaks

Conduct periodic leak detection and repair (LDAR) on all facilities above ground, to identify and repair leaks

Conduct periodic LDAR on all pipelines below ground, to identify and repair leaks

Use 'focused' or 'alternative' programs such as:

- **directed inspection and maintenance (DI&M), which is a focused program; and**
- **comprehensive monitoring programs, which are alternative programs, some of which are still being developed**

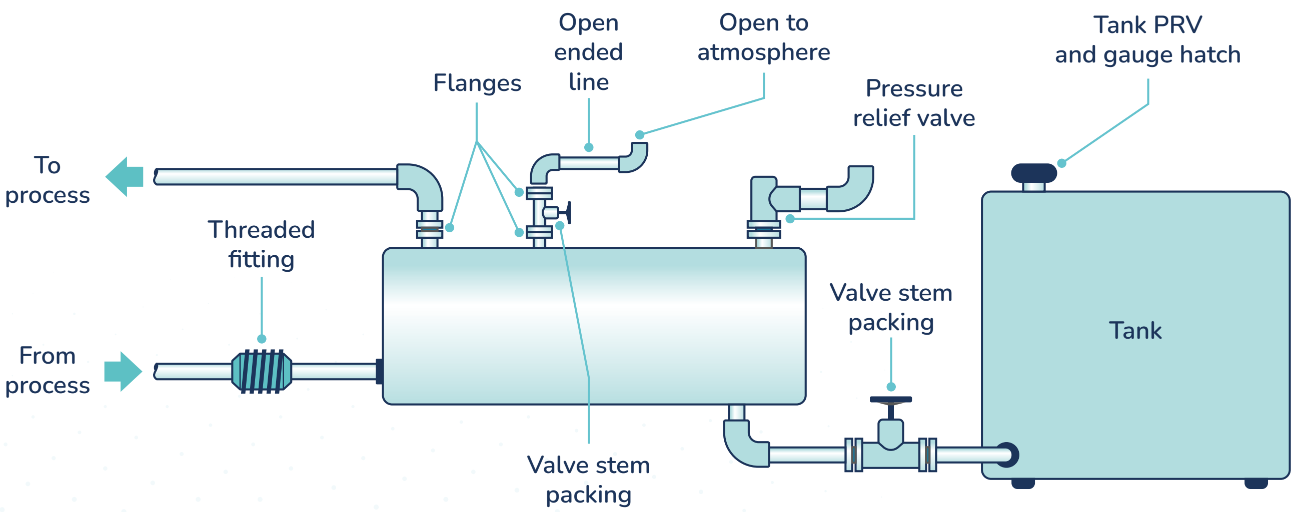
Replace or remove the need for components that persistently leak

Introduction

Unintentional leaks from pressurized equipment used in the oil and gas industry (fugitive leaks) can lead to gas being released into the atmosphere. A fugitive leak is defined as 'a loss of process fluid to the environment past a seal, threaded or mechanical connection, cover, valve seat, flaw or minor damage point on equipment components in hydrocarbon service'.

Figure 1 below shows where fugitive leaks might come from in an example piece of equipment.

Figure 1: Example sources of fugitive leaks



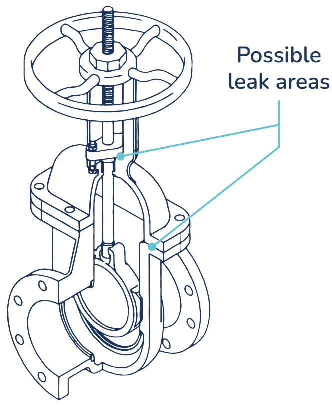
Most oil and gas sites have thousands of individual components that could be the source of fugitive leaks. While only a small percentage of those components leak, cumulatively this represents a potentially significant source of methane emissions.

Although individual fugitive leaks tend to be small, the total of all fugitive leaks is understood to be a key source of emissions. In the United States, the total annual emission of methane through fugitive leaks is estimated by the US Environmental Protection Agency (EPA) to be 16% of all methane emissions from Petroleum and Natural Gas Systems[1,2]. Similar estimates have been developed in other jurisdictions, such as Canada, where equipment is similar[3].

Common components where fugitive leaks can occur are shown below in Table 1. Note that compress seals are not covered by this document. For information about compress seals please see the Venting Guide.

Table 1: Common components

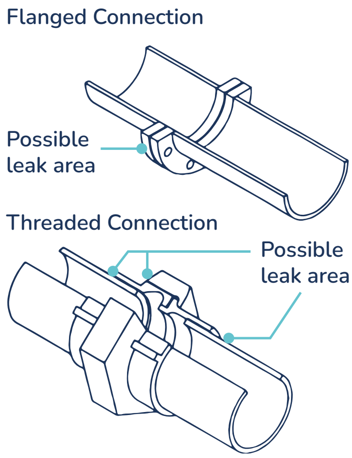
<table>
<tr><th>Component and leak location</th><th>Description</th><th>Diagram</th></tr>
<tr><td>Valves</td><td>
Leaks result from:

- normal wear;
- valve packing or rings being broken or failing; or
- a ruptured diaphragm on a control valve.
</td><td>


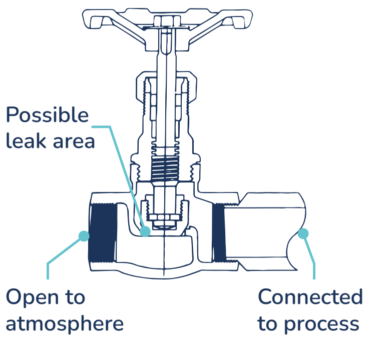
</td></tr>
<tr><td>Connectors and flanges</td><td>
Leaks from flanges are usually caused by:

- the gasket between two bolted flanges failing; or
- misalignment of two mating pipe sections.

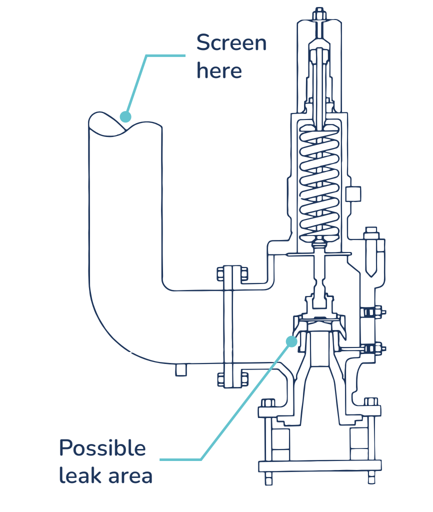
For screwed connectors, leaks may occur at the threaded connection.

(Note: the threaded connection shown is a union, which is a type of threaded connector.)
</td><td>


</td></tr>
<tr><td>Open-ended lines (OELs)</td><td>
OELs are shut-off valves that are normally closed, but when open they will vent gas directly to the atmosphere.

Leaks can be caused by wear or debris in the valve seat, or inadequate tightening of the closed valve.
</td><td>


</td></tr>
</table>

Component and leak location	Description	Diagram
Pressure relief valves (PRVs)	PRVs are usually spring-loaded safety valves, routed to the atmosphere, designed to release gas when a certain pressure is reached, so that equipment is not overpressured. Leaks can occur if the PRV's valve plug is not seated properly, if the seat seal is worn or if there is debris at the seal. Leaks can also occur from "seat simmering" when the process is operated too close to the lift pressure.	
PRVs that are gauge hatches (also called thief hatches)	Hatches can be a source of emissions when they are open or not closed properly, or when the safety device built into the hatch fails to reseal after opening. A failure to seal properly may be caused by a faulty gasket or an inappropriate set point.	
Wall of the vessel, tank or pipe	Leaks can occur as a result of corrosion or impact damage. In some cases, for older distribution pipelines underground, a leak may come from a joint or buried connection but still be considered a pipeline leak.	

Diagrams in Table 1 are based upon 'Methane Emissions from the Natural Gas Industry, Volume 8: Equipment Leaks', Gas Research Institute, US Environmental Protection Agency, June 1996[4]. Photo credit for tank hatch from HY-BON/EDI, a Cimarron Energy company.

Quantifying emissions from fugitive leaks

There are several ways of quantifying emissions from fugitive leaks. The OGMP 2.0 Leaks Guide[3] has guidance on how to quantify emissions from leaks under its program. Quantification methods for methane emissions deliver a rate, such as mass per time (e.g. kilograms per hour) or volume per time (e.g. standard cubic meters per hour), and can be produced by engineering estimations, by direct measurement of the methane sources, or by use of models. The approaches below are listed in order from the least accurate method to the most accurate method.

1. Quantify by site population – based on the number of sites and the typical emission rate from that type of site.

2. Quantify by equipment population – based on the number of a type of major equipment and the typical emission rate from that type of equipment.

3. Quantify by component:
   - Quantify by component count/populations – multiplying the number of components by the average emission rate per component.
   - Quantify by screening – if screening to detect leaks has been carried out, components may be sorted into 'leak' and 'no leak' categories, and the number in those categories is multiplied by the appropriate emission factor.
   - Quantify by direct measurement of leaks – all detected leaks on a site are measured for emission rate to produce the most accurate estimate for emissions from all fugitive leaks on the site.

Using screening or direct measurement provides a more accurate overview of fugitive leaks and the effectiveness of mitigation measures. Where this is used, it is recommended that it be repeated at intervals of no more than one year

All the above approaches can be utilized, but only the screening approach and direct measurement approach will result in quantification that reflect reductions arising from effective mitigation measures. If the population approach is used, emission estimates will not change, even if controls have reduced actual methane emissions.

Mitigation strategies

- Methane emission from fugitive leaks can be prevented by following a preventive maintenance program
  - Follow manufacture or company specific maintenance guidelines for when equipment should be serviced or replaced.
  - Review leak records to determine types of components or facilities that frequently leak and develop method to reduce leaks (i.e. replace with different make/model, increase service/replacement frequency, re-engineer to remove component, etc.)
- Methane emissions from fugitive leaks are most commonly reduced by periodic Leak Detection and Repair (LDAR) programs, where inspections are carried out to identify leaks, followed by repair of found leaks.
  - In some regions, detection and repair programs are required by regulation, but they are voluntary in others. The frequency of inspections varies (generally from monthly to annually). The inspection technique also varies.
  - Subsets of the LDAR programs are 'smart LDAR' programs or directed inspection and maintenance (DI&M) programs, where only a focused group of equipment types or components are inspected. For example, the program might be designed to only inspect types of equipment known to give rise to significant leaks, or designed to perform only limited repairs, such as those considered to be cost-effective.
- Fugitive leaks may be reduced by following an 'alternative detection and repair program', where different leak-detection techniques are combined at different intervals. Examples are varied, but include the following.
  - Frequent large-scale surveys (for example, by satellite or aerial) combined with less frequent inspections of components
  - Continuous monitoring
- Such alternative programs are currently being developed, and their suitability will depend on the particular equipment or components and so may vary from asset to asset. Fugitive leaks can also be minimized by replacing types of components that commonly leak, or designing out the need for such components.

Traditionally, before detection equipment was available, leaks were identified by a person (or people) inspecting the equipment or component without the aid of leak detection equipment. These inspections are sometimes called audio, visual and olfactory (AVO) surveys. However, these surveys, based solely on sight, hearing and smell, are not very effective in finding small leaks, leaks at noisy sites, or leaks at unmanned sites. The exception is for natural-gas distribution networks, where odorants are intentionally added, making detection easier and more effective. However, even in those distribution systems, it is better for regular surveys to be carried out with detection devices.

Available resources

Many guides on detecting and repairing leaks were developed for stringently regulated downstream petrochemical facilities. The following are examples of such guides and standards.

- 'Leak detection and Repair, A Best Practices Guide', United States Environmental Protection Agency, October 1999[6]
- 'Fugitive and Diffuse Emissions Of Common Concern To Industry Sectors. Measurement of Fugitive Emission of Vapours Generating from Equipment and Piping Leaks (British Standard)', British Standards Institution, BS EN 15446, the British (and European) standard for leak detection[7]

These guides assume that the regulatory approach developed for the petrochemical industry, in the USA called 'Reference Method 21' (RM21), is followed. That approach is a regular survey for leaks combined with a repair program. Figure 2 shows an RM21 survey where every surface of each component must be checked with an appropriate measurement device, such as a flame ionization detector (FID).

Figure 2: **RM21 survey**

There are several programs and guides for reducing methane emissions from fugitive leaks that are solely for the natural-gas industry. In natural gas, most detection and repair programs, and regulations, are currently less stringent and more flexible than the petrochemical detection and repair guides and standards because natural gas facilities are typically less complex. The guides and programs specific to natural gas include the following.

- 'Technical Guidance Document Number 2: Fugitive Component and Equipment Leaks', Climate and Clean Air Coalition's (CCAC) Oil and Gas Methane Partnership (OGMP), Modified: March 2017[8]
- Natural Gas Star Program's 'Recommended Technologies to Reduce Methane Emissions', a program by the United States Environmental Protection Agency, www.epa.gov/natural-gas-star-program/recommended-technologies-reduce-methane-emissions[9]
- 'Leak Detection and Repair', Marcogaz, April 2021[10]
- 'Best Practice Guidance for Methane Management in the Oil and Gas Sector', United Nations Economic Commission for Europe (UNECE) draft, March 2019[12] (This is very broad international guidance.)
- 'Manual 016: How to Develop a Fugitive Emissions Management Program', Alberta Energy Regulator, December 2020[13]

In the last decade, a common new tool for detecting leaks in the natural-gas industry has been the optical gas imaging (OGI) camera, which is an infrared imaging device with optics, filters and cooled sensors made specifically for detecting methane. These devices produce an image that allows an otherwise invisible plume of leaked gas to be seen. Several types of these cameras are available with different minimum detection capabilities, and manufacturers are developing improvements. Studies have shown that OGI cameras are as effective as RM21 in detecting fugitive emissions[11] Figure 3 shows OGI cameras being used.

Figure 3: OGI cameras in use

Sources: University of Texas at Austin and Heath Consultants Incorporated

There are now many new detection technologies available, or due to become available. Most of these new technologies have not yet been approved as suitable for detection and repair programs required by regulation, though they could be used in voluntary programs. There are ongoing research programs that are testing and comparing newly developed technologies. These technologies may provide more cost-effective leak detection and repair in the natural-gas industry than is currently achieved using just an OGI camera. Recent reports have summarized the available detection technologies. The following are some examples of such reports.

- 'A review of close-range and screening technologies for mitigating Fugitive methane emissions in upstream oil and gas', Fox et al, Environmental research Letters, July 2019[14]
- 'Evaluation of Innovative Methane Detection Technologies', The Interstate Technology Regulatory Council, September 2018[15]
- 'Leak detection methods for natural gas gathering, transmission, and distribution pipelines', Highwoods Emissions Management, January 2022[16]

Some new technologies including aerial overflights, continuous monitoring, and drones are being tested by companies to be used in place of or in addition to traditional leak detection methods. New technologies may have advantages of speed, cost, and temporal coverage over traditional methods. A thorough evaluation of each technology should be completed to determine if it will detect leaks as well as traditional methods. One method to determine equivalency is using open-source software such as FEAST[17] and LDAR-Sim[18]. These alternative programs / equivalent programs mitigation are covered later in this guide, and by a method outlined in the journal article 'A methane emissions reduction equivalence framework for alternative leak detection and repair programs', Fox et al, Elementa: Science of the Anthropocene, 2019[19].

The best practice for reducing emissions from fugitive leaks is summarized in table 2. More details on these mitigation strategies are given in the appendix.

Table 2: Methods of reducing methane emissions from fugitive leaks

Mitigation strategy	Description
1. **Maintain a preventative maintenance program**	Equipment should be serviced or maintained according to manufacturer's recommendations or company-specific maintenance practices (see Step 6 below) to prevent leaks from occurring.
2. **Conduct periodic leak detection and repair programs for all facilities above ground**	a. Upstream production sites and midstream sites commonly use OGI cameras, such as the specially designed, cooled Infrared cameras (examples are the FLIR GF320 or the OpGal EyeCGas cameras), to detect natural-gas leaks. OGI cameras are used in a walking survey where the user scans all views of the equipment.
	b. Other scanning detection, using devices such as the tunable diode laser absorption system (TDLAS), which measure gas concentration along all scanned paths. An example is the Heath RMLD device.
	c. Flame ionization detectors (FIDs) or similar devices are used for RM21 surveys or other similar approaches. While this may be the most sensitive and reliable leak-detection method, it is also the most complex and costly. It takes longer to scan a facility, so it is usually not the method used for oil and gas facilities. However, it is used if it is required by regulation.
3. **Conduct periodic leak detection and repair programs for all underground pipelines**	a. Leak detection is usually performed by a walking survey with a highly sensitive wand detector. Leaks have to have travelled from the point of emission on the buried pipe up to the surface in order to be detected.
	b. Leak detection can also be carried out from motorized vehicles on the ground. Aerial surveys can be used for long pipelines, such as transmission lines. However, the effectiveness of aerial surveys has not been fully proven for detecting all leaks. However aerial surveys have been seen to be effective in detecting large leaks.
4. **Follow a directed inspection and maintenance (DI&M) program**	With this approach, risk-management decisions are used to focus detection and repair only on certain equipment or components, or detection is carried out on all equipment and components, but only more significant leaks are prioritized for repair. a. A focused program requires extensive information from full detection and repair activities carried out in the past, using that information to determine where to focus efforts.

Mitigation strategy	Description
5. Follow an alternative detection and repair program, such as a comprehensive monitoring program	Research programs are testing both aerial surveys and continuous monitoring as alternatives to existing detection and repair methods. Some of these alternatives are called 'comprehensive monitoring programs'. Open-source software such as FEAST[17] and LDAR-Sim[18] can simulate various alternative programs side by side to determine if they will result in similar reductions in emissions from fugitive leaks. One such research program, based at Colorado State University, is a 'Pathway to Equivalency' initiative, which includes a wide-ranging set of stakeholders and research teams in the USA and Canada (Fox et al, 2019). The initiative involves: • testing potential solutions in field laboratories; • modeling mitigation strategies using simulation tools; • trials to test potential solutions in field conditions; and working with stakeholders to encourage them to accept qualifying alternative detection and repair programs.
6. Address components that persistently leak	Monitoring and repair records should be reviewed and components that persistently leak should be serviced more frequently or replaced. If a specific type or make of component is found to persistently leak, replace the component with better performing equipment or, where feasible, remove it from the process entirely. This step can also be done at the design stage by reducing the number of components and connections or replacing/removing components that commonly leak.

Additional details on each of these six mitigation approaches can be found in the Appendices.

As the main mitigation strategy for reducing emissions from fugitive leaks is a leak detection and repair (LDAR) program, some important elements of all LDAR programs need to be considered. It is important to note that an effective LDAR program starts with 'aware and empowered' operators who:

- are regularly looking for leaking components between formal detection and repair surveys; and
- are authorized to report and fix them.

Key elements of a detection and repair program are shown in table 3.

Table 3: Key elements of an LDAR Program

Key element	Description	Comments
Identifying components*	The operator must know about the different components, and how to find each one and identify it during a leak scan.	This applies mostly to upstream and midstream systems (production, gathering, processing, and transmission and storage). Downstream gas distribution networks, which are comprised mainly of meter and regulation stations, buried pipelines, and customer meters, have unique materials and fewer components, so component identification is a simpler issue.
Choosing detection devices and leak definition	The device chosen, along with the written procedure, sets the lowest leak rate that can be detected. (Setting this rate is known as leak definition.)	In some regulatory approaches, such as RM21, the leak definition may be at a set rate that is in a ppm concentration range (for example, 500 ppm in air). Downstream distribution operations often have leak detection defined by the utility company and regulators.
Monitoring components regularly	This element is using the specified detection device, following a written procedure, at set intervals. Most often, leaks are marked, tagged with a temporary tag and, if they are not immediately repaired, entered into a leak-tracking system.	Some regulatory approaches specify the method. For example, the Canadian rules and the US EPA's new source rules require OGI cameras used at a minimum viewing distance. Voluntary, non-regulatory programs may use other detection techniques, but they should ideally be comparable to regulatory approaches.
Repairing components	Leaking components need to be repaired as soon as possible. The component is considered to be repaired only after it has been monitored and shown not to be leaking above the leak definition (this is often specified as a non-detect by OGI camera).	First attempts at repair include the following practices. • Tightening screwed connections • Tightening valve bonnet bolts on valves or flange bolts on flange gaskets • Replacing bonnet bolts • Tightening packing gland nuts • Injecting lubricant into lubricated packing • Cleaning or replacing thief hatch gaskets and seals Items that cannot be repaired first time or that take longer to access need to be tracked and attended to during future opportunities, such as equipment or facility downtimes.

Key element	Description	Comments
Records and reviews	Records should be kept of the surveys carried out, the leaks found and from which components, and when repairs were made. This information may be useful for keeping an accurate inventory of emissions from fugitive leaks.	For regulatory required approaches, detailed and accurate records are usually required by the appropriate regulation. This may include electronic records for QA/QC and regulatory audit. In voluntary approaches, tracking should ideally be precise enough for components with repeated failures to be identified and replaced or permanently repaired.

* table 3 note: In intensely regulated industries, such as chemical plants and refineries, the task of identifying components involves assigning a unique ID number to each component and physically hanging a permanent and unique identification tag on that component. This is generally not required in the natural-gas supply chain, where components may be scanned in bulk, with only those that leak being identified and tagged.

Checklist

The following checklist allows you to assess your progress in reducing methane emissions from fugitive leaks. The last column in the checklist is for you to indicate the percentage of all equipment the mitigation strategy has already been applied to.

Activity	Completed	Percentage of all equipment or processes in this program
✓ Report annual inventories that include equipment leak emission estimates		
✓ Maintain a preventative maintenance program		
✓ Conduct a periodic LDAR program		
✓ Perform a focused DI&M program		
✓ Use alternative detection and repair programs, such as comprehensive monitoring programs		
✓ Components that frequently leak should be serviced more frequently, replaced or where feasible, removed the system		

It is important to realize that this simple checklist does not evaluate how robust detection and repair programs are, or how effective they are.

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Appendix: more details on mitigation strategies

Mitigation strategy 1:

Conduct a periodic leak detection and repair program for all facilities above ground

Cumulatively, fugitive leaks are understood to significantly contribute to total manmade methane emissions and can be reduced by following a program to detect and repair leaks.

Detection and repair programs have long been used in downstream local distribution networks, as those systems deliver gas directly to businesses and homes, so might cause the greatest exposure to the public. For many decades, long before leak-detection activities were carried out in upstream facilities, local distribution companies have conducted routine leak surveys. In North America, these are generally conducted every one, two or three years. Internationally the surveys may be more frequent. Leaks are also reported by the public, as distribution gas is odorized so leaks can be detected more easily. Many reported leaks are repaired immediately in that segment, but some small leaks are simply tracked. Some distribution leaks are not repaired immediately on the basis that they are small and not a danger to the public. In those cases, the leaks are monitored.

In distribution networks in the United States, most leaks are graded by risk to safety (1, 2, or 3). Grade-1 leaks are repaired immediately. Grade-2 leaks are most often placed in a procedure to be repaired 'sometime this season'. Grade 3 leaks are monitored. Most local distribution companies have thousands of leaks that are permanently monitored, although some jurisdictions set a maximum time for repairs to be carried out.

In midstream operations, such as natural-gas processing plants, many jurisdictions require a formal leak detection and repair program, but only on the liquids side of the plant where propane, butane, and heavier volatile hydrocarbons are handled. The upstream and outlet gas streams that were primarily methane were not usually included in the regulatory detection and repair program. Some operators voluntarily added the methane side of the plant to their detection and repair program.

Historically upstream oil and gas operations have not tended to have formal programs for detecting leaks. In the last decade, detection and repair regulations have been issued for some upstream and midstream operations in North America. For example, the US EPA requires a leak detection and repair program for new and modified sources. In other regions, leak detection and repair programs are required for all existing sources (for example, under the Canadian Oil & Gas federal rule and the Provincial Rules in Canada). Several US states have rules such as Colorado's Reg 7 that require detection and repair programs for all upstream sources.

In other cases, some operators have chosen to adopt a detection and repair program across all sites, not only in regions where they are required by regulation. Naturally, voluntary detection and repair programs tend to be more flexible than regulatory programs.

Where this strategy is appropriate
Any surface facility with pressurized equipment would be expected to reduce emissions from fugitive leaks by following a regular detection and repair program to identify leaks and then repair them.

In facilities for upstream or midstream operations, the most common tool for detecting leaks is an optical gas imaging camera (OGI camera) used at close range by someone on foot. This is usually accepted by the regulatory leak detection and repair programs required in North America. The Reference Method 21 (RM21) approach using handheld flame ionization detectors (FIDs) is also allowed, but tends not to be used because it requires immediate contact with all surfaces of each component, and so is much more labor-intensive and expensive. The FID equipment used for the RM21 approach is less expensive than OGI equipment, but the approach itself is more expensive. It is important to note that RM21 technology for detection and repair programs has not changed for more than 20 years, while OGI is still relatively new and its effectiveness is still being studied. OGI is recognized by many jurisdictions as an effective method. OGI is more rarely used in downstream industry segments because distribution systems leaks are often smaller, and generally below the OGI detection threshold.

Conclusion
Although detection and repair programs have been used in other industries for decades, their cost-effectiveness is not well defined. This is partly because detection and repair has often been used when it is required by regulation, and as such there was no driver to study the effectiveness of different frequencies or detection techniques because they were all specified. In recent rulings, the US EPA has assumed that detection and repair in upstream and midstream operations can produce a 40% reduction in emissions from fugitive leaks if carried out once a year, a 60% reduction if carried out every three months, and an 80% reduction if carried out once a month. However, this assumption has not yet been backed up by detailed findings.

The cost-effectiveness of a detection and repair program that includes all assets (equipment and components) needs to be considered when designing a voluntary program, so the frequency, technique and repair procedures could all be shaped by decisions on cost-effectiveness. For regulatory programs, the frequency, devices and methods are usually set, so there are fewer design options.

Economic evaluation of any leak-reduction measure depends on the amount of emissions reduced or eliminated. For a specific site, this usually requires a measurement or estimate of the leak rate from all identified leaks, compared against the cost of the detection and repair program. ICF studies (see the references) gather and make some assumptions on costs and cost-effectiveness.

There may be other benefits from following detection and repair programs, such as improved opinions from stakeholders and attracting investors.

Mitigation strategy 2: Conduct a periodic leak detection and repair program for all underground pipelines

Fugitive leaks from buried pipelines are understood to be a small source of manmade methane emissions from gas-gathering systems, transmission pipelines, and distribution networks. Surveys for leaks from buried pipelines are carried out primarily for safety reasons, rather than solely to reduce methane emissions.

Having a detection and repair program for buried pipelines can help identify and locate leaks so they can be repaired, ultimately reducing total emissions from such leaks.

Where this strategy is appropriate

A regular detection and repair program could reduce emissions from any pressurized gas.

It is important to note that even in regulated jurisdictions there are widely varying requirements for checking for leaks in buried pipelines. Most distribution networks and many transmission pipelines worldwide have some regulatory requirements for surveys, but most gathering pipelines have regulatory inspection requirements only for pipelines within a set distance of occupied buildings, or in other higher-risk environments, such as river crossings. Transmission pipelines often use aerial surveys (infrared or spectroscopic instruments in aircraft that survey for plumes and may also survey for disturbed ground and dead vegetation), but some also use ground-level approaches with gas detectors on vehicles that drive in rights-of-way. In transmission, the survey is often carried out more for safety reasons than with the objective of reducing emissions.

In local distribution networks, the survey to detect leaks is done with either a highly sensitive methane detector on a vehicle or with someone on foot carrying a handheld methane detector. Aerial surveys are not carried out because of interference from buildings, topography, and vegetation.

Conclusion

If a detect and repair program is required by regulation, the cost-effectiveness of the program does not necessarily need to be evaluated. For voluntary programs, the cost-effectiveness of a program for pipelines needs to be considered when the program is designed, so the frequency, technique and repair procedures could all be shaped by decisions on cost-effectiveness.

Economic evaluation of any leak-reduction measure depends on the amount of emissions reduced or eliminated. For a specific site, this usually requires a measurement or estimate of the leak rate from all identified leaks, compared against the cost of the detection and repair program.

There may be other benefits from following detection and repair programs, such as improved opinions from stakeholders and attracting investors.

Mitigation strategy 3:
Perform a directed inspection and maintenance (DI&M) program

Cumulatively, fugitive leaks are understood to significantly contribute to total manmade methane emissions and can be reduced by a program of detecting and repairing leaks. However, if there is no regulatory requirement, an operator may choose to apply the program to a limited area.

For this approach there needs to be information and knowledge from previous activities to detect leaks, so that operators can have assurance that there are types of equipment or component source types that rarely tend to leak and so can have longer intervals between checks. A full detection and repair program is preferred for most equipment.

If an operator has detailed knowledge on the sources of leaks, it may choose to focus its efforts on types of equipment or components that are known sources of larger leaks, and give lower priority to surveying other equipment or components. This approach can provide a more cost-effective and focused detection and repair program. This focused detection and repair is sometimes called 'smart-LDAR' or 'directed inspection and maintenance' (DI&M).

Even with a focused program, the rest of the equipment and components should still be examined at regular intervals.

Where this strategy is appropriate

Any surface facility with pressurized equipment would be expected to reduce methane emissions from fugitive leaks by following a focused detection and repair program.

Conclusion

For voluntary leak detection and repair programs for selected equipment or components, cost-effectiveness would need to be considered when the program is designed, so the frequency, techniques and repair procedures could all be shaped by decisions on cost-effectiveness.

The equipment and components to focus the program on could be determined by decisions based on an initial screening of all equipment to identify where the most significant leaks occur. For example, an operator might determine that most of their fugitive site emissions in the gathering segment come from compressor rod packing and compressor open ended lines, and therefore focus a DI&M program that only performed leak detection on those sources and exclude other sources that are not expected to be significant contributors.

Economic evaluation of any leak-reduction program depends on the amount of emissions reduced or eliminated. For a specific site, this usually requires a measurement or estimate of the leak rate from all identified leaks, compared against the cost of the detection and repair program. A key aspect of

a smart-LDAR program is that it is more targeted and so reduces labor costs, which may be a significant consideration.

With any detection and repair program, but especially with focused programs such as smart-LDAR, once the largest leaks have been addressed, operators are likely to get smaller returns on future LDAR cycles, so there may be a point where the frequency of detection and repair surveys can be adjusted to maintain the cost-effectiveness.

Mitigation strategy 4: Use alternative detection and repair program, such as a comprehensive monitoring program

Cumulatively, fugitive leaks are understood to significantly contribute to total manmade methane emissions and can be reduced by a program of detecting and repairing leaks. If there is no applicable regulatory requirement, or where regulatory requirements are flexible, operators may choose to perform the leak detection using an alternative program.

Research programs that look at emissions of natural gas typically find that a small number of sources of emissions (emitters) are responsible for a large portion of total emissions. A typical rule-of-thumb based on information collected in the USA is that 4 to 5% of emitters produce 40 to 50% or more of emissions (Lamb et al, 2015; Zimmerle et al, 2015; Brandt et al, 2016) 20, 21, 22. This skew in emission distributions has increased interest in continuous monitoring or more frequent leak-detection surveys of natural-gas infrastructure. In effect, these methods are designed to find big leaks quickly, prompting faster repairs and larger reductions in emissions.

Alternative programs may use alternative technologies to perform a broader scan, so reducing the need for conventional leak surveys on all equipment at all sites. Examples of alternative programs are 'continuous fence line monitoring', or a program where tiered screening for leaks uses regular surveys through facility-level technologies. For example, you might use less sensitive aerial or satellite surveys that are carried out more frequently, with follow-up limited to sending teams only to sites where leaks are detected.

These programs are still being developed and have been discussed in papers like Fox et al (2019) 19. Also, research is being carried out to compare new alternative approaches scientifically. Examples of these comparisons are the Petroleum Technology Alliance Canada (PTAC) Fugitive Emissions Management Program Effectiveness Assessment (FEMP EA), the University of Calgary and Colorado State University's 'Pathway to Equivalency' program, and the Stanford University and Environmental Defense Fund's Mobile Monitoring Challenge23.

A number of technologies and approaches for regulatory compliance have been approved by the Alberta Energy Regulator under their Alternative Fugitive Emission Management Program (Alt-FEMP) and by the Colorado Department of Public Health and Environment under their Alternative Approved Instrument Monitoring Method (Alt-AIMM) Program. Both agencies keep a list of approved technologies and details of each approval on their websites.

The ongoing development and research aim to find and compare available methods of detecting leaks, so that the most accurate and cost-effective methods, or combinations of methods, can be adopted. However, there is currently no definitive information that can be used to compare the cost-effectiveness of these methods. That may change in the near future, as programs described by Fox et al develop.

New technologies and detection methods also continue to emerge. Some have been offered commercially, and some are still in pilot testing. Recent reports have tried to catalogue the various detection technologies (ITRC, 2018) 15. Some of the technologies are still in pilot stages, such as some that emerged from the US Department of Energy's Advanced Research Projects Agency – Energy

(DOE ARPA-E), called 'Methane Observation Networks with Innovative Technology to Obtain Reductions' (MONITOR).

Many of the detection technologies are for different frequencies and with different detection thresholds. Recent studies have compared the different spatial scale (the minimum size area that can be analyzed) versus the temporal scale (frequency of observations). The diagram below from Fox et al, 201914, shows some of this comparison.

Note: these techniques are also graded by their potential uses, shown in the colored circles, and focus mostly on measuring emissions from upstream oil and gas:

M1 = Develop and refine emissions factors to improve inventories

M2 = Estimate top-down emissions from a region with multiple sources

M3 = Conventional, close-range LDAR using handheld instruments

M4 = Rapid screening for anomalous emissions

The recent studies on different techniques point out that innovations in different areas may bring improvements in efficiency, speed of detection, and the scale of methane-monitoring solutions.

Where this strategy is appropriate

Any surface facility with pressurized equipment would be able to reduce emissions from fugitive leaks by following an appropriate alternative program. However, some technologies that evaluate facility level emissions in a snapshot measurement are hindered by other vented emissions that might be occurring at the time of the scan, such as maintenance blowdowns, gas well liquids unloading, or even methane slip in compressor engine exhaust.

As these programs are still in the process of being developed and tested, an operator using them for a voluntary program should stay in touch with the latest research on the effectiveness of the methods.

A company may also want to focus an alternative program on equipment and components that could produce the largest emissions. For example, a producer might prioritize fields that have a high hydrocarbon liquids production rate, rather than a dry gas field, as wet production sites would generate the most flash gas from atmospheric tanks.

Conclusion

As there is no definitive information for comparing the cost-effectiveness of these methods, an operator would need to gather appropriate information. That may be a barrier to the uptake of these alternative programs until more information has been provided from pilot tests and ongoing research.

Economic evaluation of any leak-reduction measure depends on the amount of emissions reduced or eliminated. For a specific site, this usually requires a measurement or estimate of the leak rate from all identified leaks, compared against the cost of the detection and repair program. In some cases, an operator could definitively prove the effectiveness of an alternative program through its measurements.

Mitigation strategy 5:
Replace components that persistently leak

Cumulatively, fugitive leaks are understood to significantly contribute to total manmade methane emissions. In all cases, a small proportion of the total number of components are leaking. In some cases, the overall leak rate can be driven by leaks from particular types of component. If those sources continue to be issues, recurring after they have been repaired or regularly generating very large leaks, an operator may choose to change the type of component, or even remove a component if both the removal and continued operation post removal/replacement can be done safely.

Components that tend to regularly leak can be eliminated when systems are being designed (see the separate guide on design), or when existing equipment is modified or adapted. This guide addresses only adaptations to existing equipment.

The decision to eliminate or replace certain types of equipment or component will usually be made because detection and repair surveys that track their emissions have shown that the component or equipment persistently leaks and is a significant contributor to emissions.

Where this strategy is appropriate
Any surface facility with pressurized equipment would be expected to have some fugitive leaks during its lifetime. However, only a few sites would be expected to have 'problem components' that continue to leak again after they are repaired. An operator needs to track leaks and maintain enough information to know the type and location of the leak to be able to find repeat leakers.

Once a problem component is identified, an engineering analysis can be performed to see if it can be replaced with a different type of component or eliminated altogether. Some examples are as follows.

Source type	Possible replacement or change	Possible elimination
Connector	Replace the connector, such as replacing a union with a new union.	Welded pipe with no connector.
Valve	Change to a different type of valve, or change to a different packing type in the same valve.	Eliminate valve.
Open-ended lines	Add an extra block valve so that there is a ‘double block valve’ in the line to the atmosphere. Add a bull plug or screwed cap to the end of the OEL.	Route to a control device or flare, or eliminate the OEL if it is not needed for any operational purpose.
Pressure-relief valves	Change the type of PRV or add a burst plate.	Replace the PRV with an alternative relief device (such as a burst plate) or, if possible, route the PRV to a control system instead of to the atmosphere.
Gauge hatches	Increase relief set point or replace with a different type of gauge hatch such as a non-relieving type (lock-down)	Change pressurized tanks or change to a tankless design on well pads.
Compressor seals	Replace seals with a different type or add seal gas controls.	Eliminate compressor.

It is very important to note that eliminating components as an adaptation to existing equipment is likely to require a Management of Change review to make sure the component was not needed in operations, and that removing it will not adversely impact safety with respect to the equipment or operations. In most cases, this will prevent simple removal of a component, as they would usually be expected to have an important purpose in the original installation.

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This series of 10 Best Practice Guides have been designed to improve performance in methane emissions management across the natural gas supply chain. Each Guide provides a summary of current known mitigations, costs and available technologies as of the date of publication. The Guides are available, upon request, in English, French, Arabic, Mandarin, Russian and Spanish.