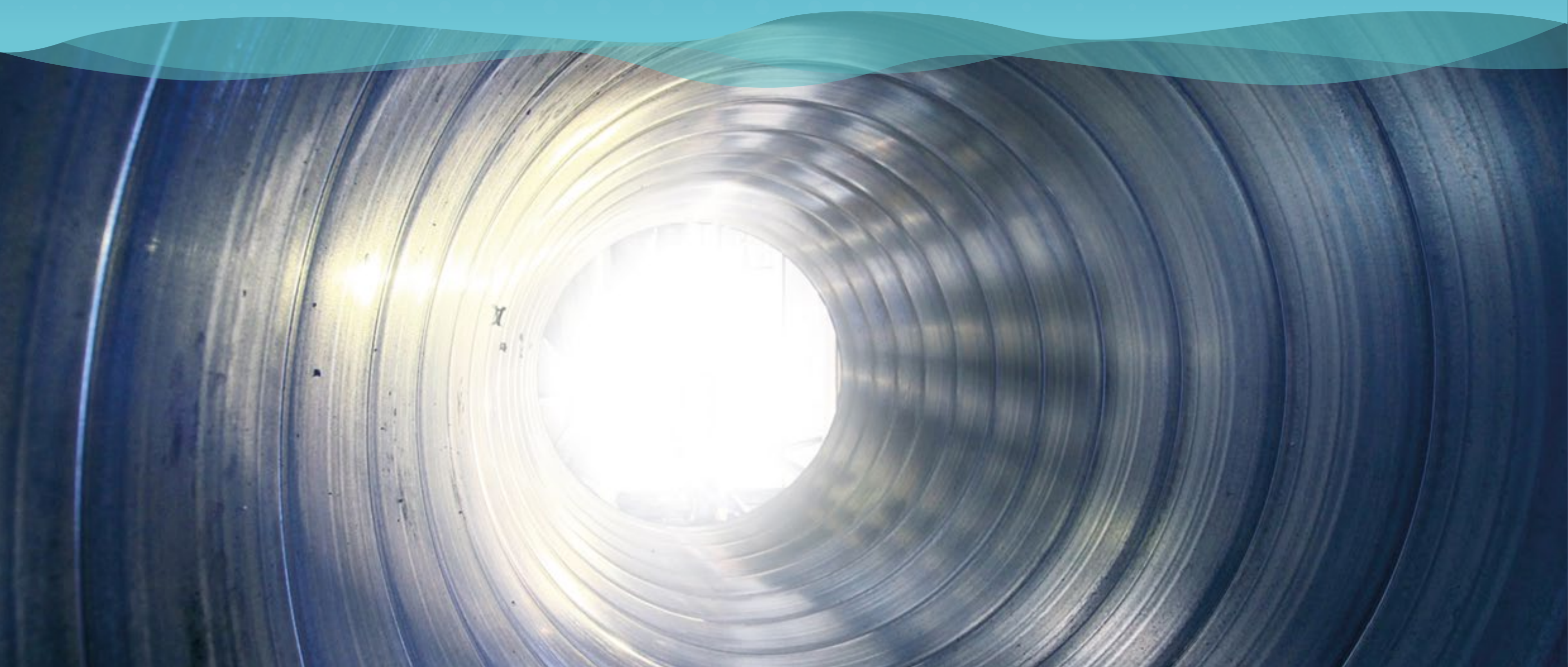
METHANE GUIDING PRINCIPLES

REDUCING METHANE EMISSIONS

Best Practice Guide: Operational Repairs

January 2024



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Summary

Operational repairs are vital for reducing methane emissions from oil and gas operations. This guide covers repairs to leaks discovered during leak detection and repair programs, as well as releases that may arise during routine maintenance and repairs of equipment.

The general strategies (mitigation strategies) to reduce emissions through operational repairs are listed as follows.

Best practice for reducing methane emissions through operational repairs

For leaks from equipment

Keep an accurate inventory of emissions from equipment leaks, and follow a regular leak detection and repair program on all facilities.

Make reducing leaks a key aim of maintenance and repair, by:

- making repairs as soon as reasonably practical and tracking any repairs that are unavoidably delayed;
- confirming when repairs have been successful;
- keeping complete and accurate records; and
- routinely analyzing information about leaks and repairs

For routine maintenance and repairs

Minimize emissions that may result from maintenance and repair by:

- having plans for reducing venting when 'blowdowns' are needed to release gas accumulated in large vessels and pipelines; and
- if venting cannot be avoided, considering flaring to reduce the impact.

Introduction

Operational repairs refer to:

1. repairs to leaks discovered during inspections carried out as part of a leak detection and repair program (leak-detection surveys); and

2. actions to minimize emissions from venting that may arise because of routine maintenance and repairs of equipment.

In the first case, operational repairs can eliminate some methane emissions by repairing leaks identified during a leak-detection survey. In the second case, traditional routine maintenance and repairs often require the equipment to be depressurized first, and mitigation strategies can reduce emissions released into the atmosphere through venting.

Emissions can usually be reduced by following monitoring and repair programs. In the case of equipment leaks and some vented sources, emissions can be reduced through following a leak detection and repair program. Other best-practice guides, on equipment leaks and venting, have covered the specific sources of emissions and methods of estimating those emissions, and those details are not repeated in this document. As explained in the best-practice guide relating to equipment leaks, every facility should consider having a leak detection and repair program. These programs can reduce losses of natural gas, increase safety for workers and operators, decrease surrounding communities' exposure to natural gas, and help facilities avoid enforcement action and fees. The equipment leaks guide covers the 'leak detection' aspect of a leak detection and repair program, by setting out recommendations for monitoring equipment and identifying leaks. This guide covers the 'repair' aspect, setting out recommendations for repairing leaks.

Traditional maintenance and repair of equipment is carried out for a variety of reasons, such as inspections, routine maintenance of moving parts, servicing equipment that is not working as well as it should, making new connections to pipelines, and regular maintenance activities, such as pipeline 'pigging' to clear pipelines of accumulated material. The equipment being serviced is often isolated and depressurized so it can be opened safely. If these activities would lead to gases being released to the atmosphere through venting, 'mitigation measures' can reduce the amount vented.

This guide covers some important aspects of reducing methane emissions through operational repairs. The two main aspects are:

- making reducing emissions an important aim of detecting and repairing leaks; and
- minimizing emissions that may result from traditional maintenance and repair.

Quantifying Emissions

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 methods of quantifying emissions from equipment leaks were discussed in the best-practice guide relating to equipment leaks. That guide recommends screening or direct measurement.

- Quantify emissions by screening
  After screening, 'leak' and 'no leak' emission factors can be applied by type of component.
- Quantifying emissions by direct measurement
  Emissions from all detected leaks on a site can be measured to produce the most accurate estimate possible for the site.

Only screening and direct measurement will result in estimates that reflect reductions made through operational repairs.

Methane emissions from traditional maintenance and repairs can usually be quantified from the known volume and pressure of the equipment before it is depressurized, the amount of methane in the gas, and the frequency of the routine maintenance and repairs.

Both the screening and the direct-measurement methods of quantifying emissions from equipment leaks are affected by the period from the time the leak was discovered (or an earlier assumed start of emission) to the time it is repaired. Therefore, if using these methods, the operator is rewarded for the timely repair of leaks by lower total emissions.

For quantifying emissions from routine maintenance and repairs, the operator needs to keep a record of the frequency of the maintenance and repairs, along with the specific estimate of the released volume for each event. In some cases, for frequent maintenance on the same equipment, a simple tally of the number of events is sufficient if there is already an accurate estimate of the emissions per event.

Mitigation Strategies

As explained in the best-practice guide relating to equipment leaks, every facility should consider having a leak detection and repair program. Best practice leak detection and repair programs include the following elements:

- Carry out repairs as soon as reasonably practical.
  – Confirm when repairs have been successful.
  – Where repairs are unavoidably delayed, they should be tracked and a date set for the repair.
  – Prioritize fixing the largest leaks
- Keep accurate records of leaks and repairs.
- Analyze records of leaks and take action when necessary.
- Avoid leaks and the need for repairs where possible.
- Minimize emissions arising from making repairs.

The following best practices should be followed to minimize emissions arising from traditional maintenance and repairs.

- Plan for venting-reduction steps such as 'pressure pumpdowns' when large vessels and pipelines need to be isolated and depressurized.
- Minimize the volume that has to be handled. For some long pipelines, this could be careful selection of where to isolate the line, or adding stops to isolate a smaller section of line.
- Reduce emissions from pigging by recapturing the released gas using a vapor-recovery unit.
- If venting cannot be avoided, consider flaring to reduce the emissions impact.

The following best practices should be followed to avoid emissions arising from traditional maintenance and repairs.

- Make new connections to pipelines using hot taps when safe to do so, and so avoid the need to depressurize the pipeline.
- Use non-intrusive inspection, such as inline inspection tools, to avoid larger blowdowns for inspections.
- Look for opportunities to co-ordinate operational repairs and routine maintenance and repairs to minimize the number of blowdowns.

Each of the best practices set out in the box above is discussed in more detail on the next page. Mitigation strategies for equipment leaks are discussed first, followed by mitigation strategies for routine maintenance and repairs.

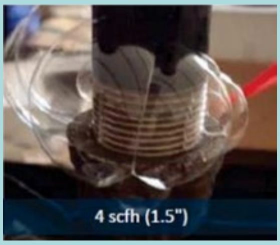
Mitigation strategies for emissions from equipment leaks

Repair equipment leaks as soon as possible
Repairing leaks as soon as is safe and practical is important to minimize total emissions, as it shortens the duration of the leak and may prevent it from growing. In practice, some teams responsible for leak detection and repair are qualified and equipped to make initial repairs to leaks as they are discovered. Initial repairs might include tightening screwed fittings, tightening packing nuts on valve stems, or injecting lubricant into packing. In some countries, regulations put a limit on the time until an initial repair is made. In most cases the initial repair is carried out within a week of the leak being discovered, if it is safe and practical to do so without shutting down the equipment

Figure 1[1]: Initial repairs being made

If the initial repair is not successful, a second attempt would need to be made, by a team that has different tools or expertise, as soon as reasonably practical.

Table 1. Bubble Test method to determine the size of leaks[8]

Size of Emissions	Bubble Test Results	Example
<0.014 scfh	Foam with few or no bubbles	
0.014-0.1 scfh	Cluster of small bubbles less than 0.25”	
0.1-4 scfh	Cluster of large bubbles	
>4 scfh	Blown off with no opportunity for bubbles to hold	N/A

Confirm that repairs have been successful

Leak detection and repair is only an effective mitigation measure if repairs are successful in stopping the leak. This guide recommends that a repair is not considered to be successful until follow-up monitoring shows that the component is no longer leaking. Follow-up monitoring can use the same leak-detection method that discovered the leak, or it can use a method that is more sensitive than the original method. In many cases, soaping (spraying soapy water on the leak area and looking for bubbles which would indicate a leak) may be an acceptable way of checking whether the repair has been successful.

Figure 2: a soaping check for leaks

Keep track of repairs that are delayed

Sometimes repairs cannot be carried out immediately or in a reasonable length of time. This may be the case if, for example, replacement parts are needed, specialized labor or technical expertise are needed, the equipment needs to be shut down for the repair to be made, or a significant amount of methane would need to be vented for the repair to be carried out immediately.

In fact, for leaks from equipment with a significant internal volume, such as a pipeline, repairing leaks as soon as possible is not always environmentally beneficial or cost-effective as the methane emissions associated with making the repair, or the cost of the repair, may outweigh the benefit of repairing the leak.

Leaks that cannot be repaired within a reasonable time should be placed on a 'delay of repair' list. This list should include the location of the leak, the date it was discovered, an estimated date for the repair, and an explanation of why the repair could not be carried out straight away.

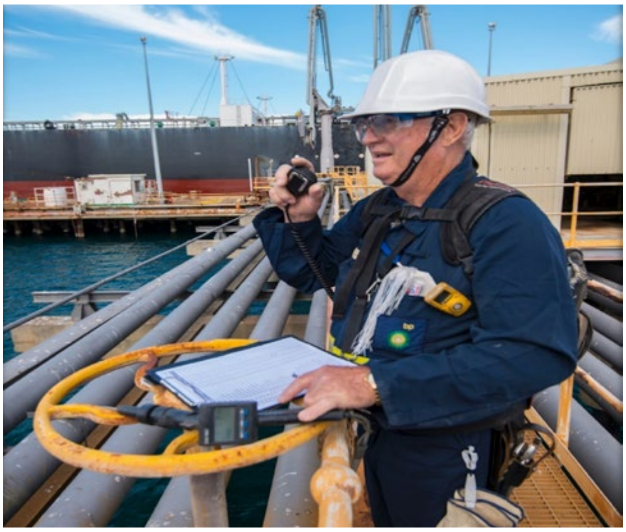
If the volume of gas that would be released as a result of repairing the leak is much larger than the amount that would be released through the leak in the year, the operator may choose to delay the repair. A record should be kept, explaining that the volume of emissions from the venting needed to carry out an immediate repair would be greater than the emissions that would arise while waiting for a planned shutdown.

Keep accurate records of leaks

When leaks are discovered, it is important that a record is kept and repairs are tracked closely. This guide recommends that each facility should do the following

- Keep a record of all leaks found during leak-detection surveys
- Keep a list of the dates of each attempt at a repair and explain the repair method
- Record details of successful repairs (such as the date of the repair, and the results of follow-up monitoring that proved the repair was successful)

Figure 3: a manual record being made of leaks found in the field.



Records of leaks found during leak-detection surveys should include the leak rate, the type of source and the location. The record must be detailed enough to allow analysis of whether the same component leaks again in the future. The repair records should show the date of each attempt at a repair, a brief description of the repair method, and the results of follow-up monitoring carried out to check that the repair was successful. It is important to record the duration of the leak, from discovering it to it being successfully repaired, for a cost/benefit analysis.

There are software programs available to perform this tracking, but many have been devised for more complicated tracking systems, such as leak detection and repair at refineries and chemical plants, where every single component has a fixed tag. This best-practice guide, which relates to natural gas, recommends that records are kept in a digital format, but the format may be a simple one created by the user. The records should be part of the site's maintenance-management system in order to manage the needed leak repairs.

Once a set of records has been established over a number of years, the asset manager will have extra options for reducing emissions through repairing leaks, as follows.

Analyze records of leaks and take action when necessary
Regularly reviewing records of leaks, at approximately the same frequency as leak-detection surveys, can identify components or types of component that persistently leak. These components or types of component should be targeted for correction or preventative maintenance.

For some sources of emissions, such as open-ended lines, correction may be as simple as adding a second valve or a screwed plug or cap to the end of the line. For other sources, there may be improved sealing technologies available, such as improved valve types or improved packing systems, or it may even be possible to replace a component with low-leak or no-leak solution, such as replacing joints with welded connections. Finally, for some leaks or vented sources that persistently produce large emissions, preventive maintenance can be carried out.

Preventative maintenance means planned repairs or replacements before a component is due to fail or leak. An example would be replacing reciprocating rod packing on an hour-of-service schedule, or at some incipient emission rate level that indicates a change in condition of the packing. Preventive maintenance varies depending on the equipment and technology that is producing the leak. For example, in underground storage systems, operators may use state-of-the-art downhole logging technologies to assess the storage well integrity and search for downhole defects; such systems might not be applied on any other above ground assets. This can lead to a prioritization of certain storage wells for further preventative remediation.

Avoid leaks and the need for repairs where possible
An example of action to avoid leaks and the need for repairs is to use inline-inspection technologies in pipelines. Inline inspection involves running a sensor through the inside of the pipeline, while the natural gas is still flowing, to analyze the condition of the pipe. Inline inspection devices can reduce methane emissions that would otherwise result from conducting hydrostatic testing as part of integrity management programs, or may allow incipient corrosion or damage to the pipe to be corrected before a leak begins.

Mitigation strategies for routine maintenance and repairs that involve opening equipment

Minimize the emissions impact of maintenance and repairs
The best-practice guide relating to venting gives many details on mitigation strategies that can reduce venting, some of which would also apply to minimizing emissions from blowdowns needed to carry out repairs. For systems that have very large volumes of gas, before repairs are carried out, special consideration should be given to how to reduce the effect from blowdown emissions.

- **Pumpdown pipelines and large vessels**
Pipeline systems in gathering, transmission, and distribution can have very large internal volumes. Significant methane emissions are often released when performing pipeline repairs and making new connections to pipelines. One source states that up to 170,000 cubic meters (m^3) of natural gas is vented when making a new connection to or repairing a pipeline, yet the majority of this gas can be recovered if time and resources allow. So mitigation strategies such as pumpdowns may minimize venting to the atmosphere. The use of pumpdowns can be limited by the configuration of the pipeline. Some configurations allow for easier pumpdowns (i.e., multiple pipelines adjacent to each other), and available compression (i.e., existing pipeline compression or temporary rental compression). Other factors may limit the ability to recover all the gas, such as having a limited time frame available to depressurize, or trying to limit the effect on customers. Before the planned repair, an operator can calculate the net gas savings from a pumpdown based on the gas that would be vented to the atmosphere by depressurizing the pipeline, and comparing this against the gas saved with inline compressors (with typical 2:1 compression) versus the gas saved with a portable compressor (with typical 5:1 compression), and consider rental and fuel cost of a portable compressor versus fuel costs for operating inline compressors. If time allows, this practice often pays back immediately.

Another way to reduce emissions from maintenance and repairs is to minimize the purging event (removal of oxygen) that must occur before the vessel or pipeline is returned to service. Some guides already exist on this subject.

- **Minimize the volume that has to be depressurized**
Another approach to depressurizing pipelines is to add temporary line stops to reduce the length of line that needs to be blown down to make a repair. A line stop is a removable, flexible plug that can be inserted through a hot tap to isolate a section of pipe where there is no existing isolation valve. In downstream local distribution systems using plastic pipe, a line squeeze off can also be used where the pipeline is simply squeezed shut in a metal clamp.

Figure 4: an example of a line stop being added to a pipeline.[2]

Certified Williamson Industries Technician performing a hot tap with a 760 Tapping Machine as part of a 123" Stopple application.

Even where pumpdowns and line stops cannot be used, mitigation measures such as flaring will reduce the effect vented gas has on the environment, as is discussed in the best-practice guide relating to flaring.

- **Reduce emissions from pigging by capturing gas with a vapor-recovery unit**
  Hydrocarbons and water condense inside wet gas-gathering lines, causing pressure to drop and reducing gas flow. This requires the operator to perform pigging to remove liquids and debris (condensate). Before and after pigging, operators depressurize the launcher and receiver of the pig, so gas is vented when a pig is launched and received. Gas is also released from storage tanks receiving the condensate removed by pigging. The amount of gas released can be reduced by having a vapor-recovery unit or flare connected to the tank.

Avoid emissions

In some cases, emissions from maintenance can be avoided completely by changing the method of the maintenance. Examples are inline inspections for pipelines, using hot taps to make connections to pipelines, and consolidating routine maintenance into single events.

- **Hot taps for new pipeline connections**
  Emissions from pipeline blowdown can be avoided by making a tap into the pipeline while it is still operating at full pressure when safe to do so. Hot taps add sleeves around the pipeline, allowing a tap machine to safely drill into the operating pipe while it is still in use. This completely avoids a pipeline blowdown.

- **Non-intrusive inspection**
  Non-intrusive inspection is inspecting pressure vessels without having to isolate or open them to inspect the interiors. The main example for this guide is inline inspection, which can inspect the condition of the inside of pipelines. Inline inspection involves running a specialized pig with sensors (often referred to as a smart pig) through the inside of the pipeline while the natural gas is still flowing.

- **Reduce the number of blowdowns**
  Co-ordinate repairs and routine monitoring or maintenance to reduce the number of blowdowns needed. This may be achieved by coordinating maintenance events into a single downtime or turn-around maintenance activity.

- **Flaring**
  If venting cannot be avoided, flaring can reduce the emissions impact of any venting event.

Available resources

Mitigation strategies for reducing emissions from equipment leaks have been used in the gas and oil industry for a long period. Guides on detecting and repairing leaks were first developed for downstream petrochemical facilities, but they do not completely apply to the natural gas segment. There are now several programs and guides specifically relating to natural gas, including the following.

- Climate and Clean Air Coalition's (CCAC) 'Technical Guidance Document Number 2: Fugitive Component and Equipment Leaks', March 2017 [3]
- Natural Gas Star Program, 'Recommended Technologies to Reduce Methane Emissions', a program run by the United States Environmental Protection Agency [4]
- 'Improving Methane Emissions from Natural Gas Transmission and Storage', a white paper by Interstate Natural Gas Association of America (INGAA), August 2018 [5]
- 'Methane to Markets: Reducing Methane Emissions in Pipeline Maintenance and Repair', a presentation by EPA and IAPG Technology Transfer, 2008 [2]
- American Gas Association (AGA), Purging Manual, 4th Edition, Catalogue Number XK1801, September 2018 [6]
- 'Leak Detection and Repair', Marcogaz, April 2021 [9]

The most common mitigation strategies for reducing emissions through operational repairs, and some key elements of those strategies, are summarized in table 2 below.

Table 2. Methods for Reducing Methane Emissions through Operational Repairs

Mitigation Strategy	Key elements of the strategy
Carry out leak-detection surveys	See the separate best-practice guide on equipment leaks.
Carry out repairs as soon as practical	Make initial repairs such as tightening screwed connections, tightening bonnet bolts on valve packing or adding lubricant to packing.
Prioritize fixing the largest leaks	The majority of total emissions from fugitive leaks come from just a small number of large leaks in an asset[10, 18]. Prioritizing fixing the large leaks, especially with limited resources can be a cost-effective way to reduce overall emissions.
Confirm that repairs have been successful through follow-up monitoring	Use follow-up monitoring through a method equivalent to, or better than, the original method used to detect the leak.
Track repairs that cannot be completed within a reasonable time	Keep track of outstanding repairs by using a 'delay of repair' list and set a date for the necessary repair.
Keep accurate records of leaks and repairs	Keep records of the findings from leak-detection surveys, including the dates of the surveys. For repairs, keep a list of the dates of each attempt at a repair, an explanation of the repair method, and how the repair was confirmed as being successful.
Analyze records of leaks and repairs	After several leak-detection surveys, review the information gathered to identify any components that persistently leak, evaluate the benefits of modifying or replacing those components with low-leak or no-leak alternatives, and carrying out preventive maintenance
Minimize venting through pumpdowns of pipelines and large vessels	When repairing or depressurizing equipment with a large volume of gas, minimize venting by reducing the pressure of the vessel before it is released to the atmosphere.
Minimize the volume that has to be depressurized	In some cases, hot taps and line stops (or line squeeze offs in the case of distribution plastic mains) can isolate a pipeline where there are no existing valves to isolate it, so minimizing the volume to be depressurized.

Mitigation Strategy	Key elements of the strategy
Reduce emissions arising from pigging by recapturing gas using a vapor-recovery unit	Install a vapor-recovery unit (or a flare) that services the tank receiving liquids from pigging, so reducing emissions. In some cases, a vapor-recovery unit can also be used to capture gas released from the pig launcher and receiver. (Also see the best-practice guide relating to venting)
Avoid emissions by using non-intrusive inspection methods, such as inline inspection tools	Using inline-inspection tools, such as a smart pig, can avoid some emissions that would otherwise arise from opening a pipeline or vessel. Although launching and receiving a smart pig can produce emissions, they are generally much smaller than the emission from blowdown and purge of a pipeline for a hydrostatic test.
Avoid emissions by making new connections to pipelines using hot taps	Hot taps can be used to connect branch fittings and permanent valves on an existing pipeline while it is still being used, so avoiding the need for a pipeline blowdown.
Reduce the number of blowdowns	Look for opportunities to co-ordinate repairs and routine monitoring or maintenance so that the number of blowdowns is minimized. This consideration is most effective for large facilities.
Where depressurizing is needed, consider flaring vented gas to reduce the emissions impact	Flaring converts methane to CO^2, which has a much lower potential for causing global warming. (Also see the best-practice guide relating to flaring)

Checklist

The following checklist allows you to assess your progress in reducing emissions through operational repairs. An operator may elect to implement these across all assets or begin only with a selected area that are a fraction of all assets.

	Checklist	Completed	Percentage of facilities involved
Repairing equipment leaks	✔ Keep accurate inventories that include estimates of emissions from leaking equipment, calculated using a method that includes the duration of any leaks that were discovered		
	✔ Have a leak detection and repair program on all facilities		
	✔ Make repairs as soon as practical after each leak-detection survey and prioritize the largest leaks		
	✔ Keep accurate and up-to-date records of leaks found and repairs carried out		
	✔ Regularly analyze records of leaks and repairs and take action where necessary		
Routine maintenance repairs	✔ Perform pumpdowns of pipelines and large vessels		
	✔ Minimize the volume of gas that has to be depressurized by using hot taps (when safe to do so) and line stops		
	✔ Reduce emissions from pigging by using a vapor-recovery unit to capture the gas that is released		
	✔ Avoid emissions by using non-intrusive inspection approaches, such as inline inspection tools		
	✔ Avoid emissions by using hot taps to make new connections to pipelines		
	✔ Reduce the number of blowdowns by coordinating operational repairs		
	✔ Where depressurizing means that makes releasing gas to the atmosphere necessary, consider flaring to reduce the emissions impact		

References

1 Photo Credit: Washington Gas, A WGL Company. https://www.washingtongas.com/safety-education/safety/natural-gas-safety

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4 US Environmental Protection Agency, Natural Gas STAR Program, 'Recommended Technologies to Reduce Methane Emissions', Available at www.epa.gov/natural-gas-star-program/recommended-technologies-reduce-methane-emissions

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7 PG&E, 'Pacific Gas and Electric Company Natural Gas Leakage Abatement Report' June 15, 2022, https://docs.cpuc.ca.gov/PublishedDocs/SupDoc/R1501008/5139/486437880.pdf

8 Beltran et al, 'Methane Emissions from Gas Residential Meter Set, PG&E', January 2021, https://publicadvocatesprodtemp.cpuc.ca.gov/-/media/cpuc-website/divisions/safety-policy-division/documents/day-1-slide-4---pgande---meter-set-emissions_jan2021_corr.pdf

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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.