Integrity Management – Continuous Improvement (IMCI) 2.0:

Managing Methane Emissions from Integrity & Maintenance Work on Natural Gas Transmission & Storage Assets

An INGAA White Paper

August 2, 2023

Table of Contents

Executive Summary

The natural gas industry has been on the forefront of developing and implementing cost-effective work practices and technologies that reduce methane emissions. This white paper provides a discussion of best practices for reducing methane emissions from pipeline integrity and maintenance-related work. Insight is provided on strategies to prevent emissions events and to mitigate resulting methane emissions if an event occurs. This paper breaks down emissions sources into three main categories – blowdowns, venting, and leaks – and their relationship to integrity and maintenance work.

Natural gas transmission and storage companies must consider situation-specific factors when evaluating how to implement these best practices. Consideration must be given to safe work assurance, environmental impact, site-specific operating conditions, customer requirements, community relations, and economic limitations. Due to these factors, emissions reduction best practices cannot be universally applied. However, through practical and thoughtful evaluation, companies can maintain safe, reliable, and efficient operations and act as good community partners and environmental stewards.

Additional resources and emissions reduction concepts that go beyond the scope of pipeline integrity and maintenance work have been shared at the end of this white paper.

The aim of this document is to provide best practices for reducing methane emissions from pipeline integrity and maintenance work within the natural gas transmission and storage industry. The intention of providing this information is to encourage operating companies to consider how these best practices and technologies can help them better understand and reduce their operational emissions and achieve their goals.

Managing Emissions from Integrity & Maintenance Work

As the natural gas industry takes strides to decarbonize the energy supply chain, a key focus is reducing methane emissions while conducting pipeline integrity and maintenance-related work. Best practices have been developed to reduce these emissions, primarily from blowdowns and venting. These best practices hold pipeline and human safety, asset integrity, and regulatory compliance paramount, with the added considerations of system reliability, community and customer impact, and cost-effectiveness. The primary component of natural gas is methane, which has a higher global warming potential than carbon dioxide and is thereby more climate forcing and the focus of this white paper.

This white paper is a collection of considerations, techniques, and technologies for managing methane emissions during integrity and maintenance work for natural gas transmission and storage systems. It is intended as a guideline and reference of best management practices for pipeline operators to consider for the prevention, reduction, and control of methane emissions.

Defining Integrity & Maintenance Work

Integrity work includes activities that are conducted to periodically inspect, monitor, maintain, or improve the integrity of a natural gas pipeline or facility. Transmission pipeline integrity work

includes integrity assessments (e.g., in-line inspection (ILI) runs, hydrotests, Direct Assessments, other surveys), repairs of anomalies or other conditions identified by assessments, repair or replacement of protective coatings, facility modifications (e.g., valve replacements, pig trap installations or modifications), installation and maintenance of cathodic protection systems, and more. Some activities can be accomplished without interrupting pipeline pressures or flows, while others require complete evacuation of gas in the pipeline or a partial reduction of pressure.

Maintenance work has a broader scope and includes both preventive and reactive maintenance. A few examples of maintenance activities that may result in methane emissions include class change replacements, maximum allowable operating pressure (MAOP) confirmation projects, leak repair programs, and scheduled equipment inspection and repairs. Maintenance occurs on the pipelines themselves and the facilities and appurtenances located within the pipeline system(s).

Why Integrity & Maintenance Work Is Necessary

Pipelines are among the safest and most reliable, efficient, and cost-effective modes of transporting large quantities of energy products essential to our economy and daily life.

A pipeline operator's integrity management program exists to protect people, property, and the environment from pipeline failures, comply with all applicable regulations, and maintain reliable service. Integrity and maintenance work, as defined above, are an integral part of integrity management programs and is a key component to achieving our goal of zero incidents.

Why Emissions Occur During Integrity & Maintenance Work

Methane emissions can occur in different phases of pipeline operations, but three primary sources are more closely related to integrity and maintenance programs: blowdowns, venting, and leaks. Blowdowns occur during some integrity and maintenance work because gas needs to be evacuated from the pipeline segment to complete the work safely. Integrity and maintenance work, governed by PHMSA, has defined timelines for some activities, which may necessitate complete gas evacuation or pressure reduction for safety. Blowing down to atmosphere is frequently the fastest way to accomplish this. In certain circumstances, it is the only viable option for safely removing gas from the pipeline segment. After work is complete, the equipment is purged of air, and natural gas is reintroduced back into the equipment to return it back to normal operation. These processes may result in methane emissions being vented to the atmosphere. Finally, there is the possibility of leaks occurring when operating the pipeline system. While most of these methane emissions occur at a small leak rate during normal operations, identifying these small leaks is used to prioritize maintenance work and implement leak prevention measures. These methane emissions sources and reduction concepts are discussed in more detail throughout this document.

Defining Blowdowns, Venting, and Leak Emissions

Methane emissions are created from both normal operation of natural gas assets and during execution of integrity and maintenance activities. While the primary scope of this document is reducing methane emissions *resulting* from integrity and maintenance activities (i.e., blowdowns and venting), some discussion is provided on *preventing and mitigating* operating conditions that lead to integrity and maintenance work and thereby reducing methane emissions. The focus on

blowdowns, venting, and leaks is largely driven by the nature of their direct release of natural gas to atmosphere if not controlled.

In most cases, blowdowns are intentional events that result from planned work. However, in some cases, blowdowns must be executed without extended planning to eliminate a potential hazard, maintain safe operation of the pipeline, and to meet regulatory requirements. In these cases, pipeline operators may implement innovative methods to reduce emissions while balancing the needs of safe and reliable pipeline operation and service to customers. The extent and duration of a service interruption can be significantly impacted by the process and equipment utilized during a blowdown. Natural gas blowdowns are defined in this document as the evacuation of natural gas from an isolated section of pipeline or equipment into another pipeline or piece of equipment, control device, or the atmosphere. Since a blowdown occurs on an isolated segment, the maximum potential emissions from a blowdown event is the quantity of gas within that segment at the operating pressure at the time of isolation.

Venting of natural gas occurs intentionally as a result of several operational functions and safe work practices. Unless controlled, vented gas typically exhausts to the atmosphere. For example, natural gas may be vented from gas-driven controllers during normal operations or during purging of equipment during maintenance. Depending on the function, some of these emissions from gas-driven controllers may be able to be eliminated with controller upgrades to zero-emission devices (i.e., air or electric driven). Modern work practices and equipment upgrades may be available to capture and control these emission sources and even reuse this vented gas. Natural gas venting is defined in this document as a release of gas from a pressurized or atmospheric piece of equipment or control system that is not isolated. Venting also includes the use of gas to purge the air/gas mixture out of the pipeline segment or equipment. Venting mechanisms are designed to release a specific quantity or rate of gas necessary for the intended operation.

Leaks may occur on natural gas pipelines and facility assets during operation. Natural gas leaks are unintentional releases and are considered fugitive emissions. Most leaks in natural gas transmission and storage systems emit a low volume of gas to the atmosphere. It is important that operators have procedures to identify, evaluate, and mitigate leaks in a timely manner.

Pipeline and facility integrity management programs are put in place to verify pipeline and facility integrity is being properly maintained, which prevents and minimizes emissions from leaks. Proactive programs include regular cleaning, in-line inspection, close interval surveys, facility direct assessment, and sophisticated data analysis and integration. To quickly identify and repair leaks, operators may implement regular pipeline and facility surveys using various leak detection technologies and develop processes to manage repair work.

Limitations and Successful Strategies

When planning and completing integrity or maintenance work on pipeline assets, operators should consider various options to achieve the goal of managing emissions without compromising personnel and public safety, pipeline integrity, interruption of service to critical deliveries, or regulatory compliance. Circumstances including type of facility, operating pressures, location, natural surroundings, activity being performed, regulatory requirements, safety protocols, and other factors contribute to the determination of applicable and/or an optimal approach to managing emissions for a given activity.

Operators need to account for various constraints that can limit methane emission reduction methods available as well as some that can result in more methane emission-creating activities. Below are some constraints and limitations that operators should understand and navigate while developing emission management strategies for integrity and maintenance work.

Prescriptive Requirements

Prescriptive requirements, such as defining specific methods or technologies to use, can be counter-productive to the overall goal of reducing emissions. A “one-size fits all” approach can result in scenarios where opportunities for more effective, more economical, or safer methods of managing emissions are restricted. Additionally, some methods may be optimal at a certain scale, but ineffective otherwise (i.e., recompression may be logical at certain pressures and volumes of gas, but not practical, effective, or emission-efficient at some lower pressures/volumes).

Prescriptive requirements may have a negative impact by constraining innovation and technological advancements. While clarity of an end goal is important, allowing for flexibility in the method of achieving such goal will promote innovation, creativity, and technological advances.

Regulations

Federal and State regulations do not always align with reducing emissions. Some regulations that focus on the safety and integrity of pipeline and storage facilities have time-dependent requirements, such as repairs of identified corrosion defects, that may limit the opportunity or options for managing emissions. Others, such as class location change and integrity assessment requirements can result in pipeline testing, inspection or replacements that result in blowdowns. Similarly, underground gas storage well integrity inspection and repair requirements can create additional blowdowns or venting.

Some regulatory requirements aimed at reducing emissions may have the opposite effect, such as stringent time requirements for repairing minor leaks or minimum reporting thresholds. These requirements can lead to additional blowdowns when the regulation does not allow time for scheduling the repair coincident with other maintenance work. These additional blowdowns may result in higher total emissions than the leak rate over the extended timeframe.

In all instances, operators should consider available options to manage emissions, without impeding safety, integrity, or compliance.

Available Technologies

Operators should utilize available technologies and practices, when applicable. New and emerging technology that assists with reducing emissions may not always be compatible with current operational equipment but should be considered when evaluating planned equipment upgrades or replacement. Emissions management strategies, rules, and regulations should include adaptability for advancement of technology, as well as new data and research that becomes available and may be feasible to implement.

Specific Conditions

The type of work being performed and the specific conditions where venting of gas is necessary should be factored into the method used to manage methane emissions. Some circumstances may allow for multiple options to manage emissions. In other situations, some emission reduction options may not be practical or safe, such as the use of a flare in a heavily forested area or use of portable compression where no viable outlet for compressed gas exists. Among other things, accessibility, weather conditions, and safety-related or regulatory driven time constraints may also impact the process and extend outage timelines. Flexibility of determining the optimal path to reduce methane emissions on a case-by-case basis, within the framework of an overall emissions reduction strategy, is important to the success of the strategy.

Goals for Managing Methane Emissions

In establishing thresholds for benchmarking effectiveness of managing emissions during integrity and maintenance work, consideration of existing commitments and data is important. Conflicting or varying thresholds can create confusion or misleading results. Strategies for managing emissions should align with INGAA's existing methane commitments (Methane Emissions Commitments - INGAA). Similarly, existing data available through industry trade groups and government agencies can be valuable resources.

Reducing Emissions

Operators invest significant time, resources, and efforts to thoroughly develop and implement integrity and maintenance programs that promote the reliability and safety of pipeline systems and minimize impacts to the environment and communities. The natural gas industry has been on the forefront of developing and implementing innovative and cost-effective work practices and technologies that reduce disruptions and emissions while enabling energy affordability. Many factors must be considered when determining the most prudent gas handling plan, including safe work assurance, environmental impact, site-specific operating conditions, customer requirements, community relations, and economic limitations. This section outlines emissions prevention and mitigation practices currently being utilized by operators, and the extent in which they are considering situation-specific factors to best serve their stakeholders.

Blowdowns

Integrity and maintenance activities may require the transmission pipeline or specific facility equipment to be blown down to allow inspection tools or test medium to be placed into the pipeline, to conduct repairs or cutouts, or to allow maintenance to be conducted in a safe manner. When executing a blowdown, natural gas is evacuated from the pipeline or equipment and routed to a safe location. This gas may be routed back into the process or pipeline system, a combustion control device, or the atmosphere. This section outlines the best practices the natural gas industry has identified to reduce emissions associated with blowdowns.

Compression Facility Assets

Preventing Blowdowns

Compressor station blowdowns are regulated and reported under multiple EPA programs. Blowdowns are necessary for maintenance and integrity work on facilities that require opening the pipeline compression facility equipment to atmosphere to conduct and/or safely perform the work. These activities may be the result of regular, scheduled work, or abnormal operating conditions. Common work types include compressor and engine maintenance, filter changeouts, integrity and emergency system testing. Operators have identified and implemented practices to reduce the number of blowdowns to maintain a reliable and safe system.

A particularly effective method to prevent the number of blowdowns is simply to extend the time between necessary blowdowns. This can be accomplished by utilizing alternate maintenance and integrity practices and by upgrading equipment and technology.

Integrity and Maintenance Work Practices

Across the natural gas industry, companies are implementing best work practices that reduce blowdown frequency and/or blowdown volume. An effective practice for reducing blowdowns from maintenance work is to implement a leak detection and repair (LDAR) program at a facility. This practice allows a company to effectively detect, repair, and track instances of fugitive emissions that can extend the useful life of a piece of equipment and increase the time between maintenance events that require a blowdown.

Consider an example. A leak detection and repair (LDAR) program may be implemented for facility valves, connectors, and other components to effectively reduce the probability of equipment failure and blowdowns. This can be accomplished through a series of activities designed for that facility, and may include:

- Conducting annual leak surveys
- Attempting the repair of all leaking components immediately
- Replacing unrepairable leaking components in a set period from the time of discovery
- Tracking performance over time through ongoing surveys
- Developing and implementing an enhanced maintenance plan

Leak surveys should be conducted using the most appropriate technology or layers of technology, depending on the situation. Types of leak detection methods are included below. More detail on advanced detection technologies is included later in this document.

- Audio, visual, olfactory (AVO) surveys
- Optical gas imaging (OGI) cameras, Method 21, gas sniffers, or soap surveys
- Optical gas imagery/infrared cameras
- Flyovers of pipeline rights-of-way, facilities, and/or storage wells
- Satellite detection of emissions over large areas
- Other advanced detection technologies

Coordination of routine and planned maintenance to reduce the number of blowdown events does not only reduce emissions generated, but it may also cut downtime. Reducing downtime for a facility or even a single unit may have a measurable impact on reliability metrics and deliverability. In some cases, minor equipment modifications, control logic, or Standard Operating Procedures (SOP) may be written in such a way to avoid releasing blowdown emissions when testing the Emergency Shut Down (ESD) system. These and other methods of coordinated preventative maintenance and controls design may help notably reduce the number of blowdowns necessary to complete integrity and maintenance work.

Upgrades to Equipment and Technology

Advancements in equipment design and technology have also provided opportunities to reduce the need for blowdowns. Compressor packages have particularly advanced in this arena, but opportunities exist across many equipment and facility types. Examples of equipment and technology upgrade opportunities are listed below. Site-specific conditions must be considered when evaluating potential emissions reduction technologies.

- Upgrade and/or Reduce Equipment and Components
    - Modernize compressor drivers to higher reliability units that require less maintenance and/or that have improved combustion efficiencies

    - Replace compressor cylinder unloaders on older reciprocating compressors
    - Eliminate or downgrade unnecessary/oversized equipment or systems
- Compressor Starts and Stops Initiated due to Maintenance
    - Upgrade compressor engine operational controls and ancillary equipment to maintain a pressurized hold on non-operating compressors (pressurized standby) instead of blowing down
    - Install vent gas recovery systems
- Preventative Maintenance
    - Strategically inspect and consider replacement of consumables during scheduled downtime events ("schedule-based" maintenance)
    - Upgrade to dry gas seal recompression on turbine compressors to extend the time between maintenance-related blowdowns

Mitigating Blowdown Emissions

In some cases, a blowdown cannot be prevented and reducing emissions is dependent on mitigation practices and technologies. The industry has developed innovative techniques to reduce the quantity of emissions in the event of a blowdown. Some of these methods and technologies are described below. Site-specific conditions must be considered when evaluating potential emissions reduction technologies.

- Replace natural gas starters with air, nitrogen, or electric starters to reduce emissions during compressor starts and stops initiated due to maintenance
- Blowdown Vent Gas Recovery
    - Install a blowdown vent gas recovery system that captures blowdown gas and reroutes it into a lower pressure fuel source, suction header, etc.
        - Able to be used for compressors and other equipment types (e.g., facility piping, filters, dehydrators, contactors, pig traps)
        - May be combined with recompression to push recovered gas into higher-pressure systems
- Combustion Control of Blowdown Gas
    - Install a blowdown vent recovery system that captures blowdown gas and routes it to a combustion control device (i.e., flare, combustor, thermal oxidizer)
        - Both permanent and temporary combustion controls may be used
        - Location-specific permission may be required prior to utilizing this approach
- ESD Blowdown Minimization
    - Install capped blowdown stacks that can be sealed during ESD system testing to minimize the amount of gas lost to atmosphere. The caps can be removed during normal operations to allow these stacks to vent in the event of an unplanned emergency.

Pipelines

Preventing Blowdowns

Integrity and maintenance work for natural gas pipeline assets is diverse in its methodology and physical span. Blowdown emissions, especially from large transmission pipelines, make up a notable portion of the direct methane emissions from the natural gas industry. Blowdowns are necessary for projects such as in-line inspection runs, hydrotests, anomaly repairs or other

conditions identified by those assessments, facility modifications to perform assessments (valve replacements, pig trap installations or modifications, class change replacements), and MAOP reconfirmation projects.

Activities such as pigging are regularly used as preventative maintenance to clean the pipelines and as a part of integrity management programs. Pigging activities cover a large physical distance on a linear pipeline asset but require pig traps to be blown down to launch and receive pigs at specific locations. Additionally, some integrity assessment in-line inspection (ILI) runs require the venting of gas to obtain the correct device speed for the inspection. By utilizing pig traps, this can greatly minimize the amount of gas blown down during pigging activities. Other types of maintenance work, such as those listed above, require a pipeline segment to be evacuated of natural gas to conduct the assessment and maintain a safe working environment. The natural gas industry has developed innovative solutions to eliminate or reduce emissions from blowdowns related to these activities.

Integrity & Maintenance Work Practices

Work practices can be effectively utilized to reduce the number of blowdowns from pipeline integrity and maintenance activities. Several of these methods are detailed below. Further joint industry efforts are underway to pursue research and regulatory approval for additional repair options.

- Develop an in-line inspection and data analysis program that tracks the progression rates of anomalies to aid in the timing of pipeline integrity work
- Use external reinforcement material, including sleeves and composite wraps, to repair pipelines instead of replacements, when possible
- Complete Pipeline Patrols
    - Pipeline patrol methods include walking, driving, flying, or other appropriate means of traversing the right-of-way.
    - Advanced leak detection technologies may make this work more efficient and cost-effective
- Coordination of multiple projects/shutdowns:
    - When planning work on a pipeline, other proposed work on that pipeline should be considered. There are occasions when a separate shutdown/blowdown can be avoided because work is combined while the line (or compressor unit) is already out of service.

Upgrades to Equipment and Technology

Upgrades to transmission pipeline infrastructure have also been proven to reduce the need for blowdowns.

- Use hot taps for in-service pipeline connections instead of evacuating the pipeline
- Maintain cathodic protection (CP) system to reduce the risk of corrosion; completing Close Interval Surveys (CIS) and other CP evaluations on the pipeline systems can verify that adequate CP is being applied to the entire length of the pipeline)
- Upgrade pipelines to be piggable so that integrity assessments can be completed with in-line inspection (ILI) rather than alternative methods (hydrotesting) that may have larger emissions volumes
- Continue to develop the acceptance of alternative materials, allowing the installation of composite pipelines that are not susceptible to integrity threats such as corrosion and cracking. Composite pipelines can include built in sensors that are capable of real time detection and monitoring for leaks and mechanical damage.

Mitigating Blowdown Emissions

Mitigating or reducing the emissions that result from the blowdown of a pipeline segment utilizes many of the same techniques as a natural gas facility. A variety of strategies can be used to reduce the pressure in the blowdown segment, which ultimately reduces the volume of gas released to the atmosphere. Building strong and collaborative relationships with upstream and downstream customers and the communities around pipeline assets is essential to maximizing the emissions reduction potential of these solutions.

Integrity & Maintenance Work Practices

- Lowering pipeline pressure before maintenance work
    - Reduce or "drawdown" pressure in the pipeline segment using downstream compression or by moving the gas into a pipeline at a lower pressure
    - Downstream customers may also be able to drawdown pipeline pressure, creating a dual benefit of reducing emissions and limiting service downtime
- Purging a portion of the natural gas out of the pipeline and into other equipment with nitrogen or pig prior to a blowdown
- Emerging technologies and practices
    - Utilize Engineering Critical Assessments (i.e., ECA, Mega Rule MAOP-Reconfirmation Method 3) as an alternative assessment method to pressure testing (e.g., hydrotest).
        - An ECA establishes the material strength and MAOP of a pipeline segment. The ECA method is accomplished by gathering and integrating existing information (e.g., inline inspection data, prior pressure tests, prior integrity assessments), identifying defect type/size, and analyzing the interaction of defects to determine the most limited predicted failure pressure for the pipeline segment without the need to perform a pressure test.
    - PHMSA allows the use of "other technologies" not specified in 49 CFR 192 regulations; however, operators must provide 90-day advanced written notification to PHMSA pursuant to 49 CFR 192.18.

Upgrades to Equipment & Technology

Gas handling and control technologies have been developed and successfully implemented to mitigate the quantity of emissions when blowdowns are necessary.

- Controllers on Main Line Valves (MLV)
    - Installation of additional main line valves on long stretches of natural gas pipelines allows shorter pipeline segments to be isolated for a blowdown
    - Installation of remote pressure monitoring and remotely controlled valves (RCV) on the pipeline allows the operator to detect and act upon potential pipeline events more quickly
- Mobile Compression
    - Pressure can be reduced using mobile Compression, where compression units are brought onsite to reduce the pressure of a subject pipeline segment
    - This technique is scalable when multiple parallel units are used
    - Small scale recompression may be an option to reduce blowdown emissions at remote locations or those within communities

    - Utilization of mobile compression is subject to project specific parameters; the final pressure achieved is subject to the time the compression operates and can increase the customer service interruption
- Combustion control
    - Routing the natural gas to a combustion control (e.g., flare, enclosed combustor, thermal oxidizer) converts the methane to carbon dioxide via combustion (carbon dioxide is less climate-forcing than methane by mass)
    - Combustion units can be installed in fixed locations or made portable
    - Combustion control can increase the duration of a service interruption due to lower evacuation rates associated with this technology
- Line stop and bypass
    - By utilizing a line stop and bypass, the length of pipeline segment being blown down is minimized
    - In-line, line stop tools can be used to minimize the length of isolated and blown down sections of pipeline where replacements are required
        - Note: Installation of line stops adds items to manage in pipeline integrity programs
- Data analysis
    - Pressure, flow, and temperature monitoring equipment can be integrated into control room operations, which may allow for near real time detection of significant releases
    - Pipeline system digital twins allow for more efficient and economical operations through machine learning, such as optimizing compressor utilization and maintenance activities to minimize system downtime and blowdowns
- Recover gas from pipeline pigging operations similar to the methods above, including blowdown gas recovery, injection, recompression, and control

Storage

Preventing Blowdowns

Integrity management of a storage field is one of the primary mechanisms for preventing unintended emissions from a potential failure, which could result in significant volumes of natural gas being released to the atmosphere. Typical integrity management and maintenance activities for storage fields include downhole well logging (wireline inspections), mechanical integrity testing, and well workovers, all of which may require some magnitude of gas blowdowns to allow safe execution of the work activity. While federal regulations require integrity management of storage fields, states may have their own unique requirements that may result in more emissions than other jurisdictions.

Due to the physical configuration and nature of storage field facilities, integrity and maintenance work is well established although somewhat constrained in terms of available techniques and practices. Improvements in assessment and monitoring technologies, such as utilizing Light Detection and Ranging (LiDAR) for subsidence monitoring or remote leak detection equipment for monitoring well bore integrity, can provide operators with various data sources that can be integrated to better plan the scope and timing of storage field maintenance activities, with the potential benefit of reducing the frequency of well entries and associated gas emissions.

In the discussion of transmission pipeline blowdown prevention, the work practices and technologies upgrades were combined.

- Advanced diagnostics and data analysis, such as quantitative risk assessment (QRA), can assist with more targeted maintenance activities based on need rather than prescriptive

scheduling. This can safely extend the durations between any required emissions for reservoir maintenance.
- Remote leak detection equipment integrated into the control room can detect potential leaks or other conditions requiring maintenance, providing additional data into maintenance planning as well as enabling faster response to any abnormal conditions.

Mitigating Blowdown Emissions

Methane emissions associated with storage field integrity management and maintenance are typically not significant as compared to gas volumes associated with other pipeline maintenance and integrity work. However, operators utilize the following work practices and technologies to minimize blowdown volumes wherever possible:

- Flaring of natural gas during storage projects is conducted to minimize methane emissions where possible. For example, it can be performed after a temporary bridge plug is set in a storage well prior to installing a new wellhead. The remaining gas in the wellbore is then flared using a portable flare trailer which includes a liquids separator to catch any free liquids. State specific permission may be required prior to utilizing this approach.
- Temporary compression may be feasible to use on storage wells to compress the gas from the well into the adjacent pipeline.
- Nitrogen can be used to expedite the time needed to flare by pushing the natural gas from the wellbore towards the flare.
- Withdrawing gas from a storage field as well as isolating the field from connected pipelines can reduce the volume of gas within the storage medium prior to any maintenance work requiring blowdowns.
- Drilling mud may be used during downhole rework projects to control storage pressure and prevent gas loss.
- A mechanical lubricator bolted to the top of a wellhead valve may be used to insert wireline logging tools under pressure into the storage well thus minimizing gas loss.
- Flow testing, while more specific to construction and commissioning of a new storage well, can require large volumes of gas to be released in order to determine the flowing capacity of a storage facility. Flaring can be used to minimize the emissions intensity.
- Utilizing multiple inspection technologies in the same tool string during well logging can reduce the amount of well entries needed, and therefore reduce the volume of gas released to atmosphere required during well logging activities.

Venting

This section lays out common equipment types and causes of venting of natural gas during integrity and maintenance activities and best practices the natural gas industry has identified to reduce methane emissions.

Compression Facility Assets and Pipelines

Preventing Venting

The controlled venting of natural gas may occur because of intentional operational control, to maintain safe operating conditions, or to safely complete integrity and maintenance work. This section combines the strategies for reducing methane emissions from venting for natural gas facilities and natural gas pipelines as these strategies overlap significantly.

Integrity and Maintenance Work Practices

Across the natural gas industry, companies are implementing best work practices that reduce the need for venting to occur.

- Verifying proper setpoints for overpressure protection systems so that natural gas is not unnecessarily vented
- Regular preventative maintenance of overpressure protection to confirm proper operation
- Regular preventative maintenance of pneumatic controllers and valves to confirm proper operation and appropriate setpoints
    - Effective design and operation of level, temperature, and pressure controllers may all impact emissions performance of venting sources
    - Ensuring that a control device and valve react as designed (i.e., prevent stuck-open dump valves)
- Evaluate and replace rod packing on reciprocating compressors ("condition-based" replacement) to reduce seal gas venting
- Include vent sources in a maintenance program to identify potential instances of improper operation of venting equipment

Upgrades to Equipment and Technology

Advancements in equipment and control design have also provided opportunities to reduce the need for venting to occur. Several of these preventive technologies are listed below.

- Eliminate or downgrade unnecessary/oversized equipment or systems
    - Note: This may require formal abandonment of capacity or FERC assets
- Replace relief valves with monitor regulators or pressure switches, as appropriate, to reduce/prevent emissions where feasible
- Design overpressure protection to effectively identify and relieve pressure throughout a natural gas system and limit venting quantity
- Optimize the control technologies utilized at a facility and along a pipeline when existing controls need maintenance or replacement
    - Replace pneumatic controllers with no-bleed controllers (i.e., electric, air-driven)
    - Evaluate the use of intermittent bleed controllers versus continuous bleed controllers
    - Replace high-bleed pneumatic controllers with low-bleed pneumatic controllers if unable to use no-bleed controllers
    - Design new facilities to minimize controller venting emissions by using no-bleed and intermittent controllers
    - Utilize electrically operated controllers
- Replace natural gas-driven pneumatic pumps with alternative pumps – instrument air, solar-charged direct current (DC) electric pumps, and standard alternating current (AC) electric pumps – when existing pumps need maintenance or replacement
- Evaluate and replace rod packing on reciprocating compressors ("condition-based" replacement)

Mitigating Venting Emissions

Where venting gas cannot be eliminated, the emissions may be able to be mitigated. The industry has developed innovative techniques to reduce the quantity of emissions from operations and safety systems that do require venting. Some of these methods and technologies are described below.

Integrity and Maintenance Work Practices

One of the primary sources of vented gas that can be mitigated through work practice are purging emissions that are the result of integrity and maintenance work. Effective techniques for reducing vented emissions from purging will vary greatly by asset type and configuration.

- Purging to put into service
    - After integrity or maintenance work is completed that allowed air to enter a piece of facility or pipeline equipment, the air must be purged, and equipment filled with natural gas
    - If using natural gas to purge, an operator may use the following techniques to reduce vented emissions
        - Do not dry the equipment with natural gas
        - Use the minimum safe purge pressure (include safety factor to ensure turbulent flow)
        - Minimize purging hold time once 100% natural gas is reached
            - Minimum duration should be established for safety to ensure all air has been removed from the pipe
            - Consider adding a not-to-exceed duration without approval
        - Utilize inert gases and pipeline pigs to complete the purge
            - Note: The utilization of inert gases will require additional steps in the gas handling plan to manage inert gas content in the pipeline and ensure that no inert gas remains in the natural gas stream

Upgrades to Equipment and Technology

The primary technique for mitigating emissions while the venting process occurs is to recover and control the vented natural gas. Through proper recovery and control, the time between maintenance activities requiring emissions may be extended. More detail on the sources and options for control are provided below.

- Vent Gas Recovery
    - Install a vent recovery system that captures vented gas and reroutes it into a lower pressure fuel source, suction header, or other equipment
    - May be combined with recompression to push recovered gas into higher-pressure systems
    - Vent gas recovery and control methods can be used on several venting sources
        - Compressor seal vents (i.e., rod packing and dry gas seals)
        - Gas-driven pneumatic controllers
        - Pneumatic pumps
        - Atmospheric tank operating, working, breathing, and overpressure venting
- Combustion Control of Vented Gas
    - Install a vent recovery system that captures vented gas and routes it to a combustion control device (e.g., flare, combustor, thermal oxidizer)
        - Both permanent and temporary combustion controls may be used
        - Location-specific permission may be required prior to utilizing this approach
- Flash Gas Control
    - Glycol dehydrator and acid gas removal units produce flash gas as a part of their regeneration process

- Flash gas, which is high in methane, can be captured and routed to the unit fuel line or a separate combustion control device

Storage

Preventing Venting

The controlled venting of natural gas may occur because of intentional operational control, to maintain safe operating conditions, or to safely complete integrity and maintenance work. Strategies to prevent venting from storage operations are consistent with those for other asset types. Please consult the Compression Facility Equipment and Pipelines section above for a description of venting prevention techniques.

Mitigating Venting Emissions

Venting is common in storage field integrity management and maintenance, typically resulting in minor emissions volumes from normal operations including valve operation and maintenance and monitoring the well bore annulus for pressure buildup, as examples. As noted above, certain states may have unique requirements for storage facility operation, integrity management, and maintenance that may result in more emissions, such as requiring an annulus vent to remain open which could otherwise be closed and monitored with remote instrumentation.

Integrity and Maintenance Work Practices

Activities performed to monitor for and reduce storage field venting related emissions may include:

- Perform directed inspection and maintenance (DI&M) at storage well sites, including frequent well head leakage surveys on valves and other related equipment (AVO, instrumented, etc.)
- Instrumented monitoring of the well bore annulus for the presence of gas, which could indicate a potential mechanical integrity issue of the tubing and casing strings. Some jurisdictions require the annulus to be continuously vented to the atmosphere.

Upgrades to Equipment and Technology

Upgrading control systems and emissions solutions when existing equipment needs maintenance or replacement can be a cost-effective strategy to reduce emissions from venting sources.

- Replacing well head and associated surface facility gas-powered, valve actuators with air-powered or electric motor actuators.
- Routing vented facilities into source control or vapor recovery piping to be either flared or recompressed into other facility piping.

Leaks

Leaks are unintended and uncontrolled emissions from natural gas equipment. These emissions are often referred to as fugitive emissions in environmental policy and regulation. Fugitive emissions may occur on natural gas equipment during normal operations and can be reduced through various preventative and mitigative practices. However, fugitive emissions do not typically occur as a direct result of integrity or maintenance work and are not covered by this white paper in detail. For more information on fugitive emissions and normal operations, you may reference the links in the Additional Resources section.

Additional Considerations in Decision Making

Safe work practices shall always be held paramount for the wellbeing of operators, others present at natural gas facilities, and the surrounding communities. Therefore, it is essential that safe work practices be well designed, trained on effectively, and executed properly. The work practices and technologies in this white paper can be utilized to reduce emissions associated with this work, but several other factors should be considered when selecting a plan of action.

Site-specific operating conditions such as available workspace, weather events, site conditions, and proximity to sensitive areas should be considered. Some natural gas facilities may have limited clearance or available space to install or bring in temporary mitigation equipment. An operating company should consider their asset distribution and configuration to determine what preventative and control measures are available to them. Further, some natural gas facilities and pipelines may be near communities or other sensitive areas. The use of portable recompression equipment or flare may cause a noise or light nuisance or general community discomfort.

Customer requirements such as system reliability or maximum outage periods may create additional obstacles to the ability to reduce blowdown emissions. Some emissions mitigation techniques such as drawdown and recompression take more time than a simple blowdown. Customers should be engaged to identify both the opportunities to reduce emissions and limitations on schedule. As meeting the needs of customers and the communities they serve is of utmost importance, communicating and partnering with your customers to reduce emissions and maintain reliability is crucial.

Another notable consideration is the economic cost of implementing both prevention and mitigation methods. As solutions are evaluated for their capacity to reduce emissions, cost-effectiveness must be built into the analysis. Several of the work practices discussed may be implementable at a low cost to the operator and should be considered for broad application. However, the modernization or addition of equipment to prevent or reduce the regularity of emissions events or quantity of emissions can be cost prohibitive. A company should individually evaluate natural gas facilities to determine the relative cost and benefits of emissions reduction work practices and technologies.

Reducing methane emissions from integrity and maintenance work requires thoughtful analysis of the operational, relational, and regulatory conditions of a facility or pipeline and cannot be blanketly applied. Natural gas facility operators should be encouraged to be innovative and agile as overly prescriptive integrity and maintenance requirements may result in increased emissions-generating events, accrued costs, and service disruptions. Operating companies should seek to understand the emissions reduction and reliability goals of their customers and the impacts of their operations to communities in which natural gas assets are located. Further, companies must be cognizant of the local and state requirements and regulations related to energy services and emissions. Leveraging the experience and innovation of local operators and building relationships with communities and customers will allow your company to be nimble and effective in decision making.

Technology and Work Practice Focus Topics

LDAR and LiDAR Programs

- The Leak Detection and Repair (LDAR) program is a emissions survey that primarily utilizes a specialized optical gas imaging camera and Method 21 sensors to survey leaks. This

program is used in a mandatory capacity designated by state and federal regulations, as well as voluntarily, to effectively identify and remediate leaks in an efficient manner. LDAR programs are designed to identify and locate leaks but may not provide quantification.

- The Light Detection and Ranging (LiDAR) program is a flight-based or handheld practice that also utilizes detection technology to survey leaks by utilizing flight patrols and imaging equipment. The LiDAR program is a process of determining ranges (variable distance) by targeting an object with a laser and measuring the time for the reflected light to return to the receiver. Methane emissions will alter the time it takes for light to be reflected thus enabling leaks to be detected. LiDAR programs are designed to identify and locate leaks but may not provide quantification.
- Information is gathered and then entered (either automatically or manually) into the appropriate database. If remediation is required, small or extremely small leak remediation should be completed in conjunction with other projects. Larger leaks may require a more rapid response to eliminate the leak.
- Leaks identified from these programs are repaired as soon as possible upon confirmation.
- Leak detection and quantification technology is advancing rapidly, and natural gas companies should evaluate their opportunities to leverage a mixture of solutions that make the identification, quantification, and reporting of fugitive emissions actionable.

Temporary Compression

- In some cases, compression is not needed when moving high pressure gas into lower pressure systems (such as a fuel line). This is an efficient way to minimize methane emissions and utilize gas for other purposes. In other cases, jumper lines and recompression are needed to move isolated gas from a lower-pressure system into a higher-pressure system.
- Temporary, and sometimes portable, compression can be utilized when logistically available, safe to operate, and when environmental impacts can be minimized. Temporary compression may be used to reduce line pressure prior to a blowdown that is required to complete integrity and maintenance work (e.g., conduct a pipe replacement, pressure test). Once the available gas in the system is minimized, the remainder can be vented to other control device or the atmosphere.
- There are various sizes of compression used depending on the project details. When possible, large- and mid-size temporary compression are used to support large pipeline drawdown projects. In some cases, small temporary compression may be used to drawdown launcher and receiver barrels, as well as other smaller volumes of natural gas. Applications of temporary compression will result in increased costs and extended outage times for projects. The relative impact on projects and customers can be significant.
- Temporary and portable compression has a great potential to reduce emissions from integrity and maintenance work. In general, the greater the volume to be recompressed, the more economical it is to utilize this technology. Note that recompression does take longer than a simple blowdown and project teams should build the extended time and impacts to the customer into the project plan.
- Intentional blowdowns of natural gas will take place in instances where temporary compression or another control strategy is unavailable or during emergency response activities where timely pressure reduction is required for public safety.

Reducing Emissions Beyond Integrity & Maintenance Activities

Other Opportunities for Methane Reduction

While INGAA's Climate Statement focuses on direct emissions from transmission and storage operations, members may also elect to adopt other goals such as improving leak detection and quantification capabilities, raising awareness about the location of pipelines to avoid third-party hits/damages, reducing Scope 2 greenhouse gas emissions (indirect emissions from the generation of acquired and consumed electricity, steam, heat, or cooling – GHG Protocol Scope 2 Guidance, 2015), supporting research and development of new technologies, or reducing emissions in other parts of the value chain. Other opportunities to promote methane emissions reductions include:

- Utilizing renewable power where it is sufficient and safe to power equipment
- Rerouting dehydrator vents to reboilers or for beneficial use
- Installing real-time methane monitors
- Using control devices rather than routing natural gas to the atmosphere
- Participating in or supporting research and development of new technologies, including the application of carbon capture, utilization, and sequestration (CCUS), hydrogen blending and other evolving combustion technologies
- Promoting the national Call Before You Dig (811) program
- Educating excavators and promoting industry-wide best practices for digging
- Taking steps to improve locating techniques, maps, and records

Additional GHG Reductions

Aside from the actions listed above that may help reduce or minimize methane emissions, companies may want to consider taking steps to reduce other GHG emissions from combustion or to lower the carbon intensity of the fuels they transport. The timeline to implement measures to reduce GHG emissions will vary from company to company and some options listed below may not be consistent with a given company's business plan. Potential options to reduce GHG emissions may include:

- Transporting renewable natural gas
- Exploring the potential application for hydrogen blending in existing natural gas systems
- Purchasing or installing energy with lower CO_2 emissions
- Optimizing compressor operations to run equipment with lower CO_2e emissions
- Using electric-driven compressors

Additional Resources & Information Sharing

Resources and Training

To build a robust program to reduce or minimize methane emissions, companies need to dedicate adequate resources and develop training programs. Senior leadership buy-in will be critical to the success of the program. Below are some programs and initiatives to consider.

Data Collection and Procedures

- Leverage existing voluntary and regulatory programs to the extent possible to streamline implementation schedule and impact on operations personnel.
- Evaluate and identify methane reduction commitment options that will result in cost-effective and tangible methane reductions, meet long-term methane emission intensity targets, and be transparent.
- When possible, make use of systems already in place that are familiar to stakeholders.
- Written procedures need to outline the program, responsible parties, and methodology to use. Guidance needs to be clear and specific.
- Develop and make user-friendly spreadsheets/databases accessible across the company, including:
    - A leak identification system
    - A system to prioritize leak repairs
    - Annual leak survey spreadsheet

Data Quality Assurance and Quality Control

- Quality data is necessary to inform decision-making.
- Measured data may be more accurate than estimates (i.e., acoustic measured data may not be very accurate).
- Use EPA-approved methods.
- Take into consideration the standard of accuracy various tools allow.

Training and Communication

- Proper training of and guidance to personnel is critical (includes internal staff and contractors).
- Communicate with all affected personnel (internal staff and contractors, as appropriate).
- Solicit feedback as the program is developed and rolled out.
- Consider the use of apps and tablets to reduce paperwork and/or minimize reporting burden.

Continuous Improvement

- Communicate up, down, and across the organization.
- Get feedback from internal stakeholders/customers.
- Implement feedback and lessons learned.
- Analyze and communicate data collected, identify trends, inform future decision-making, identify other opportunities to reduce.

Research, Development, & Information Sharing

Research and development opportunities are available for natural gas operators to participate and provide a real-world perspective. Consider partnering with academia, trade organizations, non-governmental organizations, and benchmarking with other operators.

Potential areas of opportunity may include:

- Identifying transmission and storage super-emitters, mitigation options, and best practices to reduce those emissions
- Minimizing or avoiding combustion emissions
- Monitors that can accurately detect and quantify emissions
- Flyover programs to identify super-emitters (See TCEQ program.)

Numerous research and development partnership are available for industry companies to participate:

- Research & Development Program: Research & Development Program Awards (dot.gov)
- Research & Development Program: Research & Development | Meetings/Events (dot.gov)
- Office of Fossil Energy and Carbon Management | Department of Energy
- NETL Researchers Advance Carbon Matchmaker to Make Connections for Lower Emissions | netl.doe.gov
- Carbon Storage Research | Department of Energy
- NYSEARCH - Natural Gas RD&D
- Operations Technology Development (OTD)
- Current Funding Opportunities FAQs | arpa-e.energy.gov
- METEC - Energy Institute (colostate.edu)
- GTI Energy | Methane Emissions Monitoring, Mitigation, and Insights to Address Global Climate Change Concerns
- GTI Energy | Project Veritas

In addition, natural gas operators have available options (e.g., agency and trades/other resources) on methane reduction practices:

Agency

- PHMSA Public Meetings and Documents: PHMSA Meeting Registration and Document Commenting (dot.gov)
    - May 5 - 6, 2021 Meeting – LDAR
    - November 30, 2021, Meeting – Hydrogen and Emerging Fuels (RNG)
    - February 17, 2022 Meeting – Addressing Inspections of Operator's Plans
- EPA's Voluntary Methane Programs for the Oil and Natural Gas Industry | US EPA
- Recommended Technologies to Reduce Methane Emissions | US EPA
- Greenhouse Gas Equivalencies Calculator | US EPA
- Leak Detection and Repair Compliance Assistance Guidance Best Practices Guide
- Carbon Negative Shot | Department of Energy
- Carbon Matchmaker | Department of Energy
- H2 Matchmaker | Department of Energy
- HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines | US DOE
- Point Source Carbon Capture Program | netl.doe.gov
- Gas Leak Abatement OIR R 15 01 008 (ca.gov)
- Reducing methane emissions from Canada's oil and gas sector: discussion paper - Canada.ca
- Net Zero | Canadian Gas Association (cga.ca)

Trades/Other Resources

- Methane Guiding Principles
- ONE Future - Working to Reduce Methane Emissions
- OGCI Action & Engagement | Aiming for Zero Methane Emissions Initiative
- Natural Gas Sustainability Initiative (NGSI) | American Gas Association (aga.org)
- Environment - American Gas Association (aga.org)
- Oil & Gas Methane Partnership
- Science-Based Targets | Ambitious corporate climate action
- The Texas Methane & Flaring Coalition
- Flaring management guidance | Ipieca
- NGSA
- The Environmental Partnership
- Carbon Mapper
- MiQ
- Verified Carbon Standard - Verra
- Gold Standard - Carbon Offset Guide
- Puro.earth carbon removal standard, registry and marketplace

Reporting Methane Emissions

Programs are available to report methane emissions, reductions in methane emissions intensity, and steps taken to reduce or minimize methane emissions.

Options include:

- Greenhouse Gas Reporting Program (GHGRP) | US EPA
- US EPA's Methane Challenge Program
- US EPA's Natural Gas STAR Program
- ONE Future
- Natural Gas Sustainability Initiative (NGSI)
- Oil & Gas Methane Partnership