Introduction to the AGA Purge Manual

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Abstract

Purging natural gas from piping systems is considered routine work in the oil and gas industry. However, the process remains complex and potentially hazardous. Over the past 40 years, there have been 66 purge-related incidents in the U.S. alone, most resulting in multiple casualties. That includes 10 fatalities produced by two rather larger and tragic events.

In response to those statistics, inherent risk, and the increasing regulatory and social pressures on all oil and gas operations, the American Gas Association (AGA) is once again considering revising its Purging Practices and Principles manual. The "purging manual," as it is often referred to, is the industry's authoritative guide to safely purging pipes, holders, and other facilities into or out of service.

Understanding how to use AGA guidance to plan and implement a safe and successful purging program can be complex. Whether purging is being done with nitrogen or another inert gas, a number of variables affect flammability and autoignition, including the specific composition of the pipeline product, the composition of the purge gas, purge gas flow rates, contact time, thermal gradients, static electricity and pipeline characteristics.

This white paper examines those variables, discusses how field complexities affect the purge process and describes methods for gas sampling, detection and measurement. In addition, this paper provides insight into using Gas Technology Institute's (GTI Energy) Gas Purge software for calculating various values associated with the purging and clearing of a natural gas pipeline.

Best practices for purging

Purging refers to the process of introducing or removing natural gas from piping or equipment systems. Purging is done primarily to create a safe working environment before repair, modification, maintenance or inspection work. The section to be purged is physically isolated using valves or other devices then (unless natural gas is being introduced into a pipeline directly through a process called gassing in) inert purge gas is introduced into the system to displace the hazardous pipeline product.

Although purging operations have been performed successfully for decades, the process is inherently dangerous. It can create flammable gas mixtures that instigate fires or explosions or oxygen-deficient environments that pose an asphyxiation risk to workers and the public.

Purge safety has improved over the last few decades alongside advancements in job planning practices, standard operating procedures and gas detection technology. However, purge-related safety events continue to occur. According to OSHA, 66 of 450 severe pipeline incidents (15%) recorded over the last four decades mention purging by name. A single fire- or explosion-related incident is often responsible for multiple injuries or fatalities. This was the case in 2009, when a natural gas explosion at a meat processing plant killed four workers and injured 67; a year later, a natural gas explosion at a power plant under construction killed six and injured at least 50. The U.S. Chemical Safety and Hazard Investigation Board said both incidents had the potential to be even worse.

To promote purging safety and reduce the possibility of accidents and incidents, the AGA began collecting and distilling purging best practices in 1939. This effort culminated in a first-of-its-kind standalone book in 1954, "Purging Principles and Practice." The book is a compendium of industry wisdom and acceptable operational practices for the safe introduction or removal of natural gas from piping systems.

AGA has updated the purge manual three times, in 1975, 2001 and 2018. Since the manual's most recent publication, numerous regulatory efforts, primarily at the federal level, have changed the way the industry views various aspects of the purging process. The Inflation Reduction Act, which passed in 2022, led the latest wave of change as it ushered in apparent penalties for natural resource mismanagement. This was followed by Pipeline & Hazardous Material Safety Administration's (PHMSA) passing the pipeline safety management system rule (PSMS) as well as the pipeline leak detection and repair rule (Pipeline LDAR). These regulatory efforts are a clear indication that the government's view of purge components will continue to evolve, especially regarding safety performance and emission reduction, topics covered in the current purge manual.

An approach to purging safety

It's important to note that the AGA purge manual does not teach a single solution. Instead, it outlines an approach to purging safely. This is intentional: because purging operations are tailored to the piping system of interest and vary widely, no single solution could encompass the variables encountered in the field or properly manage that risk.

Instead, AGA chose to help readers obtain a foundation of knowledge so they could develop their own effective and safe purge plans. Operators who require a deeper dive or prefer less technically complex and calculation-heavy step-by-step instructions often have to look elsewhere.

Generally speaking, the purge manual helps operators understand the importance of:

- Developing detailed purging procedures outlining steps from pre-purging activities to post-purging verification.
- Identifying the hazardous gases present in the pipeline or equipment and assessing potential risks associated with those gases, including flammability, toxicity, and reactivity.
- Determining the desired gas concentration or purity level in the purged space (referred to as end points) and continuously monitoring the purging process to ensure that those measurements are achieved.
- Selecting the appropriate purging method (direct displacement, complete filling or slug) and the inert gas to be used, based on pipeline operational conditions, geometry and a multitude of other considerations.
- Ensuring the equipment and instrumentation required for effective purging are in place, including gas detectors, flow meters, pressure gauges and ancillary equipment (i.e. – emissions mitigation).
- Implementing strict safety measures to protect personnel and the environment during the purging process.
- Maintaining detailed records of the purging operation, including the method used, parameters monitored and verification results.

Operational planning for safe, efficient purging

Proper planning and scheduling are vital to mitigating the potential negative consequences of purging, not just fires and explosions but also environmental damage, operational disruptions, regulatory non-compliance and legal liabilities. In fact, to ensure a safe purge operation, a specific sequence of events must be developed, communicated and executed with precision.

Purge planning involves considering multiple variables, including whether the gas will be vented, recompressed or flared; what, if any, mitigation measures will be implemented; and how to comply with emerging regulations and requirements.

One of the most significant decisions is choosing which purge gas to use (often nitrogen or carbon dioxide for purge-out applications). Purge gas acts as a physical but temporary barrier preventing the fuel (natural gas) from contacting oxygen introduced into the pipeline during the purge process, thus disrupting the combustion triangle (the combustion triangle refers to the three essential components needed for combustion: fuel, oxygen, and an ignition source). The purge gas must be inert, non-flammable, low toxicity and capable of displacing flammable gases. Other factors include cost, availability (on site or from a nearby supplier) and the environmental impact, such as greenhouse gas emissions.

After the purge gas is selected, calculating the required volume and optimizing purge efficiency go hand-in-hand. This requires an intimate understanding of pipeline geometry and connectivity followed by the addition of a safety factor, typically 150-200% of the expected clearance volume.

Running out of inert gas during the purge process may cause the physical barrier to deteriorate and the fuel to come in contact with atmospheric oxygen, increasing the risk of fire or explosion. Ensuring the right amount of purge gas is on hand requires clear and precise knowledge about pipeline contents and access points.

Purging operations must also consider a phenomenon called stratification velocity. Because natural gas is a mixture, it tends to separate into its individual components when system energy (flow velocities, in most cases) begins to decline. If the flow velocity drops below a critical threshold, the mixture may separate, leading to preferential flow paths. This can result in incomplete purging, as certain components of the mixture may be left behind.

Purge efficiency can be developed using the following equation. This equation calculates the percentage of the pipeline volume that is filled with purge gas. A higher percentage indicates a more efficient purge.

*Available space in square cubic feet (scf) divided by purge gas in scf * 100*
(expressed as a percentage)

In general, factors affecting purge efficiency include the size of the contact surface area between the purge gas and the gas being purged (a larger surface area promotes faster mixing and displacement); pipe length and diameter, with longer, wider pipelines often requiring longer purging times; contact time (the longer the purge and target gas are in contact, the more mixing and dilution occur); the flow rate of the purge gas, with high flow rates ensuring all constituents remain mixed during the process and are effectively removed; temperature differences, which can influence gas movements through contraction or expansion; and the placement of inlets and outlets, which can have an effect on flow patterns and the mixing of gases.

While purge efficiency is important, purge gas minimization isn't as important as the preservation of public and personnel safety.

The AGA purge manual also emphasizes the importance of:

- Designing purge plans so adequate inlet and outlet connections are available.

  Inlet connections are the points where the purge gas is introduced into the pipeline. Their nozzles should be positioned and sized to optimize the flow of purge gas, minimize turbulence and achieve the desired purge velocity without excessive friction.

  Outlet connections are where the purge gas and any displaced fluids can be vented or drained from the pipeline. They should also be sized to ensure proper backpressure is retained in the system during the entire operation. Inlets and outlets must be able to withstand the pipeline's pressure and temperature conditions to avoid leaks and downtime, be compatible with the equipment and tools used during purge operations to enable operational efficiency and be easily accessible for operation and maintenance. Most outlets are configured with a valve to help manage backpressure.

- Ensuring that the inlet and outlet control valves are in good working order.

  To prevent leaks and ensure a smooth purge operation, operators should regularly inspect valves for operability, wear, damage and corrosion and making required repairs or replacement. Furthermore, valves used for throttling inert gas during the purge operation should be sized and configured correctly so throttling is not just possible but is also easy to achieve and maintain.

- Testing the equipment used during purging operations, including pressure gauges, flow meters and gas detectors.

  Gas measurement and detection equipment is vital to managing purge effectiveness. Regular testing and calibration ensure the reliable field evaluation of accurate end point determinations, that is, when a specific gas concentration reaches a set level, and helps identify potential equipment failures that could disrupt critical operations.

- Following proper lockout/tagout procedures to prevent accidental activation of key equipment that could lead to fire or explosion.

  This typically includes all piping system valves, fittings and appurtenances, electrical switches and controls and compressors. Energy control is a critical element of all purging operations and vital for maintaining purge safety.

- Training personnel involved in purging operations and assigning specific tasks and responsibilities. (covered task #1651 per ASME B31Q)

  Human error remains a primary cause of purging incidents. Considering the complexity of the task and coordination of events, this is expected. Recent high-profile events that nearly resulted in fatalities underscore both the importance of rigorous training in purging procedures and the need to address process changes in safety meetings (tailgate meetings) to ensure understanding of system dynamics and management strategies.

- Proper evaluation of public and personnel safety.

Every purge job is different, but most are complex operations occurring in complex environments. That makes analyzing and mitigating threats to both public and personnel safety critically important. This ranges from trench boxes to help protect crews in the ditch to emissions mitigation equipment when the general public is nearby.

- Notifying relevant personnel within the organization and coordinating with other departments.

  This can minimize disruptions, ensuring staffing and equipment are in place for smooth operations and to prevent incidents. Due to the nature of these events, multiple departments are typically involved in the process, often with different needs and possible reporting obligations. Coordination ensures that all departments receive the data they need from these operations within the timeframe they expect to be informed.

- Informing regulatory agencies, local authorities and emergency responders about the planned purging operation.

  Municipalities may have specific notification or reporting requirements regarding venting before purge operations begins. Local authorities can help establish a safe perimeter around the job site during the parts of the purge operations that contain more risk (e.g. – when an operator may be actively venting).

Beyond those activities, planning safe purging operations involves many other considerations, including:

- Where to release the gas or liquid in the pipe. This critically important decision is made with regard to ventilation, ignition sources, environmental impact and safety regulations and must be well thought out.

- Pipeline design/configuration and piping materials. Purging operations are designed to use a fixed amount of gas. If the system is substantially larger than anticipated by the engineering team, the inert gas may run out before the purge is completed. This allows the inert slug to deteriorate and fuel and oxygen to contact each other once again, creating a potential fire hazard.

- Pressure fluctuations and other system dynamics. Most process systems don't contain pure substances, but house mixtures instead. Constituents may have different properties and thus behave differently. This means operational and physical variables (pressure/temperature and gas composition, respectively) may be changing at the same time. Depending on system pressures and flow rates, stratification may occur (see above).

- Unidentified and unexpected components such as valves or fittings. Closed unknown valves prevent access to the entire system, resulting in trapped flammable gas.

- Positive (full gas stoppage) versus non-positive isolation (partial gas stoppage). The goal is to achieve a positive isolation prior to the purge operation. A positive isolation is one in which the pipeline section is completely isolated from the rest of the system, and there is no flow of gas or liquid between the isolated section and the rest of the pipeline. Attempting a purge while natural gas or air continues to migrate into the isolated space (i.e., a nonpositive isolation via valve leakage) can create a situation where end points are either never reached or enough gas migrates into that space that regardless of inert gas presence, there's still enough fuel and oxygen in the system to result in a fire.

- Lack of knowledge about a pipeline's history. Older pipelines may have been modified, making it difficult to understand the physical connections between pipes, control systems and instrumentation. Liquid lines converted to carry gases often have deposits within the line that may volatilize when the pressure is reduced, or oxygen enters the system.

- Space limitations, especially in urban environments. For example, trying to purge in a high rise building where gas management may look a little different and require some extra equipment.

Many of these matters can be resolved during a system evaluation conducted as part of the purge planning process. Taking the time to understand the system and its components helps operators identify the gases and/or liquids in the pipeline, which is crucial for determining appropriate purging procedures and selecting suitable purge equipment. Analyzing the system's process and instrumentation diagrams (P&ID) provides insight into the pipeline's configuration, valves/fittings and potential hazards, while conducting field inspections to verify the accuracy of all unknown variables helps identify any unexpected factors that might affect the purging process. Finally, assessing the effectiveness of isolation valves and other sealing mechanisms mitigates risk by helping ensure that the pipeline section to be purged is completely isolated prior to proceeding with the purge operations.

Flammability risks and mitigation

With proper planning, the likelihood of fires and explosions during purge operations is relatively low. However, if they do occur, they can be catastrophic. Most are attributable to human error through poor planning or ineffective management of process change. All purge jobs will contain unexpected elements. Discussing and managing those as a team is paramount. The goal is always to render the environment non-flammable in order to avoid hazardous uncontrolled ignition.

Flammability is the ability of a substance such as a flammable gas mixture, given proper amounts of oxygen, to ignite and sustain combustion. Flammability ranges for mixtures are typically expressed as a percentage of the flammable gas in the mixture. Flammability ranges for mixtures also depend on the properties of their components, their relative concentrations and environmental conditions including pressure, such as when an inflammable mixture becomes flammable as pressure increases.

It is possible to predict the flammability range of simple mixtures (those with just two components) using relatively basic equations and the combustion properties of the individual constituents. However, predictions are more difficult for complex mixtures. The 2018 purge manual includes flammability diagrams that represent the relationship of flammable gas to atmospheric air combined with inert gas concentration. By evaluating the concentration of flammable gas remaining in the purge space, combined with current levels of air within the system, it is possible to plan a purge pathway that does NOT travel through the flammability zone of that specific mixture.

As a corollary, the increasing presence of hydrogen in natural gas pipelines is creating additional concerns about flammability during purging. Hydrogen has a very wide flammability range; it can ignite when concentrations in air are anywhere from 4% to 75%. By contrast, the flammability range for methane is just 5-15%. In addition, hydrogen flame speeds are much faster than methane's, so combustion occurs more rapidly. This acceleration of the combustion process means parameters of the purge — in particular, purge velocity — may need to be altered to ensure the purge is occurring above the flame speed of the mixture. If that is not possible, deflagration equipment may be required on the outlet side of the purge configuration to prevent back-feed of the flame into the piping system.

Ignition, the catalyst required for combustion, can be subcategorized into risks related to ignition source contact (for example, a spark or flame) and the possibility of autoignition, self-starting fires or detonations. Autoignition can occur during purging when lubricants used in purge equipment are exposed to air. Compressors with molecular sieves (porous materials used to remove impurities) are particularly susceptible and a known issue within the purging community. They can absorb significant amounts of flammable substances, which can remain trapped within the pore-space of the sieve even after the compressor is shut down. Once the sieve is exposed to air, the oxygen in the air reacts with these concentrated flammable substances and can detonate under certain conditions. Autoignition can also occur when pyrophoric solids are present in the line.

Flammability and ignition management are both moving targets during a purging operation, depending on both the ability to separate fuel from air and to recognize and mitigate potential ignition hazards as the job proceeds. In this regard, the AGA purge manual emphasizes:

- Overplanning on the volume of the inert gas required for the operation, typically 150-200% required volume.
- Keeping flammable gas concentrations below flammability limits by properly tracking end points during the operation.
- Ensuring adequate ventilation to dilute flammable gases as they exit the system.
- Using gas detectors to monitor gas concentrations and evaluating end points reliability and consistently.
- Identifying and eliminating pyrophoric materials and potential sources of ignition, e.g. - heat, flames and sparks.
- Monitoring temperature to prevent excessive heating (or cooling) or accumulation of pressure.
- Using grounding and bonding equipment to minimize friction, equalize electrical charges and dissipate static electricity.
- Maintaining pressure, including system backpressure, within safe limits during the course of the job.

Emissions reduction

No comprehensive purge plan would be complete without assessing environmental implications. One key aspect is minimizing methane emissions, however that goal must always be balanced by economic considerations, time constraints and equipment availability.

There are several proven ways to reduce methane emissions associated with purging, although none of them are ideal solutions. Each has benefits but they also have costs, e.g. time, cost, noise and light pollution. For example, isolating the segment by valving or mechanical intervention is common but can be time-consuming, especially for larger pipelines, meaning it increases costs and downtime. Moving the gas into a lower-pressure system (drawdown) can reduce the volume of gas that needs to be purged but this typically involves renting cross-compression equipment and adds time to the operation as well. Vacuum technology, which involves creating a vacuum to draw the gas out of the pipeline, is relatively new to the industry but shows significant promise as a cross-compression alternative. Finally, burning the methane using onsite or rental equipment can reduce emissions, but may not be practical as this practice often attracts the unwanted attention of the public through light or sound pollution.

With any emissions reduction method, ensuring compliance with current regulations and meeting all reporting requirements of local, state and federal regulations is essential. A strategy for purge gas disposal should be in place before the process starts. In most cases, the purge gas may be vented to the atmosphere under controlled conditions.

Monitoring and sampling

Once the purge operation is underway, continually monitoring influent and effluent is also vital, although the process differs somewhat. Inlet monitoring has to do with pressure and rate management while outlet monitoring has to do with end point evaluation in order to determine when the process is complete.

The sampling plan outlines how and when influent and effluent gas should be evaluated, which may require different instruments measuring different gases. The samples should be representative of the actual gas mixture and analyzed promptly to avoid inaccuracies.

Key considerations for sampling include selecting the right equipment, such as gas detectors. Some instruments require oxygen to function and certain types of sensors are limited in range of flammable gas concentrations. Moreover, some are easy to contaminate or confuse, rendering sample readings uncertain at best. Appropriate sampling techniques are also essential to maintaining the integrity of the sample. Sampling connections should be properly sized to preserve sample integrity and sampling probes should be intrinsically safe as they may be required to be inserted into pipes, voids or equipment. The sampling task is a covered task under ASME B31Q and required trained personnel also, see #1651.

Post-purge testing

Finally, post-purge testing involves a series of checks and measurements to verify the pipeline has been adequately purged of hazardous gases; in other words, when the process has reached its end point and is considered complete. The measured gas concentrations are compared to predefined criteria to determine if the purging process has been completed successfully. Visual inspection of the pipeline can help confirm the effectiveness of the purging process by uncovering any signs of residual liquid or solid contaminants.

In a positive isolation purge, this should be relatively straight forward. In non-positive isolation scenarios. This may prove much more difficult. Purge progress charts can be used to help the operator understand where they are in the purge process and help diagnose non-positive situations as soon as possible. Holding purges may be required in these specific instances, where purge gas is applied for a significant period to ensure non-flammable mixtures do not develop inside the isolated space.

Conclusion

Pipeline purging is a critical yet inherently dangerous operation that requires careful planning and execution. As the AGA purge manual recognizes, purging is not a one-size-fits-all process. A tailored approach is crucial, including a deep understanding of the system, its configuration, materials and operational history.

Before purging operations, it is important to anticipate potential challenges, implement robust safety protocols and develop contingency plans to mitigate risks. Effective communication and coordination among team members are also vital to ensure a smooth and safe operation.

By following these guidelines and maintaining a vigilant approach, pipeline operators can ensure the safety and efficiency of purging operations.

References

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