Avoid Natural Gas Piping Hazards

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Repairing natural gas piping is inherently dangerous. Follow these safety protocols to avoid potentially catastrophic results from improper installation and repair of natural gas lines.

Over the last 10 years, several industrial accidents related to natural gas piping problems have taken more than a dozen lives, injured hundreds of people, and cost the companies involved billions of dollars. Many more significant incidents and fires involved commercial and even residential facilities.

One of the most recent cases described on the U.S. Chemical Safety and Hazard Investigation Board's (CSB) website (www.csb.gov) is the June 2009 explosion at a food plant in Garner, NC *(1)*. A new piece of equipment was being installed and a natural gas line was being re-energized for light-off. Four people were killed and more than 40 others were sent to the hospital with injuries when the blast knocked down walls and caused the roof to collapse. Investigators concluded that the gas line was purged into the building, and that led to the accident. As a result, the state of North Carolina now prohibits the purging of gas lines into buildings.

Another purging incident in February 2010 killed six workers and injured 50 others at an energy plant under construction in Middletown, CT. The CSB determined that the explosion was most likely caused during a routine gas purging procedure *(2)*. The accumulating gas reached an ignition source, where welding and other work were being performed nearby, setting off the blast that leveled much of the facility.

The National Fire Protection Association (NFPA) has adopted sweeping changes to NFPA 54, the "National Fuel Gas Code" *(3)*, to protect against these kinds of incidents. The changes were deemed important enough to be added as a tentative interim amendment (TIA) to the standard (see www.nfpa.org for the complete changes).

Many individuals who manage or perform gas piping repairs lack the knowledge needed to do so safely. Some in purchasing or maintenance functions think that all piping is the same; they do not understand that repairing or installing an air or water line is quite different from working on a gas line.

This problem is especially relevant in the current economy, with many companies choosing the lowest bidder for repair projects. In the past, contractors apprenticed pipefitters by directly training them and sharing their experience. In addition, many businesses that provided training related to gas piping risks no longer have the resources to do so. Very few communities regulate who is qualified to perform gas piping work, and local building inspectors rarely see projects beyond low-pressure residential jobs.

NFPA 54 explains how to safely perform gas piping repairs, purging, and pressure testing. Unfortunately, many who should be familiar with NFPA don't even know that it exists, don't have time to read it, or don't interpret it correctly. Another problem is that NFPA 54 does not go into detail about the reintroduction of natural gas after repairs. Even the newest changes require some amount of interpretation depending on the project size and scope. In addition, many nuances of repair can only be learned through experience and practical examples.

This article fills some of the gaps that are not explicitly covered in NFPA 54 and summarizes some important lessons learned that can help prevent devastating natural gas accidents. It reviews ten common hazards associated with the installation and repair of natural gas piping and provides insights on how to avoid them. These tips and techniques

should be incorporated into a comprehensive documented procedure for natural-gas piping purging, piping system design, and equipment start-up.

Inadequate design and planning

A safe gas piping installation or repair job involves six basic steps:

Pre-repair

1. Planning
2. Isolation
3. Pre-repair purging

Making the repair

4. Pressure testing
5. Post-repair purging
6. Reintroduction and light-off

Before any work can be performed, significant planning is needed to ensure the job is completed safely. Proper planning includes:

• *procedures*: What specific written procedures of the work to be done and processes to be used will provide a step-by-step understanding for everyone involved?

• *people*: What is the knowledge and skill level of the staff to be involved? Is training needed?

• *design*: Has a thorough review of the design been completed to ensure that everything to be installed meets applicable codes and best practices?

• *resources*: What resources will be required? When will they be needed?

• *hazards*: What possible hazard assessments and abatement steps need to be performed at this stage?

Planning also needs to include a review of isolation points, including existing valves and flanges, the possible need to install flanges, and areas where blanks can be installed. According to NFPA 54, pressure testing cannot be carried out against valves if there is a pressurized substance on the other side of the valve. The engineer will need to evaluate the entire gas piping system to determine where the system can be sectionalized for proper testing.

It is helpful to have (at a minimum) a schematic representation of the facility's gas piping systems on hand during planning. A schematic typically shows major line sizes, valves, and equipment. A detailed natural gas piping drawing depicts much more detail and may include isometric representations of some of the piping. If neither is available for use during the planning stage, a schematic representation will need to be prepared (detailed piping drawings for a large facility could take weeks to make).

Planning is vital because it allows piping sections to be designed to be somewhat reasonable in length for testing and evaluation. For example, if the system does not hold pressure during pressure testing of all of the plant piping, the entire plant will need to be searched to locate a small leak. It is much more effective to find and repair leaks in reasonably sectionalized piping, possibly hundreds of feet at a time.

Other important considerations during the planning process include:

• Where are isolation points and how will isolation be safely achieved?

• Will the utility be involved? What will be required of the utility? What does the utility require of the facility?

• Is there an overall plan and does everyone involved understand it?

• Is there enough nitrogen to handle the purging requirements? Does everyone involved understand nitrogen hazards?

• Where will the purge stream be sent?

• Have reintroduction and start-up been discussed, including their unique hazards?

Improper isolation (an often-tragic mistake)

The U.S. Occupational Safety and Health Administration's (OSHA) lockout/tagout standard (OSHA 1910.147) *(4)* governs the isolation of hazardous energy sources. Much has been written about this issue, and most facilities comply with it when isolating electrical equipment. For gas piping, however, proper isolation is much less common. Even some sites that place locks on all electrical disconnects may close a gas valve, but not lock it.

The isolation of lubricated plug valves, which account for 60–80% of the manual shut-off valves in natural-gas piping systems, requires special attention. These valves have a small gap between the plug and the valve body. If a sealant is not applied annually, as required by code and the manufacturer, gas will leak past the plug even when the valve is in the closed position. Many facilities have never sealed their lubricated plug valves. Hence, closing or locking out a valve in this condition does not necessarily isolate the energy source.

Isolation must ensure that all active gas-filled parts of the system are safely separated from open sections of pipe and/or the areas to be repaired. Most people think of isolation as valves. However, even when they are in the closed position, valves may leak, especially if they have not been serviced properly. Because of this, the safest approach is to use blinds or double-block-and-bleed valves for isolation.

A double-block-and-bleed system consists of three valves in series — the two end valves are closed and the middle valve is open and vented to a safe place. If a valve leaks, the leaked gas can exit through the vent rather than pressurize the downstream valve and create a more serious hazard.

Effective isolation protects not only personnel from the hazard of natural gas, but it also protects components in fuel trains from the elevated pressures that may be encountered during pressure tests. Valves that are left open or leak in the closed position can overpressure and permanently damage delicate components such as regulators and pressure switches.

Improper purge points

Purge points are pipe nipples installed at strategic locations in the piping system for the purpose of introducing or removing nitrogen and natural gas at various stages of the process. These are generally 1-in. Sch. 80 nipples (which are thicker and stronger than common Sch. 40 pipes) with natural-gas-rated ball valves on the ends. It is important to select locations and orientations that minimize their susceptibility to damage from things like vehicle traffic.

For effective purging, the nipples must be installed in the piping system and the workers must know how to use them. The facility should have a purge plan that details how the system will be sectionalized, where each section's nitrogen will enter, and where purge products and/or natural gas will go.

Remember that (as required by code) purged products must go to a safe place. This is usually outside, away from air intakes and ignition points. These materials are often routed with a garden hose, although in practice only hoses rated for natural-gas piping should be used. Caution tape should be erected around the perimeter (at least 25 ft from the purge point) and an employee should monitor the area with flammability meters.

Monitoring is especially important if the purge point or equipment is within a building. Although it may require a long line to reach outside, this is vital because the lower explosive limit (LEL) of natural gas is only 4.3% by volume, and it does not take much gas to reach this point in a small enclosed area.

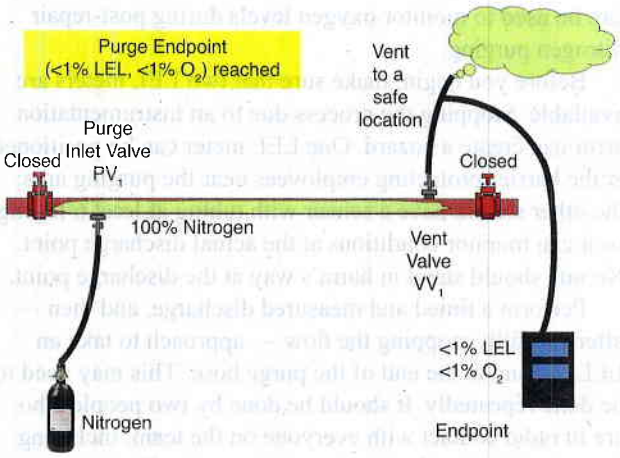
Improper piping repairs

Proper repairs start with the right materials. Gas lines are usually Sch. 40 ASTM A53B piping. If welding is needed, ensure that the welders have the proper credentials. In addition, make certain that fittings and tees are used instead of fish-mouth joints. Threaded connections must be done with tapered threads.

Hangers and supports must be carefully planned. It is important to ensure that pipe supports are adequate to prevent sections of pipe from falling when they are disconnected. It is also important that hangers do not put stress on joints or flanges. In some cases, special supports will be required, such as for large, very heavy plug valves.

NFPA 54 does not allow the reuse of flange gaskets even if they appear to be in good condition. To ensure leakfree joints, it is important to use new gaskets and correctly rated bolts for the flanges. When mating up flanges, place one raised face adjacent to another raised face and a flat face adjacent to a flat face.

Only pipe and fittings with the proper rating should be used. Verify that all suppliers are reputable and that all materials are free from manufacturing and installation



▲ **Figure 1.** Before natural gas enters a pipe, air needs to be removed to prevent the formation of a flammable mixture.

defects. Check all the fittings in advance to make sure they are free from casting defects, thread damage, and thread misalignment.

Nitrogen hazards

Even though the air we breathe is 78% nitrogen, two full breaths of pure nitrogen can kill a person. Make sure everyone involved and in the vicinity understands this hazard. Purge points should be located in well-ventilated areas and be well-marked. Verify the pressure ratings of hoses and regulators because large liquid nitrogen tanks can produce high discharge pressures. When discharging nitrogen, the purge discharge areas need to be monitored. All personnel involved in the purging and pressure testing need to be trained on the safe handling of nitrogen.

Nitrogen is used during the pre-repair purge to push the natural gas out of the line (Figure 1); then it is used to perform a pressure test before the repair; and finally after the repair, nitrogen is used again to remove the air from the pipe before gas is reintroduced. If this last step is not done properly, the air in the pipe can mix with the natural gas and create a flammable mixture. If this gets to a burner under the right conditions, the flame can travel backward and cause the pipe to explode. These three uses need to be considered when estimating the amount of nitrogen required.

Improper endpoint monitoring

Verify that purge endpoints where natural gas may be released are outside and at least 25 ft from any ignition source. Cordon off these areas to keep ignition sources, vehicles, and people away.

Do not use a combustion fluegas analyzer. Instead, use a good quality, recently calibrated LEL meter during natural gas introduction and removal. A four-gas meter

can be used to monitor oxygen levels during post-repair nitrogen purging.

Before you begin, make sure that two LEL meters are available. Stopping the process due to an instrumentation error can create a hazard. One LEL meter can be positioned at the barrier protecting employees near the purging area; the other should have a sensor with tubing at least 6 ft long so it can monitor conditions at the actual discharge point. No one should stand in harm's way at the discharge point.

Perform a timed and measured discharge, and then — after carefully stopping the flow — approach to take an LEL reading at the end of the purge hose. This may need to be done repeatedly. It should be done by two people who are in radio contact with everyone on the team, including those introducing the nitrogen or gas some distance away. In some cases, the best approach is for those doing the end-point monitoring to be equipped with breathing air. (Note that the TIA from the NFPA states, "Persons not involved in the purging operations shall be evacuated from all areas within 10 ft (3 m) of the point of discharge." We recommend a 25-ft barrier around the purge zone.)

Pressure-testing errors

All new or repaired gas piping must be pressure-tested. NFPA 54 provides information on what pressure needs to be held and for how long. Some states require pressures or timing that is more stringent than required by NFPA 54. In addition, if the natural gas is shut off, the local utility may impose special requirements before it will turn the gas back on. Each facility needs to determine which standards apply to it.

NFPA 54 also requires documentation of pressure-testing for new or repaired piping systems prior to introducing natural gas. The results of these tests should be retained for the life of the piping system. A best practice is the use of pressure chart recorders. These battery-powered paper-and-pen recorders have very small pressure increments (1 psig) and provide an excellent record of pressure and hold times.

It may also be necessary to install blinds for the pressure-testing. NFPA 54 prohibits pressure-testing against closed valves. Temporary low-pressure blinds can usually be made from sheet metal of the appropriate thickness for a short-term, one-time use. Permanent blinds, such as spectacle blinds, may require piping modifications, but are beneficial in the long run should more work need to be done.

Gas reintroduction problems

After the post-repair purge, it is imperative that the natural-gas source valve (at the inlet from the utility) be continuously attended during the reintroduction of natural gas. Communication with the individual observing the

▲ **Figure 2.** Before pressure testing, make sure that all equipment is properly isolated. Verify that all main equipment shut-off valves are closed and are able to hold pressure. Otherwise, regulators and other sensitive fuel train components could blow out.

source should be continuously maintained. If a problem is detected, the supply of natural gas will need to be immediately isolated. In addition, valves should be serviced, handles installed, and valve function verified before the repair process begins.

During reintroduction, nitrogen is pushed outside with the gas behind it, and the process is periodically stopped so the endpoint can be tested. When the LEL meter indicates 100%, the lower explosive limit has been reached — which is just 4.3% gas by volume. Sometimes this is not sufficient to light a burner. Depending on the equipment to be lit, it is a good idea to continue past this point for a short period of time to increase the gas concentration slightly.

Equipment light-off hazards

Once the gas is at the proper concentration, complete several dry light-offs — that is, attempt to start the equipment with the gas completely turned off and locked out and the combustion chamber purged of fuel. It will not light, but this will provide an opportunity to check the movement of linkages and gas pressures. Gas regulators (main and pilot) could have been compromised during pressure testing and debris could have entered orifices or control points.

If possible, light only a pilot while the main fuel supply remains off. When the pilot is lit, verify that the gas pressure is stable and that there are no damaged components. Then light the main flame, and observe it after light-off for stability and proper flame strength.

It should take only 2–3 s for the pilot to light and another 2–3 s for the main flame to light. The light-offs should not be accompanied by loud banging or popping noises. Never put your face near an observation port during light-off — look at the flame only after a flame meter or other control indicates that the flame is lit.

Light-off should not be attempted repeatedly. If ignition

does not occur after three light-off attempts, stop the process. Shut off all the gas and perform a dry light-off purge to move any accumulated flammables out of the firebox. If light-off is still not achieved after six or more attempts, verify the level of gas entering the fuel train to see what concentration was reached. If it is too low, more purging is needed.

Automatic fuel valves should be leak-checked within 30 days of major gas piping repairs. Considerable slag and debris in piping systems can be found after major repairs and construction. This is also a time to clean strainers and sediment traps.

Human error — the greatest risk of all

The most important factor in avoiding gas piping and equipment recommissioning issues is human error. Human error can be minimized by changing cultures — that is, through training and discipline.

Training includes reaching out to maintenance departments and anyone involved in this process and teaching them how to correctly perform gas piping repairs. The trade unions that provide training for pipefitters do not necessarily provide training about gas. It cannot be assumed that if someone does piping work, he/she has been taught about gas. In some facilities and locales, gas piping work is done by plumbers, not by pipefitters. The best approach is to conduct a simple knowledge assessment for everyone involved that can reveal whether they understand the basics and the nuances of safe gas piping installation and repair. Reinforcement with regular training is also a must.

Special policies need to be in place and enforced to change culture and build discipline. The following types of activities and authorizations can make a difference in gas piping safety.

Gas leak surveys and work plans involve regular inspections for gas leaks, which are then identified and prioritized. Leaks in areas where concentrations can easily build up to flammable levels, such as small or poorly ventilated rooms, become a higher priority than those outside or in open areas. An immediate repair is recommended if an LEL meter measures 10% LEL or more within 6 in. of a leak.

Line breaking permits require development of a plan before lines (pipes) that may have natural gas in them are opened. This provides an opportunity to discuss the hazards and plan for making this a safe activity.

Gas purging, blanking, and isolation permits are special permits that allow for a more-thorough review before gas piping repairs occur. These may require precautions, such as the insertion of blanks instead of just closing valves whenever a person is entering a firebox or gas-fired device. They might also call for two knowledgeable individuals to review the proposed methods of lockout, or require the installation of a blind on equipment that will be out of service for months to avoid the possibility of gas leaks through valves.

This is a compliance issue. NFPA 54 is a code — not a standard — and it has the force of law in many jurisidictions. The newest changes state that any natural-gas piping system larger than 2 in. in diameter or operating at pressures over 2 psig needs to follow the directives of the code. In many cases, this is a game changer and the maintenance and plant service people must be aware of this.

Taking lessons learned to heart

You should now have a heightened awareness of the issues involved in gas piping repairs and equipment commissioning. If you are involved in this activity on a regular basis, you may be able to put some of the advice presented here into practice immediately. If you have only casual contact with gas piping repair, please share what you have learned with those who routinely service or maintain gas-fired equipment. This is a very specialized area that many take for granted and that has proven to be anything but straightforward and simple. CEP

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