Pipeline Safety New Voices Project

Briefing Paper #2 – Natural Gas Pipelines – The Basics

The background briefing papers we will be sending you over the next few months will provide new information to many of you, and for those of you who have been involved in depth with some particular aspect of pipelines, will provide you a glimpse into new aspects of pipeline safety issues. We hope the old hands among you can be pleasantly surprised by learning something new, or discovering a new issue to explore with us. Please feel free to pass on your comments and questions to us through the listserv for this group as you read each briefing paper. We will try to include responses to questions on the listserv or in subsequent briefing papers that go more in depth into various pipeline safety issues. These early papers will necessarily be fairly general and will gloss over some of the exceptions and special cases and legal gray areas. We'll try to point those out in subsequent papers where fewer topics are covered in more detail.

Introduction to Pipelines

There are over 2.5 million miles of fuel pipelines in the United States. Who regulates pipelines and under what set of regulations depends on what the pipeline carries, how much it carries, and where it goes. Pipelines are categorized into several types.

All fuel pipelines are either:
1) **Hazardous Liquid** pipelines carrying crude oil and refined fuels such as gasoline, diesel and jet fuel. They also carry highly volatile liquids, such as butane, ethane, propane, which will form vapor clouds if released to the atmosphere, and anhydrous ammonia.
2) **Natural Gas** pipelines carrying natural gas, the principal constituent of which is methane.

Depending on where they are in a transportation system all natural gas pipelines are either:

- **Transmission pipelines** -- the large lines (typically 6-48 inches in diameter) that move gas long distances around the country, often at high pressures (typically 200 – 1500 psi); or
- **Distribution pipelines** -- are a system of mains and service lines that deliver natural gas to our individual homes and businesses. They operate at a relatively low pressure; or
- **Gathering pipelines** -- transporting gas away from the point of production (well pad) to another facility for further refinement or to transmission pipelines; or
- **Production Lines** -- the pipes and equipment, normally near the wellhead, used to produce and prepare the gas for transport.

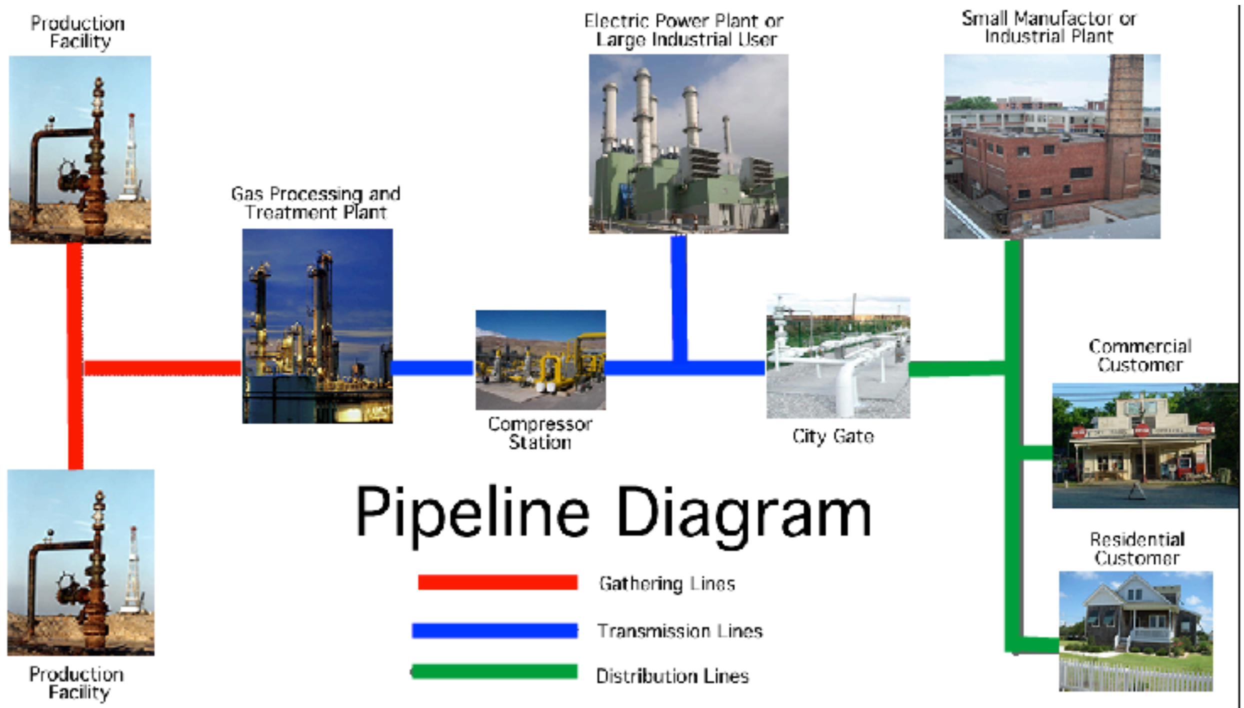
THE CURRENT U.S. PIPELINE SYSTEM

- 175,000 miles of onshore and offshore Hazardous Liquid pipelines;
- 321,000 miles of onshore and offshore Gas Transmission and Gathering pipelines;
- 2,066,000 miles of Natural Gas Distribution mains and service pipelines

Finally, (and you'd think this one would be simpler) pipelines are divided for jurisdictional purposes into:

- **Interstate pipelines** -- lines that cross state boundaries; or
- **Intrastate pipelines** -- those that operate entirely within one state.

However, some large pipelines that cross state boundaries are classified as intrastate if the pipeline ownership changes at the state line. For example, the same gas transmission pipeline designated as *inter*state in Oregon, turns into an *intra*state line when it hits California.



Unfortunately, even something seemingly so simple as determining whether a particular pipeline is a production or gathering line, or a gathering or transmission line, is not so simple under existing regulatory definitions, and they sometimes allow for some degree of choice by an operator in how a line is designated, and therefore how much of it is regulated as a particular type of line.

A few other terms that are used frequently when talking about natural gas pipelines need to be defined. Unfortunately these terms are used in many different ways and standard definitions do not exist in federal regulations. They include:

Wet Gas and Dry Gas - Natural gas is a gas comprised of multiple hydrocarbons, the most prevalent being methane. The higher the methane concentration, the "drier" the gas is. Other minor components include evaporated liquids like ethane, butane and pentane, which are collectively referred to as natural gas liquids (NGLs), or condensates. The higher the percentage of NGL's, the "wetter" the gas is. There are no definitions in the federal regulations that define at what point gas is considered wet or dry.

Sour Gas – Normally this refers to natural gas that contains an appreciable quantity of hydrogen sulfide. Hydrogen sulfide is a concern because it is extremely poisonous and can cause health problems at high enough concentrations. When mixed with water it also becomes extremely acidic causing corrosion problems for pipelines.

How Natural Gas Pipelines Work

Natural gas is moved through pipelines as a result of a series of compressors creating pressure differentials – the gas flows from an area of high pressure to an area of relatively lower pressure. Compressors are powered by electric or natural gas fired engines that compress or squeeze incoming gas and push it out at a higher pressure. As one would expect compressor stations for large transmission lines are much bigger than the compressors used to move the gas through the small distribution lines to our homes. Some gathering systems do not need compressors because the pressure of the gas coming out of the wells is enough to move the gas through the gathering lines.

Natural gas is compressed in transmission pipelines to pressures typically ranging from 500 to 1400 pounds of pressure per square inch. Compressor stations on transmission pipelines are generally built every 50 to 100 miles along the length of a transmission pipeline, allowing pressure to be increased as needed to keep the gas moving. Some gas transmission pipelines are bi-directional meaning gas can be coming from both ends of the pipeline, and depending on where gas is removed and where the compressors create the pressure differential gas may flow either direction. One example is William's Northwest Pipeline that comes past us here in Bellingham. It accepts gas from Canada to the north and from the Rocky Mountain region to the south. These bi-directional pipelines boast of greater flexibility in both supply and price to customers.

Many gas transmission pipelines are "looped," which just means there are two or more pipeline running in parallel to each other normally in the same right of way. Looping provides increased storage of gas in the system to meet demands during peak use periods.

The flow of gas through the pipeline, and monitoring for any problems, is handled in most pipelines by a Supervisory Control and Data Acquisition System (SCADA). A SCADA is a pipeline computer system designed to gather information such as flow rate through the pipeline, operational status, pressure, and temperature readings. This information allows pipeline operators to know what is happening along the pipeline, and allows quicker reactions for normal operations, and to equipment malfunctions and releases. Some SCADA systems also incorporate the ability to remotely operate certain equipment, including compressors and valves, allowing operators in a control center to adjust flow rates in the pipeline as well as to isolate certain sections of a pipeline.

The "city gate" is where a transmission system feeds into a lower pressure distribution system that brings natural gas directly to homes and businesses. At the city gate the pressure of the gas is reduced, and it is normally the location where odorant (typically mercaptan) is added to the gas, giving it the characteristic smell of rotten eggs so leaks can be detected. While transmission pipelines may operate at pressures over 1000 psi, distribution systems operate at much lower pressures. Some large gas mains (2-24 inches in diameter) in a distribution system may operate around 200 psi, but the small service lines that deliver gas to individual homes are typically well under 10 psi.

Once the gas is delivered to the local gas utility at the city gate, the gas utility's control center monitors flow rates and pressures at various points in its system. The operators must ensure that the gas reaches each customer with sufficient flow rate and pressure to fuel equipment and appliances. They also ensure that the pressure stays below the maximum pressure for each segment of the system. As gas flows through the system, regulators control the flow from higher to lower pressures. If a regulator senses that the pressure has dropped below a set point it will open accordingly to allow more gas to flow. Conversely, when pressure rises above a set point, the regulator will close to adjust. As an added safety feature, relief valves are installed on pipelines to vent gas, if a line becomes over pressured and the regulators malfunction.

Construction of Natural Gas Pipelines

The construction phase of pipeline installation is a critically important time to ensure the long-term integrity of the pipeline. Below are a few of the issues dealt with during the construction phase that affects pipeline safety. Some gathering and most production lines are not required to follow these standards.

Pipeline Construction Video

This link is to a Spectra Energy video that shows what they describe as typical gas transmission pipeline construction: http://www.youtube.com/watch?v=AvWdawmFa38

The language is certainly pro-industry, but it does show the construction of a large pipeline.

Materials

Most transmission and gathering pipelines are now made out of high carbon steel. Pipe sections are fabricated in steel rolling mills and inspected to assure they meet government and industry safety standards. Generally between 40 and 80 feet in length, they are designed specifically for their intended location in the pipeline. A variety of soil conditions and geographic or population characteristics of the route will dictate different requirements for pipe size, strength, wall thickness.

Distribution pipelines may also be made of steel, but increasingly high strength plastic or composites are being used. Older distribution pipelines were frequently made of cast iron. Cast iron gets brittle with age, and can be susceptible to fractures when subjected to ground movement from freeze/thaw cycles or other causes. Some states require regular "frost surveys" during winter months in hopes that leaks formed from pipes cracking as a result of frost heaves are found and repaired quickly. Some plastics are also known to become brittle with age. The National Transportation Safety Board has recommended replacement of Aldyl-A type plastic pipes in distribution systems for years, yet failures in these pipes are still occurring.

Pipe Burial

Historically pipelines were installed using an open trench method, and this is still used for the majority of transmission and gathering lines. New underground techniques such as boring and horizontal directional drilling (HDD) allow pipe to be installed without digging a trench. HDD is now used a good deal where pipelines need to make river crossing as a way to greatly reduce the environmental disturbance of the river and to bury the pipeline much deeper. Boring is used extensively with distribution pipelines, especially in urban areas, for road crossings and to avoid other utilities. Both HDD and boring come with their own unique risks, for instance other utilities that are hard to locate, such as plastic or clay sewer lines, can be drilled right through (see picture). These "cross bores" often go unnoticed until the sewer lines clogs and an unsuspecting plumber or homeowner tries to clear the clog with a power snake auger. The auger may break the gas line through the pipe causing gas to leak into the sewer line and into the home where it could explode.

Federal regulations require that transmission pipelines and regulated type A gathering lines be buried at least 30 inches below the surface in rural areas and deeper (36 inches) in more populated areas. In addition, the pipeline must be buried deeper in some locations, such as at road and railroad crossings

(36 inches) and crossings of navigable bodies of water (48 inches), and may be less in other locations such as when it is installed in consolidated rock (18 to 24 inches). Distribution mains must be at least 24 inches deep with some exceptions. Service lines on distribution systems must be 12 inches deep on private property, and 18 inches deep along roads and streets. The depth of burial is just for installation, and there is nothing in the federal regulations that requires this depth be maintained over time. These depth requirements went into effect in 1970, and pipelines that were installed before that time do not have to meet these requirements so could be at any depth.

Pipe Coatings

Several different types of coatings may be used to protect the exterior of steel pipe from corrosion. The most common coatings being used currently is fusion bonded epoxy or polyethylene heat-shrink sleeves. Prior to application, the bare pipe is thoroughly cleaned to remove any dirt, mill scale or debris. The coating is then applied and allowed to dry. After field coating and before the pipe is lowered into the trench, the entire coating of the pipe is inspected to ensure that it is free from defects. Older pipelines may be uncoated or have coal tar or enamel wrap coating. The picture here shows the older enamel wrap coating on the Enbridge pipeline that failed in Michigan in 2010.

Welding of Steel Pipelines

To carry out the welding process, the pipe sections are temporarily supported along the edge of the trench and aligned. The various pipe sections are then welded together into one continuous length, using manual, semiautomatic or automatic welding procedures. As part of the quality-assurance process, each welder must pass qualification tests to work on a particular pipeline job, and each weld procedure must be approved for use on that job in accordance with federally adopted welding standards. Welder qualification takes place before the project begins. Each welder must complete several welds using the same type of pipe as that to be used in the project. The welds are then evaluated by placing the welded material in a machine and measuring the force required to pull the weld apart. It is interesting to note that a proper weld is actually stronger than the pipe itself.

For higher stress pipelines over 6 inches in diameter, a second level of quality-assurance ensures the quality of the ongoing welding operation. To do this, qualified technicians sample a certain number of the welds (the sample number varies based on the population near the pipeline) using radiological techniques (i.e., X-ray or ultrasonic inspection) to ensure the completed welds meet federally prescribed quality standards. The X-ray technician processes the film in a small, portable darkroom at the site. If the technician detects certain flaws, the weld is repaired or cut out, and a new weld is made. Another method of weld quality inspection employs ultrasonic technology.

Operating Pressure

Maximum allowable operating pressure (MAOP) is the maximum internal pressure at which a pipeline or pipeline segment may be continuously operated. These pressures are set at levels meant to ensure safety by requiring that the pressure does not cause undue stress on the pipeline. How this pressure is determined is defined in federal regulations and is based on a number of different factors such as the location of the pipeline, pipe wall thickness, previous pressure tests, and the pressure ratings of various components. The combination of MAOP and the diameter of the pipeline determine the potential impact radius (PIR) if a pipeline should fail.

Valves and Valve Placement

A valve is a mechanical device installed in a pipeline and used to control the flow of gas. Some valves have to be operated manually by pipeline personnel, some valves can be operated remotely from a control room, and some valves are designed to operate automatically if a certain condition occurs on the pipeline. If a pipeline should fail, how quickly the valves can be closed and the distance between the valves are some of the main determinations for how much fuel is released.

Valves

There has been a lot of discussion about valves in the past couple years. When it took the pipeline company in San Bruno 90 minutes to drive to the valve and manually turn it off that led to new regulations nationally for automated valves on new transmission lines and a study of the idea of retrofitting certain existing lines.

On the distribution side in 2006 Congress passed a statute requiring excess flows valves (small valves that cost less than $20 that go on each service line to a house) to be installed on every new home built and when service lines are replaces. These "EFVs" shut off the gas to a home automatically if the line is broken by things such as excavation or a cross bore as explained above.

Testing of Pipelines Before They Go In Service

Generally, but with certain exceptions, all regulated pipelines constructed since 1970 had to be pressure tested before they can be placed into service. The purpose of a pressure test is to eliminate any defect that might threaten the pipeline's ability to sustain its maximum allowable operating pressure plus an additional safety margin, at the time of the pressure test. A pipeline is designed to a specified strength based on its intended operating pressure. Critical defects that cannot withstand the pressure will fail. Upon detection of such failures, the defects are repaired or the affected section of the pipeline is replaced and the test resumed until the pipeline "passes".

Hydrostatic pressure testing consists of filling the pipeline with water and raising the internal pressure to a specified level above the intended operating pressure, and is the norm for testing transmission pipelines. Distribution lines are normally pressure tested with air.

Pipeline Safety Requirements During Operation

Corrosion Protection

Unprotected steel pipelines are susceptible to corrosion, and without proper corrosion protection every steel pipeline will eventually deteriorate. Corrosion can weaken the pipeline and make it unsafe. Luckily, technology has been developed to allow corrosion to be controlled in many cases to extend pipeline life if applied correctly and maintained consistently. Here are the three common methods used to control corrosion on pipelines:

- **Cathodic protection** (CP) is a system that uses direct electrical current to counteract the normal external corrosion of a metal pipeline. CP is used where all or part of a pipeline is buried underground or submerged in water. On new pipelines, CP can help prevent corrosion from starting; on existing pipelines, CP can help stop existing corrosion from getting worse.
- **Pipeline coatings** are a principal tool for defending against corrosion by protecting the bare steel.
- **Corrosion inhibitors** are substances that can be added to a pipeline to decrease the rate of attack of internal corrosion on the steel since CP cannot protect against internal corrosion. Such inhibitors are of particular use in "wet" gas pipelines.

Right-of-way Patrols
Regulations require regular patrols of pipeline right-of-ways to check for indications of leaks and ensure that no excavation activities are taking place on or near the right-of-way that may compromise pipeline safety. For transmission pipelines, these patrols are often accomplished by aerial patrols, but federal regulations do not require them to be done by aerial inspection.

Leakage Surveys
Regulations also require regular leakage surveys for all types of natural gas pipelines along the pipeline routes. Personnel walk or drive the route using specialized equipment to determine if any gas is leaking and to then quantify the size of the leak. Very small leaks are a normal part of most gas pipeline systems.

Odorization
Processed natural gas is odorless, so all distribution pipelines, and some natural gas transmission and gathering lines (those mainly in highly populated areas), are required to be odorized so leaking gas is readily detectable by a person with a normal sense of smell.

Integrity Management
We will have a much more detailed description of the integrity management programs for both liquid and gas pipelines in a later edition. For now, the basics - Integrity Management refers to a relatively new set of federal rules that specify how pipeline operators must identify, prioritize, assess, evaluate, repair and validate - through comprehensive analyses - the integrity of their pipelines. Some form of integrity management now applies to both transmission and distribution pipelines, although gathering lines are exempt from these requirements. For gas transmission pipelines, integrity management requires that lines that could affect High Consequence Areas (mainly more populated areas) have to be reinspected by their operators every seven years. This re-inspection is done mainly with internal inspection devices called smart pigs, but may also be done through pressure tests or direct assessment. Once inspected, the rules require that operators respond to certain anomalies found on their pipeline in certain ways within certain timeframes. In the first 9 years of this program, these rules required over 39,000 repairs be made to gas and liquid transmission pipelines that fall within High Consequence Areas. Unfortunately, only about 6% of the gas transmission pipelines nationwide are required to do these important inspections, although pipeline operators have inspected far more miles of pipelines than what is required.

For further information:

Pipeline Safety Trust : http://www.pstrust.org/pipeinfo/beginners.htm

PHMSA Community Toolbox website: http://primis.phmsa.dot.gov/comm/Index.htm?nocache=2349

PHMSA pipeline basics: http://primis.phmsa.dot.gov/comm/PipelineBasics.htm?nocache=9334

Natural Gas from Wellhead to Burner Tip: http://www.naturalgas.org/naturalgas/naturalgas.asp