LOCAL DISTRIBUTION PIPELINES IN NONTECHNICAL LANGUAGE

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acknowledgments

In 2006 PennWell released *Oil and Gas Pipelines in Nontechnical Language*, which I coauthored with Bill Leffler. Without Bill's encouragement and tutelage, the transmission book, and by extension, this book, would never have been written. My thanks to Bill for his patience, encouragement, wit, and most of all his teaching.

The transmission book stopped at the city gate, and it occurred to me the natural gas pipeline story lacked the final link—local delivery.

My deep background is the hazardous liquids pipeline business—crude oil, refined products, and the like. While liquids and gas obey the same laws of physics, parts of the businesses and operations have interesting differences. Fortunately, working on oil and gas pipeline industry common issues while at Conoco brought me into contact with several natural gas transmission industry professionals. When I told them of my plans to write the first book, they enthusiastically gave me free reign to learn from their people. Making the rounds with natural gas transmission technicians and control room operators, I learned the natural gas transmission industry, but I realized there was still much I had to learn before I could write knowledgeably about the distribution side of the business.

Shortly after finishing the transmission book, I was blessed to meet Steve Vitale, who spent many years in an assortment of technical and engineering roles in the natural gas distribution business. Steve patiently explained the business to me and answered questions over the ensuing years as the book progressed. He even wrote the introductory story for the LNG chapter.

Three Davids provided valuable assistance with this book. David Waples, author of *The Natural Gas Industry in Appalachia: A History from the First Discovery to the Tapping of the Marcellus Shale* provided extensive source materials for chapter 2 and facilitated gaining permission to use various photos providing a visual history of the industry. David Klimas, senior vice president and chief engineer with EN Engineering, reviewed chapter 11, providing important upgrades to what I had written. Finally, David Vanderpool, principal, Vanderpool Pipeline Engineers Inc., whom I worked with at Conoco Pipeline for many years and with whom I wrote a chapter on pipeline engineering for another publisher, reviewed drafts of chapters 3 and 11, offering many excellent clarifications and improvements. David also generously allowed me to use some of his firm's engineering standards in chapter 11.

Through a series of litigation consulting cases, I met Mark Kazimirsky, now president of MK Consulting Services Inc. He has a deep background in controls and SCADA and provided valuable insight into those topics as relates to the LDC industry. Mark reviewed the draft of chapter 10, providing edits as he went.

Over the years, Cheryl Trench, principal, Allegro Energy Consulting has performed extensive review and analysis of natural gas distribution, natural gas transmission, and liquid pipeline incident data. When I had questions about PHMSA data or about one of the many reports she published, Cheryl always answered those questions and carefully put the data into context for me.

Leak detection and monitoring are critical issues, and I appreciate the assistance provided to me with them by Heath Consultants in the persons of Paul Wehnert and Vivian Marinelli. They spent time reviewing history, current practices, and leak survey equipment. They also paved the way for me to use various pictures from Heath in chapter 8.

Sometimes industry insiders are happy to comment but don't want acknowledgment, which is exactly what happened for chapter 8 and 14. She helped me understand important differences between transmission and distribution when it comes to leaks and release management as well as helping me think about challenges for the future as I wrote chapter 14.

A wide assortment of operating companies and professionals taught me about the local distribution business, patiently answering my questions, escorting me to their facilities, reviewing chapter drafts, and providing comments and suggestions. Unfortunately, in nearly all cases, their companies and organizations preferred that I not acknowledge them by name, which I understand and respect. Nevertheless, I am deeply grateful to these men and women who freely shared their knowledge and time. Without them this book would not exist.

Many people contributed to this book by sharing their knowledge, either teaching me or allowing me to learn by observation. Others took a keen interest and freely lent their expertise and entry to the inner workings of the industry and their company. It is impossible to thank each one by name. To all these people I express my thanks. Nonetheless, and as always, I had the last word, so I carry the burden of interpreting correctly what others offered.

Finally, I thank my family, and particularly my wife, for the patience, understanding, encouragement, and love she provided during this effort. As any well-married author will attest, those four gifts are the prerequisites of timely book completion.

chapter 1

How Pipelines Differ

Always do right. This will gratify some people and astonish the rest.

—Mark Twain

Pipelines Are Ubiquitous

In any city, in any developed country, the day begins. Families awaken and prepare for the day. Water arrives at the sink and shower via water pipelines. Sewage leaves via sewage pipelines. Natural gas arrives at the stove via an interconnected natural gas network. The school bus arrives, fueled by diesel that began as crude oil and was transported via a network of crude oil and refined products pipelines. Parents travel to work via public transportation or private cars, which also depend on fuels transported by pipelines. Once at work, employees use computers powered by electricity generated from natural gas. The natural gas is, in turn, supplied to power plants from the natural gas pipeline grid. No one really wants pipelines, but everyone needs them.

Energy Pipelines

Most people think pipelines are pipelines. All pipelines, whether gas, oil, water, or sewer, obey the same laws of physics but perform unique functions and operate differently. Put a group of oil pipeliners together with natural gas pipeliners, or even natural gas transmission pipeliners with natural gas local distribution pipeliners, and they might be speaking the same language, but with different dialects. Oil and gas pipelines (sometimes broadly referred to as *energy pipelines*) may look essentially the same, obey the same laws of physics, be installed in largely the same

Fig. 1–6. Loading a tanker at a marine export facility

Refined products pipelines

The refined products pipeline value chain begins at refineries and ends at *petroleum products terminals*, collections of large tanks along the pipeline, located near consumers (fig. 1–7).

Fig. 1–7. Refined products terminal. The storage tanks are shown on the left, and the truck loading rack is shown on the far right.

Products move down the pipeline in batches. Sometimes the entire flow of the pipeline is diverted into a terminal tank; at other times, only

Some manufacturers at first refused to risk their time and money to produce the pipelines needed for such a "foolish and unlucky thing as gas." Over time multiple piping materials such as lead, tinned steel, asphalt, cement, concrete, and even wood were tried (fig. 2–5).

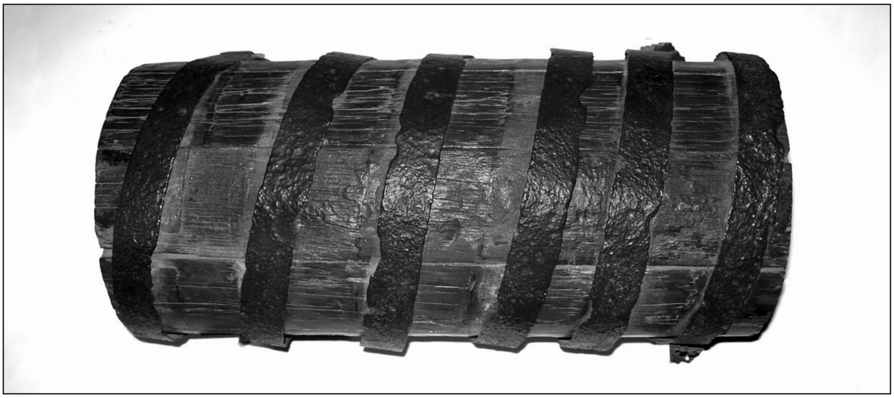

Fig. 2–5. Hollowed-out log used to transport gas. Note the iron bands added to reinforce the wood.

Cast iron pipe was first used in Langensalza, Germany, around 1562, according to the Cast Iron Soil Pipe Institute.[11] It eventually emerged as the material of choice for mains. Necessity continued to drive invention, and Aaron Manby of the Horseley Iron Works discovered how to weld longitudinal seams with machines rather than manually. This improved manufacturing method led to reduced costs and higher quality, especially for the smaller diameter service lines.

Lack of dependable meters meant gas volumes were sometimes estimated and sold by contract. Gas suppliers hired inspectors, who visited the houses of consumers and shut off the gas at the street cocks when they found gas lights still lit after the appointed contract hour. All sorts of disagreements arose under this lump-sum method as gas companies experienced large losses from customers abusing the system.[12] In 1815 the gas meter and the *governor*, a device to regulate pressure, were invented by Samuel Clegg, Sr.[13] Metering improvements followed as gas companies and customers sought fair means of buying and selling gas.

The new lighting proved irresistible to consumers, and by about 1826 most major cities and towns in the United Kingdom had gas manufacturing plants for street and factory lighting. In 1824 the Imperial Continental Gas Association was founded by Sir Moses Montefiore and some of his success. Experimentation and trial and error proved the good ideas and disposed of the bad ones.

Plastic pipe. The advent of plastic pipe, first discovered in the 1930s but not put into large-scale use until the mid-1950s, significantly changed distribution industry practices. After several false starts, the industry settled on polyethylene pipe. Now more than 90% of all new distribution mains and service lines installed around the globe are constructed of high-density polyethylene pipe.

Trenchless installations. Boring, ground piercing, and finally horizontal directional drilling (HDD) have reduced the cost and improved the safety of installing mains and service pipes without trenching. Service connections and disconnections, along with some forms of maintenance, were much improved with keyhole and small-hole techniques.

Communications, computers, and control. Formerly, operators read gauges and meters and then telegraphed, and later phoned, the information into a central dispatch center. Centralized dispatchers responded with orders, and operations were performed manually. Now, though, communications, sensors, transmitters, and actuators handle many of these tasks automatically and routinely. Smart meters are even being installed at residences, reducing the need for meter readers.

Storage. Depleted gas reservoirs still provide the majority of storage, but salt caverns are being mined to provide high-deliverability storage. LNG storage is coming back into use, particularly at import terminals.

LNG. LNG is simply natural gas in a liquid rather than a gaseous state. Liquefied natural gas requires about 600 times less storage space than natural gas at standard temperature and pressure. When pipeline transport is not economic, LNG transport by ship may be. Japan and South Korea, for example, depend primarily on the import of LNG to meet their natural gas needs. Once returned to the gaseous state, natural gas can be injected into distribution systems just like natural gas that has never been liquefied. In addition to water transport, LNG is showing signs of coming back for storage to load balance across demand changes.

Business and regulations

The 50 years between 1950 and 2000 saw vast changes to natural gas regulations and the natural gas transmission and distribution businesses. Covering these changes is beyond the scope of this chapter but they are covered in more detail later in this text.

Splitting flows

Moving inside the house offers another analogy. When someone takes a shower and someone else in the house unconscionably flushes a toilet, some of the water previously going to the shower goes to the toilet. A sudden reduction in water flow to the shower occurs. To the chagrin of the showerer, sometimes the cold water flow drops more than the hot water flow, and the shower changes momentarily to scalding (fig. 3–6).

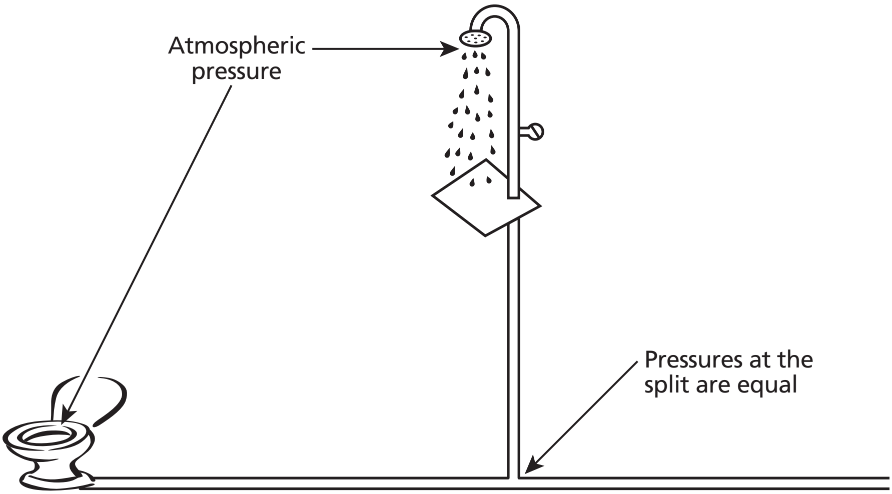

Fig. 3–6. Shower and toilet example. Pressures must be equal at the split.

When valves are open in more than one location, various laws of physics redistribute flows in ways that balance pressures and flow rates. Where the water flows split, the following equations apply:

Pressure at split = pressure at shower
+ pressure loss between shower and split

Pressure at split = pressure at toilet
+ pressure loss between toilet and split

That is the basic lesson in the physics of flow, but it only covers half the fun of hydraulics. The second part consists of the laws of fluid mechanics, most of which were developed by the great minds of the 17th, 18th, and 19th centuries. But before that comes the properties of fluids. Water has been the example for a lot so far, and natural gas follows the same laws of

Turbulent flow through gas pipelines happens the same way. The inside of plastic or steel pipe may look smooth, but to molecules even a little unevenness makes a big difference. If shoved against the side by their neighbor, they bounce off the wall, colliding with the same or other neighbors, jostling all around (fig. 3–14).

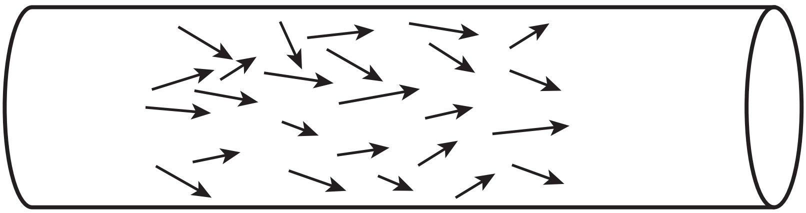

Fig. 3–14. Turbulent flow profile

Most high-pressure transmission pipelines operate in turbulent flow, but distribution lines at any time can be in laminar, transitional turbulent, or fully turbulent flow, or not flowing at all. Which flow regimen the line is operating in is unimportant to the consumer, but engineers must understand the flow regimen and calculate friction loss and flow rates accordingly.

Sir Osborne Reynolds (1842–1912) is widely credited with discovering laminar flow around 1880. He injected dye into a stream of fluid and found that at lower flow rates, the flow remained streamlined. At higher velocities, the flow went from streamlined to turbulent. In 1882, he published a paper regarding this topic and introduced a number called, not surprisingly, the *Reynolds number*. Reynolds numbers are calculated based on density, viscosity, velocity, and diameter. The size of the Reynolds number predicts whether flow is laminar or fully turbulent. Reynolds numbers appear prominently in pressure loss equations.

Friction loss

For most pipelines, friction loss and not elevation change is the major factor requiring compressor stations. Friction loss is caused by the molecules rubbing against each other and against the pipe wall. It is affected by the following:

- Viscosity
- Density
- Velocity (a function of pipe diameter and flow rate)