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OIL & GAS PIPELINES

IN NONTECHNICAL LANGUAGE

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How Pipelines Differ

The difference between a violin and a viola is that a viola burns longer.
—Victor Borge (1909–2000)

This is quite a three-pipe problem.
— Sir Arthur Conan Doyle (1859–1930)

If some veteran natural gas pipeline operators moved over to an oil pipeline, they would scratch their heads in wonderment about the different variables, controls, customer requirements, and alarm bells.

But aside from operations, oil and natural gas pipelines look essentially the same, perform the same service, and obey the same laws of physics. They are installed in largely the same manner and face the same regulatory and social dilemmas. But that does not mean they all use the same nomenclature.

Such differences in nomenclatures can occur concerning natural gas pipelines versus oil pipelines, and crude oil pipelines versus refined products pipelines. Making life easier, operations of some types of pipelines are more or less indistinguishable from oil pipelines operations. These include chemical liquids pipelines, natural gas liquids (NGL) pipelines, and liquefied petroleum gas (LPG) pipelines. On the other side, pipelines that move anhydrous ammonia, carbon dioxide, and gaseous chemicals like ethylene operate much like natural gas pipelines.

The pipeline industry further subdivides crude oil pipelines into the following categories:

- Crude oil gathering lines
- Crude oil main lines

Somewhat parallel, natural gas pipelines fall into these categories:

- Natural gas gathering lines
- Natural gas transmission lines
- Local distribution lines

Both the liquid and natural gas pipeline value chains begin in the oil patch, where oil and gas are extracted from underground reservoirs, sometimes as mixed streams, sometimes separately. If the stream at the wellhead is a mixture, field separators at the well sites segregate it into oil and gas, and the two commodities are treated separately from that point (fig. 1–1).

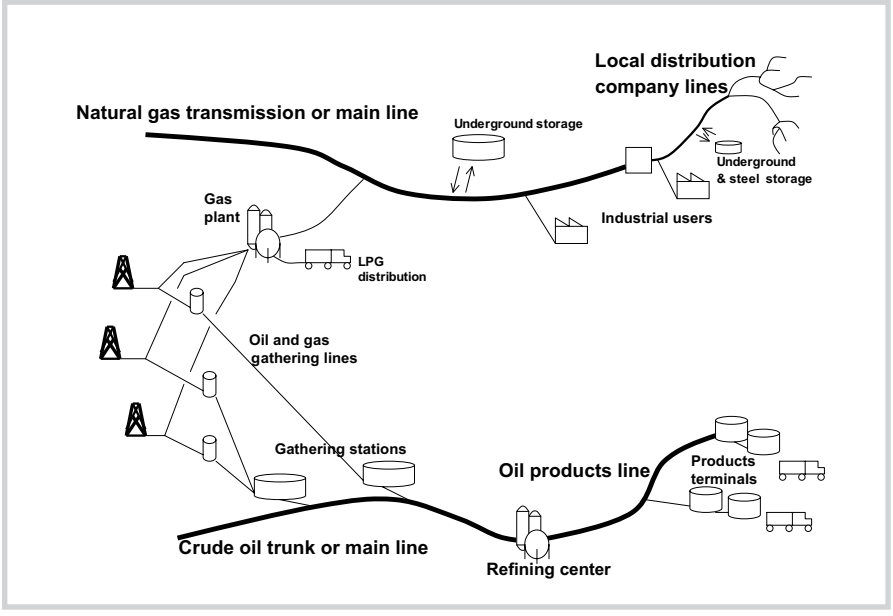

Fig. 1–1. Oil and natural gas value chain

Crude Oil Pipelines

Crude oil gathering lines are normally made from 2-inch (in.) to 12-in. pipe. They originate at the production field tank battery (fig. 1–2), a collection of smaller tanks, for transport by truck or pipeline to a gathering station (a collection of larger storage tanks).

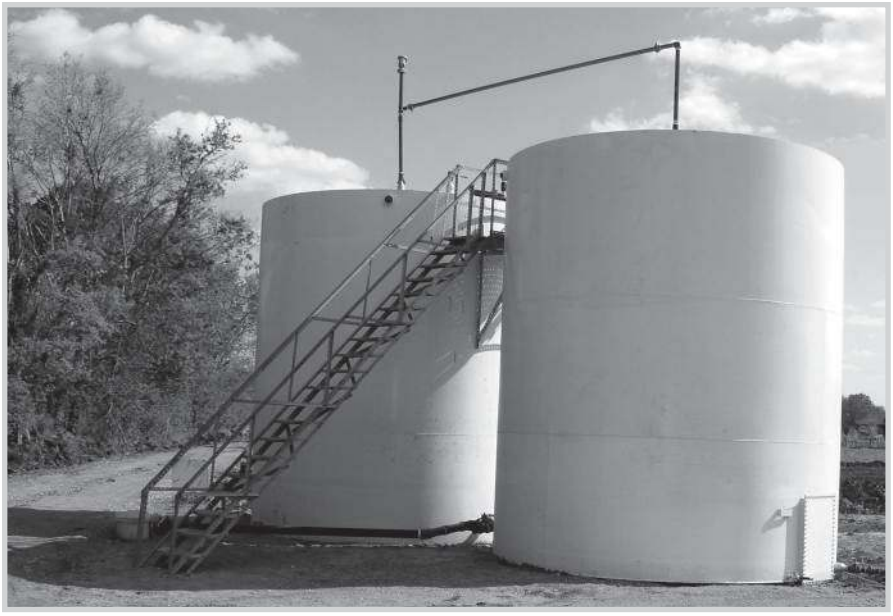

Fig. 1–2. Crude oil tank battery at a well site (Courtesy Miesner, LLC)

The gathering station aggregates crude from many sources, including deliveries by tank truck. It is normally adjacent to a crude oil mainline and has a pump station to inject the crude oil into the main line. Gathering stations may be located at the beginning of a main line or along the route. Main lines are generally 8-in. or more in diameter.

When a gathering station is located along a main line, often called a trunk line, the crude oil can be injected into the continuous flow of crude oil as it goes past. If the crude oil is sufficiently different from that flow, the pipeline can be stopped upstream of the gathering station. A volume of crude can be pumped in as a separate batch. The batch is then tracked as it moves down the pipeline and is delivered to separate customers or into segregated tanks at the destination.

Besides gathering stations, main lines receive crude oil from other main lines, regional storage facilities, and marine off-loading facilities. Conversely, main lines deliver to the same list of facilities plus, most importantly, refineries.

Refined Products Pipelines

The refined products pipeline value chain begins at refineries and ends at petroleum products terminals. This is a collections of large tanks located along the pipeline near consumers (fig. 1–3).

Fig. 1–3. Oil product tanks at a pipeline terminal (Courtesy Explorer Pipeline Company)

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

From the terminal, the petroleum products move to retail outlets or commercial and industrial consumers in tank trucks or in tank cars.

The network at either end of a product pipeline can vary. The Yellowstone Pipeline originates in Billings, Montana, where it receives batches of product from only three refineries. The pipeline moves the product to terminals across Montana. Yellowstone is the single source for those terminals.

Explorer Pipeline begins on the U.S. Gulf Coast, where it receives batches of product from a dozen or more refineries and other pipelines. When it reaches Dallas, Tulsa, St. Louis, and Chicago, Explorer competes with other pipelines coming into the area. It also competes with other refineries in the area.

Natural Gas Pipelines

Gathering lines receive natural gas at well sites, often moving it to gas plants for further processing (fig. 1–4). Sometimes, depending on gas quality and contaminants, the natural gas is injected directly into gas transmission lines without processing. The contents of the natural gas, particularly contaminants, determine whether the natural gas stream needs extensive processing at gas plants.

Fig. 1–4. Natural gas processing plant (Courtesy ConocoPhillips)

Facilities at gas plants usually remove acid gases and the NGLs. The acid gases include hydrogen sulfide and carbon dioxide, gases having the potential to corrode the facilities of both the pipeline and the consumer. Hydrogen sulfide is also toxic and is a pollutant. The NGL could include natural gasoline, butanes, propane, and sometimes ethane.

If a natural gas stream has a heavy content of NGLs, at least the natural gasoline and some of the butane has to be removed to avoid condensation in the gas transmission lines. Condensation causes operational challenges, as further discussed in chapter 5. Upon removal, the NGLs have various markets and moves from the gas plant in tank cars, trucks, or their own pipelines.

Compressor stations at gas plants or gathering systems boost the pressure of the natural gas to move or inject the gas into the main line. Sometimes compression is not needed because the natural gas is already at a high enough

pressure coming out of the ground to force it into the main line or transmission line. Natural gas is always injected into transmission lines as other gas goes by. Since the gas is more or less fungible (interchangeable), batching is not required. As natural gas enters the main line, commercial adjustments can be made for the energy content of the injected natural gas. This might be done if it is higher or lower than the typical 1,000–1,050 British thermal units (BTUs) per standard cubic foot (scf).

Natural gas transmission lines transport natural gas to the local distribution companies (LDCs) for further movement to homes and businesses. Increasingly, natural gas transmission lines deliver directly to large end users like industrial plants, businesses, commercial sites, and power generation plants, bypassing LDCs. Sometimes, instead of going directly to consumers, natural gas is stored for future use. The storage can consist of aboveground steel tanks, underground caverns, aquifers, or old, depleted oil or gas fields.

The management of daily and seasonal storage is an essential service provided by the main lines to the producers, the shippers, and the LDCs.

Pipeline Customers

Crude oil pipelines sell transportation to shippers, which could be refiners, crude oil producers and traders, or other intermediaries. The customers for refined products pipelines include refiners, traders, and commercial and industrial consumers such as airlines, power companies, government agencies, and railroads.

Natural gas transmission companies have the same generic customers as crude oil pipelines, such as producers and traders. Instead of refiners, however, they have LDCs and large-volume consumers.

In the United States, LDCs normally have an exclusive right to serve a particular area. They purchase natural gas and then provide transportation of the natural gas to residential, commercial, and industrial consumers, charging one fee for the service and the natural gas. In some markets, the resellers have a corporate affiliation with the LDC. In most cases in the United States, the natural gas transmission lines never actually own the natural gas. They simply transport the natural gas for a fee, just like railroads transport other commodities without owning them.

So natural gas is transported "as is" from the wellhead all the way to consumers, with the exception of some minor processing at gas plants. In contrast, oil goes through major transformation at refineries before it is suitable for consumption by its various customers. Because of that, oil products pipelines carry multiple products. This adds even more contrast to the operating complexities of the two types of pipelines, oil and gas, as will become abundantly clear in coming chapters.

2

The First Leg

All I really need to know I learned in kindergarten.
—Robert Fulghum (1937–)

Some historians would start a review of pipeline progress by citing the Chinese experience. A few thousand years ago, they used hollowed bamboo with mud seals to move water—and some say natural gas—for short but unspecified distances. And there might be allusions to the fresh water and toilet facilities of Crete's King Minas in the second century B.C. But all that ancient lore is more about plumbing than pipelining, and while it may be interesting, it is not all that useful.

The real history of oil and gas pipelining begins two centuries ago, and relevant remnants of the experience still abound in today's commerce.

Creating Nostalgia

In 1806 in London, the London and Westminster Gas Light and Coke Company (LWGL&C) began laying the first gas mains ever placed under a public street. LWGL&C had commercialized the process that transformed coal into gas that would burn with enough incandescence to light the streets from lamp posts every 50 feet (ft) or so. The city government

gave permission to dig from Haymarket to St. James Street, lay pipes made of sheet lead, and charge the city for municipal lighting. Thus the legal protocol for future municipal franchises was established.

This *unnatural gas* (not the methane eventually tapped in underground reservoirs) assumed the name *manufactured gas* and sometimes *town gas*. Manufactured gas consisted of a mixture of mostly methane, ethylene, carbon monoxide, and carbon dioxide. The ethylene gave it sufficient luminescence that the lamp lights needed no mantle to burn brightly, an advantage over natural gas, which contains almost no ethylene.

Only a few years later, the Baltimore City Council received a petition from some entrepreneurial Marylanders for a similar franchise. In 1817 they granted the Gas Light Company of Baltimore a contract. Its goal was "to open a street or streets for the purpose of laying pipes for trying the experiment and estimating the expense at which he could contract with the Council for lighting the city."[1]

Gaslights captured the imagination of cities around America in succeeding decades, arriving in subsequent years in the following cities:

1825 New York City
1829 Boston
1832 Louisville
1835 New Orleans
1836 Philadelphia
1843 Cincinnati
1846 St. Louis
1854 San Francisco
1867 Los Angeles
1872 Minneapolis
1873 Seattle

Evidence of gaslight districts survives in many of these cities (fig. 2–1).

The gaslight companies built plants that gasified coal and sometimes oil, wood, and even cottonseed and corn cobs. They located these plants close to their target customers, the street lamp districts, followed quickly by residential and commercial lighting customers. For the distribution systems, some fashioned pipelines initially of hollowed, wooden log segments (fig. 2–2), with inside diameters as large as 8 in. Lengths ran from 2 ft to 8 ft. By the 1820s, British-designed cast-iron pipe arrived to replace logs.

Fig. 2–1. Gas light, circa 1892. The light fixture hanging in the W. J. Murphy Grocery Store in Rawlings Cross, Newfoundland, used locally manufactured gas, undoubtedly supplied through a town gas distribution system. (Courtesy Centre for Newfoundland Studies)

Fig. 2–2. Segment of hollowed log used as a gas pipeline joint (Courtesy Midwest Energy Association; photo by Tom Miesner)

Enter Competition

In 1821, a Fredonia, New York blacksmith, William Aaron Hart, created a new industry. He pounded a few lengths of pipe into the ground in the vicinity of some strangely ignitable gas bubbling from a running creek bed. He then fashioned a floating, open-bottomed box next to his well and captured the gas as it surfaced. Finally, he ran hollowed log pipes to a Lake Erie lighthouse a half mile away and then to the nearby town. With the lighthouse beacon and chandeliers of the theater in town thus lit up, Hart had created the natural gas pipeline industry. The quiet competition between natural gas and manufactured gas continued in America for another 130 years.

Oily Beginnings

While the Fredonia smithy may have drilled the first natural gas well, Americans usually give all the credit to Col. Edwin Drake for drilling the first so-called well. He found oil in Titusville, Pennsylvania in 1859 and single-handedly instigated the petroleum industry's own version of the cosmic Big Bang. After that it expanded inexorably at remarkable speed, with no seeming bounds. In only a few decades, the "Big Bang" of oil and gas operations swirled across the oceans, creating new orbits of activity as markets sucked up this new energy source for heating and lighting.

Of modest proportions at the beginning, oil producers like Drake first loaded their product, crude oil, into barrels. Whatever barrels were handy—wine, whiskey, fish, nails, or salt pork barrels—were pressed into service. Shortly, a phalanx of coopers arrived at the oilfields to manufacture a new supply.

Along with them came teamsters with horse-drawn rigs to haul the loaded barrels to the nearest railhead or river landing, as the oil made its way to refineries and markets. The roads they traveled were generally poor, if they existed at all. Weather sometimes made the shortest passage from the wellhead impossible. A dilemma arose concerning what to do with the blessedly continuous production of oil when the roads became hopelessly mired.

The conceptual leap in the oil business from piping to pipelining, from plumbing to transportation, started haphazardly in 1862. J. L. Hutchings attempted to demonstrate his newly patented rotary pump. He began by laying a 2-in. cast-iron pipe over the hill from the historic Tarr Farm oil field near Oil Creek, Pennsylvania, to a nearby refinery. His pump performed well, but the

pipeline was a disaster. He had soldered the pipe joints with lead, but at the first increase in pressure, the connections leaked so badly none of the pumped oil reached the refinery. Disillusioned and broke, he exited the scene.

Not long after, the next step took place in nearby Pithole, a town that must have been named by someone with an interesting sense of humor. A consortium of oilmen and venturers led by Samuel Van Syckel, called the Oil Transportation Association (OTA), placed a 2-in. wrought iron pipeline over a 6-mile (mi) track from an oil field to the railroad station at Oil Creek (fig. 2–3). The pipe had threaded joints to deter leaks. Borrowing from the railroads, the OTA built a telegraph line along the right-of-way (ROW) to communicate the complicated bookkeeping of multiple shippers.

Fig. 2–3. Early Pennsylvania pipeline (Courtesy Drake Well Museum)

Three steam-driven pumps provided the power to deliver a remarkable 1,900 barrels per day (bpd), for which Van Syckel charged $1 per barrel (bbl). He undercut the teamsters by $4–$5/bbl. Riding on his success, Van Syckel built a parallel line and dropped the charge on both to 50¢/bbl and still made money.

Van Syckel's achievement did not go unnoticed. Pipelines sprouted like kudzu along the hills of Pennsylvania.

Gaseous Progress

Oilmen muttered in frustration when the first fluids from their wells were gas. They were only mildly annoyed if an oil/gas mixture appeared. For the most part, they considered natural gas a waste product. What they did not use to raise steam for their steam engines they typically burned on-site in a flare (fig. 2–4).

However, not everyone rejected as valueless the energy content of natural gas. The Rochester Gas Light Company (RGLC) saw an opportunity to displace the manufactured gas in its distribution system with natural gas from a well 25 mi away. The company laid a wooden pipeline to tap it but struggled for some time with the conversion from one type of gas to another. The lower luminescence of natural gas was bad for the lighting business, and its higher heating content meant replacing burner tips throughout the system. Still, shutting down the gasification works justified the switch.

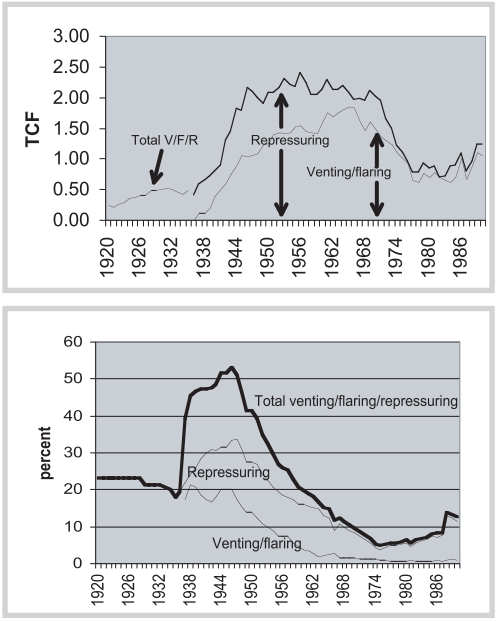

Fig. 2–4. U. S. natural gas volumes and their disposition. It was not until the middle of the 20th century that oilmen realized that pumping the gas back into the reservoir, called repressuring, would return the energy necessary to drive even more oil out. As late as 1935, 20% of the natural gas in the United States was flared.

With RGLC as their role model, producers began to market gas from gas wells and even the so-called associated gas that arrived at the surface mixed with the crude oil. Natural gas had to be separated anyway from crude oil at the wellhead before the crude oil was transportable and marketable. By the 1880s, Pittsburgh, by then a city with heavy industry, became the central focus for natural gas marketing and pipeline construction. Five hundred miles of pipelines brought natural gas from the oil and gas fields of western Pennsylvania. They fed 200 thousand cubic feet per day (Mcfd) of gas to various industries. These included 10 iron and steel mills, six glass-making factories [including the original Pittsburgh Plate Glass (now PPG) facility], and every brewery in town, including the legendary Pittsburgh Brewing Company. (The latter made Iron City beer.) In addition, producers supplied gas to the Simpson Natural Gas Crematory.

Meanwhile in 1879, the Tidewater Pipeline Company completed the first crude oil trunk line from western Pennsylvania. This was a 115-mi run to the Philadelphia and Reading Railroad depot at Williamsport (fig. 2–5). From there the crude oil moved by tank car to New York and other tidewater refineries along the Atlantic. This heroic effort represented no small achievement of civil engineering and human output. Compared to anything previous, as it crossed the Allegheny Mountains, it covered longer distances and higher altitudes by a factor of 10. Eight years later, Tidewater extended the line to Bayonne, New Jersey, eliminating the railroad haul altogether.

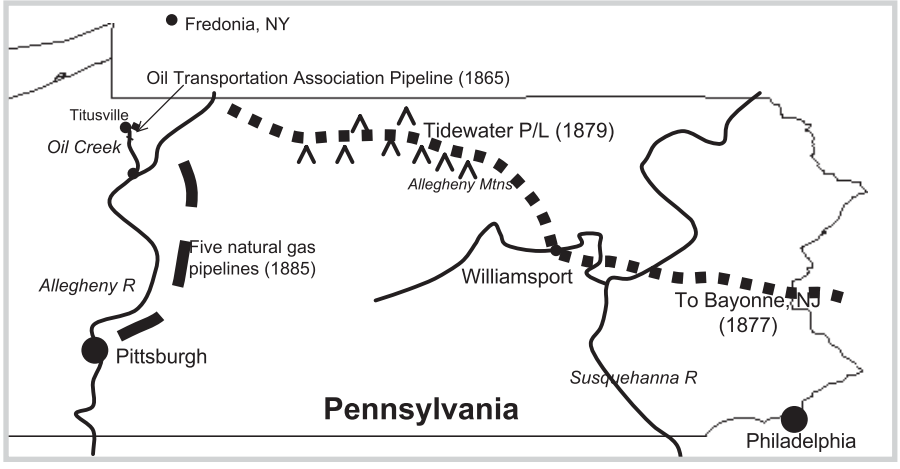

Fig. 2–5. Map of western Pennsylvania pipelines, 1865–1885