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OIL AND GAS PIPELINES

IN NONTECHNICAL LANGUAGE

2ND EDITION

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Natural gas pipeline field operations

The person who knows "how" will always have a job. The person who knows "why" will always be his boss.

—Diane Ravitch (1938–present)

"Welcome to the natural gas pipeline industry," the Division Operations Manager said to the Chief Operations Officer, newly hired from a liquids pipeline company.

"Thanks," replied the new COO. "Please help me understand the major differences between liquid and gas pipelines."

"First, there are lots of similarities between gas and oil operations," said the DOM. "The pipes, valves, and many of the other components and equipment are the same for liquid and gas pipelines, and the laws of physics apply equally to both," explained the DOM. "But, gases are compressible, whereas liquids are not (very) compressible, and most liquid lines ship batches of different fluids end to end, while natural gas pipelines move just one commodity," added the DOM.

Line Pack

The quantity contained in the line is called line pack. Adding fluid faster than it leaves the line packs the line and increases pressure. Taking fluid out of the line faster than it enters the line unpacks the line and decreases pressure.

"Compressibility means the line packs and unpacks depending on pressure, right?" asked the COO.

"Yes, one unit in does not necessarily result in one unit out," replied the DOM.

"Packing and unpacking must make leak detection more complex for gas pipelines versus oil pipelines," commented the COO.

"Yes," said the DOM, "and the fact that gas moves as one molecule means we typically have more connections—receipt and delivery points—than liquid lines, a fact which also adds complexity to gas leak detection."

"What about safety and the environment?" asked the new COO.

"Just like with oil, safety is job one," answered the DOM. "The fact that gas is lighter than air, and liquids are generally heavier than air means there are differences in the case of leaks," added the DOM.

"The first response to oil leaks is to shut down and close the valves. Is it the same for gas leaks?" the COO asked.

"Not necessarily," said the DOM, then added, "Gas systems are more interconnected than oil systems, so closing the valves might mean a power plant, hospital, or other critical facility might be deprived of natural gas."

The DOM went on to explain, "Since gas is compressible, shutting the valves does not mean flow out of the leak stops. It continues until all the pressure is dissipated. On the plus side, if the leak does not ignite, the cleanup is easy since the gas dissipates into the environment, unlike oil leaks which tend to run downhill and get into water."

"Thanks for the summary. I have a lot to learn," said the COO.

Oil and Gas Production

The properties of oil and gas determine how they behave in pipelines, so a short review of oil and gas formation and production will prove helpful to understanding gas and oil pipeline operations.

Formation

Generally accepted theory says oil and gas were formed over eons from decomposing organic materials. These organic materials, once living microorganisms and vegetable matter, were buried under layers of soil, rock, gravel, and sand transported there by ancient rivers. As successive layers of the river-borne materials buried the remains deeper, the temperature and pressure increased and essentially cooked the organic matter, transforming it into hydrocarbons.

> **Permeability**
> Property of geologic structures that determines how easily fluids can flow from or through it.

The geologic formations where the oil and gas formed are called "source rock." Since the amount and type of soil, rock, gravel, and sand surrounding the organic matter, and the depth from the surface varied by location, the geologic structure of the source rock also varied. Some of the source rock containing the oil and gas was permeable, and other source rock was not.

Oil and gas produced in source rock with high permeability flowed from it towards the surface of the earth. In some cases, the stream reached the surface and dissipated into the atmosphere. In other cases, the oil and gas, on its way to the surface, encountered impervious layers of rock or salt and were trapped, forming a reservoir. There, the oil and gas waited for geologists to identify it, drillers to bore into the reservoir, and producers to extract it.

Oil and gas formed in less permeable source rock could not flow, and there it waited until drillers bored into the formation and forced in water and sand —i.e., they fracked it. The high pressure created fractures in the formation, and sand propped open the fractures, allowing the oil and gas to flow from the source rock into the well bore. Figure 6-1 graphically recaps the previous paragraphs.

> **Proppant**
>
> Sand forced into the fractured rock to prop open the fissures created from the frack job is called, not surprisingly, the proppant.

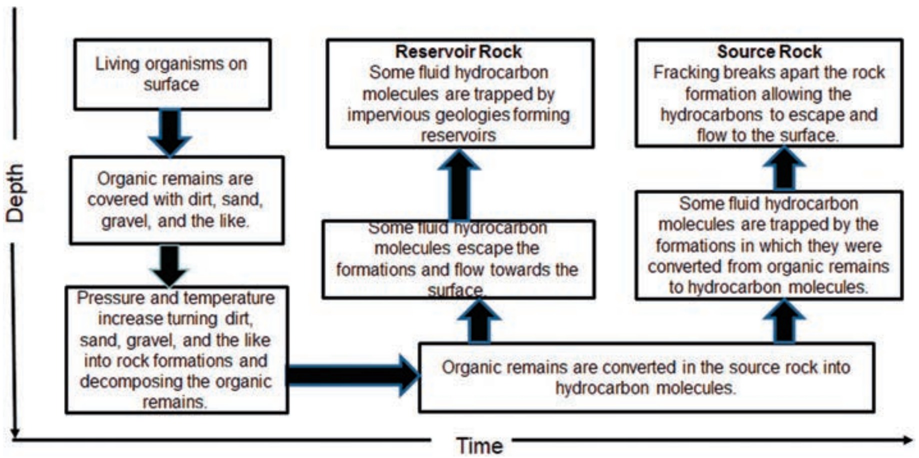

Fig. 6–1. Oil and gas formation flow chart.

The composition of the transformed hydrocarbons varied by location, cooking temperature pressure, and interval—all related to source rock depth. Every producing field yields unique combinations of molecules and, therefore, hydrocarbons of different qualities. Even hydrocarbons from producing zones at different depths in the same field may be different.

The Marcellus Shale in Pennsylvania, for example, contains much more gas than oil. In southwestern Pennsylvania, the gas stream is considered “wet”—it contains ethane, propane, and butane as well as methane. The natural gas produced in north central and northeast Pennsylvania is “dry”— it contains very little if any ethane, propane, and butane. The oil sands of Alberta are on the other end of the spectrum. They contain large, complicated molecules similar to asphalt because they were not buried very deep and were not exposed to the same pressures and temperatures.

Production

The production streams from different wells, then, contain different mixtures of molecules. Whatever the stream's composition, it exits the ground through a wellhead at the top of the well bore (Fig 6—2).

Fig. 6–2. Natural gas wellhead. Often called a Christmas tree or just tree, it is located atop a well. Production field workers adjust the various valves and gauges on it to control pressures and flows.

Each well is typically connected by a flow line to a production processing pad where the stream from the well is processed. The number of wells connected to a specific processing location, and therefore the number of flow lines connected to that processing pad, varies by factors such as well spacing, production rates, and economics. At the production processing pad, separators and treaters separate gas from oil and water and remove some impurities. The gas stream leaves the production processing pad through a meter and then into a gathering line (Figure 6-3).

Fig. 6–3. Orifice meter. The meter at the production processing area is typically the first component in the natural gas gathering system.

Natural Gas Pipelines

As discussed in Chapter 3, natural gas lines are comprised of gathering (feeder), transmission, and local distribution company (LDC) lines. Gathering lines extend from natural gas production sites, to gas treating and processing plants, and then on to transmission pipelines.

The regulations in many countries, including the U. S., treat natural gas transmission pipelines as transporters, meaning the pipeline companies take custody, but not ownership, of the gas. They transport for shippers, who could be producers, or other merchants who sell to large users (hospitals, schools, factories, malls, and electrical generation plants), LDCs, and gas marketers. Alternatively, large users or LDCs may ship the gas on transmission pipelines themselves, purchasing it directly from producers before it enters the transmission line.

LDCs sell to individual homes and businesses and to many of the same customers as those served directly by transmission pipelines. They receive gas from natural gas transmission pipelines, from LNG gasification plants, and from storage—either their own or others. Figure 6-4 shows the flow of natural gas from well to consumers.

Production, gathering, transmission, and local distribution lines may all be owned by the same company through different subsidiaries. Pipeline companies (or their parent) may even own gas processing plants or have a trading company—buying and selling gas between related and nonrelated entities.

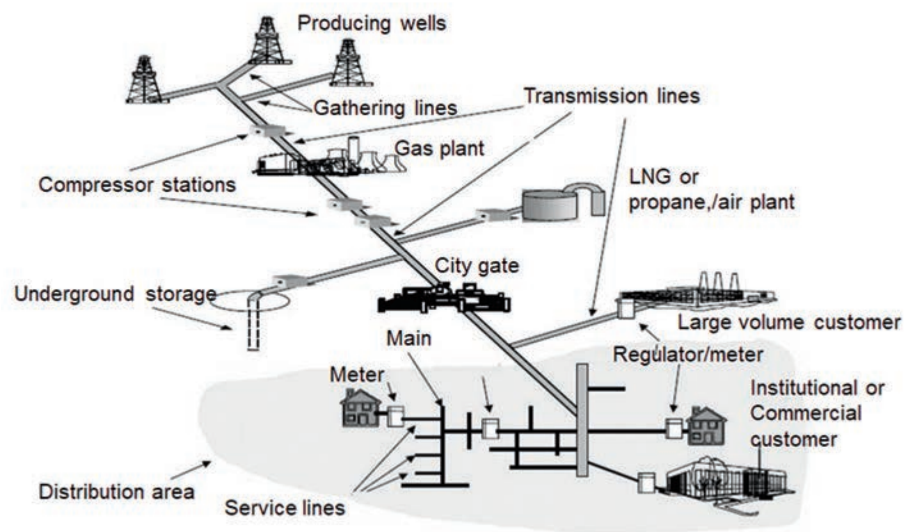

Fig. 6–4. Natural gas flow from the wellhead to the customer.

The distinction between natural gas gathering, transmission, and local distribution lines has more to do with history, regulations, traditional customers, line size, and operating pressures than hydraulics and operating principles. Natural gas, regardless of the country, obeys the same universal laws of physics. Accordingly, natural gas (and other) pipelines are operated largely the same around the globe, regardless of the ownership structures.

Gathering Lines

Gathering lines are usually between four and ten inches in diameter, with the actual size determined by the amount of gas available to move. Along its way, the gaseous stream may undergo additional treating processes as described in Chapter 1. Finally, the stream is processed in a gas plant where the methane is separated from the rest of the stream, the NGLs. The separated stream then enters the transmission line (Fig 6-5).

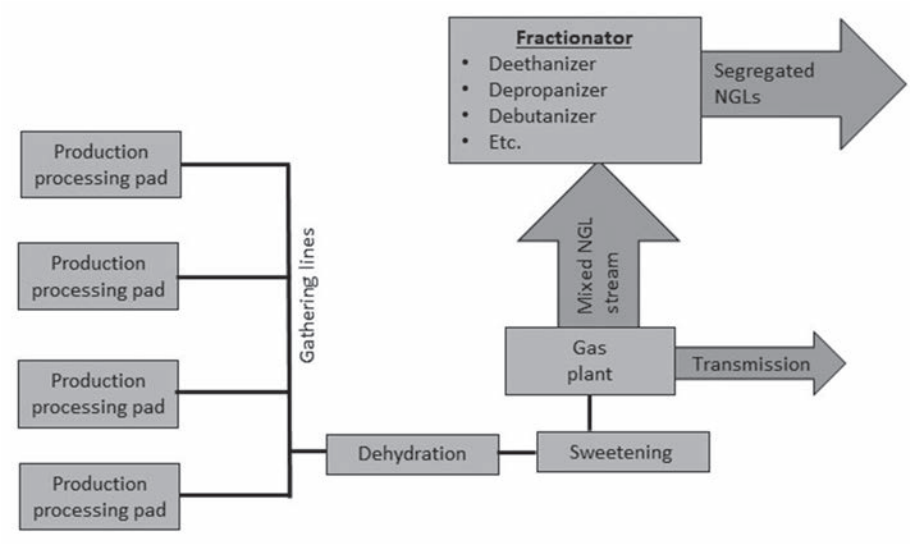

Fig. 6–5. Gathering operations extend from the production processing pad to a gas plant.

Gathering lines can be thought of as neighborhood streets, which progressively lead to larger city thoroughfares, and eventually the freeway system, i.e., the transmission line in this analogy.

Natural gas liquids (NGLs) coming from the gas processing plant are used either as fuels or as feedstocks for the chemical industry. In either case the NGLs are separated into their individual components—ethane, propane, butane, and other components—at processing plants called fractionators. Sometimes fractionation happens at the same location as the gas processing plant; other times the mixed stream moves on by pipeline to other locations for fractionation, sometimes many miles away. Chapter 8 discusses NGL and chemical pipelines.

Transmission Lines

Transmission lines range from a few to thousands of miles long. They serve as the autobahn for the natural gas industry, hauling massive amounts of energy from gas plants, LNG facilities, other pipelines, and storage fields for most, and in some cases all, of its journey to homes, schools, office buildings, commercial establishments, manufacturing plants, and electricity generation plants. Transmission lines may be as small as six inches, up to as large as 48 inches, and a few even larger, in diameter. Some transport natural gas from just a few origination points to a limited number of destinations, but many have several hundred delivery and receipt points.

According to the CIA Fact Book, there are a more than 1.2 million kilometers of natural gas transmission lines in the world. Figure 6- 6 shows the distribution of these lines between countries.

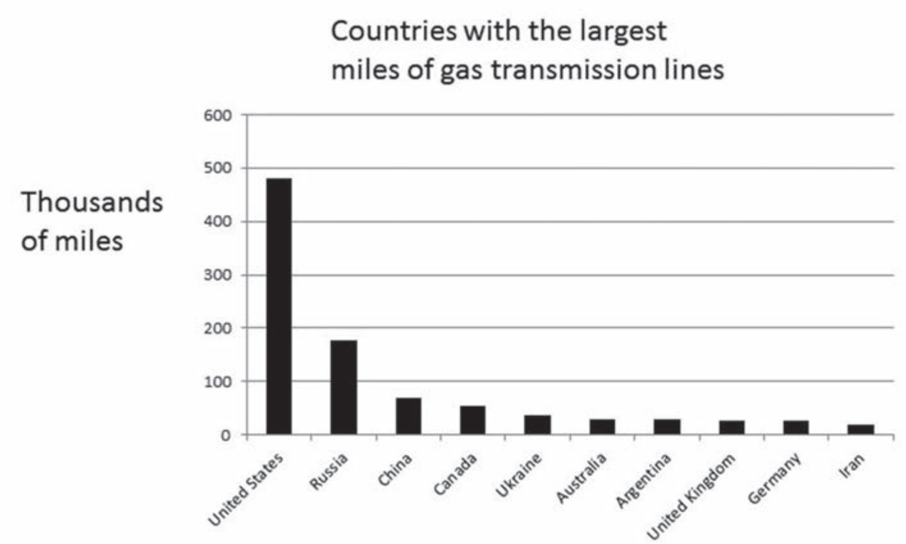

Fig. 6–6. Countries with the largest natural gas pipeline systems. Source: Compiled by Pipeline Knowledge, LLC from CIA Fact Book data.

Liquefied Natural Gas (LNG) Facilities

Things can change in a hurry. The first edition of this book, released in 2006, discussed the prospects of LNG imports into the U. S. The subsequent growth of fracking changed all that, and now the U. S. is exporting LNG. Whichever direction it goes, LNG and its impact on natural gas pipelines merits mention.

What is LNG? It is methane, the same colorless, odorless hydrocarbon molecule in current natural gas pipelines, but it has been cooled to about - 260^0 F (or -162^0 C) in an LNG plant where it turns from gas to liquid. In liquid form, natural gas takes up about 1/600th of the volume it had in its gaseous state at 60^0 F and atmospheric pressure. The smaller volume allows moving methane in specially designed ocean-going tankers from producing countries to consuming countries. Figure 6-7 shows an LNG export facility.

Fig. 6–7. LNG or liquefaction export facility. The facilities in the foreground liquefy the gas by refrigeration. The domed tank stores the LNG until it is loaded on the ship in the background. Courtesy ConocoPhillips.

At the delivery end, LNG import terminals temporarily store the LNG cargo until it is regasified—warmed back up to normal pipeline temperatures and delivered into transmission lines or distribution lines.

Compressor Stations

Origination compressor stations are located at the beginning of transmission lines. Figure 6-8 shows the outside of an origination station and Figure 6-9 is a partial view of the engines and compressors inside the station.

Fig. 6–8. Origination gas compressor station near Victoria, TX. Several gathering lines from onshore and one from offshore enter this mainline origination compression station. The natural gas is aggregated into a common suction header and a combination of the seven reciprocating compressors, driven by natural gas-fired reciprocating engines, adding pressure to the gas before it is discharged into a 30-inch natural gas mainline. Courtesy Williams Gas Pipeline.

Fig. 6–9. Inside an origination station with positive displacement compressors. From a catwalk about ten feet above the floor in the compressor station shown in Fig 6-10, five cylinders of the V-10 engine are visible. Courtesy Williams Gas Pipeline.

Farther along the line, booster stations add back the pressure (energy) lost due to friction generated as the gas flowed along. They "boost" the gas pressure as it travels along its journey (Fig. 6-10).

Fig. 6–10. Inside a booster station with centrifugal compressors. Electric motors, not gas-driven engines, are often used in stations to meet emission standards. In addition, the station may be insulated for noise reduction. The electric motor is on the left, with a variable speed drive; the compressor is connected to it on the right. Courtesy Williams Gas Pipeline.