

# Natural Gas Liquids

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# Preface

The first textbook ever, written by Peter Lombard, was published in 1158. In all the years that have followed, incredibly enough, no one has put a pen to paper to create another textbook explaining natural gas liquids (NGLs) in a simple way. This work corrects that incomprehensible void.

Just a few decades ago, most engineers and businesspeople who managed and operated NGLs inhabited offices that were situated in the back corridors of oil companies' offices or in obscure buildings out in the oil patch. Their more senior executives thought of their commodities as necessary but ancillary operations to the much larger oil and gas businesses.

In more recent decades, three waves of change rolled in to alter most of that:

- The emergent and re-emergent growth of the petrochemicals industry, which provided excellent feedstock opportunities for NGLs.
- The appearance of dynamic and entrepreneurial midstream companies whose primary business is gas plants, pipelines, storage, and any other logistical matter. Exploration and production companies were happy to outsource their midstream worries to them.
- The burgeoning supply of NGLs, especially from shale gas exploitation.

So today, numerous enterprises populate the value chain from the subsurface reservoir to the consumer. To deal with that, I am fortunate to have had the opportunity to tap into people with many different areas of expertise. In particular, I want to thank Dr. Shu Luo, Dr. Donald L. Burdick, Martin S. Raymond, Joel Sopchak, Josh Kasprzak, Gary Hunter, Michael Tusiani, and Robert R. Petrie. They all helped refine the ideas and words I have used to explain the NGL business in terms that are as nontechnical as possible. Still, they have no responsibility and get no reward (other than their name in print) for the integrity of anything in this book. I get both.

Not every chapter in this book will appeal to someone looking for a better understanding of NGLs. Certainly, the introduction and discussion of the value chain in chapter 1 and the history of the NGL business in chapter 2 should appeal to all. The science and engineering of the upstream in chapter 3 might be a dauntingly deeper background (pun intended) than some want. As technical as the chemistry and physics of NGLs is in chapter 4, it discusses a promisingly important foundation of the business and should not be missed.

The rest of the chapters, on gas plants (chap. 5), refineries (chap. 6), logistics (chap. 7), petrochemical markets (chap. 8), and fuel markets (chap. 9), speak to understanding the commercial aspects of NGLs. Chapter 10 covers safety, operations, and maintenance. Profiles of some intriguing NGL companies in chapter 11 address the elements of success in the NGLs business. For anyone even mildly into technology, the appendices give some particulars that elaborate on the exasperatingly complex problems that NGLs can present to the owners of natural gas pipelines and gas plants and to their customers.

William L. Leffler  
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# Introduction

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*The beginning is the most important part of the work.*

Plato (427–347 BCE), *The Republic*

In 1910, a frustrated motorist complained to Dr. Walter Snelling of the U.S. Bureau of Mines, “Half the gas in my tank disappears by the time I get home.” Snelling took a sample and quickly found the disappearing liquid to be vaporizing gases. He built his own still from an old water heater, some copper tubing, and wire-wrapped glass bottles. That allowed him to collect the gases as liquid and to patent the first process for capturing natural gas liquids. Two years later, Snelling’s American Gasol Company installed a propane tank at the home of John Gahring, his first commercial customer, which marked the start of the liquefied petroleum gas industry.

Snelling was an exceptional scientist but not a businessman. His ventures collapsed, and in 1913 he sold his patent to the more entrepreneurial Frank Phillips for \$50,000, a handsome sum at the time, and returned to the Bureau of Mines.

That oxymoron, natural gas liquids, can be a mystery. Are they gases? Are they liquids? Are they natural?

The answer to all three questions: yes . . . usually.

In the middle of the 20th century natural gas liquids (NGLs) operations were an obscure business run in the back corridors of most exploration and production companies, down the hall from the big traders. Later, the growth

# A Short History of the NGL Business

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*Beginning is easy. Continuing is hard.*

Japanese proverb

“The available supply of gasoline, as is well known, is quite limited, and it behooves the farseeing men of the motor car industry to look for likely substitutes” (article in *The Horseless Age*, December 13, 1905).

“The world’s total endowment of oil amounts to 60 billion barrels” (U.S. Geologic Survey, May 1920).

“The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil” (Sheikh Zaki Yamani, Oil Minister of Saudi Arabia during the 1970s).

“The USGS estimates that the mean undiscovered, conventional reserve additions in the world total 665 billion barrels of oil, 1,429 trillion cubic feet of natural gas, and 16 billion barrels of natural gas liquids” (U.S. Geologic Survey, June 2012).

Colonel Edwin Drake kicked off the oil and gas industry when he drilled his well in Titusville, Pennsylvania, in 1859. For the first 35 years the demand for lamp oil (kerosene) buoyed the growth of oil. But by 1890 people began to use light bulbs instead of lanterns, and oil’s future turned uncertain. Then came the automobile. Up to that time, all that white stuff—gasoline and natural gas liquids—was considered a waste product. Most producers left the “wild” material, sometimes called fizz gas, greased oil, wet gas, or overhead



The first round of ships, dubbed *semirefrigerated*, dealt with all three.

The growing availability of LPG from the Persian Gulf found ready markets in Europe by the 1970s. Along with increased crude oil production came associated natural gas from the same wells. NGLs were part of the mix. Before 1970 most of the natural gas associated with crude oil production was flared. Bothered by conscience and by international abhorrence at the waste, the new national oil companies in the Persian Gulf states began to reinject the gas into the reservoirs for future use. Before doing that, they built natural gas processing plants to recover the NGLs for marketing.

A large shift in international trade patterns started around 1975. Most of the huge increases in Persian Gulf NGL production went to Japan, Korea, and China, as demand in those markets started to accelerate (fig. 2–6) with rising incomes, infrastructure development, and, importantly, the advent of larger LPG ships.

In 1962 the Mitsubishi shipyard delivered a new class of LPG ship, the *Bridgestone Maru*, known then as a VLGC (very large gas carrier). Refrigeration plants on this class of huge vessels kept the cargo at  $-45^{\circ}\text{F}$ , below propane boiling temperature. That allowed virtually zero working pressure, with less tank weight (but more expensive nickel-steel alloy). The tanks no longer had to be cylindrical and could match the contours of the ship's hull. Some VLGCs now carry more than 20 million gallons of LPG (fig. 2–8).



Fig. 2–8. VLGC—very large gas carrier for LPG

## Setting casing

Eventually, the mud gets so heavy that it might start to move into the surrounding layers of sediment at the upper part of the well hole. At that point, the driller stops drilling and pulls the drill pipe and bit out. This seemingly archaic and arduous effort, called *making a trip*, takes hours of effort by the rig crew. (They have to do this whenever they have to change a worn-out drill bit as well.) They have to pull the drill pipe out, length by length, wedge it so that the rest does not fall back in the hole, unscrew it, stack it, and pull the next length out.

Once the hole is clear of the drill pipe, the driller inserts steel casing into the hole, again adding it, piece by piece, to the bottom of the hole. The driller then pumps cement down through the casing and up its outside, between the casing and the wall of the wellbore. The cement and casing provide a permanent barrier, ensuring the integrity of the well and preventing disastrous collapse. At the same time, the steel casing prevents any fluids from the wellbore from penetrating the walls of the well and contaminating aquifers, water tables, or any other formations. Besides that environmental imperative, loss of mud into the formation would be no small money matter either.

After the drill bit and drill pipe go back in the hole (piece by piece) though the casing, drilling resumes. As the bit goes deeper, the driller has to repeat the process every time the drilling mud gets too heavy for the formation below the last casing string. Of course, to fit in the hole, every additional set of casing has to be a smaller diameter than the one above it. The drill bit has to be smaller as well. The driller has to carefully balance mud and casing in wells in order to reach depths of 25,000 feet or more.

While the bit is turning in the hole, the driller watches the weight of the drill pipe pressing down on the drill bit. After a while, if the driller were to allow the full weight of the drill string to sit in the bottom, it may well crush the drill bit. While drilling, the driller continually receives measurements of pressure, temperature, formation composition, and fluid content—usually water, but maybe some hydrocarbon along the way. Geologists examine the cuttings that came up with the mud. They look for formation characteristics and the presence of water or hydrocarbons.

Finally, the driller reaches the target depth. Several things can happen at this point:

- If nothing of commercial interest has been found, the driller can abandon the well by pulling all the tubulars and plugging the hole with cement.
- The driller can run a short drillstem test, letting the fluids in the reservoir flow thorough the drill pipe.

## How much?

Inevitably someone will want to know, “How much NGL is there in natural gas?” The answer is always, “It depends.”

Every natural gas field has a unique composition of methane and NGLs, as well as some other, more or less undesirable compounds. Table 4–4 shows some approximations that cover many fields. *Dry gas fields* contain almost all methane and little NGLs. The so-called *liquids rich* production coming from shale gas fields is lower in methane and higher in NGLs. Natural gas fields in Pennsylvania, for example, have both kinds. In the north central and northeast part of the state, the bulk of the natural gas produced is dry. The natural gas production from the Marcellus shale is one of the natural gas streams most heavily laden with NGLs, particularly ethane.

Table 4–4. Natural gas composition mole content\*

	Typical	Range
<b>Hydrocarbons</b>		
Methane (C <sub>1</sub> )	93.0	80.0–98.0
Ethane (C <sub>2</sub> )	3.4	0.5–10.0
Propane (C <sub>3</sub> )	1.5	0.2–4.7
Isobutane (iC <sub>4</sub> )	0.4	0.05–2.0
Normal butane (nC <sub>4</sub> )	0.5	0.06–2.0
Isopentane (iC <sub>5</sub> )	0.2	0.03–1.00
Normal pentane (nC <sub>5</sub> )	0.1	0.0–0.4
Hexane and heavier (C <sub>6</sub> +)	0.3	0.0–0.8
<b>Inerts</b>		
Nitrogen (N <sub>2</sub> )	0.3	0.1–0.9
Helium (He)	Trace	0.0–2.0
<b>Impurities</b>		
Carbon dioxide (CO <sub>2</sub> )	0.6	0.1–1.9
Hydrogen sulfide (H <sub>2</sub> S)	Trace	0.0–0.2
Oxygen (O <sub>2</sub> )	Trace	0.0–3.0
Water (H <sub>2</sub> O)	Trace	0.0–0.01

\*The engineers who calculate the NGL content in natural gas use mole percent instead of volume percent. The latter is more or less useless in calculating the outturn of NGLs from a gas plant because each NGL has a different conversion as it goes from gas to liquid, from the inlet to the outlet of the gas plant. The engineers have to use mole percents to get it right. Mole percents are rooted in the atomic weights of each of the NGLs. A mole of ethane has the same number of molecules in it as a mole of any other NGL, but has its own mole weight in pounds. None of this is intuitively obvious; see appendix 3 for a deeper explanation.

with natural gasoline—same chemical constituents and properties, same processing schemes.

The units in the refinery that involve gas liquids fall into five categories:

- Separation
- Crackers
- Rearrangers
- Treaters
- Blenders

Only the first four make gas liquids. The fifth uses butane and natural gasoline.

## Separation

### Crude oil distillation unit

The crude oil distillation unit in a refinery, shown on the left of figure 6–1, separates the incoming crude oil into various fractions or cuts. Each one has hydrocarbons with molecules that boil between specific boiling temperatures. That is how distilling units work—by dealing with boiling temperatures in the same way as was explained in chapter 5, on gas plants. All distilling units or fractionators take in a mixture of vapor and liquids. The liquids fall toward the bottom of the column, and the vapors work their way to the top. The trays or packing in the column act as multiple distillation steps as the vapors move up and the liquids move down, passing and scrubbing each other over and over to ensure that the correct molecules go all the way up or all the way down.

The crude oil distilling column in figure 6–1 has not only vapors coming out the top and liquids out the bottom, but also *side draws*. From those outlets, intermediate boiling-temperature fractions emerge. How does that happen? After all, didn't the description that went along with figure 5–5 have only tops and bottoms, nothing coming out in between? It is easier to think of a crude oil distillation column with side draws as a set of five or six distillation columns in series, with tops and bottoms coming out. But in this case, they are stacked on top of each other, so the tops of one go directly into the bottoms of the one above it, and the bottoms of one go . . . well, you get it.

### The role

The crude distillation unit may be called the refinery postmaster. It sorts the molecules and sends them to be dealt with in different processing units