

KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	 Solution, Standards, and Software www.klmtechgroup.com	Page : 1 of 124
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KLM Technology Group #03-12 Block Aronia, Jalan Sri Perkasa 2 Taman Tampoi Utama 81200 Johor Bahru Malaysia	Kolmetz Handbook of Process Equipment Design Natural Gas Liquid Units (NGL) (ENGINEERING DESIGN GUIDELINE)	Co Author Rev 01 Aprilia Jaya Rev 02 Aprilia Jaya
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INTRODUCTION

Scope

This design guideline covers the basic elements in the field of Natural Gas Liquids Units in sufficient detail to allow an engineer to design a NGL unit with the suitable size of diameter, reflux rate, actual stages, exergy efficiency, liquefied temperature, minimum work and heat during liquefaction. This design guideline includes design of the fractionator of NGL unit.

NGL units play an increasing role in the development of giant gas fields, as most countries, especially net oil importers, are interested in developing their gas reserves, however stranded, for greater energy independence and extending domestic oil reserves where applicable, as well as for environmental reasons.

The design of NGL unit may be influenced by factors, including process requirements, economics and safety. In the theory section, there are figures that assist in making these factored calculations from the vary reference sources. Include in this guideline is a calculation spreadsheet for the engineering design. All the important parameters use in the guideline are explained in the definition section which help the reader more understand the meaning of the parameters or the term used.

In the application section of this guideline, three case studies are shown and discussed in detail, highlighting the way to apply the theory for the calculation. The theory section explained about fractionator sizing, and feed gas processing.

Example Calculation Spreadsheets are part of this guideline. This Example Calculation Spreadsheets are based on case studies in the application section to make them easier to understand.

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INTRODUCTION

General Design Consideration

Natural gas was, for a long time, an unwanted by-product of oil production. Without economic ways of bringing it to market, gas was mostly flared or released to the atmosphere. However, in recent decades, natural gas's abundance and its low carbon content compared with other fossil fuels have considerably bolstered interest in natural gas.

The natural gas industry began to expand rapidly in the 1970s, following technological breakthroughs in the transportation of gas (e.g. steel pipelines and liquefaction) and in end uses of gas (e.g. jet-engine gas-turbine technologies applied to power generation), and as a result of concerns over security of energy supply. In 2013, natural gas demand reached 3.5 tcm and accounted for 21% of primary energy supply. It continues to lag behind coal and oil as a primary energy source, but represents an increasing share of the production portfolio of the majors. Going forward, growth in the natural gas industry is likely to be supported by new conventional discoveries and by the development of unconventional sources of gas, which began in earnest in the 2000s, increasing and diversifying available gas supply

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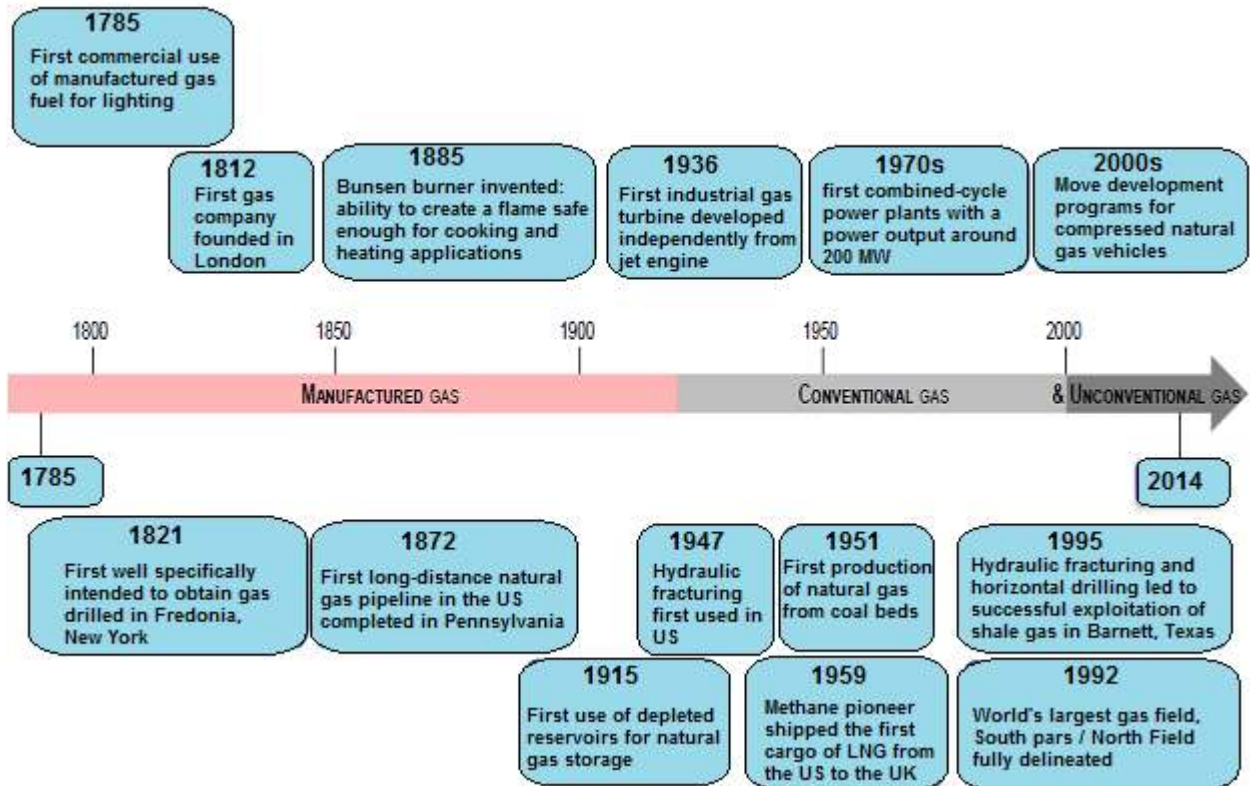


Figure 1: Natural gas development timeline

As with oil, natural gas is formed by the gradual decay of organic matter under specific geological heat and pressure conditions. Organic matter, such as the remains of recently living organisms (e.g. plants, algae, animals, plankton...), is the origin of all the hydrocarbons generated in the earth. A very small portion of this organic matter is deposited in poorly oxygenated aqueous environments (seas, deltas, lakes...), where it is protected from the action of aerobic bacteria and is mixed with sediments to form the source rock. Overtime, the weight of gradually accumulating organic material and debris causes source rock to subside to great depths, where its organic contentment rapped In a mud-like substance known as kerogen, is subject to increasing temperature and

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pressure. These conditions lead to the thermal cracking of kerogen's long molecular chains into smaller and lighter hydrocarbon molecules.

Soon after being buried, the organic matter may be converted into dry gas under the action of methane organic bacteria, in a phase known as diagenesis (under 50°C). This dry gas usually leaks into the atmosphere. During the catagenesis phase (50-150°C), kerogen bonds are gradually cracked into oil or into wet gas depending on the kerogen type. As temperatures rise in proportion with depth, hydrocarbon molecules become lighter as depth beneath the surface increases.

During a last stage, known as meta genesis, additional heat and chemical changes eventually convert most of the remaining kerogen into methane and carbon residues. Hydrocarbon molecules are then expelled from the source rock during a "primary migration" phase, mainly as a consequence of high pressures. Hydrocarbons will then set off a "secondary migration" phase, making their way upward through rocky layers. If stopped by an impermeable layer of rock, also referred to as seal, hydrocarbons may accumulate in the pores and fissures of a reservoir rock. Otherwise, they may escape from the surface or solidify into bitumen.

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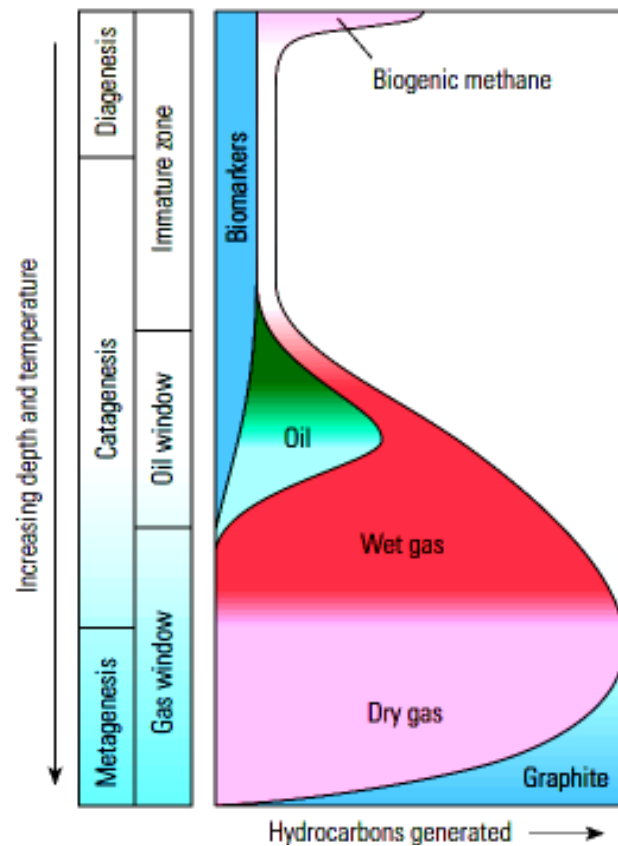


Figure 2: Thermal transformation of kerogen

Natural gas is not solely methane. It is composed of a mixture of hydrocarbon components, including methane, ethane, propane, butane and pentane – commonly known as natural gas liquids (NGLs) – and of impurities such as carbon dioxide (CO₂), hydrogen sulfide(H₂S), water and nitrogen. The composition is highly variable and depends on the resource’s location. In some fields, contaminants, especially those that characterize sour gas (CO₂ or H₂S), represent a high proportion of the natural gas mixture, making exploitation harder and more expensive.

Sometimes, NGLs – hydrocarbons that are in gaseous form in the reservoir, but that become liquid under ambient conditions – account for a significant share of natural gas; a mix rich in NGLs, known as wet gas. In 2013, wet gas yields 9 million barrels of oil

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equivalent a day, contributing 10% to global liquid hydrocarbon supply. In all situations, natural gas must be processed to remove NGLs and contaminants.

There are primarily three sources for “raw” natural gas. These are recognized as:

1. Crude oil wells
2. Gas wells
3. Condensate wells

Natural gas that comes along with crude oil is normally known as associated gas. It can exist separately from crude oil, forming what is known as a gas cap or dissolved in the crude oil. Natural gas from gas wells and from condensate wells-in which there is little or no oil is termed, on the other hand non-associated or free gas. Gas wells differ from condensate wells, since the former type produces raw natural gas only, while the latter one produces natural gas along with very light liquid hydrocarbon known as natural gasoline. Basically, raw natural gas consists of methane along with varying amounts of:

- Heavier gaseous hydrocarbons
- Acid gases that may include hydrogen sulfide, carbon dioxide and others
- Other gaseous components, such as nitrogen and helium
- Water that may be found in both liquid form and as water vapor
- Liquid hydrocarbons

The schematic diagram shown in Figure 3 illustrates how natural gas produced by gas-oil separation (associated natural gas), may contain heavier hydrocarbons.

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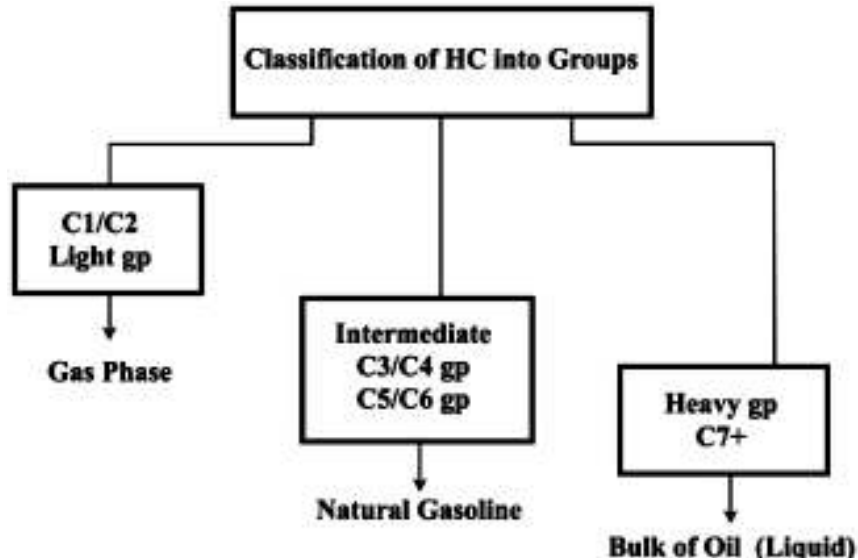


Figure 3: Classification of Hydrocarbons Found in Wellhead

Natural gas processing begins at the wellhead (Table 1). The composition of the raw natural gas extracted from producing wells depends on the type, depth, and location of the underground deposit and the geology of the area. Oil and natural gas are often found together in the same reservoir. The natural gas produced from oil wells is generally classified as “associated-dissolved,” meaning that the natural gas is associated with or dissolved in crude oil. Natural gas production absent any association with crude oil is classified as “non-associated.”

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Table 1. The composition of the raw natural gas

Hydrocarbon components		Typical	Attributes and uses
Methane	CH ₄	70% to 98%	Commercial gas for residential, industrial and power generation use
Ethane	C ₂ H ₆	1% to 10%	Colorless, odorless, feedstock for ethylene
Propane	C ₃ H ₈	Trace to 50%	Burns hotter than methane, common liquid fuel; liquid petroleum gas (LPG)
Butane	C ₄ H ₁₀	Trace to 2%	Safe, volatile, used in pocket lighters; LPG
Pentane	C ₅ H ₁₂	Trace	Commonly used solvent
Non-hydrocarbon components			
Water vapor	H ₂ O	Inert	Occasionally used for reinjection
Carbon dioxide	CO ₂	Inert	Colorless, odorless, used for reinjection
Nitrogen	N ₂	Inert	Colorless, odorless, used for reinjection
Helium	HE	Inert	Colorless, odorless, light gas; specialty uses
Hydrogen sulfide	H ₂ S	Inert	Poisonous, lethal, foul odor, corrosive

Hydrocarbon components of natural gas that are heavier than methane are called natural gas liquids (NGLs). Natural Gas Liquids (NGL) is those hydrocarbons in natural gas that are separated from the gas as liquids through the process of absorption, condensation, adsorption, cooling in gas separators, gas processing, or gas cycling plants. Generally, natural gas liquids include natural gas plant liquids and lease condensate. They can be extracted in a processing plant and commercialized as liquid fuels.

In NGLs as most hydrocarbons have a wide range of labels and at times different definitions. The very flexibility of NGL uses leads to much uncertainty. To avoid confusion, it is important to define the terms used:

- **Natural Gas Liquids (NGLs):** Liquid hydrocarbons suspended as particles in gas, under conditions of subterranean pressure and temperature, are called NGLs. True gas consists of methane (one carbon molecule – C1); ethane (C2) is considered both an NGL in many regions (N. America, Europe and the Mideast), but a part of natural gas in most of Asia. Other NGLs consist of LPG (C3/C4, propane, butane and iso-butane) and condensate, C5 and heavier. While LPG is produced in substantial volumes in refining and ethane in limited volume, most NGLs originate

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from gas production. When NGL is contained within a gas stream, it is called “in a vapor phase.”

- When separated into respective NGL components from ethane to iso-butane, at least 90% of the NGL stream has only one type of carbon molecule, which NGLs are known as “purity products.” The term “Heavy NGLs” in the US refers to natural gasoline and butane/iso-butane, but this is somewhat misleading. The only heavy NGL that can be separated, stored and transported without special containment is condensate.
- “Mixed” NGLs: In the US market NGLs are often sold in a mixed stream, particularly in petrochemicals. The most common is ethane/propane called E/P Mix, consisting of 80% ethane/20% propane.
- Natural Gasoline: This refers to heavy NGL, taken out of gas in plant processing, and the term, though widely used in the US market, generally is considered not used in the rest of the world.

Natural gas that is rich in NGLs is usually called wet gas or rich gas, as opposed to dry gas or lean gas. Liquefied petroleum gas (LPG), to make a further distinction, is a subset of NGLs, comprising propane and butane. LPG can be liquefied through pressurization (i.e. without requiring cryogenic refrigeration), and used as a liquid fuel. In 2012, supply of NGLs amounted to 9 million barrels a day, representing about 10% of world liquid hydrocarbon production. While total liquid supply has increased at a 1% compound average annual growth rate (CAGR) since 1980, NGLs production has more than doubled with a CAGR of 3.1%.

NGLs all have their own prices and pricing mechanisms. It may become commercially attractive to produce NGLs, depending on the composition of NGLs in a given natural gas stream and on average price spreads with methane. For instance, natural gasoline (the pentanes-plus fraction of NGLs) sells in the U.S. at prices that are 4 to 5 times higher than natural gas on a comparable energy basis. Conversely, ethane was in 2013 cheaper than natural gas in the U.S.

The mix of hydrocarbon fractions and contaminants in natural gas is specific to each field¹. In some fields, natural gas liquids (NGL) account for significant share of the natural gas mix, leading to important volumes of liquid hydrocarbons produced.

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NGLs produced by gas processing are separated from the overall gas stream at a processing plant, which separates the raw NGL mix from dry gas. The dry gas is then sent through pipeline to consumers, while the raw mix is sent to a fractionation facility, which processes and separates the mix into different NGLs (ethane, propane, butane, iso-butane, and natural gasoline), also known as “purity products.”

NGL (Natural Gas Liquid) typically refers to ethane, propane, butanes, and natural “gasoline” (pentanes) NGL’s are hydrocarbons removed (condensed) as a liquid from a hydrocarbon stream that is typically in a vapor phase (i.e. natural gas). NGLs have traditionally been considered a byproduct of natural gas production. The five NGLs — ethane, propane, normal butane, isobutene and natural gasoline (pentanes+) — are produced when natural gas is processed for delivery to market.

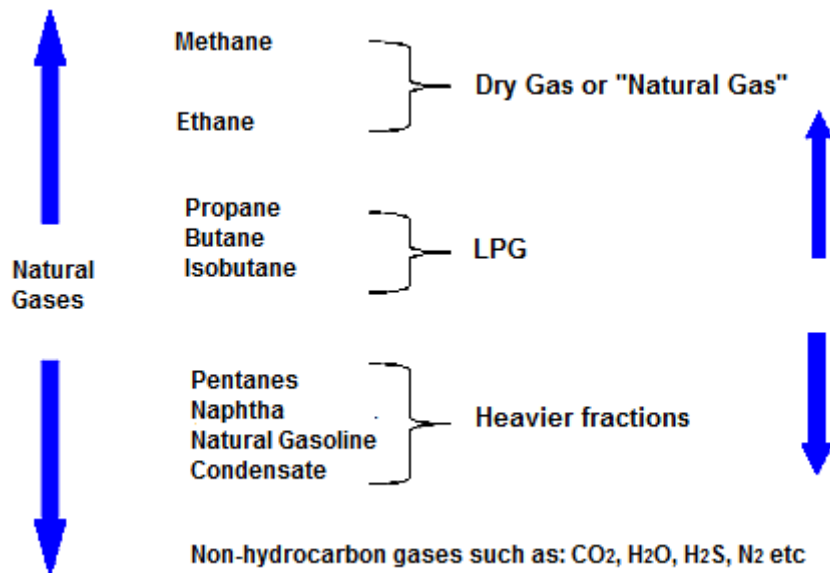


Figure 4: Difference between NGL and LPG

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Table 2: NGLs Component Characteristics

Product	Characteristics	Sectors
Ethane (C2)	Both dry gas & NGL; major value as petchem feedstock; needs pipelines, big gas output	As in methane; also petchem
Propane (C3/LPG)	Needs containment; generally stripped from gas; higher capex and opex in transport; safer than butane	Generally home & business; transport use; gas supplement
Butane (C4/LGP)	Containment needed; higher BTU value; like propane, high capex & opex	Mainly industrial; also in transport
Condensate (C5+)	Light, sweet crude lookalike; almost always > 50% naphtha; Can be naphthenic or paraffinic; Moderate mid-distillate; once a liquid, remains a liquid; from wellhead or gas processing; some output sold as naphtha	Like crude, full range of products; strong impact on gasoline & petchems; can produce large volume of jet & ADO

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Table 3: NGL Composition – A Snapshot

NGL Composition	Vaporization / Boiling Point	Use	Notes
Ethane/C2	- 126F / - 88C	Petrochemical, Calorific	
Propane/C3	- 44F / - 42C	Petrochemicals/Residential/ Commercial/Transport	With butane used to enrich lean regasified LNG in Asian gas demand
Butane/C4 N-Butane, Iso-butane	32F / 0C 11F / -12C	Petrochemical/Residential/ Commercial/Transport/Gasoline blending and high-purity butane used to make gasoline component isomerate Residential/Industrial/Transport/Indus trial process heat; gasoline blending & basis for component alkylate	Part of LPG AKA methylpropane; isomer of butane; different arrangement of hydrogen molecules; lighter than butane
Condensate/ mainly C5- C10 molecules	Wide range	Petrochemical feedstock; Full range of oil products; Solvent & ethanol production, diluent, gas turbine power generation	Many names; paraffinic or naphthenic; remains liquid without special containment.

As shale natural gas production continues to expand, it has a direct impact on supply of NGLs. Whether the infrastructure and market for NGLs can absorb these increasing volumes and how the new supplies will impact demand for NGLs and related products are key questions facing producers and consumers of these important petrochemical products.

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The impact of increasing natural gas production on NGL supplies is a function of three factors:

- (1) the amount of natural gas that is processed to remove the NGLs;
- (2) the amount of NGLs that are contained in the natural gas that is processed;
- (3) the processing technique used to remove the NGLs.

Increases in the first factor are primarily being driven by the shale revolution. The second factor is associated with the physical composition of natural gas as it is produced at the wellhead.

Natural gas production at the wellhead is typically composed of a number of hydrocarbon and other compounds. The largest hydrocarbon component of most natural gas is methane. But wellhead gas, also known as “wet gas” or “gross gas production,” contains NGLs. NGLs are generally in gaseous form at the wellhead and are extracted from natural gas by chilling to very low temperatures to produce liquid hydrocarbons—hence the name “natural gas liquids”. In some situations, NGL extraction is required to produce a natural gas stream that can meet pipeline or industrial specifications. In other cases, when the price of NGLs is higher than that of natural gas, NGLs are extracted for economic reasons.

Figure 5 is a simplified representation of the NGL supply chain. NGLs are produced by both natural gas processing plants and petroleum refineries. Natural gas processing plants separate dry gas (i.e., methane) from wellhead gas production, or wet gas (natural gas containing quantities of NGLs—i.e., ethane, propane, normal butane isobutane, natural gasoline), while refineries produce NGLs as a byproduct of refinery distillation and cracking processes.

Each successive NGL has an additional carbon molecule and different chemical properties. For example, ethane is C_2H_6 , propane is C_3H_8 , butane is C_4H_{10} , and natural gasoline is C_5H_{12} . NGLs are used by the petrochemical industry as feedstock to produce a variety of plastic products, for heating in the case of propane, as components in the motor gasoline pool (“motor gasoline”), and are exported in some cases.

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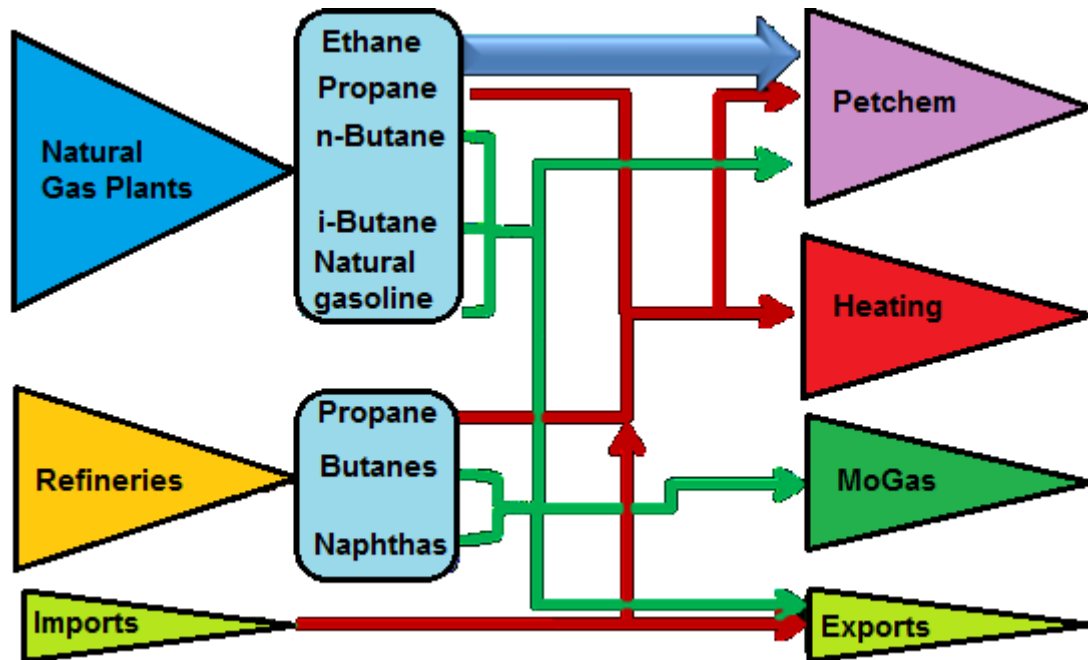


Figure 5: the NGL supply chain

Fundamentals of the NGL Market pricing is cyclical. As the primary consumer of NGLs, the petrochemical industry is an integral factor in determining prices, particularly in the case of ethane, which represents roughly 40% of the NGL stream. Industrial consumers bid for NGLs depending on the difference between the price of NGLs and the price of gas, also known as the “spread.”

During periods of strong industrial-sector demand, the spread increases and gas processors continue to pull ethane out of the natural gas stream. As NGL production increases, prices for NGLs come down and it is more economic for gas processors to leave ethane in the gas stream, a process known as “ethane rejection.”

Leaving ethane in the gas stream increases the physical volume of natural gas, putting downward pressure on prices and reducing gas—and NGL—production. Declines in NGL production leads to an increase in prices, and the trend repeats itself (see Figure 6).

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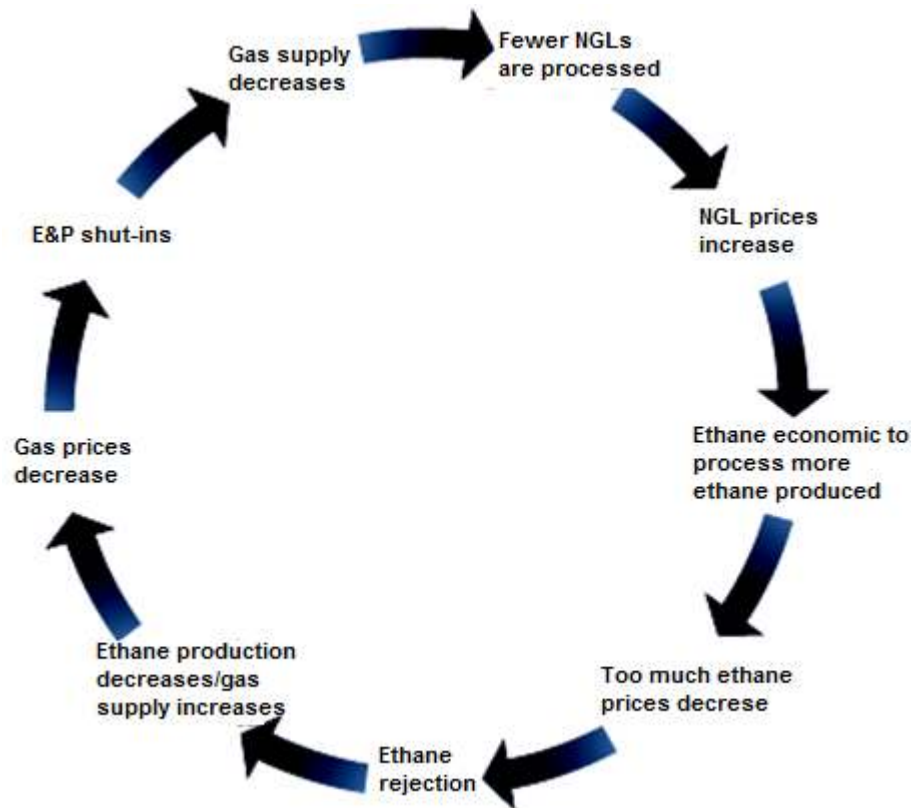


Figure 6: cycles of NGL production effect to prices

By studying the natural gas and NGL outlook country by country, four global trends in natural gas production can be identified that impact NGL supply. The importance of each trend varies by country or region, while multiple trends blur the picture in some regions. Trends 1 to 3 have a positive impact on the supply outlook for NGLs and the liquids ratio, while trend 4 has a negative impact.

1. Large scale natural gas developments characterized by

- Participation by International Oil Companies (IOC) that tend to have a high NGL awareness compared to prevailing host country awareness.

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- The development of large gas condensate fields. The IOCs often see a larger potential in such fields than in standalone gas projects.
- The development of LNG projects for which it is important to strip liquids out of the gas to make the sales gas match the spec of the target market and to optimize the value of the project by monetizing valuable associated liquids. Integrated LNG and NGL infrastructure reduce the costs in the NGL value chain.

2. Increased utilization of associated gas

- Higher awareness of the value of associated gas, both as marketed gas and for reinjection to support oil production.
- Initiatives to reduce flaring of associated gas.
- Better infrastructure to gather and process associated gas.

3. Higher liquids content in traditional dry non-associated gas

- When traditional shallow gas reservoirs are depleted, oil companies drill deeper down and find structures with higher pressure, generally containing more condensate and other NGLs.
- Technology improvement, higher energy prices and experience make oil companies less reluctant to develop complex reservoirs.
- The NGL awareness is higher, and therefore the value of gas condensate fields is rated higher.

4. Wet associated gas is being replaced by dry non-associated gas

- As oil production declines in many countries compared to gas production, traditional associated gas with a high liquids content declines too.
- Countries must replace associated gas with non-associated gas to meet domestic needs. This non-associated gas tends to be drier.
- Growth in non-conventional gas production may result in lower liquids ratios.

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The number of steps and the type of techniques used in the process of creating pipeline-quality natural gas most often depends upon the source and makeup of the wellhead production stream. In some cases, several of the steps shown in Figure 7 may be integrated into one unit or operation, performed in a different order or at alternative locations (lease/plant), or not required at all.

Natural gas collected at the well head must usually be processed to meet the pipeline-quality standards defined by each system (energy content, water content...) and to ensure safe and clean operation, both of the grid and of end-appliances. The type of gas processing required depends on the composition of the raw gas and on the pipeline system's quality specifications. Although it is less complex than crude-oil refining, natural-gas processing is a crucial stage in the natural gas value chain. In addition to its primary purpose, cleaning, processing also performs the vital role of extracting the heavier hydrocarbons that raw natural gas contains, to varying degrees (these hydrocarbons are gaseous at underground pressure, but liquefy under ambient conditions into natural gas liquids).

The processing layout can be configured in numerous ways. It can be sited, entirely or partially, at the field or at a compressor station close to the producing area. Processing facilities may be split up along these locations or grouped together in a dedicated processing plant.

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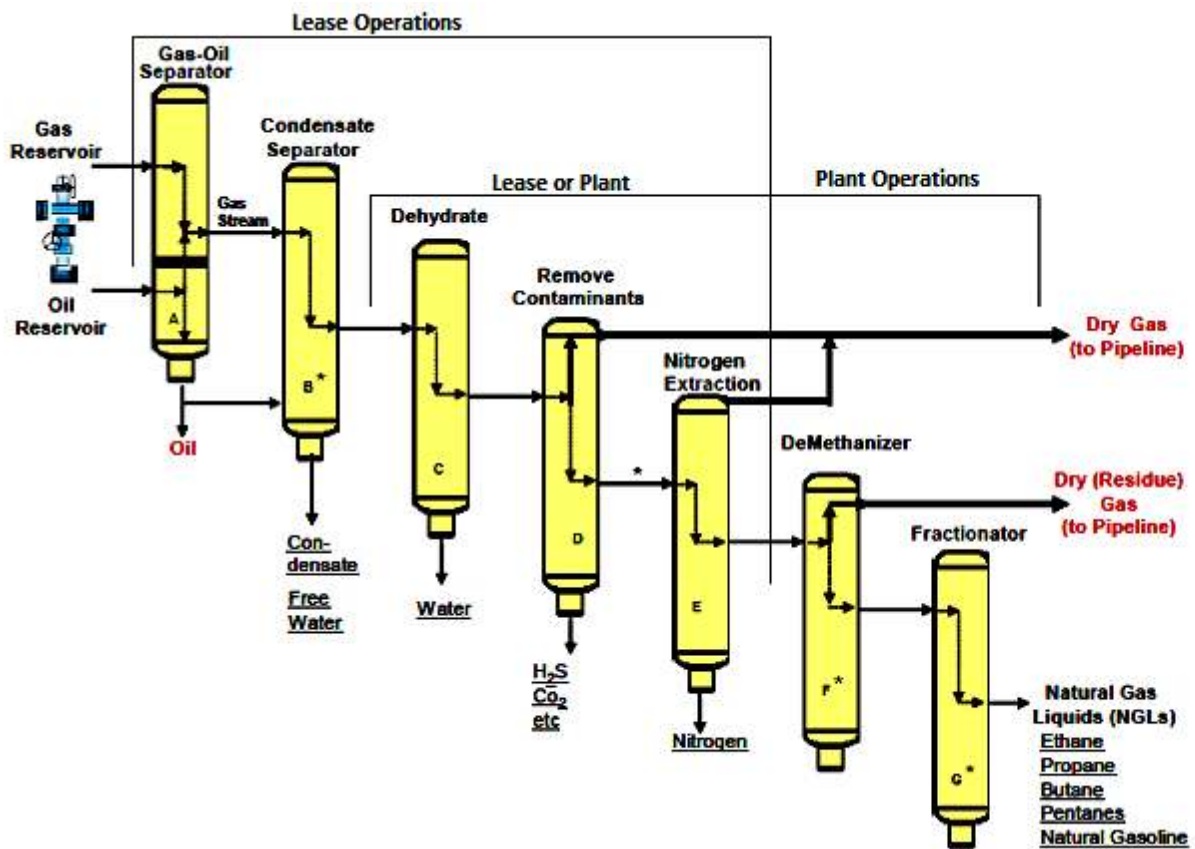


Figure 7: Schematic steps for natural gas processing

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The process above can be simplified in figure 8

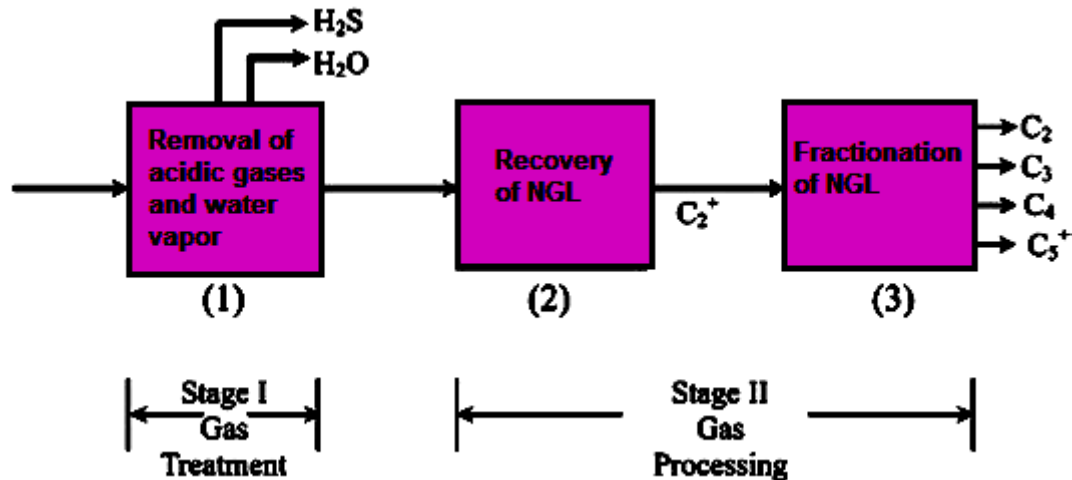


Figure 8: Natural Gas Processing System

- (a) Stage I and is known as gas treatment or gas conditioning
- (b) Stage II and is known as gas processing

The gas treatment operations carried out in stage I include the removal of gas contaminants, in particular H₂S (gas sweetening) followed by the separation of water vapor (dehydration). On the other hand, stage II, comprises two operations: NGL recovery and separation from the bulk of gas and its subsequent fractionation into the desired products. A sum up of these operations is given as follows.

- Gas sweetening
- Gas dehydration
- Recovery and extraction of NGL (C₂ plus)
- Fractionation of NGL into individual products, which may include: ethane, propane, butane, isobutene, and natural gasoline.

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Among the several stages (as lettered in figure 8) of gas processing/treatment are:

Gas-Oil Separators:

In many instances pressure relief at the wellhead will cause a natural separation of gas from oil (using a conventional closed tank, where gravity separates the gas hydrocarbons from the heavier oil). In some cases, however, a multi-stage gas-oil separation process is needed to separate the gas stream from the crude oil. These gas-oil separators are commonly closed cylindrical shells, horizontally mounted with inlets at one end, an outlet at the top for removal of gas, and an outlet at the bottom for removal of oil. Separation is accomplished by alternately heating and cooling (by compression) the flow stream through multiple steps. Some water and condensate, if present, will also be extracted as the process proceeds.

Condensate Separator:

Condensates are most often removed from the gas stream at the wellhead through the use of mechanical separators. In most instances, the gas flow into the separator comes directly from the wellhead, since the gas-oil separation process is not needed. The gas stream enters the processing plant at high pressure (600 pounds per square inch gauge (psig) or greater) through an inlet slug catcher where free water is removed from the gas, after which it is directed to a condensate separator. Extracted condensate is routed to on-site storage tanks.

Dehydration:

A dehydration process is needed to eliminate water which may cause the formation of hydrates. Hydrates form when a gas or liquid containing free water experiences specific temperature/pressure conditions. Dehydration is the removal of this water from the produced natural gas and is accomplished by several methods. Among these is the use of ethylene glycol (glycol injection) systems as an absorption* mechanism to remove water and other solids from the gas stream. Alternatively, adsorption* dehydration may be used, utilizing dry-bed dehydrators towers, which contain desiccants such as silica gel and activated alumina, to perform the extraction.

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Contaminant Removal:

Removal of contaminants includes the elimination of hydrogen sulfide, carbon dioxide, water vapor, helium, and oxygen. The most commonly used technique is to first direct the flow through a tower containing an amine solution. Amines absorb sulfur compounds from natural gas and can be reused repeatedly. After desulphurization, the gas flow is directed to the next section, which contains a series of filter tubes. As the velocity of the stream reduces in the unit, primary separation of remaining contaminants occurs due to gravity. Separation of smaller particles occurs as gas flows through the tubes, where they combine into larger particles which flow to the lower section of the unit. Further, as the gas stream continues through the series of tubes, a centrifugal force is generated which further removes any remaining water and small solid particulate matter.

Nitrogen Extraction:

Once the hydrogen sulfide and carbon dioxide are processed to acceptable levels, the stream is routed to a Nitrogen Rejection Unit (NRU), where it is further dehydrated using molecular sieve beds. In the NRU, the gas stream is routed through a series of passes through a column and a brazed aluminum plate fin heat exchanger. Using thermodynamics, the nitrogen is cryogenically separated and vented. Another type of NRU unit separates methane and heavier hydrocarbons from nitrogen using an absorbent* solvent. The absorbed methane and heavier hydrocarbons are flashed off from the solvent by reducing the pressure on the processing stream in multiple gas decompression steps. The liquid from the flash regeneration step is returned to the top of the methane absorber as lean solvent. Helium, if any, can be extracted from the gas stream in a Pressure Swing Adsorption (PSA) unit.

Methane Separation:

The process of demethanizing the gas stream can occur as a separate operation in the gas plant or as part of the NRU operation. Cryogenic processing and absorption methods are some of the ways to separate methane from NGLs. The cryogenic method is better at extraction of the lighter liquids, such as ethane, than is the alternative absorption method. Essentially, cryogenic processing consists of lowering the temperature of the gas stream to around -120 degrees Fahrenheit. While there are several ways to perform this function the turbo expander process is most effective,

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using external refrigerants to chill the gas stream. The quick drop in temperature that the expander is capable of producing condenses the hydrocarbons in the gas stream, but maintains methane in its gaseous form.

The absorption* method, on the other hand, uses a “lean” absorbing oil to separate the methane from the NGLs. While the gas stream is passed through an absorption tower, the absorption oil soaks up a large amount of the NGLs. The “enriched” absorption oil, now containing NGLs, exits the tower at the bottom. The enriched oil is fed into distillers where the blend is heated to above the boiling point of the NGLs, while the oil remains fluid. The oil is recycled while the NGLs are cooled and directed to a fractionator tower. Another absorption method that is often used is the refrigerated oil absorption method where the lean oil is chilled rather than heated, a feature that enhances recovery rates somewhat.

Fractionation:

Fractionation, the process of separating the various NGLs present in the remaining gas stream, uses the varying boiling points of the individual hydrocarbons in the stream, by now virtually all NGLs, to achieve the task. The process occurs in stages as the gas stream rises through several towers where heating units raise the temperature of the stream, causing the various liquids to separate and exit into specific holding tanks.

Natural gas processing and the removal of various components from it tend to involve the most complex and expensive processes. All of the H₂S and most of the water vapor, CO₂, and N₂ must be removed first. The separation of the hydrocarbons, known as NGL (C₂ plus) is carried out next producing methane as the sole product commercially marketed as natural gas.

The following are some of the most important parameters to be considered in the design of a system for natural gas processing:

1. Estimated gas reserve (both associated and free)
2. Gas flow rate and its composition
3. Market demand for both local export
4. Geographic locations and methods of shipping of finished products
5. Environmental factors
6. Risks imposed in implementing the project and evaluation of its economic feasibility

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In general, the type of processing operations recommended for any specific plant, depend on the kind of gas under consideration along with the distribution of the hydrocarbons found in the gas. In particular the following factors are significant:

- The contents of heavier hydrocarbons
- The percentage of acid gases
- The presence of inert

Transportation and Storage

Pipeline

Some NGL pipelines carry mixed NGLs to fractionation facilities. Other NGL pipelines transport purity products, many times in batches, from fractionators or storage facilities to end users or related storage. In the current fast gas growth environment, NGL available pipeline capacity is limited; therefore, truck and rail become viable options.

Truck/Railroad Transport

Due to its high vapor pressure, ethane is not typically transported by truck or rail. However, heavier NGLs are commonly transported via truck or railroad. These methods of transport are normally more costly than pipeline, and therefore less preferred

Cargo Ships

Hundreds of ships carry propane and butane between different ports around the world.

Storage

While NGL storage is seasonal for propane and normal butane, it is relatively steady for ethane, isobutene and pentanes plus. Since demand for propane as a heating fuel is seasonal like natural gas, propane stocks build during the warmer months and are drawn down in colder months. Refineries produce more butane than they consume in the summer, and the opposite is true during the winter. Sufficient storage capacity for NGLs balances the market and allows it to cope with seasonality or supply/demand disruptions.

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DEFINITIONS

Acid Gas - Natural Gas containing Carbon Dioxide or Hydrogen Sulphide which forms an acid compound when combined with water.

Field production of crude oil: Represents crude oil production on leases, including lease condensate. Excludes plant condensate and other processed liquids.

Fractionation: Fractionation is the process that involves the separation of the NGLs into discrete NGL purity products (i.e., ethane, propane, normal butane, isobutane, and natural gasoline).

Gas plant operator: Any firm, including a natural gas processing plant owner that operates a gas plant and keeps the gas plant records.

Hydrocarbon gas liquids (HGL): A group of hydrocarbons including ethane, propane, butane, isobutane, and pentanes plus, and their associated olefins, ethylene, propylene, butylene, and isobutylene. Equivalent to sum of natural gas plant liquids and liquefied refinery gases on the supply side, and the sum of natural gas liquids and olefins on the market side. Includes propane and normal butane produced at gas-to-liquids plants. Excludes liquefied natural gas (LNG).

Lease condensate: Light liquid hydrocarbons recovered from lease separators or field facilities at associated and non-associated natural gas wells. Mostly pentanes and heavier hydrocarbons. Normally enters the crude oil stream after production

Liquefied petroleum gases (LPG): A group of hydrocarbon gases, primarily propane, normal butane, and isobutane, derived from crude oil refining or natural gas fractionation. These gases may be marketed individually or mixed. They can be liquefied through pressurization without refrigeration for convenience of transportation or storage.

Liquefied refinery gases (LRG): Hydrocarbon gas liquids produced in refineries from processing of crude oil and unfinished oils. They are retained in the liquid state through compression and/or refrigeration. The reported categories include ethane, ethylene, propane, propylene, normal butane, butylene, isobutane, and isobutylene.

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Natural gas liquids (NGL): A group of hydrocarbons including ethane, propane, normal butane, isobutane, and pentanes plus. Generally include natural gas plant liquids, and all liquefied refinery gases, except olefins.

Natural gas liquids (NGL): NGLs are extracted from the raw natural gas stream into a liquid mix (consisting of ethane, propane, butane, isobutane, and natural gasoline). The NGLs are then typically transported via pipelines to fractionation facilities.

Natural gas plant liquids (NGPL) Production: The reduction in volume of natural gas due to the removal of natural gas plant liquids constituents such as ethane, propane, butane, and pentanes plus.

Natural gas plant liquids (NGPL): Those hydrocarbons in natural gas that are separated as liquids at natural gas processing plants, fractionating and cycling plants. Products obtained include ethane, liquefied petroleum gases (propane and butanes), and pentanes plus. Component products may be fractionated or mixed. Lease condensate is excluded

Natural gasoline: A commodity product commonly traded in NGL markets, which comprises liquid hydrocarbons (mostly pentanes and hexanes) that generally remain liquid at ambient temperatures and atmospheric pressure. A subset of pentanes plus.

Olefinic hydrocarbons (olefins): Unsaturated hydrocarbon compounds with the general formula C_nH_{2n} containing at least one carbon-to-carbon double-bond. Olefins are produced at crude oil refineries or petrochemical plants and are not naturally occurring constituents of oil and natural gas. Sometimes referred to as “alkenes” or “unsaturated hydrocarbons.” Excludes aromatics.

Paraffinic hydrocarbons (paraffins): Saturated hydrocarbon compounds with the general formula C_nH_{2n+2} containing only single-bonds. Sometimes referred to as alkanes or natural gas liquids

Pentanes plus: A mixture of liquid hydrocarbons, mostly pentanes and heavier, extracted from natural gas in a gas processing plant (i.e., plant condensate) or from crude oil in a refinery. Natural gasoline is the largest component of pentanes plus.

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Plant condensate: Liquid hydrocarbons recovered at inlet separators or scrubbers in natural gas processing plants at atmospheric pressure and ambient temperatures. Mostly pentanes and heavier hydrocarbons, equivalent to pentanes plus

Raw NGL Mix. Raw NGL mix or “y” grade refers to the heavier NGL components that are extracted via natural gas processing. The resulting NGL mix is commingled product consisting of ethane (depending on whether ethane rejection took place), propane, butane, isobutane, and natural gasoline. It is not until fractionation, the next step in the NGL value chain, that the raw NGL mix is further separated into individual NGL components.

Refinery gas: Still gas consumed as refinery fuel

Still gas: Any form or mixture of gases produced in refineries by distillation, cracking, reforming, and other processes. The principal constituents are methane and ethane. May contain hydrogen and small/trace amounts of ethylene, propane, propylene, normal butane, butylene, isobutane, and isobutylene. Still gas is typically consumed as refinery fuel or used as petrochemical feedstock.

NOMENCLATURE

B	= bottoms molar flow rate, lb/hr
C	= sizing constant, ft/s
D	= distillate molar flow rate, lb/hr
d	= column diameter, ft
E_{oc}	= overall plate efficiency
F	= feed molar flow rate, lb/hr
h_B	= enthalpy of bottom product,
h_D	= enthalpy of distillate product,
h_F	= enthalpy of feed,
M	= number of theoretical stages in the stripping section,
N	= number of theoretical stages in the rectifying section,
Q_C	= condenser heat duty,
Q_R	= reboiler heat duty,
Q_V	= volumetric vapor flow rate, ft ³ /s
R	= actual reflux ratio,

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- R_m = minimum reflux ratio,
 S = actual number of theoretical trays,
 S_m = minimum number of theoretical trays
 t_s = tray spacing, in
 V_{max} = maximum vapor velocity, ft/s
 X_B = mole fraction of a component in the bottoms
 X_D = mole fraction overhead light key
 X_F = mole fraction of a component in the feed,
 X_{HK} = mole fraction of the heavy key component,
 X_{HKD} = composition of heavy key in the distillate.
 X_{HKF} = composition of heavy key in the feed,
 X_{LK} = mole fraction of the light key component,
 X_{LKB} = composition of light key in the bottoms,
 X_{LKF} = composition of light key in the feed,

Greek letters

- α = relative volatility
 μ_L = liquid viscosity, Cp
 ρ_L = liquid density, lb/ft³
 ρ_V = vapor density, lb/ft³

These design guidelines are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

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