LNG Properties and Plant Design Part 1: LNG Properties

An Online Continuing Education Course for Engineers

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LNG Properties and Plant Design
Part 1: LNG Properties

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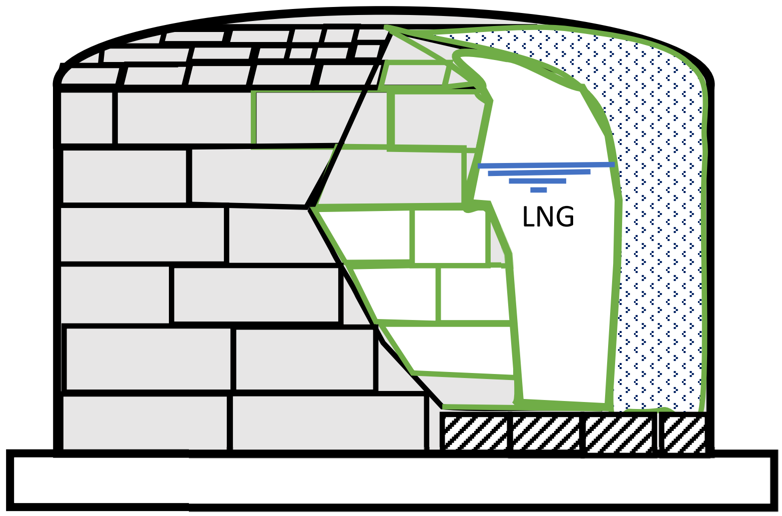


What is LNG?

LNG is Liquefied Natural Gas, a colorless, odorless liquid composed primarily of liquified methane with trace amounts of other liquid hydrocarbons, including ethane, propane, butane, and pentane. LNG was invented by British scientist Michael Faraday in 1820. German engineer Karl Von Linde developed the first air separation and gas liquefaction processes in 1871. The history of LNG is closely intertwined with advances in cryogenic technology used to separate air into liquid components such as oxygen and nitrogen.

Properties of LNG

LNG may also contain trace amounts of other heavier hydrocarbons as well as nitrogen. At atmospheric pressure, LNG is a saturated liquid at -260 degrees Fahrenheit. Depending on its composition, one standard cubic foot of LNG will have a heating value ranging from 1030 - 1100 btu. Although higher btu LNG can be produced, most LNG is produced within this range to ensure interchangeability with domestic pipeline gas. LNG has a specific gravity of approximately 0.43, making it significantly lighter than water. Because it is commonly used as a fuel in its gaseous state, LNG is often measured in equivalent gas units such as Standard Cubic Feet (SCF), Thousand Cubic feet (MCF), or Billion Cubic feet (BCF). Large amounts of LNG can be stored in liquid form because it occupies 1/600th of the volume in liquid form as it does in its gaseous state. For this reason, LNG has become a widely used energy source that is transportable via ships known as LNG tankers and domestically via over-the-road LNG trailers. Countries with little or no natural gas reserves can import LNG using specially designed LNG import terminals that can offload ships and store large volumes of LNG in storage tanks.

LNG is transported extensively via ship to countries that need energy. The leading exporters of LNG in the world are Australia, Qatar, and the United States. Storing and transporting LNG requires specially designed ships with cryogenic storage tanks, pumps, and piping for loading and unloading the ship.

Although it is compatible and very similar to natural gas, LNG is not actually the same as natural gas. This is due to the fact that there are components in natural gas that will freeze at cryogenic temperatures and must be removed from the feed gas stream before it can be cooled and liquefied to make LNG. Carbon dioxide and water vapor, for example, are found in natural gas but not in LNG for this reason. LNG is made by liquefying natural gas and has similar properties in its vapor form to natural gas, but it does not occur naturally. LNG is man-made.

LNG Storage

LNG is stored in special cryogenic storage tanks. Many peak shaving facilities have field-erected tanks capable of storing anywhere from 600 mmscf to 1000 mmscf.

One gallon of LNG, after being vaporized, will occupy 81.5 cubic feet of space at atmospheric pressure. Common field erected LNG tank sizes for peak shaving plants range from approximately 7 million gallons to 12.0 million gallons. These tanks typically have an inner vessel to hold the LNG and a surrounding outer vessel. The space between the vessels is filled with insulation. Since the LNG is stored at atmospheric pressure, it will constantly boil due to heat leaking into the tank from the ground as well as the sides and dome.

LNG storage requires tanks made of materials that do not become brittle at cryogenic temperatures. These tanks are well insulated, and the LNG within them can remain liquid without supplemental cooling for long periods of time. For example, a full tank containing 600 million standard cubic feet of LNG will require approximately 5 ½ years for the entire contents to boil off.

LNG is stored in large, field erected flat bottom tanks or in smaller cylindrical pressure vessels. Field-erected tanks have outer and inner tanks. The space between the two tanks is filled with an insulating material such as perlite in a nitrogen environment. The annual space can be several feet wide. Tank floors are insulated and supported by a layer of foam glass or other suitable cryogenic insulation that can support the load of full inner tanks. Inner tanks are made of aluminum, 9% Nickel steel, or stainless steel. Outer tanks can be carbon steel, stainless steel, or prestressed concrete. Field-erected tanks are normally operated at slight positive pressure (10 – 15 inches w.c. measured at the top vapor space.

Cylindrical pressure vessels also have an inner and outer tank with the annular space filled with insulation and under vacuum. Cylindrical tanks can be purchased in sizes from 50,000 to 90,000 gallons. They are normally operated at 15 – 30 psig and can withstand much higher inner pressure than field-erected flat bottom tanks due to their cylindrical shape. Because LNG storage tanks do not have supplemental cooling, LNG slowly boils inside the tank creating boil-off gas.

Boil-off Gas

LNG is a saturated liquid at atmospheric pressure of -260 degrees Fahrenheit. LNG normally boils due to heat leaks from storage tanks, and as it does so, the pressure in the storage tank will gradually increase. In order to control storage tank pressure, the cold boil-off gas is withdrawn from the tank to be re-directed to a nearby local gas distribution system or used as fuel within the plant. Boil-off gas must be warmed, compressed, odorized, and sent back to the gas pipeline. Since boil-off is subtracted from the net production of a plant, minimizing boil-off improves the production rate and saves energy. In order to minimize boil-off, LNG plants are often equipped with sub-coolers.

Subcooling LNG

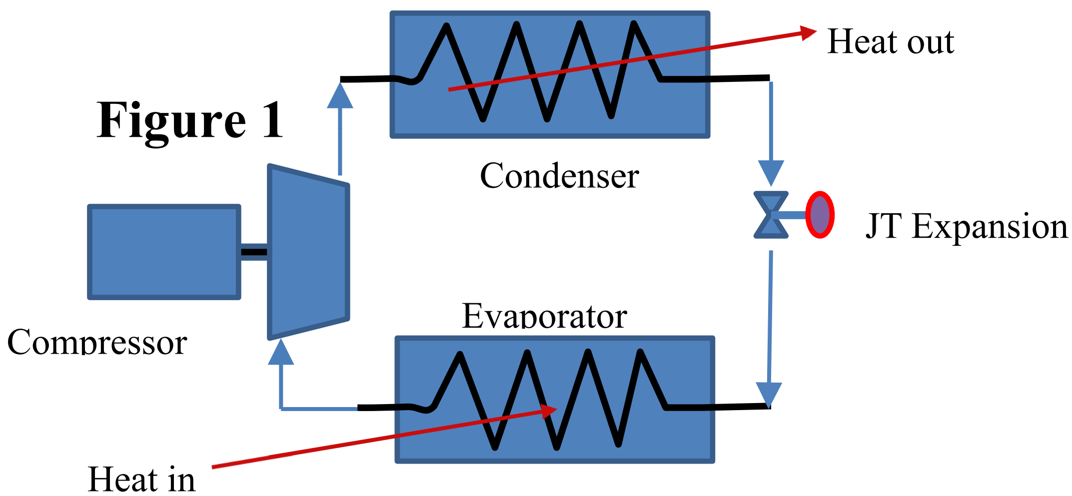
Many liquefaction processes include a final heat exchanger that sub-cools the LNG before it enters the storage tank. Subcooling the LNG reduces boil-off rates and is a desirable feature. The savings obtained by subcooling result from saving the energy that was expended to create the LNG before it boiled, coupled with the energy to heat and compress the boil-off. Although it would be desirable to re-liquefy boil-off, the economics of a small-scale liquefier dedicated to this purpose does not normally support the cost to operate and maintain the equipment.

How LNG is Produced?

The process of creating LNG is commonly referred to as "liquefaction." This process has matured as equipment designs and costs have changed over time. There are several ways to accomplish this using current technology.

Although a basic vapor compression refrigeration process would not be capable of achieving the cryogenic temperature necessary to liquefy natural gas by itself, this process is shown and discussed as a foundation for the other processes discussed in this course. The most basic refrigeration process is the vapor compression refrigeration process. A typical single-component vapor compression refrigeration process has a compressor, a condenser, an evaporator, an expansion valve, and a refrigerant. Refer to Figure 1.

Figure 1



Refrigerant gas is compressed using a mechanical compressor.

Heat is removed from the refrigerant by the condenser. The refrigerant condenses to a liquid during this phase of the process.

Liquid refrigerant under pressure flows through a JT valve in an isenthalpic expansion, meaning that no change in enthalpy occurs. As the liquid expands, it undergoes a phase change from liquid to a saturated vapor. In the evaporator, the saturated vapor absorbs heat and becomes superheated vapor at the compressor inlet, w e cycle re

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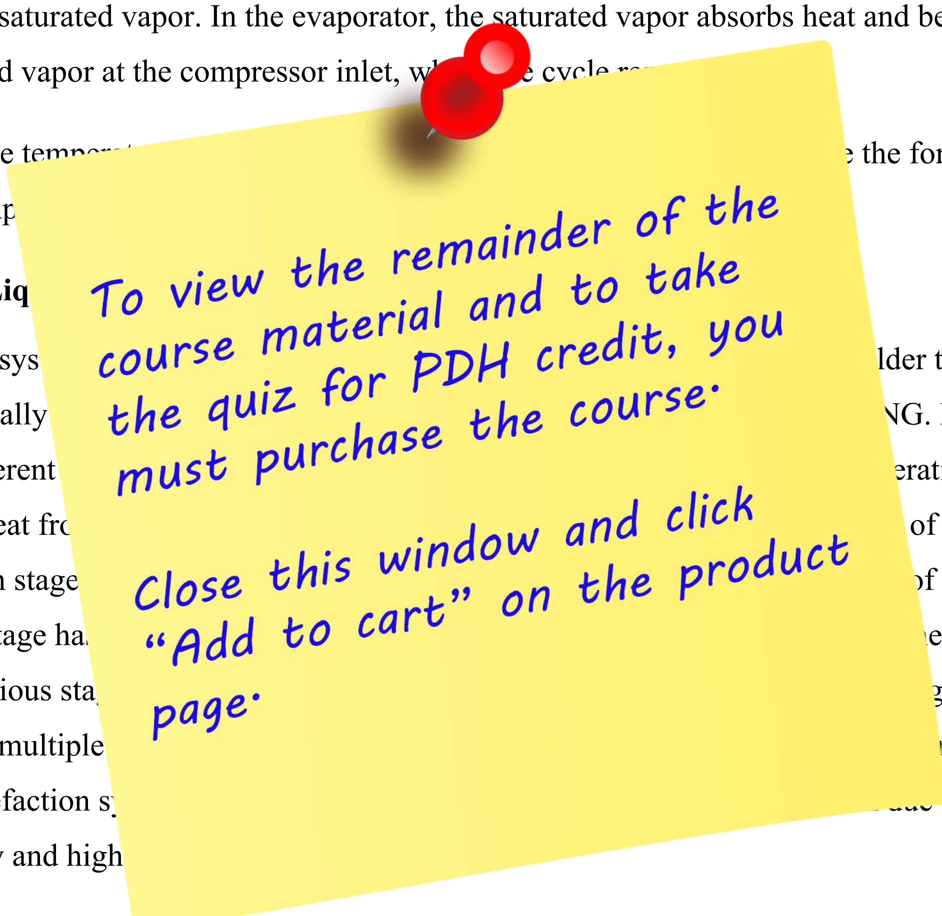

Cascade Liq

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Mixed Refrigerant Liquefaction System

Mixed Refrigerant plants are currently the most efficient in terms of energy consumption, and this process is commonly used at base-load LNG ship-loading terminals that have high liquefaction rates.

One of the goals of a process engineer in designing a liquefaction process is to choose a refrigerant whose evaporation curve matches the liquefaction curve of natural gas. This is typically a mixture of light hydrocarbons C1 – C5 with nitrogen added. This selection drives heat exchanger efficiency by managing what process engineers refer to as "pinch points." The