LNG Plant Components and Design Part 2: LNG Vaporization Systems

An Online Continuing Education Course for Engineers

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LNG Plant Components and Design Part 2: LNG Vaporization Systems

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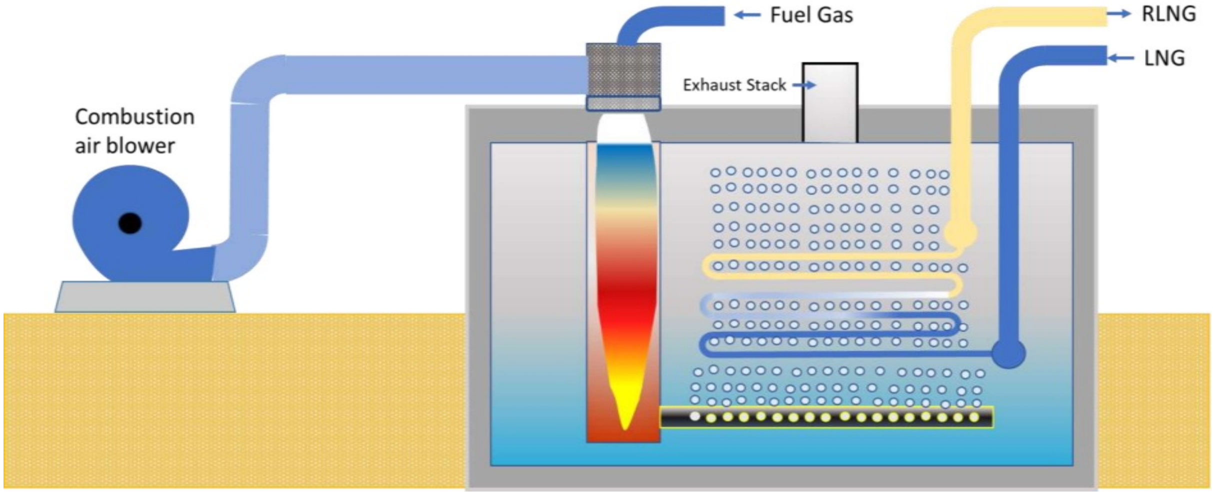

Course Objectives

1. **Become familiar with six (6) LNG Vaporizer Design Types**
2. **Learn the advantages/disadvantages related to each design type.**
3. **Become familiar with calculating vaporizer capacity.**
4. **Become familiar with the Process Safety aspects of vaporizer design.**

Liquefied Natural Gas (LNG) Vaporization Systems

Liquefied Natural Gas (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 technology to convert natural gas into LNG that could be transported via ship, truck, or pipeline gave rise to the need to convert LNG t back into vapor that could be transported by existing pipeline infrastructure. Some of the earliest vaporizers were direct-fired, water bath, and submerged combustion. The first commercially available submerged combustion LNG vaporizers were developed by a company called T-Thermal, currently known as Selas Linde of North America, in the mid-1960s. The design was both safe and reliable as well as efficient. Many of these vaporizers are still in operation today. Direct-fired vaporizers provided a less complex, economical means to vaporize LNG but eventually were replaced with water baths and vertical shell and tube vaporizers.

The vaporizer may be considered the most important piece of operating equipment in an LNG Plant. It is here that the LNG is converted back to its gaseous state to be transported within a pipeline to its eventual users. Converting LNG into vapor is accomplished by adding heat to the LNG in a heat exchanger.

Vaporizer Design Criteria:

1. The vaporizer materials must be able to withstand exposure to cryogenic liquid at temperatures of -260 degrees Fahrenheit as well as elevated temperatures associated with combustion.
2. The vaporizer must heat the LNG liquid to a point well above its saturated liquid temperature to enable the gaseous vapor to be transported in carbon steel and plastic pipelines as found in most distribution systems. These systems are composed of cast iron, steel, and plastic pipe which are not designed for cryogenic temperature.
3. The vaporizer tubes and piping must be capable of handling pressures as high as the system piping to which it is connected. This may range from 60 psig up to over 1000 psig.
4. The vaporizer must be:
    a. capable of coming online relatively quickly. This time frame is approximately 1 to 2 hours maximum.
    b. extremely reliable, often left in a dormant state for days until brought into operation.
    c. capable of meeting local air quality standards for emissions such as NOx.
    d. able to vaporize LNG at a consistent temperature and flow rate without frequent adjustment
    e. capable of operating in both cold and warm environments without detrimental effects occurring to its materials of construction.
    f. safely designed with controls to safeguard against events that could contribute to a fire or explosion.

The most common types of LNG vaporizers are:

1. Direct Fired Vaporizers
2. Submerged Combustion Vaporizers
3. Water bath vaporizers
4. Ambient air vaporizers

5. Vertical shell and tube heat exchangers

6. Open Rack vaporizers

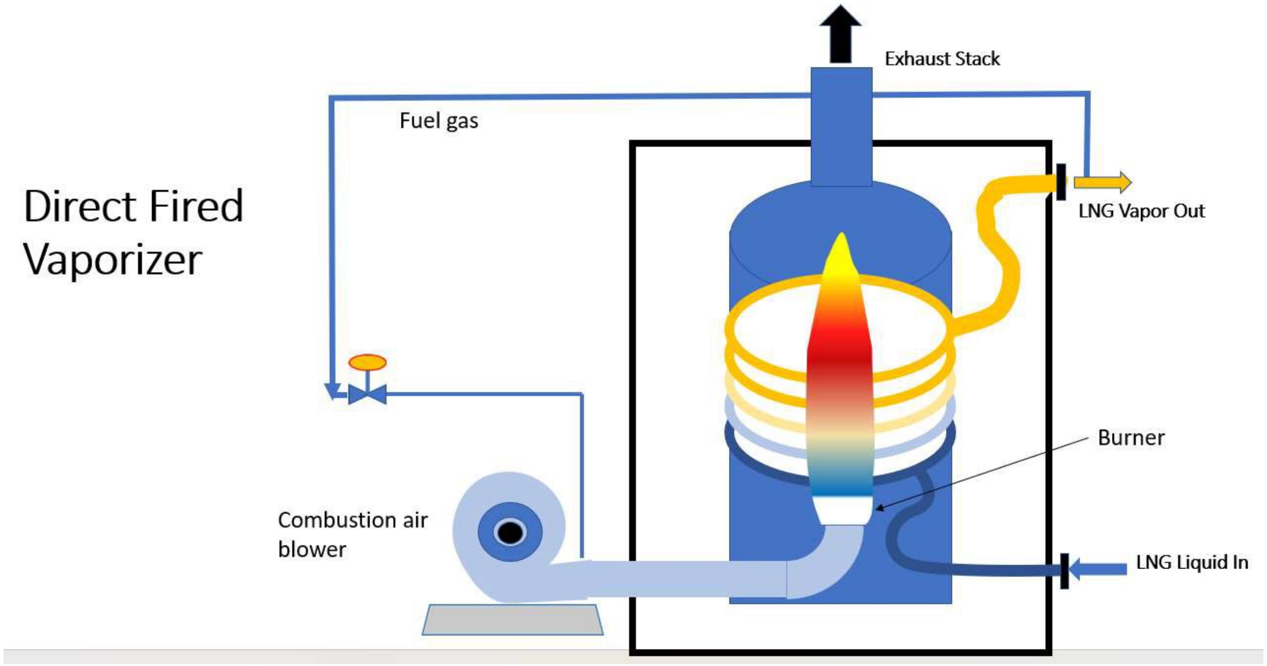

Figure 1

1.0 Direct Fired Vaporizers

Refer to Figure 1 above. In this configuration, a burner mixes air and fuel to produce a flame inside the combustion chamber. Surrounding the flame is a wound coil of metal tubing that contains the substance to be vaporized, in this case, LNG. In some designs, the flame directly impinges on the tubes. Thus, the tube material must be able to withstand both high and low temperatures without deformation or cracking. Alloys containing Fe, Cr, and Al are typically used. Given that the combustion temperature of natural gas is over 3500 degrees Fahrenheit, LNG plays a significant role in keeping the tubes cool. In this case, the substance is LNG entering the tubes at -260 degrees F and LNG vapor exiting at a temperature of +40 – 50 degrees F. LNG vapor exits the top of the coil, as shown.

Direct-fired vaporizers transfer heat from the products of combustion directly to the pressure vessel or tubes containing the LNG. There is not an intermediate heat transfer medium, such as water or glycol. The tube configuration will vary. Figure 1 shows a typical arrangement with the combustion products flowing upward through the center of a coil of pipe that contains the LNG. Direct-fired vaporizers are simple, efficient, and usually lower in upfront cost than other types of vaporizers. In applications such as this, where the tubes contain a flammable liquid such as LNG, it is necessary to closely monitor and maintain the tube integrity as leaks in the tubes will allow the LNG to enter the combustion chamber where it will ignite. As with any LNG vaporizer, it is advisable to include a flue gas analyzer to sample the exhaust stack for flammable vapor and to interlock this with the ignition system. By introducing a positive pressure in the tube bundle using natural gas, any tube leaks will cause natural gas to escape into the combustion area and eventually to the exhaust stack, where the analyzer will detect the gas and prevent the ignition sequence from completing. A small tube leak may go unnoticed during operation but can be detected when the equipment is not operating if the coil is left with positive pressure. A combustible gas analyzer with a sample probe in the exhaust stack is normally provided to detect the presence of methane as it exits a leaking tube and rises the stack.

For direct-fired vaporizers, outlet temperature control is sensitive to changes in LNG flow and needs to be balanced with changes to the fuel gas flow. These units tend to work well when the rate of vaporization is constant. Turning down the flow of these vaporizers will cause the outlet vapor temperature to increase, and turning up the flow will cause the outlet temperature to decrease.

2.0 Submerged Combustion Vaporizer

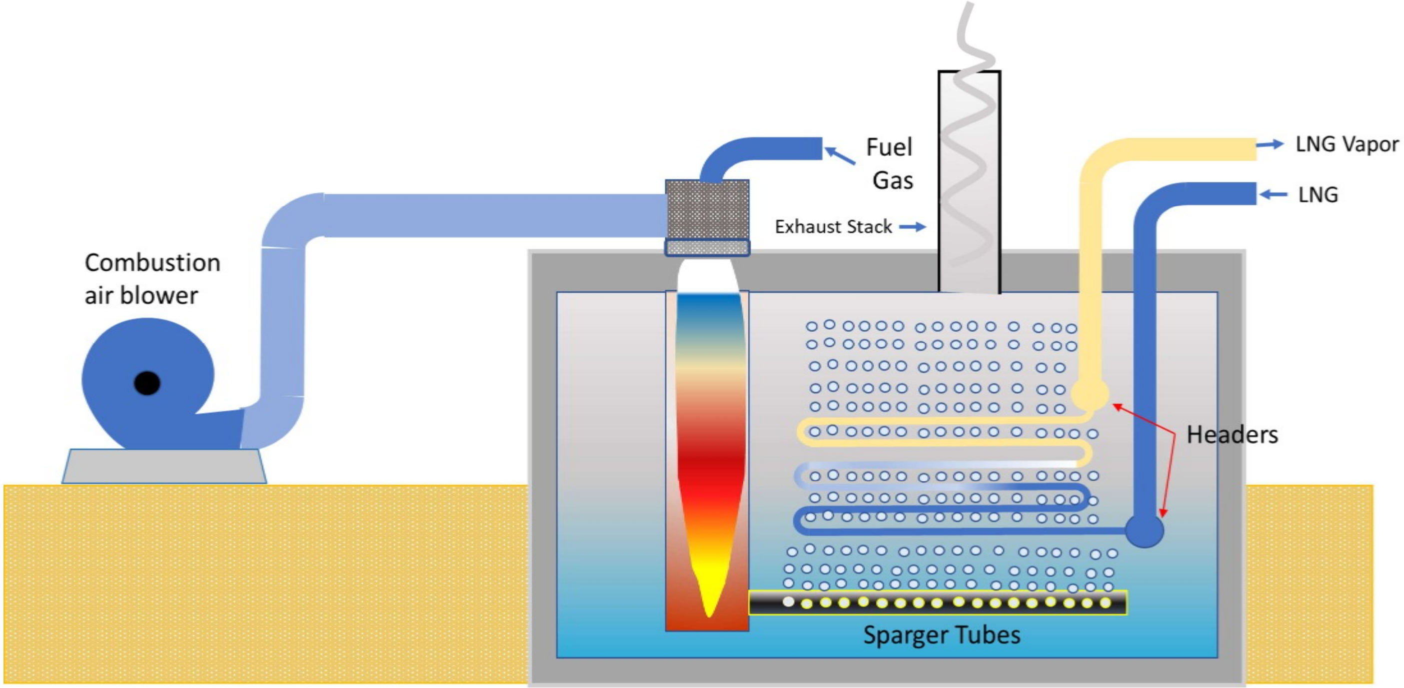

Figure 2

Design and Operation: The term "submerged combustion" vaporizer is used to describe units such as the one illustrated in Figure 2, where combustion occurs below the water level. Although the combustion process occurs below the water level, the combustion chamber is kept free of water by the forced air from the combustion air blower when the unit is in operation. In a submerged combustion vaporizer, LNG enters a stainless steel tube bundle as a liquid starting at the lower header and exits as vapor through an upper header. A combustion air blower forces air into the top of the burner. There can be multiple burners, but only one is shown for illustrative purposes. Fuel gas is mixed with air from the blower inside the burner and ignited. The hot combustion gas products are directed downward through a series of "sparger tubes," causing the combustion gas to bubble through the water and around the tube bundle containing LNG. Heat is transferred from the hot water surrounding the tubes to the LNG inside the tubes. The LNG vaporizes inside the tubes. One of the byproducts of the combustion process is water. This water mixes with the bath water, eliminating the need for water makeup. The exhaust gas also causes the pH of the bath water to gradually decrease, requiring the need to monitor and control the pH of the water to avoid corrosion. This is commonly done by adding alkalinity-increasing chemicals such as soda ash to the water bath periodically. Excess water in the bath is spilled over to a drainage system (not shown). An electric heating element in the water bath keeps the water from freezing during periods of non-use where the ambient temperature is below freezing. An onboard electric cooling pump forces bath water to circulate through water jackets in the burner to keep the burner from overheating. Special supports suspend the tube bundle in the water bath. Contact between the stainless steel tubes and the supports is designed to reduce friction and thereby reduce the possibility of tube abrasion from vibration. The tube geometry and header design allow for an even distribution of LNG from the headers to the tubes.

Advantages: Inherently safe design wit … ak. Due to the
high heat capacit … ns and maintain
stable o … the large
amount … ge volume of
water ca … rners or shut
the flow c … am piping.
Because a … tively high
thermal eff … enheit.

The overall

Knowledge C

The function c

1. Direct
2. Decreas
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