What Every Energy Engineer Needs to Know About Liquefied Natural Gas Safety

An Online Continuing Education Course for Engineers

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1. LEARNING OBJECTIVES

This is the second in a series of progressively more in-depth courses on Liquefied Natural Gas. Although this learning focuses on LNG facilities, many of the concepts presented also apply to any petrochemical plant.

This course introduces the learner to the safety topics related to the production, storage, transportation, and vaporization of Liquefied Natural Gas (LNG). In-depth books can be written on LNG safety; this course is not all-inclusive. This course should be considered a high-level starting point introduction to select topics related to LNG safety.

LNG is widely used around the world. It is a very compact form of natural gas in liquid form. It is used on frigid days to supplement gas from the interstate pipelines and supply gas load centers like New York, Boston, and other major gas load areas.

Natural gas, the same as vaporized LNG, is the cleanest burning fossil fuel as it contains the least amount of carbon of all the fossil fuels. Thus, many electric power plants now use natural gas or are converting from dirtier fossil fuels to natural gas or vaporized LNG. Upon completion of this course, the learner should, at a high level, be able to:

- Understand the profound importance of putting safety first when dealing with petrochemicals, particularly LNG.
- Explain the characteristics and properties of LNG.
- Understand the hazards associated with LNG and natural gas.
- Understand the safety measures used in the design and operation of LNG facilities.
- Understand the methods of hazard detection.
- Understand the methods of preventing hazards from escalating to accidents.
- Understand some of the safety measures and devices needed to manage an LNG facility.
- Understand the significant need to train human resources and develop a culture of safety and reliability.

2. INTRODUCTION

Liquefied Natural Gas (LNG) is essentially natural gas in liquid form. To get natural gas to become a liquid, components that may freeze to a solid need to be lessened in concentration, and the remaining gas must be chilled down to ~ -260 F.

Natural gas is mostly methane (typically 90+%); thus, LNG is also typically 90+% methane. Therefore, we will treat vaporized LNG as natural or methane gas for the rest of this study.

Natural gas is measured in standard cubic feet. A.G.A. defines a standard cubic foot as a cubic foot volume of gas at 60 F and 14.73 psia. Natural gas is also measured in decatherms. A Therm is, by definition, 100,000 Btu of energy, and a Decatherm is, thus, 1,000,000 Btu of energy. A Btu of energy is the amount of heat to raise 1 pound mass of water (Lbm) 1 degree F.

Many people think of Btu as an accurate way to measure energy. Still, it needs to be better defined because different countries or industries use different water temperatures to measure the heat required to raise the water by 1 F. Since the specific heat of water changes with temperature, the amount of heat measured in Btu output may differ (by a very small amount) across different countries or industries.

Btu measures are presented in the introduction to give the learner a sense of the amount of energy stored in an LNG tank. LNG tanks range in size. The typical tank size is 1 Bscf (billion standard cubic feet), but tanks can be as large as 4.2 Bscf. A 1 Bscf LNG storage tank inventory contains enough energy to run a typical single-house heating system (125,000 Btu/hr.) 24 hours per day, seven days a week, for ~ 1,000 years.

Engineers designing and operating LNG plants are responsible for a massive amount of energy.

Like all hydrocarbons, natural gas liberates a large amount of heat energy when it burns with oxygen. Regardless of the heat released during combustion, burning can be a hazard if uncontrolled. In a house heater or a stove, it is a controlled combustion. However, uncontrolled combustion due to a leak of natural gas or a spill of LNG, which converts to vaporized LNG, is hazardous.

Unintentional combustion of LNG vapors is an obvious hazard related to LNG. This hazard, as well as many other hazards unique to LNG, will be presented. Further, methods to lessen these hazards and how to react to other threats of LNG will be explained.

Many hazard mitigation measures can be designed into the plant operating hardware and software. Passive and active steps can be built into the design and procedures. However, operator error is a more significant hazard that is more difficult to design against occurring in a plant.

An airplane can have many safety features built into its automatic operating systems, which can compensate for, but cannot eliminate a pilot's error in judgment. Often, such errors are due to a lack of the operator's knowledge or experience.

The purpose of this training is to present the basics of LNG safety. This training can be a springboard for further training to help engineers understand the hardware, software, and human interface needs for safe LNG systems. Further, this training can assist engineers who train LNG operators to understand the technologies they oversee. Although this training is not all-inclusive, it is intended to stimulate the learners to think not only of the expected hazards that could accelerate a crisis but also of what is unexpected.

Understanding what is technically happening is a necessary part of understanding how to recognize abnormal operations.

In this training, we will present:

- Combustion hazards
- Cryogenic hazards
- Thermal hazards
- Asphyxiation hazards
- Myths about LNG operations
- How the essential safety asset is you – the design and training engineer.
- Human resource development
  - Integrity
  - Trust
  - Open communication
  - Leadership
  - Teamwork
  - Creativity
  - Continuous improvement
  - **Developing a culture of safety and reliability (highlighted intentionally)**
- Who is ultimately responsible for safety – Everyone involved in the plant

- If you see an unsafe act or condition, the responsibility is yours to remedy it
- Preventive actions
  - Wearing Personal Protective Equipment (PPE)
  - Following “all” procedures
  - Following “Management of Change” (MOC) requirements
  - Knowing and implementing emergency procedures
  - Initiating a partial or complete plant shutdown, if necessary
  - Having procedures updated if they are found to be inadequate.
- If you identify a needed repair or dysfunctional equipment – get it fixed.
- The technician’s life and that of his co-worker is everyone’s responsibility.
- You must understand the hazards.
  - Basics of combustion
  - Effects of extreme cold
  - Consequence of low oxygen levels

This learning document is meant to be at an introductory technical level. The most crucial intention of this document is to give you the basic technical knowledge, at an elementary level, that you need to start your study on how to continue to make the Liquid Natural Gas Industry “Safe and Reliable.”

The image to the right is placed here as a reminder that everyone has someone who loves and needs them to come home at the end of their shift.

Reliability is also related to safety because if the LNG plant cannot make send out when needed, the consuming public may be out of gas during the worst of cold weather times. This would put the public at a severe health risk.

As engineers, we must ensure that our design, planning, operation, and maintenance of LNG facilities help assure safety and reliability.

This will help ensure that everyone comes home at the end of their shift and that gas is supplied when the end-use customers need it.

Culture

Plant Safety

Figure 1: Beautiful Granddaughter

Source: Self-made photo

3. TERMS AND UNITS OF MEASURE FOR NATURAL GAS AND LNG

The following abbreviations, terms, and units will be used in this document for natural gas and LNG:

U.S.	United States
Peak Shaver	An LNG facility used t… high gas demand.
Satellite	
Send out	…ustomers.
Boil-off gas	…m the
BOG	
Pad gas	…or vessel
F	
Psia	
Psig	P…
Lbm	Po…
Lbf	Po… …32.2 ft./sec^2)
Cu.ft.	A cu… …1 foot x 1 foot x 1 foot (1’ x 1’ x 1’)

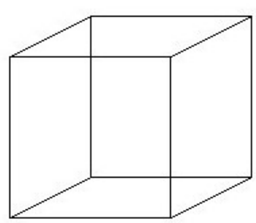

Figure 2: Cubic Foot is a volume 1’ x 1’ x 1’
Source: Self-made

SCF	A standard cubic foot is a 1’ x 1’ x 1’ volume of gas at a standard temperature and pressure. The American Gas Association (A.G.A.) defines standard pressure and temperature as 14.73 psia and 60 F (this is used for this document)