Liquefied Natural Gas: A New Urban Legend?

BY CRAIG H. SHELLEY

In recent years, many cities in the United States, particularly those on the east and west coasts, have participated in the discussion of liquefied natural gas (LNG) after the cities' management had been asked to approve an LNG facility in their jurisdictions. Debates surrounding the approval process delivered information that may or may not have been accurate. This false information has begun to evolve into urban legend status. This article serves to accurately present the known information about LNG so all fire service personnel can prepare to speak on the subject as well as be better equipped for an LNG emergency.

The History of LNG

During the 19th century, British chemist and physicist Michael Faraday experimented with liquefying various types of gases, including natural gas. In 1873, a German engineer built the first practical compressor refrigeration machine in Munich. In 1912, the first ever LNG plant was built in the United States. The plant, erected in West Virginia, became operational in 1917. In 1941, the first commercial liquefaction plant was built in Cleveland, Ohio. Liquefaction of natural gas meant that it could be transported over great distances. This led to construction of the first LNG tanker in 1959, the conversion of a World War II liberty freighter, which later transported an LNG cargo from the United States to the United Kingdom.¹

What is LNG?

LNG is a gas in liquid form. It is colorless, odorless, and nontoxic. It is also a simple asphyxiant. Natural gas is supercooled to a liquid at −260°F. Because of these extreme low temperatures, the liquid is classified as a cryogenic. Cryogenic liquids are defined as "gases that have been transformed into extremely cold liquids which are stored at temperatures below −130°F".² LNG is composed predominantly of methane, usually but not always in the 85-percent to 99-percent range (1); other components include ethane, propane, and butane. The composition will vary depending on the natural gas source of the gas that has been liquefied.³ Gas produced from both gas (nonassociated gas) and liquid hydrocarbon wells (associated gas) varies widely in composition. (1)

LNG is clear and colorless, like water, but weighs one half as much as the same volume of water. The vapor density of LNG at its normal boiling point (NBP) of −250°F to −260°F is 1.47. As the temperature of gas decreases, the density increases, affecting the behavioral properties of a cold methane vapor cloud. At temperatures below −160°F, the density of LNG vapor is greater than air at an ambient temperature of 60°F. This vapor is negatively buoyant and will accumulate in low areas, hugging the ground as it travels. As the temperature of the LNG rises above −160°F, the vapors become positively buoyant, rising and dispersing more easily. The flammable range of LNG is five to 15 percent by volume of gas in air. The ignition temperature will vary with the composition of the LNG. If the concentration of heavier hydrocarbons increases, the autoignition temperature decreases. Within the flammable range, LNG vapors can be ignited immediately from the energy in a spark or open flame.

LNG Hazards

A major hazard may result from the formation of a vapor cloud following an accidental LNG release. LNG has an expansion ratio of 1:600 when vaporized at one atmosphere and warmed to room temperature. Adequately mixed with air, this vapor cloud becomes flammable, and wind serves to carry the cloud away from its source. In addition to carrying the vapor cloud, the wind may also disperse or dilute the concentration. Other factors, such as humidity, terrain, and ground-to-air temperature differences, also affect dispersion. At some point, the outer edge of the vapor cloud may no longer be flammable, spreading so that it is below the lower flammable limit. During the initial spill, the vapors are colder and heavier than the ambient temperature air, thereby reducing diffusion. When the vapor reaches −160°F, the vapor density is 1.0, compared with ambient air temperature. At temperatures higher than −160°F, the vapor density is less than 1.0 and becomes buoyant. The vapor cloud is usually visible, although it must be remembered that vapor also exists outside the visible cloud; therefore, the hazard also exists outside the visible cloud.

A flash fire hazard exists when LNG vapors are ignited at a distance from the spill or release source. If there is no confinement, the vapors will burn back toward the source.
This flash back may take several seconds and is affected by the distance of the vapors from the liquid and air-fuel mixture of the vapor cloud. Although some have stated that LNG flash travels at a slow speed, this cannot be expected in an emergency. A misconception in the fire service is that firefighters can outrun an LNG flash. Do not consider this action an option.

Although LNG possesses a set of hazards that need managing, when we examine past LNG incidents, we see very few of them placed surrounding areas in jeopardy.

As stated, LNG vapors will explode if confined; they may also explode in heavily congested plant areas. LNG industry experience indicates that a boiling-liquid, expanding-vapor explosion (BLEVE) will not occur in onshore LNG storage tanks. In Spain in 2005, an LNG road tanker rolled over and caught fire. Subsequently, a BLEVE-style fireball occurred. Generally, an LNG road tanker has an inner and outer shell with perlite insulation between the tanks. The properties of LNG and the insulated tank may reduce the occurrence of a BLEVE. Whereas ignition may occur during a road tanker incident, a BLEVE-like incident has only been recorded during this one occasion. During a fire that impacts an LNG storage tank, the outer shell prevents flame impingement while the insulation keeps the fire from rapidly vaporizing the LNG, as may occur in an uninsulated tank. At low pressure, even in a tank failure, a fire, not an explosion, would result.

Because LNG is cryogenic, it can cause severe damage to the skin and eyes and make ordinary objects brittle and fracture.

**LNG STORAGE**

LNG is stored at more than 100 facilities in the United States, for use during periods of peak natural gas demand (peakshaving) or as a baseload source of natural gas. Double-walled insulated tanks store the LNG at very low (near atmospheric) pressure. The inner tank contains LNG; the outer...
tank contains the insulation and prevents any natural gas from escaping.

The storage at slightly above atmospheric pressure prevents air from leaking into the tank. Since there is no air in the tank, the LNG is neither flammable nor explosive. However, if the LNG leaks to an impoundment area or on water, it will mix with air and may ignite, forming a pool fire, or will rapidly vaporize. When LNG is in its flammable range, it can ignite in the presence of an ignition source. As stated, LNG will not explode in its storage tank, since no air is present. Remember, LNG vapors mixed with air are not explosive in an unconfined environment but may be explosive in heavily congested industrial areas.

RAPID PHASE TRANSITION

Rapid phase transition (RPT) is an explosion caused by fast LNG vaporization. This explosion does not involve combustion. Many have concerns that an RPT may occur from an LNG ship leak and would be very destructive. During tests, it has been proven that RPTs are less energetic than combustion explosions. Unconfined RPTs are not considered hazardous. However, they can cause structural damage if they occur in a confined space. RPTs are more likely to occur in LNG mixtures containing high proportions of ethane and propane. High-methane content LNG is unlikely to undergo an RPT. (1)

TRANSPORTATION OF LNG

LNG may be transported using a standard 10,000- to 12,000-gallon LNG tanker truck. A typical storage vessel used on the tanker truck would have the following components:

- Inner pressure vessel made from nickel steel or aluminum alloys exhibiting high-strength characteristics under cryogenic temperatures.
- Several inches of insulation in a vacuum environment between the outer jacket and inner pressure vessel (stationary tanks often use finely ground perlite powder; portable tanks often use aluminized mylar superinsulation).
- Outer vessel made of carbon steel and not normally exposed to cryogenic temperatures.
- Control equipment consisting of loading and unloading equipment (piping, valves, gauges, pump, etc.) and safety apparatus (pressure relief valve, burst disk, gas detectors, safety shutoff valves, etc.).

The double-walled construction of the LNG tanker truck is inherently stronger than the design of similar liquid transporters. Therefore, the shipping of LNG is safer from the perspective of fuel spills resulting from an accident. A rupture of the outer vessel would cause the loss of insulation and result in an increased venting of LNG vapor. While this is of concern, it is relatively minor compared to an LNG spill.

The explosion of an LNG tanker is highly unlikely, possible only if the pressure relief equipment or system fails completely or there is some combination of an unusually high vaporization rate (because of loss of insulation) and obstruction of the venting and pressure relief system. This may prevent adequate vapor flow from the inner pressure vessel. If the pressure buildup causes the
vessel to burst, the resulting explosion will cause the container pieces to be propelled outward at a very high velocity. However, pressure relief valves and burst disc requirements built into the design codes make this scenario highly unlikely.

If the vessel is ruptured and LNG is spilled, a fire may result, since a flammable natural gas vapor/air mixture will form immediately around the LNG pool. In a road accident, there is a high probability of ignition because of electrical sparking, hot surfaces, or a fuel fire created from the engine fuel of the tanker or other involved vehicles.

LNG is also shipped by oceangoing tankers to import terminals. There are two basic tanker designs, both consisting of an outer hull, an inner hull, and a cargo containment system. The first design uses an Invar® or stainless steel double-walled liner, structurally supported by the tanker’s inner hull. The second design uses structurally independent spherical or prismatic tanks constructed of stainless steel or an aluminum alloy.

The safety record for LNG transportation has a history that may be unparalleled in the shipping industry. Since 1959, when commercial LNG transportation began, there has never been a shipboard death reported involving the product, and only eight marine incidents involving LNG tankers that resulted in LNG spillage have occurred worldwide (in these cases, there were no cargo fires). There were seven additional marine incidents with no significant cargo loss. It should be noted that “the cargo-carrying capacity of the world’s LNG fleet will double within a few years,” so fire departments with LNG terminals either in or soon to be in their districts should become familiar with LNG and its properties.

The most severe accident that may realistically occur to a loaded LNG tanker would be a storage tank (or tanks) breach, resulting in LNG discharge overboard. However, this type of incident has never happened, partially because of the double-hulled construction required and the separation between the cargo tank and the inner hull.

**EMERGENCY RESPONSE AND FIREFIGHTING**

Emergency responses to LNG incidents generally involve a spill or fire. For spills inside LNG facilities, the product will usually be diverted to containment impounding pits. Vapors are produced and may be in their flammable range. The recommended methods for dealing with an unignited and contained LNG spill include high-expansion foam and/or water curtains. High-expansion foam reduces the vaporization, thereby reducing the vapor cloud. It cannot, however, completely prevent vaporization. Initially, it may increase the rate, since the foam adds heat to the LNG. However, once this vapor surge is dispersed, the foam reduces vaporization. Tests using high-expansion foam have
LIQUEFIED NATURAL GAS

shown a 60-percent vapor reduction. (1) Using nonaspirated or low-expansion foams does not significantly reduce vaporization and should not be used; water curtains can be used to control the vapor cloud. Do not allow runoff to come in contact with the LNG pool, because it will increase the vaporization rate.

For burning pool fires, the use of high-expansion foam, dry chemical (such as potassium bicarbonate), and exposure protection are recommended tactics. For complete extinguishment, only dry chemical will be effective. (Portable high-expansion foam generators may not be effective, since radiant heat may not allow the proper positioning of the generator.) High-expansion foam should be used to reduce vapors and radiant heat; the LNG will continue to burn through the foam and can either be left to burn, consuming the fuel, or extinguished using dry chemical. A three-foot blanket of foam should be maintained on top of the LNG. Exposed equipment can be protected with water streams.

Jet fires may occur in pressurized LNG vaporizers or the unloading during tanker operations. A jet fire may cause severe damage, be confined to a localized area, and would be limited by safety systems that would stop the flow.

PREINCIDENT RESPONSE PLANNING

As with any industrial response, the key to success is preincident response planning, facility visits, drills, exercises, and training. Fire departments with LNG facilities within their first response or mutual-aid districts should visit to gain as much intelligence as possible. Preincident response plans should contain the minimum the following elements:

• Additional resources (equipment, staffing, expendables, third-party companies).
• Staging areas and incident command post locations.
• Communications plan.
• Specialized firefighting tactics. Schedule annual visits to the facility, and update preincident response plans during these visits. Drills and exercises are essential to effectively prepare an industrial emergency organization and to test the effectiveness of the preincident response plan. A department could be used in a participatory or command function. Whatever the assignment, it must be practiced in conjunction with other response organizations. Failure of any one part of an emergency plan could result in the failure of the entire mission. All response organizations should be included in the drills and exercises.

LNG exhibits traits unlike other lique-
LIQUEFIED NATURAL GAS

fied gases, and specialized training is required. Therefore, it is essential for departments that may come in contact with LNG to train under realistic conditions; this training is offered only by a handful of schools in the United States. Texas Engineering Extension Services, Emergency Services Training Institute (a member of the Texas A&M University System), and the Massachusetts Firefighting Academy offer such training. Firefighters must feel the differences and product characteristics when extinguishing LNG fires.

For additional information on LNG, visit www.firemarshals.org and download "Liquefied Natural Gas: An Overview of the LNG Industry for Fire Marshals and Emergency Responders."

ENDNOTES
4 Perlite—a glassy volcanic rock used as insulation.
9 Invar™—a steel alloy containing approximately 36% nickel. It has a low coefficient of thermal expansion. It was trademarked by Imply Alloys since 1907.

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