CHARACTERISTICS AND COMMON VULNERABILITIES INFRASTRUCTURE CATEGORY: LNG TERMINALS

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Preventing terrorism and reducing the nation's vulnerability to terrorist acts requires understanding the common vulnerabilities of critical infrastructures, identifying site-specific vulnerabilities, understanding the types of terrorist activities that likely would be successful in exploiting those vulnerabilities, and taking preemptive and protective actions to mitigate vulnerabilities so that terrorists are no longer able to exploit them. This report characterizes and discusses the common vulnerabilities observed at liquefied natural gas (LNG) terminals, which handle large quantities of LNG, which is flammable and also potentially explosive when vaporized under the right circumstances.

LIQUEFIED NATURAL GAS (LNG) TERMINAL CHARACTERISTICS

Common Terminal Characteristics

LNG is typically created in a three-step process. First, gaseous-form natural gas, extracted from the ground in neighboring oil reservoirs, is "frozen" into a liquid state through a complex cryogenic process (called liquefaction). The LNG boiling point is -260°F. In a liquid state, the volume of the gas is greatly reduced; it would take 600 ships carrying natural gas to equal the cargo contained on just one LNG tanker. Thus, it is practical and economical to import natural gas from overseas. The density of LNG is 26.5 pounds per cubic foot, or less than half that of water. LNG is odorless, colorless, non-corrosive, and nontoxic.

Second, after the gas is liquefied, it can be stored in cryogenic holding tanks or pumped directly from the cooling vestibule into special insulated transportation vessels, such as railcars, trucks, or ships. Third, upon delivery of the vessel to its final destination, LNG is pumped from the vessel either into another cryogenic storage tank for later delivery or directly into a regasification unit that uses sea water or air to reheat the LNG, converting it back into gaseous natural gas. The Lake Charles, Louisiana, LNG Import Facility, owned by CMS Energy, is shown in Figure 1.

LNG tanks are always of double-wall construction with extremely efficient insulation between the walls. Large tanks have a low aspect ratio (height to width) and are cylindrical with a domed roof. Storage pressures in these tanks are very low, less than 5 pounds per square inch gauge (psig). Smaller quantities of LNG (70,000 gallons and less) are stored in horizontal or vertical vacuum-jacketed pressure vessels. These tanks may be at pressures anywhere from less than 5 psig to more than 250 psig. LNG must be maintained cold at a cold temperature (at least below –117°F) to remain a liquid, independent of pressure.

Figure 1 Lake Charles, Louisiana, LNG Import Terminal (Source: Quillen 2002)

The method of transporting and receiving LNG makes this energy source a matter of concern for infrastructure protection. The intensely cold LNG is transported at atmospheric pressure in special, heavily insulated cryogenic tankers to a marine terminal, where it is stored in insulated tanks (Figure 1).

When needed, LNG can be piped to a nearby gasification plant, where it is vaporized and then distributed to customers by pipeline, like wellhead gas.

Alternately, LNG can be transported to satellite storage tanks via specially insulated trucks for future regasification during periods of heavy demand (i.e. peak shaving.)

There are different types of LNG facilities and operations. Three major LNG terminals in the United States import LNG into the country (a fourth is about to start operations). Many more LNG facilities exist in the United States in different sizes and configurations. Their purpose is to store LNG either from conversion of natural gas or directly from delivery by truck for later regasification. The LNG can then be injected into transmission and distribution systems during peak natural gas periods.

Common Components

Below is a list of components, equipment, and facilities that are typically found at LNG facilities:

- Port/pier/wharf (Figure 1),
- Articulated unloading arms (both for LNG and for cold vapor return),
- LNG storage tanks (Figure 1),
- Water-bath vaporizers for regasification (Figure 2), and
- Header system feeding into transportation pipelines.

Figure 2 Water Bath Vaporizers

Standards

The U.S. Department of Transportation (DOT) has established very stringent and specific safety standards for LNG storage facilities (49 USC 60101 et seq.; 49 CFR 193). These standards do not apply to the marine cargo transfer system and associated facilities between the marine vessel and the last manifold (or in the absence of a manifold, the last valve) located immediately before a storage tank. These safety requirements apply to any siting, design, construction, equipment, fire protection, operation, and maintenance associated with LNG facilities placed into service after March 31, 2000, or to any major modification of existing facilities. Those federal standards that could also pertain to security vulnerabilities are set out in Table 1 below.

Table 1 Selected Federal Standards for LNG Facilities

Standard	Citation
• Each LNG container and LNG transfer system must have a thermal exclusion zone calculated in accordance with Section 2-2.3.1 of American National Standards Institute/National Fire Protection Association (ANSI/NFPA) 59A • Certain additional requirements concerning allowable models and the wind speed/ambient temperature/humidity levels are to be used.	49 CFR 193.2057
• Structural requirements must be implemented to prevent impairment of the system's performance reliability and structural integrity as a result of certain circumstances (e.g., exposure to fire from impounded LNG or from other sources or loading on the dike due to collision by or explosion of a train, tank car, or tank truck if the facility adjoins the right-of-way of any highway or railroad).	49 CFR 193.2155
• Each LNG facility must have a control center from which operations and warning devices are monitored. • The control center must be protected from other LNG facilities during a controllable emergency, must be able to operate each remotely actuated control system and automatic shutdown control system, and have personnel in continuous attendance when the facility is in operation.	49 CFR 193.2441

Table 1 Selected Federal Standards for LNG Facilities	
Standard	Citation
• Electrical control systems, means of communication, emergency lighting, and firefighting systems must have at least two sources of power that function so that failure of one source does not affect the capability of the other. • Auxiliary generators (and associated fuel supply) must be located apart and protected from the rest of the plant so that they are usable during a controllable emergency.	49 CFR 193.2445
• Each operator must have written procedures to provide safety in normal operation and in responding to an abnormal operation. • Each component that might pose a hazard to persons or property must be monitored to detect fire or any malfunction or flammable fluid that could cause a hazardous condition. • Monitoring must be accomplished by watching or listening from an attended control center for warning alarms, such as gas, temperature, pressure, vacuum, and flow alarms, or by conducting an inspection or test at intervals specified in the operating manual.	49 CFR 193.2503; 193.2507
• Each operator must determine the types and places that emergencies other than fires might reasonably be expected to occur as a result of operating malfunctions, structural collapse, personnel error, forces of nature, and activities adjacent to the plant. • The plant must coordinate with appropriate local officials in evacuations and emergencies requiring mutual assistance and keep these officials advised about the plant's fire control equipment, its location, the number of units, potential hazards at the plant, communication and emergency control capabilities at the plant, and the status of each emergency.	49 CFR 193.2509
• Each operator must investigate the cause of any explosion, fire, or LNG spill or leak that results in death or injury requiring hospitalization or property damage exceeding $10,000. • As a result of the investigation, appropriate action must be taken to minimize recurrence of the incident.	49 CFR 193.2515
• Personnel, including security personnel, must meet certain training and qualification requirements (e.g., how to recognize breaches of security, carry out security procedures).	49 CFR 193.2715; 193.2717
• Each operator must prepare and follow written procedures for security, including: o conducting security inspections and patrols, carrying out methods for determining which persons are allowed access to the plant, o making positive identifications of all persons entering the plant, including checking picture badges, and o working with local law enforcement officials to keep them informed.	49 CFR 193.2903
• Certain components must be surrounded by a protective enclosure; these include: o storage tanks; o impounding systems; o vapor barriers; o cargo transfer systems; o process, liquefaction, and vaporization equipment; o control rooms and stations; o control systems; o fire control equipment; o security communications systems; and o alternative power sources. • Access to each protective enclosure must be locked unless it is continuously guarded. • During normal operations, an access may be unlocked only by persons designated to do so in writing by the operator. • Each protective enclosure must be of sufficient strength and in a configuration to obstruct unauthorized access to the facilities enclosed.	49 CFR 193.2905; 193.2907

Table 1 Selected Federal Standards for LNG Facilities

Standard	Citation
• Openings in or under protective enclosures must be secured by grates, doors, or covers with a construction and fastenings of sufficient strength such that the integrity of the protective enclosure is not reduced by any opening.	
• Where warning systems are not provided as part of security monitoring, the area around certain facilities and each protective enclosure must be illuminated between sunset and sunrise. • Each protective enclosure, and those facilities therein, must be monitored for the presence of unauthorized persons, either by visual observation in accordance with a specific schedule or by a warning system that continuously transmits data to an attended location. • A facility must have a security communications system that allows prompt communications between security personnel and law enforcement officials and direct communications between security personnel and the control room and control stations.	49 CFR 193.2911; 193.2913; 193.2909
• Warning signs, including “No Trespassing” signs, must be posted around the facilities.	49 CFR 193.2917

CONSEQUENCE OF EVENT

When vaporized, LNG is combustible in the range of 5% to 15% volume concentration in air. Neither LNG, nor its vapor, can explode in an unconfined environment. According to the project manager for Westcoast Gas Services, Inc., who was discussing the proposed LNG facility in Howe Sound, British Columbia, "Modeling of the absolutely worst case scenario by world class LNG authorities has determined that the maximum potential area for damage is limited to a 3.5 kilometer radius. There would not be damage from an explosion but rather from the burning of natural gas vapors dispersing from the site. Analysis by these authorities of more plausible, though still unlikely, scenarios shows that the area of influence would not exceed 500 meters. Beyond this point, the gas dispersing from any failure would be at a concentration lower than one-half the lower flammability limit (i.e., less than one-half of 5%). There is no plausible event that would result in the release of liquid natural gas from the earthen dike surrounding the site."

There has been a concern that a boiling liquid expanding vapor explosion (BLEVE) could be a possibility under the right circumstances for an LNG storage facility or tanker. Studies have indicated that a BLEVE resulting from an LNG accident or terrorist attack is very unlikely because tank and ship designs favor burning over explosion. The ignition and sustained burn of a vaporized LNG cloud is difficult; multiple ignition sources would probably result in a burn back to the source (Juckett 2002).

COMMON VULNERABILITIES

Critical infrastructures and key assets vary in many characteristics and practices relevant to specifying vulnerabilities. There is no universal list of vulnerabilities that applies to all assets of a particular type within an infrastructure category. Instead, a list of common vulnerabilities has been prepared, based on experience and observation. These vulnerabilities should be interpreted as possible vulnerabilities and not as applying to each and every individual facility or asset.

Exhibit 1 Economic and Institutional Vulnerabilities	
Economic and institutional vulnerabilities are those that would have extensive national, regional, industry-wide consequences if exploited by a terrorist attack.	
1	Portions of the United States (e.g., Northeast, Midwest) rely on LNG to help meet peak natural gas demand periods.
2	LNG consumption is projected to rise in the future to help meet natural gas demand.

Exhibit 2 Site-Related Vulnerabilities	
Site-related vulnerabilities are conditions or situations existing at a particular site or facility that could be exploited by a terrorist or terrorist group to do economic, physical, or bodily harm or to disable or disrupt facility operations or other critical infrastructures.	
Off-Shore Access and Access Control	
1	LNG vessels are usually unique in shape and easy to distinguish.
2	Information on potential LNG vessel explosions and impacts may be publicly available.
3	LNG vessels may be difficult to protect in open waters.
4	LNG vessels come into major harbors.
5	Airport flight paths may exist over LNG vessel waterways.
6	Access control at ports/piers, via either water or a beach, may be difficult to enforce.
On-Shore Access and Access Control	
7	Public roads may be in close proximity to critical assets (e.g., storage tanks) or LNG plant entrance points.
8	Critical assets may be set close to the perimeter fence.
9	Access control at ports/piers, via either water or a beach, may be difficult to enforce.
10	Gates and critical assets near the perimeter fence line may not be protected by appropriate barriers or other hardening equipment.
11	Although there must be positive identification of all persons entering the plant, facilities may not have procedures in place to inspect trucks and other vehicles before entering the site.
12	Security staff may not be armed.
Operational Security	
13	Risk Management Plan information, if required, is publicly available. Worst-case scenario for toxic and flammable release may be available.
14	Background checks conducted on employees and contractor personnel may be limited. Some states or even union contracts may limit the use of background investigations..
15	Large LNG tanks are usually easy to distinguish.
16	Additional coordination of emergency plans may be needed with industry neighbors.
17	Websites may provide detailed information on LNG facility locations, critical assets, maps, and other operational data.
18	Hacking may provide adversaries with additional information.
19	Lists of LNG locations may be available through public sources.
SCADA & Process Control	
20	A potential exists for intruders to hack into SCADA/process/security networks.
	(Continued on next page.)

21	There is the potential for a disgruntled controller to cause an undesirable event.
22	Facilities may not maintain separate, remote back-up control centers.
Emergency Planning and Preparedness	
23	Contingency plans, even though well developed and exercised annually, may not address terrorist events.
24	Spare parts that are large and/or expensive may be in short supply. Economic considerations may have reduced spare part inventories. Some parts may have long lead times to obtain or may be available only from overseas vendors.
25	On-site aboveground pipelines may be vulnerable to attack.
26	Over pressurization may result in BLEVE in large LNG tanks.
Other System Operation Considerations	
27	Natural gas utilities rely on receiving natural gas supplies from LNG facilities.
28	Shipping LNG by truck involves en route security issues.

Exhibit 3 Interdependent Vulnerabilities

Interdependency is the relationship between two or more infrastructures by which the condition or functionality of each infrastructure is affected by the condition or functionality of the other. Interdependencies can be physical, geographic, logical, or information-based.

Water	
1	Loss of water supply may shut down LNG operations (e.g., insufficient cooling and/or warming water or fire-fighting resources).
Electric Power	
2	LNG requires electric power to operate, especially during the liquefaction cycle. Loss of electric power may shut down operations.
Telecommunication	
3	Telecommunication systems are important for field operations, SCADA support, and linkage with natural gas distribution/transmission systems.

USEFUL REFERENCE MATERIAL

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