PREPAREDNESS AND RESPONSE CONSIDERATIONS FOR LNG SPILLS

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Introduction

This paper highlights emergency preparedness and response considerations that face communities where new liquefied natural gas (LNG) marine terminals have been proposed, but have not yet been constructed. These considerations influence siting decisions, the ability of a community and port area to minimize safety risks and to feel confident that, in the event of an LNG incident, responders are as well prepared as they can be to deal appropriately with the response.

LNG is an energy source experiencing a growing consumer demand. Overall, the global LNG industry is expected to grow by more than 5% each year (Vopak, 2005). In the US and Western Europe, energy demand will continue to increase for residential, commercial, transportation, and industrial uses, but these increases will be much lower than the projections for energy use in emerging economies. Natural gas use is projected to grow by more than 50% in some places for commercial uses. In Western Europe and Japan, natural gas is expected to continue displacing petroleum products and coal as the preferred heating fuel (EIA, 2005).

Major natural gas production areas of the world include Africa, the Middle East, and South America. When possible, natural gas is moved to consumer areas through pipelines. But when the gas must be transported between continents, it becomes necessary to transport the natural gas as LNG (liquefied natural gas) via large, specially designed tankships (EIA, 2004). Japan is the world's largest LNG importer and imports 100% of its LNG supply, which accounts for one-third of their primary energy needs. In Europe, new import terminals for LNG have been proposed for Milford Haven in the UK, Rotterdam, Netherlands, and near Marseilles, France. New import marine terminals have also been proposed along all three coasts in the US.

Natural gas is shipped in bulk as a cryogenic liquid to reduce the required container volume for transport. Natural gas is reduced in volume by liquefying it at very low temperatures, and at ambient atmospheric pressure. Liquefaction reduces the volume of natural gas by a factor of approximately 600. Tank ships transport LNG in volumes on the order of 125,000 to 140,000 cubic meters of cargo, although vessels carrying up to 250,000 cubic meters are being planned. These specially-designed ships are double-hulled and have highly insulated tanks to help keep the LNG cold. Figure 1 provides examples of the two primary types of LNG vessels. The cargo tanks are not refrigerated and have been likened to giant thermos bottles, with layers of insulation and protection. This simple concept belies the fact that LNG ships are among the most sophisticated in the world. The double hull construction and insulating layers around the tanks keep approximately 9 to 15 feet between the cargo tanks and the sea.


Figure 1. **A.** LNG vessel at berth (membrane-type cargo tanks);
B. LNG vessel underway (Moss-spherical cargo tanks).

Given this projected growth in LNG imports, decision makers for coastal communities are evaluating the potential for construction of new marine terminals and the risks associated with LNG transport through their respective jurisdictions. Recently-proposed import terminals in the UK at Milford Haven, for example, are being subjected to significant scrutiny and concern for the safety of citizens living in adjacent communities. Fears have been expressed over the possible consequence of a shipping accident or leak that could put people at the “risk of death” (BBC News, 2005).

People living in coastal communities have serious concerns about the safety aspects associated with LNG and the prospect of having large volumes of LNG pass by in ships. Since many coastal communities have experienced large marine oil spills in the past, they know from experience that ships have accidents and marine spills can occur. What they need to know more about are the hazards of LNG, specific shipping risks and emergency response issues for LNG, e.g., how to counter the effects of an LNG spill.

Shipping Safety

The LNG shipping industry has a distinguished and outstanding safety record that exceeds any other sector of the shipping industry. International LNG transportation by sea started in 1959 with the conversion of a small cargo ship to a 5000m^3 LNG Carrier. This was the *Methane Pioneer*. This ship carried the first cargoes of LNG between Lake Charles, Louisiana in the United States and Canvey Island in the U.K. In over 40 years of shipping LNG and over 36,000 voyages, there has never been a loss of primary containment (Society of Gas

Tanker & Terminal Operators - SIGTTO, May 2004).

The International Maritime Organization (IMO) has developed many regulations that govern international shipping, including regulations for hazardous substances. Individual countries also have developed regulations to govern the storage, transportation, use, and distribution of energy sources and other substances that can be hazardous under certain conditions. Industry organizations also have a vital role in providing technical information and guidance on how to operate safely. An overview of the significant regulations and guidelines that have been developed to assure safe LNG shipping and terminal operations, and mitigate risks, is presented in Hopkins and Walker (2000). For example, SIGTTO is an international organization based on London that was formed in 1979. SIGTTO's goals are to encourage safe and responsible operation of liquefied gas tankers and marine terminals handling liquefied gases, to develop guidance and advices for best practices among its members, and to promote criteria for best practice for those who have responsibilities for or an interest in gas tankers and terminals (SIGTTO, May 2004). SIGTTO represents approximately 92% of the gas carriers in service. Over the years, SIGTTO has developed an impressive body of reference material and guidelines for its members.

The LNG industry is characterized by a high degree of "self policing" by promoting uniquely high standards and best practices for safe operations among the world's gas carriers and terminals. This is likely due to the realization that "loss of confidence in the industry in one part of the world will undermine confidence elsewhere and threaten the reputation of the industry as a whole (SIGTTO, 2006)."

Properties and Hazards of LNG

Hazards of any substance, that is, how it can be a source of danger, are determined by its properties and how those properties interact – or behave – in ambient conditions. LNG is routinely stored and transported in a liquid form at atmospheric pressure and at a temperature of -162 degrees C (-260 degrees F). Liquefying natural gas vapors reduces the volume that the gas occupies more than 600 times. Natural gas is a colorless, practically odorless petroleum hydrocarbon, comprised of low molecular weight hydrocarbons, mostly methane (approximately 85% to 99%). It also has small amounts of ethane, propane and butane. Like crude oil, the actual composition of the gas varies from place to place with geologic conditions. The properties of LNG and its exact composition are important since this affects the LNG's behavior, as under spill conditions.

LNG will vaporize when released into ambient temperatures on land or water. The boiling point at which LNG converts from a liquid to a gas is about -161 degrees C. When LNG begins to warm, it resembles boiling water (Figure 2). This boiling effect, or vaporization, is caused by the rapid transfer of heat from the surrounding atmosphere, ground, or water, to the LNG. Vaporization rates vary and are discussed in later sections of this paper.

The vapor density of natural gas is .5539 and is temperature dependent. From about -160 degrees C to -107 degrees C, the vapors remain heavier than air, and will hug the ground. When the vapors reach temperatures above - 107 degrees C, the vapors will rise (Texas A&M, 2005) and disperse into the surrounding atmosphere. A vapor cloud may form and its lateral movement will depend upon prevailing atmospheric conditions and type of topography in the immediate vicinity of the spilled LNG.

Figure 2. LNG vaporizing in an empty 1 gallon beaker – table top demonstration (Houston, 2002).

LNG vapors can displace oxygen and act as an asphyxiant in a vapor cloud until the vapors rise and disperse.
LNG also presents a cryogenic hazard for people and other living organisms (plants and animals). Since the temperature of LNG is -160 degrees C, it will freeze any tissues that it contacts.

LNG has a specific gravity of about 0.45 or half that of water, so it will float if spilled on water. It is insoluble in water and non-toxic to both water and land organisms. LNG spilled into water can lower the water temperature in the immediate vicinity and, depending upon how much is spilled and how quickly it vaporizes, it will probably freeze some water which will float as ice on the surface. LNG spilled on land will also freeze any moisture in the ground. However, it leaves no residue once it evaporates so there is no cleanup to perform on the ground or on the water. It is viewed as a clean fuel from an environmental standpoint.

Natural gas is flammable but LNG is not. In its liquid form, LNG will not burn because of the lack of oxygen. In fact, if you drop a lighted cigarette into LNG, it will be extinguished. LNG released on to land or water will vaporize into natural gas. The natural gas will become flammable as it is diluted by the surrounding air. Natural gas vapors are flammable when they comprise 5-15% of the atmosphere. The natural gas used in stoves, ovens and heaters require mixing with the oxygen in the air (at flammable limits) to stay lit when in use. When the air has more than 15% or less than 5% of natural gas (methane), the methane will not ignite.

The principal hazards associated with LNG are the flammable vapors that are formed when LNG is warmed, the intense radiant heat emitted by an LNG fire, and possible radiant feedback when a large LNG vapor cloud is ignited. In comparison to gasoline, LNG fires feel hotter than gasoline fires because methane burns 3-4 times faster and has a higher radiation intensity value. The burn rate for LNG is 12.5mm/minute and the burn rate for gasoline is 4 mm/minute. The heat of combustion of gasoline (126,300 Btu/gal) is higher than LNG (80,445 Btu/gal) but this heat is released more slowly in fire than the heat from LNG fires. Because the LNG fire burns faster, the radiation intensity value from an LNG pool fire (methane) is about 220 kW/m^2 and whereas the radiation values of a gasoline fire at about 140 kW/m^2 (Texas A&M, 2005). For an equal volume of liquid, gasoline fires will yield more total heat (over the complete burn), but this heat when burned will be released more slowly and therefore not feel as hot as an LNG fire.

Spill Behavior

Any discussion of spills needs to be preceded with the acknowledgement of how LNG incidents are being prevented through the rigorous industry operating standards and practices, and the use of sophisticated hazard detection equipment and systems (vapor, heat and cold, flame). All new facilities and new ships will use hazard detection systems to aid in preventing emergencies. Hazard detection systems help assure that should a release occur, appropriate measures can be implemented quickly and effectively to control and mitigate the situation, including preventing the leak or spill from becoming an emergency. Accidental spills of LNG are unlikely to occur but if they do, hazard detection equipment is in place to immediately alert terminal and vessel personnel to the presence of hazardous vapors or fires.

The physical processes associated with LNG spills are the subject of numerous studies and models. Considerable research was conducted in the 1970s and earlier, and the current market and the threat of terrorism have led to additional new studies. Three recent studies provide detailed and relevant information to address the potential for incidents that could cause LNG spills, as well as subsequent consequences of, and response to, LNG spills. They include: the Sandia report (Hightower et al, 2004) prepared under contract to the US Dept. of Energy; the joint industry Det Norske Veritas (DNV) study (Pitblado et al, 2004); and the American Bureau of Shipping (ABS) study (2004) that was commissioned by US Federal Energy Regulatory Commission (FERC). Of particular interest is the Sandia report, which was developed in consultation with the US Coast Guard, LNG industry and ship management, and government intelligence agencies. It comprehensively investigates, using a risk-based analysis approach, the consequences of an accidental breach of the cargo tanks due to a collision and an intentional breach of cargo tanks by a terrorist attack.

The above studies, and others, analyze in detail the technical aspects of LNG behavior, spills, and consequences. This paper draws on elements from these studies to highlight the considerations that responders need to be aware of when considering what might happen if an LNG spill occurs.

Like oil, when LNG is released outside its containment, it immediately begins to form a pool and begin spreading. The pooled, spreading LNG immediately is warmed by ambient temperatures and begins to vaporize. A number of situation variables influence how spilled LNG behaves and how hazardous the resulting situation could become. These variables include:

- How much is released and how quickly (instantaneous, or rate of flow if continuous);
- Where the spill occurs and the ambient conditions affecting how the spilled liquid pools, spreads out and vaporizes, and
- How the hazardous situation develops, e.g., location of vapors in relation to nearby populations and presence of an ignition source when flammable limits are reached.

The rate of LNG vaporization occurs varies with the situation. LNG vaporizes more quickly if it is spilled on water than it does if spilled on land. When spilled on land, initial vaporization rates are about 10 cubic feet per minute/ square foot of spilled LNG (thin pool). When spilled on water, vaporization occurs about 5 times more rapidly, or at 50 cubic feet per minute of square foot of spilled LNG. After the initial vaporization rate, and as the LNG warms, the rate of vaporization reduces to a steady state of approximately 1 cubic foot per minute for each square foot of pooled LNG. At steady state with a calm wind, a 1 ft. deep pool would evaporate in about 10 hours (Texas A&M, 2005).

The expansion ratio of liquid to vapor means that 1 square foot of liquid will vaporize to 620 cubic feet of gas. The rate at which this expansion occurs depends upon several factors:

- The proportion of the methane in relation to the other components in LNG,
- Where a spill occurs (on land or on water, in confined spaces or open air), and
- Ambient weather conditions.

Under some conditions, the rate of vaporization can happen almost spontaneously resulting in a rapid phase transition (RPT) as the cold LNG is vaporized from the heat of the underlying surface. This can cause a small but serious local overpressure release. Energy releases equivalent to several kilograms of high explosive have been observed. The impacts are localized in the immediate area of the vaporizing liquid (Texas A&M, 2005).

During vaporization, any moisture in the air will freeze, causing fog, and the vapors that form will mix with the fog. For this reason, a white cloud of fog is generally associated with spilled LNG, but it is the water in the vapor that is actually visible. The visible vapor cloud is a good indicator of where flammable vapors can be. The gas cloud is flammable when natural gas vapors are present in the ratio of 5-15% to the air. Any air movement will cause some patchiness of flammable limits within the cloud.

Initially, the vapors are likely to hug the ground or water surface. As the vapors warm, they will rise and gradually dissipate below the flammable limits. The vapors formed by spilled LNG have different buoyancies at different temperatures. When they have warmed to about -107 degrees C, the vapors will become positively buoyant and the vapors will rise. Clearly the temperature inside an LNG vapor cloud will be very cold. Once the vapors rise, they continue to dilute to be outside their flammable limits, move farther (higher) away from most ignition sources, and ultimately be further removed from direct contact with people.

Misperceptions about LNG's ability to explode or detonate are common. LNG properties have been widely investigated in this regard. At the risk of overly simplifying complex technical concepts, principles, and variables, LNG is not characterized by experts as a material that explodes or detonates. Under rare conditions, vapor cloud explosions (VCE) are possible, yet considered by experts as not probable. Nor does LNG create the fireballs that are associated with BLEVEs (boiling liquid expanding vapor explosion) when it ignites, in part because the LNG tanks are not pressurized (Texas A&M).

If an ignition source is present when an LNG vapor cloud has formed and concentrations in the cloud are within flammable limits, the ignited cloud will burn back quickly, or "flash back", across the part of the cloud that is within the flammable range to the source. Some cases have been reported that flash backs have self-extinguished when the cloud was full of condensed moisture and could not sustain ignition. A vapor cloud from LNG that ignites in an unconfined area will cause a flash fire that moves at a relatively slow speed of about 1.2 feet/second in unconfined areas (Richardson, 2006). To generate overpressure conditions, the flame front would have to move on the order of 200 m/s (Texas A&M). Overpressures are more likely to occur when vapors are in confined areas, e.g., under structures or in areas where air flow is inhibited by piping.

Response Considerations for LNG Spills

Coastal communities are interested in worst case scenarios and what could happen if terrorists attacked an LNG vessel. A Google search reveals numerous media articles and websites that document the public fear of LNG vessel incidents associated with new import terminals. LNG studies conducted since 9/11 have assessed from the consequences of spills from LNG vessel incidents.

These studies definitively characterize the worst case scenario (high consequence yet low probability) as being a terrorist attack. Scientists, engineers and other technical experts have examined the construction, systems, and procedures of LNG vessels and concluded that the worst case scenarios, of highest consequence, could not occur in normal or accidental situations (Hightower et al, 2004).

Preparing for response to worst case scenarios is addressed in a later section. The following discussion of what can be done to respond to accidental LNG spills is generalized because formulating an appropriate response is dependent upon the incident situation and site-specific conditions. As all responders know, the best way to respond to a spill is to have prepared as much as possible in advance because time is the enemy during an emergency. Operating in a response mode means working “in compressed time” (faster than normal and under pressure) and effectively to control the incident by intervening in the situation to make it better than if no action was taken, and to avoid taking actions that could make the situation worse. Basic response rules of thumb include: detect a leak or spill as soon as possible, secure the source, and prevent it from worsening.

Generally, if LNG spills, it is important to secure the leak and the area, shelter people a safe distance away from the leak and/or spill, prevent ignition sources, and monitor the vapors until no vapors remain in the flammable limits and all the LNG has evaporated. As noted earlier, a spill of LNG creates no residue to cleanup, on land or water. Cryogenic hazards can be limited by restricting access and preventing direct contact with LNG. Fire fighter turnout gear does not prevent frostbite from exposure to the cryogenic temperatures of LNG. For example, rubber boots become brittle and break apart after a very short immersion in LNG. The shattered boots would provide a route of exposure to the cryogenic liquid. Asphyxiation can be prevented by assuring that responders remain outside confined areas, upwind of vapor clouds, and have appropriate personal protective equipment (PPE).

In 2004, the National Emergency Response and Rescue Training Center at Texas A&M University began offering a new LNG Live Fire Training Workshop that provides fire fighters and others involved in LNG emergency preparedness an opportunity to learn in detail about LNG, detection methods, how LNG fires behave, and fire suppression and control strategies. Texas A&M has offered fire fighting training programs since the late 1970s. The fire “props” on the field provide settings for LNG fire fighting in both terminal and ship scenarios. This 3-day, hands-on training program was developed with support of BP’s Global LNG and Group Technology and fire fighting technology manufacturers. Since LNG spills and fires are so rare, the course is especially valuable because students can learn hands-on and fight actual LNG fires, for both liquid spilled on land and on water (in specially constructed pits). The materials from this course are the principal references for the following response information on LNG spills and fires. Another key reference for LNG fire hazards and management is the recent publication, "Liquefied Gas Fire Management" (SIGTTO, 2004).

LNG Spills

Vapors behave differently in confined and open areas. Confined areas include places with piping or other structures that limit air circulation and restrict movement of liquids and vapors. Vapor detection equipment (some have remote monitoring screens, e.g., in a control room) can be used to monitor flammable vapors.

Foam and water spray curtains help control the vapors in a proactive manner. The use of foam on land spills of LNG, or on-water areas that are contained, e.g., storm drain or small pond) is an effective hazard control technique. On spills, applying and sustaining a "blanket cover" of high expansion foam can minimize ignition risk, control vaporization rates, and control vapor dispersion, when such action is appropriate for the specific situation. The use of water curtain sprays to form curtains between LNG vapors and potential ignition sources can be helpful in managing the vapors from a liquid spill.

Water curtains can be effective in controlling the height and width of small spills, divert and dilute vapors, and serve as barriers to vapor clouds, especially in open areas (Figure 3).

Figure 3. Water spray curtain and LNG vapors. Texas A&M Live Fire Training Workshop (2005).

As noted earlier, when LNG begins to vaporize, the cold temperatures condense water in the air, even in very dry climates, and the resulting vapor cloud will be visible. The cloud will tend to be long, thin and cigar-shaped and it can travel some distance before concentrations fall into and below the flammable limits. Field experiments have shown that there can be flammable vapors just at the perimeter of the visible vapor cloud, especially under calm conditions. Winds increase warming and mixing and cause the vapors to rise and disperse more quickly. At neutral buoyancy, the temperature in the vapor cloud is about -107 degrees C (-160 degrees F). In some situations, it can be safe and desirable to accelerate warming by using water spray to warm the LNG pool faster, which will make it buoyant faster, and reduce the flammability hazard.

LNG Fires

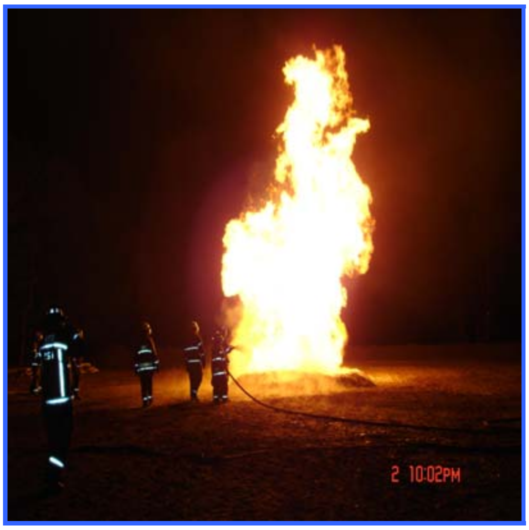

Figure 4. LNG pit fire, night burn, 2005.

If an ignition source is present when the vapors are within the flammable limits, the vapor will burn. When methane burns, it burns with very little smoke, not the billowing black smoke associated with oil fires. The ignition of an unconfined vapor could not produce a pressure wave. Upon ignition of an LNG vapor cloud, the fire burns back to the source in an unconfined area at about 1.2 feet/second (Richardson, 2006). This is considered a slow moving flame speed. But an LNG fire will burn very quickly and therefore release heat quickly, at about 12.5 mm/minute in a steady state (when it is spilled on land). Depending upon the pool size, shape of the pool, wind speed, and exact composition of the LNG, the height of flames from an LNG pool fire will be approximately 2-3 times the width of its base (Figure 4). The fire will feel quite hot and the radiant heat from an LNG fire is its distinguishing hazard. An equal volume of gasoline will produce more total heat but will burn with less intense thermal radiation and a smaller flame height than LNG.

The most effective method of extinguishing an LNG fire is "starvation" by closing off or restricting the source of the fuel through the use of dry extinguishers or foam blankets. Where it is not possible to close off the source of LNG, careful consideration should be given to the implications of extinguishing an LNG fire, particularly in regard to the vapor cloud that will develop when the fire is extinguished if all the vapors have not burned.

Dry chemicals and foam are good methods to control LNG fires and reduce hazards. Using dry chemicals is most effective on smaller fires to break the chemical chain reaction in the LNG fire. A good application technique can make the difference in whether or not a pool fire can be extinguished. Of the various types of dry chemical, Potassium Bicarbonate (Purple K) is regarded as the most effective on LNG fires. Dry chemical extinguishers range in size from the 20 pound hand-held units up to 350 lb. wheeled units.

Medium expansion foam (20:1 up to 200:1) and high expansion foam (200:1 up to 1000:1) can be very effective methods in managing LNG fires (Figure 5). The effective ratio for high expansion foam on LNG fires should be at least 500:1 (Angus Fire, 2005)

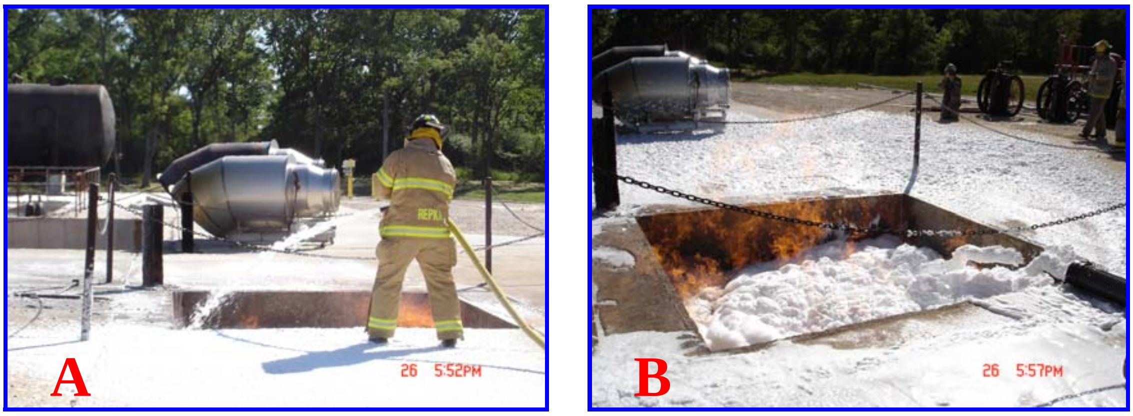

Figure 5. **A.** Medium expansion foam added to LNG fire in pit at Texas A&M Live Fire Fighting Workshop (2005).
B. Foam blanket on LNG fire in pit (2005).

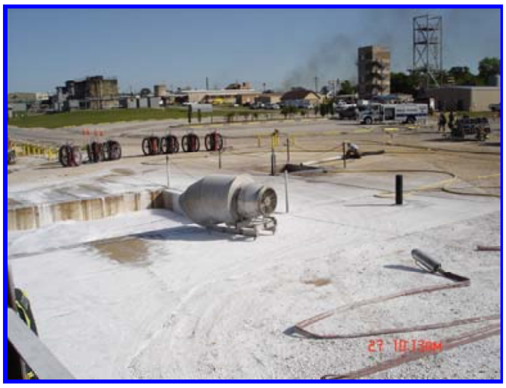

Figure 6. Turbex high expansion foam generator at Texas A&M (manufactured by Angus Fire Company).

High expansion foam performs best since it has the lowest proportion of water and the highest expansion rate. The application of high expansion foam on an LNG fire allows a controlled burn off. The foam blanket would need to be maintained until the fire ceases burning and no vapors are detected in the flammable range. By insulating the flames, the foam reduces radiation hazards, both radiant heat and radiation feedback. Foam also decreases the intensity of the fire by blanketing the LNG surface and reducing the rate of vaporization. Gaz de France experience has shown that the use of high expansion foam on LNG fires can reduce the flame height by as much as 60% and that radiant heat can be reduced by approximately 90% (Texas A&M, 2005). Fixed systems, like the one in Figure 6, can generate up to 114 cubic meters a minute of high expansion foam.

Perhaps the most important point to convey about water and LNG fires is that, contrary to intuition, applying water to an LNG fire will not extinguish it. Rather, water will cause the liquid to vaporize more quickly and, since the fire provides an ignition source, the fire will be larger than if no water was involved. Adding water to an LNG fire will make it burn faster and hotter.

Water spray, however, is used to mitigate fire hazards by blocking movement of the vapor cloud and cooling the area in the vicinity of the fire, thereby protecting property and equipment. In some fire situations, e.g., pipe leaks, water sprays can move flames away from valves and cool them so that responders can turn off the valve, secure the source, and thereby extinguish the fire.

When the LNG vessels begin their transits up bays and rivers, they generally are accompanied by special “tractor” tugs that are among the most powerful in the industry. Their primary mission is assisting the movement of the LNG vessels in port areas. A secondary mission is fire fighting assistance. These tugs can deliver high volumes of water spray. Some of the recently-delivered tugs have multiple fire-fighting water pumps with a total capacity each of 5800 gpm (including 500 gpm for a deluge system), and have a range of 400 feet.

LNG vessels are equipped with a broad range of fire detection systems and control equipment, including quick closing valves and dampers, fire fighting mains and pumps, dry chemical and fixed CO2 systems, and water mist systems. These systems are located throughout the ship, including crew spaces, on deck, in engine rooms and other spaces, in addition to cargo spaces. LNG crews have special training in shipboard fire management and control (SIGTTO, 2004).

Emergency Preparedness Considerations

Coastal communities in which LNG import terminals are proposed are understandably fearful about the potential for incidents involving ships carrying large quantities of LNG that can become a flammable gas cloud. The term fireball is not uncommon in the media. Fireballs are considered, by technical investigators, as highly improbable consequences of large LNG spills, and not possible in unconfined areas (as on a river). However, the hazard of radiant heat from an LNG fire is the probable consequence of an ignited LNG vapor cloud and a serious concern. It is important to recognize the valid point that accidents can happen. Whenever a spill occurs, and especially oil spills which have impacted many miles of coastal communities, voices of public skepticism rise over industry’s messages that they can operate safely and spill impacts can be controlled. A vital and prerequisite preparedness activity for new marine import terminals is planning for the possibility having to respond to an LNG emergency.

A central preparedness issue is assessing whether or not the risk associated with allowing marine terminals, and the ships that carry the LNG to the terminals, is acceptable. Risk is defined as the potential for suffering harm or loss. Assessing risks can be performed quantitatively by estimating the probability of occurrence of the threatening event times the system vulnerability to that event and the consequences of that event (Hightower et al, 2004). Risk assessment is a process by which quantitative information is developed for consideration in the LNG decision making process.

In the US, preparedness activities are initiated for proposed LNG marine terminals and their transits long before they begin operation. Multiple agencies and standards organizations oversee the siting, construction and operation of LNG exploration, shipping, terminals, and pipelines. They are summarized in Foss (2003). Two agencies in particular affect the siting of LNG marine import terminals. The US Federal Energy Regulatory Commission (FERC) has the authority to approve the location of new LNG import terminals and the US Coast Guard under law provides a recommendation to FERC regarding the suitability of the waterway and port to accommodate a new LNG facility and shipping traffic. Siting of these facilities in the US will not be approved by government entities without the development of emergency response plans and working with stakeholders who could be affected by spills from the proposed terminal and ships during the transit.

The Coast Guard's Letter of Recommendation (LOR) traditionally emphasized navigation and safety. However, since 9/11, new guidance has been issued that specifically addresses potential security risks of having LNG ships and terminals within the port area. Any new marine terminals proposed in the US are subject to the Cost Guard's Navigation and Vessel Inspection Circular (NVIC) No. 05-05: Guidance on Assessing the Suitability of a Waterway for LNG Traffic. The Sandia report (Hightower et al, 2004) provides the foundation for the Coast Guard's position on LNG safety and security and the basis for evaluating risks associated with LNG marine spills. The Sandia report discusses in detail various accidental or intentional spill scenarios and resulting consequences. Worst case scenarios and their consequences are methodically analyzed, based on a review of many technical studies in the 165-page report. Some portions of the analysis dealing with security scenarios are omitted from the published report because they contain sensitive security information (SSI).

<u>Assessing the Suitability of an Area for an LNG Terminal</u>

The NVIC outlines a process for assessing the potential risks associated with allowing a new terminal and shipping to be added to a port area. This approach requires continuing and substantive engagement by all stakeholders, including the company proposing the terminal, political representatives, as well as shipping, safety, law enforcement and responders from all levels of government in the port area. Conducting a waterway suitability assessment (WSA) for LNG marine traffic is the core of the Coast Guard's risk-based approach. Topics to be addressed in a WSA include:

- ***Port characterization:*** Port stakeholders describe the port environment as it is currently and what would change with the addition of the LNG facility and transit.
- ***Characterization of the LNG facility and tanker route (transit):*** This characterization includes describing in detail the proposed facility, tankers, and frequency of deliveries, identifying "zones of concern" (based on the Sandia report), identifying areas along the transit of high and medium population density, and identifying critical infrastructure and key assets, such as power plants.
- ***Risk assessment for safety and security:*** Given the preceding characterizations, this part of the WSA analyzes risks that arise from introducing LNG operations into the port. The WSA requires assessing both accidental and intentional releases. The security risk assessment

includes a threat assessment, vulnerability assessment, and consequence analysis.

- ***Risk management strategies:*** During this part of the process, participants identify ways in which identified risks of attack or accident can be prevented or mitigated, such as by improved traffic management, patrolling the waterfront or escorting the vessels.
- ***Resource needs for safety, security and response***: This part addresses specifically how risk management strategies can be implemented, that is, who will provide what resources and what funding will ensure their timely implementation.

For the newly proposed facilities in the US, the Coast Guard is implementing the WSA process. This process provides a logical and methodical way to reason through risks, which incorporates the Sandia report's technical conclusions of potential hazards and consequences with the knowledge and experience of relevant stakeholders from the port community in the decision making process. The Sandia report integrates the technical analyses of LNG properties, worst case scenarios (which would result from an intentional spill attack on an LNG vessel), spill behavior, and radiant fire hazards into safety guidelines that communities can use to achieve a credible level of preparedness for possible LNG spill emergencies. These safety guidelines for managing risks are communicated in the form of "zones of concern" (Hightower et al, 2004).

Planning Distances for Worst Case Scenarios

The zones of concern are areas of potential impact from radiant heat that could result if an attack on an LNG vessel were successful (US Coast Guard, 2005).

Zone 1: This is the area with the most severe consequences around an LNG tanker, where an LNG spill could pose a severe public safety and property hazard and could damage or significantly disrupt critical infrastructure and key assets located within this area. Zone 1 is considered to extend about 500 m (approximately.3 miles) for an intentional breach of an LNG tanker.

Zone 2: This is an area with less severe consequences than Zone 1 and is considered to extend from 500 m to 1,600 m (about 1 mile) for an intentional breach of an LNG tanker.

Zone 3: This is an area with the least likelihood of severe consequences and is considered to be from 1,600 m to a conservative maximum of 3,500 m (2.2miles).

Figure 7 shows a graphic way to use these three zones in identifying the geographical areas that could be at risk from an intentional attack on an LNG tanker while in transit to a proposed facility. Applying these zones to an aerial photo helps to understand what nearby populations, key assets, and critical infrastructure could be potentially at risk. The same zones around the terminal would appear as concentric circles, rather than parallel lines.

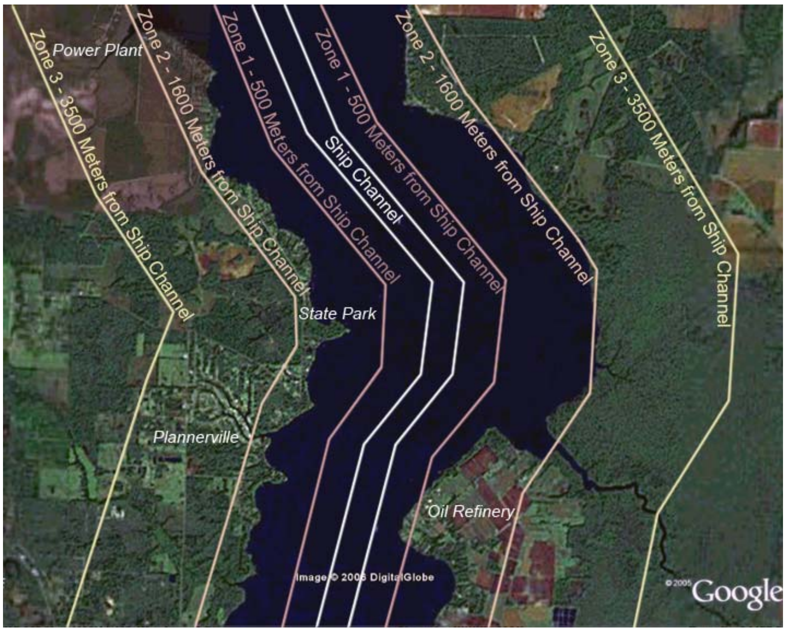

Figure 7. Zones of concern for intentional LNG spills portrayed for a **hypothetical location**.

FERC, and the Coast Guard, believe that early involvement by agency and citizen stakeholders helps achieve consensus and settlements among the groups and the company about an acceptable project design (FERC, 2001). In one WSA, which is still currently in progress, stakeholders were included from the following entities: local fire departments, fire marshals, and law enforcement agencies; county emergency managers; pilots association and shipping agents; responder organizations; state and federal counterterrorism and law enforcement agencies. The participation of other non-governmental organizations (NGOs) in the WSA process is a possibility if they are willing to sign and adhere to non-disclosure agreements since sensitive security information is discussed during the WSA. However, in some cases, they have been unwilling to agree to restrictions which prohibit their distributing sensitive and proprietary information. In the US, outreach to and dialogue with NGOs and individual citizens on proposed projects can also occur through citizen advisory panels (CAPs) and through attending or giving presentations on the proposed project at meetings for other organizations in a community. Other outreach methods are websites to share information on the proposed project with the public. These websites convey information as well as provide ways to direct questions to the company and obtain answers through the “contact us” page.

The result of the WSA is a reasoned assessment and a letter of recommendation from the Coast Guard Captain of the Port in whose area of responsibility an LNG project is proposed to FERC. This letter will convey the result of the Coast Guard’s assessment as to whether the waterway is suitable for LNG traffic; that it is not suitable; or that to make the waterway suitable additional measures will be necessary to responsibly manage the safety and security risks (identified by the WSA). Such additional measures can include security patrols, for example (Figure 8).

The final deliverable of the WSA is an LNG transit management plan for assuring that LNG vessel operations during transit and at the terminal are conducted safely and security risks have been anticipated and actions taken to mitigate the identified risks. This plan reflects a unified approach by appropriate federal, state, and local authorities to deploy the resources needed to assure safe and secure transit and vessel operations within the port area.

Figure 8. US Coast Guard patrol boat by LNG at a terminal.

By the time a proposed project is approved in the US, preparedness activities to plan for possible incidents are quite advanced. A transit management plan will be developed, maintained, and implemented by the Coast Guard and other government stakeholders for normal transit operations. It will refer to and link with terminal, vessel and transit emergency response plans that will be developed by the company. The company’s emergency response plan(s) will spell out company and government response roles and actions, notifications and communications, response procedures and equipment for various potential scenarios in the zones of concern.

Summary

How emergency preparedness and response issues are addressed is determined in large part by the regulatory environment of the area where a potential LNG terminal is proposed. The governmental and industry entities, which are responsible for making decisions about the siting of energy facilities, ultimately determine the scope and quality of emergency preparedness. Their decisions consider tradeoffs, such as balancing the national need for energy with determining best how to manage risks associated with proposed projects, and assure that decisions are made in the overall interest of the public. Risk-based decision making, along with early, informed stakeholder education and involvement, enables the risks associated with new LNG import terminals and shipping to be managed and incorporated into the mix of other uses in ports and on waterways (Figure 9).

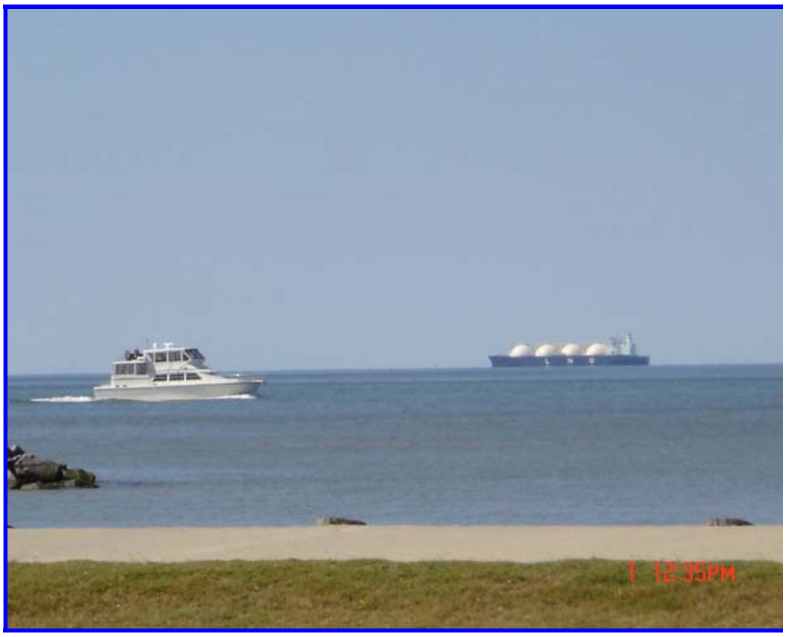

Figure 9. LNG vessel in transit by coastal community located on the Chesapeake Bay, USA.

Given the properties and behavior of LNG, as analyzed by experts, the most serious hazards from LNG spills are flammable vapors, fires if the vapors are ignited, and the radiant heat from large pool fires. Fire detection and fire management systems (trained personnel, equipment, techniques and procedures) already exist at terminals and on the LNG vessels, which can help respond effectively to LNG spills, by controlling vapors, and preventing, detecting and managing fires.

Based on recent studies, the worst case spills of LNG would result from terrorist attacks on vessels carrying LNG cargoes, not accidental spills. A new risk assessment process is being implemented in the US, which involves stakeholders in the port area, and takes into account potential terrorist spill scenarios. One important result of the process is a determination by the Coast Guard as to whether or not the port community believes that the operation of a new LNG marine import terminal, including the transit of LNG vessels, can be managed safely and securely, and what additional measures must be implemented by the company, law enforcement, and other government entities to assure safe and secure operations. Early and continuing education and involvement by first responders and other stakeholders helps assure that the community has an accurate understanding of the potential risks associated with the project. Sustaining involvement through government representatives from law enforcement and fire departments among others, promotes confidence in decisions and actions regarding LNG emergency preparedness and response.

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