

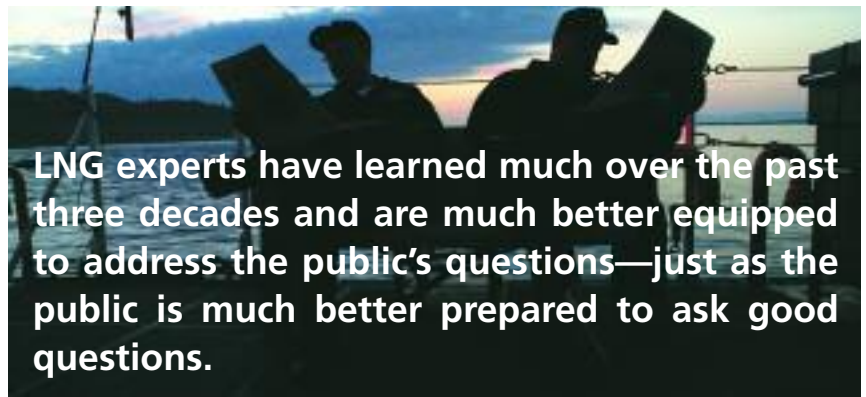
# LNG and Public Safety Issues

*Summarizing current knowledge about potential worst-case consequences of LNG spills onto water.*



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In 1976 Coast Guard Admirals were being called to Capitol Hill to answer the question: If 25,000 m<sup>3</sup> of liquefied natural gas (LNG) were spilled on water without ignition, how far might a flammable cloud travel before it would not pose a hazard? As technical advisor to the Office of Merchant Marine Safety in the Coast Guard's Bulk Hazardous Cargo Division, I was assigned to provide an answer on the LNG vapor cloud issue within a couple of weeks. Although no longer with the Coast Guard, I am still working on the problem 30 years later.



## Past Lessons

The tragic events of September 11, 2001, changed everything. Watching the World Trade Towers fall sharply focused my research of LNG spills on water. It is understood now that the towers fell because the insulation was knocked off the steel, which could then not withstand the extreme fire exposure. The lesson from this is to understand the consequences of such events, not only in planning for decisions that are within our control, but in planning for events over which we may have little or no control.

LNG experts have learned much over the past three decades and are much better equipped to address the public's questions—just as the public is much better prepared to ask good questions. For space constraints this discussion sidesteps many important issues in

the LNG debate; however, it summarizes what is currently known about potential worst-case consequences for public safety of LNG spills onto water.

The description of current LNG knowledge is aided by reference to reports prepared in 2004 by the ABS Shipping Group for the Federal Energy Regulatory Commission<sup>1</sup> and by the Sandia National Laboratory for the Department of Energy.<sup>2</sup> These two reports, which appear to be largely accepted by all of the regulatory agencies involved, emphasize for their analyses one scenario of the consequences of LNG marine spills—spillage onto water of 12,500 m<sup>3</sup> of LNG, which is representative of approximately one half of a single tank on a typical LNG ship. While the Sandia report does provide some consideration of multiple-tank spills, it suggests that such occurrences would not involve more than three tanks at one time. The

choice of spillage of only half a tank appears to be the result of the report's consideration of the extreme implausibility of the rapid spillage of the entire tank as an initial result of a terrorist attack. However, limiting discussion to the initial results of a terrorist attack is not necessarily sufficient.

### LNG Vapor Cloud Dispersion

My year-long look at the LNG vapor dispersion issue for the Coast Guard produced a report<sup>3</sup> in 1978 that reviewed several predictions by leading authorities of the vapor cloud extent, following spillage of 25,000 m<sup>3</sup> LNG onto water. Those estimates ranged from 0.75 mile to a little over 50 miles. The range was narrowed by showing the errors in reasoning underlying the lowest and highest estimates, but the uncertainty range could not be tightened closer than three to 10 miles.

The estimates, which range between approximately two and three miles, presented in the Sandia and ABS Group reports are endorsable. Note, though, that these estimates are for the spillage of 12,500 m<sup>3</sup> of LNG, half the amount considered in the Coast Guard report produced in 1978. Nonetheless, the estimate of two to three miles of flammable vapor cloud travel that could result from an unignited spill of LNG from a single containment is at once reasonable and sufficient for regulatory planning purposes. Indeed, given the uncertainties involved, the point of diminishing returns has been reached on this scenario for vapor dispersion from a 12,500 m<sup>3</sup> LNG spill on water.

### Thermal Radiation from LNG Pool Fires

For thermal radiation from pool fires, the findings of the ABS Group and Sandia reports are also endorsable. Both reports appear to provide estimates of approximately one mile as the distance from a pool fire on a 12,500 m<sup>3</sup> spill on water to which unprotected persons could receive second-degree burns in 30 seconds (based on a thermal flux criterion of 5 KW/m<sup>2</sup>). Although this estimate is reasonably representative of the best available estimates of the distance to which the public could be exposed (to

this damage criterion), the endorsement is qualified as follows.

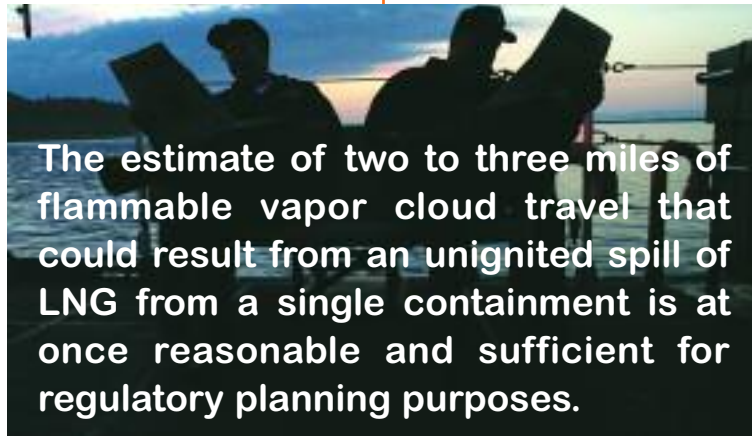
First, the use of a thermal flux criterion that would result in second-degree burns in 30 seconds is not necessarily appropriate to ensure public safety, as such exposure essentially ensures that serious burns will occur at that distance to persons who cannot gain shelter within 30 seconds. Aside from questions about the ability of even the most able to gain shelter in such a short time, questions are also raised about the safety of those less able. Lower thermal flux criteria (~1.5 KW/m<sup>2</sup>) are prescribed in other national and international regulations

designed to provide safe separation distances for the public from fires. Since such lower thermal flux level criteria could increase the distances prescribed in the ABS Group and Sandia reports by as much as one and a half to two times, this end point criteria for ensuring public safety from

LNG fires should be reconsidered, especially if the goal is to provide for public safety.

Second, the mathematical modeling methods in the reports that predict the various levels of thermal radiation intensity from a massive LNG pool fire are not on as firm scientific ground as are the methods for predicting vapor cloud dispersion. The vapor cloud question has been more extensively studied to provide data for the models' verification. The physical basis for extrapolation from small-scale experimental data is better understood for vapor dispersion than are the methods in present predictions of thermal radiation extent from pool fires. Sandia and others are considering the need for further large-scale LNG fire testing. Such tests should be conducted with appropriate scientific planning and for the purpose of obtaining experimental data that could be used to verify mathematical modeling methods; this additional testing is advised to provide a better understanding of large LNG fires on water.

However, the Sandia report states that cascading events, resulting either from brittle fracture of structural steel on the ship or failure of the insulation that



results in LNG vaporization at rates exceeding the capability of the relief valves, cannot be ruled out. Foamed plastic insulation, widely used on LNG carriers, would be highly susceptible to failure by melting or decomposition. It is a cardinal safety rule that the pressure limits on tanks carrying flammable or reactive materials should not be exceeded, as such excess portends catastrophic rupture of the containment. While the Sandia report concludes that such cascading events would be very unlikely to involve more than three of the five tanks on a typical LNG carrier, the report's optimism in this regard is unexplained. Once cascading failures begin, what would stop the process from resulting in the total loss of all LNG aboard the carrier? More research is indicated, but such efforts should not delay immediate attention to ascertain or disprove this potential vulnerability.

### Other Hazards

Other hazards associated with spilling LNG onto water include oxygen deprivation, cold-burns, rapid phase transitions, and explosions in confined spaces, as well as the potential for unconfined vapor cloud explosions (UVCEs) if the LNG contains significant heavies. As the hazards of oxygen deprivation and cryogenic burns are not expected to affect the public, they will not be considered further here.

Explosions in confined spaces, either combustion events or events of rapid phase transition, may have the potential for causing secondary damage that could lead to further spillage of LNG. Unconfined vapor cloud explosions cannot be dismissed if the cargo contains significant amounts—perhaps greater than 12 to 18 percent, based on Coast Guard-sponsored tests at China Lake in the 1980s—of gas components heavier than methane. Enrichment in higher boiling point components of LNG remaining on the water can lead to vapor cloud concentrations that pose a UVCE hazard, even if the concentration of liquid initially spilled does not. LNG contact with ship structural steel, rapid phase transitions, and gas explosions in confined spaces on the ship are not expected to pose hazards to the public, except as they may relate to the ship's vulnerability to further damage following the cryogenic cargo spillage onto ship structures, with or without ignition.

### Vulnerability Issues

Coast Guard Navigation and Vessel Inspection Circular No. 05-05, "Guidance on Assessing the Suitability of a Waterway for Liquefied Natural Gas (LNG) Marine Traffic," incorporates requirements for

a vulnerability assessment that identifies the exposures that might be exploited to ensure the success of an attempted terrorist attack.<sup>4</sup> Two types of vulnerabilities are considered: system and asset. System vulnerabilities consider the ability of the terrorist to successfully launch an attack; asset vulnerabilities consider the physical properties of the target that may influence the likelihood of success of a terrorist attack.

### Worst Case?

The hazards of brittle fracture, rapid phase transitions, and explosions in confined ship spaces, as well as cascading events that may result from the extreme fire exposure a ship would experience if a nominal 12,500 m<sup>3</sup> spill on water around the ship was ignited, will require careful consideration. The definition of the worst case event that could be realized as a result of a terrorist attack is likely to hinge on the assessment of the asset vulnerabilities that is required to be considered in NVIC 05-05. This is largely where our unfinished work remains.

### References

- <sup>1</sup> ABS Consulting, "Consequence Assessment Methods for Incidents Involving Releases from LNG Carriers," FERC contract FERC04C40196, May 2004.
- <sup>2</sup> Hightower, M., et al., "Guidance on Risk Analysis and Safety Implications of a Large LNG Spill Over Water," Sandia Report SAND2004-6258, December 2004.
- <sup>3</sup> Havens, J. A., "Predictability of LNG Vapor Dispersion from Catastrophic Spills onto Water," Report CG-M-09-77, Office of Merchant Marine Safety, USCG HQ, 1978.
- <sup>4</sup> Navigation and Vessel Inspection Circular No. 05-05, "Guidance on Assessing the Suitability of a Waterway for Liquefied Natural Gas (LNG) Marine Traffic," Commandant, United States Coast Guard, June 2005.

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