CRITICAL LNG HAZARD SOLUTION

Ravi Kiran Dasari

Process Engineering Manager, Audubon Engineering Companies, Texas, USA

---***---

Abstract

In this study, the main objective is to analyze different hazards and potential hazardous areas and investigate mitigation methods using computational fluid dynamics. The analysis focuses on the use of thermal radiant heat flux and temperature to evaluate the effectiveness of materials on both the LNG bunker and the cargo vessel. Additionally, the study considers the use of water curtains to prevent material stress cracking in case of LNG leakage as a potential mitigation method for the radiation hazard. The analysis is expected to provide insights into effective strategies for mitigating hazards associated with LNG storage and transportation.

Keywords: Boil-off LNG vapor, Dispersion cloud, RPT (rapid phase transformation), bunkering, cryogenic

1. INTRODUCTION

Natural gas is usually liquefied through a process called liquefaction, which involves cooling the gas to a very low temperature, around minus 260°F (minus 162°C), at ambient pressure through cold box or different refrigeration technologies. This process converts the natural gas into LNG (Liquefied Natural Gas), which is then stored in specially insulated and refrigerated tanks for transportation. One of the benefits of using LNG is its high energy density, which makes it a very economical fuel for transportation and storage. LNG takes up to 1/600th of the volume of natural gas in its vapor state, making it much more efficient to transport and store. To use LNG for pipeline or as fuel gas, it is necessary to convert it back to its gaseous state through a process called regasification, which involves heating the LNG to turn it back into natural gas. Once regasified, the natural gas can be used for a wide range of commercial, industrial, and household purposes.

2. ENVIRONMENTAL RISKS OF LNG

It is crucial to consider the potential environmental risks and adhere to the necessary regulations regarding the location of LNG tanks and pipelines. The primary concern is the risk of fire resulting from LNG vaporization and contact with an ignition source. However, the possibility of a large LNG release is highly unlikely, as the vapor cloud typically cannot extend beyond 30 miles. Additionally, LNG has an excellent safety record.

There are atmospheric emissions associated with LNG, such as CO2, SOX, and NOX, which come from combustion during power generation, in-plant heat, and LNG tanker propulsion units. Emissions can also come from LNG production and re-gasification plants and natural gas handling. It is critical to consider CO2 limitations in the feed and explore carbon capture technology. Small-scale LNG feed typically contains 2% CO2, and minimal emission limitations must be followed to avoid environmental issues with greenhouse gas emissions.

Another risk to consider is liquid effluents from transportation, mainly offshore LNG plants, where discharge into the sea with proper treatment is necessary. It is important to take marine life and the environment into consideration and follow necessary limitations. Sanitary waste is also a significant concern in every industry, and site-specific land expansion or dredging wastes must be taken into account, and necessary limitations must be followed. [10] [11]

3. LNG HAZARD POOL FIRE DISCUSSION

The boil-off LNG vapor, which can occur during ship-to-ship bunkering or any other handling of liquefied natural gas, is a significant hazard due to its cryogenic temperature and the fact that it initially behaves as a denser-than-air vapor. This means that if it is released, it can quickly spread and displace oxygen in the immediate area, creating a hazardous environment for workers and potentially leading to asphyxiation. As the vapor cloud is heated up by the surrounding environment, it will eventually disperse, but there is a risk of ignition and explosion if there is a source of ignition present. In addition, LNG pool fires can occur if the source ignites immediately or a flash fire burns back to the source, potentially causing thermal radiation damage to the surrounding area[1] [2] [3]. Rapid Phase Transition (RPT) is a phenomenon that occurs when LNG is released from its container into the atmosphere and undergoes a rapid phase change from a liquid to a gas state. This phase change results in a significant volume expansion, which can create high pressure and cause damage to the surrounding area. RPT can occur due to a number of factors, including inadequate insulation, equipment failure, or human error. To prevent RPT, it is important to ensure proper design and operation of LNG storage and handling facilities, as well as regular maintenance and inspection of equipment. Additionally, emergency response plans should be in place to quickly address any incidents that may occur [7].

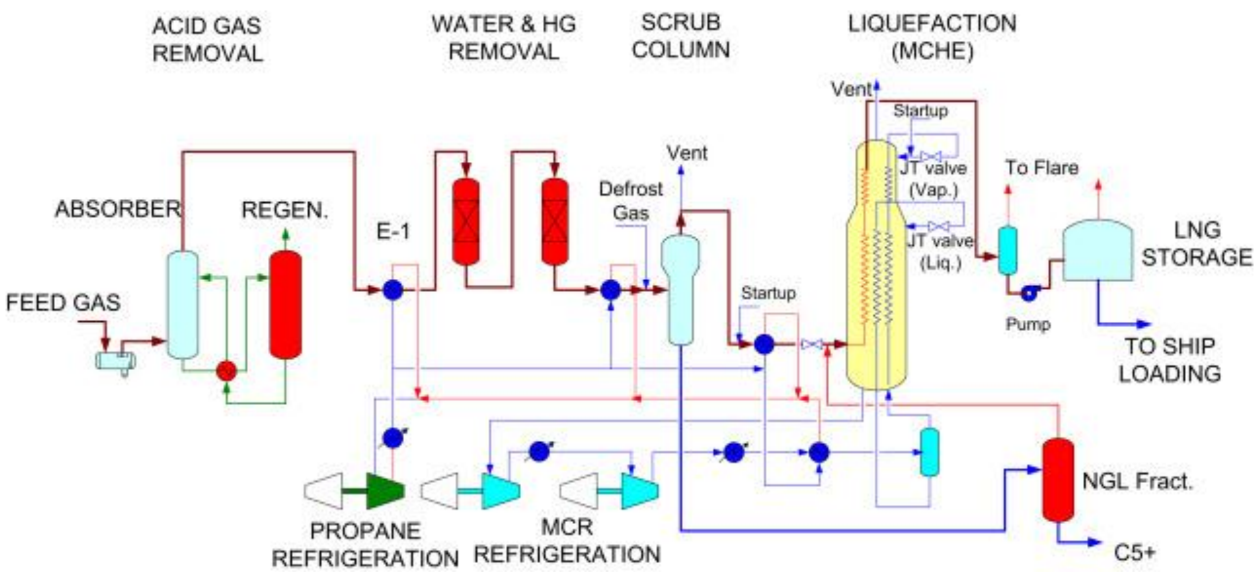

Fig 1: LNG Process schematic Diagram

It is important to note that incidents involving LNG vaporizing violently upon contact with water, resulting in a physical explosion or "cold explosion," are rare and typically occur during the transportation or storage of LNG [13]. As for the incident at the Texas Gulf Coast plant, while it did cause a spike in global LNG prices, it was not caused by a physical explosion, but rather a fire that occurred during the maintenance of a storage tank.

What are the hazards of LNG cargo?

Fig 2: LNG Cargo

Unwanted releases of LNG can lead to hazards such as asphyxiation, cryogenic burns, and cryogenic damage to the ship, as well as dispersion, fires, and explosions. Accurate modeling of the gas cloud resulting from a spill on land is crucial to predict the hazards associated with it. Factors such as wind direction and speed, atmospheric stability, temperature, humidity, and topography can also affect the behavior and dispersion of the gas cloud. Therefore, a comprehensive understanding of the physical and meteorological conditions at the spill site is necessary for accurate modeling and risk assessment.

Fig 3: Major pool fires during the tests

Impoundment structures, also known as containment structures, are typically constructed around LNG storage tanks and pipelines in land-based LNG facilities. These structures are designed to contain and control the spread of LNG in the event of a leak or release. They are typically made of concrete or other materials that can withstand the extremely cold temperatures of LNG [8]. The impoundment structure can hold the spilled LNG until it can be safely removed or transferred to another location. These safety systems are designed to detect and respond to any leaks or spills that may occur in an LNG facility. Gas detectors can detect the presence of LNG vapors in the air, while fire detectors can detect any flames or heat sources. Temperature sensors can detect any changes in temperature that may indicate a leak or other problem [4].

Once these systems detect a potential problem, firefighting and vapor suppression systems are automatically activated. Firefighting systems typically use water, foam, or other agents to extinguish any fires that may break out, while vapor suppression systems use water spray or mist to disperse LNG vapors and prevent them from igniting [9].

Overall, these safety systems are critical to ensuring the safe operation of LNG facilities and protecting nearby communities and the environment from the potential hazards associated with LNG. [6]. Emergency shutdown devices are crucial for shutting down equipment and isolating the source of a leak or release. These devices can be manual or automatic and are designed to prevent further escalation of an incident. In addition, LNG facilities are required to have emergency response plans and trained personnel who can respond to incidents quickly and effectively.

Regular maintenance and inspection of LNG facilities and equipment are also critical for ensuring their safe operation. This includes inspecting and testing emergency shutdown devices, fire and vapor suppression systems, and gas and fire detectors. Additionally, staff training and regular emergency response drills are necessary to ensure that personnel are prepared to respond appropriately in case of an emergency [11]. The LNG facility operator is responsible for maintaining the safety of the facility, which involves developing and following detailed maintenance procedures to ensure the integrity of various safety systems. These procedures may include regular inspections and testing of equipment, as well as preventative maintenance activities to identify and address potential issues before they become a problem. It's important for the operator to stay up-to-date on industry standards and best practices for LNG facility maintenance, and to train their employees on proper safety procedures to minimize the risk of incidents or accidents.

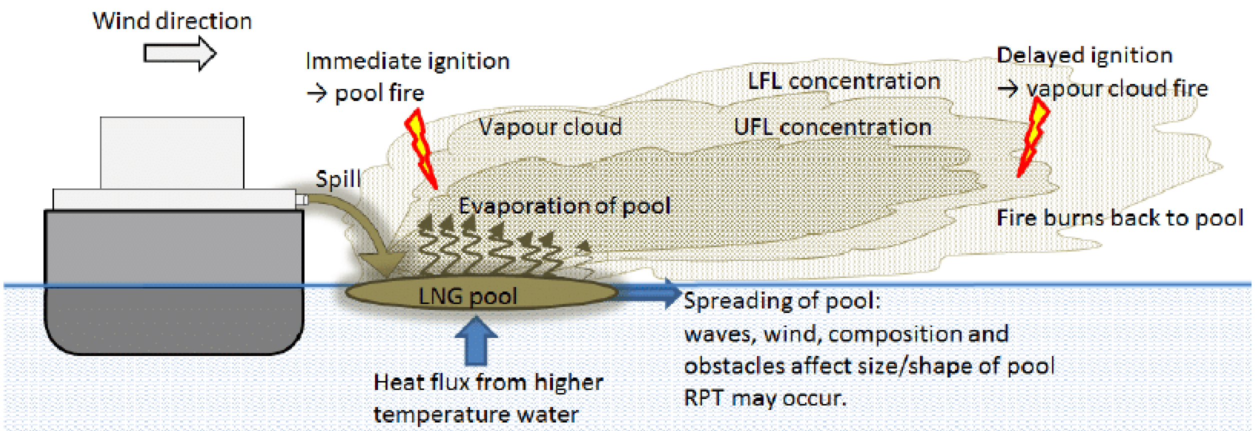

Fig 4: Possible outcome of LNG spill over water

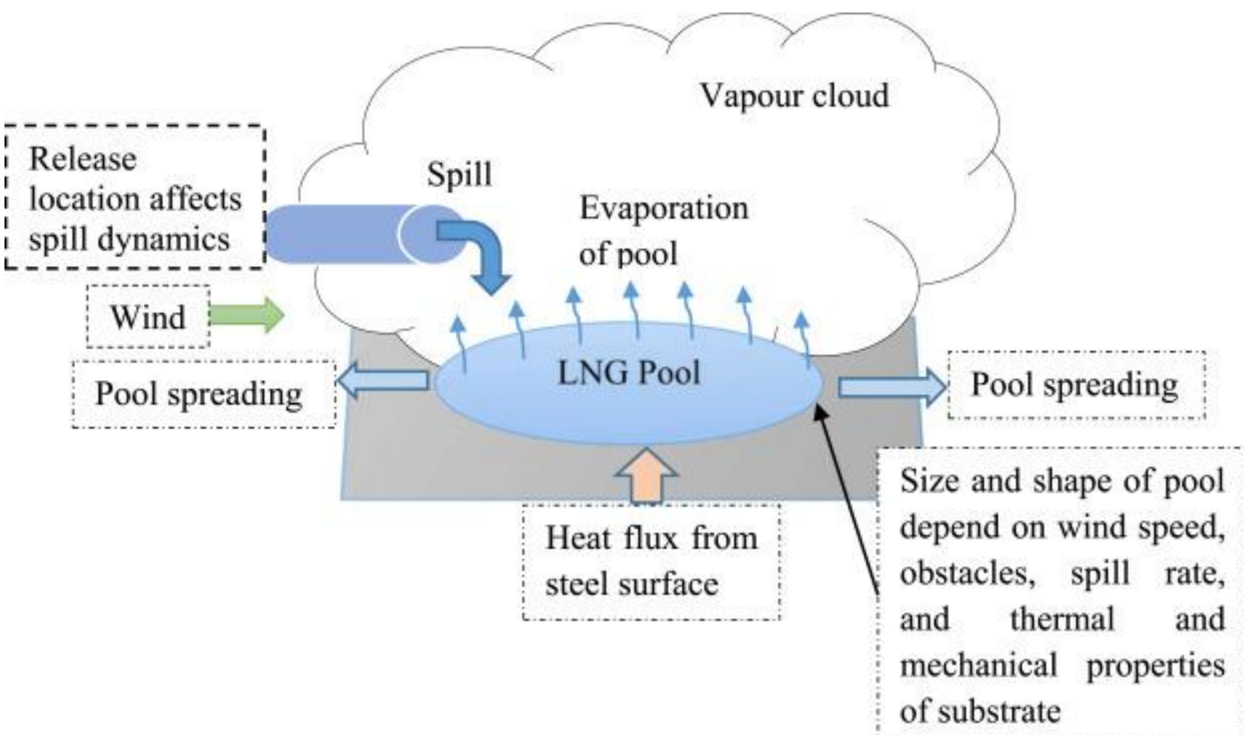

Fig 5: Methodology of LNG spill on steel structure for marine offshore facility

4. CONCLUSION/RECOMMENDATION

Computational fluid dynamics (CFD) [5] is used to determine the vapor dispersion modeling to predict the vapor exclusion zone. It's basically hydraulic model for the LNG flow into troughs or trenches. Expansion foam application is recommended for LNG Hazard Mitigation. Also effective use of water curtains is recommended in LNG Vapor Cloud.

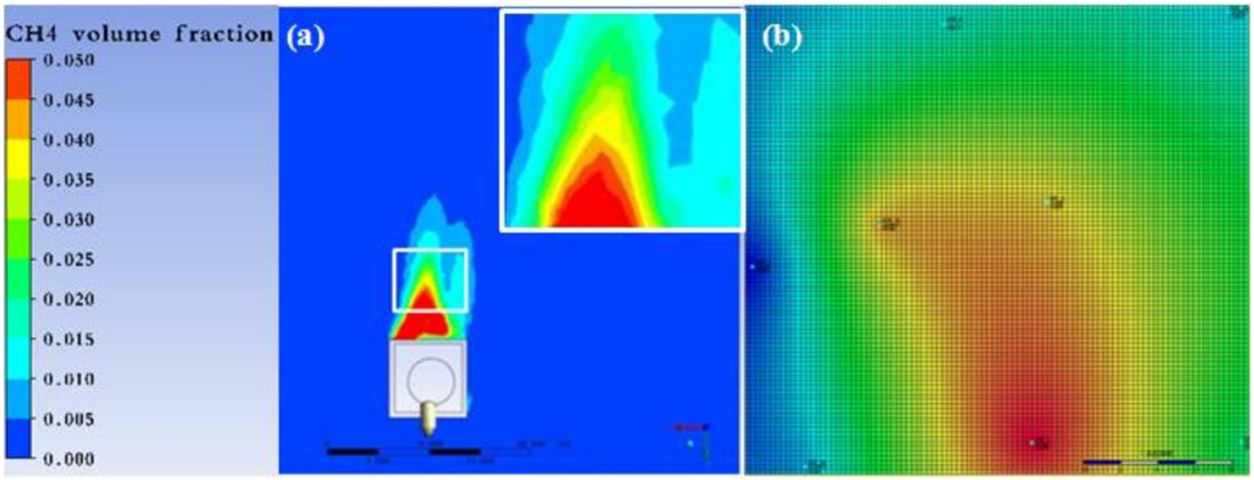

Fig 6: LNG Vapor Dispersion Modeling with CFD codes

REFERENCES

[1] SIGTTO (2009). Report on the Effects of Fire On LNG Carrier Containment Systems, Society of International Gas Tanker & Terminal Operators, March 19, 2009, Witherby Seamanvessel International Ltd, Scotland, UK

[2] Blanchat, T., Helmick, P., Jensen, R., Luketa, A., Deola, R., Suo-Anttila, S., Mercier, J., Miller, T., Ricks, A., Simpson, R., Demosthenous, B., Tieszen, S., and Hightower, M., (2010). The Phoenix Series Large Scale LNG Pool Fire Experiments, SAND2010-8676, Sandia National Laboratories, Albuquerque, NM.

[3] Blanchat, T. (2011). LNG Carrier Tank Insulation Decomposition Experiments with Large Scale Pool Fire Boundary Conditions, SAND2011-1880, Sandia National Laboratories, Albuquerque, NM.

[4] Luketa, A. J. (2011), Recommendations on the Prediction of Thermal Hazard Distances from Large Liquefied Natural Gas Pool Fires on Water for Solid Flame Models, SAND2011-9415, Sandia National Laboratories, Albuquerque, NM.

[5] Morrow, C., Cascading Damage from LNG Pool Fire – Potential for Overpressure or Thermal Damage to Adjacent Cargo Tanks, SAND2011-9414, Sandia National Laboratories, Albuquerque, NM. Adaptive Research, (2008). CFD2000 - A general-purpose CFD program intended for complex scientific and engineering flow calculations), Keith Kevin O'Rourke.

[6] Kalan, R. J., Petti, J. P.(2010). LNG Cascading Damage Study Volume I: Fracture Testing Report, SAND2011-3342, Sandia National laboratories, Albuquerque, NM.

[7] Luketa, A.J., (2005). A Review of Large-Scale LNG Spills: Experiment and Modeling, SAND2005- 2452J, Sandia National Laboratories, Albuquerque, NM.

[8] Luketa, A.J., M.M. Hightower, S. Attaway, (2008). Breach and Safety Analysis of Spills over Water from Large Liquefied Natural Gas Carriers, SAND2008-3153, Sandia National Laboratories, Albuquerque, NM.

[9] Petti, J.P., Wellman, G.W., Villa, D., Lopex, C., Figueroa, V.G., Heinstein, M. (2011), LNG Cascading Damage Study Volume III: Vessel Structural and Thermal Analysis Report, SAND2011- 6226, Sandia National Laboratories, Albuquerque, NM.

[10] Figueroa, V.G., Lopez, C., O'Rourke, K.K.,(2011). LNG Cascading Damage Study Volume II: Flow Analysis for Spills from MOSS and Membrane LNG Cargo Tanks, SAND2011-9464. Sandia National Laboratories, Albuquerque, NM.

[11] GAO (2007). "Public Safety Consequences of a Terrorist Attack on a Tanker Carrying Liquefied Natural Gas Need Clarification," Government Accountability Office report, GAO -07-316, February 2007.

[12] Hightower, M., et al. (2004). Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural (LNG) Spill Over Water, SAND2004-6258. Albuquerque, NM: Sandia National Laboratories.

[13] Hightower, M., Luketa-Hanlin, A., Gritzo, L.A., Covan, J.M. (2006). Review of Independent Risk Assessment of the Proposed Cabrillo Liquefied Natural Gas Deepwater Port Project, SAND2005- 7339, Sandia National Laboratories, Albuquerque, NM.