

Liquified Natural Gas (LNG) as a Marine Fuel

Background

Use of Liquified Natural Gas (LNG) as a marine fuel is expanding, as a cleaner alternative to conventional marine fuels. This development is driven by stringent environmental regulations, the availability of natural gas, and its cost effectiveness supporting the maritime industry's shift towards decarbonization. LNG bunkering facilities are in place or being planned for many U.S. ports. Bunkering can be done in port via land-based facilities or by ship-to-ship transfer at anchorage or in port. This fact sheet summarizes what is known about how a release of LNG to water may behave, drawing heavily from ITOPF (2024).

LNG Properties

- The specific composition of LNG varies depending on the gas source and type of processing. LNG is mainly composed of methane (more than 85% of the volume) and ethane, but also trace amounts of propane, butane, carbon dioxide, nitrogen or other heavier hydrocarbons and contaminants.
- In its liquid state, LNG is a colorless, non-toxic liquid that is typically transported and stored at -162°C , just below its boiling point.
- In its liquid state, LNG has a specific gravity of 0.41–0.45 at -162°C and negligible water solubility; therefore, liquid LNG will float if released on water.
- Vapors of LNG at ambient conditions are lighter than air (specific gravity of 0.55–1.0) and will easily disperse in open or well-ventilated areas. However, when LNG initially vaporizes, and the vapor temperature is less than -106°C , the vapor is heavier than air.

Flammability Hazards

- LNG is not flammable in a liquid state. However, LNG will rapidly volatilize if it escapes containment or cryogenic systems fail. This vapor is highly flammable with a Lower Explosive Limit (LEL) of 5% and an Upper Explosive Limit (UEL) of 15%. Because of this low and narrow range of flammability, the fuel air mixture may be too “rich” to burn near the source and the area of greatest fire hazard could be some distance downwind from the release site.
- If flammable vapors come into contact with an ignition source, a vapor cloud fire can result, which may propagate back to the spill point and may cause a pool fire. The flame burns slowly and therefore, if the wind speed is moderate (>10 mph) the flame might not be able to propagate back to the leak source and will burn downwind from the ignition point, until all LNG is consumed below the LEL or is extinguished.

Environmental Behavior

- If liquid LNG is released on or above the waterline, it will first float and, depending on the quantity spilled, may form a shallow cryogenic pool on the water surface before vaporizing. There is also potential for some seawater in the immediate vicinity of the release to freeze due to LNG's low temperature, causing localized ice patches.
- If released below the waterline, it will rise to the water surface before rapidly boiling and volatilizing into the atmosphere. When vaporizing, the cold LNG vapors are heavier than air and stay close to the ground or sea (the maximum height of the vapor cloud is reported as about 40 feet). These vapors condense the moisture in the air, forming a visible white cloud of water vapor (or fog), mixed with gaseous LNG, close to the ground or sea (Figure 1).
- Once the fuel vapor temperature rises and the cloud disappears, the gases will not be visible. The cloud will likely disappear within 30 minutes for large discontinuous spills. It is likely that the water vapor cloud will persist for longer than the LNG cloud.



Figure 1. Release of LNG at sea. From MerCurio and Ryu (2024).

- The footprint and height of the vapor cloud depends on the weather conditions at the time of the release. In low wind conditions (<5 mph), the vapor cloud footprint is smaller on the sea surface and is expected to dissipate at a higher altitude (Figure 2), whereas in moderate wind conditions (>5 mph), the vapor cloud plume is likely to be knocked down on the sea surface, therefore being more low-lying and spreading over a larger footprint on the sea surface (Figure 3). The initial dense, cold vapor cloud could be trapped by a low-level inversion.

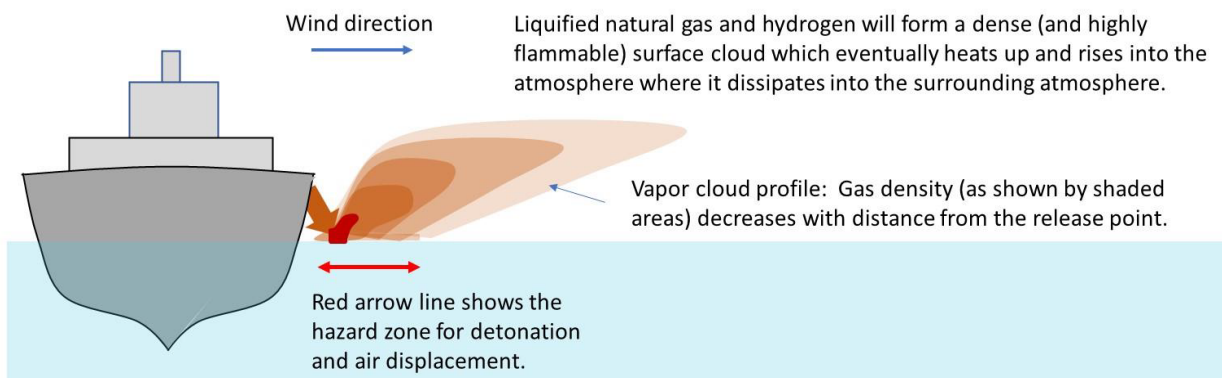


Figure 2. General vapor cloud profile of a sudden release of LNG or liquid hydrogen under low wind speed (<5 mph). From Kass et al. (2021).

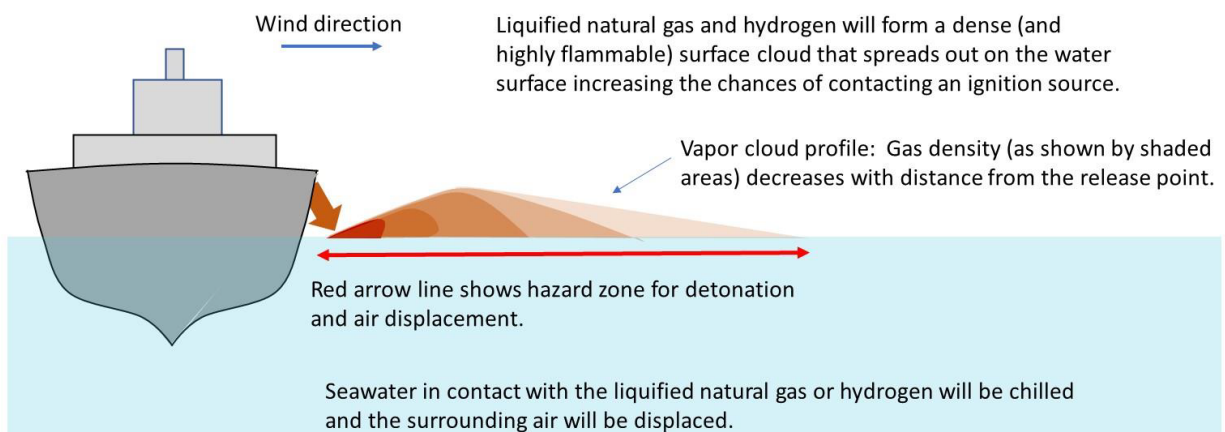


Figure 3. General vapor cloud profile of a sudden release of LNG or liquid hydrogen under moderate wind speed (>5 mph). From Kass et al. (2021).

- In particular conditions, LNG could potentially undergo a boiling liquid expanding vapor explosion (BLEVE), which is an explosion caused by the rupture of a tank containing a pressurized liquid that has

reached a temperature above its boiling point, in the case of LNG, -162 °C. This would be the case if the temperature of the tank were to rise and gas release systems were to fail.

- Studies have indicated that vapor clouds spread roughly at the same rate as wind speed and are likely to persist in the order of tens of minutes, depending on multiple factors such as hull puncture size, location of the breach, discharge rate, and environmental conditions at the time of the spill. However, the vapor cloud will persist for a longer time for low wind speeds and stable atmospheric conditions.
- There is a potential that, with the sudden release of LNG to water, a **rapid phase transition** will occur when it contacts the water. A rapid phase transition is a flameless overpressure due to a very fast change of phase, in this instance from liquid to gas. The vapor cloud expands so quickly that a sonic boom and localized overpressure occurs. As a result, the immediate vicinity of where the LNG contacts the seawater may be subjected to a damaging shock wave.
- In confined spaces, high concentration of LNG vapors displace oxygen in the air, decreasing oxygen availability and possibly leading to asphyxiation of those present.
- The cryogenic temperature of liquid LNG will result in the freezing of any tissue (plant or animal) upon contact and can cause materials to become brittle and lose their strength or functionality.

Response Monitoring

- Spilled LNG is not recoverable; therefore, allowing natural attenuation to occur is the only appropriate option other than source control.
- Monitoring of an LNG release would include the use of expert atmospheric plume modeling and/or the use of multi-gas monitors or sensors mounted on small, non-spark UAVs to evaluate the potential presence of a flammable vapor/air mixture, which may pose a risk to local environmental and economic sensitivities. Infrared sensors could be used to detect the temperature reduction of ship and water surface, which could lead to the delimitation of exclusion zones.

Helpful References

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