
Lloyd's Register: Marine
LNG as a Marine Fuel
Environmental Impact of LNG in Emergency Scenarios
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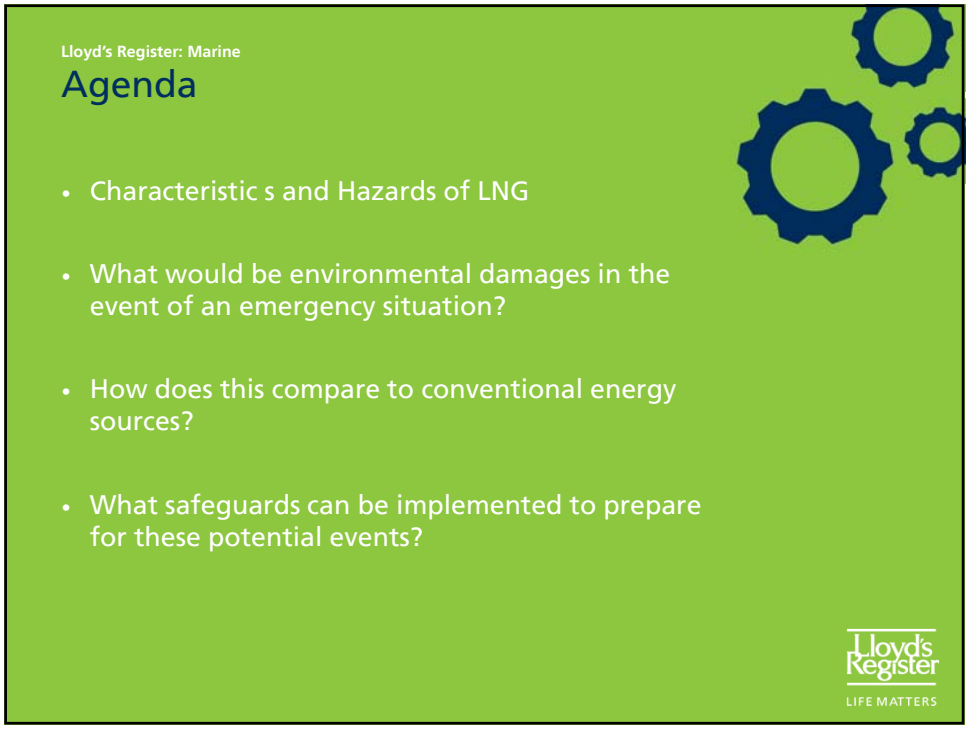
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Agenda
• Characteristic s and Hazards of LNG
• What would be environmental damages in the event of an emergency situation?
• How does this compare to conventional energy sources?
• What safeguards can be implemented to prepare for these potential events?
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Who is Lloyd's Register

- At its heart, a charity with a mission to protect life and property and to advance transport and engineering education and research.
- 7,900 employees at offices in 240 cities and towns covering all parts of the world
- We celebrated our 250 year anniversary in 2010
- Four business divisions:
  - Marine
  - Energy
  - Transportation
  - Management Systems (LRQA)
- Three regions: Asia, EMEA (Europe, Middle East and Africa) and Americas

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Characteristics of LNG

- LNG is a cryogenic liquid.
- It is comprised of mostly methane (94%) with small amounts of ethane, propane and inert nitrogen.
- Stored at ambient or near ambient pressure, its temperature approximates minus 162C and its specific gravity is about 0.42.
- Released into atmospheric conditions, LNG rapidly boils forming a colourless, odourless and non-toxic gas that remains visible as it warms to ambient temperature.
- At ambient temperature, volume is 600 times that of liquid with relative vapour density of 0.55 (much lighter than air = 1).

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Characteristics of LNG

	LNG	Fuel Oil
Toxic	No	Yes
Carcinogenic	No	Yes
Flammable	Yes	Yes
Asphyxiate	Yes, in closed spaces	No
Other health risks	Low temperature	Eye irritant, narcosis, nausea
Flammability range (V)	5% to 15%	1% to 6 %
Auto-ignition temp	540 C	>220 C
Spill behavior	Evaporates and forms a visible cloud that quickly dissipates	Forms a flammable pool requiring pollution control measures
Behaviour when ignited	Ignited gas clouds burn back into LNG pools at the source of the spill.	Fierce intense flame.

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LNG Hazards

Hazard	Description
Cryogenic Burns	Liquid contact with skin will cause burns and can result in fatality. Inhalation of gas can cause burns to the lungs and lead to fatal injury.
Low Temperature Embrittlement	Equipment/structures can fail on contact with liquid.
Rapid Phase Transition (RPT)	Released onto the sea a near instantaneous 'explosive' transition from liquid to gas can occur. This can result in structural damage to the hull.
Gas Expansion	A liquid pool rapidly boils, and as the gas warms and expands it requires a volume 600 times that of the liquid. This can result in equipment damage.
Asphyxiation	In a confined space, displacement and mixing of the gas in the air will reduce oxygen content and can cause asphyxiation.

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LNG Hazards

Hazard	Description
Pool Fire	Gas/vapour above the pool can ignite resulting in a pool fire. The intensity of the radiation can cause fatal injury and fail structure and critical equipment.
Flash Fire	Gas/vapour can disperse away from the pool and ignite resulting in a flash fire. The short-duration and intense radiation can instigate secondary fires, and cause fatal injuries to those within the fire and to critical equipment. Most probably the fire will burn back to the pool and result in a pool fire.
Explosion	Gas/vapour can disperse and collect in confined areas and ignite resulting in an explosion. The explosion can cause fatal injuries, instigate secondary fires, and fail structure and critical equipment. Most probably the explosion will burn back to the pool/gas source and result in a pool fire or jet fire.

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What happens during an LNG spill?

When exposed to ambient temperature, LNG will vaporise or "boil off"

- Two-phase process:
  - 20-30 seconds high rate of boiling
  - Cold vaporised gas insulates liquid surface causing evaporation rate to decline (depending on heat transfer from surrounding area).
- Vaporisation rate may increase depending on:
  - Continuing leakage
  - Wind
  - Application of water
  - Ignition, i.e. greater heat flow to the liquid
  - Agitation of the surface

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What happens if ignited following a spill?

- LNG vaporizes extremely quickly when ignited, strictly limited by the flammability of natural gas in air.
- Ignited gas clouds burn back into LNG pools at the source of the spill.
- The fire is therefore limited to the vessel and does not spread like other hydrocarbon spills.
- If ignited, the flames of an uncontained vapor cloud spread slowly and the cloud will not explode.
- LNG flames are radiant, and radiation intensity depends on the size of the fire (flame surface) and the distance of the flame source.

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What would be environmental damages in the event of an emergency situation?

- Four areas could possibly be detrimentally affected by spillage of LNG:
  - Ship / shore structures
  - Ocean environment
  - Air / atmospheric environment
  - People

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What would be environmental damages in the event of an emergency situation?

Ship / shore structures

- Given low temperature, LNG spill on or within hull can cause brittle fracture (carbon & low alloy steel) fracture on contact with liquid.
- Rapid Phase Transition (RPT) - Near instantaneous 'explosive' transition from liquid to gas can result in structural damage.
- Gas Expansion - Liquid pool rapidly boils, and as gas warms & expands, requires a volume 600X that of liquid. Can result in equipment / structural damage in a confined space.
- Fire & Explosion: Gas/vapour above the pool can ignite resulting in a pool fire; gas/vapour can disperse away from the pool and ignite resulting in a flash fire; gas/vapour can disperse and collect in confined areas and ignite resulting in an explosion, all of which can result in equipment / structural damage.

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What would be environmental damages in the event of an emergency situation?

Ocean environment

- LNG floats on water
- LNG pool vaporizes and dissipates rapidly (faster than an equal sized pool on land)
- LNG can undergo "rapid phase transition", a physical vapour explosion (not combustion)
- Most LNG MSDS publications reviewed provided no indication of detrimental environmental impact to the ocean space from LNG as a pollutant.

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What would be environmental damages in the event of an emergency situation?

Air / atmosphere

- Potentially flammable gaseous cloud.
- Methane is a very potent greenhouse gas (comparative impact of CH_4 on climate change is over 20 times greater than CO_2 over a 100-year period).

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What would be environmental damages in the event of an emergency situation?

People

- Cryogenic burns: Liquid contact with skin will cause burns and can result in fatality. Inhalation of gas can cause burns to the lungs and lead to fatal injury.

- Asphyxiation: In a confined space, displacement and mixing of the gas in the air will reduce oxygen content and can cause asphyxiation.

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How does this compare to conventional energy sources?

Area of Contact	LNG	Fuel Oil
Structure	Brittle fractures	Oil-covered surfaces
Ocean	Negligible	Significant impact
Atmosphere	Significant impact as greenhouse gas	Volatile organic compounds
People	Cryogenic burns, asphyxiation	Carcinogen
Atmosphere	Significant impact	Volatile organic compounds

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What safeguards can be implemented to prepare for these potential events?

Design Considerations – Bunker Stations

- Truck, barge or dedicated Station
- Bunker station position / segregation
- Manifold size / compatibility
- Deck loads / cryogenic protection
- LNG piping path to tanks
- Vapour management
- Fire protection / detection / ESD
- Ships Compatibility / Checklists

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What safeguards can be implemented to prepare for these potential events?

Design Considerations

- Promote an inherently safer designs that focus on:
  - the elimination or significant reduction of leak sources
  - reduction of leakage rate, volume and duration
  - reduction of high complexity & poor design that promote leaks

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What safeguards can be implemented to prepare for these potential events?

The Humans Element

- Common human factors issues:
  - Competency
  - Complacency
  - Fatigue
  - Shifting paradigms
  - Repetition
- **Foreseeable (not random)**
- **Solvable**

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What safeguards can be implemented to prepare for these potential events?

Operational Considerations

- System Reliability
  - Equipment operating too close to maximum design values
  - System reliability issues associated with operational activities (start-ups and shut-downs).
  - Climatic and environmental conditions.

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What safeguards can be implemented to prepare for these potential events?

Mitigating Measures

- Containment
  - leak containment, minimising liquid contact and evolution of gas;
- Detection
  - leak detection, emergency actions can be instigated in good time;
- Ventilation
  - ventilation, to safely disperse gas;
- Ignition Source Minimisation
  - elimination or minimisation of ignition sources, to reduce the likelihood of subsequent fire and explosion.

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What safeguards can be implemented to prepare for these potential events?

Mitigating Measures

- **In the event of ignition**, measures should cover:
  - Fire-fighting
    - fire detection, fire-fighting and extinguishment;
  - Separation/Protection
    - physical separation and/or protection from fire and explosion;
  - Evacuation
    - evacuation of personnel.

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In Summary

Bunkering LNG will see higher frequency of LNG interactions by a broader spectrum of people who have a varying level of familiarity with cryogenic liquids and natural gas. As such we need to focus on

- Better designs
- The human element
- Cryogenics, and
- Don't rely on the status quo

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