Key excerpts adapted from a study and analysis of

LNG Release Hazards

by
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Vallejo Disaster Council**

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Education and Experience

Ronald P. Koopman Ph.D. P.E.

- BS and MS Engineering - University of Michigan
- PhD Applied Science - University of California, Davis
- Created and managed Liquefied Gaseous Fuels Program, 1978-1988
  - Created Spill Test Facility at Nevada Test Site
  - Performed large scale field experiments and/or modeling with LNG, Ammonia, HF, N_2O_4, propane, and chlorine.
  - Studied atmospheric dispersion, combustion, and detonation
- Expert witness at trials
  - Marathon HF accident 1987
  - Suburban Propane bomb plot 1987
- Congressional testimony on transport of hazardous materials; input to the Clean Air Act
- California legislative testimony on safety of refineries using HF processes
- Worked for LLNL for 35 years
  - Most work sponsored by the US Department of Energy and Department of Defense
- After 9/11, conducted vulnerability assessments at refineries
- Currently engaged in Chem/Bio National Security work
- Managed joint projects with:
  - Oil company participants including Shell
  - Gas Research Institute
  - US Coast Guard
  - Other companies and government agencies
- Worked with Bechtel on design and construction of spill test facility in Nevada

Overview

The purpose of this study is to assess the hazards posed by the handling of bulk quantities of LNG and the affects an accidental release would have on the surroundings. The following four scenarios were considered to provide a practical range of consequences.

- LNG tanker ship failure and Unloading Line failure, no fire
- LNG tanker ship failure, with pool fire
- Storage tank failure, with and without fire
- 747 crash into LNG storage tank creating fireball

Of the numerous risks inherent in handling LNG, analysis of the four scenarios provides conclusions regarding flammable LNG vapor cloud formation, pool fires, and Fireballs. The results of the analyses are summarized on the following pages and are accompanied by maps indicating the proposed Bechtel-Shell LNG site, and the surrounding areas that could be affected during an accidental LNG release.

Dr. Koopman’s findings from the Vallejo Health and Safety Study have been applied to the location in this handout for the purpose of helping local residents better understand the risks associated with the LNG project proposed for their community.

LNG UNLOADING LINE FAILURE
or
LNG TANKER SHIP COLLISION
NO IGNITION - FLAMMABLE VAPOR CLOUD DRIFT

The following are the areas at risk from the releases shown below. The distance the vapor cloud can travel before it is no longer flammable is the radius from the release point to the "Lower Flammability Limit" (LFL) of the drifting vapor cloud. The LFL is the lowest concentration of LNG vapor capable of burning in air.

1 Unloading line failure
55,000 gpm spills for 10 minutes onto water.
5 m/s wind, Atmospheric stability: D *
Distance to Lower Flammability Limit of the drifting vapor cloud: 0.4 miles.

2 LNG Tanker Ship collision
Rupture of one 25,000 cubic meter tank, spills onto water.
1 meter hole in tank.
5 m/s wind, Atmospheric stability: D *
Distance to Lower Flammability Limit of the drifting vapor cloud: 0.7 miles.

3 LNG Tanker Ship collision
Rupture of one 25,000 cubic meter tank, spills onto water.
5 meter hole in tank.
5 m/s wind, Atmospheric stability: D *
Distance to Lower Flammability Limit of the drifting vapor cloud: 1.5 miles.

4 LNG Tanker Ship collision
Rupture of one 25,000 cubic meter tank, spills onto water.
5 meter hole in tank.
5 m/s wind, Atmospheric stability: F *
Distance to Lower Flammability Limit of the drifting vapor cloud: 2.8 miles. (radius extends beyond map)

* **Atmospheric Stability D** is characterized by fully overcast or partial cloud cover during both daytime and nighttime. The atmospheric turbulence is not as great during D conditions as during A conditions; thus, the gas will not mix as quickly with the surrounding atmosphere.

Atmospheric Stability F corresponds to the most "stable" atmospheric conditions. Stability F generally occurs during the early morning hours before sunrise (thus, no solar radiation) and under low winds. The combination of low winds and lack of solar heating allows for an atmosphere which appears calm or still and thus restricts the ability to actively mix with the released gas.

LNG TANKER SHIP COLLISION
IGNITION AND POOL FIRE AT TANKER

The following are the areas at risk from a release of LNG from a ship and subsequent pool fire. The radius is the distance from the center of the pool fire to the threshold for burns and blisters.

1 LNG Pool Fire
Distance to Third Degree Burns: 0.35 miles. *
Rupture of one 25,000 cubic meter tank.
5 meter hole in tank.
LNG spill forms pool on water and ignites.

2 LNG Pool Fire
Distance to Second Degree Burns: 0.5 miles. *
Rupture of one 25,000 cubic meter tank.
5 meter hole in tank.
LNG spill forms pool on water and ignites.

3 LNG Pool Fire
Distance to Skin Blister Threshold: 0.8 miles.
Rupture of one 25,000 cubic meter tank.
5 meter hole in tank.
LNG spill forms pool on water and ignites.

* **Second Degree Burns:** Lethal 1% of the time for a person wearing average clothing. Heat flux of about 17 kw/m^2 (6,000 Btu/hr/ft^2) for 30 seconds.

Third Degree Burns: Lethal 50% of the time for a person wearing average clothing. Heat flux of about 30 kw/m^2 (10,000 Btu/hr/ft^2) for 30 seconds.

LNG STORAGE TANK RUPTURE
NO IGNITION - FLAMMABLE VAPOR CLOUD DRIFT

The following are the areas at risk from the release of 95,000 cubic meters of LNG onto land, followed by the formation of a vapor cloud capable of drifting downwind. The distance the vapor cloud can travel before it is no longer flammable is the radius from the release point to the "Lower Flammability Limit" (LFL) of the drifting vapor cloud. The LFL is the lowest concentration of LNG vapor capable of burning in air.

1 LNG Tank rupture
1 meter hole in tank.
5 m/s wind speed, Atmospheric stability: D *
Distance to Lower Flammability Limit of the drifting vapor cloud: 0.2 miles.

2 LNG Tank rupture
1 meter hole in tank.
5 m/s wind speed, Atmospheric stability: F *
Distance to Lower Flammability Limit of the drifting vapor cloud: 1.1 miles.

3 LNG Tank rupture
5 meter hole in tank.
5 m/s wind speed, Atmospheric stability: D *
Distance to Lower Flammability Limit of the drifting vapor cloud: 1.6 miles.

4 LNG Tank rupture
5 meter hole in tank.
5 m/s wind speed, Atmospheric stability: F *
Distance to Lower Flammability Limit of the drifting vapor cloud: 3.25 miles.
(radius extends beyond map)

* **Atmospheric Stability D** is characterized by fully overcast or partial cloud cover during both daytime and nighttime. The atmospheric turbulence is not as great during D conditions as during A conditions; thus, the gas will not mix as quickly with the surrounding atmosphere.

Atmospheric Stability F corresponds to the most "stable" atmospheric conditions. Stability F generally occurs during the early morning hours before sunrise (thus, no solar radiation) and under low winds. The combination of low winds and lack of solar heating allows for an atmosphere which appears calm or still and thus restricts the ability to actively mix with the released gas.