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LNG SAFETY MYTHS and LEGENDS

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Natural Gas Technology

Investment in a Healthy U.S. Energy Future

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Introduction

- North America is Becoming the Focal Point of Global LNG Industry
- Physical Properties of LNG
- Myth and Legend - “the big boom!”
- Knowledge and Common Sense
- Hazards

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US Natural Gas

- 23.5 % Total Energy Demand
- 22.7 Tcf Consumed in 2001
- Canadian Pipeline Imports 3.8 Tcf
- 230 Bcf LNG Imported 2001
- LNG Imports Projected to Increase 8.6% Annually to 830 BCF in 2020

Oil & Gas Journal 1/28/02, EIA May.2002

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Everett LNG Terminal

Source: LNG in the Atlantic Basin Conference 2000

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Lake Charles Terminal

CMS Trunkline LNG

Source: CMS Energy, 2001

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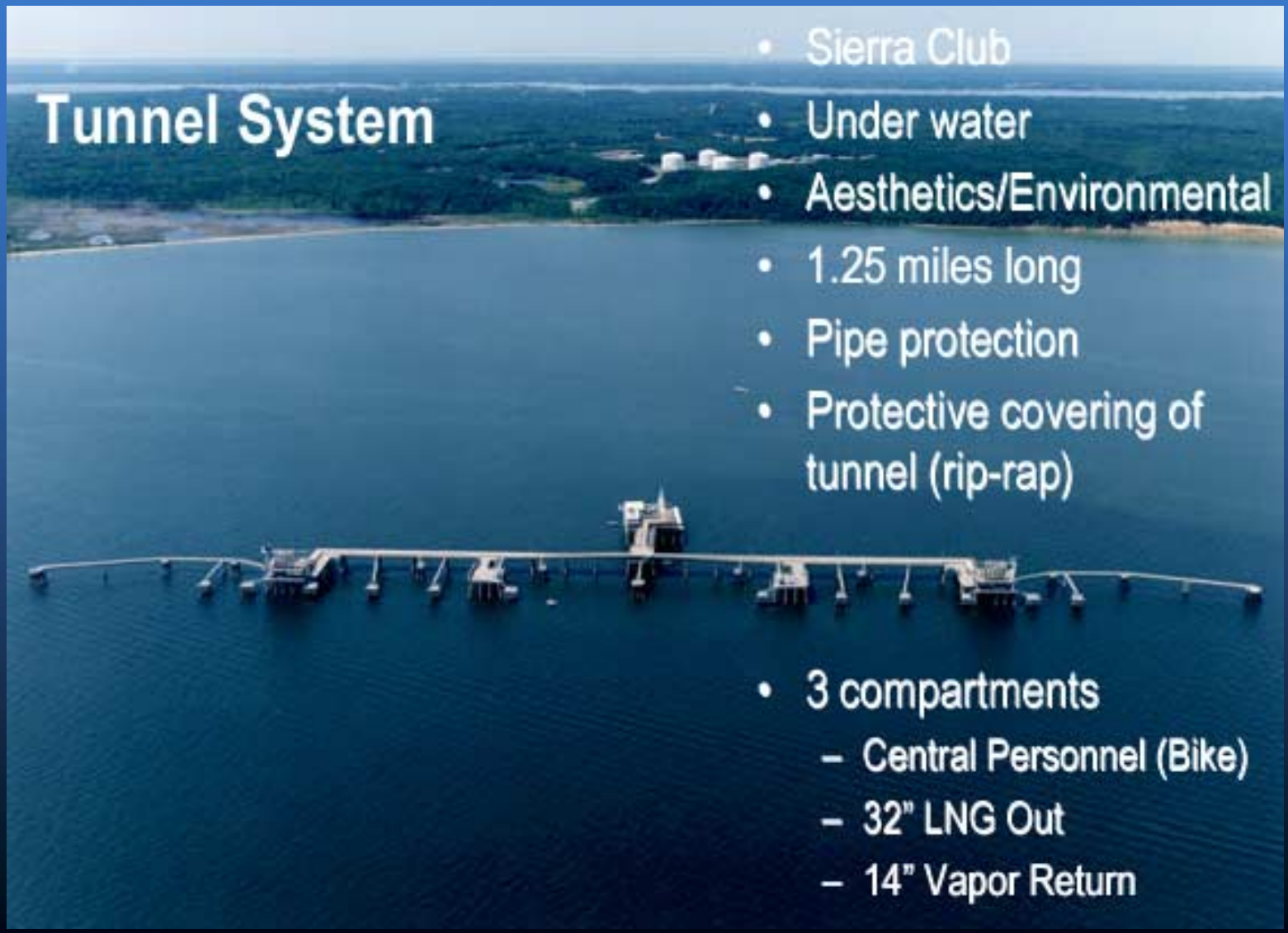
Cove Point LNG Terminal



Source: William, Zeus LNG Conference 2001

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Elba Island LNG Terminal
El Paso

Source: El Paso, 2000

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LNG-Natural Gas Properties

- **Liquefied Natural Gas is a Cryogenic Liquid**
  - LNG Density - 26.5 LB./Cu. Ft.
    - Lighter than water (65 LB/Cu. Ft.)
  - LNG Boiling point - (-259^{o} F)
- **Natural gas is lighter than air**
  - Natural Gas Density - 0.47
    - (Air - 1.0)
- **Natural gas rises under normal atmospheric conditions**

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Myth and Legend

- "Catastrophic release of LNG creates a BLEVE -- boiling liquid expanding vapor explosion"

NOT TRUE

  - In laboratory and open ocean combustion tests, there have been *no* documented cases of LNG **BLEVEs**

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Myth and Legend

- **"An LNG Tanker is a floating Bomb"**

NOT TRUE

- Liquefied Natural Gas tankers have been run aground, experienced loss of containment, suffered weather damage, been subjected to low temperature embrittlement from cargo spillage, suffered engine room fires, and been involved in serious collisions with other vessels - **NO CARGO EXPLOSIONS REPORTED**

Common Sense and Knowledge

- Natural gas needs to be in vapor form and mixed with air to burn
- Natural gas is combustible in the range of 5% to 15% volume concentrations in air
- Combustible mixtures in confined space will burn explosively
  - LNG does not explode or burn

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Common Sense and Knowledge

- LNG is a cryogenic liquid – physical contact or spillage constitute a personnel and equipment hazard
- LNG → Natural Gas
- Natural Gas presents an asphyxiation hazard

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What Happens with a Spill on Water?

- LNG pool vaporizes rapidly (faster than an equal sized pool on land)
- LNG spill on or within hull can cause brittle fracture (carbon & low alloy steel)
- LNG can undergo “rapid phase transition”, a *physical* vapor explosion (not combustion)
- LNG pool formation accompanied by ignition
- Natural gas cloud formation with subsequent burn back

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Assessing The Hazard
30 Years of LNG Experience

- LNG history in the US dates back to 1940's
- LNG tanker trade initiated with exports in 1969
- Eight marine incidents have resulted in spillage of LNG - some hull damage due to cold fracture and no cargo fires
- Seven incidents not involving spillage - two from grounding - no significant cargo loss
- LNG carriers are inherently much more robust than typical crude, fuel, and chemical tankers

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LNG Tanker at Loading Berth, Kenai, Alaska

Photo: Courtesy of Phillips Petroleum

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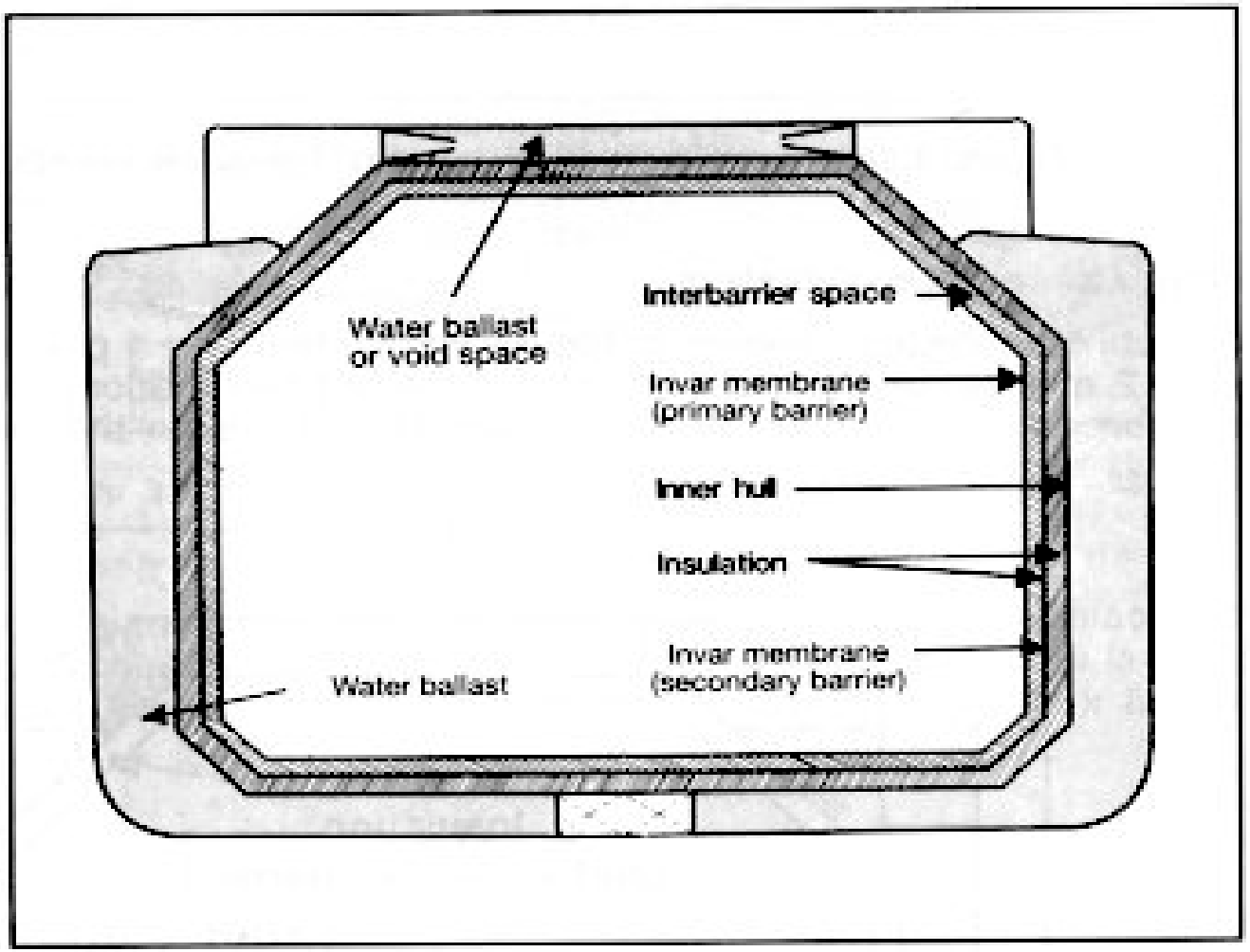
Cross Section of LNG Tanker



Assessing the Hazard

- LNG vaporizes and causes condensation of atmospheric moisture – visible cloud
- As LNG vapor cloud warms it lifts
- Water is a superior heat source compared to soil/solids
- Spills on water tend to vaporize rapidly creating a potentially combustible plume that migrates until a) the LNG source is exhausted, and b)dilution by air reduces the concentration below the lower flammability limit (LFL)

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Assessing the Hazard

- An ignition source close to the origin of the spill is likely to cause ignition and result in rapid burn off of natural gas vapors
- Absence of an ignition source would result in a plume that could migrate downwind for a considerable distance.
- A remote (downwind) ignition of a plume in the flammable portion of the vapor cloud would result in relatively slow (subsonic) burn back to the spill pool

Assessing the Hazard

- The opinion of experts indicate that a catastrophic failure caused by collision or terrorist act would result in numerous ignition sources close to the vessel and ignition and burn down would occur

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What has Changed since Sept. 11, 2001?

- Everyone is looking at their environment differently
- Potential threat to infrastructure has increased - Responsible parties are reacting
- Assumptions about what constitutes threats are being reassessed

Assessing the Risk

- Following suspension of LNG tanker dockings at the Distrigas (Tractebel) facility in Boston Harbor DOE, working with FERC, DOT (OPS), local and state public safety officials, commissioned a series of model runs intended to mimic a serious and catastrophic breaching of a single tank of an LNG carrier.

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Assessing the Risk
Modeling Catastrophic Failure

- One meter (3.3ft.) and five meter (16.4 ft.) hole in one tank of a tanker
- Rapid (but not instantaneous) loss of cargo onto water
- Variable atmospheric conditions
- Dispersion, Fire Radiation and Burn Times

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Dispersion Model Results

QUEST Consultants

Release From Tanker

Hole Size	Atmospheric Conditions	Pasquill-Gifford* Atmospheric stability	Liquid Impoundment	Distance to Lower Flammability Limit (LFL)
5 meters	1.5m/s	F	No	2.5 miles
5 meters	5 m/s	D	No	0.6 miles
1 meter	1.5m/s	F	No	2.3 miles
1 meter	5 m/s	D	No	0.5 miles

* **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.

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.

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Pool Fire Results

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Release from 25000m^3 Tank

Hole Size	Atmospheric Conditions	Liquid Impoundment	Distance To 7000 Btu/hr-ft^2	Distance To 4000 Btu/hr-ft^2	RFL (ft) * 500 Btu/hr-ft^2
5 meter	9m/s	No	1020	1260	1770
1 meter	9m/s	No	835	1020	1420

* **Radiant Flux Levels** - measured from center of pool

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Estimated Burn Times

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Spill Description	Inventory Spilled (cubic meters)	Time to Burn Out (minutes)
5 m. hole in ship	25,000.	37.
1 m. hole in ship	25,000.	64.

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Summary of Conclusions from the Lloyd's Report

Report draws from many sources, historical, experimental, and modeling

- Historically for all types of LNG - no loss of life - land based property damage - environmental damage
- LNG carriers inherent strength has prevented loss of containment
- A missile hit or explosion will provide a large number of ignition sources
- If containment loss should occur under specific conditions
  - Holing may not be visible

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Summary of Conclusions from the Lloyd's Report

- There is potential for escalating failure due to embrittlement - with subsequent explosion/fire
- Ignition and sustained burn of a vaporized LNG cloud is difficult - multiple ignition sources would probably result in a burn back to the source
- Unconfined LNG vapor cloud detonation has not been demonstrated and unlikely
- External ignition (of vapor cloud) results in slow moving flame
- Rapid Phase Transition will not cause ignition but potentially damaging for ship/equipment

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Summary of Conclusions from the Lloyd's Report

In terms of pool spread

- The LFL for methane/air mixtures is ~5% so the LFL boundary is well within the visible cloud
- Modeling of dispersion cloud 3-6 km. Dispersion on that scale unlikely because of local ignition sources
- Exposure at 300 meters (1000ft) from a pool fire would cause pain within 60 seconds
- Warming gas cloud will become lighter than air and rise
- No direct environmental damage or clean up from primary spill
- A fire fed by single (25,000 m^3) cargo tank vented through a 1m^2 hole would last 1hr - burn diameter 25 meters

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Summary

- The US market for natural gas is growing -
- Part of that market demand will be met by LNG
- The experience of the LNG industry suggests that hazards are manageable
- 30+ years of experience with marine transport of LNG - no major failures carriers and cargo inherently safer than other hydrocarbon fuels transported by ship
- Post September 11, 2001- new risk not new hazard

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Summary

- Fundamental properties and behavior of LNG and natural gas remain the same
- Risk scenarios do not produce results outside of those contemplated in previous EIS documentation for siting facilities and transportation of LNG