Marine Transportation of LNG

Intertanko Conference
March 29, 2004
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Development
Marine Transportation of LNG

Topics

- What is LNG?
- History of LNG Marine Transportation
- LNG Carrier Fleet
- Major LNG Trade Routes
- LNG Vessel Types and Particulars
- Safety and Risks of LNG Transportation
- Technology Advances for LNG Vessels
- New LNG Projects
- Qatar LNG Projects
What is LNG?

- LNG is natural gas that has been liquefied by being cooled to approximately \(-160^\circ C (-260^\circ F)\)

  - LNG ~ 1/600 volume of Natural Gas, making it practical to transport by ship
What is LNG?

- **Properties and characteristics**

  - Typically ~ 95% methane (CH₄) with small amounts of ethane, propane, butane and nitrogen
  
  - Colorless, odorless, non-toxic, non-carcinogenic and in liquid form is ~45% the density of water
  
  - Vapors are ~ 50% density of air and will rise under normal atmospheric conditions (propane/butane heavier than air)
  
  - Can be stored and transported in insulated tanks at standard atmospheric pressure
What is LNG?

- **Flammability characteristics**
  - Flammable when mixed with air concentrations between 5% - 15% (methane)
  - Not generally considered explosive
What is LNG?

- LNG spill characteristics
  - No pollution issues
    - Small spills evaporate quickly
    - Large spills flow prior to vaporization
    - Not a persistent cargo: OPA 90, etc. are not applicable
  - LNG is cryogenic, contact with some non-cryogenic material causes material to become brittle and fail; exposure to skin will cause cryogenic burns
History of LNG Marine Transportation

- **Historical LNG shipping timeline:**
  - **1912:** First LNG plant built in West Virginia
  - **1914:** Godfrey Cabot patents a barge to carry liquid gas, waterborne transportation technically feasible
  - **1959:** METHANE PIONEER, converted cargo ship, carries 5km$^3$ of LNG between Lake Charles and UK demonstrating feasibility of waterborne transportation
History of LNG Marine Transportation

- **Historical LNG shipping timeline:**
  - **1964:** Methane Princes & Methane Progress, 27.4 km$^3$, become first commercial LNG vessels, operating between Algeria and the UK.
  - **1969:** Gas Transport membrane system vessels Polar Alaska & Arctic Tokyo, 71.5km$^3$, begin service from Alaska to Tokyo.
  - **1971:** Kvaerner develops 88km$^3$ Moss spherical containment system.
History of LNG Marine Transportation

- Historical LNG shipping timeline:
  - 1975: 100 km$^3$ size exceeded with delivery of French built BEN FRANKLIN, 120km$^3$
  - 1979: Formation of Society of International Gas Tanker and Terminal Operators (SIGTTO) to promote safe and reliable operation of gas tankers and terminals
  - 1993: Polar Eagle and Arctic Sun, 83.5km$^3$, with IHI prismatic containment system begin service from Alaska to Tokyo
LNG Carrier Fleet

- **Current Fleet Profile**

  - Approximately 155 LNG carriers in operation with a total capacity of about 18 million m$^3$
    - 120 km$^3$ or larger ~ 125 carriers
    - 50 km$^3$ to 120 km$^3$ ~ 15 carriers
    - Less than 50 km$^3$ ~ 15 carriers
LNG Carrier Fleet

- **Current Fleet Profile**
  - About Fifty-five LNG carriers are currently under construction
    - 138 km³ or greater ~ 46 carriers
    - Less than 138 km³ ~ 9 carriers
    - 5 N/B delivered so far 2004
    - 6 new orders placed so far 2004
LNG Carrier Fleet

Historical LNG Fleet Growth

Source: The Gas Carrier Register 2003, Clarkson
Major LNG Trade Routes

Major LNG Trade Movements, 2002 (Billion cubic feet)
LNG Vessel Types and Particulars

- LNG Carriers are classified by their cargo containment designs

- Types of cargo containment systems:
  - Kvaerner-Moss spherical tank
  - Membrane system
    - Gaz Transport and Technigaz (GTT) Membrane systems
      - Mark III, No96, Cs1
    - IHI Prismatic
LNG Vessel Types and Particulars

Existing Worldwide Fleet
Cargo Containment System Market Share

- Kvaerner-Moss: 51%
- Gaz Transport: 37%
- Technigaz: 11%
- Various: 1%

Source: Lloyd’s Register Fairplay, July 2003
LNG Vessel Types and Particulars

- Kvaerner-Moss
LNG Vessel Types and Particulars

- Kvaerner-Moss
LNG Vessel Types and Particulars

- GTT No 96 Membrane Containment System
LNG Vessel Types and Particulars

- GTT No 96 Membrane Containment System

- Tank cross section showing dual membrane interior to hull tank
- Stacked plywood boxes covered by 0.7mm Invar membranes
- Invar anchor
- Perlite Insulation
- Prefabricated Plywood Box
- Box Anchor
LNG Vessel Types and Particulars

- GTT Mark III Membrane Containment System
LNG Vessel Types and Particulars

- GTT Mark III Membrane Containment System

Stacked foam panels covered by Triplex and Stainless Steel membranes

Tank cross section showing dual membrane interior to hull tank
LNG Vessel Types and Particulars

- IHI Self Supporting Type B Prismatic Tank

Inside View of SPB Tank

- Horizontal Girder
- Easy Inspection
- Pump Well
- Complete Discharge
- Cargo pump
- Spray pump
- Effective Purging
- Extended Filling Line
Safety and Risks of LNG Transportation

- LNG shipping industry has an excellent safety record
  - No shipboard fatalities over the life of the industry associated with cargo
  - No major losses of cargo and only one minor LNG onboard fire (lightning strike near vent riser, cargo tanks not affected)
  - Two groundings resulting in major hull breaches without cargo loss
Safety and Risks of LNG Transportation

- LNG shipping industry has an excellent safety record
  - Since 1974 there have been on average ~ 75 LNG carriers in operation, last major grounding incident was in 1980 with no loss of cargo
  - Over 33,000 LNG voyages covering more than 60 million miles during the history of the industry
  - LNG shipping is viewed as a lower risk vs. crude oil, all things being equal (i.e. operator experience, vessel size)
  - P&I insurance is ~ 25% less that for LNG carriers vs. crude oil carriers
  - Liability focus is on fire and damage vs. pollution
Technological Advances for LNG Carriers

- Containment Systems
- Onboard re-liquefaction
- Alternative Propulsion Units
Technological Advances for LNG Carriers

- Large LNG vessel Containment Systems

- Membrane containment system for LLNG ships considered more favorable design
  - More capacity vs. spherical ship of similar size
  - Suez Canal toll advantage
  - Faster cool-down of tanks
  - Lower cost due to inherent cost of the system and increased competition due to greater shipyard capacity
Technological Advances for LNG Carriers

Benchmark Membrane CLNG Ship
Representative 138 km$^3$, 4 cargo tanks
270m length x 43m beam x 11.5 draft

Qatar Membrane LLNG Ship (Q-Flex)
About 205 km$^3$, 5 cargo tanks
315m length x 50m beam x 12m draft

Qatar Membrane LLNG Ship (Q-Max)
About 250 km$^3$, 5 cargo tanks
345 m length x 55 m beam x 12 m draft
Technological Advances for LNG Carriers

Conventional design is steam turbine with duel fuel: HFO and boil-off

- Diesel more efficient and may be required for higher HP LNG vessels:
  - Slow speed diesel - twin screw fueled by HFO
    - Cannot burn boil-off, requires on board re-liquefaction
  - Medium speed dual fuel diesel - single or twin screw, direct or electric drive, fueled by MDO with boil-off or HFO
  - Gas turbines aero-derivative units - mainly twin screw, fueled with MGO or gas, possible waste heat recovery to achieve competitive efficiency and high flexibility but with increased investment
### New LNG Projects


<table>
<thead>
<tr>
<th>Project</th>
<th>Est. Capacity (MMtpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trinidad Train 4</td>
<td>5.2</td>
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<tr>
<td>Nigeria Trains 4, 5</td>
<td>8.4</td>
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<tr>
<td>Egypt</td>
<td>12.0</td>
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<tr>
<td>Norway (Snohvit)</td>
<td>4.0</td>
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<tr>
<td>Malaysia Tiga (Train 2)</td>
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<td>Australia</td>
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<td>Ras Laffan (Train 4)</td>
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<tr>
<td>Sakhalin</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>55.3</strong></td>
</tr>
</tbody>
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* 2003 Worldwide LNG demand about 125 MM tons

GTI & other industry sources
Qatar LNG Projects

- **RasGasII**: Requires 8 CLNG vessels for RG train 5. Production commences end 2006
  - Destination Europe

- **QatargasII**: Requires 16 LLNG vessels for QGII trains 4 and 5. Train 4 production commences early 2008
  - Destination UK

- 3-4 additional large trains planned to commence production by 2010-11, each requiring 10-12 Q-Flex size vessels
  - Destination US