Ship Transportation of Natural Gas

Market and Technology.

Presented by
Jan Koren,
Business Director – Tankers
26th May, 2005
The Scene is changing – what is happening?

- Dramatic increase in number of LNG carriers
- Significant increase of ship size and size of cargo tanks
- New yards (building and docking yards)
- New owners and ship managers
- New officers/crews and superintendents
- New terminals and terminal operators
- New trades – including heavy weather (wind, waves, darkness, cold climate, etc)
- Spot trade – partly filled tanks. Sloshing?
- Longevity: 40 years life expectancy?
- Heavier competition – lower profit margins
- Compressed Natural Gas (CNG) arriving as a supplement to LNG

Consequences for safety?
Transportation of Natural Gas

- Pipeline
- By ship as liquefied natural gas (LNG)
- By ship as compressed natural gas (CNG)
**What is LNG/CNG?**

<table>
<thead>
<tr>
<th>Liquefied Natural Gas</th>
<th>Compressed Natural Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>• cryogenic liquid</td>
<td>• pressurized gas</td>
</tr>
<tr>
<td>• -160°C</td>
<td>• 45°C to -30°C</td>
</tr>
<tr>
<td>• 0.25 bar</td>
<td>• 100-275 bar</td>
</tr>
<tr>
<td>• 0.42 t/m³</td>
<td>• 0.2-0.25 t/m³</td>
</tr>
<tr>
<td>• gas/liquid: 600/1</td>
<td>• gas/liquid: ~ 300/1</td>
</tr>
</tbody>
</table>
Energy loss by gas transformation and transportation

Current status (typical figures)
• Pipelines : 3-5 % loss
• CNG ships : 5-8 % loss
• LNG ships : 15 % loss
• GTL : 30-40 % loss

Future technological developments may change the picture
LNG / CNG business chains

- CNG = Compressed Natural Gas
Marine transportation alternatives

![Diagram showing the relationship between Distance to Market (kNM) and Production Volume (mill. MT/y) for different transportation methods: Pipeline, LNG, CNG, and NON-COMMERCIAL.](image-url)
Present and future LNG Trades

Well established main LNG trades
New main LNG trades
Growth in LNG Shipping
DEMAND OUTLOOK FOR LNG TRADE 2003 – 2009

Average yearly growth in traded volume:

- 1990’s: 6.6%
- 1998-2003E: 8.2%
- 2003-2009: 9.2%

R.S. Platou
Economic Research a.s

MANAGING RISK
Development of LNG Fleet

[Bar chart showing the development of the LNG fleet from 1999 to 2010, with data points for Fleet Start, Deliveries, Scheduled Deliveries, Estimated Deliveries, and Scrapping.]
LNG Fleet Development

Source: Fairplay
# World LNG Fleet

31 December 2004

<table>
<thead>
<tr>
<th></th>
<th>World</th>
<th>DNV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Fleet</td>
<td>176</td>
<td>25 (14%*)</td>
</tr>
<tr>
<td>Order book</td>
<td>108</td>
<td>22 (20%*)</td>
</tr>
</tbody>
</table>

* Based on number of ships
2 dominating LNG Cargo Containment Principles

- Spherical tanks (Moss Design):

- Membrane Design:

3 membrane designs: - Mark III
- GT NO 96
- CS 1
Membrane Concept

INTEGRATED LNG CARGO TANK

Complete double hull ship structure
Primary & secondary membranes
Load bearing cryogenic insulation
Membrane Cargo Containment System

MARK III
SUS Membrane Standard Corner Panel Mark III
**Triplex Membrane Mark III**

- Aluminium foil between two glass cloths
- Glued between primary and secondary insulation during prefabrication
- Triplex strip joining panels glued after erection
Highlighting Critical - Fatigue

Details to pay particular attention to:

1. Hopper tank, lower knuckle
2. Hopper tank, upper knuckle
3. Side longitudinals
4. Alignment, bulkhead - bottom structure
5. Deck opening

Life expectancy 40 years for LNG carriers
Sloshing simulations - COMFLOW animations

80% filling
-bow quartering seas

30% filling
-bow quartering seas
The Future Membrane LNG Carrier Design?

COP Marine envisages LNG super tankers with innovative trapezoid-shaped tanks for containing the cargo that will allow use of shorter vessels.
New Membrane Concept

Prism Tank Development
(patents pending)

Conventional Shape
Large free surface
Sloshing
Limited Volume for low SG LNG
Boil Off ~0.15%/day

New COP Prism Tank Shape
Small free surface
Limited Sloshing
Increased Volume for low SG LNG
Boil Off ~0.13%/day
LNG Technology Support by DNV

- Development of Moss design was heavily supported by DNV laboratories and in-house experts during the 60’s.
LNG Membrane Design invented by DNV

- Invented by DNV, first membrane model tank, built in Oslo 1962
- Patented and later sold to France
Different Containment Systems: Market Shares

Change in containment system preference

Deliveries by containment system

- CS1
- GT
- Moss
- TGZ

Source: Fairplay, December 2004

Spherical/membrane: ~ 20/80
Coastal LNG carrier: “Pioneer Knutsen”

- delivered 2004, 1 100 m3 cargo carrying capacity
- 2 x engines for gas fuel only + 2 diesel engines, - diesel electric propulsion
- 2 pods for main propulsion
- redundant propulsion
## Gas emissions from LNG carriers

<table>
<thead>
<tr>
<th></th>
<th>Fuel</th>
<th>NOx</th>
<th>SOx</th>
<th>CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam turbine</td>
<td>HFO + LNG</td>
<td>200</td>
<td>2.400</td>
<td>180.000</td>
</tr>
<tr>
<td>Low speed diesel</td>
<td>HFO</td>
<td>3.950</td>
<td>1.800</td>
<td>120.000</td>
</tr>
<tr>
<td>+ re-liquefaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual fuel electric</td>
<td>LNG only</td>
<td>240</td>
<td>0</td>
<td>100.000</td>
</tr>
<tr>
<td>Gas turbines and</td>
<td>LNG only</td>
<td>850</td>
<td>0</td>
<td>108.000</td>
</tr>
<tr>
<td>COGES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: ALSTOM

Emissions: Tonnes / year / ship
The Capacity Advantage

Based upon an LNG carrier of around 200,000 m³ capacity – Twin Skeg

Slow Speed Diesel with Reliquefaction

Frame No. 69

Rolls-Royce data

MANAGING RISK
LNG storage and re-gasification
LNG Trade in cold Climate

- Cold climate: Is this the future environment for LNG carriers?
DNV has an additional class notation DEICE:

*Technical standard to maintain safety and operability*
Competence and performance of crew is essential for safe operations.

Availability of experienced personnel?
Training/Experience!
Experienced personnel, - a serious challenge!

.. insufficient supply of competent people may have a knock-on effect on other shipping sectors?
Compressed Natural Gas - CNG

- Why is it necessary to look for new concepts for NG transportation?
  - more than 50% of offshore NG is stranded: small to medium size fields in remote areas

- What are the most important performance factors of CNG concepts?
  - Containment system
  - Operation & logistics
Recent CNG Carrier Concepts

• Many concepts proposed - most are based on transportation in “pipeline” pressure vessels
  – Williams Coselle (steel, coiled, 275 bar, ambient)
  – Knutsen (steel, vertical pipes, 250 bar, ambient)
  – EnerSea (steel, vertical pipes, 130 bar, -29°C)
  – Trans Ocean Gas (composite)
  – CETech: (Statoil, Teekay, Höegh)
    (steel, horizontal pipes, 200-250 bar, ambient)
  – TransCanada Pipeline (wrapped steel liner)
  – Institute Français du Pétrole (IFP)
    (steel/GRP composite hybrid, 130-135 bar, -35°C)
Recent CNG Carrier Concepts

- TransCanada Pipeline Ltd.
- Williams (Coselle)
- Enersea
- Knutsen OAS
- Trans Ocean Gas
- CETech
Ship and cargo containment cost

LNG : Proven concept with established cost level

CNG : Ship cost well established as for normal cargo vessels: Cost of cargo containment system becomes key to success for CNG
CNG Cargo containment cost

- If designed as normal pressure vessels the weight becomes excessive

- If designed according to modern risk based standards for offshore pipelines, CNG may become viable
The DNV CNG Rules

• Issued January 2003

• Based on DNV pipeline standard, DNV-OS-F101:
  – Used for most deepwater offshore pipelines today
  – Used for all known CNG concepts

• CNG: based on safety level equivalent to LNG (International Gas Code)
End of Presentation

Thank you!