Marine Transportation of LNG

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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°C (-260°F)
  - LNG ~ 1/600 volume of Natural Gas, making it practical to transport by ship

What is LNG?

- Properties and characteristics
  - Typically ~ 95% methane (CH_4) 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

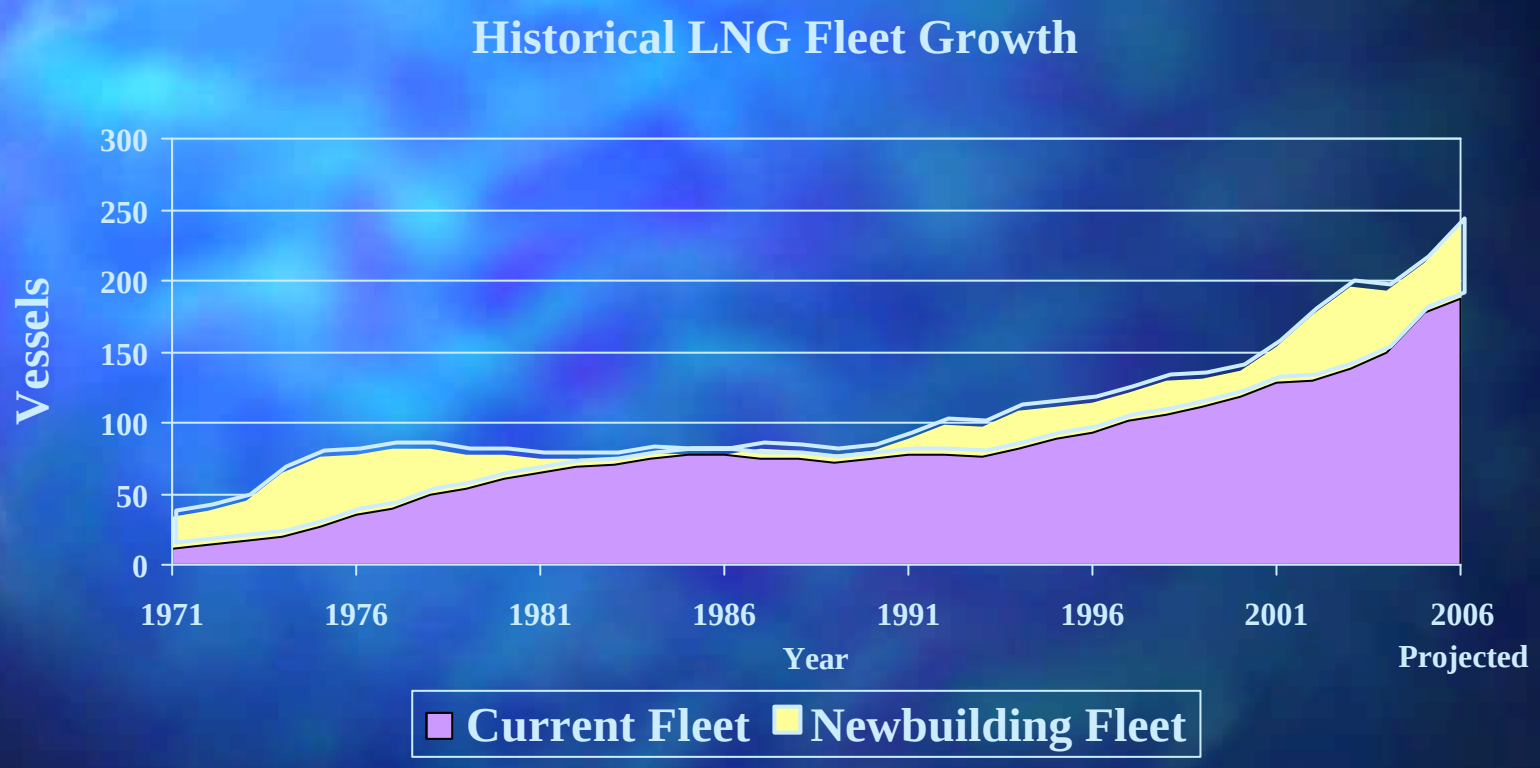
LNG Carrier Fleet

- 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

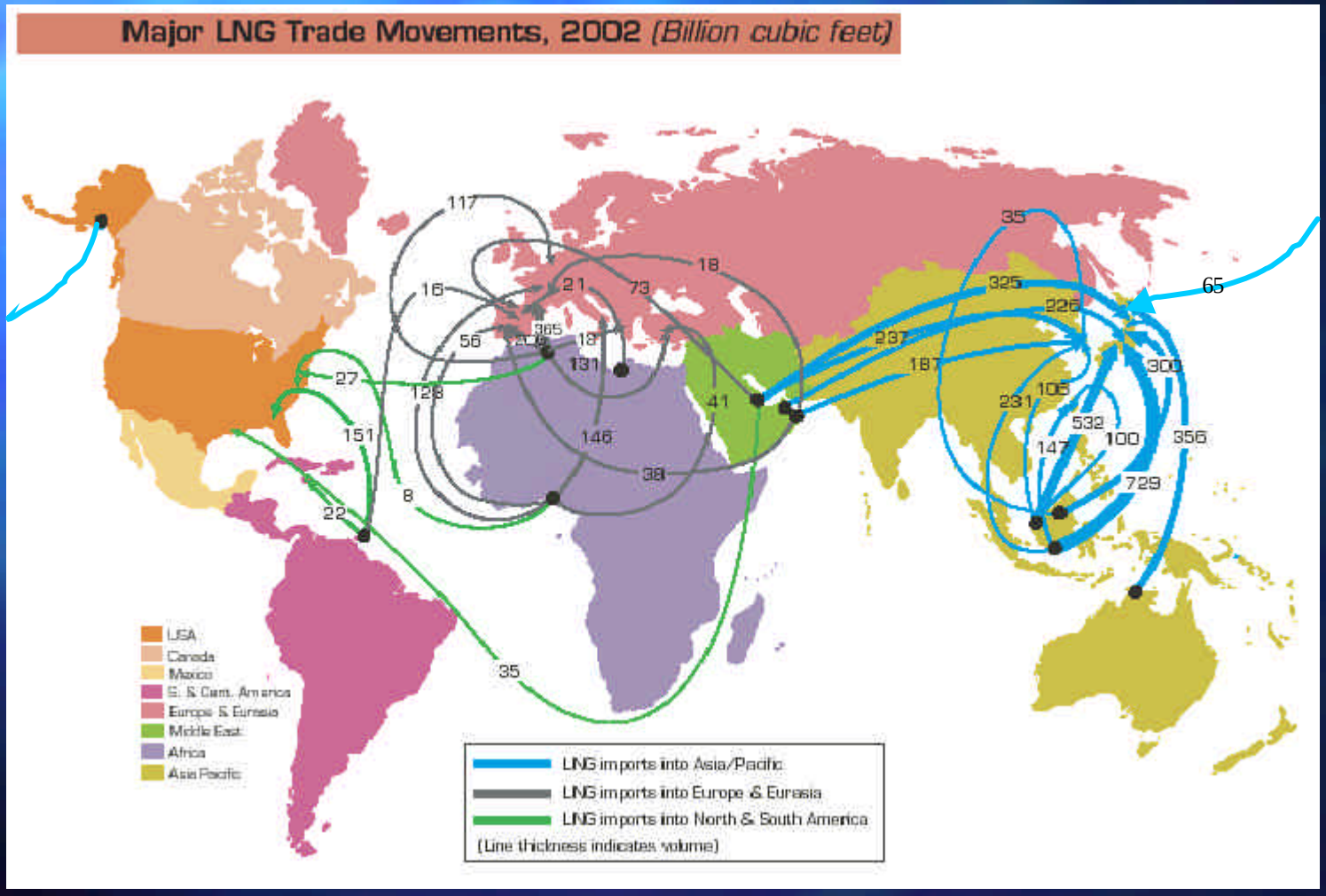
- Current Fleet Profile
  - About Fifty-five LNG carriers are currently under construction
    - 138 km^3 or greater ~ 46 carriers
    - Less than 138 km^3 ~ 9 carriers
    - 5 N/B delivered so far 2004
    - 6 new orders placed so far 2004

LNG Carrier Fleet



Source: The Gas Carrier Register 2003, Clarkson

Major LNG Trade Routes



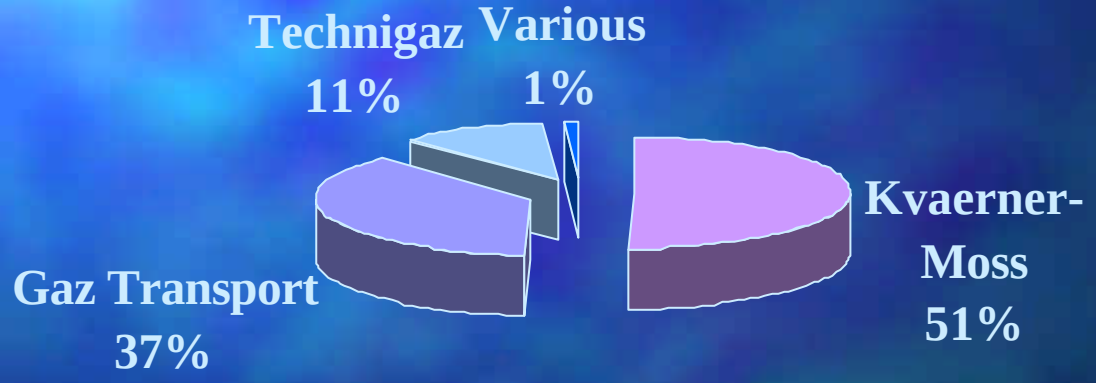
LNG Vessel Types and Particulars

- 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



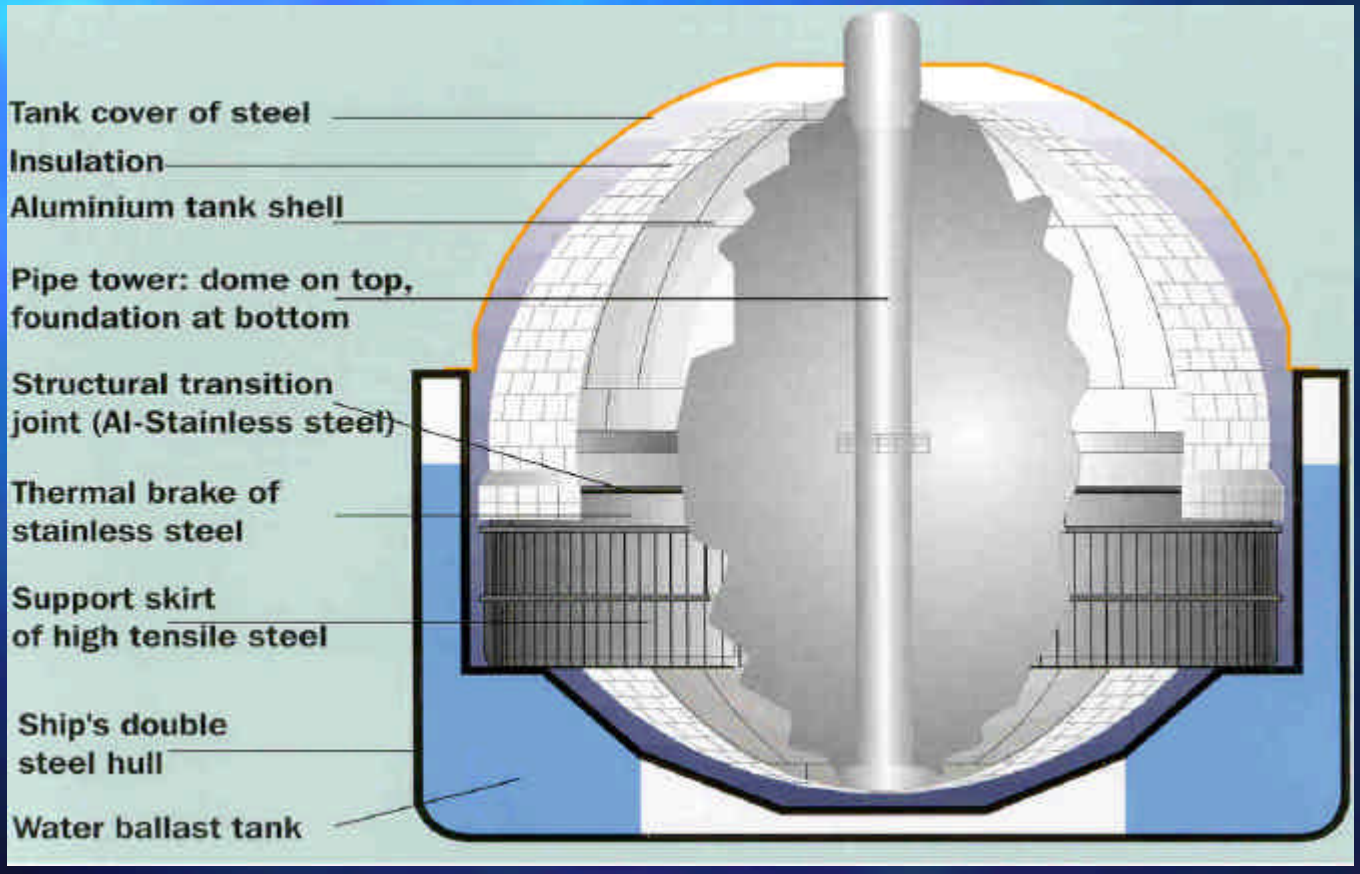
Source: Lloyd's Register Fairplay, July 2003

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

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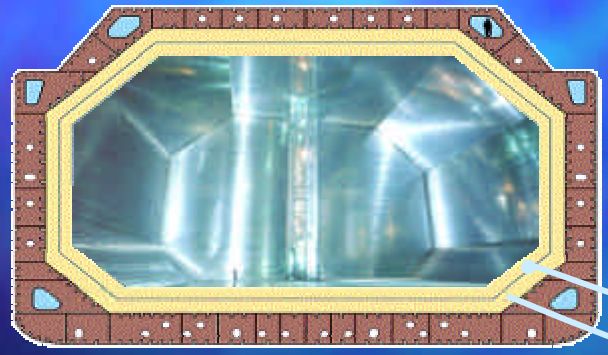
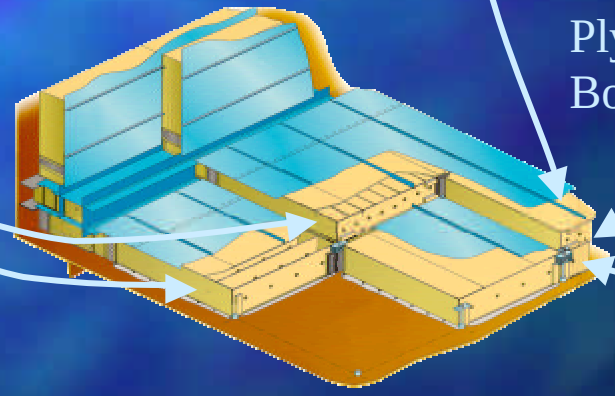


Tank cross section showing dual membrane interior to hull tank



Stacked plywood boxes covered by 0.7mm Invar membranes

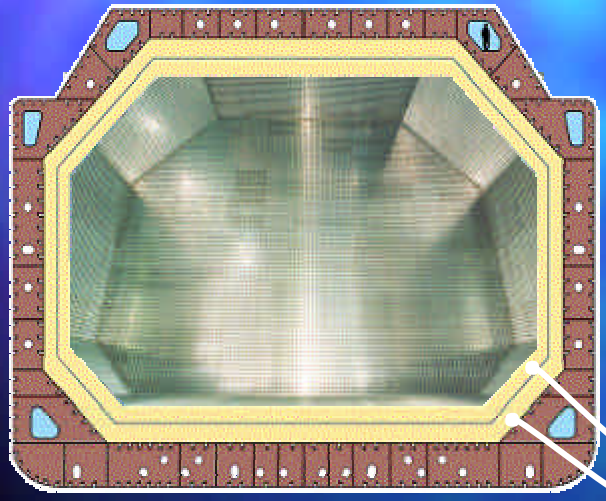
LNG Vessel Types and Particulars

- **GTT Mark III Membrane Containment System**

LNG Vessel Types and Particulars

- GTT Mark III Membrane Containment System

Stainless Steel



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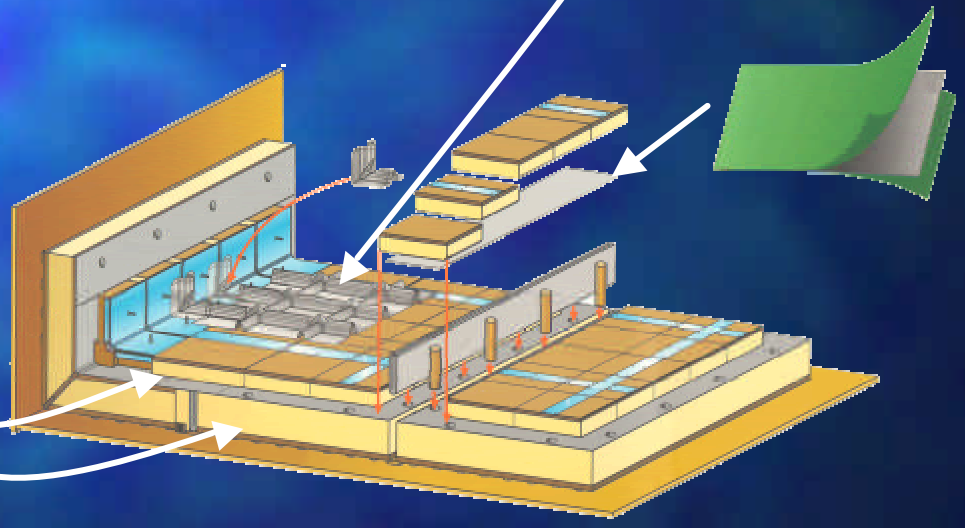
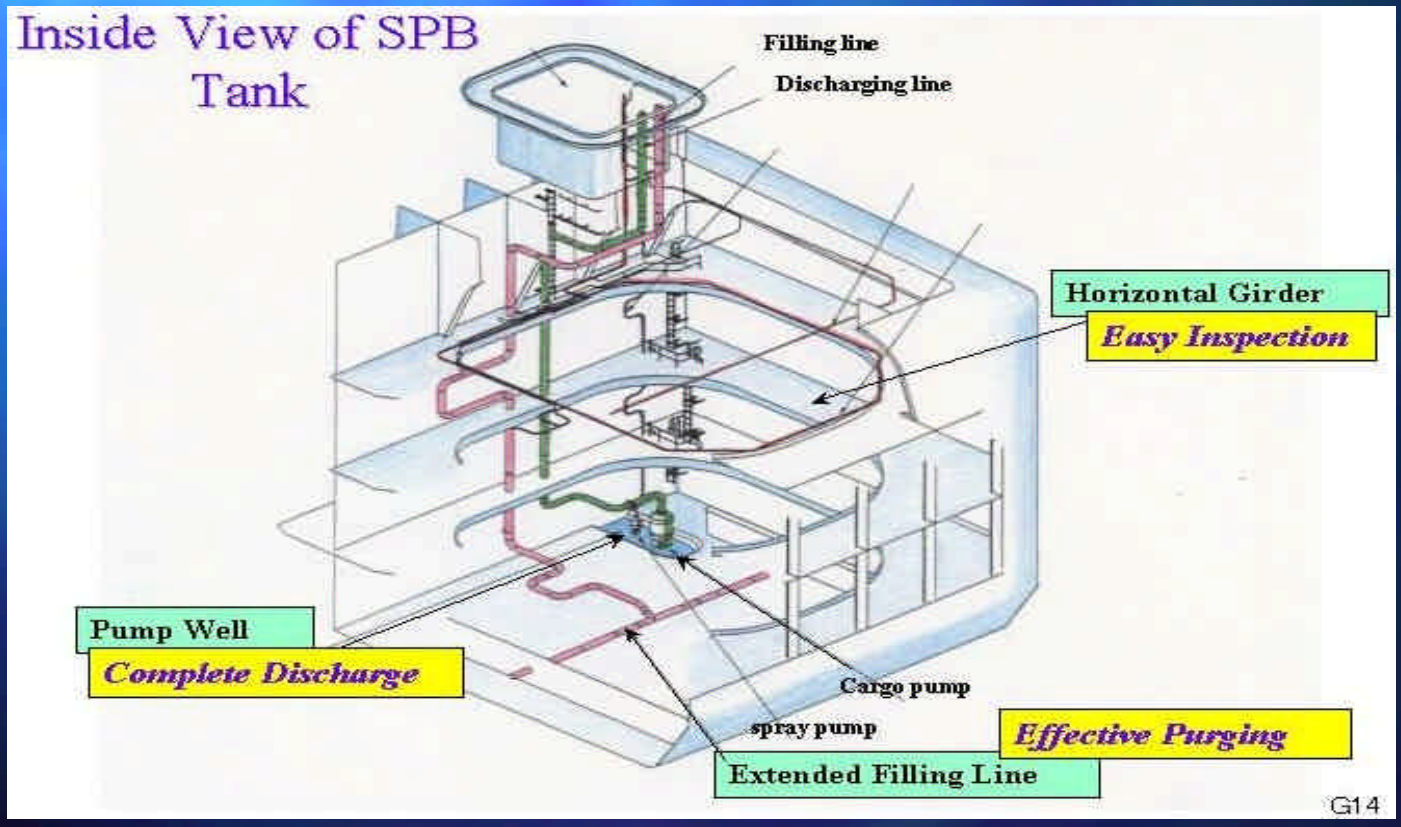


Stacked foam panels covered by Triplex and Stainless Steel membranes

LNG Vessel Types and Particulars

- IHI Self Supporting Type B Prismatic Tank



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 on-board 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

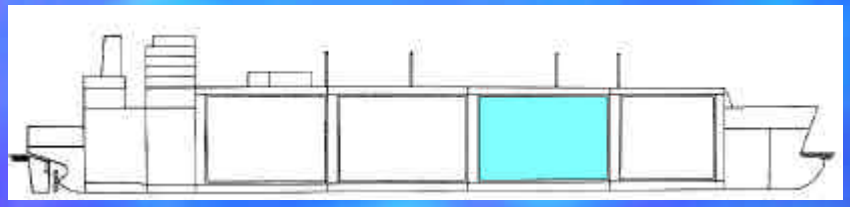
Technological Advances for LNG Carriers

- Containment Systems
- Onboard re-liquefaction
- Alternative Propulsion Units

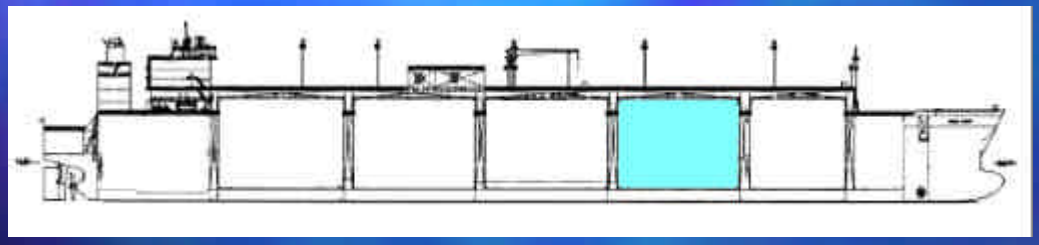
Technological Advances for LNG Carriers

- 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 km3, 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 LLNG 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

Liquefaction Capacity* Under Construction (2003)

Project	Est. Capacity(MMtpa)
Trinidad Train 4	5.2
Nigeria Trains 4, 5	8.4
Egypt	12.0
Norway (Snohvit)	4.0
Malaysia Tiga (Train 2)	3.4
Australia	8.0
Ras Laffan (Train 4)	4.7
Sakhalin	9.6
Total	**55.3**

* 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