Warwick Pointon
General Manager
Shipping Strategy and Development
Woodside Energy Ltd (Perth)

"LNG Shipping Basics"

Woodside Presentation

LNG Shipping Basics
MLAANZ Nov 2008

An operational overview of the expanding marine transportation of LNG

What is LNG?

LNG : Liquefied Natural Gas

- **Natural gas is a mixture of hydrocarbon gases**
  - **Methane (approx 80 to 98% depending on the reservoir)**
  - **Contains some heavier hydrocarbons:**
    Ethane, Propane, Butane & Pentanes C5+ as well as Nitrogen
- **Natural gas may be found in oil and gas reservoirs "associated gas" or from gas fields "non-associated gas"**
- **Natural gas is non-toxic, non-corrosive, has high calorific value and is clean burning.**

What is LNG?

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LNG : Liquefied Natural Gas

- LNG is natural gas converted to a liquid by reducing its temperature to its boiling point -160 degrees centigrade.
- LNG Density is typically in the range 0.421 – 0.466
- LNG is a clear, colourless, non corrosive liquid at atmospheric pressure
- Methane cannot be converted to liquid under pressure alone (unlike propane and butane LPG's)
- Temperature must be reduced below –80C before it can be converted to liquid under pressure

Why Make LNG?

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1 cubic metre of LNG = 600 cubic metres of Natural Gas

Reducing volume of gas to 1/600th makes transportation by ship economic

<u>The only reason to make large volumes of LNG is to enable sea transportation</u>

- LNG is also used for peak shaving (Localised generation)
- LNG Trucking as an alternate to utility pipeline distribution. (mainly as an offshoot of a major export or import facility)

- Rule of thumb - Economics for transporting Natural Gas
  - Gas by pipeline < 4000 km - cost of land pipeline plus cost of initial gas treatment
  - LNG shipping > 4000 km - LNG capital, plant, ships and opex
  - CNG (compressed natural gas) shipping 1000 to 4000 km (no commercial project developed)

Many factors influence shipping decision in addition to distance : pipeline route – subsea or land, type of terrain, security, politics, etc.

LNG History

1917: First LNG plant commenced operation West Virginia. (peak shaving)

1944: Cleveland tragedy – Storage tank ruptured, many killed

1959: "Methane Pioneer", carries 5,000 m3 of LNG between Lake Charles and UK demonstrating feasibility of marine transportation

1964: First commercial LNG export terminal Arzew Algeria operating "Methane Princes" & "Methane Progress", 27,400 m3, become first commercial LNG vessels, operating between Algeria and the UK

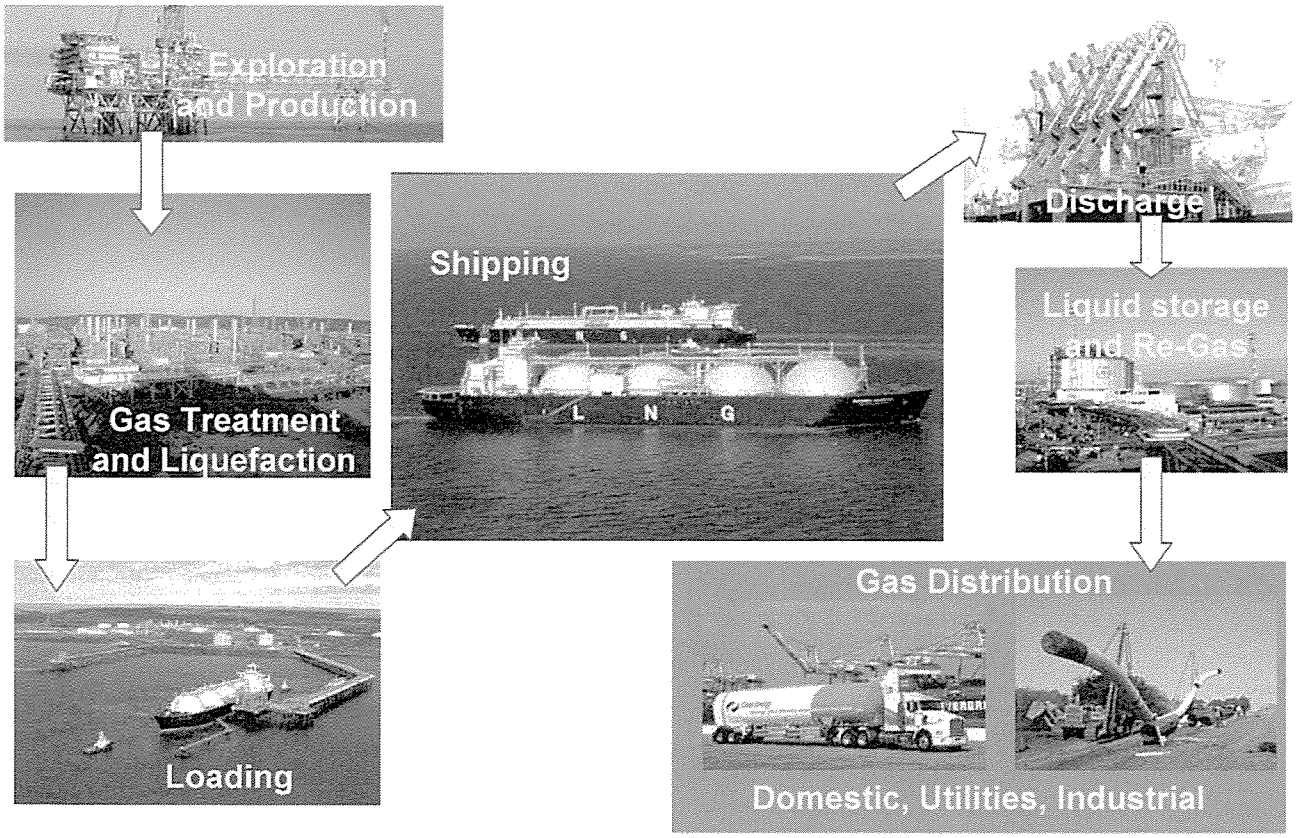
1969: Gas Transport "Polar Alaska" & "Arctic Tokyo", 71,500 m3, begin service from Alaska to Tokyo – first to Japan.

1975: 100,00 m3 size exceeded with delivery of French built BEN FRANKLIN, 120,000 m3

1979: Formation of Society of International Gas Tanker and Terminal Operators (SIGTTO) to promote safe and reliable operation of gas tankers and terminals

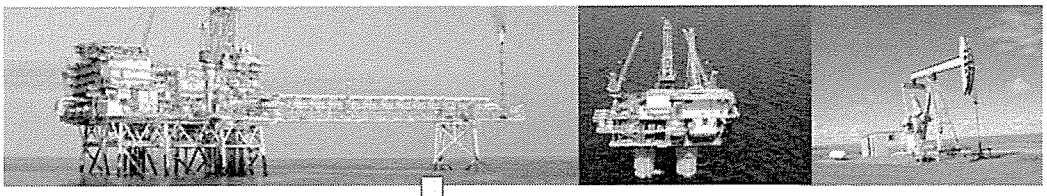
1989: North West Shelf commences delivery First Australian LNG to Japan

LNG Value Chain

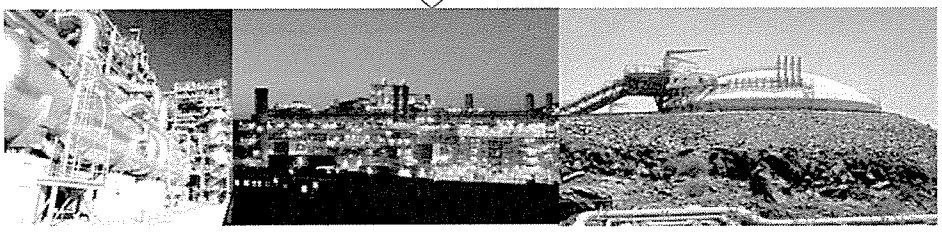


LNG Value Chain

Exploration and Production



Gas Treatment and Liquefaction



Gas treatment

Removal of any liquid hydrocarbons (oils, condensate)

Removal of acid gases such as Hydrogen Sulphide, Mercury etc

Removal of Carbon dioxide, water

Staged cooling process (air or sea cooled heat exchanges)

LNG Shipping – what is different

The Market:

LNG is sold on basis of energy content, usually $US per mmbtu (per million British Thermal Units).

The composition of the gas is important to the buyer (percentage of methane and other gases), the export markets have differing heating value requirements.

1 Cubic metre LNG weighs approximately 0.46 tonnes.

Energy equivalents for 1 Cubic Metre of liquid			
LNG	23.9 mmbtu	Petrol	35 mmbtu
Butane	29.6 mmbtu	Ship Bunkers	36 mmbtu
Coal	15 to 21 mmbtu	Diesel	39.6m mmbtu

LNG Shipping – what is different

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The Market:

Traditionally LNG has been sold through long term agreements (20 years).

Huge investments in infrastructure (Buyer and Seller) and shipping needed certainty of supply and income.

Buyers and sellers entered into Sales and Purchasing Agreements (SPA's). Shipping requirements are part of these agreements. LNG sold on DES Terms (Delivered ex ship) with Sellers providing ship by ownership or long term charters.

Last 10 years has seen the growth of the spot market with FOB sales (Free on board) where the Buyer or in a few cases, traders, have bought cargoes at the loading terminal.

Buyers in the Asian market have been building there own shipping capacity looking to adjust the balance in the control of shipping.

LNG Shipping – what is different

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Control of Shipping:

For LNG Sellers (producers), control of shipping is a core value issue to ensure loading schedules are tuned to production. Shutting down or slowing LNG train production needs to be avoided.

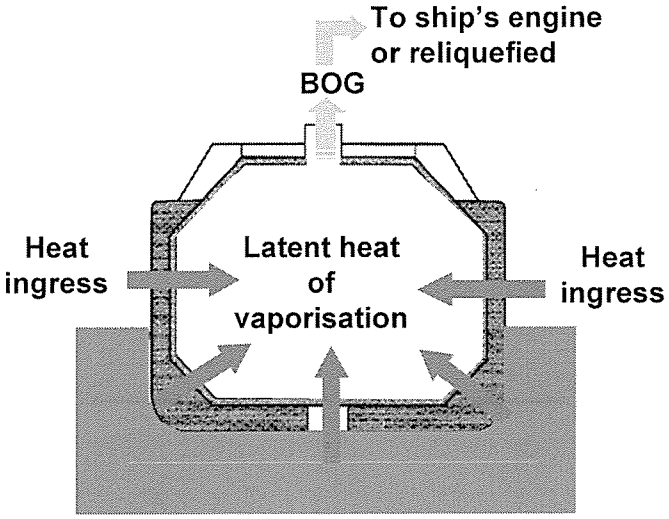
Control of shipping does not necessarily require "ownership" or "operatorship", charters, both short and long term provide sufficient control.

Having certain abilities to "tune" an FOB ship schedule and heel management can also provide sufficient "control" - (arrival, loading schedules and cargo heel management).

Note: To have involvement in voyage tuning of FOB ships requires consideration of the apportionment of shipping and commercial liabilities.

LNG Shipping - Containment

- LNG Carried at boiling temperature -160 centigrade
- Carried in non pressurised tanks (atmospheric pressure)
- Cargo is boiling therefore continually creating vapour (Boil Off Gas - BOG)
- BOG can be reliquefied or used for propulsion (mostly used for propulsion)
- LNG Cargo is measured by ship's systems not by shore tank systems



(Auto refrigeration)

LNG ships are designed for an average of 0.15% Boil Off per day

Laden approx 0.2%

Ballast approx 0.1%

9 day voyage to Japan with port time:

Approximately 2 to 2.5% of cargo is boiled off.

LNG Shipping - Cargo Custody Transfer

Custody Transfer Measurement System. (CTMS)

- Cargo volume loaded and discharged is measured by the ship's CTMS.
- Tank volumes, temperatures and pressure are automatically read and provide the volume on board at the start and completion of cargo.
- Systems are certified and must meet fiscal requirements, most ships will have a Japan Customs Certificate which is acceptable world wide.
- Systems use Radar, ultrasonic or capacitance in tank measuring systems and are required to have a back up, usually a mechanical float gauge.
- Calculations are all computerised, however some customers insist on surveyors doing a back up hand calculation!
- CTMS measures the cargo in the tanks, if gas is being burned while alongside for ship power will not be accounted for by the CTMS. It can be measured by the ship but not as accurate. Presently some customers insist on burning HFO or Diesel during discharge. There are also some fiscal issues.

LNG Shipping - Propulsion Options

Use of LNG cargo for ship's fuel:

Only LNG cargoes may be used for ship fuel

There have been some changes in the last five years with respect to LNG ship engines and the treatment of boil off.

The vast majority of the world LNG Fleet is powered by steam turbines burning LNG "Boil Off" with or without additional HFO (Heavy Fuel Oil).

Last 5 years Duel Fuel Diesel Electric (DFDE) ships burning either "Boil Off" or Diesel (and now some which can burn HFO) have been introduced.

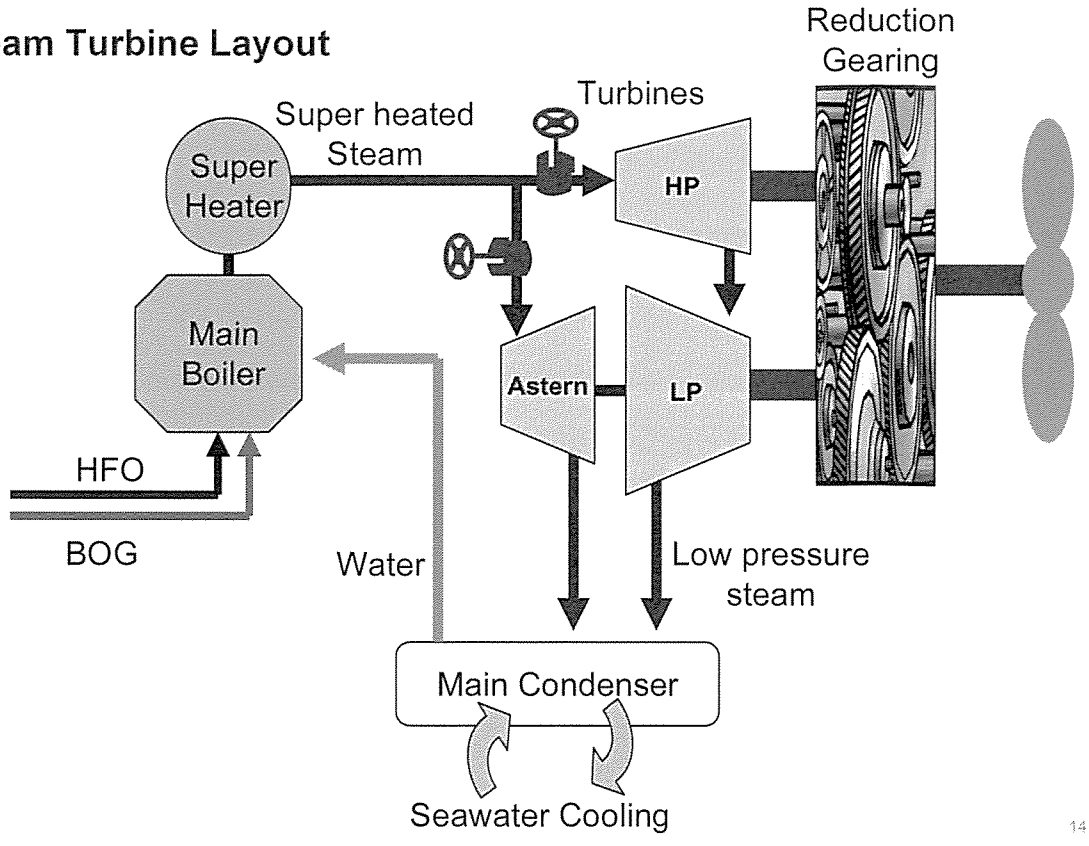
Except for a small amount of diesel for pilot fuel, DFDE cannot burn a combination of BOG and Diesel or HFO.

For long haul market Gulf to US - Q Flex and Q Max now being built with slow speed engines burning HFO only with reliquefaction for LNG.

Where boil off rate is not sufficient to maintain required speed, ships supplement with HFO (Steam ships) or by "forcing" more vapourisation.

LNG Shipping - Propulsion Options

Basic Steam Turbine Layout



LNG Shipping - Propulsion Options

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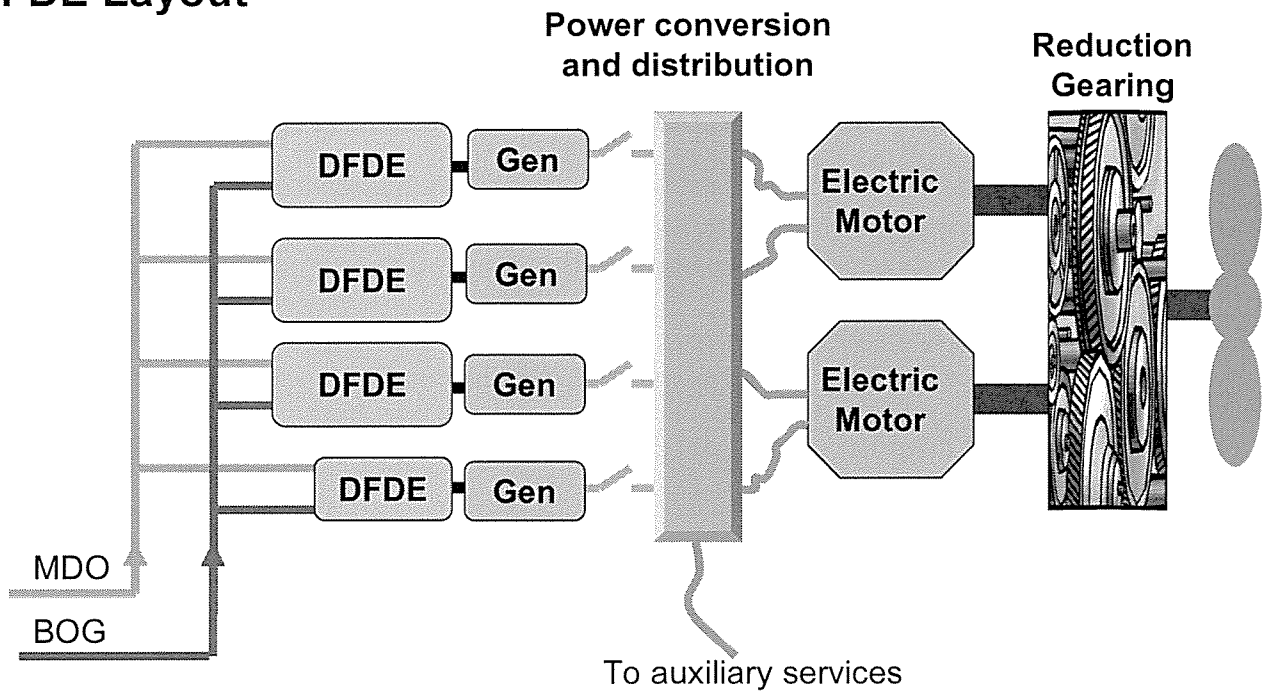
DFDE Layout



LNG Ship – Propulsion Options

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Steam Turbine (ST):

- Benefits: High reliability, low maintenance costs, high fuel flexibility
- Challenges: Low fuel efficiency
- Environment: High CO2, low NOx & SOx

Dual/Tri Fuel Diesel Electric (D/TFDE):

- Benefits: Higher fuel efficiency, higher redundancy (multi-engines)
- Challenges: Higher capital cost, lower fuel flexibility, high maintenance costs
- Environment: Lower CO2, low NOx & SOx

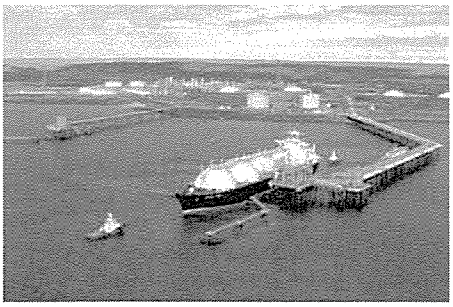
Slow Speed Diesel with Re-Liquefaction (SSDRL):

- Benefits: Highest fuel efficiency and cargo deliverability
- Challenges: High capital cost (re-liquefaction), no fuel flexibility, high maintenance
- Environment: Lower CO2, high NOx & SOx

Choice of propulsion system is highly correlated to:

- Commercial drivers (fuel savings vs. flexibility vs. maintenance)
- Type of trade (point-to-point, short or long voyages, merchant trading)
- Relative experience of shipping organisation

LNG Shipping - Loading Operations



- Ships normally arrive Cold – ready to load
  - Usually on regular round voyage (temp circa -120 mostly C2's etc)
- Warm - gassed up – needing cooldown
  - Depending on circumstances can need partial or full cooldown.
- Warm - not inerted – needing "Gas up" and cooldown
  - From dry dock, lay up, repairs etc.

Who pays for cooldown? SPA and/or Time Charter reference. Full cooldown can require more than 500 tonnes LNG.

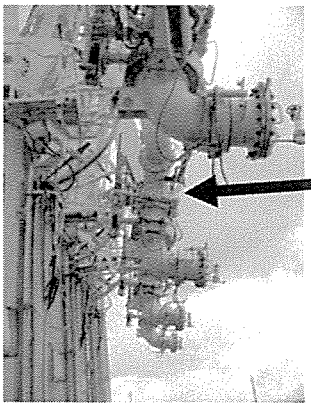
"CTMS" Custody Transfer Measurement System.

- Before ship manifold valves opened, cargo measured on board.
- On completion of loading and closure of ship manifold valves.

During loading, displaced and "boiled off" vapour returned to shore, some used in utilities some flared. How is this accounted for?

Is burning of gas in ship boiler/generators allowed during loading? It is not accounted for in CTMS

LNG Shipping - Discharge Operations

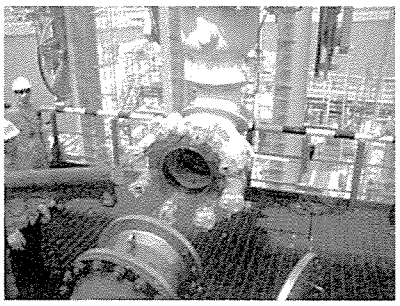


Loading and Discharge "Hard" arms

Emergency Shut Down Valve (ESD)

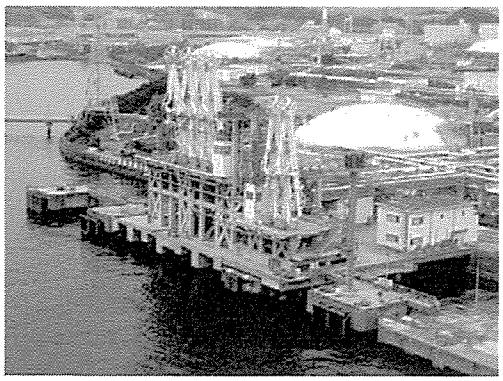
ESD 1 stops cargo

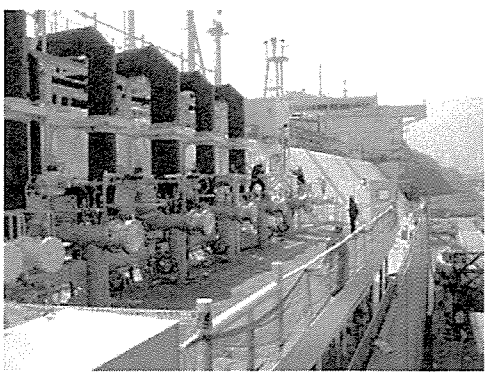
ESD 2 disconnects arm



Cargo Measurement by ship system

Vapour returned from shore to displace liquid discharged

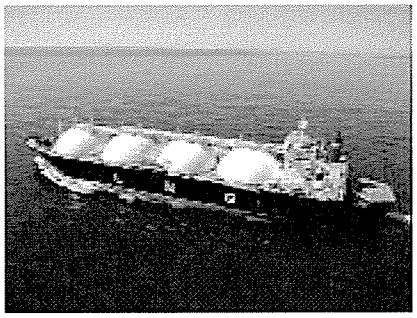




LNG Ship Voyage

Laden Passage

Cargo boils off and most ships use gas for propulsion – Percentage "boil of" greater than for ballast passage



Boil Off

The SPA and Time Charters will reflect how gas used by ship is accounted.

What happens if there is breakdown? cargo continues to boil off.

Ballast Passage

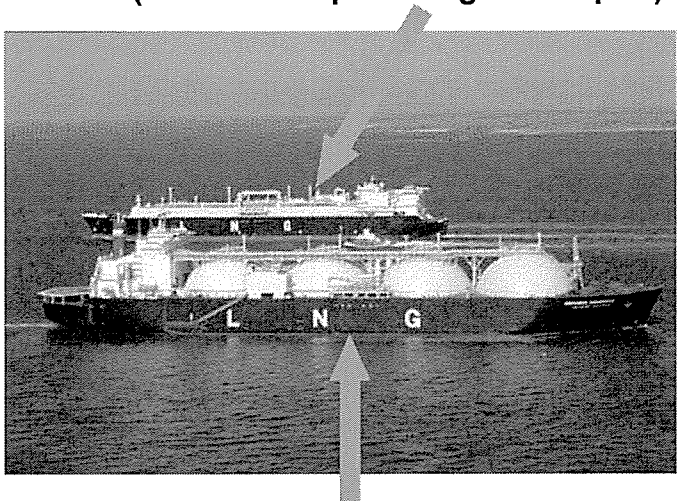
Cooldown for LNG ships from ambient temperatures takes between 12 and 24 hours and utilises a large amount of LNG which vapourises and is returned ashore, some used for terminal utilities but a large proportion is flared.

Avoiding cooldowns is preferred so a small proportion of LNG is kept on board as a "heel" after discharge for ballast passage propulsion and to keep ships tanks cold and ready to load as well as acting as fuel (usually arrive -110 to -120 C2+ Ethane etc).

LNG Shipping Containment Systems

Ship Types (Cargo Containment systems)

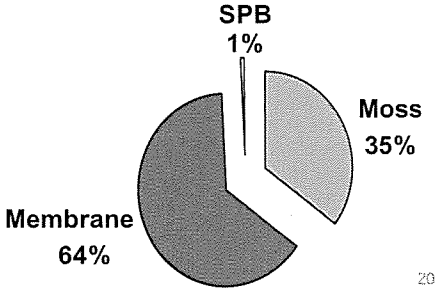
Membrane: GTT Mark III or GTT No 96 (plus CS1)
(other concepts being developed)



Self supporting tank: Kvaerner Moss

Self supporting tank: IHI SPB

Ships by Containment 2007



LNG Shipping Containment Systems

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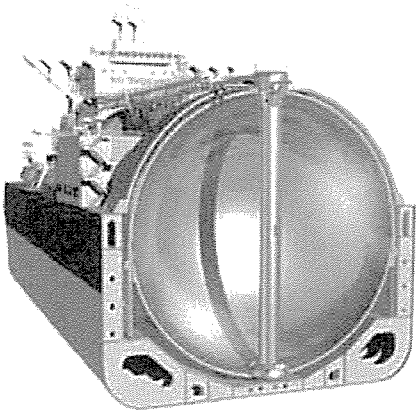
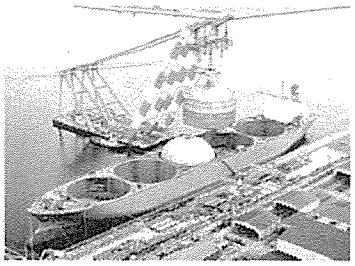
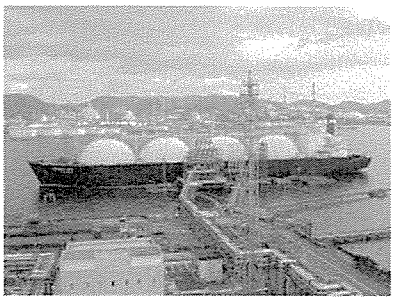
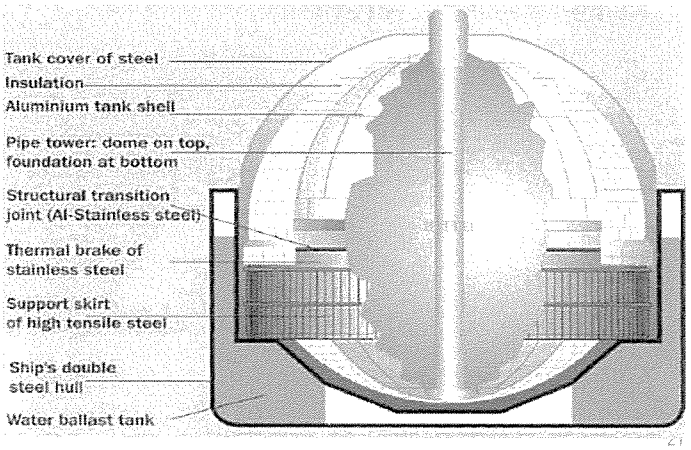
Self supporting tank: Kvaerner - Moss









Cooldown approx 24 hours

No sloshing, robust tanks

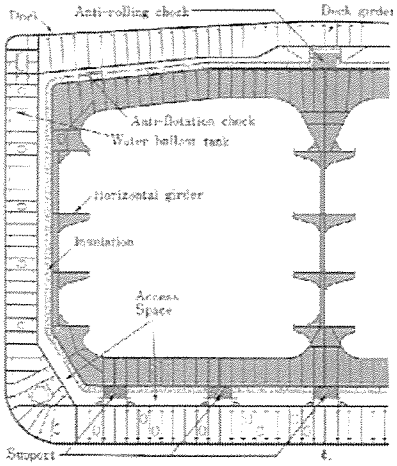
Large windage

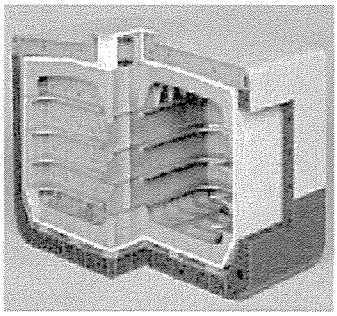
not good use of hull space

LNG Shipping Containment Systems

WOODSIDE

Self supporting tank: IHI SPB





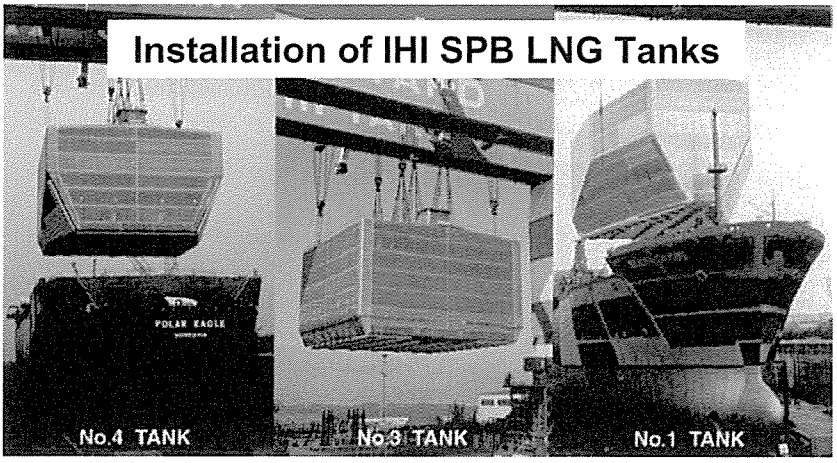
Cooldown approx 24 hours

No sloshing, robust tanks

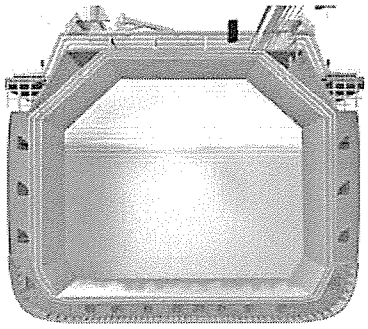
Good use of hull space

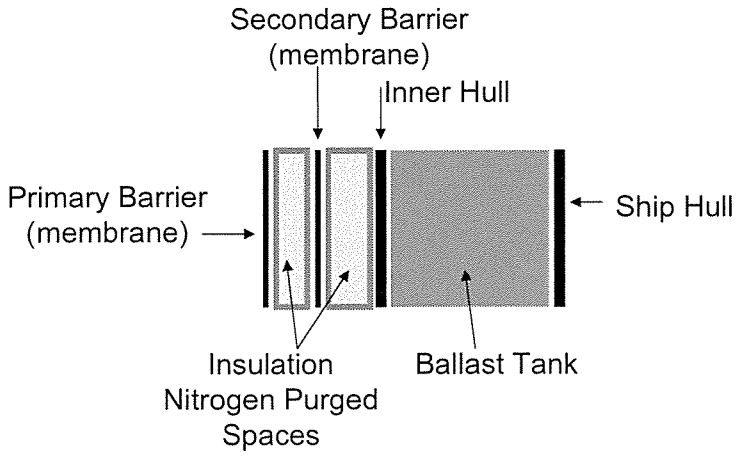
Most expensive system

Potential for FLNG



Membrane containment system



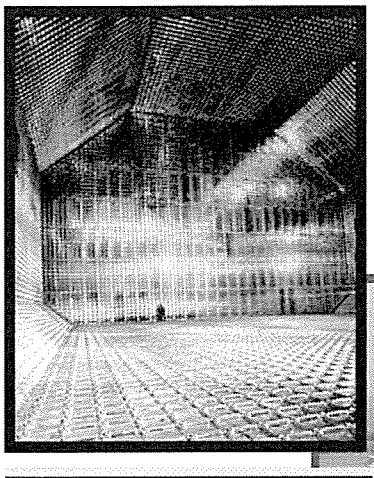


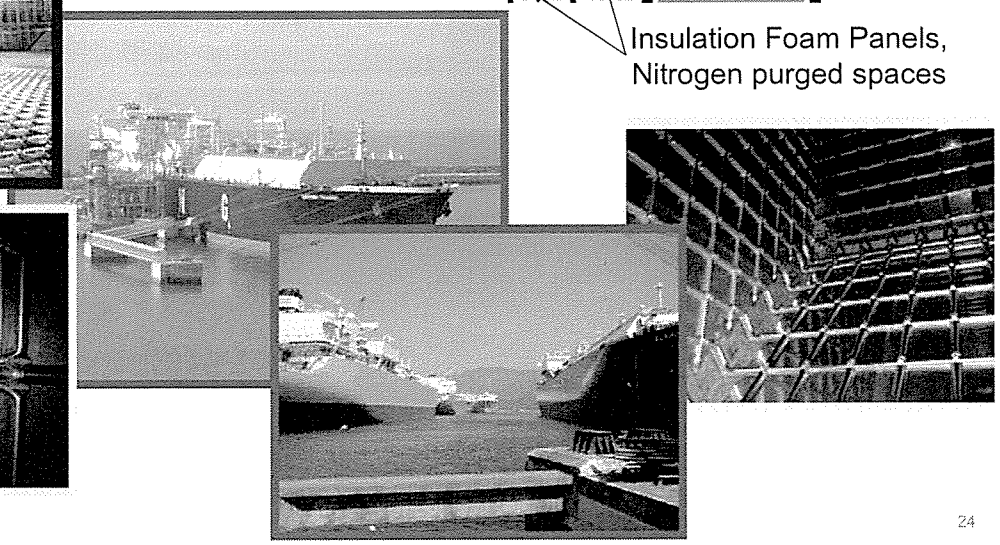
Cooldown approx 12 hours

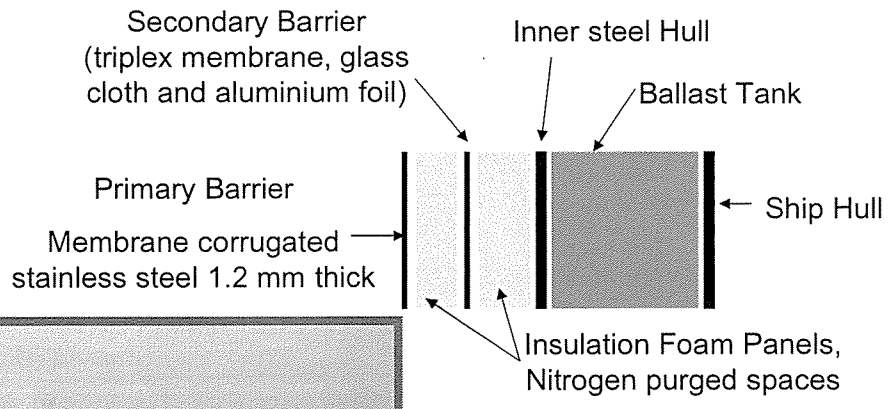
Sloshing issues, tanks not robust

Efficient use of hull space

Membrane: GTT Mark III

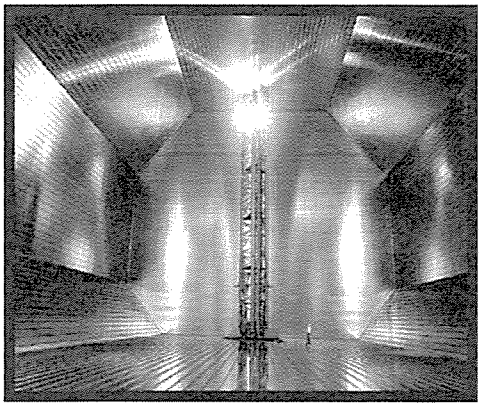


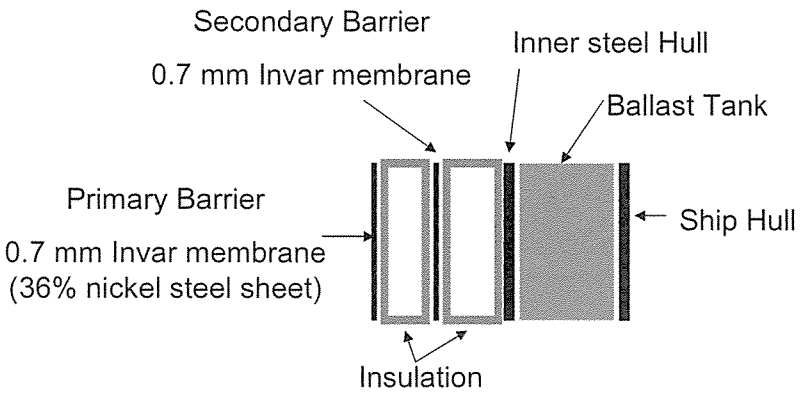




LNG Shipping Containment Systems

Membrane: GTT No 96

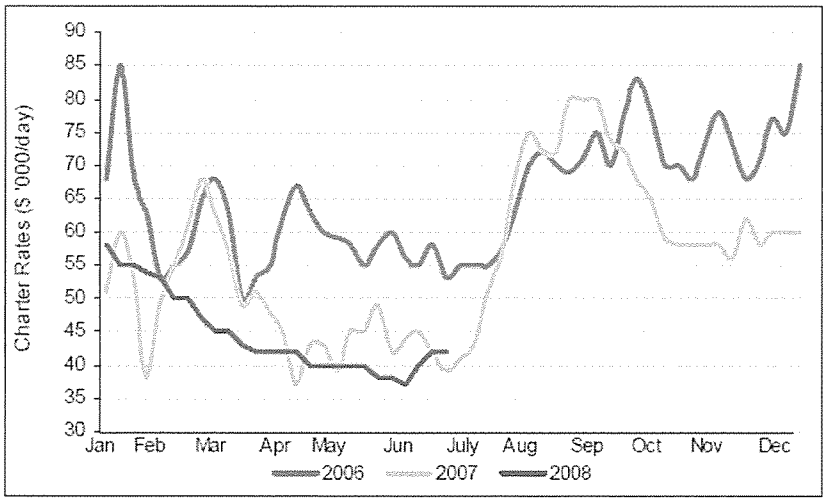




Plywood boxes filled with perlite, nitrogen purged spaces

LNG Charter Rates

Short Term Market – Rate Assessments



Seasonality!!