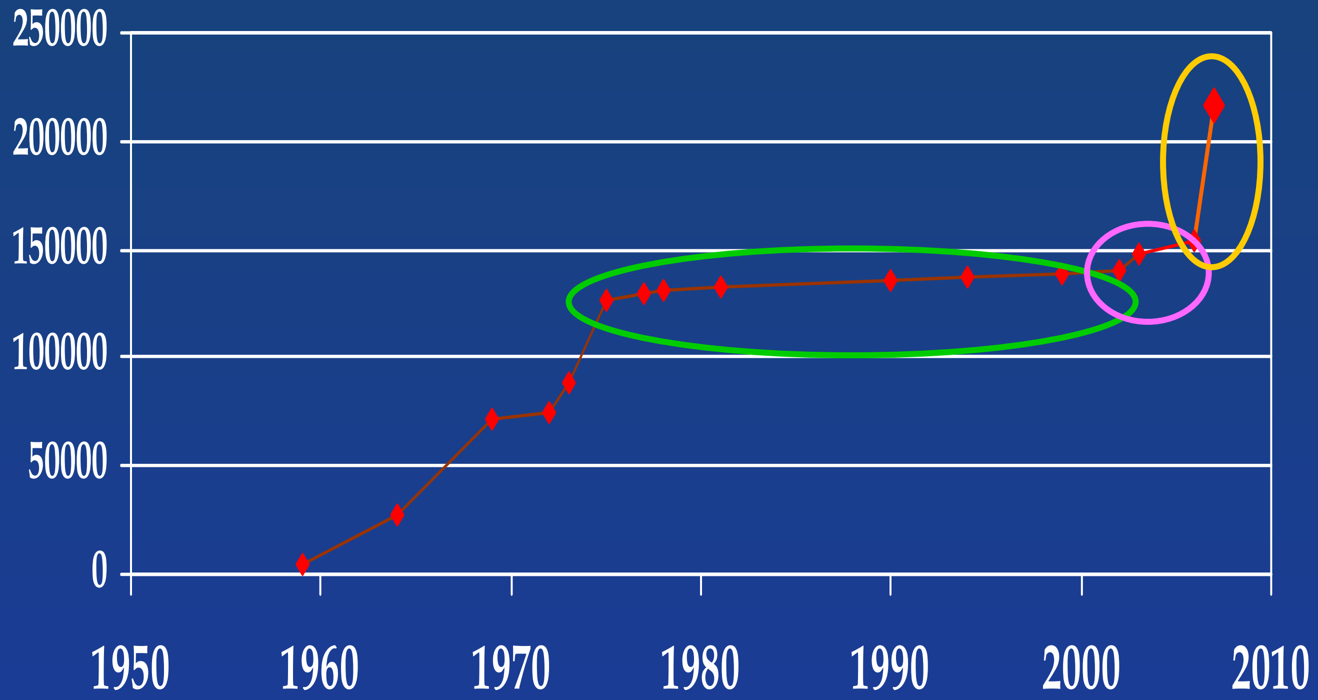
Nor-Shipping LNG Conference

Structural and Containment System Design Aspects of Large LNG Ships

by **Jim MacDonald**

LNG Ship Maximum Capacity – Progression



Mid 1970's ~ 2002: 130 ~ 140.5k

2002 ~ 2006: 140.5 ~ 153.5k

2007 ~ Onwards: Large LNG Ships 216k ~ +

Mid 1970's ~ 2002: 130 ~ 140.5k

- Worldwide service capability
  - Japanese max displt 105k
  - US max draft 11.3m

- Conservative design

2002 ~ 2006: 140.5 ~ 153.5k

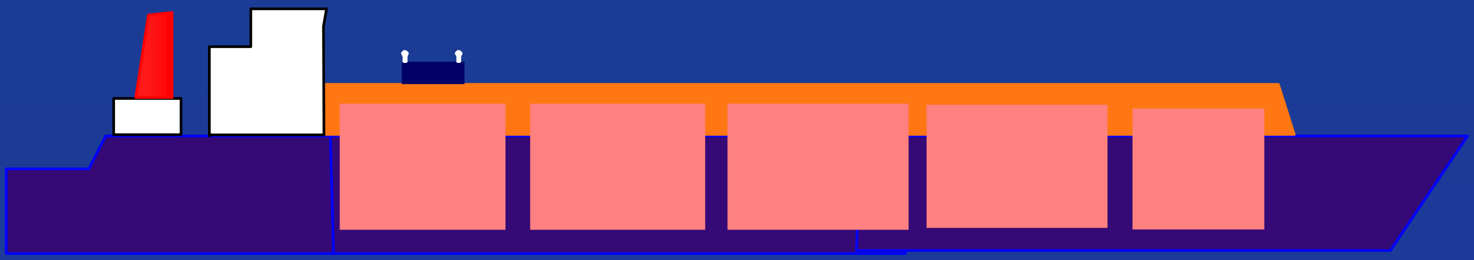
- Worldwide service capability retained
  - Japanese max displacement 105k
  - US max draft 11.3m

- Optimised design
  - Ships larger within above constraints
  - Trend towards membrane, esp MkIII
  - Reduced size engine rooms (diesel elec, etc)
  - Minimum steelweight

2007 ~ Onwards: Large LNG Ships 216k ~ +

- Dedicated service
  - Worldwide capability given up

- Owners have chosen minimum risk design initially



Large LNG Ships – Choice of Containment System

- Moss
  - More expensive
  - High Suez Canal tonnage
  - Sloshing no problem

- Membrane
  - Cheaper
  - Low Suez Canal tonnage
  - Sloshing question

… Commercial advantages of membrane have predominated, but the sloshing question has needed to be addressed

Moss ~ Membrane Ship
Illustration of Dimensions and Tonnage

Typical 135k Ships:

	LOA	Breadth	Suez Canal Tonnage
4 Tk Moss	289	48.2	105,000
4 Tk Membrane	280	43.0	82,000

... The SC Tonnage is a reflection of the larger size of Moss ships and the +20% difference would also be expected for Large LNG Ships

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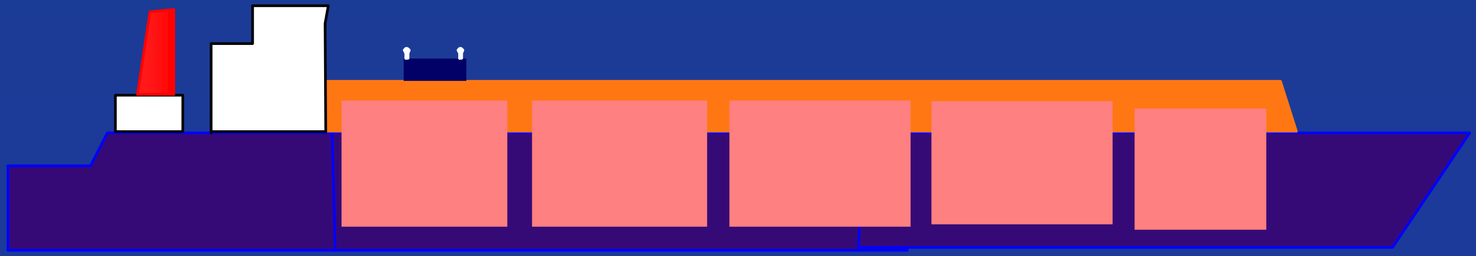
Considerations with Large Membrane LNG Ships

- Proportions of Ship
- Containment System
  - Sloshing
  - Strength
  - Fatigue
  - Pump mast
- Ship
  - Structural
  - Propulsion
  - Stern arrangement



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Proportions of Ship - Comparison between 135k and 216k Membrane Ship Dimensions

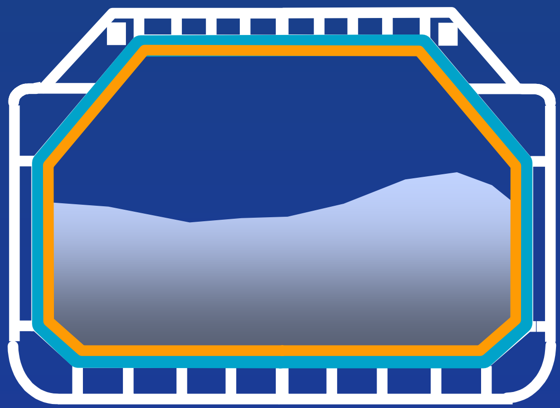
Dredging constraints in the Gulf have caused the Owner to specify 12 metres design draft:

	LOA	Breadth	Draft
135k Membrane	280	43	11.3
216k Membrane	303	50	12

... Note that the small increase in draft leads to a large increase in breadth

Sloshing in Large Membrane LNG Ships – Provisional Conclusions

- Can only occur in slack tanks, and owners want 70/10 filling flexibility to be retained
- Exacerbated by convergence of tank natural period with ship motion
- Larger tanks tend to have natural periods closer to ship motion periods



- Owners have specified number of cargo tanks increased to 5 to reduce their length to avoid convergence in fore-aft sloshing

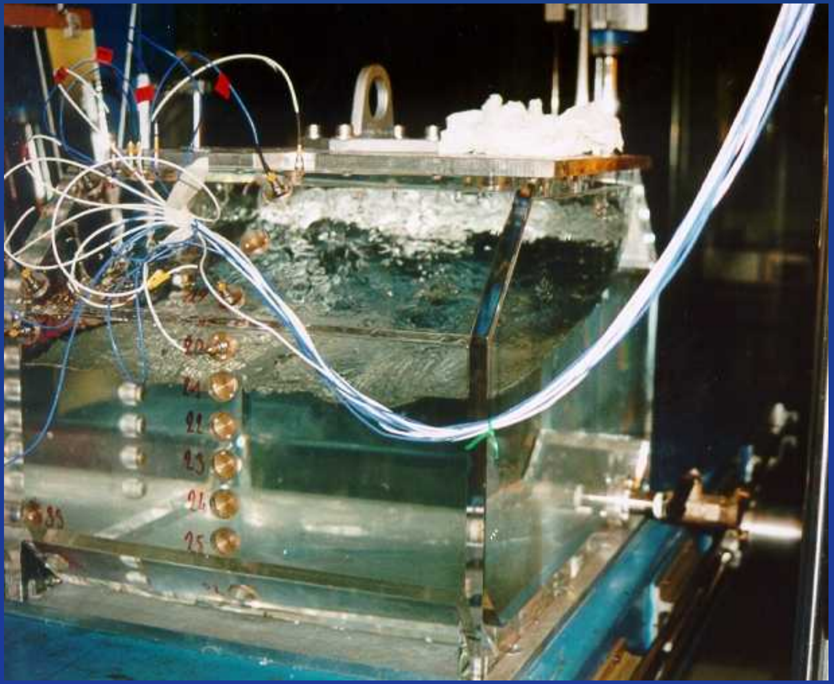
135k ~ 216k Membrane Tank Dimensions (midship tanks)

	Length	Breadth	Height
150k Membrane (4 tank arrgt)	45	38	27.5
216k Membrane (5 tank arrgt)	40	44.5	32

... Note the increase in tank breadth, following on from the increased ship breadth consequent from minimal draft increase

Sloshing in Large Membrane LNG Ships

- Preliminary pre-contract investigations indicated some increases in sloshing pressures
- 30% strength increase versions of containment systems (NO96 and MkIII) developed
- Post-contract investigations continue between GTT and class societies
- (Lloyd's Register have recently issued a sloshing guidance procedure)



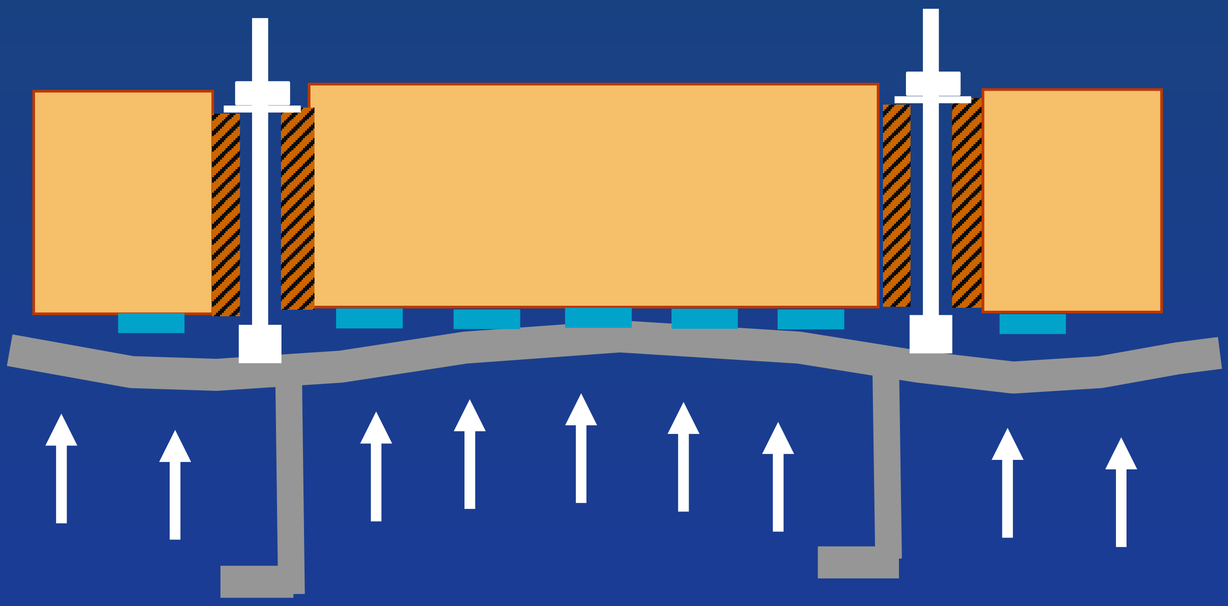
Containment System Strength – Global

GTT's normal limitations are maintained:

- NO96 ~ Longitudinal hull girder imposed limitation retained at 120N/mm2
- MkIII ~ Longitudinal hull girder imposed strain retained at 9E-4 (= 175N/mm2)

… ships are bigger but global loading no greater than present conventional size

Containment System Strength – Local Imposed Deflection Leading to Tight Local Curvature of Inner Hull



… MkIII similarly critical under local imposed deflection, but Rule scantling requirements mitigate against tighter local curvature

Containment System Fatigue

- Caused mainly by wave pass loading
- Of the120N/mm2 inner trunk deck limit for NO96, it is the wave bending Component which drives fatigue (9E-4 strain similar for MkIII)
- Trend to greater Wave BM as a proportion of Total BM through to 145k, but …
- Early indications are that Wave BM proportionally no greater on Large LNG ships than conventional size ships

Pump Mast

- Similar situation as for tanks themselves – broader tanks likely to lead to increased drag loading due to sloshing motion
- Further consideration being given to calculation procedure between GTT and class societies
- Vibration may be a factor for slow speed diesels

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Ship Structural

- Ship structural strength also affected by disproportionate increase in breadth, also the increase in web spacing proposed by shipyards
- However, these changes are not extreme when compared to other ship types
- The major class societies have the experience and design tools to check this out

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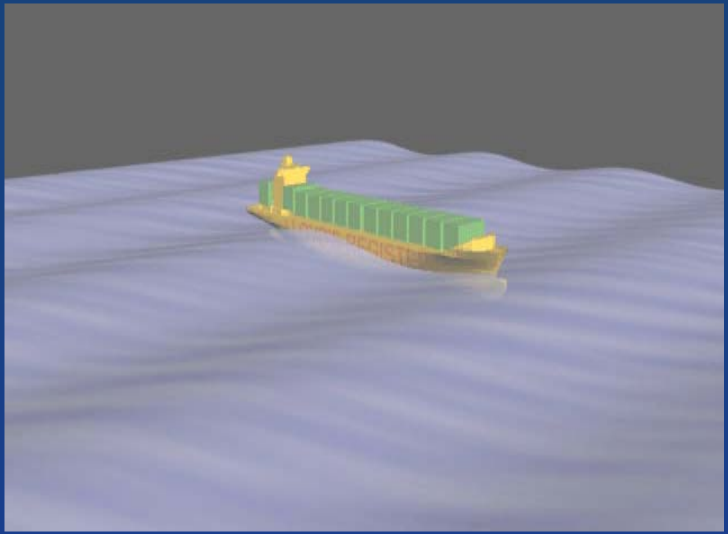
Ship Propulsion

- Power needs to be increased to maintain ship speed at abt 20kts
- Small draft limits propeller diameter, and power which a single shaft arrangement can deliver
- Owners have specified twin slow speed diesels, with reliquefaction (shipborne reliq as yet unproven) to deal with boil-off
- Alternatives would have been medium speed dual fuel diesel electric, or perhaps gas turbine

Stern Arrangement

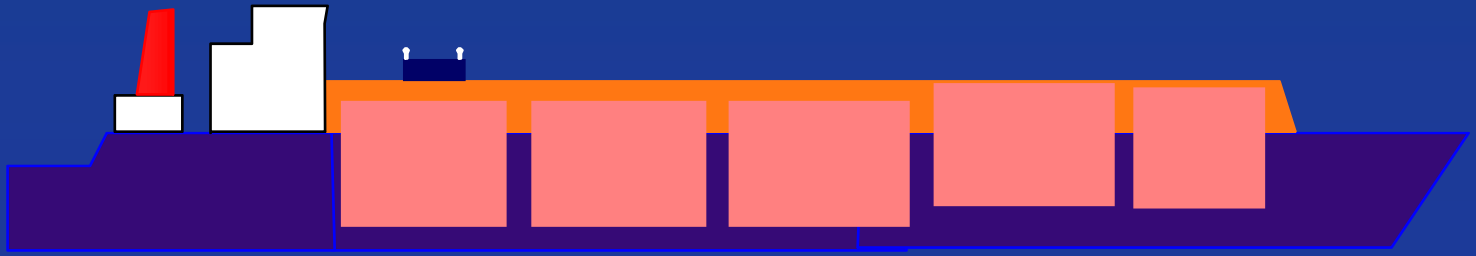


- Twin screw arrangement leads to flat sections just above the waterline
- Potentially susceptible to
  - stern slamming
  - parametric roll (cf large container ships)

… strengthening of stern against slamming can be arranged, and possibility of parametric roll is under further investigation by Lloyd's Register

Large Membrane LNG Ships – Critical Aspects

- Proportions of Ship
- Containment System
  - Sloshing
  - Strength (global, local)
  - Fatigue
  - Pump mast (strength, vibration)
- Ship
  - Structural
  - Propulsion (reliquefaction)
  - Stern arrangement (aft end slamming, parametric roll)



Next Step – Possible Optimisation of 216k Large LNG Ships

- Reduction down to 4 cargo tanks, which would be both longer and broader than before

… significant consequences on sloshing, which would need to be very carefully evaluated

Next Step: 250k+ Large LNG Ships

- Assuming draft is set as minimal increase on 216k size, then cargo tanks will become *much* broader again

… FURTHER possible BIG consequences on sloshing, which would need to be very carefully evaluated

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LNG Reliquefaction

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