Concept Design of LNG Bunkering Ship

~ To meet the growing demand of LNG fuel in the world and in Japan ~

November 2012

Kawasaki Heavy Industries, Ltd.

The 6th Asian Shipbuilding Expert's Forum, Guangzhou, 2012

Contents

1. Introduction of Kawasaki Heavy Industries
2. Growing Demand of LNG as fuel for Ships
3. Concept design of LNG fuel bunkering ship
4. Conclusion

Kawasaki's contribution to Small Scale LNG

"Shinju Maru No.1"
(Delivered in 2003)

For domestic distribution of LNG in western Japan

"Shinju Maru No.2"
(Delivered in 2008)

Kawasaki's contribution to Small Scale LNG

"North Pioneer"
(Delivered in 2005)

"Akebono Maru"
(Delivered in 2011)

"Kakurei Maru"
(Delivered in 2008)

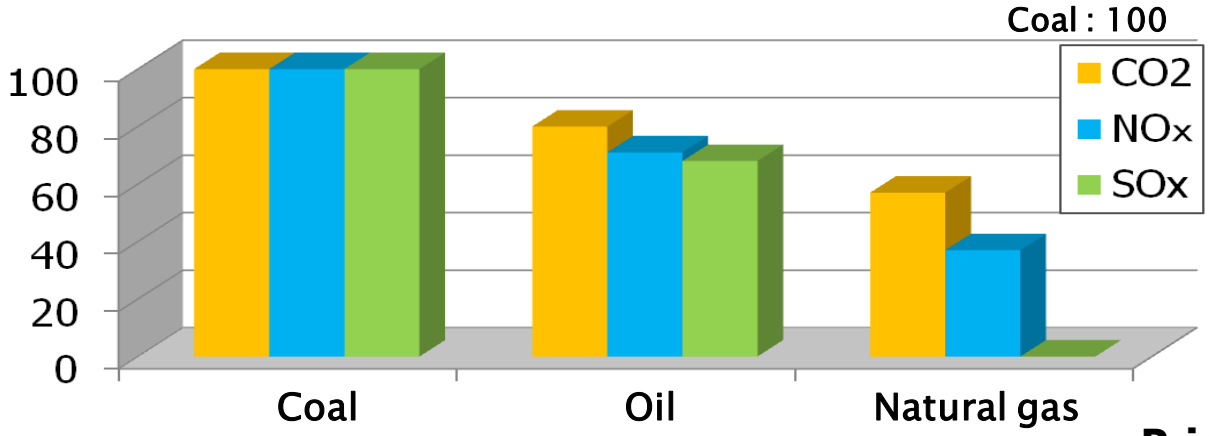
For domestic distribution of LNG in eastern Japan

Contents

Growing Demand of LNG as fuel for Ships

Two main reason for the growing demand

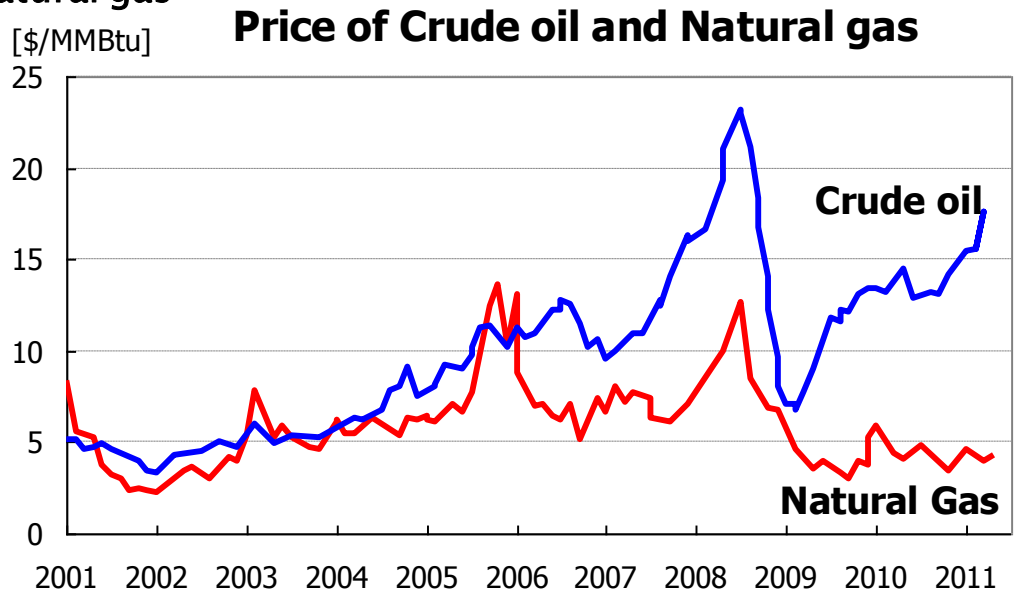
Natural Gas … Fuel with low CO_2, NO_X, SO_X emission



(depending on type of main engine)

Natural Gas

… Reasonable fuel compared with fuel oil



Source: IMF Primary Commodity Prices (WTI), Henry Hub

Upcoming Environmental Regulations

1. NOx emission regulation

- Stricter regulation in ECA from 2016 (80% reduction)
- Expected expansion of ECA

2. SOx emission regulation

- Stricter regulation in ECA from 2015
  → Content of sulphur in fuel <= 0.1%
- Expected expansion of ECA

3. CO_2 emission regulation

- Energy Efficiency Design Index (EEDI)
  → Entry into force in 2013
- Emission of CO_2 will be regulated

With LNG…

- Up to 90% reduction of NOx (Depending on type of engine)
- No (or reduced) special equipment required for NOx reduction other than for LNG

- 100% reduction of SOx
- Reasonable cost compared with low sulphur fuel oil
- No special equipment for SOx reduction required other than for LNG

- Higher calorific value than fuel oil
  → about 20% reduction of CO_2

Shift from oil to LNG is already going on…

- More than 25 LNG fuelled vessels are already operating in Europe now…

Shift from oil to LNG is going ahead in Europe
(Due to strengthening of emission control in ECA in Europe is going ahead)

The movement is now spreading in the world…

Increasing interest in LNG as fuel in Japan

Some recent articles on newspapers in Japan

- Japan to Develop LNG Marine Safety Standards (Nov. 1, 2011)

- Japan To Develop Natural-Gas-Fueled Ships (Nikkei, May 10, 2012)

- Japan and Norway strengthen maritime ties (May 11, 2012; relating to gas fuelled ships)

  One of the main topic of a maritime workshop with Japan and Norway government was collaboration regarding to LNG fuel ships.

日本経済新聞 2012年(平成24年)5月10日(木曜日) (7面)

天然ガス外航船 実用化

政府、15年度にも 一部建造費を補助

政府は温暖化ガスの排出量が少ない天然ガスを動力源にした大型外航船を2015年度中にも実用化する。海運分野の温暖化対策として、国内の海運・造船会社に建造費の一部を補助する。重油を動力源にした船に比べ、二酸化炭素(CO2)の排出量を25%減らせる。天然ガス船は窒素酸化物(NOx)や硫黄酸化物(SOx)の排出量も抑えることができ、国際環境規制の強化に備える。

海運の温暖化対策 規制強化に備え

ノルウェーなどが国内で運航するタンカーなどの外航船で使う小型内航船の燃料を天然ガス船に代えた例はあるが、長距離を航行する大型船では世界初になる。

造船分野は韓国や中国の台頭で競争が激しさを増している。日本主導で天然ガス船を実用化することで、日本の造船業の国際競争力強化につなげる狙いもある。

国土交通省が参加企業を募り、今夏をめどに必要な技術開発の調査を始める。船内の液化天然ガス燃料タンクや供給装置に必要な技術を調べるほか、船舶機関の模擬実験を実施。安全確保に向けた手続きを整える。

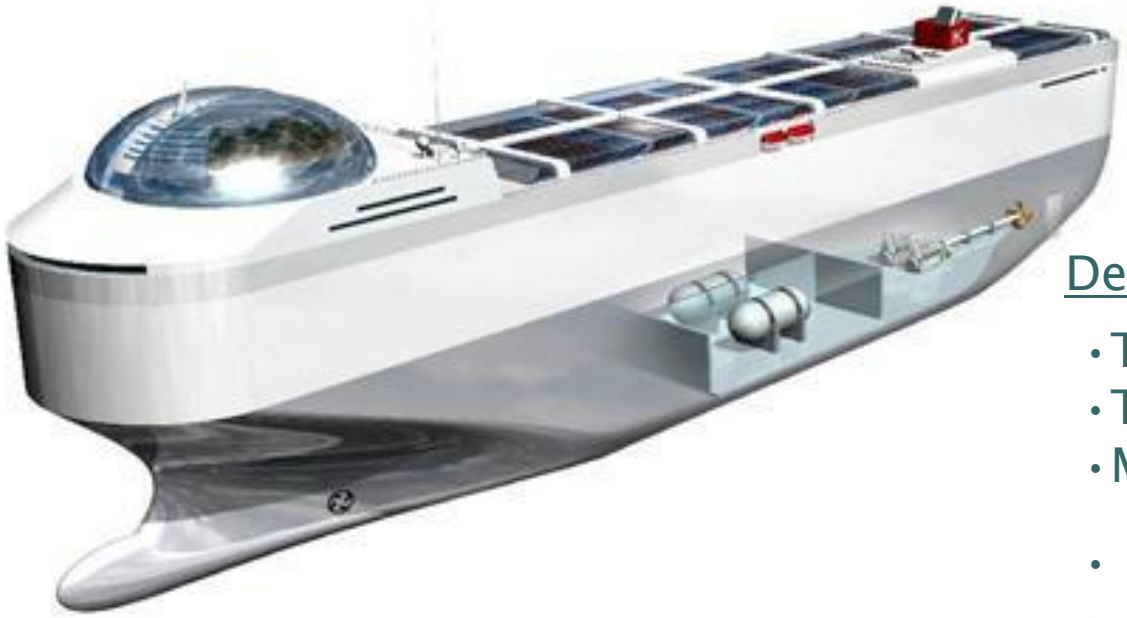
18年度からは海運・造船会社の建造費の一定割合を支援する。建造費は従来の重油船に比べて2割程度高くなり、積載量20万トン以上の大型船で100億円を超す見込みだ。

これまでにない新しい船になるため、日本政府は3年程度にも技術調査を基に安全基準の素案をまとめる。国際安全基準のたたき台として、国際海事機関(IMO)に提案。

Kawasaki's contribution to LNG fueled ships

2,000 cars type LNG fuelled car carrier

Developed collaborating with "K" Line and DNV



Length overall : 143 m
Breadth : 25 m
LNG fuel tank : 300 m^3 x 2 sets

Design Features

- Type C LNG fuel tanks
- Two sets of gas engines
- Mechanical driven

- CO_2 emission reduction by 40%
- NOx emission reduction by 80-90%

Kawasaki's contribution to LNG fueled ships

9,000 TEU type container LNG fuelled ship

Length overall : 308 m
Breadth : 48.4 m
Draught : 14.5 m
LNG fuel tank : 7,000 m^3

Design Features

- Type B LNG fuel tank
- Twin island arrangement
- Two stroke dual-fuel main engine (Electronically controlled)
- Compatible with IMO Tier III NOx standard and SOx standard

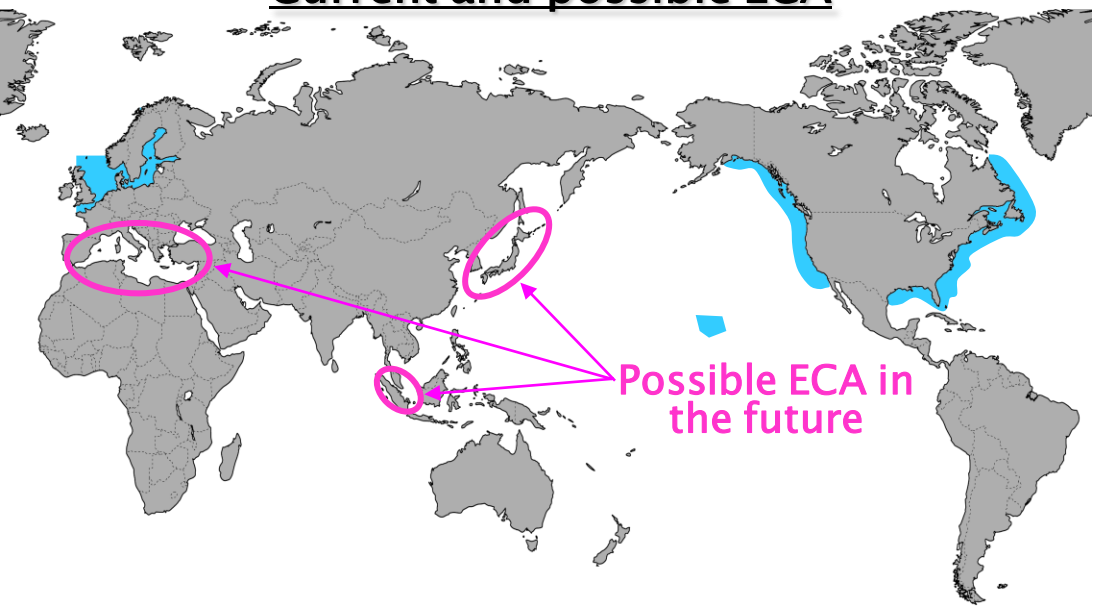
Obtained Approval in Principle from DNV in January 2012

Increasing interest in LNG as fuel in Japan

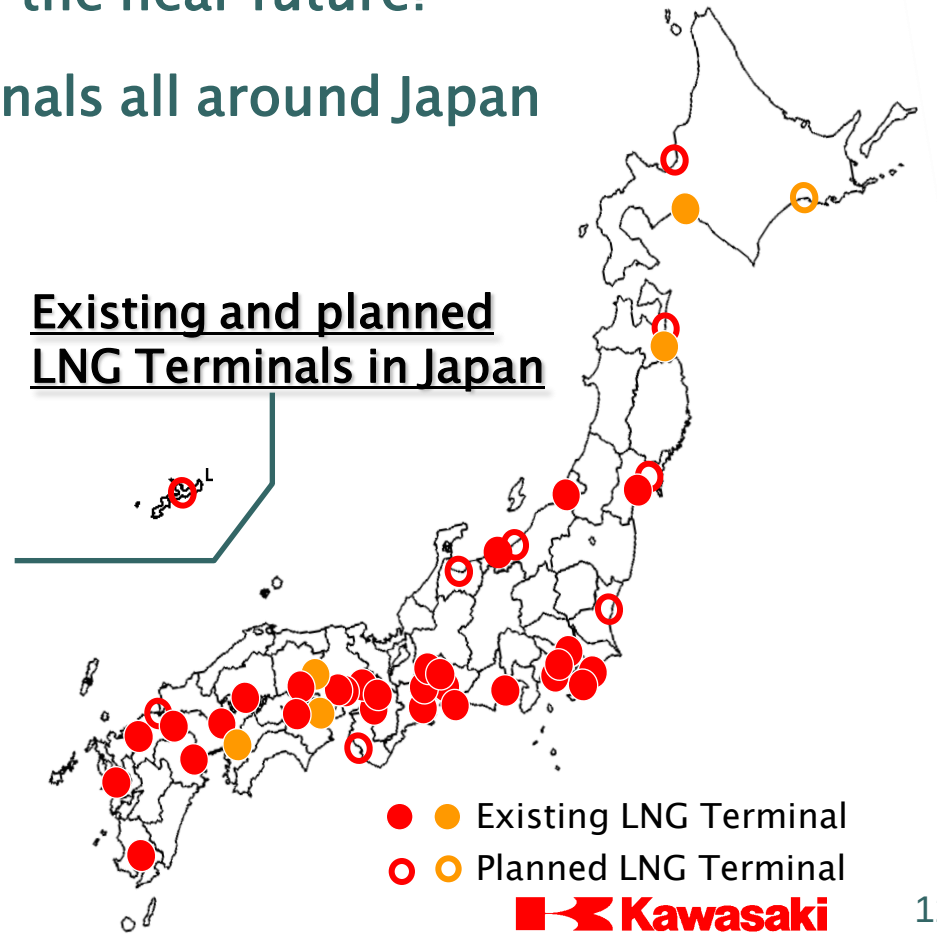
Some factors for increasing interest in LNG as fuel in Japan

- Sea around Japan to become ECA in the near future?
- Many existing & planned LNG terminals all around Japan

Current and possible ECA



Existing and planned LNG Terminals in Japan



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Issues to be solved for commercial viability of LNG fuelled ships

Issues to be solved;

1. Propulsion system for LNG fuel
2. LNG fuel tank(s)
3. System for supplying LNG fuel to engine(s) and handling boil-off gas
4. LNG fuel bunkering system
5. Sufficient LNG fuel supply chain

Already technically ready or feasible

Way for sufficient LNG fuel supply chain

Ideas for bunkering LNG fuel;

1. Via LNG fuel bunker station
   (Similar way for LNG carriers)

2. Via LNG tanker lorries
   (Currently popular way in North Europe)

3. Via LNG fuel bunkering ship
   (Ship-to-ship)

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Technical issues for LNG fuel bunkering ships

Basic idea of LNG fuel bunkering ship

Kawasaki's small scale LNG carrier

+ Special equipment onboard
(in comparison with small scale LNG carrier)

Technical issues

1. LNG storage
2. Use of LNG on LNG bunkering ship
3. Way to handle BOG from own LNG tank and from LNG receiving ship
4. Way to transfer LNG to LNG receiving ship

Technical issues for LNG fuel bunkering ships

Basic idea of LNG bunkering ship

Kawasaki's small scale LNG carrier

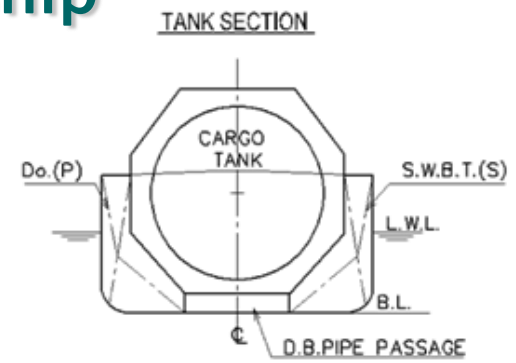
+ Special equipment onboard
(in comparison with small scale LNG carrier)

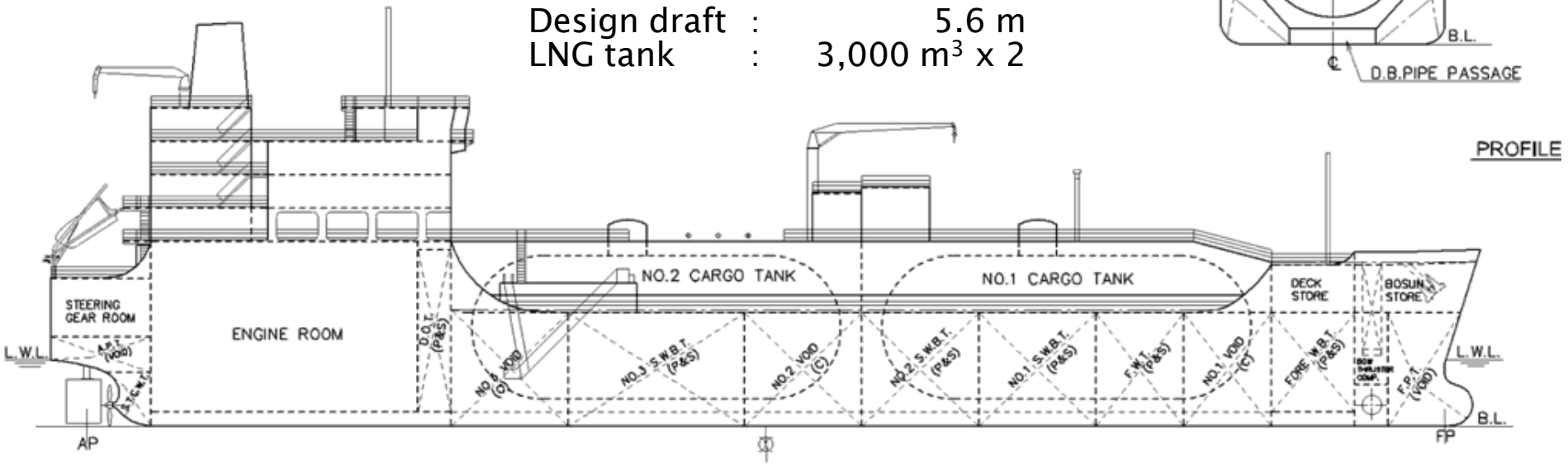
Design issues

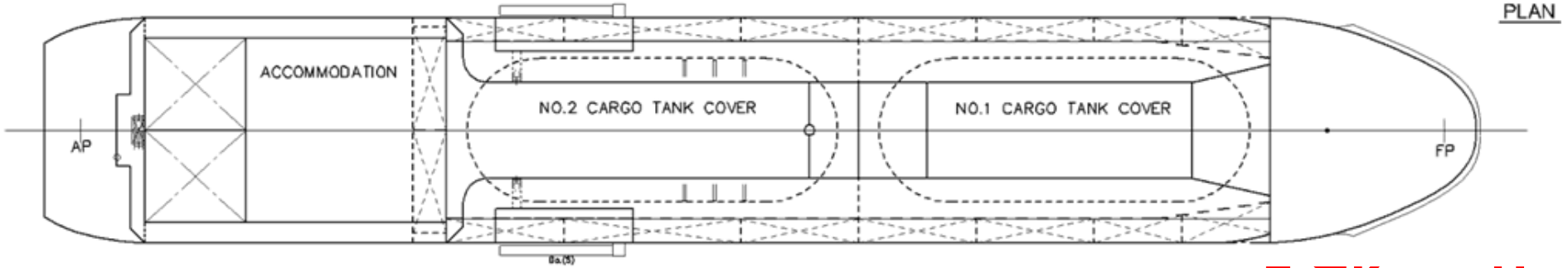
1. LNG tank
2. Propulsion system and LNG fuel supply system
3. LNG bunkering interface with LNG receiving ships
4. Special equipment onboard

6,000m³ type LNG fuel bunkering ship

Loa	:	about 120.0 m
Lpp	:	114.0 m
Bm	:	18.8 m
Dm	:	9.5 m
Design draft	:	5.6 m
LNG tank	:	3,000 m³ x 2







Issue 1: LNG tank for LNG fuel bunkering ship

Requirement for LNG tanks;

1. Flexibility in partial cargo loading
2. Easy boil-of gas management
   (To cope with unfixed bunkering schedule)
3. Low boil-off rate
   (To avoid loss of quality and amount of cargo)
4. Low cost and low weight

IMO Type C cylindrical aluminum LNG tank
(Design pressure : 5 barG)

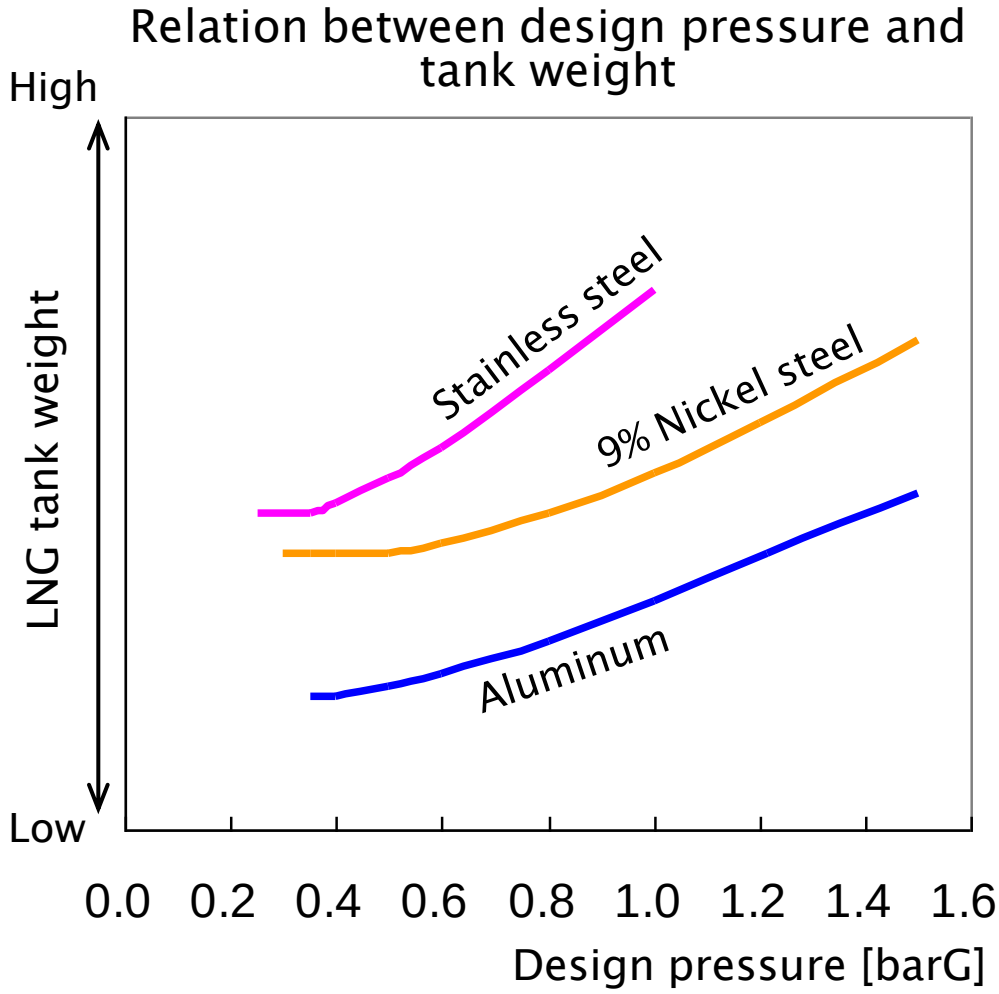
Issue 1: LNG tank for LNG fuel bunkering ship

Why Aluminum?

Weight : Al < 9% Ni < Stainless steel

Cost : Al < Stainless steel & 9% Ni

★ Kawasaki has proven technology and track record for Aluminum tank



Issue 1: LNG tank for LNG fuel bunkering ship

Design pressure : 4 to 8 barG

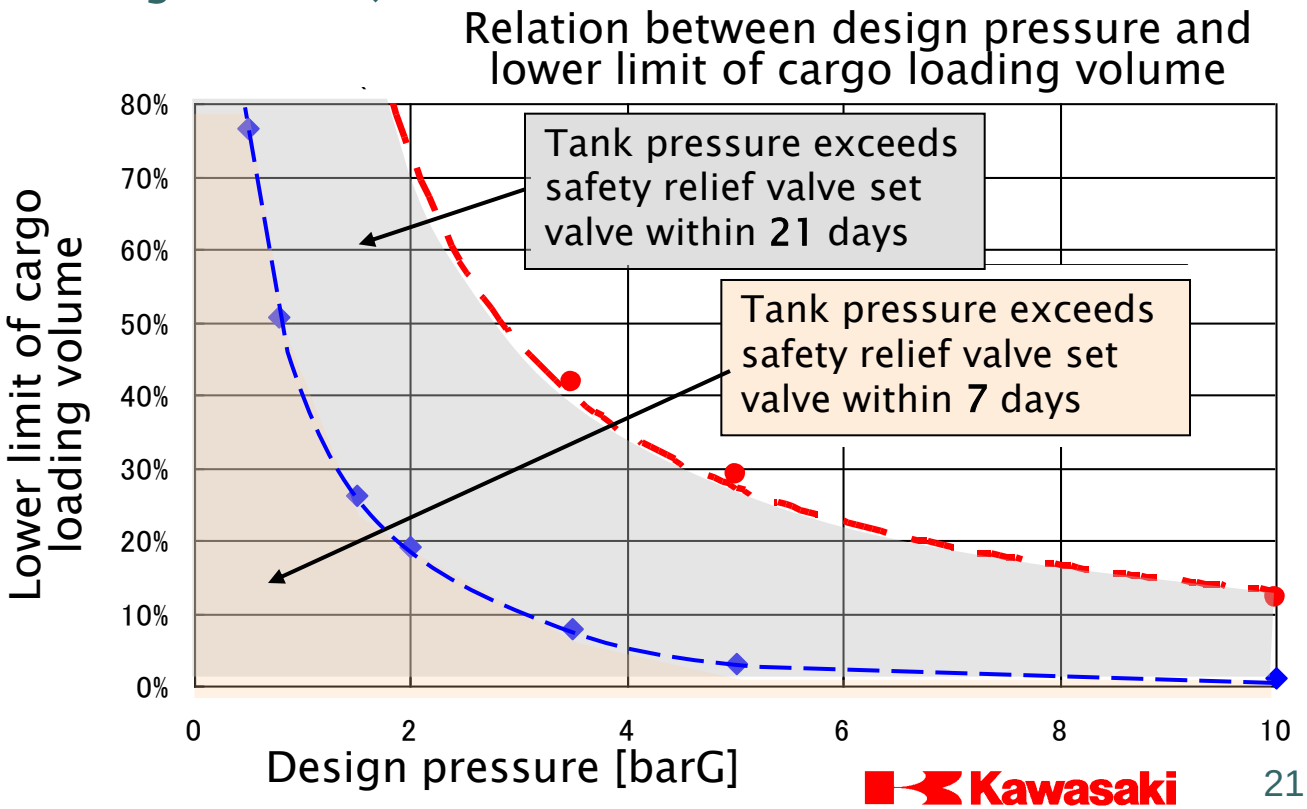
"Cargo tank weight & cost" vs. "Operational flexibility"

Design pressure ↗ = Operational flexibility ↗

Design pressure ↗ = Cargo tank weight & cost ↗

4 to 8 barG

= Good to balance both operational flexibility and weight & cost



Issue 2: Propulsion system and LNG fuel supply system

Requirement for propulsion system and LNG fuel supply system;

1. Utilize LNG at propulsion system
2. Driven also by fuel oil
   (To flexibly select suitable fuel in accordance with fuel market)
3. Handle boil-off gas from LNG tank
4. Redundancy
5. Low fuel oil/gas consumption
6. Reasonable initial cost

DFD mechanical driven propulsion system

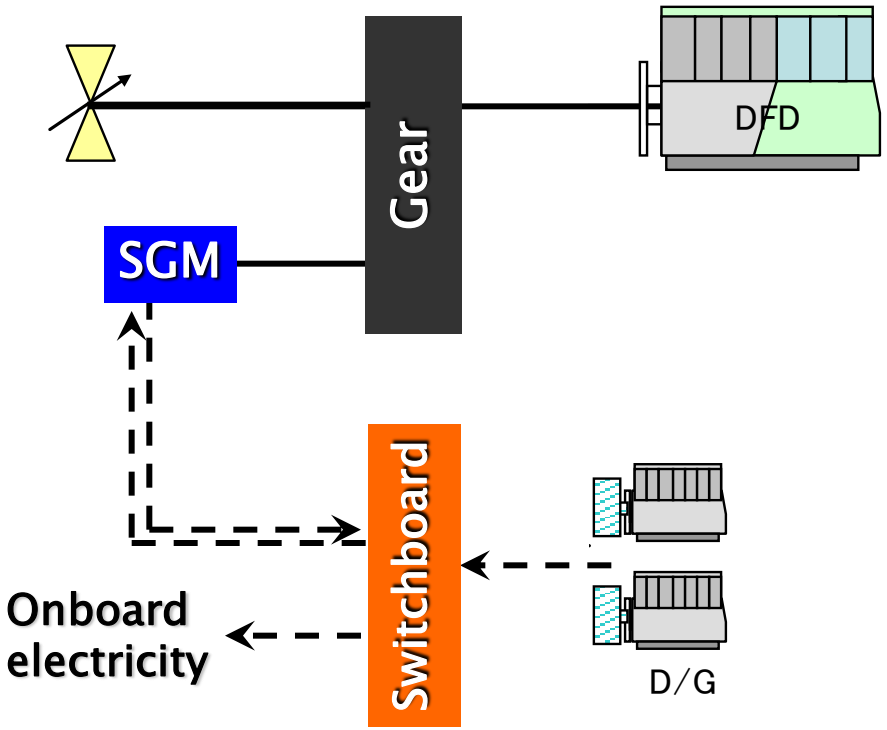
+

BOG compressor & heater/vaporizer as LNG fuel supply system

Issue 2: Propulsion system and LNG fuel supply system

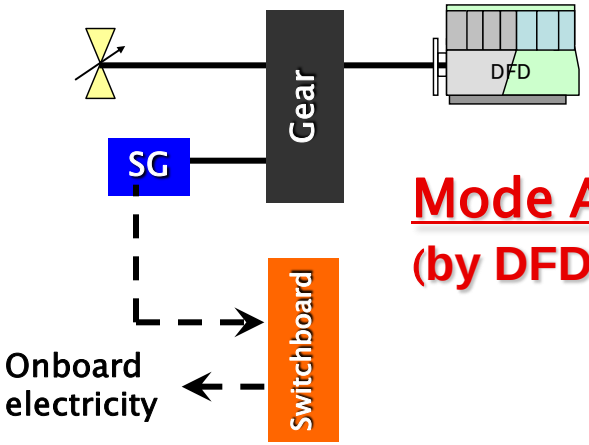
DFD mechanical driven propulsion system

Mode B
(by DFD generators)

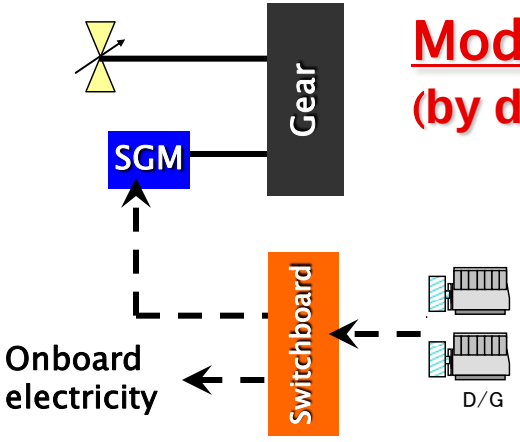


SGM : Shaft generator motor

Issue 2: Propulsion system and LNG fuel supply system



Mode A
(by DFD engine)



Mode B
(by diesel generators)

SGM : Shaft generator motor

Operational mode

During voyage:
Mode A :Propeller shaft output
+ Shaft generator

Berthing/Unberthing
Mode B :Onboard electricity +Thruster

Unloading
Mode B :Onboard electricity
+ Cargo equipment

Docking
Mode A (DO mode DFD)

Emergency navigation
Mode B :SGM shaft output
+ Onboard electricity

Issue 3 : LNG bunkering interface with LNG receiving ships

Ideas for LNG bunkering interface with LNG receiving ships;

1. By loading arms → ・Similar concept to LNG terminals, but specialized modification for ship-to-ship use is necessary

2. By flexible hose → ・Some actual cases already done by Ship-to-Ship using flexible hose
   ↓
   Most feasible way at this time

Concept design of LNG fuel bunkering ship

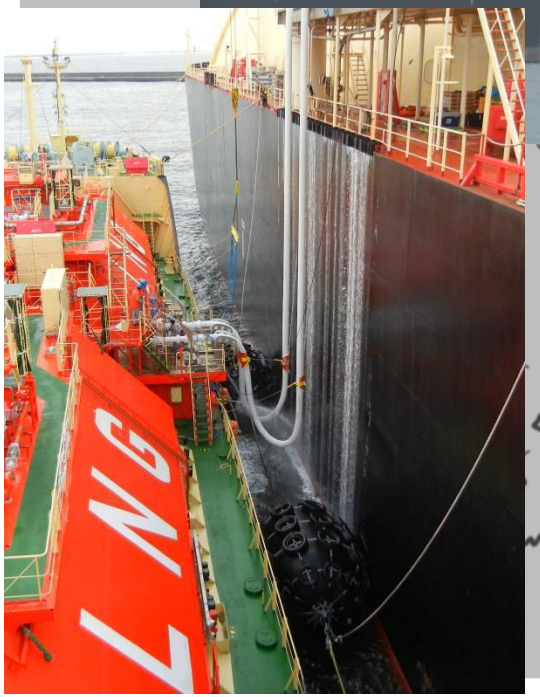
Issue 3 : LNG bunkering interface with LNG receiving ships

An instance of ship-to-ship LNG transferring

~ Executed for the first time in Japan ~

- At Tomakomai, Japan
- From Nov. 2011 to Feb. 2012, total 34 times
- To fulfill the region's temporary demand
- LNG transferred;
  A 126,000m^3 LNG carrier
  ↓
  A 3,500m^3 LNG carrier
  ↓
  The region's small scale LNG terminal

Important milestone for LNG fuel ship-to-ship bunkering



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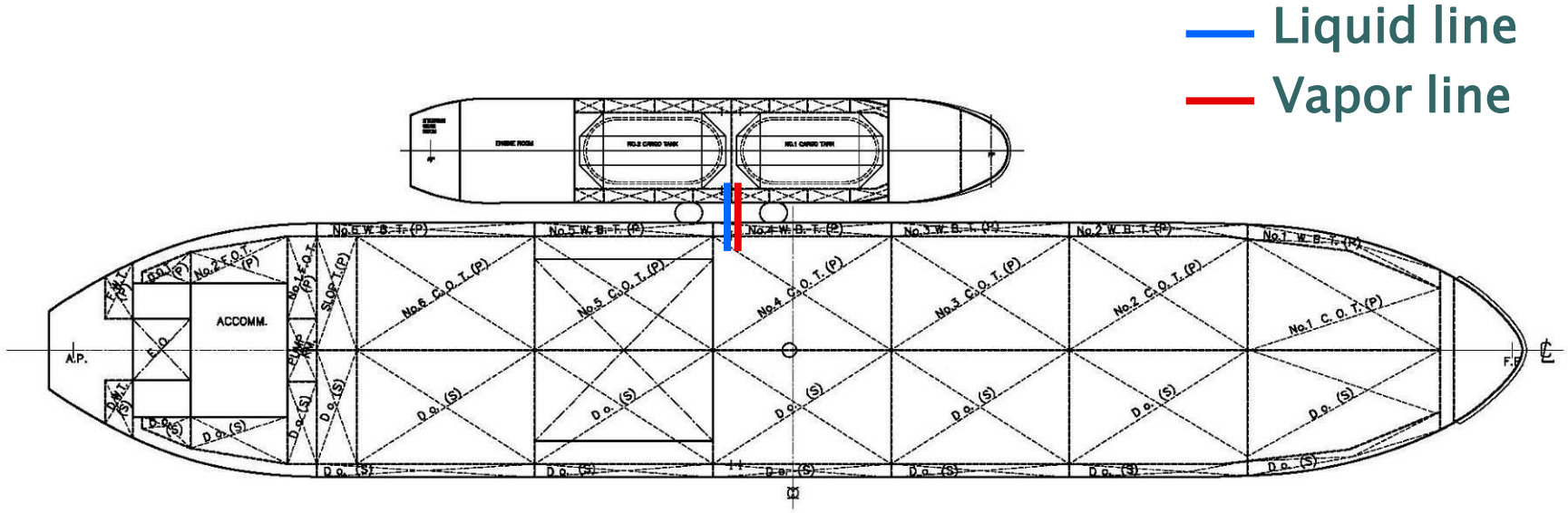
Issue 3 : LNG bunkering interface with LNG receiving ships

Case study of bunkering LNG

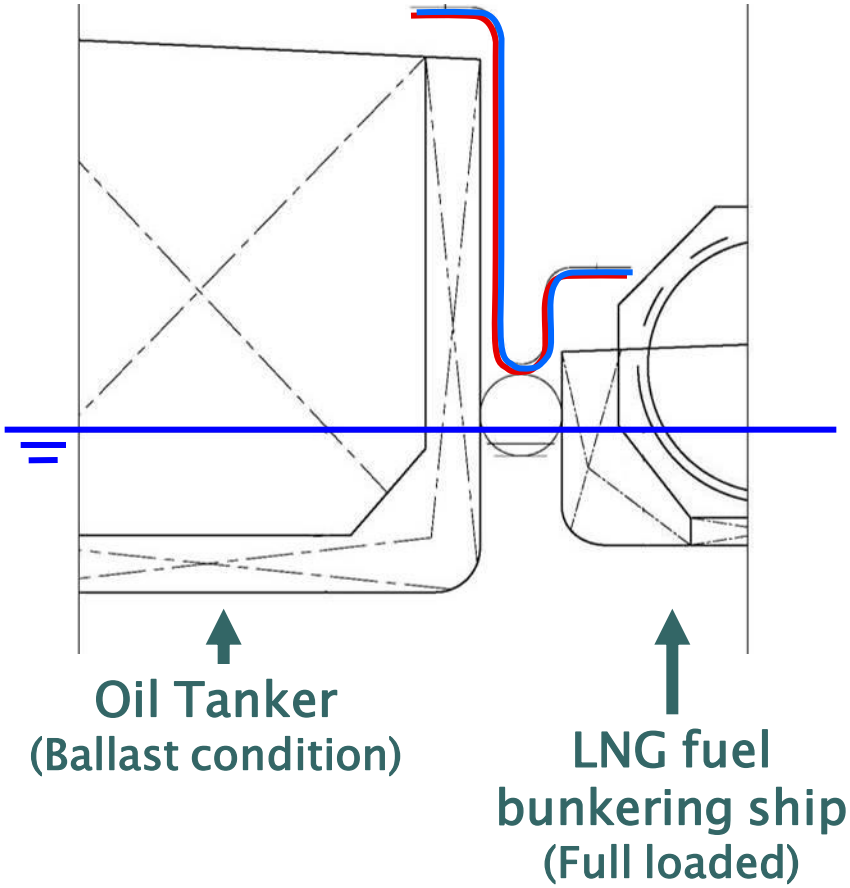
~ from LNG bunkering ship to LNG fuelled oil tanker ~

Ship-to-ship arrangement

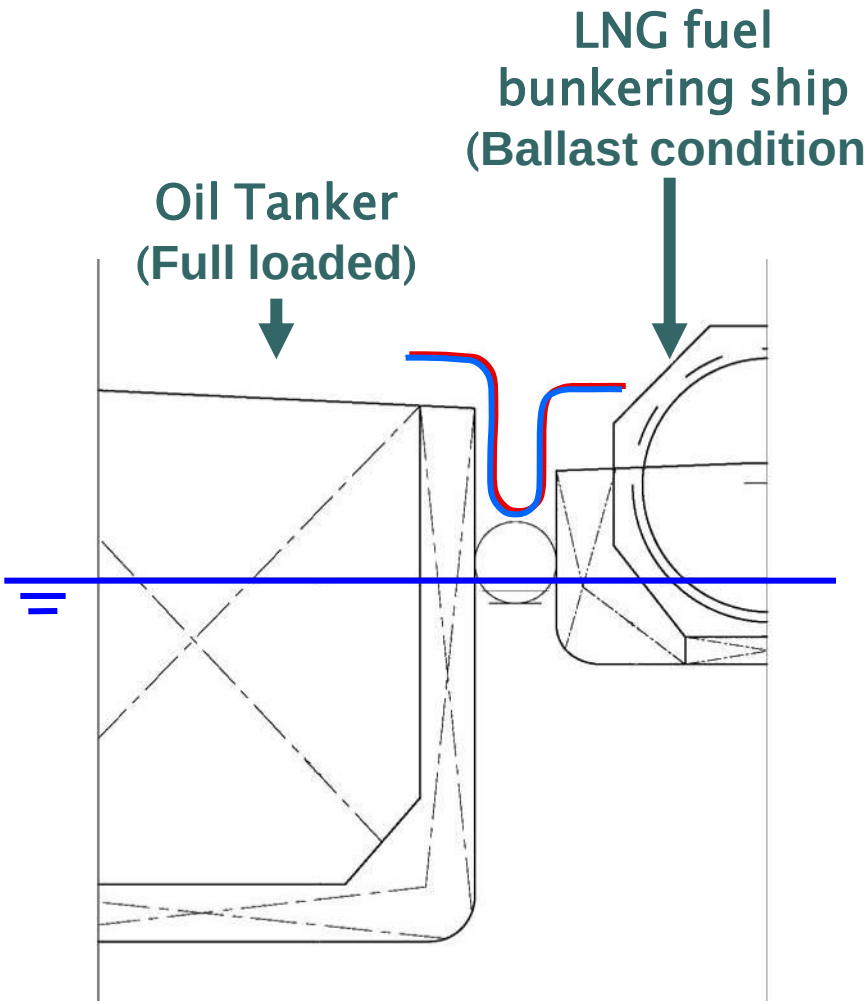


Issue 3 : LNG bunkering interface with LNG receiving ships

Two typical bunkering conditions



Case 1



Case 2

Issue 4 : Equipment for LNG fuel bunkering ship

Necessary additional equipment

~ in comparison with small scale LNG carrier for domestic distribution ~

For transferring boil-off gas to main engine(s)

- BOG compressor
- Vaporizer
- LNG Heater

For bunkering LNG fuel to receiving ship

- LNG bunkering interface (manifold)
- Return gas compressor
- Gas combustion unit
- BOG re-liquefaction plant

For providing service for pre-docking

- Inert gas generator

Necessity depends on receiving ships' specifications

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Conclusion

- Demand of LNG fuel for ships is increasing in the world and in Japan, and LNG fuel bunkering ship would play an important role to back-up the trend.
- Adding special equipment for bunkering function on a proven small scale LNG carrier can make a basic concept of LNG bunkering ship.
- Necessary equipment for bunkering function needs to be determined considering LNG fuelled ship's specifications.

- **Thank you for your attention!**