Activities of ClassNK
- LNG Fuelled Ships -

July 2014

LNG-Fuelled Vessel Technologies Seminar

ClassNK / Nippon Kaiji Kyokai

Contents

Background – Why LNG fuelled ships?

✓ Response to IMO Regulations (NOx, SOx, EEDI(CO_2))

Reduction in emissions by fuel conversion (Petroleum oils → Natural gases)

NOx	SOx, PM	GHG
80%～90% reduction	Zero emission	20%～25% reduction

✓ Possible fuel cost reduction

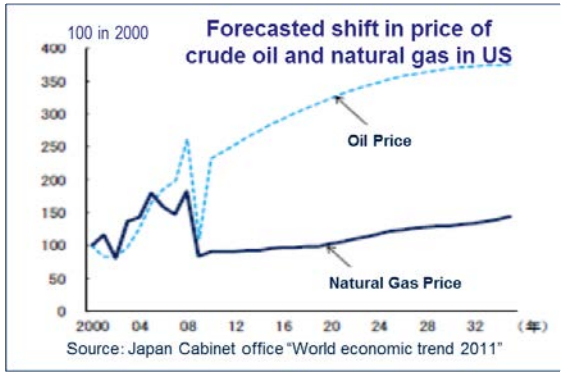
Oil price : reserve-production ratio, geopolitical risk

→ expected runaway growth of oil price

use of higher priced low sulfur fuels

Natural gas price: Development of shale gas production

→ expected stable and lower price



High potential as an alternative fuel

Construction / Operation Record in North Europe 1/3

- ✓ Over 40 LNG fuelled ships have been built & operated.
  (coastal ferry, PSV, patrol vessel, chemical tanker, RoPax)
- ✓ Supported by beneficial tax scheme & funds (e.g. Nox fund in Norway)
- ✓ Improving LNG fuel supply infrastructure

Bergensfjord "Fjord 1"

(Double ended ferry、passenger 589, Car 212）

Tarbit Shipping AB "Bit Viking"

(Chemical tanker, DF type, 25,00DWT）

EideViking "Energy Viking"

(Offshore support vessel, DF type, L=95m）

Construction / Operation Record in North Europe 2/3

Passenger Ferry “Viking Grace” & Bunkering Ship “SEAGAS”

- ✓ Delivery: Jan 2013, M/E: DFD (Electrical propulsion, Quad-engine, Twin-propeller)
- ✓ 2 LNG fuel tanks are installed on open deck aft space

Operating between Turku and Stockholm

Length	214 m	Main engines	4× Wartsila 8L50DF, 7600 kW per unit
Breadth	31.8 m		
GT	57,000 ton	LNG fuel tanks	2 ×Type C cylindrical cryogenic tanks, 2 ×200m^3
Service speed	abt. 22 knots		
Passenger	2800		

Length	50 m	Breadth	11.3 m
Service speed	abt. 12 knot	Bunker Capacity	200m3

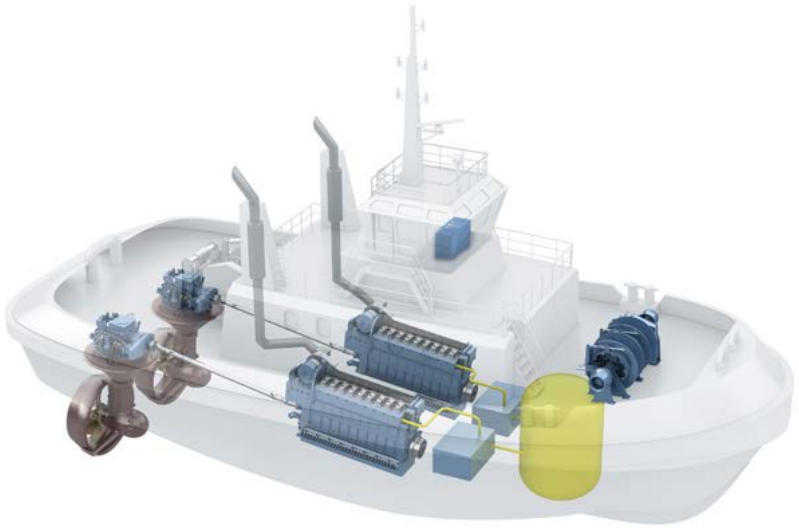
LNG bunkering for “Viking Grace”

Reference： Viking Grace Home Page

Construction / Operation Record in North Europe 3/3

LNG Powered Tugboat

- ✓ Shipyard: Sanmar (Turkey)
- ✓ Owner & Designer: Bukser og Berging
- ✓ Delivery: October 2013
- ✓ Twin-gas only fuel engines (Rolls Royce), direct coupling with azimuth thrusters
- ✓ Single LNG fuel tank installed under deck (no diesel back up)

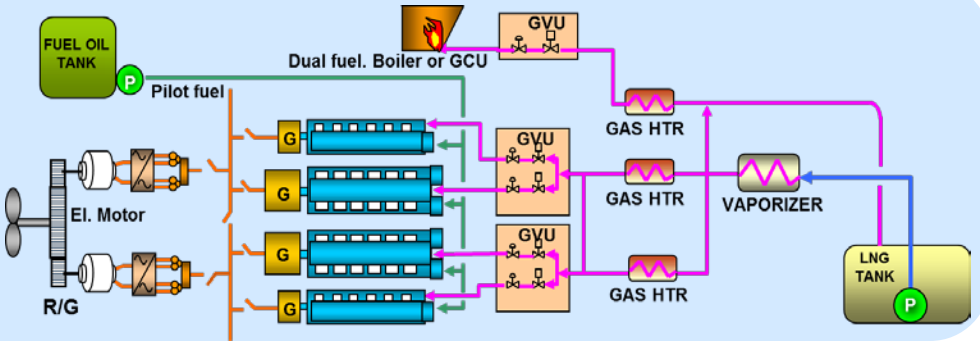


Source: Shipbuilding tribune.com

Typical system configuration

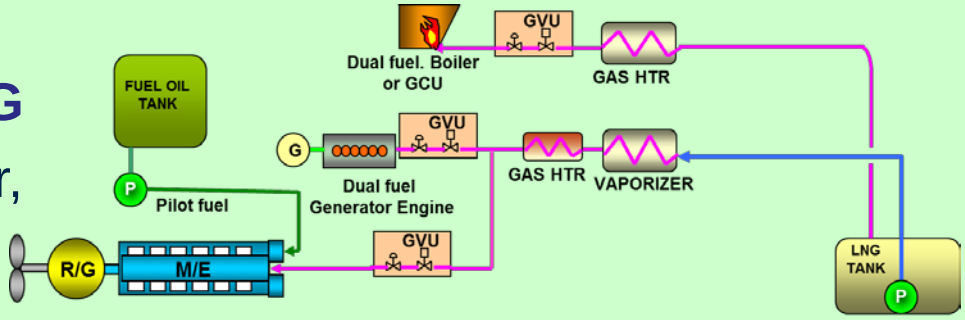
[1] 4 stroke DF or Gas Engine / Electric Propulsion

- ✓ Track records of ferry, OSV etc.



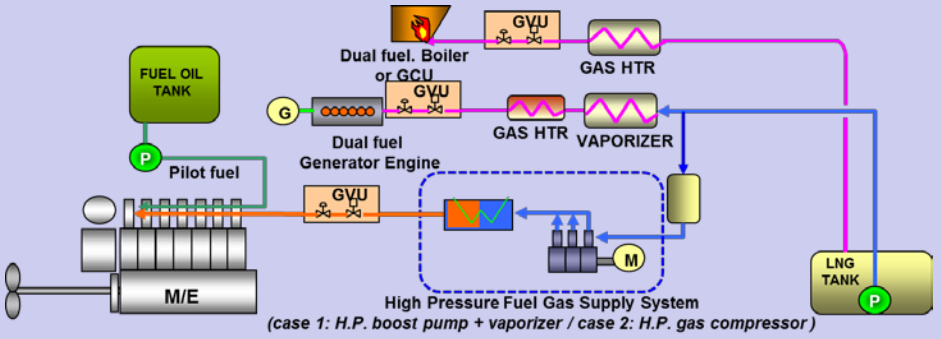
[2] 4 stroke DF or Gas Engine / coupling with propeller via R/G

- ✓ Track records of chemical tanker, tugboat etc.



[3] 2 stroke Dual Fuel Engine / direct coupling with propeller

- ✓ No track record
  （will apply to US coastal container carriers , LNGCs in near future）



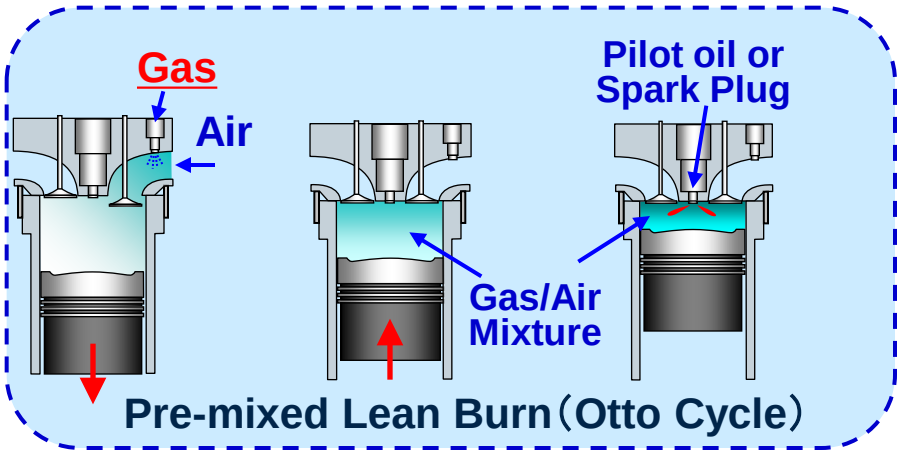
Gas fuel engine types 1/2

[1] 4 Stroke Gas Engine

- Mitsubishi: GSR
- Rolls Royce: Bergen
- (Kawasaki)*

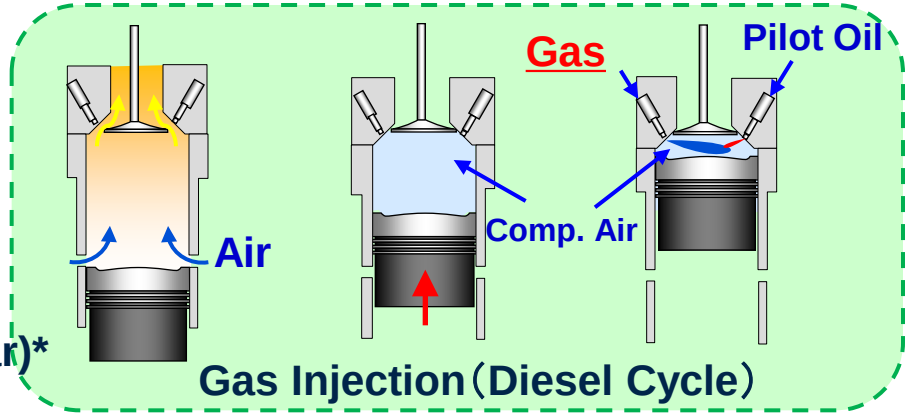
[2] 4 Stroke Dual Fuel Engine

- Wartsila: 50DF, 34DF, 20DF
- MAN: 51/60DF
- Hyundai: HiMSEN
- (Nigata Power System, Daihatsu, Yanmar)*



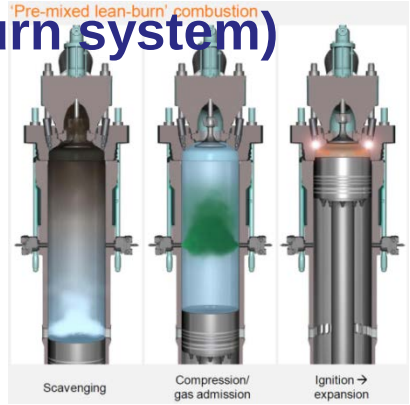
[3] 2 Stroke Dual Fuel Engine

- MAN: ME-GI
- (MHI: UEC-LSGi)*



[4] 2 Stroke Dual Fuel Engine (pre-mixed lean burn system)

- (Wartsila: RT-flex DF)*



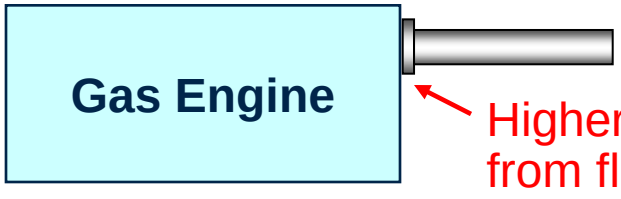
Gas fuel engine types 2/2

Type	[1] 4 Stroke Gas Engine	[2] 4 Stroke DF Engine	[3] 2 Stroke DF Engine
Ignition	Spark plug	Pilot oil	
Gas supply pressure	4~5 bar	4~5 bar	300 bar
NOx Tier III	Conformable	Conformable	SCR, EGR, etc.
SOx ECA	Conformable	Pilot oil ：Low sulfur fuel oil	
Methane slip	1~2%	1~2%	Nil
Gas fuel quality	≧80 Methane number	≧80 Methane number	No specific requirement
Records	Good	Good	Nil
Remarks	• Knocking concern • Propulsion back up system required	• Knocking concern • Fuel consumption on FO mode (low compression ratio)	• Safety assessment for HP system required

Common concerns of gas fuel engine

✓ Gas leakage from piping (especially on high pressure piping)

Direct injection type

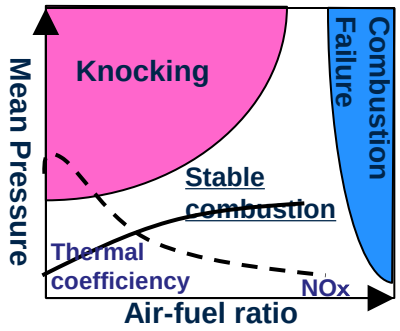


➡ Can be tackled by special seals

✓ Knocking (abnormal combustion)

Pre-mixed burn type

- There are defined knocking & combustion failure area due to pre-mixed lean-burn combustion
- Stable combustion area is influenced sensitively by air-fuel ratio, temperature of gas supply, composition of fuel gas, etc.

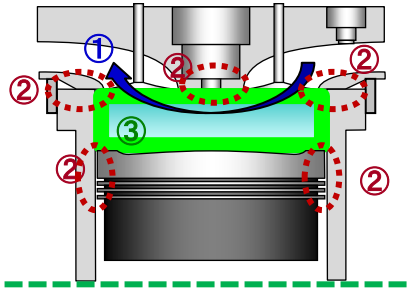


➡ Can be managed by improvement of combustion control

✓ Methane slip (Emission of unburned methane)

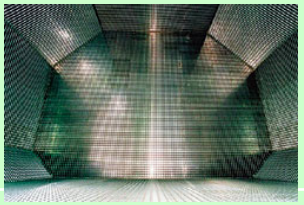
Main causes:

1. Blow-by during overlap
2. Unburnt gas in interspaces
3. Internal boundary area of combustion chamber



➡ Can be reduced by technical improvements

Gas fuel storage tank types

Type	Independent Tank Type A	Independent Tank Type B	Independent Tank Type C	Membrane
Shape				
Design Vapor Press.	< 0.07MPa	< 0.07MPa	High pressure	≦0.025MPa
Records	Nil	Nil (under consideration)	Good	Nil
Features	• Complete secondary barrier • Good volume efficiency • No records of LNG tank	• Partial secondary barrier • Volume efficiency: Spherical : Low Prismatic : Good • High reliability	• No secondary barrier • Volume efficiency: Cylindrical: Low • High reliability	• Complete secondary barrier • Good volume efficiency • Sloshing concern

Gas fuel storage tank location

- ✓ **Abt. twice volume of FO tank (calorie equivalent)**
- ✓ **Tank location limited by rule requirements**
- ✓ **On deck arrangement**
  - No reduction of cargo capacity
  - Simple arrangement
  - Tank size limited by the deck space
  - Protection from mechanical damage

Source: http://www.marinelink.com/news/developed-fuelled-carrier350229

- ✓ **Under deck arrangement**
  - For ships with small space on deck
  - Reduction of cargo carrying capacity
  - Safety against gas leakage in enclosed space (tank connection space)

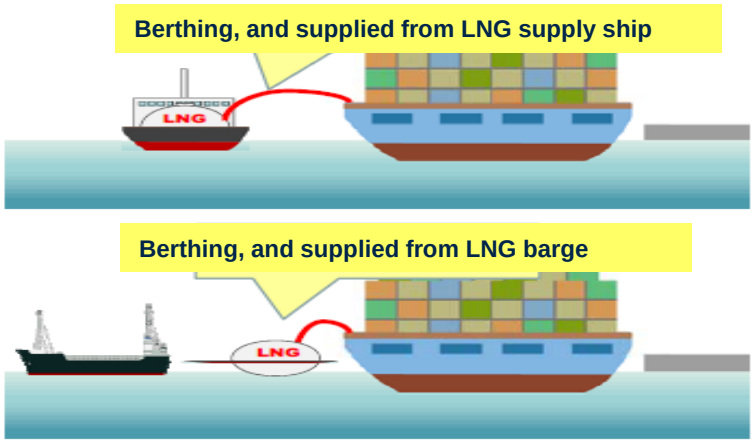
Source: Wartsila, Tidewater to Promote Use of LNG as Marine Fuel (Australian)

LNG bunkering (1/2)

✓ Possible bunkering procedures

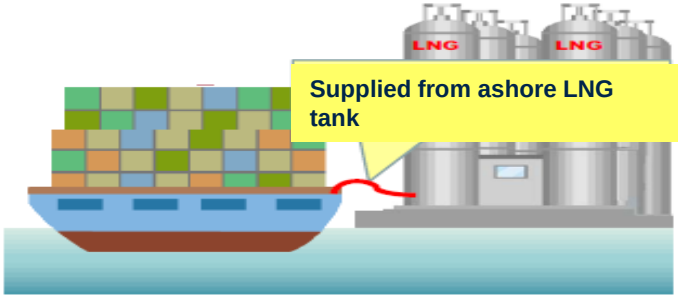
【Ship to ship transfer type】

- Fuel supply from other ship or barge



【Direct supply type】

- Fuel supply from ashore facility

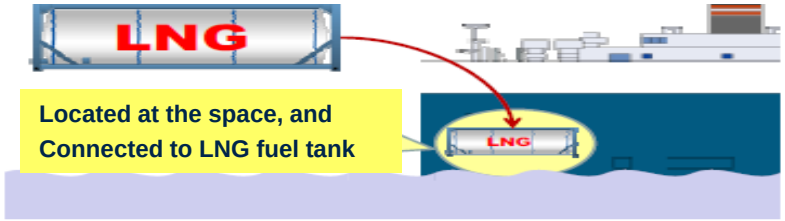


【Tanker truck type】

- Fuel supply from tank truck

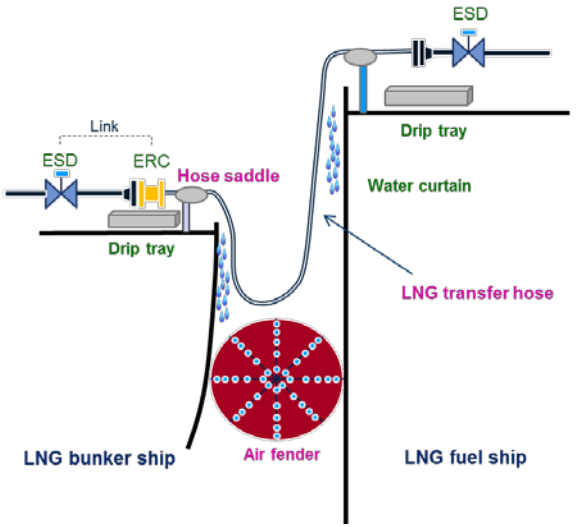
【Tank container type】

- Fuel supply with storage tank containers

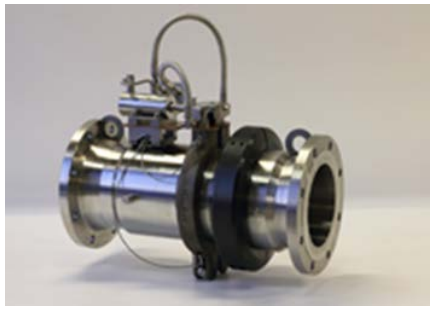


LNG bunkering (2/2)

- ✓ **Ports under consideration of LNG fuel supply :**
  Goteborg (Norway), Zeebrugge (Belgium), Rotterdam (Netherland), Stockholm (Sweden), Singapore, etc.
- ✓ **Standard of LNG bunkering interface (operation, equipment, etc.):**
  ISO/DTS 18683, Guidelines by relevant organization
- ✓ **Risk assessment to establish safe bunkering procedure :**
  Potential hazard : leakage, overfilling, overpressure, gas vent, fire, collision, loss of power, etc.



Arrangement of LNG bunkering equipment (example of STS)



ERC (Emergency Release Coupling)

LNG transfer hose

LNG loading arm

IGF Code History

- ✓ **Res. MSC.285(86) "INTERIM GUIDELINES FOR NATURAL GAS-FUELLED ENGINE INSTALLATIONS IN SHIPS"** : issued in 2009
- ✓ **INTERNATIONAL CODE OF SAFETY FOR SHIPS USING GASES OR OTHER LOW-FLASH POINT FUELS(IGF Code):** under discussion in IMO
- ✓ **Remaining issues to be discussed :**
  - Flexibility on the location of fuel tank installation
  - Additional requirements for ships using Ethyl or Methyl Alcohol as fuel
  - Training and operational requirements, etc.

➡ Continuous discussions toward the IMO approval of the code draft in 2014

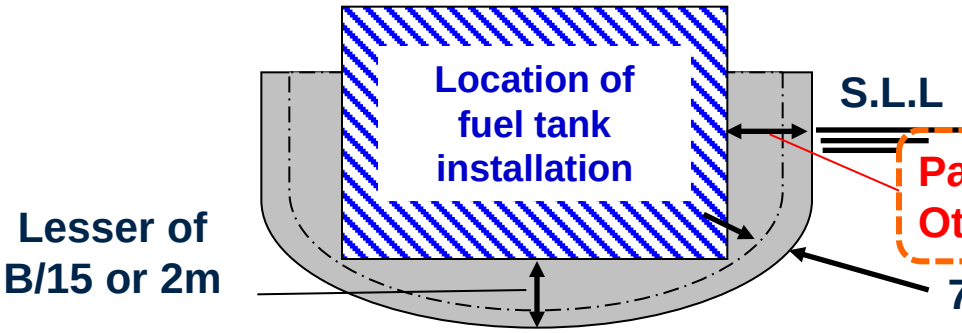
IGF Code Structure (latest draft)

Ch.1	Preamble
Part A	
Ch.2	General
Ch.3	Goal and functional requirements
Ch.4	General requirements
Part A-1	Specific requirements for ships using natural gas as fuel
Ch.5	Ship design and arrangement
Ch.6	Fuel containment system
Ch.7	Material and General pipe design
Ch.8	Bunkering
Ch.9	Fuel supply to consumers
Ch.10	Power generation (including propulsion and other energy converters

Ch.11	Fire safety
Ch.12	Explosion protection
Ch.13	Ventilation
Ch.14	Electrical installation
Ch.15	Control, monitoring and safety systems
Part A-2	Additional requirements for ships using Ethyl or Methyl Alcohol as fuel
Part B	
Ch.16	Manufacturing, Workmanship and Testing
Part C	
Ch.17	Training and operational requirements

Major requirements : *Fuel Tank Location*

- ✓ **Minimum distance from shell plating:**
  - Protection against effects of external damage caused by collision, grounding, fire or other possible operational damage



[Note] These values are changing & still under discussion at IMO

Passenger ships : Lesser of B/5 or 11.5m
Other ships : Smaller than B/5 accepted

ClassNK "Guidelines for Gas Fuelled Ships" = "d" in New IGC Code 2.4

.1 V ≦ 1,000 m³ : d = 0.80 m;
.2 1,000 m³ ≦ V ≦ 5,000 m³ : d = 0.75+ V x 0,20/4,000;
.3 5,000 m³ ≦ V ≦ 30,000 m³ : d = 0.8 + V/25,000;
.4 30,000 m³ ≦ V : d = 2 m
(V: Tank volume, d: distance from ship's outer shell)

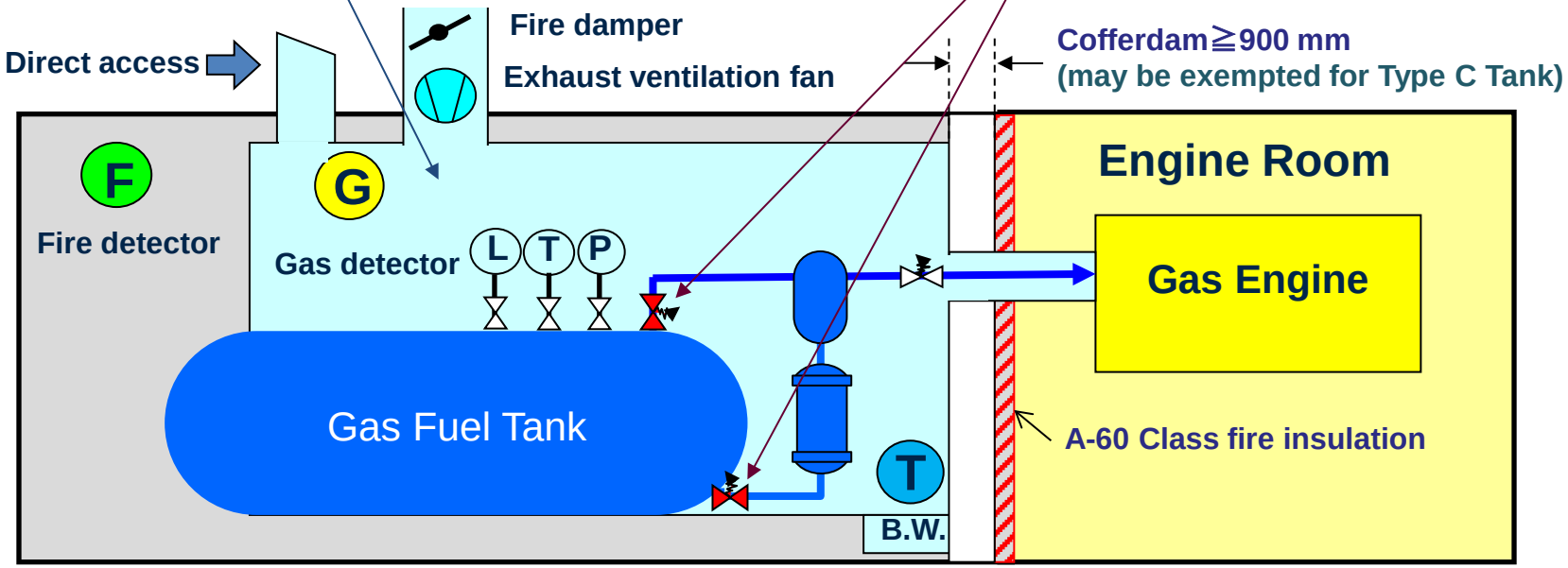
Major requirements : *Fuel Tank Installation below Open Deck*

Tank Connection Space:

- ✓ Space surrounding all tank connections & valves
- ✓ Gas tight toward adjacent space
- ✓ Safely contain any leakage from the tank (Design temperature same as fuel tank)
- ✓ Thermally insulated from hull structure

Main Tank Valve shut-down:

- ✓ Gas leakage（40%LEL)
- ✓ Fire detection in hold space
- ✓ Loss of ventilation
- ✓ Bilge well low temp. etc.



Major requirements : *Fuel Supply to & inside Engine Room 1/3*

Gas Safe Machinery Space

- ✓ Gas fuel piping to consist of double wall or be installed in duct
  → A single failure not to lead to gas release into E/R
- ✓ Redundancy of propulsion: segregation of dual piping system

ESD-protected Machinery Space

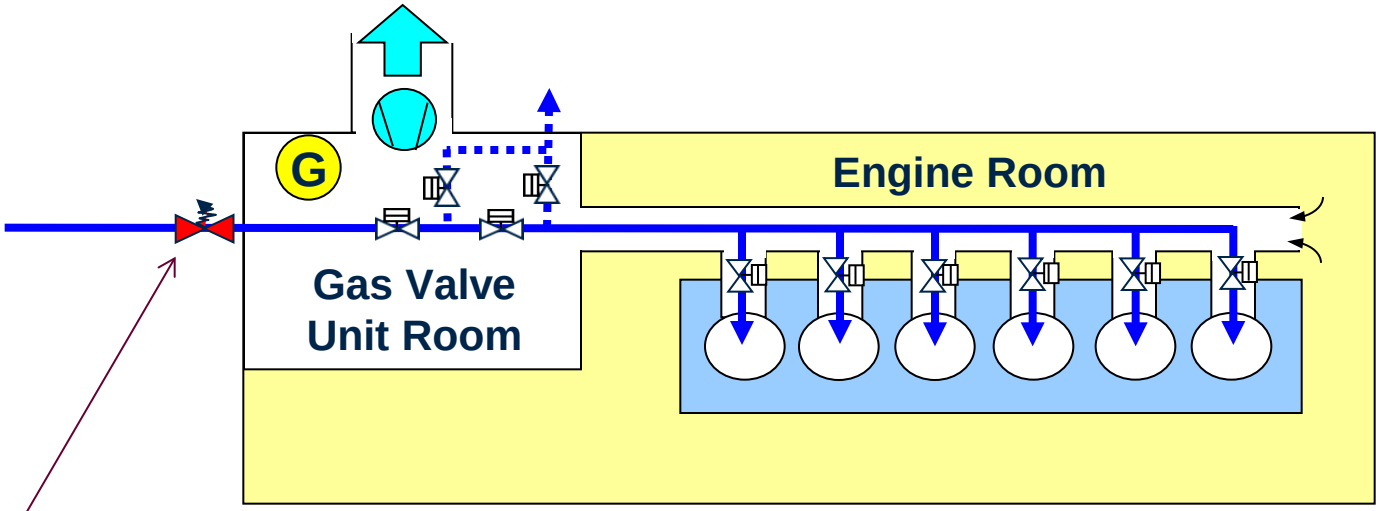
- ✓ Gas fuel piping may consist of single wall (dbl. wall or other housing not required)
  → Shut-down of gas supply and non-explosion proof electrical equipment (all ignition sources) where gas leaks are likely
- ✓ Redundancy of propulsion: two or more engines installed in separate machinery spaces

Major requirements : *Fuel Supply to & inside Engine Room 2/3*

Gas Safe Machinery Space

✓ **Double wall piping or Duct:**

- Ventilation by exhaust fan（30 changes / Hr）, or
- Space between pipes pressurized with inert gas greater than gas pressure, etc.

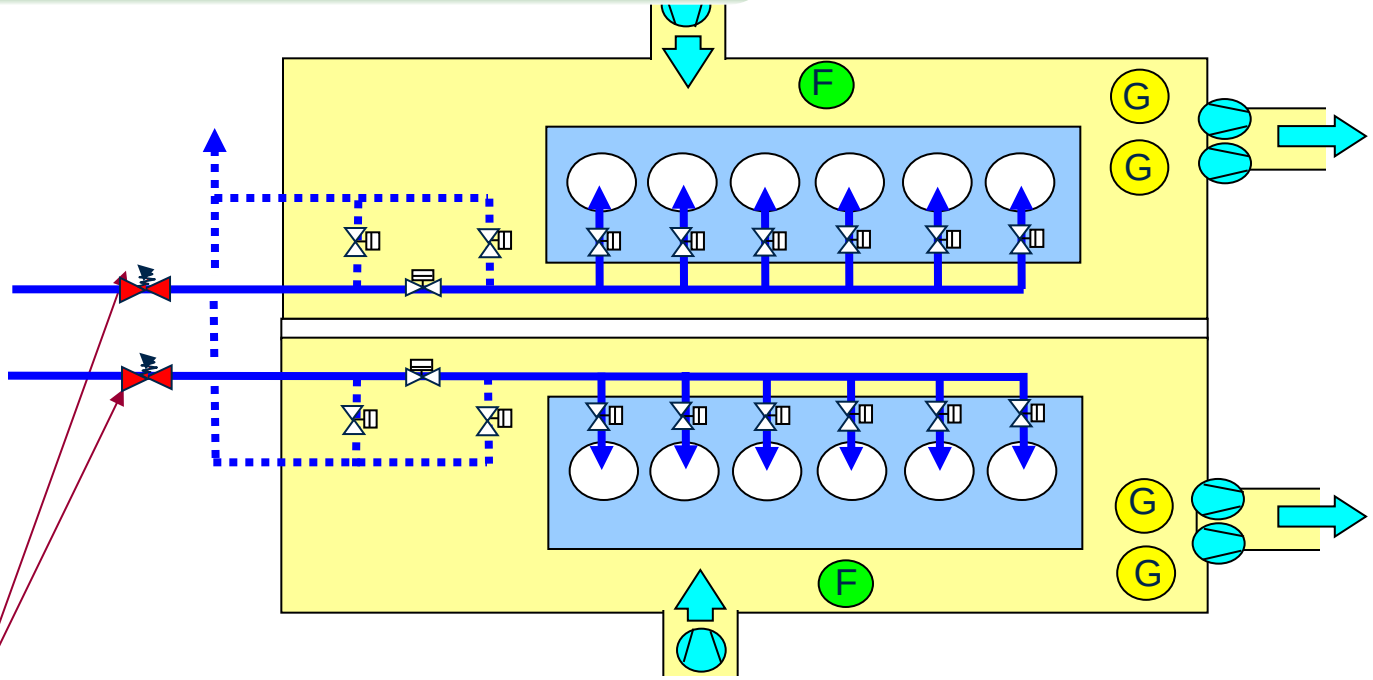


✓ **Fuel gas master valve shut**:

- Gas leakage（60% LEL)
- Loss of ventilation in outer pipe / duct
- Abnormal Pressure in gas pipe, etc.

Major requirements : *Fuel Supply to & inside Engine Room 3/3*

ESD-protected Machinery Space



- ✓ **Fuel gas master valve shut**:
  - Gas leakage（40% LEL)
  - Loss of ventilation in Engine Room
  - Abnormal Pressure in gas pipe, etc.

+

- ✓ **Shut down of non-explosion proof electrical installations**

Frameworks & Goals

ClassNK R&D Activities

Japanese government-led R&D Project

- **Basic understanding of associated risks for rule feedback**
- **Standard operational guidance for LNG bunkering**

Joint Industry R&D Project

- **Technical assistance in developing commercial LNG fuelled system**

ClassNK solo R&D Project & related Activities

- **Development of own guidelines**
- **Design review & granting approval (AIP etc.)**

Japanese Government-led R&D Project

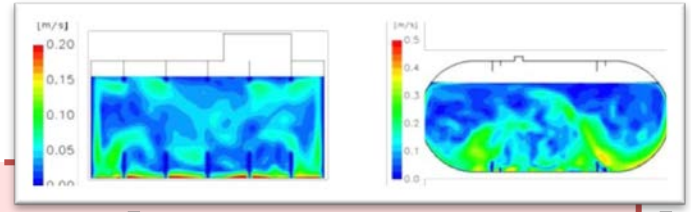
Comprehensive research for promotion of natural gas fuelled ships

- ✓ Fuel transfer safety committee
- ✓ Navigation safety committee
- ✓ Maritime disaster prevention committee

Technical assistance

ClassNK

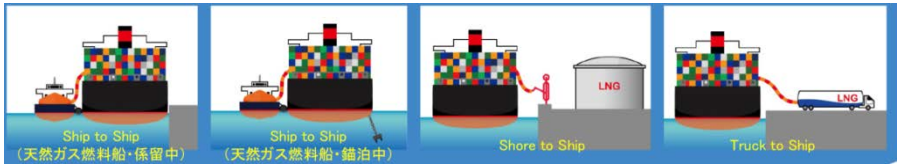
Providing tech. expertise
Class Rules & Conventions (IGC, IGF Code), Survey



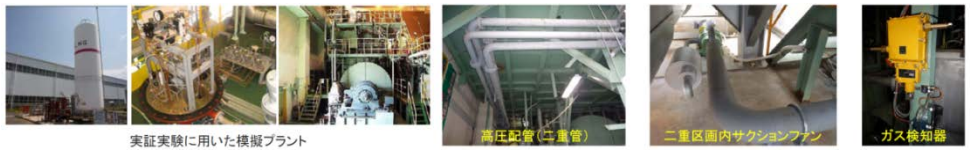
【Study of roll-over in fuel tank】

Key Outcome

- ✓ **LNG bunkering guideline and operation manual**
- ✓ **Safety requirements for high pressure fuel gas supply system**
- ✓ **Requirements for docking of natural gas fuelled ships**
- ✓ **Safety requirements for harbor operation without bunkering**



【Study of various bunkering modes】



【Study of high pressure gas system through pilot plant】

Joint Industry R&D Project

ClassNK Joint Industry R&D project on LNG fuelled ship (1/2)

Project	Industry Participants
Prelim. design development of LNG fuelled ships & feed back to IGF Code	JSTRA, IHI MU (JMU), Imabari, KHI, Namura, MES, MHI, Universal, K-Line, MOL, NYK, MTI
Research for practical use of ocean-going LNG fuelled ship	JMS
Research for LNG fuel application on coastal tug boat	JMS, TLT
Preliminary design development for coastal tug boats with LNG fuel system	NYK, Keihin Dock, Niigata Power System
Risk assessment of H.P. fuel gas supply system for low speed DFD	MES, MOL

Joint Industry R&D Project

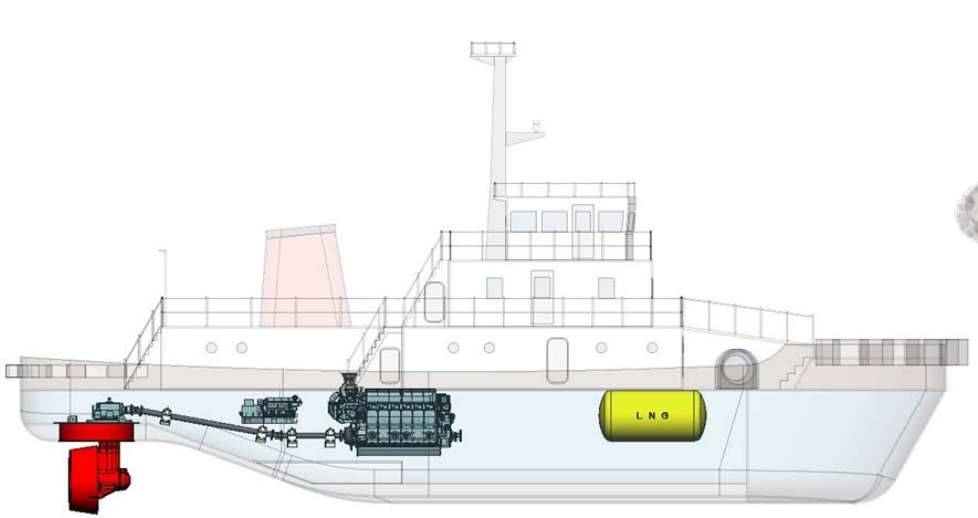
ClassNK Joint Industry R&D project on LNG fuelled ship (2/2)

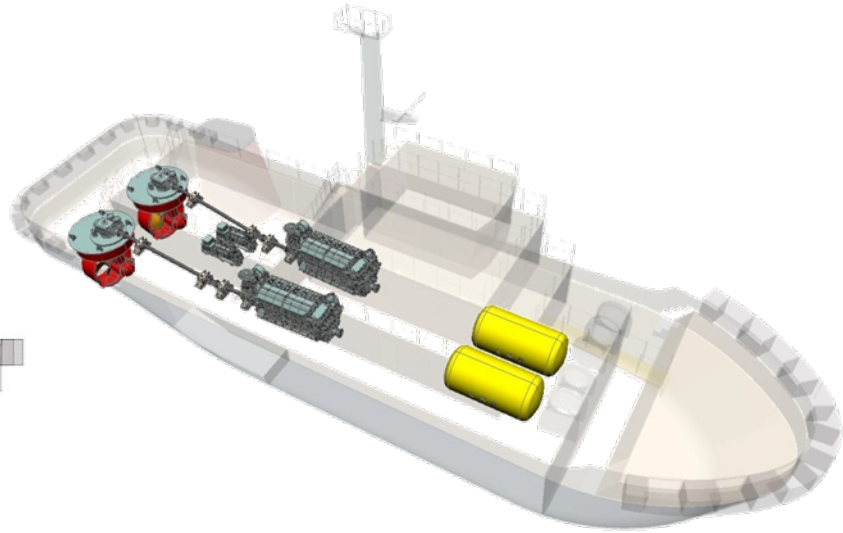
Project	Industry Participants
Research on on-deck arrangement of LNG fuel tank with prismatic type B design	MHI
Feasibility study of varying types and materials of LNG fuel tank	MHI
Prelim. design development of ocean going LNG fuelled ship & bunker ship	MHI, NYK, JMS
Development of 4-stroke marine dual fuel engine	Daihatsu
Development of small scale LNG carrier / bunkering ship with DF Engine	Kobe Senpaku, Higaki, Sanwa Dock, Daihatsu, Izumi Steel, CAJS

Joint Industry R&D Project

Development of Coastal Tug Boat with LNG fuel system

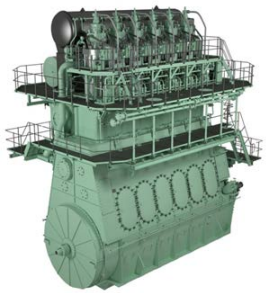
- ✓ Study of optimum design (comparison in engine type, shafting & propellar, LNG/CNG tank system, etc.)
- ✓ Study of infrastructure in Tokyo Bay
- ✓ Compliance with safety requirements (IGF Code, NK Guidelines) reviewed
- ✓ Challenges identified: Vent mast arrangement, DF engine with sufficient maneuverability, Bunkering procedure, etc.

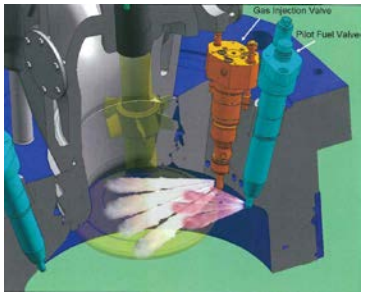




Joint Industry R&D Project

Risk Assessment for HP Fuel Gas Supply System for Low Speed DFD



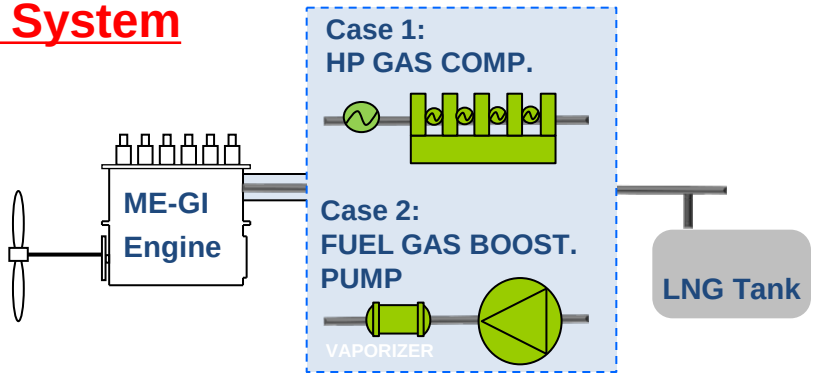


Advantages:
- ✓ High efficiency
- ✓ SOx, NOx, CO_2(abt.20%) reduction
- ✓ Stable combustion (No knocking)
- ✓ Less emission of unburned Methane

MITSUI – MAN B&W ME-GI Engines *Two Stroke Low-speed Gas Injection type Dual Fuel Engine*

High Pressure (abt. 300bar) Fuel Gas Supply System

Challenges:
- ✓ Prevention of gas leakage H.P. piping
- ✓ Stable propulsion under any operation mode
- ✓ System behavior prediction on control malfunction

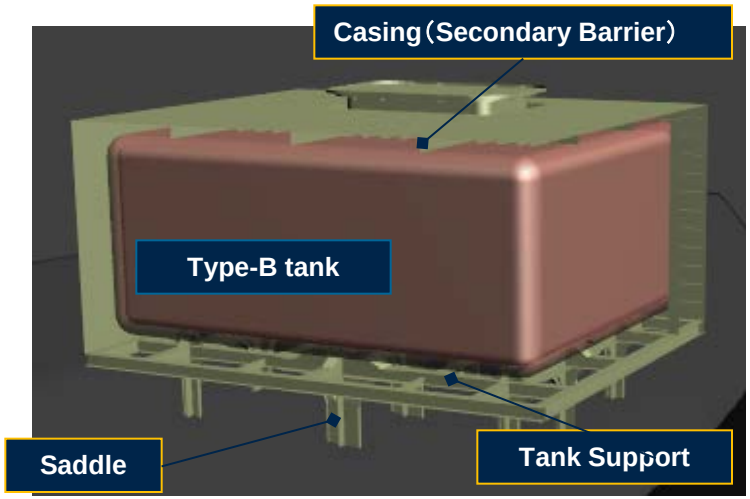


Risk assessment (HAZOP, HAZID) was conducted to ensure;
- ✓ Safety improvement by taking countermeasures to identified hazards, and
- ✓ Continuous safety operation in case of failure on LNG fuel gas supply system

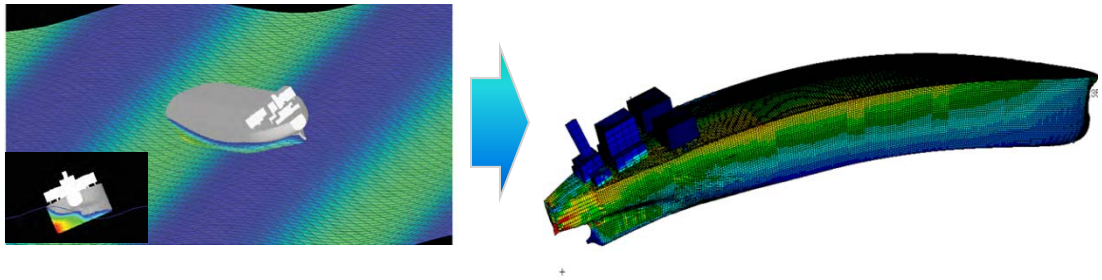
Joint Industry R&D Project

On-deck arrangement of LNG fuel tank with prismatic type B design

- ✓ Trial design of on deck arrangement of LNG fuel tank (Type B) for VLCC
- ✓ Structures of tank, casing, tank support were confirmed as feasible.

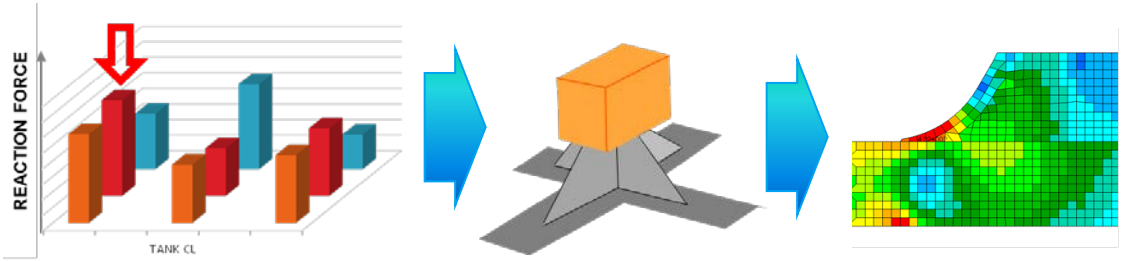


Buckling analysis of hull & tank combined structure



Visibility

Fatigue strength analysis of critical part (e.g. tank support)



Joint Industry R&D Project

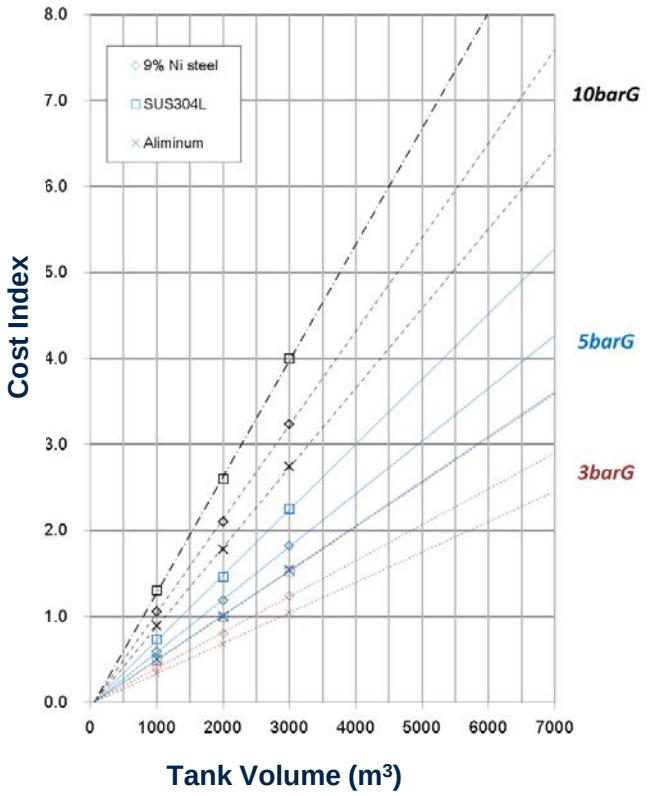
Feasibility study of varyng types and materials of LNG fuel tank

- ✓ Building cost comparison* among varying types & materials to identify design parameters for economical LNG fuelled ships

*[*Costs in material / construction / inspection considered]*

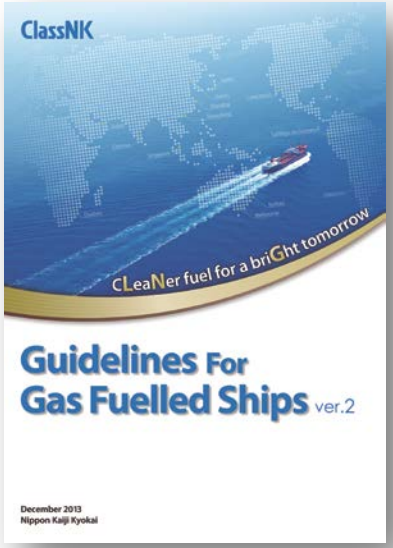
Derived Cost Index

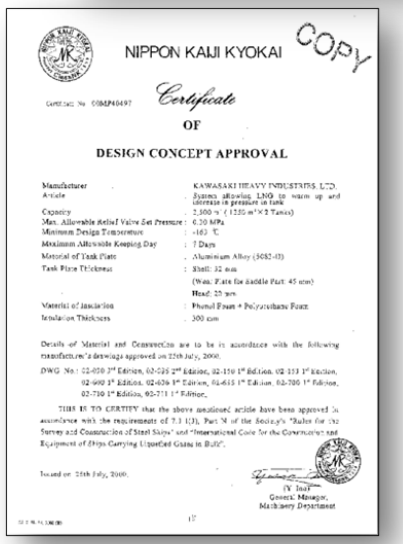
- **Material (2000m³, 5bar, Cylindrical Type C Tank):**
  Aluminum: SUS304L: 9%Ni St. = 1: 1.5 : 1.2
- **Tank Volume (5bar, Alminum, Cylindrical Type C Tank):**
  5% cost* increase and decrease / 100m³ in proportion
- **Design Pressure**
  (2000m³, Aluminum, Cylindrical Type C Tank):
  16% cost* increase and decrease / 1bar in proportion
- **Tank Type (2000m³, 5bar, Aliminum Tank):**
  Cylindrical type C tank : Prismatic type B tank = 1: 1.5



ClassNK solo R&D Project

- ✓ **ClassNK “Guidelines for Gas fuelled ships” issued.**
  - Guidelines for the design of LNG fuelled ships prior to enforcement of IGF Code
  - Latest draft of IGF Code plus NK interpretations
  - Applicable only to natural gas fuel
  - To be reviewed periodically, considering updated IGF Code, new technological developments, etc.
  - Available at NK Home Page（https://www.classnk.or.jp)
    (Home>Products & Services>classification Service> Rules & Guidelines)
- ✓ **Approval in principle (AIP) has been granted for relevant new installations/technologies**




NIPPON KAIJI KYOKAI

COPY

Certificate

OF

DESIGN CONCEPT APPROVAL

4. Summary

- ✓ Basic technology for LNG fuelled ships has been established.
- ✓ For the spread of LNG fuelled ships, especially for ocean going service, comprehensive solutions (infrastructure development, national support etc.) are necessary.
- ✓ ClassNK is currently working on ;
  - Rule development (involvement of IGF Code drafting, updating own “Guidelines for Gas Fuelled Ships”)
  - Funding & leading Joint Industry R&D Projects
  - Approval in principle for design proposals
  - Technical advise / support from a point of safety of the ships

ClassNK continuously strives to contribute to promoting LNG fuelled ships based on sufficient experience for LNGC technology and knowledge through relevant R&D projects.

THANK YOU

for your kind attention