Activities of ClassNK
- LNG Fuelled Ships -

July 2014

LNG-Fuelled Vessel Technologies Seminar
ClassNK / Nippon Kaiji Kyokai
Contents

1. Current Situation & Technical Trends
2. IGF Code & its discussion at IMO
3. ClassNK activities
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Background – Why LNG fuelled ships?

- **Response to IMO Regulations (NOx, SOx, EEDI(CO2))**
  - 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
1. Current Situation & Technical Trends

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, 25,000DWT)

EideViking “Energy Viking”
(Offshore support vessel, DF type, L=95m)
1. Current Situation & Technical Trends

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

<table>
<thead>
<tr>
<th>Length</th>
<th>214 m</th>
<th>Main engines</th>
<th>4 × Wartsila 8L50DF, 7600 kW per unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breadth</td>
<td>31.8 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GT</td>
<td>57,000 ton</td>
<td>LNG fuel tanks</td>
<td>2 × Type C cylindrical cryogenic tanks, 2 × 200m³</td>
</tr>
<tr>
<td>Service speed</td>
<td>abt. 22 knots</td>
<td>Passenger</td>
<td>2800</td>
</tr>
<tr>
<td>Bunker Capacity</td>
<td>200 m³</td>
<td>Length</td>
<td>50 m</td>
</tr>
</tbody>
</table>

Operating between Turku and Stockholm

Reference: Viking Grace Home Page

LNG bunkering for “Viking Grace”
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
1. Current Situation & Technical Trends

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)
1. Current Situation & Technical Trends

Gas fuel engine types 1/2

[1] 4 Stroke Gas Engine
- Mitsubishi: GSR
- Rolls Royce: Bergen
- (Kawasaki)*

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

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

(pre-mixed lean burn system)
- (Wartsila: RT-flex DF)*
1. Current Situation & Technical Trends

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Ignition</td>
<td>Spark plug</td>
<td>Pilot oil</td>
<td></td>
</tr>
<tr>
<td>Gas supply pressure</td>
<td>4~5 bar</td>
<td>4~5 bar</td>
<td>300 bar</td>
</tr>
<tr>
<td>NOx Tier III</td>
<td>Conformable</td>
<td>Conformable</td>
<td>SCR, EGR, etc.</td>
</tr>
<tr>
<td>SOx ECA</td>
<td>Conformable</td>
<td>Pilot oil : Low sulfur fuel oil</td>
<td></td>
</tr>
<tr>
<td>Methane slip</td>
<td>1~2%</td>
<td>1~2%</td>
<td>Nil</td>
</tr>
<tr>
<td>Gas fuel quality</td>
<td>≥80 Methane number</td>
<td>≥80 Methane number</td>
<td>No specific requirement</td>
</tr>
<tr>
<td>Records</td>
<td>Good</td>
<td>Good</td>
<td>Nil</td>
</tr>
<tr>
<td>Remarks</td>
<td>Knocking concern</td>
<td>Knocking concern</td>
<td>Safety assessment for HP system required</td>
</tr>
<tr>
<td></td>
<td>Propulsion back up system required</td>
<td>Fuel consumption on FO mode (low compression ratio)</td>
<td></td>
</tr>
</tbody>
</table>
1. Current Situation & Technical Trends

**Common concerns of gas fuel engine**

- **Gas leakage from piping** (especially on high pressure piping)
  - Gas Engine
  - Gas supply
  - Higher risk of leakage from flange joints
  - Can be tackled by special seals

- **Knocking (abnormal combustion)**
  - 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

![Diagram of Gas Engine and Knocking/Combustion Failure Areas](image)
### Gas fuel storage tank types

<table>
<thead>
<tr>
<th>Type</th>
<th>Independent Tank Type A</th>
<th>Independent Tank Type B</th>
<th>Independent Tank Type C</th>
<th>Membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shape</strong></td>
<td>![Tank Type A Image]</td>
<td>![Tank Type B Image]</td>
<td>![Tank Type C Image]</td>
<td>![Membrane Image]</td>
</tr>
<tr>
<td><strong>Design Vapor Press.</strong></td>
<td>(&lt;0.07\text{MPa})</td>
<td>(&lt;0.07\text{MPa})</td>
<td>(\text{High pressure})</td>
<td>(\leq 0.025\text{MPa})</td>
</tr>
<tr>
<td><strong>Records</strong></td>
<td>Nil</td>
<td>Nil (under consideration)</td>
<td>Good</td>
<td>Nil</td>
</tr>
<tr>
<td><strong>Features</strong></td>
<td>Complete secondary barrier Good volume efficiency No records of LNG tank</td>
<td>Partial secondary barrier Volume efficiency: Spherical: Low Prismatic: Good High reliability</td>
<td>No secondary barrier Volume efficiency: Cylindrical: Low High reliability</td>
<td>Complete secondary barrier Good volume efficiency Sloshing concern</td>
</tr>
</tbody>
</table>
1. Current Situation & Technical Trends

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

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

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

- **Ship to ship transfer type**
  - Fuel supply from other ship or barge
  - Berthing, and supplied from LNG supply ship
  - Berthing, and supplied from LNG barge

- **Direct supply type**
  - Fuel supply from ashore facility
  - Supplied from ashore LNG tank

- **Tanker truck type**
  - Fuel supply from tank truck
  - Tanker truck

- **Tank container type**
  - Fuel supply with storage tank containers
  - Located at the space, and Connected to LNG fuel tank
1. Current Situation & Technical Trends

**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.

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**Arrangement of LNG bunkering equipment (example of STS)**

- ERC (Emergency Release Coupling)
- LNG transfer hose
- LNG loading arm

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KLAW Product LTD: HOME PAGE
FKAB MARINE DESIGN: HOME PAGE
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
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<td>Part A</td>
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<td>General</td>
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<td>Goal and functional requirements</td>
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<td>Ch.4</td>
<td>General requirements</td>
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<td>Part A-1</td>
<td>Specific requirements for ships using natural gas as fuel</td>
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<td>Ch.5</td>
<td>Ship design and arrangement</td>
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<td>Material and General pipe design</td>
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<td>Ch.9</td>
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<td>Power generation (including propulsion and other energy converters</td>
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<td>Control, monitoring and safety systems</td>
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<tr>
<td>Part A-2</td>
<td>Additional requirements for ships using Ethyl or Methyl Alcohol as fuel</td>
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<td>Part B</td>
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<td>Manufacturing, Workmanship and Testing</td>
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<td>Part C</td>
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<tr>
<td>Ch.17</td>
<td>Training and operational requirements</td>
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### Minimum distance from shell plating:
- Protection against effects of external damage caused by collision, grounding, fire or other possible operational damage

**ClassNK “Guidelines for Gas Fuelled Ships” = “d” in New IGC Code 2.4**

1. \( V \leq 1,000 \text{ m}^3 \) : \( d = 0.80 \text{ m} \);
2. \( 1,000 \text{ m}^3 \leq V \leq 5,000 \text{ m}^3 \) : \( d = 0.75 + \frac{V}{4,000} \);
3. \( 5,000 \text{ m}^3 \leq V \leq 30,000 \text{ m}^3 \) : \( d = 0.8 + \frac{V}{25,000} \);
4. \( 30,000 \text{ m}^3 \leq V \) : \( d = 2 \text{ m} \)

\( V \): Tank volume, \( d \): distance from ship’s outer shell

(Note) These values are changing & still under discussion at IMO.
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.

- **Cofferdam ≥ 900 mm** (may be exempted for Type C Tank)
- **Fire damper**
- **Exhaust ventilation fan**
- **Direct access**
- **Gas Engine**
- **A-60 Class fire insulation**

**Engine Room**

**Gas Fuel Tank**

**F** Fire detector

**G** Gas detector

**L**

**T**

**P**
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
Fuel gas master valve shut:
- Gas leakage (60% LEL)
- Loss of ventilation in outer pipe / duct
- Abnormal Pressure in gas pipe, etc.

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.

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

Gas Safe Machinery Space
2. IGF Code & its discussion at IMO

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**
3. ClassNK activities

Frameworks & Goals

- **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.)
Comprehensive research for promotion of natural gas fuelled ships

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

Japanese Government-led R&D Project

ClassNK

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

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
### ClassNK Joint Industry R&D Project

#### Preliminary design development of LNG fuelled ships & feedback to IGF Code
- **Industry Participants:** 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
- **Industry Participants:** JMS

#### Research for LNG fuel application on coastal tug boat
- **Industry Participants:** JMS, TLT

#### Preliminary design development for coastal tug boats with LNG fuel system
- **Industry Participants:** NYK, Keihin Dock, Niigata Power System

#### Risk assessment of H.P. fuel gas supply system for low speed DFD
- **Industry Participants:** MES, MOL
### ClassNK Joint Industry R&D project on LNG fuelled ship (2/2)

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

Joint Industry R&D Project

Development of Coastal Tug Boat with LNG fuel system

- Study of optimum design (comparison in engine type, shafting & propeller, 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

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

Advantages:
- High efficiency
- SOx, NOx, CO₂ (abt. 20%) reduction
- Stable combustion (No knocking)
- Less emission of unburned Methane

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
3. ClassNK activities

**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**

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

- **Visibility**

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**Type-B tank**

**Casing (Secondary Barrier)**

**Saddle**

**Tank Support**

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**ClassNK activities**

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3. ClassNK activities

**Joint Industry R&D Project**

**Feasibility study of varying 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, Aluminun, 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 “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
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

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