Emploi du GNL comme carburant pour les navires de commerce et Retour d'expérience sur l'exploitation des moteurs dual fuel et
GAZOCEAN, one of the oldest companies specialised in maritime transportation of liquefied gases and, is pioneer in the development of LNG carriers technologies as containment systems or propulsion systems.

Founded in 1957, present shareholders are GDF Suez (80%) and (20%).

GAZOCEAN is providing Crew, Technical and Commercial Management services for LNG and LPG carriers and Consulting services and Training for the Gas Industry.

1. Introduction

2. Description des installations de propulsion DFDE à bord des méthaniers

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5. Conclusion
Sox

• MARPOL A.VI target: to be reduced by 9 within 10 years
  ✓ 2006: <4.5%
  ✓ 2012: <3.5%
  ✓ 2020: <0.5% (with possibility to be reduced to 0.1%, after a review in 2018)
• In SECA (Baltic, Channel, North Sea)
  ✓ 2007: <1.5%
  ✓ 2010: <1%
  ✓ 2015: <0.1%
• European directive 2005/33/CE
  ✓ 2010: 0.1% at Berth

Nox

• MARPOL A.VI Nox emission levels for internal combustion engines
  ✓ 17 g/kWh for existing engines
  ✓ 14.4 g/kWh for engines built after 01/01/2011
  ✓ 3.4 g/kWh from 2015

GHG

✓ For the moment, there is no compulsory limit value for Green House Gases (GHG) emissions; 4 technical and market-based tools in order to reduce shipping industry (GHG) emissions: EEDI, EEOI, SEEMP, MEPS
1. Use of low sulphur HFO: Not Available at 0,1%

2. Gas Oil or MDO: Cost issue

3. Exhaust gases treatment units (scrubbers/Selective Catalytic Reduction (SCR))
   - Efficiency and Reliability not proven today,
   - High Installation cost
   - Space required not always feasible

4. Alternatives fuels as Bio Gas or Natural Gas

Reduction of Emissions compared to HFO:
- CO2: -20%
- Nox: -80% (without catalytically system)
- Sox: -99%
LNG consists of liquefied NATURAL GAS
(87%-99% methane)

Atmospheric Pressure: -162°C

Other characteristics
- Odorless
- Colorless
- Non-corrosive
- Non-flammable
- Non-toxic

Liquefaction reduces gas volume by 600

LNG « boiling » at atmospheric pressure and temperature
(source: Osaka Gas, GIGNL)

600 m³(n) of natural gas

1 m³ of LNG
- About 370 LNG carriers, consuming BOG

- 20 car/passenger ferries

- 4 offshore vessels

- 3 patrol boats

- 7 cargo ships in order (source DNV)
<table>
<thead>
<tr>
<th>AGENDA</th>
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</thead>
<tbody>
<tr>
<td>1. Introduction</td>
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Since, about 100 DFDE LNG carriers have been ordered in various shipyards worldwide.

Steam Turbines is still powering about 2/3 of the world LNG carriers fleet.

Source: BS energy services/MNG Journal Nov-Dec 2011
Feed-Back on DFDE Propulsion
Characteristics of DFDE Installations

Provalys & Gaselys - 154,500 cum

- Wärtsilä Dual Fuel Generators
  - DG4: 3 x 12V50DF
  - DG3: 1 x 12V50DF
  - DG2: 1 x 6L50DF

Installed Power: 39,900 KW

ABB Electrical Propulsion
2 x 14,000 KW

GDF SUEZ Global Energy - 74,500 cum

- Wärtsilä Dual Fuel Generators
  - 4 x 6L50DF

Installed Power: 22,800 KW

Converteam Electrical Propulsion
2 x 9,500 KW

19 Knots
Feed-Back on DFDE Propulsion
Dual Fuel Engines Principle

- Otto Principle
- Low Pressure gas admission 4 to 6 barg
- Pilot Diesel Injection
- Power 2,5 MW to 17,5 MW

Source: Wärtsilä
Feed-Back on DFDE Propulsion
Characteristics of DFDE Installations
<table>
<thead>
<tr>
<th>Steam Turbine</th>
<th>DFDE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency</strong></td>
<td><strong>Efficiency</strong></td>
</tr>
<tr>
<td>- Depends of respective efficiency of both boilers and turbines, but steam turbines leads to an efficiency which does not exceed 30% at full load.</td>
<td></td>
</tr>
<tr>
<td>- steam turbine propulsion are mainly designed and optimized for a one dedicated speed.</td>
<td></td>
</tr>
<tr>
<td><strong>Safety and Redundancy</strong></td>
<td><strong>Safety and Redundancy</strong></td>
</tr>
<tr>
<td>- steam turbine is the reference</td>
<td></td>
</tr>
</tbody>
</table>

**Feed-Back on DFDE Propulsion Characteristics of DFDE Installations**

- DFDE propulsion efficiency is typically around 40%
- DFDE provides the flexibility according to the power demanded.
- DFDE provides high redundancy with 4 Diesels Generators and 2 Electric Motors
Main Particulars (L, B, C) of Grace Cosmos and Provalys are similar, but cargo capacity at 100% of Grace Cosmos (150,000 cbm) is 3% less than the cargo capacity at 100% of Provalys (154,500 cbm).

Part of this difference is due to the reduced size of DFDE’s engine compartment; the other part is due to the difference of between insulation system CS1 and MKIII (Shape of Tank 1).
PROVALYS/GASELYS

- Regular trade between loading terminals in Mediterranean, Yemen or Snohvit and unloading terminals Worldwide
- 10 to 15 Voyages per year in average

GDF SUEZ GLOBAL ENERGY

- 4 to 5 voyages per Month in Mediterranean Sea

© GAZOCEAN

ENSM – Optimisation énergétique des navires de commerce 18 janvier 2012
Measured BOG & Gas Fuel Consumptions *(in usual weather conditions)*
DF Engines operate 90% of the running time in gas mode.

<table>
<thead>
<tr>
<th>MDO at 70% load</th>
<th>12V</th>
<th>6L</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,4 t/day</td>
<td></td>
<td>0,3 t/day</td>
</tr>
<tr>
<td></td>
<td>Provalys</td>
<td>Gaselys</td>
</tr>
<tr>
<td>------------------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>DG4</td>
<td>19765</td>
<td>18118</td>
</tr>
<tr>
<td>DG3</td>
<td>21151</td>
<td>22865</td>
</tr>
<tr>
<td>DG2</td>
<td>24683</td>
<td>26370</td>
</tr>
<tr>
<td>DG1</td>
<td>15214</td>
<td>15649</td>
</tr>
</tbody>
</table>

**Feed-Back on DFDE Propulsion Operational Experience Maintenance**

- **Consolidated Running Hours - December 2011**
- **Yearly Average Running Hours:** 3,000 to 6,000 hours
Maintenance is performed both in operation and in Dry Dock.

**18,000 H: 10 days, 2 shifts of 12 people**

<table>
<thead>
<tr>
<th>Visit (Hours)</th>
<th>Location</th>
<th>Team</th>
</tr>
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<tbody>
<tr>
<td>6,000</td>
<td>At sea</td>
<td>Ship’s Crew</td>
</tr>
<tr>
<td>12,000</td>
<td>At sea</td>
<td>Ship’s Crew + Assistance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wärtsilä</td>
</tr>
<tr>
<td>18,000</td>
<td>Dry-Dock</td>
<td>Wärtsilä</td>
</tr>
</tbody>
</table>

© GAZOCEAN

ENSIM – Optimisation énergétique des navires de commerce 18 janvier 2012
Maintenance will be done depending on the actual need based on the analysis by Wärtsilä of:

- Condition Based Monitoring (CBM) reports (i.e. WECS data)
- Parameters and Quality of Oil and Fuel recorded by the crew,
- Results of the annual inspection performed by Wärtsilä which scope is:
  - Dismantling of 1 cylinder on 2 engines
  - Endoscopic inspection on the 2 other engines for one 1 cylinder
  - Check of Equipment automation system

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<td>Ship’s Crew + Assistance Wärtsilä</td>
</tr>
<tr>
<td><strong>24,000</strong></td>
<td><strong>Dry Dock or at Sea</strong></td>
<td><strong>Ship’s Crew + Assistance Wärtsilä</strong></td>
</tr>
</tbody>
</table>
Feed-Back on DFDE Propulsion on Board LNG tankers  

**Conclusion**

• Performance and efficiency of DFDE LNG carriers, was targeted and reached but optimal operation mode taking advantage of all ship’s performance and flexibility is still to be found.

• Maintenance of DFDE propulsions systems remain a challenge but New programs as Dynamic Maintenance System, demonstrates that DFDE propulsion is a young system, which should gain in experience, but showing encouraging results, confirming that the broke in LNG industry tradition initiated by GDF SUEZ was a relevant decision.
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LNG as Fuel - Technical Challenges

LNG Propulsion in Ships - Gas Fuel Engines

Dual Fuel Engines
- Wärtsilä or MAN
- DFDE or mechanic

Lean Burned Prechamber spark ignition
- Mitsubushi or Rolls Royce
- Gas mode only
- Low Pressure gas admission 4 to 6 barg
- Spark ignited
- Power 0.2 MW to 10 MW

High Pressure Two Strokes Diesel Engines
- Wärtsilä or MAN
- Dual Fuel
- High Pressure gas admission 200 barg
- Mechanic
Double-wall, vacuum insulated, stainless steel tanks. The tank pressure is defined by the requirement of the engines burning the gas and is usually less than 5 bar. A higher (typically 9 bar) tank design pressure is selected due to the natural boil-off phenomenon.

Space required for the LNG tanks.: An equal energy content of LNG requires about 1.8 times more volume than MDO. When adding the tank insulation, noting the maximum filling ratio of 95%, the required volume is increased to about 2.3 times.

The practical space required in the ship increases four times when taking into account the squared space around the cylindrical LNG tank. If compared to an MDO tank located above a double bottom, the total volume difference is smaller, about 3.0. The typical tank size is less than 200 m3.

The weight of LNG is marginally lower than for MDO when considering the fuel itself. However, the special tank and tank room steel structure may increase the total weight for LNG storage to approximately 1.5 times over MDO.
Typical LNG Membrane Tank,

- atmospheric pressure, Temp -163°C,
- BOG rate of 0.15% in volume at minimum.
- Integrated tanks.
- Applicable if capacity is over 5,000 cum.

Pressurized Container Tanks
Located on deck or on a garage deck for a RoRo in dedicated zone

Figure 11-1 Tank sizes for ships already built or under construction
LNG as Fuel - Technical Challenges

Regulations

✓ Class Societies Guidelines on Gas Fuelled Ship Installations

✓ IMO International Code for the Construction and Equipment of Ships Carrying Liquefied Gas in Bulk (IGC Code)

✓ IMO Draft International Code of Safety for Gas-fuelled ships (IGF Code)

✓ SIGTTO/OCIMF/ICS Guidelines on LNG Ship to Ship Transfer /Stolgoe

✓ National/Local land based regulations and Ports regulations

✓ IMO MARPOL Annex VI

✓ EU Directives

✓ ISO standards TC 67
Retail LNG terminals are approximately 50 times smaller than large scale terminals.
LNG as Fuel - Technical Challenges

LNG Distribution Network

Source: GIIGNL
LNG as Fuel - Technical Challenges

LNG Bunkering

- By Truck

Source: Fluxys

Source: Gasnor

- By Sea

Source: GDF SUEZ
Ships currently operating on LNG in Norway are either served by dedicated trucks or stationary LNG tanks on the quay.

The stationary tanks are in turn served by either trucks or small LNG carriers.

The tanks on the quay serving three sister ferries with 12 MW power installed each are 1000 m³ in total.

This facility is served by the small LNG carrier Pioneer Knutsen from the LNG plants in Kollsnes and Karmøy.
LNG as Fuel - Technical Challenges

Where are we in 2012?

• Ships
Some existing ships in Norway, some on order and more and more projects worldwide.

• Studies/Working Groups
Numerous studies in Nordic countries, JIP project pilot by DNV for SE ASIA, European Shipowners Association, BP2S/Armateurs de France, etc.

• Technologies
Improvement of gas Propulsion Technologies: Engines, Storage, etc.

• Ports and terminals
Some ports and terminals are contemplating dedicated jetties for LNG Bunkering (Zeebrugge, Singapore, Gothenborg, etc.)
• **Safety**
Natural gas activities will always have the potential of causing accidents as the gas is flammable under certain conditions.

• **Crew qualification**
On LNG carriers, crew need a STCW Gas tanker qualification. A training and qualification will be required for Gas Ships Propulsion.

• **Economical issues**
  - Ships CAPEX/OPEX
  - Cost of the Fuel on Board
  - Infrastructure
Pioneer in Maritime Transportation of Liquefied Gases