Innovative solutions for LNG carriers. A classification society view.

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Oil Tankers and Gas Carriers
Bureau Veritas - An Extensive Geographic Footprint

- **66,500 employees**
- **1,400 offices and laboratories in 140 countries**

- **Europe**
  - **14,400 employees**
  - **400 laboratories**

- **Africa, Middle East, Eastern Europe**
  - **9,000 employees**
  - **260 laboratories**

- **Americas**
  - **20,100 employees**
  - **330 laboratories**

- **Asia, Pacific**
  - **23,000 employees**
  - **410 laboratories**
Fleet & Orderbook Breakdown – Bureau Veritas

► ACTIVE FLEET
  • OVER 11,500 SHIPS
  • APPROX. 110 mmGT

Fleet (% in GT)
- Bulk: 36.6%
- Tanker: 18.0%
- Gas: 6.8%
- Container: 16.1%
- Cargo: 6.9%
- Passenger: 3.5%
- Offshore: 5.8%
- Other: 6.2%
- REST: 93.2%
- Total: 100.0%

► ORDERBOOK
  • OVER 1,800 SHIPS
  • APPROX. 17 mmGT

Orderbook (% in GT)
- Bulk: 25.2%
- Tanker: 24.2%
- Gas: 18.3%
- Container: 13.5%
- Cargo: 3.8%
- Passenger: 3.9%
- Other: 5.7%
- Autres: 5.3%
- REST: 81.7%
- Total: 100.0%

As of 1st February 2016
Breakdown Gas Carrier Segment – Bureau Veritas

Breakdown (% Number of Ships)

Ships in Service
- LPG: 73%
- LNG: 25%
- LNG/LEG/LPG: 2%

Orderbook
- LPG: 35%
- LNG: 57%
- LNG/LEG/LPG: 8%

As of 1st February 2016
LNG carriers - How it all started in Bureau Veritas

► 1962:
• BV survey tests on experimental LNG carrier "Beauvais“ (26,000 m³ in 3 different cargo tank types)
• First Rules for classification of LNG Carriers.

► 1965:
• Classification of "Jules Verne“ (25,000m³ LNG ship).
• 6 self-supporting cylindrical/conical tanks in 9% Ni steel
Deepest Involvement

First membrane LNG built in Korea

First ever DFDE LNG

First ever multipurpose gas carrier

First ever Regasification LNG
The LNGc World Fleet

LNG FLEET WORLD vs. BV (end of period)

<table>
<thead>
<tr>
<th>Year</th>
<th>WORLD (LNG)</th>
<th>BV (LNG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>362</td>
<td>53</td>
</tr>
<tr>
<td>2011</td>
<td>373</td>
<td>56</td>
</tr>
<tr>
<td>2012</td>
<td>372</td>
<td>57</td>
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<tr>
<td>2013</td>
<td>386</td>
<td>58</td>
</tr>
<tr>
<td>2014</td>
<td>415</td>
<td>61</td>
</tr>
<tr>
<td>2015</td>
<td>447</td>
<td>67</td>
</tr>
</tbody>
</table>

SS LNGc (<40k) | BV | World | BV share
LNG carrier fleet in service | 7  | 29  | ~24%

Anthony Veder’s Coral Energy

Castillo de Santiesteban (Elcano)

LNGc (>40k) | BV | World | BV share
LNG carrier fleet in service | 60 | 418  | ~14.4%

Sources: Clarksons Research / Bureau Veritas (01.02.2016) – Include LNG/LEG/LPG carriers
The LNGc World Orderbook

<table>
<thead>
<tr>
<th>Orderbook</th>
<th>SS LNGc (&lt;40k)</th>
<th>BV</th>
<th>World</th>
<th>BV share</th>
<th>LNGc (&gt;40k)</th>
<th>BV</th>
<th>World</th>
<th>BV share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orderbook</td>
<td>6</td>
<td>12</td>
<td>~50.0%</td>
<td></td>
<td>25</td>
<td>139</td>
<td>~18%</td>
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</table>

Number of ships

<table>
<thead>
<tr>
<th>LNG carriers orderbook</th>
<th>BV</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>151</td>
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</table>

EVOLUTION

<table>
<thead>
<tr>
<th>BV</th>
<th>BV share</th>
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<tbody>
<tr>
<td>31</td>
<td>~20.5%</td>
</tr>
<tr>
<td>29</td>
<td>~18.3%</td>
</tr>
<tr>
<td>17</td>
<td>~15.2%</td>
</tr>
</tbody>
</table>

Sources: Clarksons Research / Bureau Veritas (01.02.2016) – Include LNG/LEG/LPG carriers
A new ERA in the LNG transportation

► From traditional LNG (A to B concept) to a complex environment.
► New exporters. New routes (m3 x mile – Panama canal).
► Yamal LNG. New capacity and very specific new trade (NSR).
► Demand in Japan vs. nuclear restart.
► China. A general slow down.
► India, South East of Asia and Latin America may increase demand.
► Stagnation of demand in Europe. New alternative uses for LNG.
► Offshore terminals vs. LNG prices. FSU and FSRU’s is the focus.
Technical Major Challenges – Containment Systems

► Innovations to cope with market expectations (BOG & Sloshing)
► Multipurpose gas carriers
► Strong competition among the different systems

IMO Classification of LNG Carriers (IGC Code)

Independent tanks
(separated from hull structure)

- Type A
  - "simple" design
  - $P_0 \leq 0.7$ bar
  - Full secondary barrier

- Type B
  - "refined" design
  - $P_0 \leq 0.7$ bar
  - Partial secondary barrier

- Type C
  - $P_0 \geq 2$ bar
  - No secondary barrier

Integrated tanks
(part of hull structure)

- Membrane
  - $P_0 \leq 0.7$ bar
  - Full secondary barrier

  - GTT NO96
  - GTT Mark III
  - GTT CS1
Containment Systems – Orderbook Trends

- NO 96
- MARK III
- MOSS
- IHI
- TYPE C
- KC-1
- TYPE A
LNG Cargo Containment Systems (CCS)

► BV active in all technologies of LNG containment

   Membrane NO96, Mark III, CS1 / MOSS / SPB / TYPE C

   New systems: Mark III Flex, NO96 Low BOR, Mark V, KC1 (Kogas), SCA (SHI)

► Stretching the limits of LNG carriers designs

   Largest LNG carriers with 4 cargo tanks (Membrane 180.000 m³ and Moss stretch type 182.000 m³)

   Large bilobe tanks for type C LNG carriers

► Sloshing assessment

   Assessment of Hydrodynamics and Sloshing.

   Rule and guidelines development.

   Bureau Veritas & research projects.
Assessment of Cargo Containment Systems (CCS)

- Assessment is generally done in two steps
  - **Basic Approval (BA)**
    - Also called Approval in Principle (AiP)
    - A minimum list of information is to be provided
    - Scope of assessment may be different
  - **Design Approval (DA)**
    - Approval level required for a system to be installed in a ship
    - GASA terminology used by some other class societies
    - More detailed information required
    - Scope of documents to assess
- Finally the classification of the ship integrates the containment system final approval (FA).
- Approval based on IGC and classification rules (NR.467)
<table>
<thead>
<tr>
<th>GTT CS</th>
<th>LEVEL OF ASSESSMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO96 / NO96GW</td>
<td>(FA) BV Class Ships / 1995</td>
</tr>
<tr>
<td>Mark III</td>
<td>(FA) BV Class Ships / 2005</td>
</tr>
<tr>
<td>CS1</td>
<td>(FA) BV Class Ships / DA in Nov. 2004</td>
</tr>
<tr>
<td>NO96 L03</td>
<td>(FA) BV Class Ships / DA in Aug. 2013</td>
</tr>
<tr>
<td>Mark III Flex</td>
<td>(FA) BV Class Ships / DA in Dec. 2014</td>
</tr>
<tr>
<td>NO96 L03+</td>
<td>DA in Feb 2015</td>
</tr>
<tr>
<td>MARK III Flex HD</td>
<td>DA in May 2015</td>
</tr>
<tr>
<td>Mark V</td>
<td>DA in Oct 2015</td>
</tr>
<tr>
<td>NO96 Max</td>
<td>AiP – Ongoing assessment for DA</td>
</tr>
<tr>
<td>NO96 Vacuum</td>
<td>AiP</td>
</tr>
<tr>
<td>MARK III (LEG)</td>
<td>AiP</td>
</tr>
<tr>
<td>MARK III (ARCTIC)</td>
<td>AiP</td>
</tr>
<tr>
<td>NO xx</td>
<td>AiP</td>
</tr>
</tbody>
</table>
## Other CCS

<table>
<thead>
<tr>
<th>NAME</th>
<th>TYPE</th>
<th>LEVEL OF ASSESSMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOSS</td>
<td>TYPE B</td>
<td>BV Class Ships (FA)</td>
</tr>
<tr>
<td>CYLINDRIC</td>
<td>TYPE C</td>
<td>BV Class Ships (FA)</td>
</tr>
<tr>
<td>IHI</td>
<td>TYPE B</td>
<td>DA / Offshore unit under const.</td>
</tr>
<tr>
<td>KC-1</td>
<td>MEMBRANE</td>
<td>DA</td>
</tr>
<tr>
<td>SCA</td>
<td>MEMBRANE</td>
<td>DA</td>
</tr>
<tr>
<td>DSME ACT-IB</td>
<td>TYPE B</td>
<td>AiP</td>
</tr>
<tr>
<td>NORDIC YARDS ADBT</td>
<td>TYPE B</td>
<td>AiP</td>
</tr>
<tr>
<td>LNG NEW TECHNOLOGIES</td>
<td>TYPE A</td>
<td>AiP</td>
</tr>
<tr>
<td>LPV Latice</td>
<td>TYPE C</td>
<td>AiP in progress</td>
</tr>
</tbody>
</table>

![Image of ships and vessels](image-url)
Sloshing Assessment for LNG CCS

► BV high skills and expertise in the assessment of Hydrodynamics and Sloshing in LNG CCS.

► Development of rules and guidelines.

- Bureau Veritas Guidance Note NI 554, “Design Sloshing Loads to be Applied on the Cargo Containment System and the Inner Hull Structure”.

- Bureau Veritas Guidance Note NI 564, “Strength Assessment of LNG Membrane Tanks under Sloshing Loads“.

► Bureau Veritas participate in many different research projects.
Top Experience in FSRU’s

- Currently 9 FRSU’s in service with BV class
  - 8 vessels 138,000 to 151,000m³ for Exmar/Excelerate Energy at DSME
  - 1 FSRU of 173,500m³ for Excelerate Energy at DSME in 2014

- BV also involved in the biggest ever FSRU (under construction) and in the conversion of an LNGc into FSU
The Largest FSRU

- The largest ever built FSRU.
  - Qmax size – 263,000 m³
    - 5 NO96 tanks / DFDE propulsion
  - Sloshing
  - Mooring
  - Risk analysis
  - Surveys under in service condition
  - Regulations to apply. Ship vs. offshore notations
Yamal LNG carriers

15 ships under construction at DSME
1st ship just launched

Arc7 + Winterization (-52C)

3 Pod propulsion (45 MW)

Membrane NO96 CCS (170,000 m³)

• Structural assessment
• Sloshing in ice navigation
• Winterization
• Propulsion system
LNGc ACTING AS BUNKERING SHIPS

► Deep involvement in LNG bunkering ships. References
  • NYK / ENGIE / MITSUI 5.100 m³ at HHIC under construction
  • SIRIUS VEDER 5.800 m³ at BODEWES under construction
  • Conversion of oil tankers into LNG bunker ships
  • AiP GTT 4.000 m³ MEMBRANE (including 2barg application)

► Key aspects
  • Management of BOG
  • Assessment of transfer system

► Specific notation developed NR.620 “LNG Bunkering Ship” notation
Technical Major Challenges – Propulsion Systems

- Propulsion systems evolve driven by:
  - Main engine technical developments
  - Regulations (New IGC Code)
  - Economical aspects

- A second modern trend (2 strokes DF engines)

*Courtesy MAN B&W*
Propulsion Systems – Orderbook Trends

- STEAM & STEAM REHEAT
- DFM
- DIESEL+RELIQ
- DFDE/TFDE
- MEGI
- XDF

Graphs showing trends in the number of ships for different propulsion systems from END 2013 to END 2015.
2 STROKES DFM LP vs. HP
## Advisory Services – Energy Efficiency

### Energy Consumption & Gas Emissions

<table>
<thead>
<tr>
<th></th>
<th>0.02%mol N2</th>
<th>1%mol N2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DFDE</td>
<td>HPLS</td>
</tr>
<tr>
<td>GCU</td>
<td>187</td>
<td>290</td>
</tr>
<tr>
<td>FBOG</td>
<td>978</td>
<td>690</td>
</tr>
<tr>
<td>NBOG</td>
<td>2633</td>
<td>2633</td>
</tr>
<tr>
<td><strong>Total Gas</strong></td>
<td>3424</td>
<td>3032</td>
</tr>
<tr>
<td>Pilot fuel</td>
<td>32</td>
<td>150</td>
</tr>
<tr>
<td><strong>Total CO₂</strong></td>
<td>10019</td>
<td>9549</td>
</tr>
</tbody>
</table>

- CFD analysis (optimization of hull, propeller, appendices) - **HYDROCEAN**
- Ship systems (incl. engines) - **SEEoAT**
Multi-Purpose Gas Carriers

- Built by Sinopacific for Evergas (2015)
- The largest multipurpose gas carriers in service
- 4 more units under construction
- Design by Sinopacific and Wartsila (cargo and gas fuel systems)
- DF engines and generator sets
- **First ethane fuel** as an alternative to methane fuel (DF 4 strokes)
Technical Major Challenges – Transfer Systems

► LNG transfer technologies leaded by:
  • Offshore developments
  • LNG Bunkering

► BV Regulations included in NR.542 and NR.620 respectively
EXMAR - Floating LNG

► Exmar FLNG.

- Wison Heavy Industry Co (China)
  - Hull and type C LNG tanks
- Black & Veatch (USA)
  - PRICO® LNG technology – 0.5 MMTPA
  - LM2500+ turbine drive (26 MW)
  - Water cooled interstage
  - On board storage 16,000 m³
- Bureau Veritas involvement: Classification, Gas Process System, Risk Analysis

► Exmar FSRU. IHI Type B tanks (25,000 m³).

► World experience with IHI Type B

- Only 2 ships in service
- 5 ships under construction (165,000 m³) in Japan + FSRU a.m.
New IGC Code - Gap analysis

- Revised IGC Code. Adopted 22th May 2014. Resolution MSC.370(93)
- In force 1st January 2016. Application keel laying 1st July 2016 or after

Bureau Veritas contribution to the industry

- Detailed Gap analysis started in 2014
- First relevant report released in December 2014
- 3 Revised reports have been issued
- Reports distributed to clients
- Further discussion and feedback with clients.
THANK YOU