CNG Transportation under the GASVESSEL project perspective
ABS CNG Carrier Experience

- Major Ship Class Society, Leader in Oil and Gas and Offshore industry
- In the forefront of CNG Technology development, consistently with our mission
- Approved more than 13 design concepts either at AiP or FDA stage
- FPC Lincoln – 40ft pressure vessels (cargo containers) certified by ABS 8 years ago for ship, truck and train transportation without any major incidents recorded
- Regular Interaction with USCG and other Flag Administrations regarding CNG Projects
ABS CNG Carrier Experience

- Dedicated engineering and survey staff to handle CNG Projects – more than 15 years of experience
- Participated in many studies and analysis for CNG Projects:
  - HAZID/HAZOP
  - Emergency Systems and Survivability analysis
  - Temporary Refuge, Escape and Rescue
  - Gas Dispersion and Gas Dynamics
  - Fire and Explosion
  - Smoke and Gas Ingress
  - Inspectability
- First CNG Carrier in the world delivered in China with ABS Class in 2017
- ABS is currently participating in EU funded project – GASVESSEL [www.gasvessel.eu](http://www.gasvessel.eu)
## ABS CNG Carrier - Experience

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>CIMC-CNG Carrier</th>
<th>Sea NG</th>
<th>GEV</th>
<th>Ener Sea</th>
<th>Sea One</th>
<th>Neptune</th>
<th>Trans Canada</th>
<th>Trans Ocean Gas</th>
<th>Blue Power</th>
<th>FPC</th>
<th>Lincoln</th>
<th>Naval Progetti - CNGV</th>
<th>CS &amp; Ass.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>Cylinder</td>
<td>Coiled pipe</td>
<td>Cylinder</td>
<td>Cylinder</td>
<td>Cylinder</td>
<td>Cylinder</td>
<td>Cylinder ISO Container</td>
<td>Pressure vessels</td>
<td>Cylinder ISO Container</td>
<td>Cylinder ISO Container</td>
<td>Cylinder ISO Container</td>
<td>Cylinder ISO Container</td>
<td></td>
</tr>
<tr>
<td><strong>Approval Status</strong></td>
<td>Full Approval – 1st vessel built</td>
<td>Full Approval</td>
<td>Basic Design Approval</td>
<td>Full Approval</td>
<td>AIP</td>
<td>AIP</td>
<td>AIP</td>
<td>AIP</td>
<td>AIP</td>
<td>AIP</td>
<td>Full Approval – Container Certification</td>
<td>AIP</td>
<td>AIP</td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td>Steel cylinder</td>
<td>Steel pipe</td>
<td>Steel API SLX75</td>
<td>Composite reinforced steel pipe</td>
<td>Comp. glass or carbon fiber</td>
<td>Steel</td>
<td>Comp. Reinforced steel pipe</td>
<td>Comp. glass or carbon fiber with liner</td>
<td>Comp. glass &amp; carbon fiber with steel liner</td>
<td>Comp. glass or carbon fiber</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>300 bar</td>
<td>275 bar</td>
<td>250 bar</td>
<td>90-130 bar</td>
<td>199 bar</td>
<td>200 bar</td>
<td>250 bar</td>
<td>240 bar</td>
<td>275 bar</td>
<td>250 bar</td>
<td>250-300 bar</td>
<td>250 bar</td>
<td></td>
</tr>
<tr>
<td><strong>Temp.</strong></td>
<td>Ambient</td>
<td>-30 ºC</td>
<td>-40 ºC</td>
<td>Ambient</td>
<td>-40 ºC</td>
<td>-30 ºC</td>
<td>Ambient</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Diameter</strong></td>
<td>610 mm</td>
<td>150 mm</td>
<td>500mm</td>
<td>1040 mm</td>
<td>1067 mm</td>
<td>2000 mm</td>
<td>1067 mm In containers</td>
<td>2500 mm</td>
<td>1067 mm</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Regulatory Issues

- No International (IMO) code for CNG transportation in bulk
- Most flag States signatory to IGC applicable to liquefied gases (LNG)
- Provision for equivalents
- Receptive to Probabilistic Approach
- Use IMO Formal Safety Assessment (FSA) and Tripartite Agreement
- Tripartite Agreement – (Flag State + Export State + Import State)
- Early communication with Flag State and Local authorities is recommended
ABS Guide for CNG Carriers

- Developed based on same philosophies of IGC Code with equivalent level of safety
- Modified IGC code to account for:
  - Extended use of risk assessment (in line with FSA)
  - CNG containment system
    - Materials’ requirements in fatigue and fracture limited applications
    - In-service inspection
    - Specific safeguards
    - Pressure protection in cargo holds
    - PV codes as applicable
  - Active and passive fire safety
- USCG was on the ABS CNG Guide technical committee
ABS Approach to the Flag Administration

• ABS approach formally discussed with various Flag Administrations (Bahamas, Marshal Island and others) and USCG

• Ship design complies with
  - All SOLAS requirements applicable to a “cargo ship”
  - Applicable international (Load Line and MARPOL) and national regulations

• CNGC Ship will be designed, constructed and maintained in compliance with the structural, mechanical and electrical requirements of ABS

• CNGC design comply with ABS Rules and ABS CNG Guide

• Local requirements of export port and import state

• Formal Safety Assessment (FSA)
Design Assessment for CNG Carrier

- **Risk Assessment**
  - Risk analysis
  - HAZID & HAZOP
  - FMEA
  - Fault tree
  - Quantitative

- **Special Study**
  - Fire, Blast and Gas Dispersion
  - Gas Dynamics
  - Inspectability
  - Emergency Systems & Survivability analysis
  - Temporary Refuge, Escape and Rescue
  - Vibration

- **Prototype Testing**
  - Full Scale to prove manufacturing and fatigue performance
  - Small scale to prove tolerances, fatigue and burst
  - Material qualification tests

- **Prescriptive Rules**
  - ABS CNG Guide
  - ABS Steel Vessel Rules
  - ABS Novel concept and Risk Guide
  - ABS Facilities Guide
  - ABS Offshore Installation Guide
  - Industrial Std. - API Codes, NFPA, SIGTTO, OCMIF
Necessary Steps on a New CNG project

• Risk Assessment Plan
  - Provides a clear Road Map on how each aspect of the system will be addressed with regard to risk
  - Initiates the process of identifying and describing the novel aspects of the system as well as the associated interfaces with other conventional aspects of the ship
  - Provides the framework for ensuring all hazards and failure modes are identified and adequately addressed during the design development

• Quantitative Risk Assessment (QRA) of CNG Carrier Critical Systems
  - Containment system
  - Loading and cargo handling systems
  - Additional systems based HAZID, HAZOP or other risk studies
Risks / Hazards

- Safety studies such as Gap Analysis and Risk Analysis to identify CNG hazards and requirements such as:
  - Over pressure of cargo hold from accidental gas release
  - JT effect and impingement of cooled gas
  - Dispersion of released high pressure gas
  - Jet fire
  - Radiant heat from fire
  - Asphyxiation due to dispersed CNG and N2
  - Corrosion by gas contaminants and marine environment (H2O, H2S, CO2)
  - Fatigue and fracture
  - Inspectability – during manufacturing and in-service
  - Fabrication and welding
  - Materials
GASVESSEL – EU H2020 funded project

Motivation

• EU dependency on imported Gas in 2014 was 70% (40% by one single supplier)
• Removing barriers to cost-effective transport will reduce the dependency from external sources
• EU consumption of Natural gas is increasing
• There are huge amounts of stranded gas and associated gas which is not used or wasted (flared)
• GASVESSEL Project concerns the development of a novel method for waterborne/land transportation and distribution of natural gas
GASVESSEL – EU H2020 funded project

Outline

- Patented concept of CNG (Compressed Natural Gas) Pressure Vessel – 300 bar
- New conceptual ship design
- CONSORTIUM formed by 13 Partner Companies
- 8 EU Countries represented (Belgium, Cyprus, Germany, Greece, Italy, Norway, Slovenia, Ukraine)
- Project duration: 48 months (started June 1st 2017)
- EU contribution = Project’s financial value = 12 M€
GASVESSEL – EU H2020 funded project

Work Packages

- WP2: Analysis of 3 real-life geo-economical gas exploitation scenarios (East Mediterranean, Barents Sea, Black Sea)
- WP3: Design of Pressure Vessels and optimization process (Stainless steel liner + carbon/glass fibers Cylinder 300 bar, 70% lighter than any other previous technology)
- WP4: Pre-industrial Prototyping Pressure Vessels (custom built/self designed facilities in Italy, L= 11.5m, diameter 2.5 m)
- WP5: CNG Ship Design
- WP6: Loading/unloading systems
- WP7: Cost Benefit Analysis: define optimal composition of a fleet in order to minimize the transportation tariff.
- WP8: Class design review, Risk and Safety Assessments
GASVESSEL – EU H2020 funded project
Achievements

• Full completion of the hydroforming equipment (design, construction, erection and testing).
• Complete knowledge of the technological behavior of liner base material.
• Identification of the necessary types of carbon fiber filament and resins suitable for the pressure cylinders.
• Validation of the welding process and methods for the liners.
GASVESSEL – EU H2020 funded project

Achievements

• Development of the filament winding optimization software completed.
• 3 geo-logistic scenarios identification, and Decision Support Model realization.
• Project web-site realization and communication and exploitation systems set up
• CNG Ship Basic Design and tank tests
• HAZID workshop completed
GASVESSEL – EU H2020 funded project

Goals and Prospects

- GASVESSEL concept is expected to open-up important business opportunities for European industry from shipbuilding, shipping, pressure vessels manufacturers, epoxy resin and carbon fiber manufacturers as well as oil and gas and energy production companies
- Perspective of initially 1 – 2 fully operational CNG ships by 2025
- GASVESSEL project will make the actual flaring of associated gas economically unattractive by delivering a commercially sustainable alternative to transport and utilize this gas
Thank you