Workshop on liquid hydrogen safety
Wednesday 6 March 2019, Bergen

Liquid Hydrogen Bunker Vessel

Morten Bøhlerengen
Manager HSE & Technical Safety, Moss Maritime
LH2 Bunker Vessel

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LH2 Bunker Vessel
Background

- Steadily more stringent air emission requirements for ships
  - IMOs global ambition of reducing the environmental footprint from global shipping
    - 40% CO2 reduction by 2030
    - 70% CO2 reduction by 2050
  - National/local requirements to «emissions free» shipping in harbours and special areas (e.g. Norwegian fjords on UNESCO’s world heritage list)
- Developments in FC technology and production making FC an increasingly viable alternative to conventional combustion engines on ships (especially on ferries, cruise ships, etc.)
- «Missing link» - Infrastructure for supply of hydrogen!
- Sponsored by Innovasjon Norge
LH2 Bunker Vessel Objectives

• Review status and challenges with respect to design and operation
  – Applicable regulations & standards
  – Special hazards related to storage and handling of LH2 compared to LNG
  – Technology status and market availability of required equipment for storage and handling of LH2
• Develop a conceptual design for an LH2 Bunker Vessel capable of loading, transporting and discharging liquefied hydrogen to merchant ships and receiving terminals

_The focus for the JDP has been on the design of the cargo containment system (storage and handling) and not on the ship as such._
LH2 Bunker Vessel
Main particulars

- Length overall: Abt. 137.0 m
- Breadth mld: Abt. 19.8 m
- Cargo (LH2): 500 tonnes
- LH2 loading: 600 m³/h
- LH2 unloading: 300 m³/h
- Cruising range: 20 000 nm
- Speed: 15 knots
- Power system: TBD ¹)
- Accommodation: TBD ¹)

Notes:
(1) Depends on specification, operation pattern, etc.
LH2 Bunker Vessel
Design philosophy for the cargo containment system

- **Philosophy**
  - Minimize loss of hydrogen during storage and transfer in order to ensure LH2 as a cost efficient fuel
  - Vapour pressure after 25 day voyage < Operating pressure of the receiving tank

- **Remedies**
  - Use of high performance insulation ensuring low heat ingress
  - Use of in-tank pumps for transfer of LH2

- **Why?**
  - Enables pressure accumulation in tanks instead of removal of boil-off gas
  - Loading without need for cooling of tanks after ballast voyage
  - Reduces flashing during transfer due to favourable delta-p between bunker vessel and receiving vessel
  - Enables vapour return by free-flow (avoiding blowers), if possible
  - In-tanks pumps add less energy than unloading by tank pressurization by vaporization
LH2 Bunker Vessel
Cargo containment system

2 x IMO Type C cargo tanks

- Double wall stainless steel cylindrical tank with MLI installed inside vacuum space
- Supplementary insulation (PUR, 300 mm) on the outer surface of the outer tank provided for redundancy (i.e. avoid abrupt evaporation of cargo in case of loss of vacuum)
- Vacuum insulated dome provided at top of each tank for arrangement of pipe connections, fittings and access into the tanks

Main particulars:

- Gross volume: 2 x 4500 m³
- Design pressure: 5 barg
- Boil off rate: Low

Main features:

- Well proven technology
- Heat ingress to cargo tanks handled by tank pressure accumulation
- Protected by weather cover
- Space between weather cover and tanks filled with N2 and kept slightly higher than atmospheric pressure
LH2 Bunker Vessel Safety

• Safe cargo containment system
  • IMO Type C tanks (double wall)
  • Safe distance from shipside and bottom
  • Designed for pressure accumulation during laden voyage

• Common vent mast for emergency disposal of H2
  • Molecular seal/Buoyancy seal
  • Continuous helium purge
  • Gas snuffing system

• Gas combustion Unit (GCU)
  • Redundancy (Vapour/BOG handling)
  • Special cargo operations
  • Safe disposal of contaminated H2 (N2/H2 mixes from purging)
LH2 Bunker Vessel
LH2 transfer system

- BV equipped with transfer system for bunkering to receiving ships and onshore receiving terminals
  - Vacuum insulated flexible pipes, or
  - Vacuum insulated loading arms (hard arms)
- Transfer system equipped with emergency stop and disconnection system designed for safe isolation and disconnection in case of an emergency (similar to those used on LNG ships)
  - QCDC (Quick Connect/Disconnect Couplings)
  - ERC (Emergency Release Couplings)
    - Double shut-off valves with powered emergency release coupling (PERC)
    - Manual or automatic emergency release
- Offloading to receiving ship in side-by-side mode or at jetty if delivering to onshore receiving terminals
LH2 Bunker Vessel
Loading and unloading

• **Loading**
  - BV arrives jetty at loading terminal with cargo tanks in cold condition
  - Inerting and cooldown of liquid loading lines
  - Excess H2 vapour (displacement and flash gas) returned to shore terminal for reliquefaction
  - Drainage and inerting of liquied loading lines

• **Unloading (bunkering)**
  - BV arrives receiving vessel and moors side-by-side (both sides)
  - Inerting and cooldown of liquid lines prior to unloading
    - LN2 and/or LH2
    - Vacuum pumps used to remove N2 from piping system prior to loading to avoid frozen nitrogen
  - Transfer with use of submerged cargo pumps
    - Two (2) pumps in each tank
    - Pressure discharge as redundancy
  - Excess vapour from receiving vessel returned to BV cargo tank
  - Drainage and inerting of liquied loading lines
LH2 Bunker Vessel Technology evaluation

- No show-stoppers identified
  - Vendors of critical equipment have confirmed that their existing equipment for LNG may be modified/adapted to LH2
- Modification/adaption of existing equipment for LNG to LH2 will require further engineering and testing (qualification)
- Required qualification of equipment will first take place when it has been established a more definite LH2 market
• Develop detail design of the cargo tanks to achieve the target BOR
• Clarify interfaces with LH2 production terminal(s)
• Clarify interfaces with receiving ships and/or onshore terminals
• Qualify for LH2 service equipment currently being used for LNG
  – Ship-To-ship (STS) transfer systems
  – Submerged offloading pumps
  – Heaters
  – Vaporizers
  – GCU
  – Etc.
• Conduct detailed analysis concerning safety of vented hydrogen gas (particularly when moored alongside receiving vessels)
LH2 Bunker Vessel
Conclusion

The feasibility of a LH2 bunker vessel has been proven!

Moss Maritime is ready to support the maritime industry in taking this LH2 bunker vessel design to the next level and/or developing solutions for more large scale transport of liquefied hydrogen in future projects.