New generation of modern LNG carriers
with type C cargo tanks and LNG propulsion system

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Introduction

• TGE Marine Gas Engineering is one of the world’s leading engineering contractors specialising in gas carrier and offshore units.

• The Group was founded in 1980 as “Liquid Gas International” (LGI) and in 1993, was acquired by Tractebel/Suez operating as “Tractebel Gas Engineering”. Since an MBO in 2006, the Group has been called “TGE Marine AG” (“TGE Marine Gas Engineering GmbH”).

• Major shareholders: 49.9% Caledonia Investment plc and GASFIN Group approx. 47.4%, Management, employees, individual shareholders approx. 2.7%

• Address: Mildred-Scheel-Str. 1, 53175 Bonn, Germany

• Web: www.tge-marine.com
Key facts

• 30 years of experience

• More than 140 gas carrier contracts

• Delivery of several novel and innovative gas plant solutions:
  • Five 22,000 m³ ethylene carriers, largest purpose-built ethylene ship in the world built at Jiangnan Shipyard
  • Topsides for 95,000 m³ LPG-FSO built at Samsung
  • World’s first combined 7,500 m³ LNG/ethylene carrier built at Remontova for Anthony Veder Group
  • Lloyd’s List Ship of the Year Award in 2008 for 8,000 m³ ethylene carrier “Isabella Kosan” built at Sekwang HI for Lauritzen Kosan Group

• Well established in East Asia with Shanghai branch office since 1994

• Fabrication and delivery of more than 200 cargo tanks

• More than 50%* market share of ethylene carrier gas plants
  (*historically by total, >70% market share from 1992 to present)

• Own patented LNG tank support design for shuttle tankers and floating units

• In-house ship design packages available for a wide range of gas carriers
New generation of modern LNG carriers with type C tanks and LNG propulsion system

- Existing vessel
- Vessels under construction
- Sizing limits and ship design ranges for LNG carrier with type C cargo tanks
- Gas plant design
- Components
- Terminal compatibility
- Tank design
- Fuel gas systems
- Operation Modes
- Dynamic simulation of fuel gas systems
Business activities and expertise

**Cargo handling systems and tanks for gas carriers**
- LPG carriers, CO₂ carriers
- Ethylene carriers
- LNG carriers

**Cargo handling systems for offshore units**
- FSO/FPSO for LPG
- FSRU and FPSO for LNG
- CO₂ liquefaction, storage and offloading units

**Fuel gas systems**
- LNG fuel supply for merchant vessels
- Type C LNG tanks
- Gas processing system
• Introduction

• Vessels Delivered/Under Construction

• Gas plant Design

• New Designs
**7,500 m³ LNG/LEG carrier:**
- Owner: Anthony Veder, Holland
- Yard: Remontova, Poland
- Classification: BV
- Completion: 2009
- Cylindrical type C tanks
- Dual fuel, diesel/gas electric drive

**15,600 m³ LNG carrier:**
- Owner: Anthony Veder, Holland
- Yard: Meyer-Werft, Germany
- Classification: BV
- Completion: 2012 (under construction)
- Bilobe tanks
- Duel fuel, direct drive
**6,500 m³ LNG/LEG carrier:**
- Owner: Anthony Veder, Holland
- Yard: Dingheng, China
- Classification: BV
- Completion: 2012 (under construction)
- 1 cylindrical, 1 bilobe
- Direct drive, diesel

**20,000 m³ LNG carrier / 25,000 LNG FSRU:**
- Owner: Gasfin / EDF
- Yard: tbn
- Classification: BV
- FID: early 2012
- Completion: 2014
- 1 cylindrical
- 2 x 25K LNG FSRU
- 1 x 20K LNGC
- 1 x 20K LNG/LPG (back up vessel)
• Introduction
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• Gas Plant Design
• New Designs
Gas Plant Design

• Objective: minimize the CAPEX
• Utilize the know-how from design of Ethylene carriers
• Main questions:
  • Terminal Compatibility
  • Cargo tank design
  • Boil-off gas handling / propulsion system
    – Fuel Gas Systems
  • Multi cargo vessel
  • Equipment sizing
Terminal Compatibility

- Manifold position → Elevated Manifold
- Manifold Sizing
- Loads
- Mooring Arrangement
- Fenders – parallel body length
- ESD ship shore connection
- CTS – custody transfer

Artist impression from SLNG press release Aug. 2011

- Singapore, Zeebrugge and Gate have confirmed their intentions to build small jetties -

Coral Methane loading in Seebrugge
Cargo Handling System 15,600 cbm LNG carrier
Cargo Handling System 6,500 cbm LNG carrier
Tank Design

**Tank Design**
- (internal insulation tanks)
- (Integral tanks)
- (Semi-membrane tanks)
- Membrane Tanks
- Independent tanks
  - (Type A)
  - Type B
  - Type C

**Type C tanks**
- Self supporting pressure vessel
- Cylindrical or bilobe with outside insulation
- No secondary barrier required
- No restriction concerning partial filling
- Tank design temperature: -163°C
- Tank material:
  - (Aluminium)
  - 9% Ni-steel
  - SS AISI 304L

**Tank Sizing**
- Ship capacity < 20,000 m³
  - Cylindrical tank design
    - 2 tank design up to abt. 12,000 m³
    - 3 tank design up to abt. 20,000 m³
- Ship capacity > 20,000 m³
  - Bilobe tank design
    - 3 tank design up to 25,000 m³
    - 4 tank design up to 45,000 m³
Type C tanks for LNG

- Design constraints for LNG compared to Ethylene:
  - Higher material shrinkage due to:
    - Larger delta T during cooling down
    - Higher material shrinkage factor for AISI 304L
  - Problem especially for bi-lobe tanks:
    - For 15 m diameter tanks the shrinkage is 35 mm (304L)
  - Detailed design review and complete re-design of supports necessary (displacement and stress analysis, temperature profiles)!
  - Design appraisal by a classification society
  - FEM analysis of tank shell, supports and shipside steel structure for different loading cases

→ Patented design for type LNG tank supports

- Tank insulation
  - Same insulation type applied as for LPG or ethylene carriers
    - LPG/LEG carriers: polystyrene slabs up to 240 mm: k-value 0.186 W/m²K
    - Increase of insulation thickness to 360 mm: k-value 0.121
    - Improvement of insulation with combined polystyrene/polyurethane slabs (300 mm): k-value 0.121
  - Modification of design details of the insulation due to:
    - shrinkage
    - stress
FEM Analysis of cargo tanks

- Total deflection of bilobe type cargo tank -

- Stresses in support stiffeners -
Temperature distribution calculation

- FE Model of tank support ship structure - (Cylinder tanks)

- Temperature distribution results -
**BOG Handling**

- Pressure increase
  - Ease of operation
  - Limited sailing time
- BOG consumption as fuel
- Diesel/Gas electric
- Direct drive
- BOG reliquefaction
  - High capex
  - Sophisticated operation
  - High maintenance cost
  - High trading flexibility
- Gas combustion unit (GCU)
  - Ease of operation
  - Loss of cargo

**Multi cargo / Equipment**

- Multi cargo vessels have been designed and are available
- Qualification of new vendors and technologies for LNG, e.g.
  - Deepwell pumps
  - Valves
  - Standard ‘Ethylene’ compressors as LNG fuel gas compressors
- Optimization of Capex with a market specific approach to upgrade the technology of Ethylene carriers to LNG instead of downsizing full size LNG carriers to small scale LNG

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Gastech, London 2012
Fuel Gas Systems

- Diesel electric $\leftrightarrow$ Direct Drive
- Two stroke $\leftrightarrow$ Four Stroke
  - Supply pressure
- Dual Fuel $\leftrightarrow$ Single fuel
- Burning of BOG, Forced vaporization
- Separation of fuel Tanks
- BOG Compressors, Fuel gas compressors, Transfer Compressors
- LNG Compositions
- Dynamic behaviour of fuel gas system
- Buffer capacities
LNG fuel gas system – BOG mode

BOG mode

Forced vaporization mode
Dynamic Simulation of a 4-stroke fuel gas system
System simulation of a 2-stroke fuel gas system

- performance of system and components
- evaluation of control system
- comparison with test results
- system response
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LNG bunker vessel

3,000 cbm LNG BUNKER SUPPLY VESSEL
FOR INLAND WATER AND COASTAL AREAS

Principal particulars

- Length overall: 98.80 m
- Length between perpendiculars: 93.00 m
- Breadth moulded: 14.20 m
- Depth to main deck: 7.60 m
- Cargo tank capacity (100%): 3,000 cbm
- Design deadweight: 4,000 t
- Corresponding deadweight at loadline: 1,900 t
- Service speed at design draught (28% MCR / 28% bermarginal: 12.00 km/h
Design of LNG Bunker vessel

- Tank size: 2 x 1,500 cbm cylindrical
- Multi cargoes (LNG and MGO, MDO)
- LNG deepwell pumps with frequency controlled drive for different bunkering rates
- Loading manifold cannot be suitable for full size LNG terminal due size of vessel
- Mechanical/hydraulic system to handle bunker hoses or arms with coupling
- Dry-break emergency release coupling
- Vapour return connection
- Optional transfer compressor
- Signal interface, including ESD with loading terminal and customer vessel
- Possible additional services:
  - Inerting with Nitrogen
  - Tank purging and cooling with NG/LNG, tank
  - Emptying and warming-up
Mid Scale LNG carrier Designs

- 20,000 cbm LNG carrier
- 3 cylindrical tanks
- LNG version designed for the Trinidad-Guadelupe/Martinique trade
- LNG/LPG Version as back up vessel
**Mid Scale LNG carrier Designs:** 30,000 cbm LNG carrier with bilobe tanks

- **Principal particulars:**
  - Length o. a. 184.60 m
  - Length b. p. 175.20 m
  - Breadth moulded 27.60 m
  - Depth moulded 18.50 m

- **Tanks**
  - Tank 1: conical bilobe
  - Tank 2-4: bilobe

- **Draught/Deadweight:**
  - Design Draught 8.80 m
  - Corresponding deadweight 17,600 T

- **Speed/Endurance:**
  - Service speed at design draft 16.00 kn
  - Endurance 12,000 nm

- **Machinery**
  - Dual fuel engine 9000 kWe
Conclusions

• The small scale LNG fleet is growing
• abt. 20 LNG carriers (1,000 – 20,000 cbm) exist, but mostly dedicated to specific trades
• Carrier designs have been adapted for small scale LNG
• The technology, especially for fuel gas systems has been adapted to new engines designs.
• Several small scale LNG projects planned and close to FID’s
• LNG as fuel will demand bunker vessels and LNG feeder vessels
• There will be more small scale LNG carriers in the near future
For further information please email:

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Thank you for your attention

www.tge-marine.com