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Technological Guidance on LNG Bunker Vessels & Barges

Stavros Niotis
Senior Engineer, Piraeus Tech & Business Development

Hamburg, Germany
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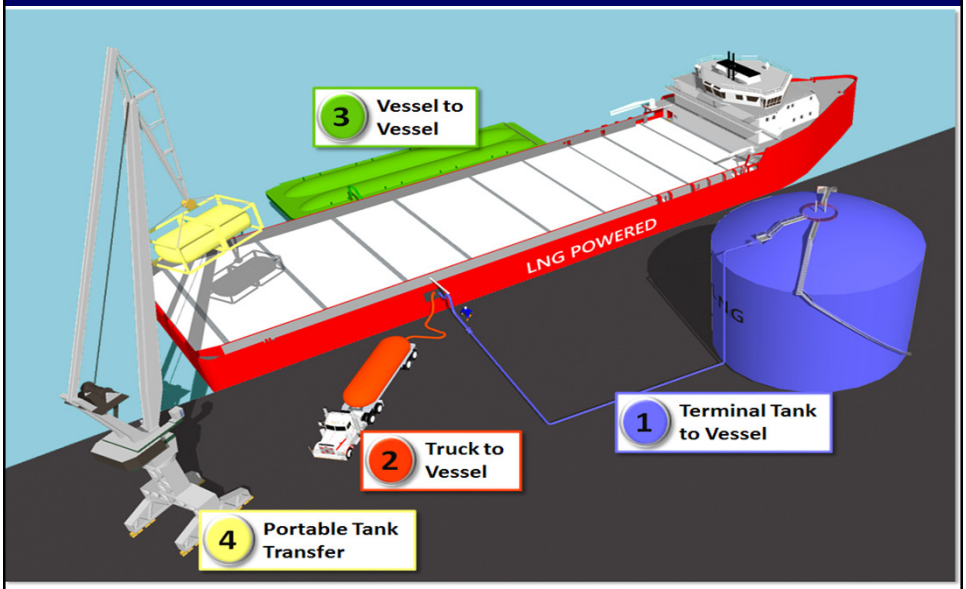
Bunkering Scenarios



Content

- **What is an LNG Bunker Vessel or Barge?**
- Applicable Standards, Regulations and Guides
- Cargo Containment Systems
- Overview of Cargo / Discharge Operations
- Bunkering Operations
- Safety Considerations and Personnel Training

What is an LNG Bunker Vessel?

Self-propelled bunker vessels are considered LNG carriers

✠A1, Liquefied Gas Carrier

- Rule Sets
  - **ABS Rules for Building and Classing Steel Vessels (Jan. 2015)**

SOURCE: AGA Presentation at Stockholm-Turku Conference 11 Sept. 2013

What is an LNG Bunker Barge?

Bunker barges are
considered LNG barges

✠A1, Liquefied Gas Tank Barge

- Rule Sets
  - **ABS Rules for Building and Classing Steel Barges (Jan. 2015)**

What is an LNG Bunker Vessel?

As far as the LNG activities are concerned EMSA uses the following classification:

Applied definitions of large-scale, medium-scale and small-scale in different activities or aspects

Activity/Aspect	Large scale	Medium scale	Small-scale
On shore storage capacity	Import terminal ≥ 100,000 m^3	Intermediary terminal 10,000-100,000 m^3	Intermediary terminal < 10,000 m^3
Ship size, LNG capacity	LNG carriers 100,000 – 270,000 m^3	LNG feeder vessels 10,000-100,000 m^3	LNG bunker vessels 1,000-10,000 m^3 LNG bunker vessels/barges 200 – 1,000 m^3
Tank trucks			40 – 80 m^3

This presentation will mainly cover Small-Scale LNG Bunker vessels

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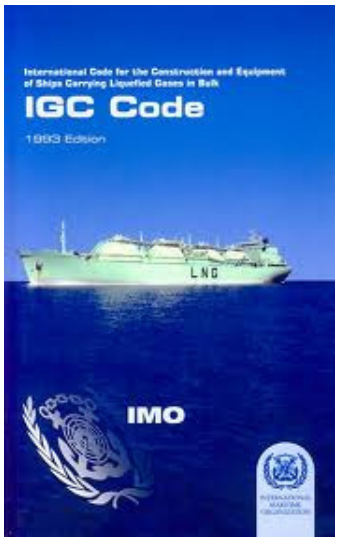
Applicability to Bunkering Vessels

- For Liquefied Gas Carriers or Liquefied Gas Tank Barge
- IMO International Gas Code (IGC)

Note:

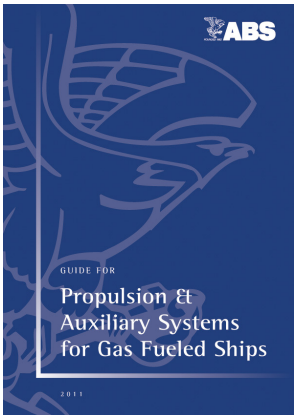
- New IGC to enter into force for vessels with keel laying after 1 January 2016

- Vessel interface with gas fueled ships and IGF code may be required by the flag Administration



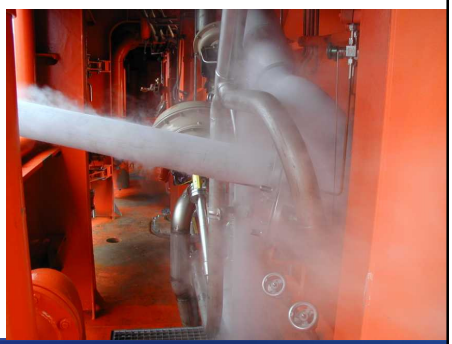
ABS Guide for Dual Fueled Vessels

- ABS has published on May 2011 and last updated on May 2015 a "Guide for Propulsion and Auxiliary Systems for Gas Fueled Ships"
- Section 4 of this Guide covers "Fuel Gas Bunkering Systems"
- This Section can be taken as a reference also for the design of the bunkering vessels



Bunker Station Requirements

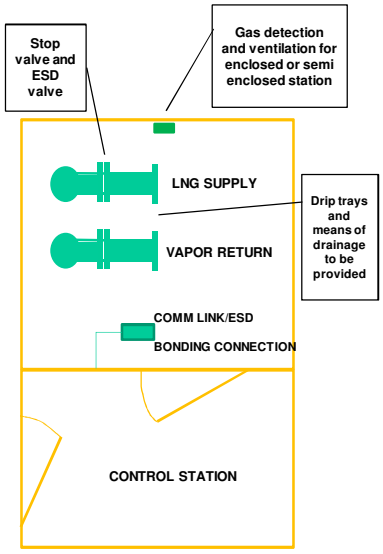
- No gas is to be discharged to air during bunkering operations
- Key bunker station requirements
  - Sufficient natural ventilation
  - Physical separation and structural protection
  - Stainless steel drip trays
  - Class A-60 protection
  - Vapour return line provision
  - Manifold filters
  - Manual and remote ESD valves
  - ESD valve closing speed



Source: Wartsila

Bunker Station Requirements

- Key bunker station requirements
  - ESD and bonding connections
  - Remote control and monitoring
  - Local pressure gauges
  - Draining/purging/inerting provision
  - Gas detection of enclosed or semi enclosed bunker stations
  - Ventilation and gas detection of enclosed bunkering lines
  - Fixed fire detection and extinguishing system



ABS Technology Initiatives on Bunkering

- ABS is preparing a new "Guide for Remote Control and Monitoring and Systems on Barge Installations"
- Other on-going initiative of ABS Technology are studies on:
  - Parametric motion simulation of ship-to-ship LNG fuel bunkering
  - Various projects on containment systems
    - Cumulative fatigue analysis
    - Longevity
    - New generation
    - Sloshing
    - BOR estimation

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IMO IGC Classification of Containment systems

Independent Tanks

Type A
p < 700 mbar
Full Secondary barrier

None in operation
New systems under development:
- Aker ADBT
- LNT A-Box
- Torgy

Based on classical ship structure design rules

Type B
p < 700 mbar
Partial Secondary barrier

Spherical (Moss)

Prismatic (IHI SPB)

Based on first-principle analysis and model tests

"Leak Before Failure"

Type C
p > 2000 mbar
No Secondary barrier

Cylindrical

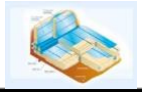
Bilobe

Pressure vessels, based on pressure vessel code

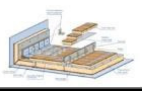
Integrated tanks

Membrane Tanks
p < 700 mbar
Full Secondary barrier

GTT No 96



GTT Mark III

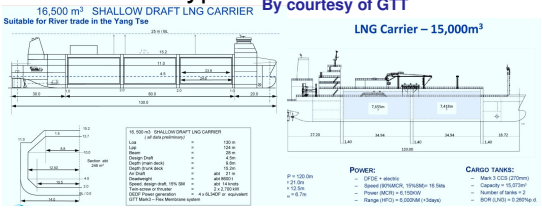


Other Systems:
- GTT MARK V
- KOGAS KC-1
- SHI SCA-WS
- HHI LNG Membrane
- DSME Membrane

Tank Types on LNG Carriers

- Membrane Type

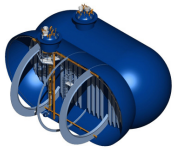
By courtesy of GTT



- Type B Tanks

- Type C tanks / Bilobe Tanks

By courtesy of TGE



New Cargo Containment Systems?

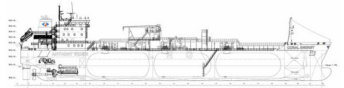
- LNT A-Box IMO type A tank
  - Complete double hull
  - Independent type A tank located in the holds
  - Insulation arranged on the internal surface of the inner hull of the vessel
  - Secondary barrier membrane on top of insulation

Key Factors on Selecting Tank Type

- Design Pressure
  - Vessel's operational profile
  - BOG handling equipment requirements
- Volume space efficiency (ship's main dimensions)
- Secondary barrier – inerting requirements
  - Additional equipment
  - Operators skills
- Filling limits restrictions (sloshing)
- Loading limits restrictions (design pressure)
- Design and building specialized workforce (availability of shipyards / builders)
- Cost

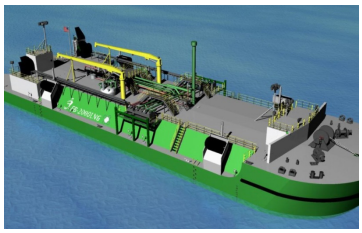
LNG Bunker Vessels

- The 'Seagas' is the only LNG bunkering vessel currently in operation serving seagoing vessels
  - Converted ferry
  - IGC Code
  - Type C tank 187m^3
  - No vapor return
  - Pressure decant
- Other concepts/projects
  - Conrad Shipyard project
  - White Smoke
  - Wilhemsen
  - Kawasaki
  - Argos Oil – LNG membrane tanks 2x935m^3 and MGO
  - Inland LNG carrier 2250m^3



LNG Bunker Barge Designs

- Elliott Bay Design Group
  - ABS AIP
  - 2000 m^3



- LNG America
  - Jensen Maritime Design
  - ABS AIP
  - Mercury – 1000 m^3
  - Gemini – 3000 m^3

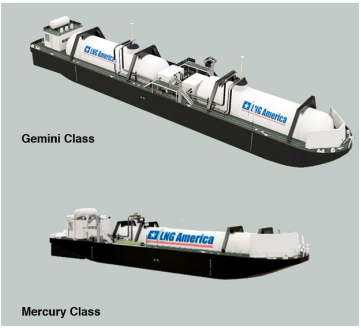
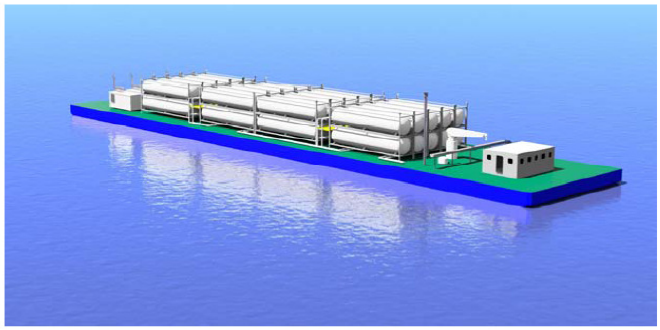


Photo Source: Jensen Maritime Consultants / LNG America / World Maritime News

Argent Marine Bunker Barge

Intermodal Bunker Vessel (IBV)



Patented

Argent Marine Companies

Conrad to Build First LNG Bunker Barge in NA (February 2015)

- Serve TOTE's Orca-class RO-ROs and Marlin-class containerships
- 2,200 cubic meter (cbm) barge
- Expected delivery in early 2016; ABS Class
- Deployed in Tacoma (Washington State)
- 1 MARK III Flex tank (GTT - Gaztransport & Technigaz)
- Bristol Harbor Group Inc. design

Approval-In-Principle (AIP)

- General scope of review:
  - General arrangement
  - Engine selection
  - Gas system equipment selection
  - Hazardous areas plan
  - LNG fuel containment type
  - Tank location and supporting structure
  - Fuel gas and ventilation systems routing plan
  - Bunkering operation philosophy

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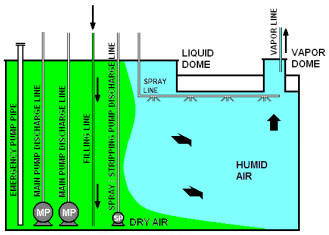
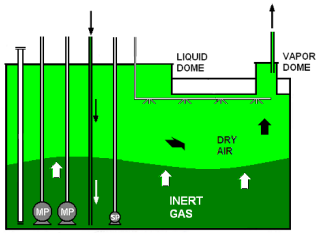
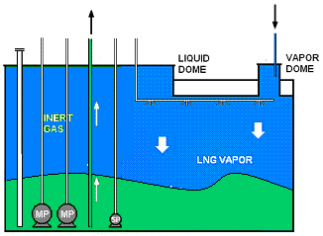
Preparing Cargo Tank after Drydocking



Aeration (dry air)



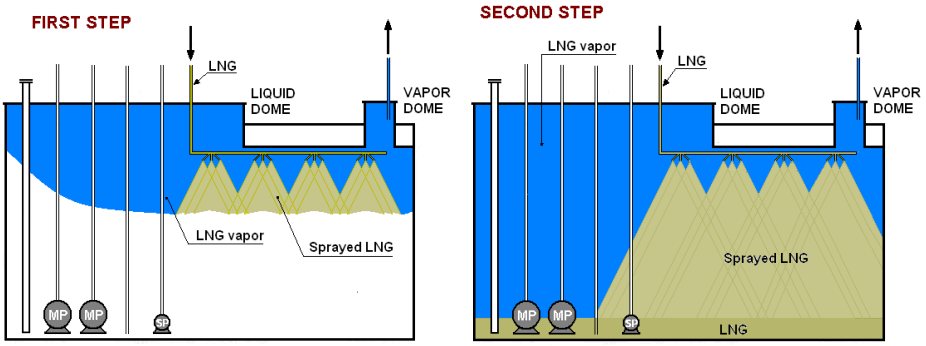
Inerting (dry IG)



Gassing up

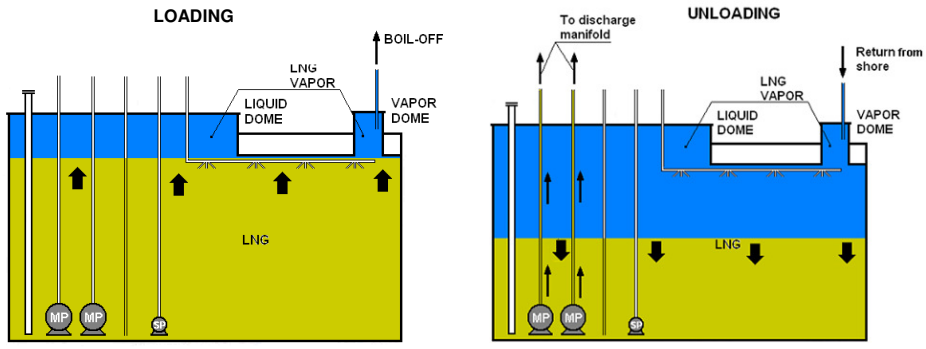
- Notes:
  - Aeration/Inerting dew point to be kept below –45 °C

Cooling Down Prior to Loading



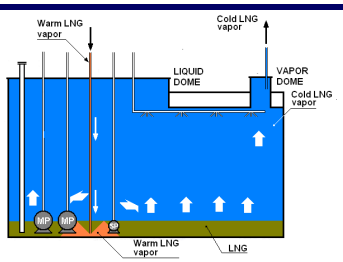
- Notes:
  - Cooling down process generates boil off
    - To be sent back to shore, vented or burned

Loading & Unloading

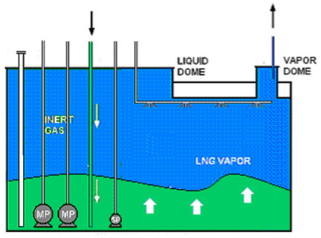


- Notes:
  - Loading/unloading can be performed with or without vapour return
  - If no vapour return is used:
    - The discharging ship will need to generate vapour to avoid vacuum
    - The loading ship must control the tank pressure through use of spray

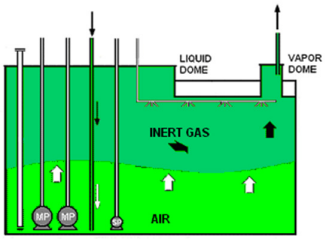
Preparing Cargo Tank before Drydocking



Warming up



Inerting



Aeration

Notes:

- Warming up process will generate boil off gas. To be sent to shore or burned

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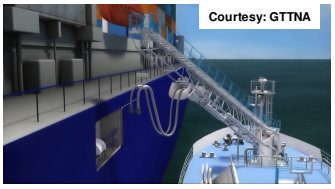
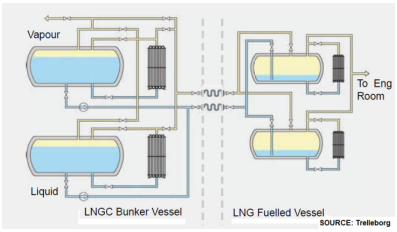
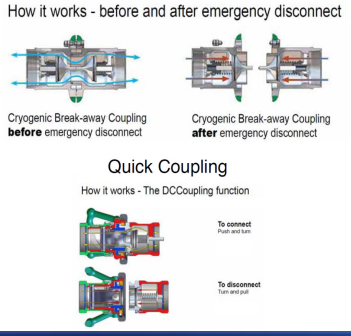
Main Components

- Transfer systems
  - Cryogenic composite hoses
  - Mechanical cryogenic arms
  - Hybrid systems with hose manipulators
- Quick couplings/ dry-break couplings

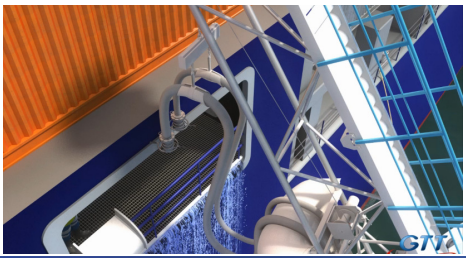






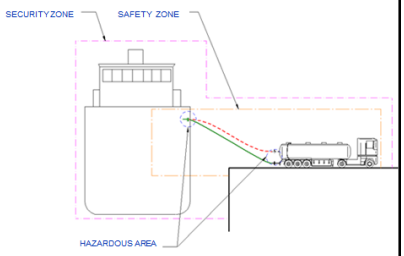
Fuel Transfer

- GTT
  - REACH4 (Refueling Equipment Arm, Methane [CH4])
    - Ensures simple and safe transfer of LNG fuel to the client vessel
    - Features break-away couplings for safe and reliable emergency disconnections
    - Patented configuration prevents rapid disconnections and keeps the breakaway couplings in a fixed position on the mast to ensure simple and safe deployment



LNG Transfer Systems

- Loading rates
- Local requirements
  - Exclusion zones
  - Hazardous area, safety zone, security
  - Simultaneous operations
  - Firefighting requirements
  - Environmental issues
- Fuel delivery measurements
  - Quantity
  - Gas properties

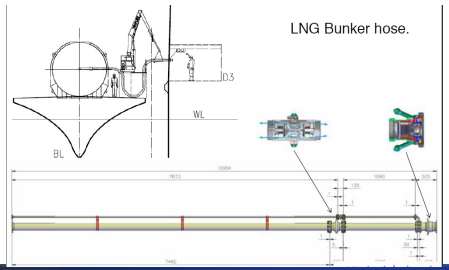


11.7 Loading Arms

Installed loading arms are to be designed and tested in accordance with a recognized standard such as EN1474-1 (transfer arms) and/or EN1474-2 (transfer hoses).

Industry Experience with STS LNG Transfer

- LNG STS transfer is now common practice, e.g. for several FSRU projects
- SIGTTO/OCIMF STS bunkering guide developed leveraging on the existing experience
- LNG bunkering barge operating in Sweden

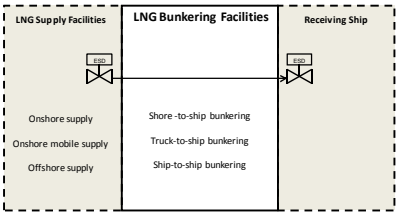


Industry Initiatives on Bunkering & Use of LNG

- Swedish Maritime Technology Forum published LNG STS bunkering procedures
- EMSA study on LNG bunkering to assess viability of EU wide guidelines for LNG bunkering
- European Sustainable Shipping Forum (ESSF)
  - LNG as fuel sub-group
- MPA in Singapore study on the technical procedures for LNG bunkering in the Port of Singapore
- Society for Gas as Marine Fuel (SGMF) LNG-Bunkering Safety Guidelines
- USCG Guidelines for LNG Bunkering
- Class Advice and Guidance

ISO/TS 18683:2015: LNG as Fuel for Ships

- Guidance on the minimum requirements for the design and operation of the LNG bunkering facility, including the interface between the LNG supply facilities and receiving ship
- Requirements and recommendations for:
  - Operator and crew competency training
  - Roles and responsibilities of the ship crew and bunkering personnel
- Functional requirements for equipment necessary to confirm safe LNG bunkering operations of LNG fuelled ships
- Covers
  - Ship-to-ship, Shore-to-ship, Truck-to-ship
- ABS part of new ISO TC8 / WG8 Committee
  - Create a bunkering standard
  - Include criteria for class society systems certification



ISO/TS 18683:2015

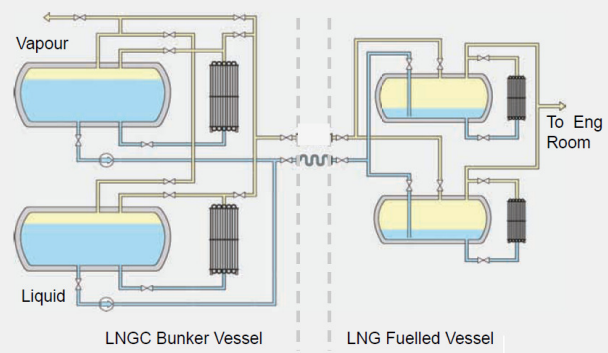
- The main requirements to the bunkering system are presented as a number of functional requirements
- The document addresses:
  - All equipment between the supplier shutdown valve and the presenting flange on the ship
  - The necessary information exchange between supplier and ship in order to ensure a safe operation
  - The key characteristics and differences between LNG and other marine fuels and give reference to other relevant codes and regulations
  - The main requirements to the bunkering system are presented as a number of functional requirements

Bunker Transfer with Vapor Return Line

- The LNG in the fueled vessel will likely be at a higher vapour pressure and temperature than the LNG bunkering vessel
- Design pressure of the bunkering vessel can be lower than the design pressure of the LNG fuel tank on the LNG fueled vessel
- The LNG bunker tank normal operating pressure can be in the range of 6 barg, the bunker vessel may be operating at near atmospheric pressure
- A connected vapour space will potentially result in:
  - Excessive boiling of the LNG in the LNG fueled vessel
  - Overpressure in the bunkering vessel
  - LNG fueled vessel may need to maintain pressure in its fuel tanks to feed its power generation plant
- Some sort of pressure control will be required on the vapour return line

Bunker Transfer without Vapor Return Line

- The pressure in the LNG fueled tank must be controlled by the LNG fueled ship, through use of top spray and bottom fillling line
- Loading rates can be restricted in this operation
- Requires good understanding of the process from the LNG fueled vessel crew

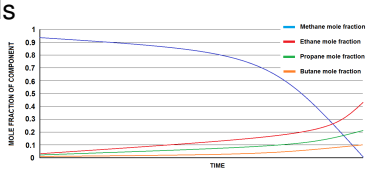


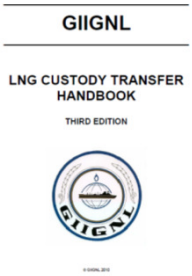
STS Considerations

- Ship compatibility
- Transfer area
- Environmental conditions and Navigation warnings
- Cargo sloshing considerations
- Electrical Isolation
- STS operations Risk Assessment
- Safety Issues during transfer
- Emergency Response
- Communications

Bunker Quality Considerations

- ISO 8217:2010 Specifications of marine fuels
  - TC28/SC4/WG6 now has a sub group for LNG technical specification
- LNG is sold based on its energy content
- The energy content of LNG is dependent on its actual composition AND temperature
- The LNG composition is likely to change in time ("aging")
- Gauging method to be determined (level gauging, flow metering…?)
- Universal standards for sale and purchase of LNG bunkers need to be developed. Meanwhile terms need to be agreed between seller and buyer.





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What is so Special about LNG?

- Very low temperature (abt. -160 ℃)
  - Any contact with carbon steel will lead to brittle fractures
  - Skin contact will result in severe burn injuries
- Constantly boiling liquid
  - The LNG is kept cool by constantly boiling off cargo
  - During a cargo transfer excessive BOG is generated and must be handled
  - Ageing Cargo (Composition changes in time)
- Flammable
  - Hazardous area classification
- LNG composition can vary

Safety Issues

- Cryogenic fuel spill
  - Liquid on deck
  - Liquid on side shell
  - Pooling and pool fires
  - Personnel hazard
- Gas release
  - Migration to enclosed space
  - Exposure to ignition source
  - Environmental impact
- Interaction with loading facility
  - Overpressure and underpressure
  - Vapor return provision
  - Overfilling

Considerations on Safety

- Excellent safety record in LNG shipping industry through:
  - Accurate verification to which the design of an LNG carrier is subjected to by the designer and the classification societies
  - Construction of the vessels and in particular of cargo containment system and cargo handling system only by a few specialized shipyard (with stringent quality assurance procedures)
  - Top tier owners and operators assure a careful maintenance of high standard with respect to other vessels
  - Vessel crew made of well trained and skilled personnel

Some Safety Concerns towards LNG as Fuel

- Understanding of LNG and associated risks
- Crew competency, training, experience, understanding of gas related problems
- Lack of universally adopted international safety measures, in particular for the interfacing between bunker vessels and LNG fuelled vessel and difficulties to navigate among many standards issued by different Authorities
- Regulation and control

Personnel Training

- The LNG Bunkering operations is potentially more complex than a standard LNG carrier discharge operation:
  - Different condition of the residual LNG in the LNG fueled vessel (Higher temperature, different composition) makes control of the generated BOG more complex
    A good coordination and cooperation between the bunker vessel crew and the LNG fueled vessel is critical
  - The LNG bunker tank is potentially at high pressure, requiring higher transfer pressures (design pressure of a fuel bunker tank generally in the range of 10 barg, normal operating pressure 6 barg)

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