Gas Carriers: Arrangements & Characteristics

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Overview

- LNG carriers
  - History
  - Fleet size and ship size
  - Regulatory framework
  - Cargo containment
About ABS

- Founded in 1862
- Not-for-profit marine classification society
  - 3,500+ employees
  - 200 offices, 70 countries
- ISO 9000 and 14000 certified
- OSHAS 18001 certified
- More than 200 Rules and Guides
- More than 12,200 ships in class totaling over 212 mGT
- More than 2,600 new construction ships under survey
What is Classification?

- Classification societies establish and apply technical standards in relation to the design, construction and survey of marine related facilities including ships and offshore structures.
- Classification addresses the life cycle of a ship or offshore unit from design to decommissioning.
How Many Class Societies?

- More than 50 organizations offer some form of classification service
- 12 societies form the membership of IACS – class in excess of 90% of the world’s tonnage
IACS Members

International Association of Classification Societies
ABS Experience

- Gas carrier experience
  - First to offer classification services to gas industry
  - More than 50 years experience
  - Contributed to the development of the IMO Gas Code
  - First classification society invited to join the Society of International Gas Tanker and Terminal Operators (SIGTTO)
  - Over 80 LNG carriers classed
LNG Carriers: History
A Short History of Marine LNG Transportation

- Transporting Liquid Methane
  - 1915 – Godfrey Cabot receives a patent for transporting LNG by river barge
  - 1951 – William Wood Prince (Chairman, Union Stock Yards, Chicago) begins to put the concept into use:
    - Load LNG in Louisiana
    - Barge LNG up the Mississippi
    - Unload, re-gasify and use at Union Stock Yards
    - Fails to yield a successful design
  - 1950’s – a number of US and European interests combine to develop a safe concept to economically transport gas over long distances
    - French and British interest originated from a need to convert customers from ‘town gas’ to natural gas

Source: LNG: A Nontechnical Guide (Tusiani & Shearr)
A Short History of Marine LNG Transportation

- Transporting Liquid Methane (1958-1959)
  - Conversion of *Normati* (built in 1945)
  - Renamed *Methane Pioneer*
  - Owners were Conch International Methane Limited:
    - Conoco
    - Union Stock Yards
    - Shell
  - 5,000 m³ LNG tanker
  - 5 Aluminum self-supporting prismatic cargo tanks
  - Balsa insulation
  - 27 day trip – Lake Charles, LA to Canvey Island, UK
  - Beauvais and Phytagore
A Short History of Marine LNG Transportation

- 1965 – Purpose Built Ships
  - *Methane Princess* and *Methane Progress*
    - Conch International
    - 9 prismatic cargo tanks
    - 27,400 m³ capacity per tanker
A Short History of Marine LNG Transportation

- 1965 – *Jules Verne*
  - Société Gaz-Marine
  - Cylindrical cargo containment
  - 25,840 m³ tanker

- 1971 – *Descartes*
  - Gazocean
  - Membrane tank concept
  - 50,000 m³ tanker
LNG Construction

Source: LNG: A Nontechnical Guide (Tusiani & Shearr)
LNG Construction

**Shift from West to East**

<table>
<thead>
<tr>
<th>Year</th>
<th>Country/Region</th>
<th>LNG Type</th>
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<tbody>
<tr>
<td>1965</td>
<td>France &amp; UK (Cyl. - Conch)</td>
<td>GT-TGZ</td>
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<tr>
<td>1969</td>
<td>Sweden &amp; Italy (GT - Friam)</td>
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<tr>
<td>1970</td>
<td>Sweden &amp; Italy (GT - Friam)</td>
<td></td>
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<tr>
<td>1973</td>
<td>Spain (Moss - GT)</td>
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<tr>
<td>1977</td>
<td>Norway (Moss)</td>
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<tr>
<td>1981</td>
<td>Germany &amp; USA (Moss - TGZ)</td>
<td></td>
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<tr>
<td>1994</td>
<td>Japan (Moss - TGZ - GT)</td>
<td></td>
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<tr>
<td>1996</td>
<td>South Korea (Moss - TGZ - GT)</td>
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<tr>
<td>2003</td>
<td>Spain's reentry (GT)</td>
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<tr>
<td>2006</td>
<td>P. R. China (GT)</td>
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<tr>
<td>2007</td>
<td>Korean Q-sized ships (GT - TGZ)</td>
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Follows the LNG market shift from majority Atlantic to majority Pacific.

Source: LNG: A Nontechnical Guide (Tusiani & Shearr)
Ship Sizes
LNG Fleet Increasing in Size

- Evolution in LNG Carrier Size
LNG Carrier Fleet Age Profile

Existing Fleet...Current Orderbook...Projected New Business

LNG Carrier Fleet Profile - No. Ships
1 Jan 2011 Existing Fleet - Projected Current Orderbook - Projected New Business
By Date of Build
Spring 2012 Outlook - Base Case

- Projected New Business
- Current Orderbook
- Existing Fleet

42 Ships
Age 31+
LNG Carrier Fleet Age Profile

Source: Clarksons.com
Regulatory Framework for LNG Carriers
Regulatory Framework: Safety

- IMO
  - International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
  - Revised IGC Code
  - International Convention for the Safety of Life at Sea, 1974 (SOLAS)
Class Requirements

- ABS Steel Vessel Rules
  - Part 5C, Chapter 8
- ABS Guides
  - ABS Guide for Dual Fuel Engines
  - ABS Guide for Propulsion Systems for LNG Carriers
  - ABS Guide for Gas Fueled Ships
- IACS
Regulatory Framework: Safety

- Additional requirements may be imposed by flag Administrations
  - Regulations of each harbor and terminal
  - US Regulations, 46 CFR
  - Other National Regulations, such as Regulations on Transportation and Storage of Hazardous Substances by Ships (Japan)
USCG Requirements: LNG Carriers in US Ports


- **Certificate of Compliance**
  - Foreign flag vessels must obtain a **Certificate of Compliance** from the US Coast Guard (as opposed to a “Certificate of Inspection”, which is issued to US flag vessels)
  - Guidance for applying for this Certificate is found in 46 CFR 154.22
Chemical Transportation Industry Advisory Committee

- CTAC was established to provide direct industry input to the USCG on dealing with chemical and gas carrier issues
- ABS one of 8 original members
- CTAC helped form US position on the development of the original Gas Code (1973-1975)
- Still an important voice in the US LNG industry
Cargo Containment Systems

- A cargo containment system is the total arrangement for containing cargo including, where fitted:
  - A primary barrier (the cargo tank)
  - Secondary barrier (if fitted)
  - Associated thermal insulation
  - Any intervening spaces; and
  - Adjacent structure, if necessary, for the support of these elements

- The basic cargo tank types utilized on board gas carriers are Independent and Integral
Independent Tanks

- Independent tanks are completely self-supporting and do not form part of the ship’s hull structure
  - They do not contribute to the hull strength of a ship
- IGC Code Chapter 4 (para. 4.2.4) defines three different types of independent tanks for gas carriers:
  - Type A
  - Type B
  - Type C
IMO Classification of LNG Vessels

**Independent Tanks**

- **Type A**
  - $p < 700$ mbar
  - Full secondary barrier

- **Type B**
  - $p < 700$ mbar
  - Partial secondary barrier

- **Type C**
  - $p > 2000$ mbar
  - No secondary barrier

**Integral tanks**

- **Membrane Tanks**
  - $p < 700$ mbar
  - Full secondary barrier

*Based on classical ship structure design rules*

- Spherical (Moss)
- Prismatic (IHI SPB)
- Cylindrical
- Bilobe
- GTT No 96
- GTT Mark III
- GTT CS1

*Based on first-principle analysis and model tests* 

*Pressure vessels, based on pressure vessel code* 

Sources: Moss Maritime, IHI, TGE, GTT
Type A Tanks

- Constructed primarily of flat surfaces
- Independent self-supporting prismatic tank which requires conventional internal stiffening
- Maximum allowable tank design pressure in the vapor space for this type of system is 0.7 barg – operate near atmospheric pressure
- Tank is externally insulated with foam
- Requires secondary barrier – hold space may act as secondary barrier if constructed of steels capable of withstanding low temperatures
- Found on LPG carriers
Type A Tanks

- The IGC Code stipulates that a secondary barrier must be able to contain tank leakage for a period of 15 days (IGC 4.7.4)
  - The secondary barrier must be a complete barrier capable of containing the whole tank volume at a defined angle of heel and may form part of the ship’s hull
  - Appropriate parts of the ship’s hull are constructed of special steel capable of withstanding low temperatures. The alternative is to build a separate secondary barrier around each cargo tank.

- The hold spaces must be filled with inert gas to prevent a flammable atmosphere being created in the event of primary barrier leakage (IGC 9.2)
Type A Tanks

Based on classical ship structure design rules
Type B Tanks

- Constructed of flat surfaces or they may be of the spherical type
- Maximum allowable tank design pressure in the vapor space for this type of system is 0.7 barg – operate near atmospheric pressure
- Found on LNG carriers
- Tank is externally insulated with foam
- Cargo hold spaces contain dry air but may be inerted
Type B Tanks

- Because of the enhanced design factors, a Type ‘B’ tank requires only a partial secondary barrier in the form of a drip tray.
- This type of containment system is the subject of much more detailed stress analysis compared to Type ‘A’ systems, and include an investigation of fatigue life and a crack propagation analysis.
- The most common arrangement of Type ‘B’ tank is a spherical tank, known as the Moss Rosenberg, Kvaerner Moss or simply Moss design.
- There are Type ‘B’ tanks of prismatic shape in LNG service. The prismatic Type ‘B’ tank has the benefit of maximizing ship and deck space.
Type B: Spherical Tanks – MOSS

- Historically spherical tanks are dominant as first choice of Japanese shipyards
Type B: Spherical Tanks – MOSS

- General layout of ship

Source: Mitsui O.S.K. Lines
Type B: Spherical Tanks – “SAYAENDO”

- MHI design that features a continuous cover integrated with the ship's hull
- Builds on the strength of spherical tank LNG carriers (reliability)
- Lightweight construction
- Suitable for cold regions
Advantages of Moss Tanks

- The spaces between the inner hull and outer hull are used for ballast and provide protection to the tanks in the event of collision or grounding.

- No secondary barrier, primarily due to their spherical construction – high degree of safety against fracture or failure.

- ‘Leak before Failure’ concept – presumes that the primary barrier will fail progressively, not suddenly and catastrophically.
  - In the case of a crack occurring in the tank material, a small leakage of LNG within the insulation detected by gas detection.
  - The drip pan, installed directly below each cargo tank, is fitted with temperature sensors to detect the presence of LNG.
Moss Type LNG Containment System

tank concept
Tank dome; providing all penetrations into the tank
Tank cover of steel
Insulation
Aluminium tank shell
Pipe tower: providing access and support for cargo pipes
Structural transition joint (Al-Stainless steel)
Thermal brake of stainless steel
Support skirt of high tensile steel
Ship’s double steel hull
Water ballast tank

Source: Moss Maritime
Moss Type LNG Containment System

![Diagram of Moss Type LNG Containment System](source: Moss Maritime)
Moss Type LNG Containment System

Source: Moss Maritime
Type B: Prismatic Tanks – IHI SPB

- Self-supporting, Prismatic, Independent Type B tank (IHI SPB)
- Strong and robust system, but expensive
- So far only 2 ships built (ABS class)
- Cargo tank material
  - Aluminium
  - Stainless steel
  - 9% Ni Steel
Type B: Prismatic Tanks – IHI SPB

- Advantages:
  - Eliminates sloshing loads, so can be used partially filled
  - Advantageous for ‘cargoes of opportunity’
  - Relatively flat surface, allowing processing gear for Floating LNG facilities
  - Can be tailor built to fit a hull
IHI SPB System (Self-Supporting Prismatic Type B)
IHI SPB System
Type C Tanks: “Cryogenic Pressure Vessels”

- Normally spherical or cylindrical pressure vessels having design pressures higher than 2 barg
- Designed and built to conventional pressure vessel codes
- No secondary barrier is required and the hold space can be filled with either inert gas or dry air
- Technology of choice for the small LNG or LPG carriers
- Dominant design for LNG fueled ships
Type C Tanks

- May be vertically or horizontally mounted
- Easily subjected to accurate stress analysis
- Comparatively poor utilization of the hull volume – can be improved by using intersecting pressure vessels or bilobe type tanks
- Bilobe may be designed with a taper at the forward end of the ship
Type C Concepts: World’s Largest Bilobe-Liquid Gas Storage Tanks

9,686 m³ bilobe Type C LNG tanks building at Sinopacific for Denmark's Evergas

Source: Maritime Propulsion, Feb 2014
Independent Tanks: Type C – Bilobe

- Bilobe tanks being considered for 20-30,000 m$^3$ size ships
Independent Tanks: Type C

- The dominant choice for LNG fueled ships – why?

Source: TOTE, Harvey Gulf
Membrane Tanks

- Very thin primary barrier (membrane – 0.7 to 1.5 mm thick) which is supported through the insulation (IGC 4.2.2 allows up to 10 mm)
- Tanks are not self-supporting like independent tanks - inner hull forms the load bearing structure
- Membrane containment systems must always be provided with a secondary barrier to ensure the integrity of the total system in the event of primary barrier leakage
- Thermal expansion or contraction is compensated without over-stressing the membrane itself
Membrane Tanks: Principle

- Hull Structure
- Secondary insulation
- Secondary membrane
- Primary insulation
- Primary membrane
Membrane Tanks: Principle
Membrane Tank: GTT No. 96

Insulation:
Plywood boxes filled with perlite or fiberglass

Membranes - Invar (36% Ni)
Membrane Tank: GT No. 96

Source: GTT
Membrane Tanks: GTT Mark III

Insulation: Reinforced Polyurethane
Primary Membrane: Corrugated SUS 304
Secondary Membrane: Glued “triplex”
Other Membrane Tank Designs

GTT CS-1

GTT Mark V

Mark V: General description

Primary membrane identical to Mark III

No perforation of membrane

Anchoring to the hull with mastic

Source: GTT
Lower Boil-off Rate: GTT Membrane Systems

- **MARK III Flex**
  - Increased insulation thickness from 270 up to 400 mm BOR < 0.1 %

- **No.96 Evolution**
  - Using other insulation materials such as glass wool: No. 96 GW
  - Modifications of the insulation layers or boxes (including PUR foam)
  - BOR about 0.1 %

Source: GTT
New Cargo Containment Systems being Developed

**Samsung SCA-W/S Membrane System**
- Primary barrier with PRS
- Secondary barrier welded by Laser
- Insulation board with mechanical securing
- VIL between Top and Bottom Insulation board

**KOGAS KC-1 Membrane System**
- Thick Corner Plate
- Corner Membrane
- Primary Membrane
- Inter-bARRIER Board
- Corner Anchor
- Corner Insulation
- Insulation Panel
- Membrane Anchor
- Secondary Membrane

**Hyundai Membrane System**

**WAVEspec FPS (NASSCO)**

Source Samsung H.I.
Source KOGAS
Source Hyundai H.I.
Source Tradewinds/WAVEspec
Advantages of Membrane Tanks

- Generally smaller gross tonnage
- Maximum use of hold’s volume for cargo
- Unrestricted navigation visibility
- Lower wheelhouse and cargo control room air drafts
Trends for Containment System

Status November 2013

Fleet by Containment system

Orderbook by Containment system
LNG Bunkering
LNG Bunkering: Shore, Ships & Barges

- Infrastructure availability to support LNG as a Marine Fuel
- From Shore
  - Dedicated facility
  - Truck on jetty
  - Containerized fuel
- From Sea
  - LNG bunker barge or vessel
  - Mooring dolphin
  - Ship-to-ship
- Bunkering procedures
- Crew training requirements
- Risks, hazards and safeguards

Courtesy: Jensen Maritime Consultants
ABS Approves GTTNA’s LNG Bunker Barge Design

Houston-based GTT North America (GTTNA), U.S. subsidiary of French engineering and technology company Gaztransport & Technigaz SA (GTT), has received approval in principle (AIP) from ABS for the design of a 2,200 cubic meter liquefied natural gas (LNG) bunker barge. The distinctive design incorporates GTT’s proven membrane Cargo Containment System (CCS), which is utilized in 70% of the global LNG carrier fleet and nearly 90% of LNG carrier projects on order.

Image courtesy GTTNA
Argent Marine Bunker Barge

Intermodal Bunker Vessel (IBV)

Patented