LNG Transportation Via Ships

ABS Presentation – 21 Sep, 2021

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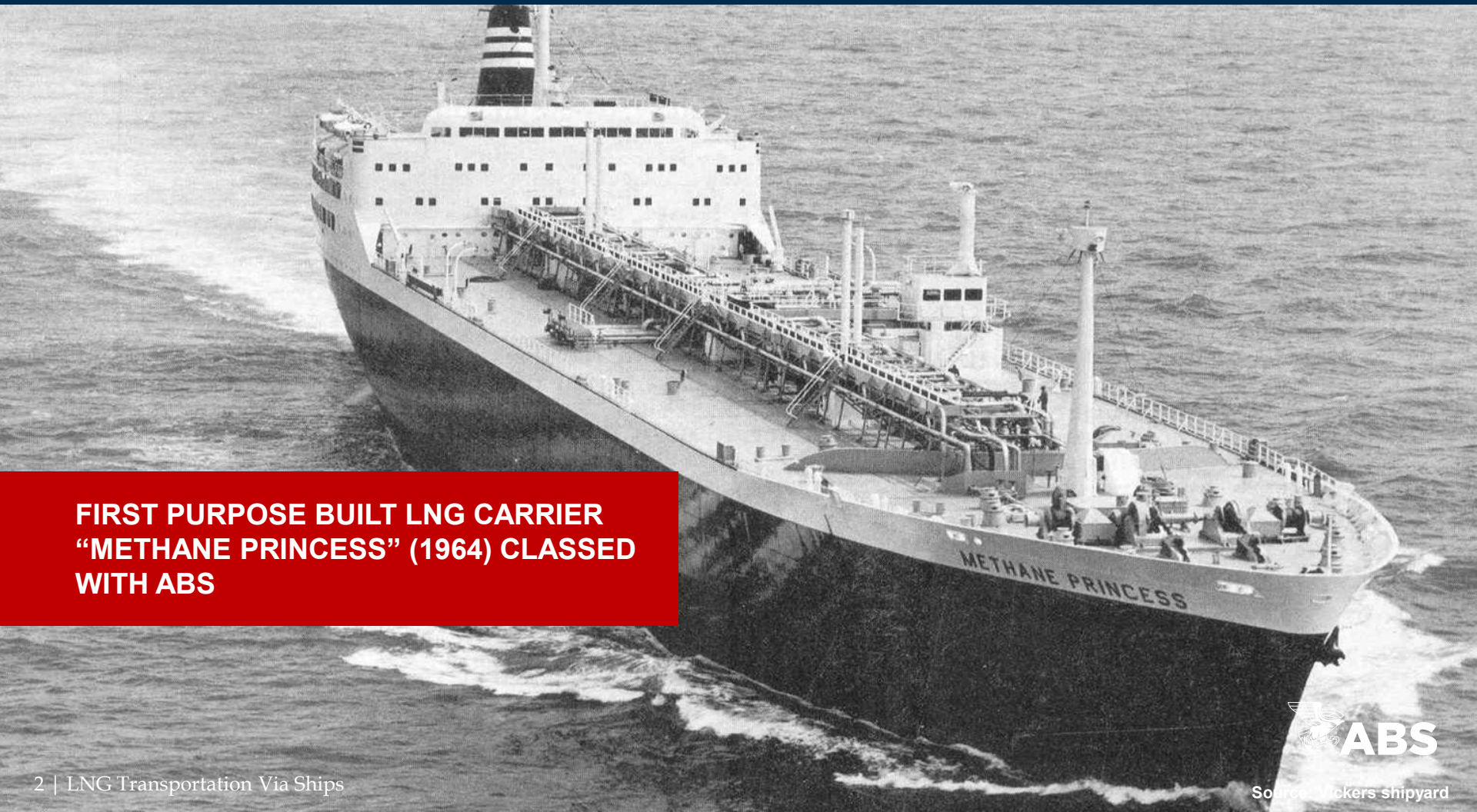
The Mission of ABS is to serve the public interest as well as the needs of our members and clients by promoting the security of life and property and preserving the natural environment.



FIRST PURPOSE BUILT LNG CARRIER "METHANE PRINCESS" (1964) CLASSED WITH ABS

Source: Vickers shipyard

Classification Societies

- Independent arbiters of standards
- Mission – promote the security of life and property and preserve the natural environment
- Achieved by establishing and administering standards known as Rules for marine vessels and structures:
  - Design
  - Construction
  - Operational maintenance

- Classification addresses the life cycle of a ship or offshore unit from design to decommissioning

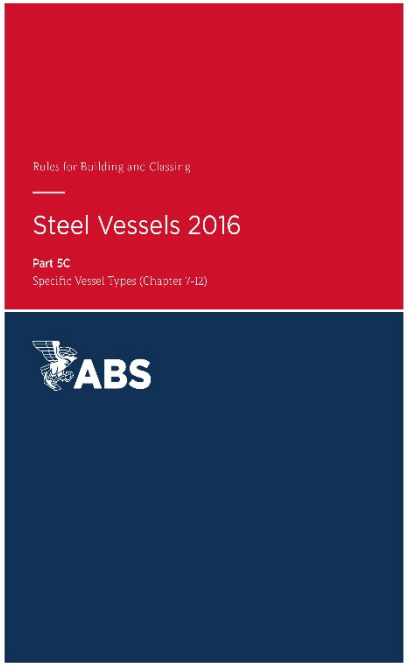
Integrated Closed Loop Process

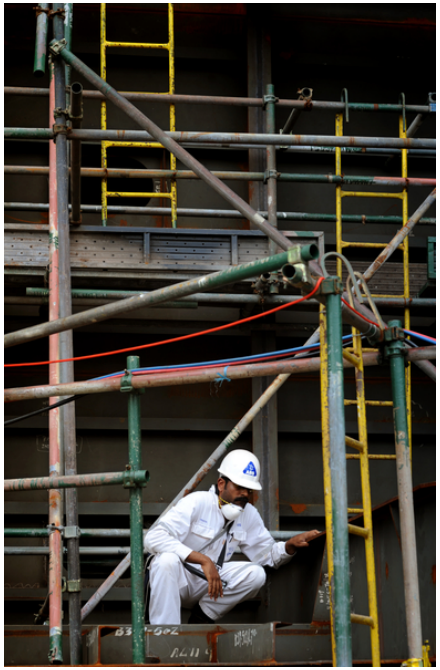
Establish recognized technical standards

Review designs against Rules and standards

Confirm the vessel is built in accordance with approved plans

Verify the vessel is maintained to the accepted standards





ABS: Classification Partner for Gas Carriers

- 120 LNG Carriers delivered to ABS Class from 2009 to 2021
- 32 LNG Carriers on order to ABS Class
- 75 LPG Carriers delivered to ABS Class from 2000 to 2021
- 22 LPG Carriers on order to ABS Class including 12 Ethylene/Ethane carriers
- 18 of 45 Q-Flex and Q-Max LNG Carriers classed with ABS
- First Dedicated LNG carrier and first LNG fuelled vessel (1964)
- First Very Large Ethane Carriers (87k m3)
- First LNGC with SPB cargo containment system
- First LNGC with LNT “A-Box” Type A cargo containment system
- First LNGC with Sayaringo cargo containment system
- First LNGC with GTT Mark III Flex+ cargo containment system
- First CNG carrier
- First Very Large Ethane Carriers (VLEC)
- First 174k FSRUs to be built in China
- Experience with all gas-fueled propulsion systems:
  - 2-stroke DF Engines - MAN ME-GI
  - 2-stroke DF Engines - WinGD X-DF
  - MHI STaGE
  - DFDE, GCU / DFDE, GCU, Re-liquefaction
  - Twin Screw conventional diesel engine, Re-liquefaction, GCU
  - Conventional Steam Turbine
  - Ultra Steam Turbine

Classification

LNG Carriers

Typical LNG Carrier Project

- Pre-contract Review
- Engineering Plan Review
- Construction Site Supervision
- Commissioning and Testing
- Post Delivery

Pre-contract Stage

- Review of contract specifications
- Technical consultation
  - Class notation selection
  - Additional analyses recommended
  - Hull structure
  - Propulsion and machinery
  - Environmental Issues
  - Ship performance and vibration
  - LNGC cargo containment system and sloshing
  - Water ballast treatment and EEDI

Plan Approval & Independent Analyses

- Review of design drawings and calculations
  - ABS reviews the design drawings and analysis.
  - Independent analyses are performed to verify the design to meet the requirements of ABS Rules/Guides. The scope of work includes the following major items but not limited to:
    - Hull structures and containment system
    - ABS SafeHull Analysis
    - Direct Calculations by DLA/SFA
    - Sloshing load and strength assessment of CCS
    - Pump tower structure and base support
    - Bottom slamming analysis
    - Vibration analysis
    - Cargo systems, marine systems, propulsion, electrical systems

Site Supervision Planning & Coordination

- Shipyard project planning schedules are tightly adhered to
  - Weekly progress meetings carried out as agreed by shipyard, owner and class
  - Ad-hoc meetings at any stakeholder's request
  - Continuous communications with project representatives of all parties
  - Detailed meeting topics
    - HSE issues
    - Ongoing deficiencies
    - Schedule updates

Quality Management

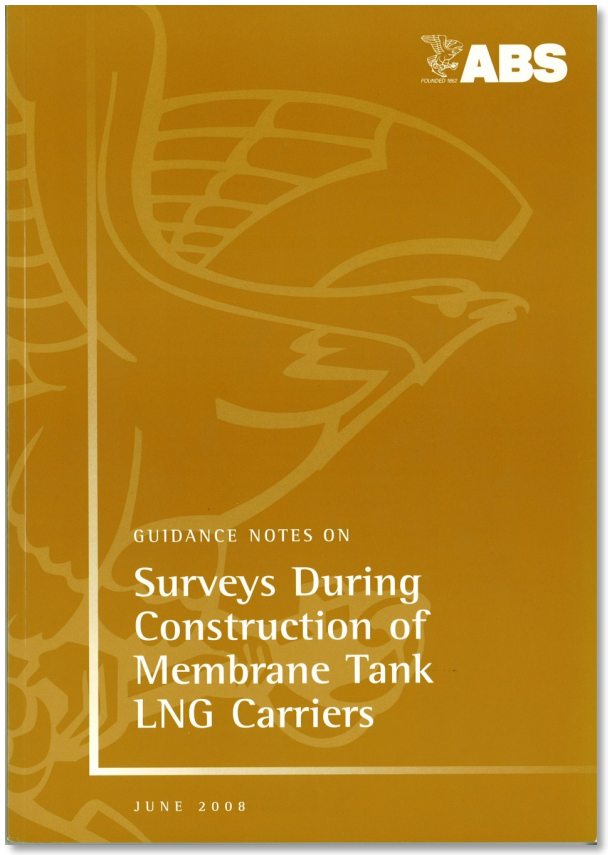
- QA/QC Management
  - Continuous communications with individual project QA/QC representatives from kickoff to delivery
  - Inspection and test procedures reviewed and approved by attending surveyors
  - All inspections and tests carried out in concert with QA/QC representatives
  - Interpretation of Rules and regulations provided by survey and engineering
  - Corporate Survey and Engineering or Technical Consistency input as needed

Safety

- HSE enhancement
  - ABS Safety Program
    - Commitment of senior management team of ABS to promote awareness of health and safety of personnel
  - Safety patrolling is an integral part of daily activities
  - Surveys will not be conducted under unsafe conditions
  - ABS strictly implements safety program
  - Periodic safety meetings with ABS, shipyard and owners

Commissioning & Testing Requirements

- In general, neither the IGC Code, nor the classification societies Rules give defined criteria on commissioning and testing for LNG carriers
- ABS has published a detailed list of the inspection and testing activities to be performed by its surveyors during the construction and trials of LNG carrier, for example, "*Guidance Notes on Surveys During Construction of Membrane Tank LNG Carriers*"

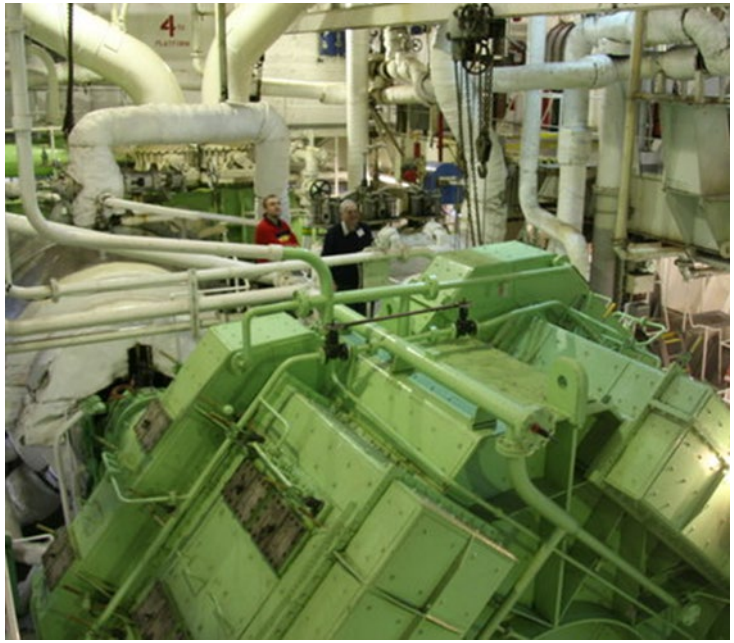


ABS Inspection Plans: Cargo Containment System

- Guidance Notes for each type of cargo containment system
  - A general description of the system
  - Requirements relative to welders and welding procedures qualifications
  - Description of inspections, testing and certification on components
  - Description on inspections during construction
  - Description of final testing and commissioning
  - Inspection plans

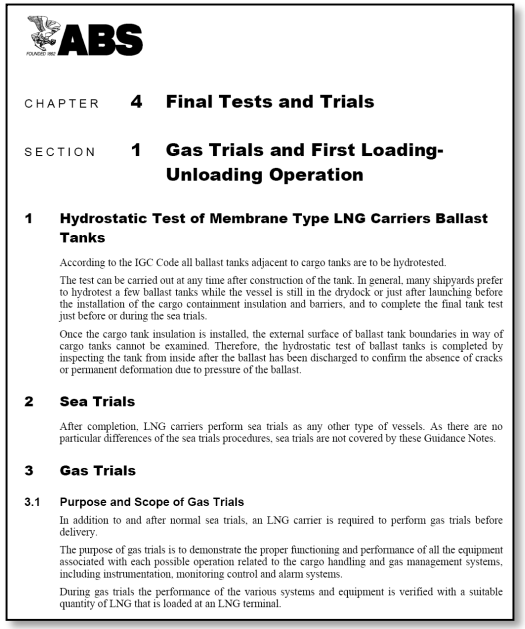
ABS Inspection Plans: Machinery

- In the Machinery section, after a general description of the main components and machinery systems of cargo handling and other systems peculiar of LNG carriers and a general description of the ABS surveyor's activities, there are two inspection plans
  - One relative to the certification of the components
  - The other relative to system commissioning



Gas Trials: Further Final Inspections

- The last chapter covers with detailed descriptions the final tests and trials, including cold tests, gas trials and the inspections to be carried out during first loading and unloading operations
- It also includes the SNAME Technical and Research Bulletin No.5-2
- Gas Trials Guide for LNG Vessels
- Normal procedure agreed among owners, shipyards and ABS for the performance of gas trials



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CHAPTER 4 **Final Tests and Trials**

SECTION 1 **Gas Trials and First Loading-Unloading Operation**

1 Hydrostatic Test of Membrane Type LNG Carriers Ballast Tanks

According to the IGC Code all ballast tanks adjacent to cargo tanks are to be hydrotested.

The test can be carried out at any time after construction of the tank. In general, many shipyards prefer to hydrotest a few ballast tanks while the vessel is still in the drydock or just after launching before the installation of the cargo containment insulation and barriers, and to complete the final tank test just before or during the sea trials.

Once the cargo tank insulation is installed, the external surface of ballast tank boundaries in way of cargo tanks cannot be examined. Therefore, the hydrostatic test of ballast tanks is completed by inspecting the tank from inside after the ballast has been discharged to confirm the absence of cracks or permanent deformation due to pressure of the ballast.

2 Sea Trials

After completion, LNG carriers perform sea trials as any other type of vessels. As there are no particular differences of the sea trials procedures, sea trials are not covered by these Guidance Notes.

3 Gas Trials

3.1 Purpose and Scope of Gas Trials

In addition to and after normal sea trials, an LNG carrier is required to perform gas trials before delivery.

The purpose of gas trials is to demonstrate the proper functioning and performance of all the equipment associated with each possible operation related to the cargo handling and gas management systems, including instrumentation, monitoring control and alarm systems.

During gas trials the performance of the various systems and equipment is verified with a suitable quantity of LNG that is loaded at an LNG terminal.

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Survey After Construction

- The base line for periodical survey interval is a five-year cycle commencing at delivery date of every vessel. The delivery date is also called the Anniversary Date.
- Every vessel must undergo a Special Periodical Survey at the end of every five-year cycle.
- Annual Survey to be carried out annually between Special Periodical Surveys. Survey windows of plus/minus three months of the due date (anniversary date).
- An Intermediate Hull Survey is due midway between Special Surveys, i.e. two and a half years after each Special Survey starting after Special Survey No.1.
- Minimum of two bottom surveys in every five-year special survey period with one in conjunction with the Special Survey.

Regulatory Framework

LNG Carriers

Statutory Requirements

- International Maritime Organization (IMO)
- Specialized Agency of United Nations
- Established under a 1948 UN Convention in Geneva
- Forum to harmonize/adopt regulation
  - Ship and personnel safety
  - Pollution prevention (sea and air)
  - Ship and port security
- 174 Member States and three Associate Members
- Members are representative of individual Governments

International Maritime Organization (IMO)

- Members' either sign to indicate their acceptance of resolutions or resolutions are put in force by tacit approval
- Commercial and other interested organizations (IACS) have observer status
- Conventions have the force of law
- Governments implement/enforce regulation, not the IMO

International Conventions

Delegation of Authority to ROs

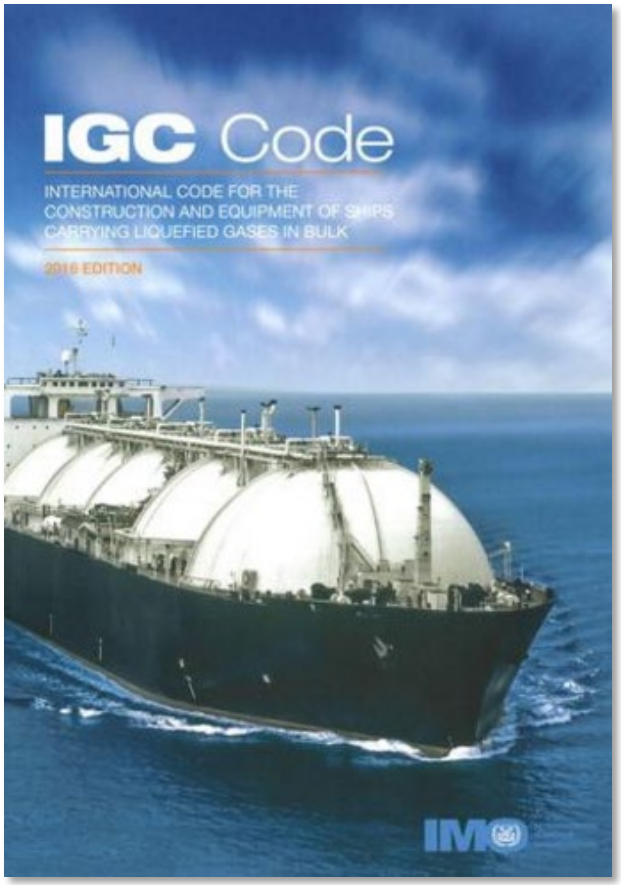
- Administrations may delegate authority to recognized organizations (ROs) to perform statutory surveys and issue certificates on their behalf
- ROs issue certificates on completion of an audit confirming compliance with the requirements of the relevant Convention

Applicable Statutory Regulations

- International Gas Carrier (IGC) Code
- SOLAS 1974 as amended
- MARPOL 73/78 Annexes I, IV, V and VI
- Loadline 1966 as amended
- International Tonnage 1969
- Collision Regulations
- ILO-MLC 2006
- ISPS Code
- ISM Code
- Anti-Fouling Systems (AFS) Convention

IGC

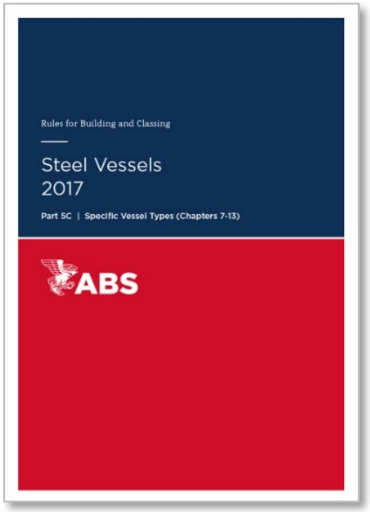
- *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk*
- Adopted by most countries and is invoked through SOLAS



IGC Chapters

CHAPTER 1 General	CHAPTER 11 Fire Protection and Extinction
CHAPTER 2 Ship Survival Capability and Location of Cargo Tanks	CHAPTER 12 Artificial Ventilation in the Cargo Area
CHAPTER 3 Ship Arrangements	CHAPTER 13 Instrumentation and Automation Systems
CHAPTER 4 Cargo Containment	CHAPTER 14 Personnel Protection
CHAPTER 5 Process Pressure Vessels and Liquids, Vapour, and Pressure Piping Systems	CHAPTER 15 Filling Limits for Cargo Tanks
CHAPTER 6 Materials of Construction and Quality Control	CHAPTER 16 Use of Cargo as Fuel
CHAPTER 7 Cargo Pressure/Temperature Control	CHAPTER 17 Special Requirements
CHAPTER 8 Vent Systems for Cargo Containment	CHAPTER 18 Operating Requirements
CHAPTER 9 Cargo Containment System Atmosphere Control	CHAPTER 19 Summary of Minimum Requirements
CHAPTER 10 Electrical Installations	APPENDICES

ABS Marine Vessel Rules



- Rules for Gas Carriers incorporated in MVR Part 5 Ch.8
  - ABS adopted the IGC Code as its own Rules.
  - The content of the Code is integrated with a number of additional requirements and interpretations, originating from IACS or ABS, that are to be complied with as “class requirements”.
    - Parts in “*italic*” font are identical to IGC Code;
    - Parts in “regular” font are ABS additions.
- Liquefied Gas Carriers with Membrane Tanks incorporated in SVR Part 5 Ch.12
  - supplies detailed design criteria for the structures of membrane ships and for their fatigue assessment
  - Replaces former Guide for membrane type gas carriers

Cargo Containment System

LNG Carriers

Cargo Containment Systems

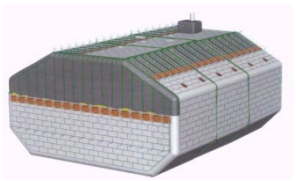
- A cargo containment system is the total arrangement for containing cargo including, where fitted:
  - A primary barrier (the cargo tank)
  - Secondary barrier (if fitted)
  - Associated thermal insulation
  - Any intervening spaces; and
  - Adjacent structure, if necessary, for the support of these elements
- The basic cargo tank types utilized on board gas carriers are Independent and Integral

IMO Classification of LNG Vessels

Independent Tanks

Integral tanks

Type A
p < 700 mbar
Full secondary barrier

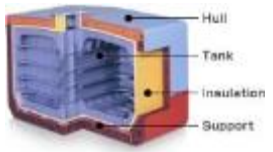


Based on classical ship structure design rules

Type B
p < 700 mbar
Partial Seondary barrier

Spherical (Moss)

Prismatic (IHI SPB)



Based on first-principle analysis and model tests

Type C
p > 2000 mbar
No Secondary barrier

Cylindrical

Bilobe

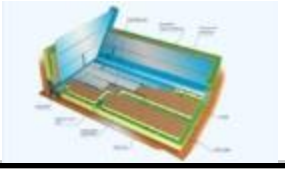
Pressure vessels, based on pressure vessel code

Membrane Tanks
p < 700 mbar
Full secondary barrier

GTT No 96

GTT Mark III

GTT CS1



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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 defines three different types of independent tanks for gas carriers:
  - Type A
  - Type B
  - Type C

Type A Tanks

- The IGC Code stipulates that a complete secondary barrier must be able to contain tank leakage for a period of 15 days
  - The secondary barrier must be a complete secondary 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)
  - Including make-up gas for at least 30 days

Type B Tanks

- Due 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 - “leak before failure” principle
- 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 C Tanks

- Normally spherical or cylindrical pressure vessels having design pressures higher than 2 barg
- Designed and built to conventional pressure vessel criteria
- No secondary barrier is required and the hold space can be filled with either inert gas or dry air
- 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

Membrane Tanks

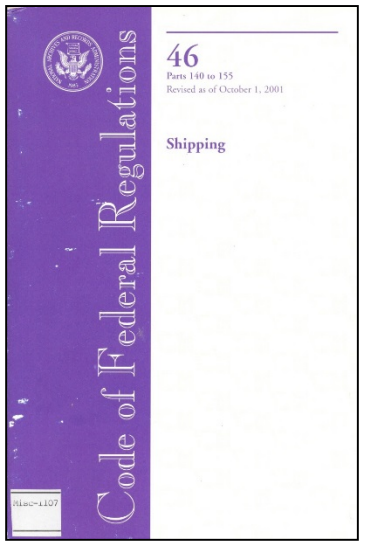
- Very thin primary barrier (membrane – 0.7 to 1.5 mm thick) which is supported through the insulation (IGC allows up to 10 mm)
- Tanks are not self-supporting like independent tanks - inner hull forms the load bearing structure
- Membrane containment systems must always be provided with a secondary 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

United States Coast Guard

LNG Carriers

Bulk Liquefied Gas Carriers in US Waters

- IMO recommendations defer some matters to the Administration i.e. Reference Ambient Temp, Enhanced Steel Grades
- Title 46 of the United States Code of Federal Regulations (or '46 CFR') Part 154 – "Safety Standards for Self-Propelled Vessels Carrying Bulk Liquefied Gases"
- Safety
  - Foreign-flagged Bulk Gas Carriers must hold a valid IMO Certificate of Fitness and be examined for and receive an Endorsed *Certificate of Compliance* (COC). Prior to scheduling a COC Exam, the vessel owners must apply for a Subchapter O Endorsement (SOE) from MSC.
  - 'Equivalency' aspect to be reviewed by USCG
- Cargo Containment Systems
  - New Cargo Containment Systems reviewed/approved



Thank You

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