U.S. Coast Guard

Maritime Transport of LNG
Presentation to the National Academies' LNG-by-Rail Committee: History, Design, & Operations

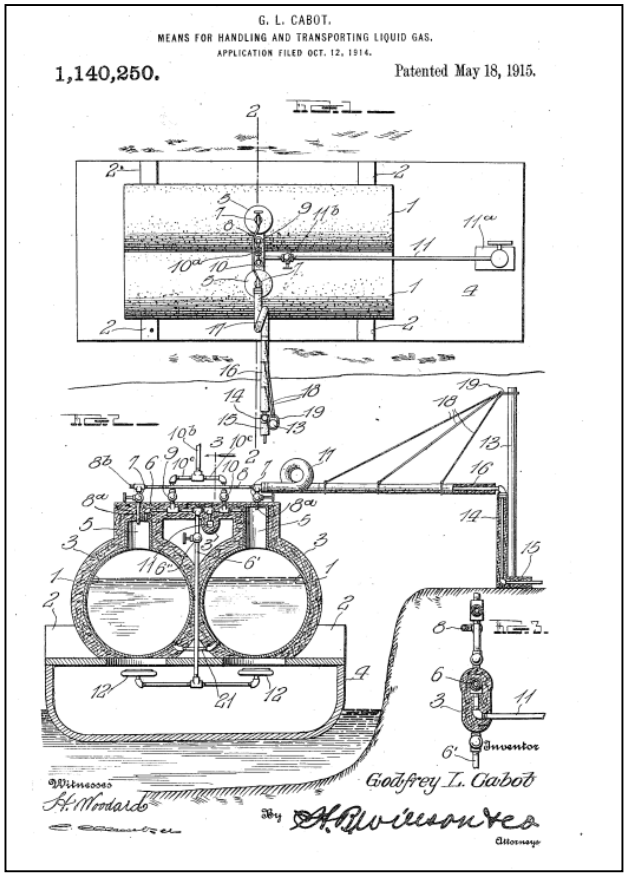
Date: 21 Sept 2021

Objectives

- Describe U.S. LNG History.
- Provide Overview of Liquefied Gas Carrier Design.
- Provide Overview of Liquefied Gas Carrier Operations.

U.S. Liquefied Natural Gas History

- Commercial liquefaction dates back to 1910 to a small plant in West Virginia.
- 1912, First LNG peak-shaving plant built.
- 1914, “Means For Handling and Transporting Liquid Gas” via barge.
- 1941, the Cleveland Natural Gas Liquefaction Plant, a peak-shaving plant, of the East Ohio Gas Company commences operation.


G. L. CABOT.
MEANS FOR HANDLING AND TRANSPORTING LIQUID GAS.
APPLICATION FILED OCT. 12, 1914.
1,140,250. Patented May 18, 1915.
Witnesses: H. Mudard
Inventor: Godfrey L. Cabot
By H. B. Williamson & Co.
Attorneys

U.S. Liquefied Natural Gas Carrier History

1950's

- Industry's gas supply falls under the "interruptible" category.
- Due to the inconsistent supply of natural gas, Continental Oil Co. and Union Stock Yards explore avenues to transport LNG.
- January 25th, 1959, The *Methane Pioneer* left the Lake Charlies, LA transporting the worlds first ocean-going LNG cargo to Canvey Island, UK.

U.S. Liquefied Natural Gas Carrier History

1965

- Phillips Petroleum contacts the USCG requesting approval of tanks for Alaska/Japan LNG trade by manufacturer Worms & Co, now known as Gaztransport Technigaz.
- Oct, 26, 1969 Polar Alaska departs Kenai, Alaska with Japan's first-ever LNG cargo.
- Phillips utilized its patented shore-based "Optimized Cascade" process for reliquefying LNG vapors. A technique still used today.

Newport News Built Vessels

1979

- Originally planned to utilize a spherical cargo tank, the yard opted for the Technigaz Mark 1 membrane system. By 1979 three vessels were delivered
- Due to tank insulation failure during gas trials, the vessels were deemed unsuitable for LNG trade and sold.
- El Paso Savanah receives a $300 million insurance settlement

Foreign Flagged Liquefied Gas Carriers in the United States

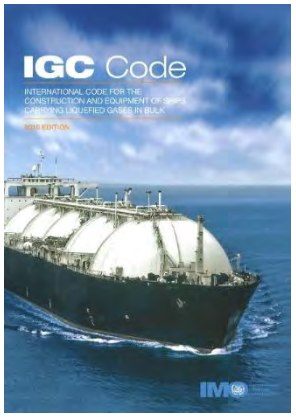
- There are no traditional U.S. Flagged LNGCs currently operating.
- U.S. LNG exports and imports are transported solely by foreign flagged LNG Carriers (LNGC) with foreign crews.
- The worlds LNGC fleet is around 642 vessels.

U.S. Liquefied Natural Gas Carrier History

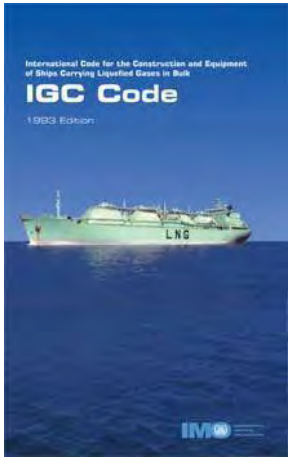
- In 2018, the first-in-US LNG Bunker Barge was delivered by Conrad Industries in Orange, TX to TOTE Maritime.
- Entered into service for Tote Maritime in the Port of Jacksonville, FL. Primary purpose is to bunker two Marlin Class container ships operating on LNG as Fuel.
- In 2020, the first US LNG ATB by VT Halter to Shell Trading on a long-term time charter.

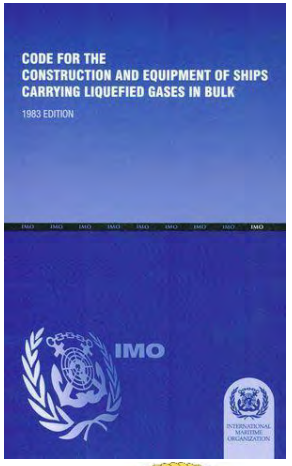
Q-4000 ATB (above) CLEAN JACKSONVILLE (below)

Gas Carrier Construction Standards

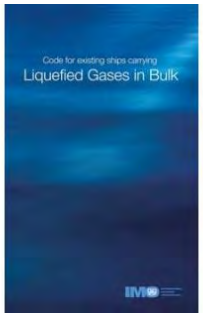


Keel Laid	IMO Gas Code	IMO Resolution	Document Issued
01 Jul 16	IGC Code Adopted 22 May 2014	MSC.370(93)	International COF
01 Oct 94 – 30 Jun 16	IGC Code 1993 Edition	MSC.30(61)	International COF
01 Jul 86 – 30 Sep 94	IGC Code	MSC.5(48)	International COF
31 Dec 76 – 30 Jun 86	Gas Carrier Code	A.328(IX)	COF
**Prior to 31 Oct 76 **	Existing Gas Carrier Code	A.329(IX)	COF





**Ships built *prior* to the application of the GC Code are required to comply to the extent that they can do so. Areas unable to be complied with must be identified on the COF



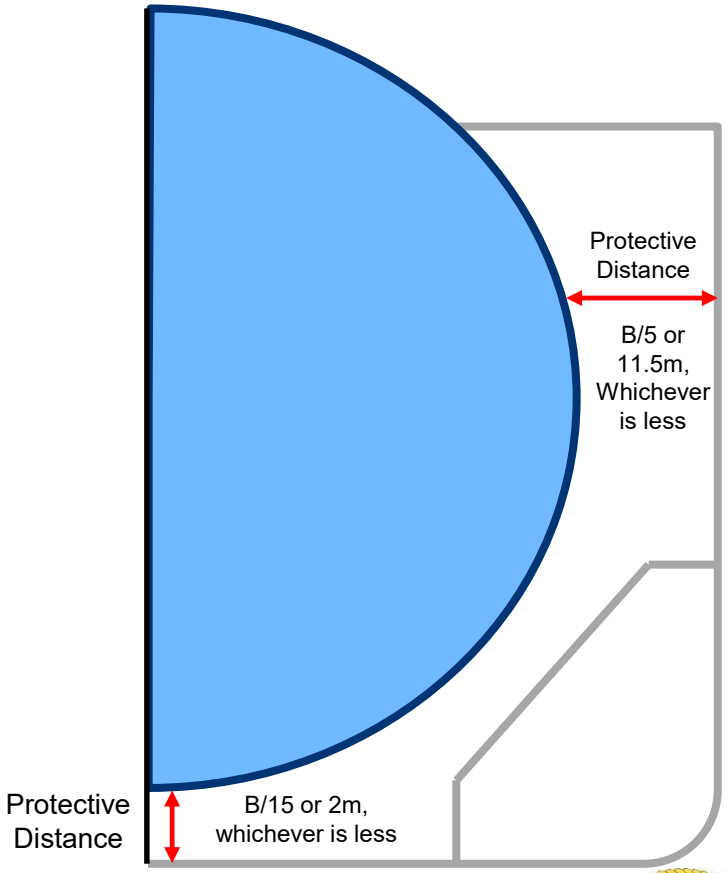
Cargo Tank Locations & Ship Survival Capability

The IGC Code divides gas carriers into four categories according to the hazardous ratings of the cargoes that the ship is certified to carry:

- 1G – **Maximum** preventative measures where cargo tanks are located the greatest distance from side shells (Chlorine)
- 2G – **Significant** preventative measures (LNG, Ethane)
- 2PG – **Significant** preventative measures in vessel carrying cargoes in type C tanks with MARVs exceeding 0.7 BAR
- 3G – **Moderate** preventative measures (Nitrogen, refrigerant gases)

2G Pressure Type Tank

with significant preventative measures



Cargo Containment Systems

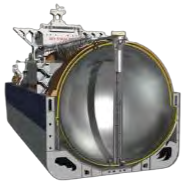
Independent Tanks

Type A
P < 0.7 bar
Complete Secondary Barrier

Prismatic

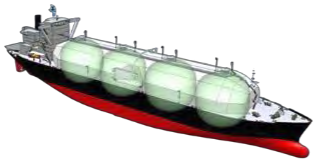
Type B
P < 0.7 bar
Partial Secondary Barrier

Spherical (Moss)



Prismatic (IHI SPB)

Apple-Shaped (MHI Sayaringo)



Type C
P > 0.7 bar
No Secondary Barrier

Cylindrical

Bilobe

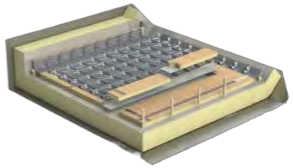
Trilobe

Non-Self-Supporting Tanks

Membrane
P < 0.7 bar
Complete Secondary Barrier

GTT No 96

GTT MKIII



Fully-Pressurized

- Simplest gas carriers fitted with Type C pressure vessels.
- Operates at ambient temperature with design pressure of 18 bar.
- No thermal insulation or reliquefaction plant required.
- Fully pressurized ships are small due their tank weight. Cargo tanks are extremely heavy due to their robust build to contain high pressures.
- Commonly found on the Ammonia and VCM trade.

Semi-Pressurized/Refrigerated

- Similar to fully pressurized ships, they use Type C cargo tanks.
- Operate between 5 and 7 bar, meaning the thickness of the cargo tank can be reduced allowing more cargo to be carried.
- Requires a reliquefaction plant.
- Have the flexibility to discharge either refrigerated or pressurized cargo.
- LNG bunker barges use sub-cooler technology to indirectly cool the cargo.

Fully-Refrigerated

- Carries cargoes at approximately atmospheric pressure less than .7 bar.
- Fitted with booster pumps and cargo heaters to have the option of discharging refrigerated or pressurized cargo.

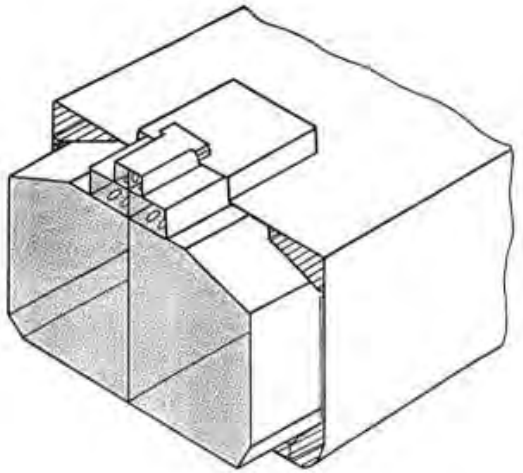
Secondary Barrier

- Liquid resisting outer element of containment system designed to afford temporary containment if a leakage occurs and prevents lowering temperature of the ship's structure.
- Must hold leak for 15 days

Fuel temperature at atmospheric pressure	-10°C and above	Below -10°C down to -55°C	Below -55°C
Basic tank type	No secondary barrier required	Hull may act as secondary barrier	Separate secondary barrier where required
Membrane Independent Type A Type B Type C		Complete secondary barrier Complete secondary barrier Partial secondary barrier No secondary barrier required	

Type A Tank

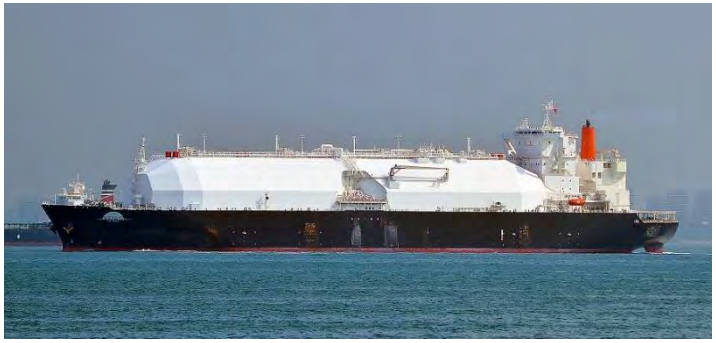
- Designed using classic ship-structural analysis in accordance with vessel administration or class rules.
- Maximum allowable tank design pressure in the vapor space is 0.7 barg or less, operates near atmospheric pressure.
- Requires full secondary barrier, hull may act as secondary barrier under special conditions.
- Tank is externally insulated with foam
- Most common LPG cargo tank.
- Hold spaces filled with inert gas per IGC Code.



Type B Tank

- Three designs: Spherical, apple-shaped, or prismatic
- Max allowable tank pressure in vapor space is 0.7 barg
- Designed to leak before failure.
- Due to design factors, type B tanks only require a partial secondary barrier.
- Hold space may contain dry air or inert gas

Apple-Shaped Sayaringo Containment System



MOSS Spherical Containment System

IHI-SPB:
Ishikawajima-Harima Heavy Industries Self-Supporting Prismatic Type B

Type C Tank

- Based on pressure vessel criteria.
- Easy to build, transport, and install while the ship is being built.
- Can be mounted vertically or horizontally
- No secondary barrier required
- Technology of choice for small LNG or LPG carriers

Trilobe Type C

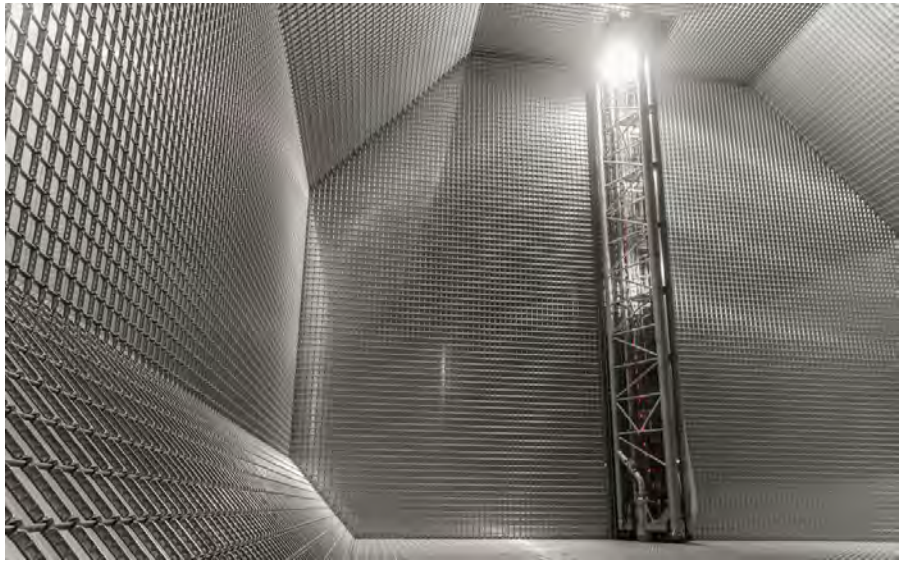
Cylindrical Type C

Bilobe Type C

Membrane Tank

- Uses inner hull of ship as primary load bearing structure.
- Thin primary barrier (0.7 to 1.5mm) supported by insulation and hull.
- Secondary barrier must be provided to protect the vessel if the primary barrier fails.
- Manages boil off gas by utilizing vapors as fuel.
  - Low boil off rate
- Susceptible to damage due to sloshing, so cargo loading is very restrictive (less than 10% but greater than 70%).
- Currently used on LNG carriers and Ethane carriers only.

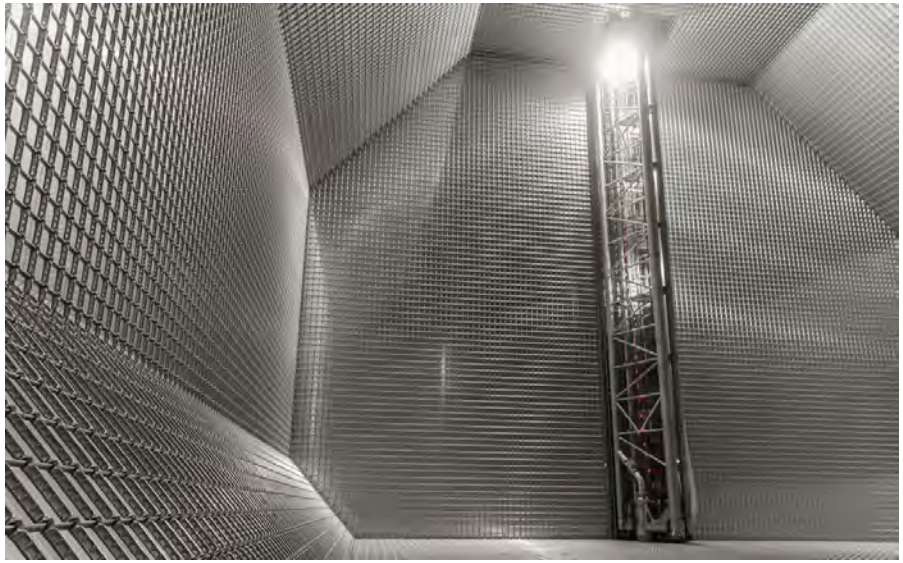
GTT Mk III Membrane Tank



GTT MKIII Membrane Tank

- Primary barrier is stainless steel
  - Waffle design allow for expansion/contraction
  - 1.2mm thick
- Secondary barrier is triplex
- Reinforced polyurethane foam (PUF) for insulation
- 270mm total thickness (11in)

GTT Mk III Membrane Tank

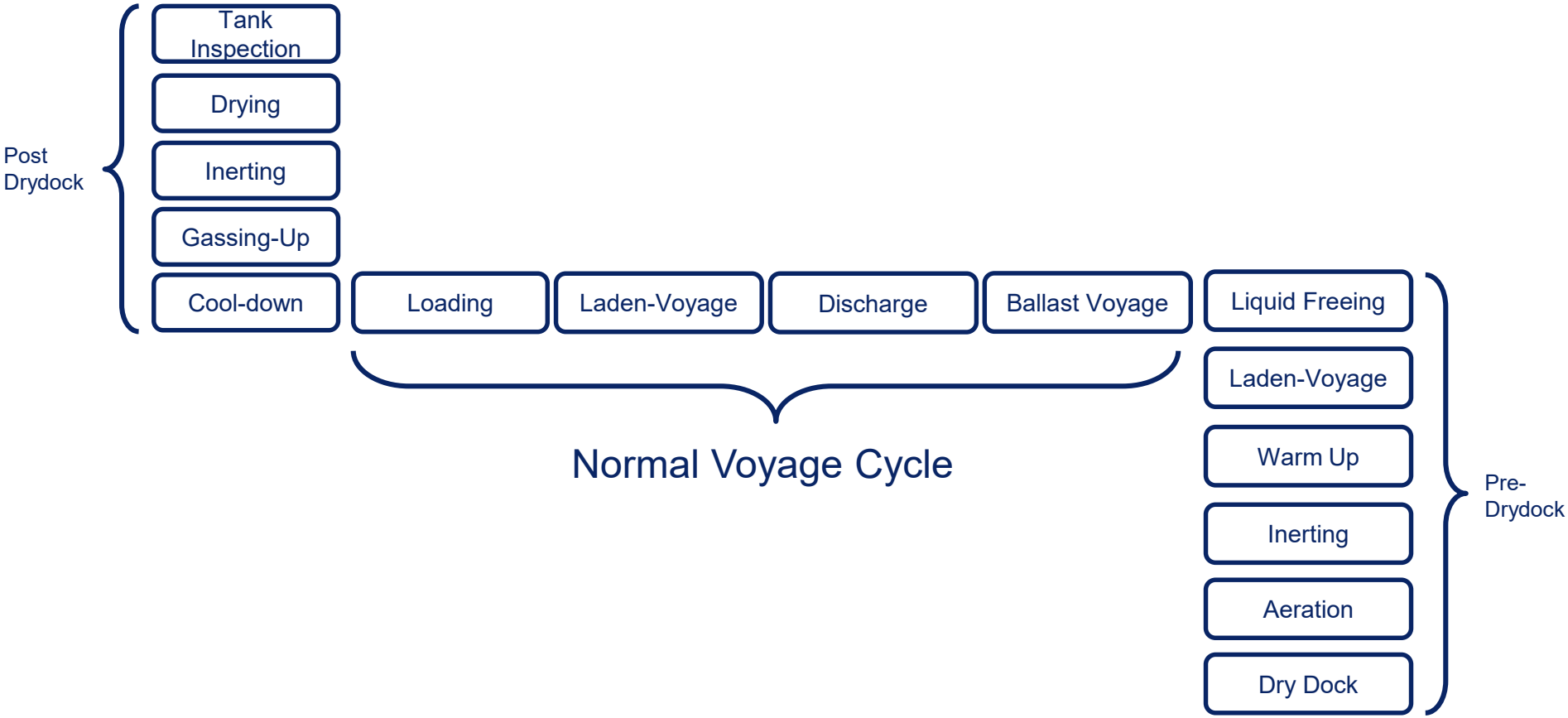


GTT No. 96 Membrane Tank

- Primary and secondary barriers are Invar
  - 0.7 mm thick
  - 36% nickel steel
  - Low coefficient of thermal expansion
- Insulation:
  - Plywood boxes with perlite or fiberglass wool
- 530mm total thickness (21in)

GTT No. 96 Membrane Cargo Tank

Drydock to Drydock Operations



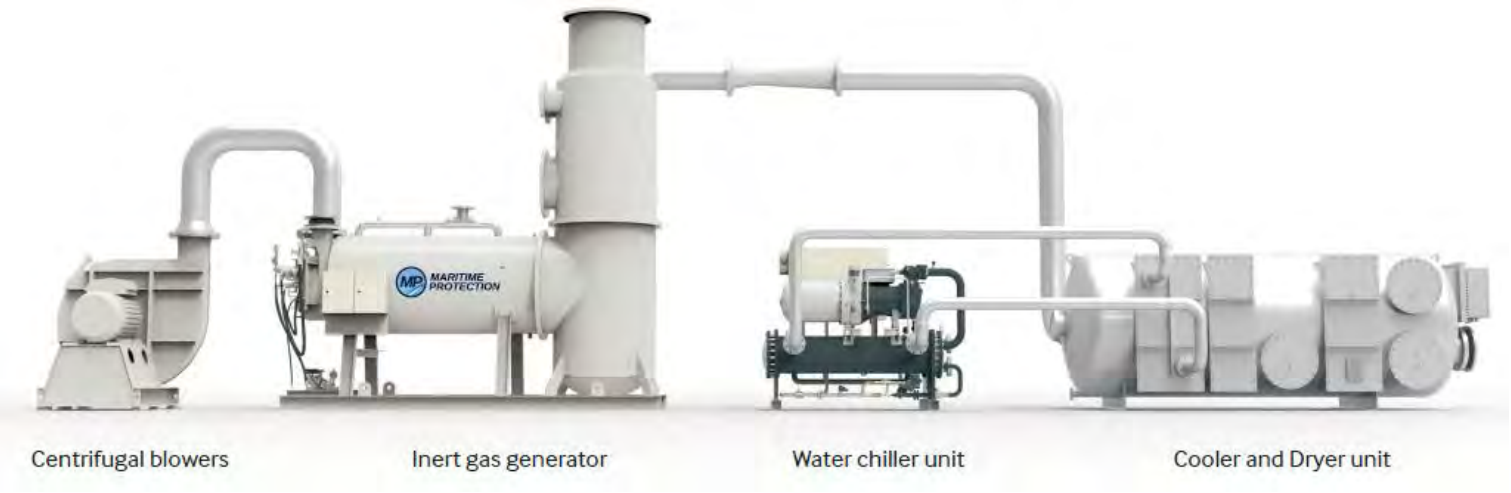
Gas Carrier Cargo Handling Operations

Cargo Loading

1. Vessel to ensure the cargo tanks, piping, and equipment are pre-conditioned.
   - Dried
   - Inerted
   - Gassed-up alongside (most common for LNG) or at sea
   - Cooled down

Ballast Voyage

Laden Voyage



Cargo Unloading

Gas Carrier Cargo Handling Operations

Cargo Loading

2. Per the IGC Code a vessel/terminal pre-cargo operations meeting shall take place.
3. Essential cargo handling controls & alarms are checked and tested prior to cargo transfer. *The list below is not all inclusive*
   a) Cargo tank relief valve settings and pressure alarms
   b) Remote operated valves
   c) Cargo handling equipment
   d) Gas detection and ventilation systems
   e) Alarms & controls
   f) Topping off procedures
   g) Responsibility for stoppage of transfer
   h) Maximum loading rate

Ballast Voyage

Laden Voyage

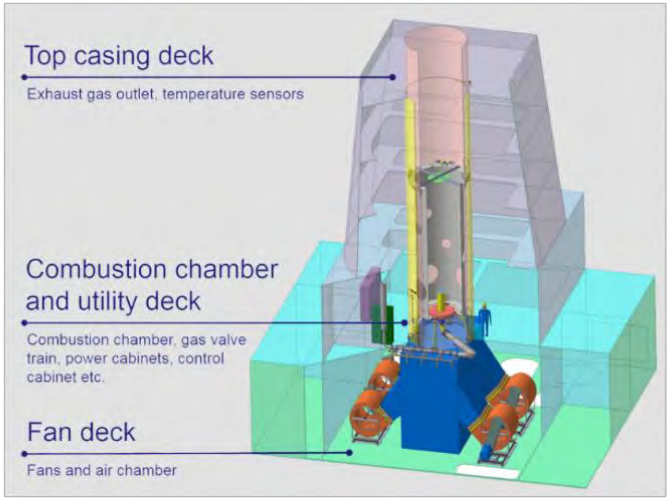
Cargo Unloading

Gas Carrier Cargo Handling Operations

Cargo Loading

4. Pressure must be managed during loading operation
   a. LNG: Vapor generated during loading operations is sent ashore via vapor line. If equipped, can utilize reliquefaction equipment.
   b. LPG: Vapor generated is managed through reliquefaction equipment; in an emergency can be sent ashore via vapor line.

Ballast Voyage



Gas Combustion Unit by Alfa Laval

LPG Reliquefaction Plant

Laden Voyage

Cargo Unloading

Gas Carrier Cargo Handling Operations

Cargo Loading

5. The vessel must adhere to cargo tank loading limits & filling limits
   a) Default filling limit = 98%
   b) To prevent cargo tanks becoming liquid-full during a fire, loading limits are set to account for the thermal coefficient of expansion of liquefied gases.

$$LL = FL\left(\frac{\rho_R}{\rho_L}\right)$$

Ballast Voyage

Laden Voyage

LL = loading limit expressed in percent which means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded

FL = filling limit, 98% unless certain exceptions apply.

ρR = relative density of cargo at the reference temperature

ρL = relative density of cargo at the loading temperature and pressure.

Cargo Unloading

Gas Carrier Cargo Handling Operations

Cargo Loading

1. Fully-refrigerated and semi-refrigerated gas carriers must maintain cargo temperature and pressure while loaded
   a. LNG carriers utilize gas consumers & gas combustion unit
      - If equipped, will utilize reliquefaction plant
   b. LPG carriers will utilize their reliquefaction plant
2. Equipment in the cargo machinery room must be maintained and monitored.
   a. Compressors
   b. Heaters
   c. Vaporizers
   d. Condensers
   e. Glycol/water cooling systems
   f. Gas detection
   g. Ventilation

Ballast Voyage

Laden Voyage

Cargo Unloading

Gas Carrier Cargo Handling Operations

Cargo Loading

3. Equipment in the motor room must be maintained and monitored.
   a. Motors
   b. Gas detection
   c. Ventilation
   d. Shaft seals
   e. Portable and Fixed (if equipped) firefighting systems.

Ballast Voyage

Laden Voyage

Cargo Unloading

Gas Carrier Cargo Handling Operations

Cargo Loading

1. As with loading, a pre-transfer meeting will occur.
2. The method of discharge will depend on the type of ship, terminal storage, and pre-arranged cargo specifications set by the charterer.
   a. Discharge via pressure – fully pressurized type C tanks, and under emergency situations, some type B tanks.
   b. Discharge by cargo pump – most common practice
   c. Discharge via booster pump and cargo heater – when delivering refrigerated cargo to pressurized storage.
3. Tank pressure must be managed as cargo is discharged
   a. Utilizing the ship's vaporizer or vapor returned from shore

Ballast Voyage

Laden Voyage

Cargo Unloading

Questions?