



LNG INFORMATION PAPER

# #3

2019 Update

## LNG Ships

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*GIIGNL's Technical Study Group introduces a series of Information Papers that provide factual information about Liquefied Natural Gas (LNG). This paper explains how LNG is transported in large ships known as LNG carriers. This paper also summarizes the international security measures established by the International Maritime Organisation (IMO) to ensure safe and secure transits around the world.*

### INTRODUCTION

LNG ships, or carriers, provide the link in the LNG Chain (**Information Paper No. 2**) between the location where the natural gas is liquefied and where it can be consumed. LNG ships enable large amounts of clean natural gas energy to be transported to the consumer over large distances from the LNG Liquefaction Plant. The LNG is delivered to marine import terminals where the LNG is warmed and converted back into a gas, through a regasification process, before being delivered into the gas pipeline network. LNG can also be distributed to consumers in road tank trucks, bunker vessel/barges.

Almost 2,000 liquefied gas ships operate around the world, most of which transport liquefied petroleum gas (LPG). There are currently more than 500 LNG ships involved in worldwide trade and the majority of them can each carry from 90,000 to 175,000 m<sup>3</sup> of LNG. In comparison, there are approximately 12,000 oil tankers; of those approximately 800 are very large crude carriers (VLCC's).

New vessel construction has increased the LNG carrier ship cargo capacity up to 267,000 m<sup>3</sup> (71 million gallons). The cost of LNG ships today is between \$185 million for a 175,000 m<sup>3</sup> carrier up to approximately \$250 million for larger ships.

### SHIPPING SAFETY RECORD

The LNG shipping industry has an excellent safety record. Since the first cargoes of LNG were shipped on a regular commercial basis in 1964, almost 100,000 shipments have been made without a single incident of LNG being lost through a breach or failure of the ship's tanks.

There have been a few major grounding incidents, but none resulted in loss of cargo. The robust design of the ships and cargo tanks and the LNG industry's extraordinary attention to safety details have collectively served to prevent the release of cargo and to facilitate this noteworthy safety record.

### ABOUT LNG SHIPS

#### Vessel Size

A typical modern LNG ship is approximately 300 meters (m) (975 feet) long, 43m wide (140 feet) wide and has a draft of about 12 m (39 feet). LNG ships vary in cargo capacity, from 1,000 cubic meters to 267,000 cubic metres, but the majority of modern vessels are between 125,000 cubic metres and 175,000 cubic metres capacity. Smaller LNG ships (1,000 – 25,000 cubic meters capacity) also operate in some areas, such as Norway and Japan. LNG carriers are capable of speeds of up to 21 knots (oil tankers operate at 15-20 knots) in open waters. A typical construction time for a LNG carrier ranges between 20 and 36 months. In the arctic region ice breaker LNG carriers allow the transport of LNG in icy waters. LNG carriers are able to cross canals such as Suez and Panama Canal.

### Containment System

The majority of large LNG ships sailing today have been designed to carry LNG either in spherical tanks (Moss sphere design) or in geometric membrane tanks (membrane design). Small LNG ships/barges carry LNG in membrane or type-C pressurised tanks (Figure 1). LNG ships may also be utilised to function as Floating Storage

Units (FSU) or Floating Storage and Regasification Unit (FSRU). Floating facilities allow LNG terminals to be sited offshore or moored alongside jetties or piers. LNG ships with on-board regasification facilities are operating in Argentina, Bangladesh, Brazil, China, Columbia, Egypt, Indonesia, Israel, Italy, Jamaica, Jordan, Kuwait, Lithuania, Malaysia, Malta, Pakistan, Turkey, UAE and the US (Figure 2; next page).

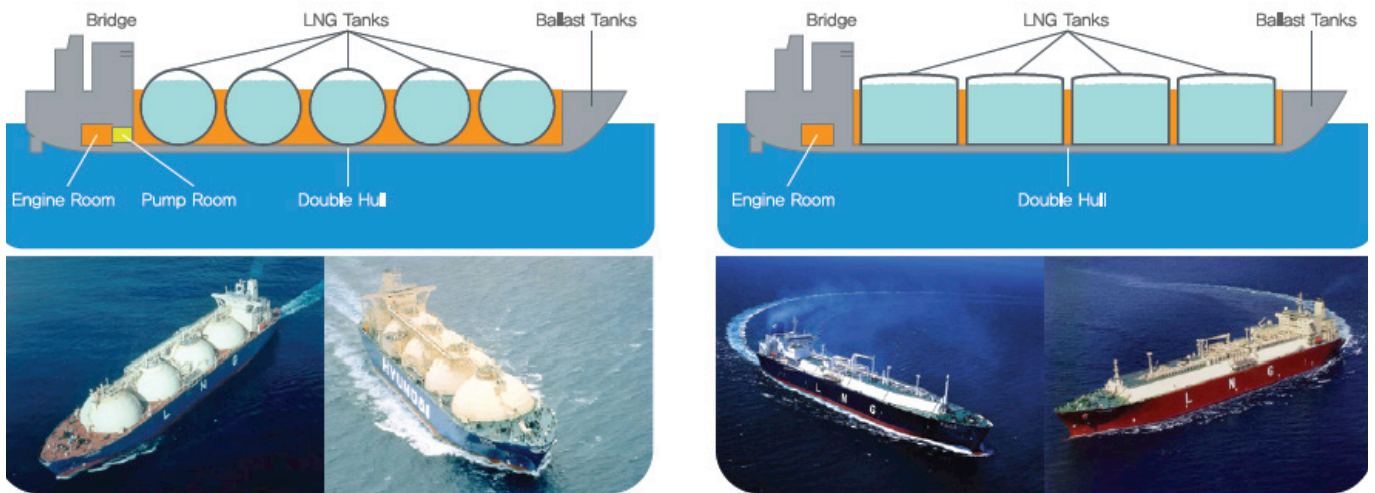


Figure 1.a. Example LNG carrier types: Moss sphere design (Left) and membrane design (Right) (Source: KOGAS)

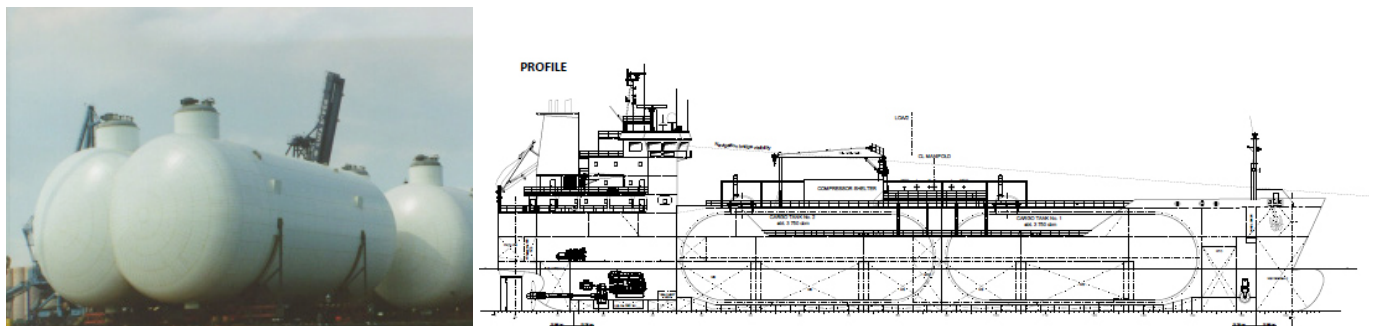


Figure 1.b. Type-C pressurised tanks and LNG carrier (Source: TGE Gas Engineering, SHIPTECH PTE LTD)



Figure 2. Floating facilities: FSU (Left) and FSRU (Right) (Source: Reganosa, Excelerate LNG)

## Propulsion

Traditionally, LNG carriers were propelled by steam turbines which can use the boil-off gas for propulsion. Increasingly steam boilers are replaced by multiple-fuel engines (such as Dual Fuel Diesel Electric / Tri-fuel Diesel Electric engines).

## Ice-breaking LNG Carrier

In December 2017, the world's first ice-breaking LNG carrier, *Christophe de Margerie*, was successfully loaded from Yamal LNG project located at Sabetta on the Yamal Peninsula in Northern Russia. This special ARC 7 ice-class carrier, by Russian classification standards, has been custom-designed and has been built for this LNG project located above the polar circle. The vessel is capable of navigating independently through 2.1 m-thick ice and 15 m-high waves. It can sail at a speed of 19.5kt in open seas and at 5kt in 1.5m-thick ice. It will have the ability to withstand temperatures of -50°C when operating in arctic environments. (Figure 3)



**Figure 3. Christophe de Margerie - the world's first icebreaking LNG carrier** (Source: DSME)

## General Operational and Safety Facts

LNG ships must comply with all relevant local and international regulatory requirements including those of the International Maritime Organisation (IMO), International Gas Carriers Code (IGC) and US Coast Guard (USCG).

All LNG ships have double hulls. The cargo is normally carried near atmospheric pressure in specially insulated tanks, referred to as the cargo containment system inside the inner hull, although some smaller carriers and bunker barges have tanks capable of operating at pressures of up to 10 barg. International codes govern the design and construction of gas carriers. There are additional international requirements set out in the codes which vary with the type of cargo that the ship will carry. All commercial vessels have to be registered in a country – the “Flag State”. Countries with more than one LNG ship in their registry include Algeria, Australia, The Bahamas, Bermuda, Brunei, France, Isle of Man, Italy, Japan, Korea, Liberia, Malaysia, Malta, the Marshall Islands, Norway, and United Kingdom. No inference can be drawn automatically from

a ship's flag of registry, the supplier of the cargo, or the nationality of the ship's crew to a particular characterisation of the importers.

All countries implement IMO Rules including the IGC, the International Safety Management (ISM) Code and the International Convention on Standards of Training, Certification and Watching (STCW) Convention. The government administration of the country of registry may impose additional requirements over and above the international codes.

A Classification Society is a non-governmental organisation which forms an integral part of the shipping industry, and is often referred to as “Class”. It establishes and maintains standards for the construction and classification of ships and offshore structures, according to technical rules, confirms that designs and calculations meet these rules, and conducts surveys of ships and structures during the process of construction and commissioning. Classification societies periodically survey vessels in service to ensure that they continue to comply with the rules and required codes. Insurance underwriters require that the ships are “in class”; without insurance the ships cannot trade.

Marine quality assurance for LNG carriers (as well as other ships) is provided through the process of vetting, which assesses ship quality against a known standard to determine its acceptance for use. Ships are assessed in relation to such international conventions and industry recommendations as IGC, Safety of Life at Sea (SOLAS) and International Convention for the Prevention of Pollution from Ships (MARPOL). Guidance detailed in the International Safety Guide for Oil Tankers and Terminals (ISGOTT) is pertinent to all tanker types and the Society of International Gas Tankers Terminal Operators (SIGTTO) to gas carriers. The process of assessing the ship quality should include the assessment of operational standards of the vessel including crew competency and training, and the ship's physical condition. Information on ship quality is gathered from many sources, including vessel inspections on behalf of ship companies, owner assessments, terminal and operational feedback, market intelligence, casualty data, reputation and questionnaires. The “Port State Controls” established by the Memorandum of Paris (1981) are recorded in the “Equasis” database available for worldwide access. Such port state control databases and Class reports also provide information which assist in making the vetting decision. Generally, operators perform ship inspections according to the Oil Companies International Marine Forum (OCIMF) standards or to their own standards to assess the ship conditions. Reports on the ship's technical and survey status are available through the OCIMF Ship Inspection Report (SIRE) Programme, via the ship's classification society, and through the ship owner.

In addition to the aforementioned safeguards for the LNG ships, the entire LNG shipping process is replete with sophisticated operational and safety systems. Operationally, the ships use communications technology, global positioning and radar to continuously monitor the ship's



course, speed and position (as well as that of nearby vessels). Additionally, comprehensive safety systems begin monitoring the precious (LNG) cargo at the very outset of the loading process, and –at that point – initiate the constant procedure of checking for leakage. Such checks start when the gas is loaded into the ship's pre-cooled cargo tanks as a refrigerated liquid at atmospheric pressure via a closed system from insulated storage tanks at the liquefaction plant. In a modern membrane LNG ship, the cargo containment system consists of a primary barrier, a layer of insulation, a secondary barrier, and a second layer of insulation as shown in **Figure 4**. Thus, if there should be any damage to the primary barrier, the secondary barrier will prevent leakage. The insulation spaces are filled with nitrogen and continuously monitored for any sign of leakage. The equipment used for tank detection is so sensitive that it can detect leakage through a hole the size of a pinhead. The LNG is kept fully refrigerated by allowing a small amount of cargo to evaporate during the voyage to the import terminal. This is referred to as boil-off gas (BOG); in addition to keeping the LNG cold, it provides a source of clean fuel for the ship's engines. A typical boil-off gas rate for large vessels is in the range of 0.15% per day of the gross cargo. In pressurised vessels, the boil-off gas is suppressed and the heat input through the insulation results in tank pressure increase.

### Training

The LNG ship's officers and crew undergo extensive training to meet internationally recognised standards. The ships carry detailed contingency plans to cover the vast spectrum of potential incidents and conduct regular exercises to ensure that all crew members know how to respond effectively and efficiently during any emergency. All receive specific LNG training in cargo handling, fire-fighting and relevant safety systems, including drills encompassing various scenarios related to the cargo and the vessel itself.

When the LNG ship arrives at the import terminal, it is pumped from the ship into onshore storage tanks. Before

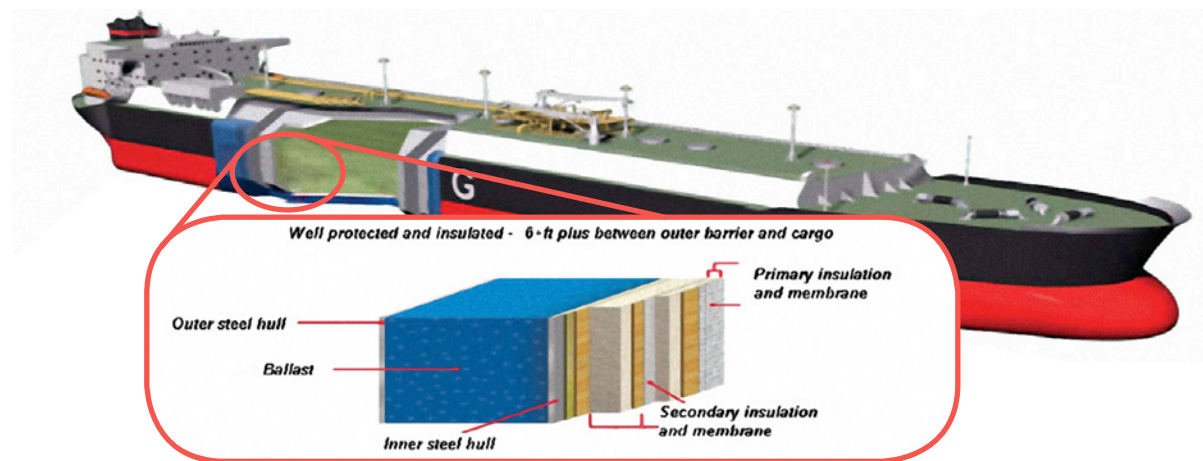
this transfer takes place, a pre-discharging meeting is held on board during which a safety checklist is completed to comply with international guidance by organisations such as IMO, SIGTTO, and ISGOTT. Special cryogenic transfer arms or hoses are used to transfer the LNG from the ship to shore. When the loading and unloading operations are taking place, the ship and terminal are connected by means of a special Emergency Shut Down (ESD) system which enables cargo transfer to be shut down automatically and rapidly in case of any problems. Some modern LNG ships are fitted with a reliquifier to conserve boil-off gas.

From the onshore tanks, the LNG is pumped to the regasification plant, i.e., warmed and converted back into a gas, before entering into the pipeline distribution system. Alternatively, LNG can also be pumped from the tanks and either reloaded onto a smaller carrier/bunker barge (LNG reloading or bunkering service) or onto a LNG truck (LNG truck loading service).

### SHIPPING SECURITY

Shipping safety and security risks are managed through the use of strict operational procedures, putting a priority on safety, and on well-trained, well-managed crews. Safety and security assurance is a key part of company hiring, training and operations practices.

As a result of the acts of terrorism in the US on September 11, 2001, IMO agreed to new amendments to the 1974 SOLAS (International Convention for the Safety of Life At Sea) addressing port facility and ship security. In 2003, IMO adopted the International Ship and Port Facility Security (ISPS) Code. This code requires that vulnerability assessments be conducted for ships and ports and that security plans be developed. The purpose of the ISPS code is to prevent and suppress terrorism against ships; improve security aboard ships and ashore; and reduce risk to people (including passengers, crew, and port personnel on board ships and in port areas), and to



**Figure 4.** Example tanker safety construction requirements for LNG transport at sea (Source: DSME)



vessels and cargoes. Cargo vessels 300 gross tons and larger, including all LNG vessels, as well as ports servicing those regulated vessels, must adhere to these IMO and SOLAS standards.

For ships, IMO requirements include:

- Ships must develop security plans and have a Ship Security Officer;
- Ships must be provided with a ship-security alert system. These alarms transmit ship-to-shore security alerts to a competent authority designated by the Administration, which may include the company, identifying the ship, its location and indicating that the security of the ship is under threat or has been compromised;
- Ships must have a comprehensive security plan for international port facilities, focusing on areas having direct contact with ships; and
- Ships also may have certain equipment onboard to help maintain or enhance the physical security of the ship.

For port facilities, IMO requirements include the following:

- Port facility security plan;
- Facility Security Officer; and
- Certain security equipment may be required to maintain or enhance the physical security of the facility.

For both ships and ports, security plans must address the following issues:

- Monitoring and controlling access;
- Monitoring the activities of people and cargo;
- Ensuring the efficacy of security communications procedures and systems, and their ready availability; and
- Completion of the Declaration of Security. A Declaration of Security (DOS) is a declaration which addresses the security requirements that could be shared between a port facility and a ship (or between ships) and stipulates the responsibility for security each shall take.

Security plans also address issues such as: port of origin, port of destination, control of ship movements, cooperation with shipping authorities and appropriate internal and external communications.

In addition to the security measures listed above, in the US the USCG requires additional security measures based on a location-specific risk assessment of LNG shipping including among other things:

- Inspection of security and carrier loading at the port of origin;
- On-board escort to destination terminal by USCG “sea marshals”; and
- Ninety-six hour advance notice of arrival (NOA) of an LNG carrier.

### SHIPPING SAFETY ZONES

In most ports, the LNG ships transit through port areas in a moving “safety zone” until they berth and then a fixed safety zone around them is established. This fixed zone exists while they discharge cargo, for about 24 hours, until they transit back out again. The safety zone is a way to keep other vessels away from the LNG carrier so as to prevent accidental collisions and intentional attacks. The concept of a safety zone is not unique to shipping. Similarly, the aviation industry applies safety zones to aircraft. The size of the safety zone for a specific port is determined by assessing the potential risks and hazards in that port and its approaches. A tug escort is used to manage the safety zone around a vessel. In operating the safety zone, the ports also have to manage and coordinate all their other shipping traffic. Specialised companies work with the host port authority and coast guard authorities to carry out a risk assessment, which determines the optimal configuration and management of safety zones.



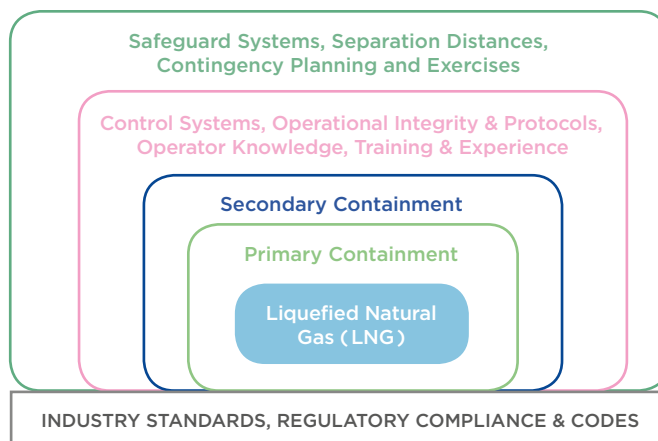
## KEY POINTS AND CONCLUSIONS

In closing, the key points of this information paper are:

1. A typical modern LNG ship, or LNG carrier, is approximately 300 m long, 43 m wide and has a draft of 12 m. Cargo capacities range from 1,000 cubic meters up to 267,000 cubic meters. Sailing speeds can approach up to 21 knots in open waters.
2. The main types of cargo containment on LNG ships are spherical (Moss sphere design) or geometric membrane (membrane design). Pressurised LNG tanks are also frequent on smaller LNG carriers/barges (type-C design). Classification societies maintain standards for design and construction and conduct surveys while under construction and throughout a ship’s service life. Insurance underwriters require that ships are “in class”; without insurance the ships cannot trade.
3. LNG ships must comply with all relevant local and international regulatory requirements, including but not limited to those of the IMO, IGC and the USCG.
4. Marine quality assurance for LNG carriers is provided through the process of vetting, which assesses ship quality against a known standard to determine its acceptance for use. Vetting is conducted by shipping companies using employees or independent contractors on their own ships as well as chartered ships.
5. Clearly, shipping safety and security for LNG ships is maintained at a very high level, especially considering the very low historical accident/incident rate of the industry. LNG tankers have sailed over 92,000 voyages without major accident or loss of cargo.

This excellent safety record is a result of the LNG industry’s stringent design practices and diligent operating standards, enhanced and supported by strong regulatory oversight. In that specific regard, a graphic illustration of these “Multiple Safety Layers” is reflected in the figure below. These “safety layers” include several key components of the industry’s Risk Management framework. Included among them are Primary and Secondary Containment, Control Systems which promote Operational Integrity; Protocols, Operator Knowledge and Experience (which are reinforced by comprehensive and ongoing training). A protective umbrella of Safeguard Systems, Separation Distances, and Contingency Planning further enhances the safe management of LNG.

## Multiple Safety Layers Manage LNG Risk



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