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Tale of LNG and LPG Ships

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Abstract. Liquefied Natural Gas (LNG) mostly consists of methane but it has little amount of other hydro-carbon. Liquefied Petroleum Gas (LPG) is heavier than LNG and mainly consists of butane and propane. The materials used in the inner design of LNG tankers can withstand low temperatures and for LNG tankers can withstand either high pressure or low temperatures. LNG carriers have membrane tanks with high vacuum multilayer insulation. The layers of membrane tanks include the primary barrier or metal layer, the insulation layer, a liquid proof layer, and a second insulation layer. Again, most fully pressurized oceangoing LPG carriers are fitted with two or three horizontal, cylindrical or spherical cargo tanks. LPG tankers often can carry some other gases such as ammonia, propylene and vinyl chloride. Gas carriers have certain features common with other tankers used for the carriage of bulk liquids such as oil and chemical tankers.

Key Words. Gas carriers, LNG, LPG, bulk liquids, dome, etc.

Introduction

A gas carrier or gas tanker is a ship designed to transport LPG, LNG or liquefied chemical gases in bulk. In gas carrier, cooling the gas turns it into a liquid and warming it turns it back into a natural gas. Liquefied Natural Gas (LNG) mostly consists of methane but it has little amount of butane, ethane, and propane. On the other hand, Liquefied Petroleum Gas (LPG) is heavier than LNG. It can be liquefied through refrigeration or by applying high pressure.[1,2] LPG naturally remains liquid at room temperature. Butane and propane are the primary constituents of LPG, which retains its weight even under heating conditions. When subjected to heat, LPG has the ability to undergo evaporation. Therefore, it is transported under high pressure to keep it in liquid. LNG is a very cold gas that requires to be transported in the very low temperatures to remain liquid. That’s why; the materials used in the inner design of LNG tankers can withstand low temperatures.[3,4] On the other hand, LPG is a heavy gas that can be transported either under high pressure or under low temperature. Major impurities of LNG gas, like sulphur and carbon dioxide has been removed, is carried in LNG carrier ships. LPG gas along with some other gases like ammonia, propylene, ethylene as their construction and equipments are suited to carry in LPG carrier ships.[5]

When a major international company put two combined oil/LPG tankers into operation in 1934, then seaborne transport of liquefied gases began.[6,4] The gas carrier ships, basically oil tankers, had been converted by fitting small, riveted, pressure vessels for the carriage of LPG into cargo tank spaces. Hence, this enabled transport over long distances of substantial volumes of an oil refinery by-product that had distinct advantages as a domestic and commercial fuel. LPG possesses not only an odorless and non-toxic nature, but also boasts a high calorific value and low sulphur content. As a result, when LPG is burned, it exhibits remarkable cleanliness and efficiency.[7,8] The majority of LNG carriers are between 125000 and 135000 m^3 in capacity.[9] Today, in the modern fleet of LNG carriers, there is an interesting exception concerning ship size. This is the introduction of several smaller ships of between 18000 and 19000 m^3 having been built in 1994 and later to service the needs of importers of smaller volumes. Once more, the majority of fully pressurized oceangoing LPG carriers are equipped with either two or three cargo tanks, which can be horizontal, cylindrical, or spherical in shape and have typical capacities between 20000 to 1000000 tones and length overall ranging from 220 to 260 meter. However, in recent years a number of higher capacity fully pressurized ships have been built, most notably a series of 10800 m^3 ships, and those built in Japan between 2003 and 2013. Fully pressurized ships are still being built in numbers and represent a cost-effective, simple way of moving LPG to and from smaller gas terminals. This is a review article which briefly describes the meaning of LPG and LNG ship, those two types of tankers, basic design, operation and safety matters, etc.

LPG and LNG

Usually, 1 volume of LPG is equivalent to over 250 volumes of vapor and 1 volume of LNG equivalent to 600 volumes of vapor. The physical properties of a liquefied gas depend on its molecular structure.[3,10] Naturally some compounds have the same molecular formula but a different arrangement within the structure. These different compounds of the same basic substance are called ISOMERS.[11] The single most important physical property of a liquefied gas is its saturated vapor pressure or temperature relationship. This property governs the design of the containment system suitable for each cargo. LPG is mainly propane and butane, shipped either separately or in mixtures. Refinery by-product gases are typically the source or can be generated alongside crude oil or natural gas. Almost all liquefied gases are hydrocarbons and the key property that makes hydrocarbons the world's primary energy source; combustibility and also makes them inherently hazardous.[12,2,13] Minimizing leakage and controlling ignition sources are crucial when dealing with significant quantities of these gases. A liquefied gas refers to a substance that exists in its liquid state at both ambient temperature and atmospheric pressure, despite being a gas.[14] The pressure of a closed container containing the same liquefied gas at the same temperature will remain constant. As a result, butane at the same temperature has an identical pressure irrespective of whether the container is the tank of a gas carrier, a simple gas cigarette lighter, a storage tank, or a domestic gas bottle, always all are pressurized containers. Again gases are normally liquefied for transportation in bulk simply because more cargo can be accommodated in a given volume.

Types and Regulatory Requirement of LPG and LNG Carriers

There are principally two types of gas carried by ships.

- LPG is mainly propane and butane. LPG ships carry their cargo at -42° C, at a relative density of approximately 0.500 with a volume contraction ratio of 1 in 300. LPG cargo may be carried under pressure.
- LNG is mainly methane and ethane. LNG ships carry their cargo at -161° C, at a relative density of approximately 0.600 with a volume contraction ratio of 1 in 600. LNG cargo is carried at ambient pressure.

International Maritime Organization (IMO) describe that, a liquefied gas ship can only run in international waters if it is constructed and operated as per International Gas Carrier (IGC) 1986 code and complies with SOLAS 74 chapter VII part C; construction and equipment of ships carrying liquefied gases in bulk.[12,2,16,17] The brief requirements described in IGC code are:

- Damage limitations to cargo and ship survival in case of collision or grounding.
- Safety arrangement requirements for such ship.
- Cargo containment and cargo handling procedure.
- Material of construction for containment and carriage facility.
- Requirements for cargo loading and discharging.

- Fire protection requirements.
- Pollution control requirements.
- Usage of cargo as ship's machinery fuel.
- provision for thermal expansion and contraction is provided

Basic Design Characteristics of Modern Liquefied Gas Carrier

LNG required high insulation and low temperatures to be transported in liquid form. The gas is transport at its boiling point, which is -162^{o} C.LNG carriers have membrane tanks with high vacuum multilayer insulation.[18] The layers of membrane tanks include the primary barrier or metal layer, the insulation layer, a liquid proof layer, and a second insulation layer. LNG is also transported in spherical tanks or self-supporting tanks that most people think of as LNG carriers. These tankers were first made of nickel steel but there are now covered with aluminum. The spherical tanks are also insulated heavily to avoid leakage. The IGC code defines three types of independent tanks used to transport gas. The three types include type A, B and C. LNG tankers fit the type B category, while LPG tankers fit the type A category. It is interesting to know that LNG tankers can have flat surfaces. As indicated earlier, anytime people see a spherical tanker, they immediately assume that it is an LNG carrier. The truth is that, LNG carriers or tanks can have either flat surfaces or a spherical shape.[19] LNG carriers are often subjected to more inspections or analysis than LPG carriers are. LNG carriers are analyzed for crack propagation and fatigue life. Type B tanks do not require many modifications, because they already have several layers of insulation.[20,2,16] Dry inert gas is often used to fill the hold space in type B tanks. However, dry air is used in the modern designs. A protective dome made of steel is applied over the primary barrier.[21] Another insulation layer is added to the outer surface of the tank. LPG is transported with both Type A and C independent tanks. Types A tanks are mostly constructed with flat surfaces. The maximum limit for pressure in the vapor space is 0.7 barg. Hence, LPG or any other cargo transported with these tanks must be fully refrigerated. The pressure inside should be close to the normal atmospheric pressure, and that is below 0.25 barg. A basic amidships cross-section view [22,2] of a typical Gas Carrier has been shown in fig 1 below. A basic general arrangement plan view [22,2] of a typical Gas Carrier has been shown in fig 2 below.

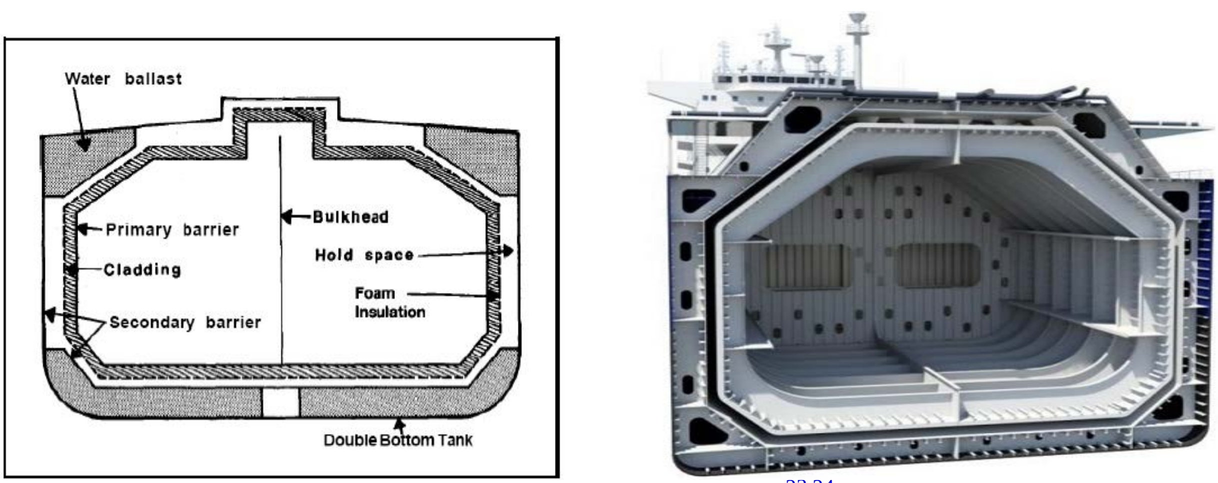


Fig 1: Amidships cross-section views of a typical Gas Carrier[23,24]

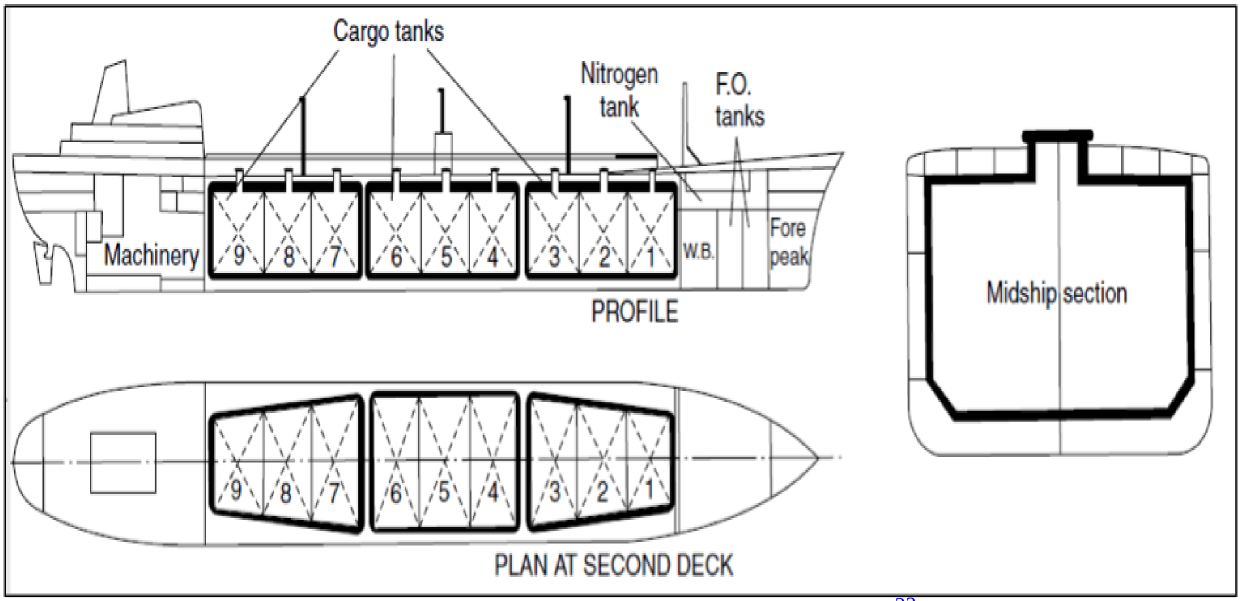


Fig 2: A basic general arrangement plan view of a typical Gas Carrier[23]

A fully refrigerated LPG tanker requires internal stiffening. It is a self-supporting tank with foam insulation. Perlite insulation is also used in some designs. LPG carriers have a primary barrier like LNG carriers. However, LPG tanks do not have resistance for crack propagation. The tanks require a secondary barrier, which is also known as a secondary containment system. The secondary barrier enables type A tanks to carry cargo of temperatures below -10^{o} C. If an LPG carrier is fully refrigerated, the secondary barrier should be completed. The barrier should have enough capacity to hold the whole tank volume.[20,2,25,26] A fully refrigerated carrier cannot carry gas or any other cargo of temperatures below 55^{o} C. The tanker's hull is made of special steel that can withstand extremely low temperatures. Sometimes the secondary barrier is constructed around the cargo tanks. Both LPG and LNG carriers have a space between the primary and secondary barriers. The designated area is referred to as the hold space. In the case of an LPG carrier, this space is filled with inert gas, while for an LNG tanker, it can be filled with either dry air or inert gas. The purpose of filling the space with inert gas [2] is to ensure that a leakage from the primary barrier will not create a flammable atmosphere. LPG is also transported in type C tanks, which are cylindrical or spherical tanks. The tanks have a design pressure that is above 4 barg.[27,02,28] The tanks are either carried horizontally or vertical. The design of type C tanks is used in full pressurized and semi-pressurized gas tankers. Type C differs from other gas tankers in that they do not have a secondary barrier. Cut up view of a typical gas tank dome placed inside a Gas Carrier [2] has been shown in fig 3 below. Gas carriers are classed in three types based on hazard potential:

- Type 1G, designed to carry the most hazardous cargoes.
- Type 2G and 2PG, designed to carry cargoes having a lesser degree of hazard.
- Type 3G, designed to carry cargoes of the least hazardous nature.

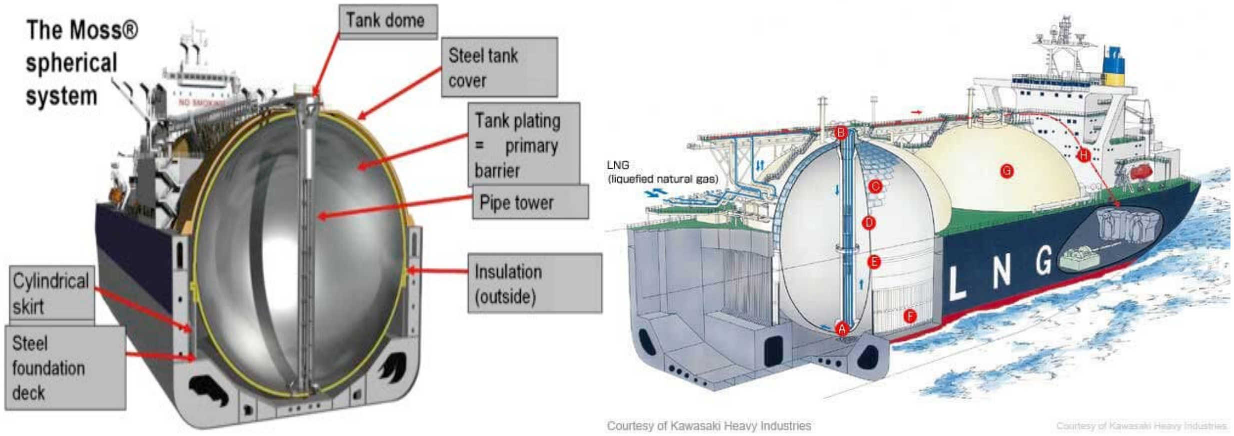


Fig 3: Cut up view of a typical gas tank dome placed inside a Gas Carrier [29,30]

Usually gas cargoes are transported in liquid form, because of their physical and chemical properties; they are carried either at pressures greater than atmospheric, or at temperatures below ambient, or a combination of both. Therefore, gas carriers are generally grouped as; fully pressurized, semi-pressurized and refrigerated and fully refrigerated. In principle, the design is 'a box within a box that is separated by a void space', similar in effect to the principle of a flask. Gas carriers can be split into two distinct groups as LPG and LNG carrier. The cargo tank construction of LNG and LPG ships can be of (a) prismatic design (b) membrane design or (c) spherical design.[23] Materials used for these cargo tanks can be aluminum, balsa wood, plywood, invar or nickel steel, stainless steel, with pearlite and polyurethane foam. Because of the demand for insulation at these extremely low cargo temperatures, the first costs of these specialized ships are extremely high. A very high standard of workmanship is required for the building of these types of vessel. Their capacity ranges from 75000 to 138000 m^3 of gas, their length up to 280 meter and their breadth up to 46 m. When fully loaded, their service speeds up to 21 knot. They are fine form vessels. Gas carriers must comply with the standards set by the gas codes or national rules, and with all safety and pollution requirements common to other tankers. The safety features inherent in the tanker design requirements have helped considerably in the safety of these tankers. Equipment requirements for gas carriers include temperature and pressure monitoring, gas detection and cargo tank liquid level indicators, all of which are provided with alarms and ancillary instrumentation.[2,10,31] The variation of equipment as fitted can make the gas carrier one of the most sophisticated tankers afloat today. Cargo containment systems may be of the independent tanks or of the membrane type. Typical A, B and C type tank arrangement[19] and view of a Gas Carrier [2] has been shown in fig 4 below.

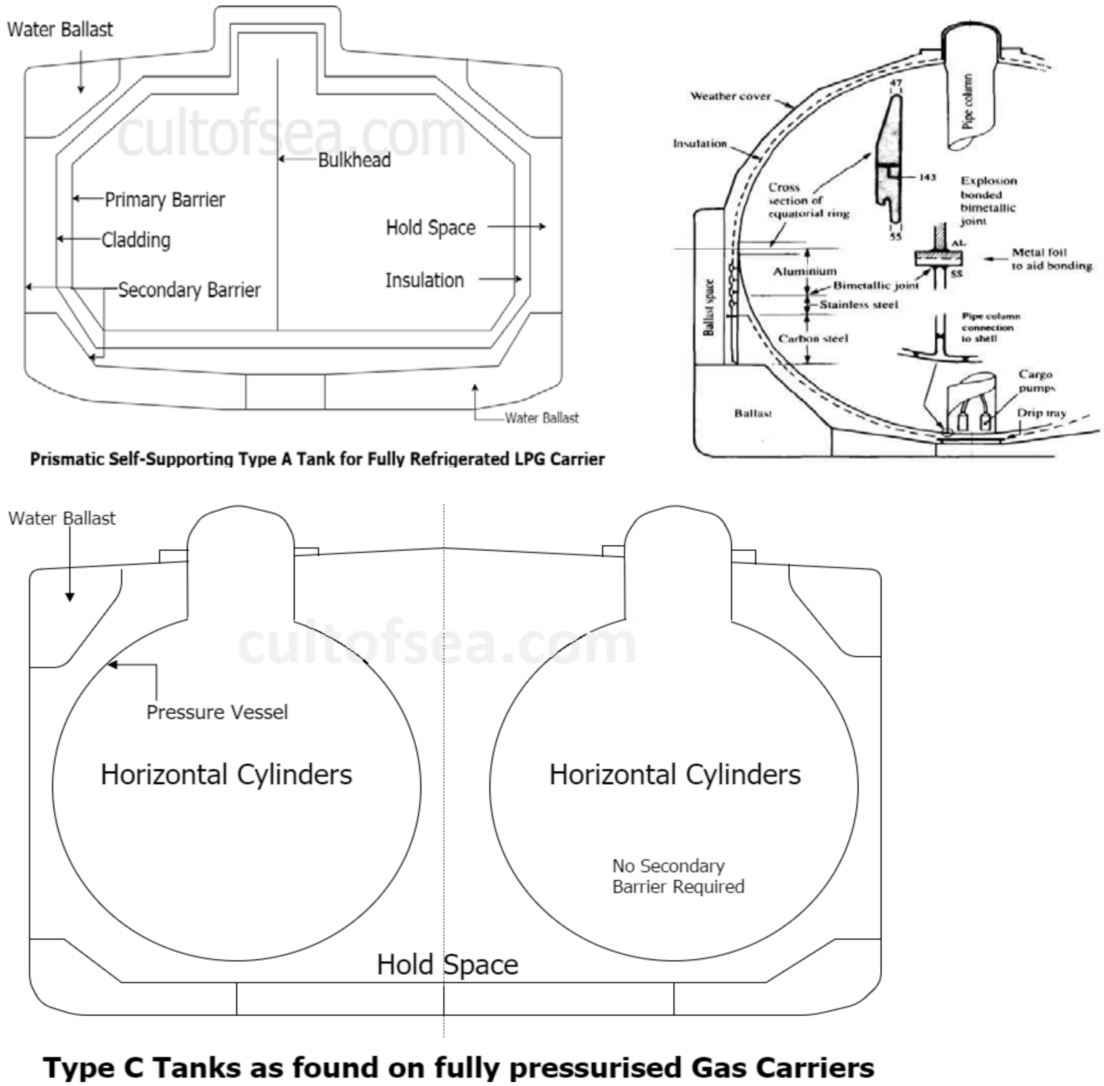


Fig 4: Type A, B and C Tank being installed into ships hold [23,32,33]

Brief Description and Operation of LPG Tanker

LPG tanker is a gas carrier built for the transportation of petroleum gases in bulk. LPG tankers frequently transport additional gases like ammonia, propylene, and vinyl chloride. The cargo requirements for an LPG carrier determine the types of cargoes the vessel must be equipped to handle. Virtually all LPG carriers are capable of managing LPG, ammonia, propylene, and VCM. However, larger gas carriers are starting to exclude certain cargoes from their cargo list.. Wartsila oil and gas system has a significant market share in the delivery of cargo handling system for both LPG and LEG vessels. LPG carriers can be classified into three categories based on the required temperature and pressure: full pressure type, semi refrigerated type, and fully refrigerated type. Small size ships (less than 4000 m^3 of cargo capacity) are usually the full pressure type. Example of tank and dome type LNP Carrier has been shown in fig 5 below.[31,34] The semi refrigerated technique is used for the cargo spaces around 7500 m^3, and fully refrigerated technique is intended for the cargo spaces from 10000 to 100000 m^3. Different types of cargo tanks should be provided with special material at maintained pressure as described in the constructional and cargo handling requirement of IGC code for both LPG and LNG ships.List of LPG carrier builders are:

- Hyundai Heavy Industries
- Kawasaki Shipbuilding Corporation
- Mitsubishi Heavy Industries
- Damen Shipyards Group

There are mandatory requirement for LPG ship to carry cargo by sea.LPG can be carried by sea if any one of the three criteria described below has been fulfilled:

- It is solely under pressure maintained at ambient temperature.
- It is fully refrigerated at its boiling point.
- It is semi refrigerated but at elevated temperature and elevated pressure.

There are few other important auxiliary criteria that also have been fulfilled:

- A well insulated and refrigerated LPG tank to fulfill any of the above criteria
- A compressor room with compressors and refrigeration plants
- A nitrogen bank as well as an inert gas generator with dryer system
- The cargo temperature and environment data monitoring system
- Tank atmosphere and temperature data is monitoring system

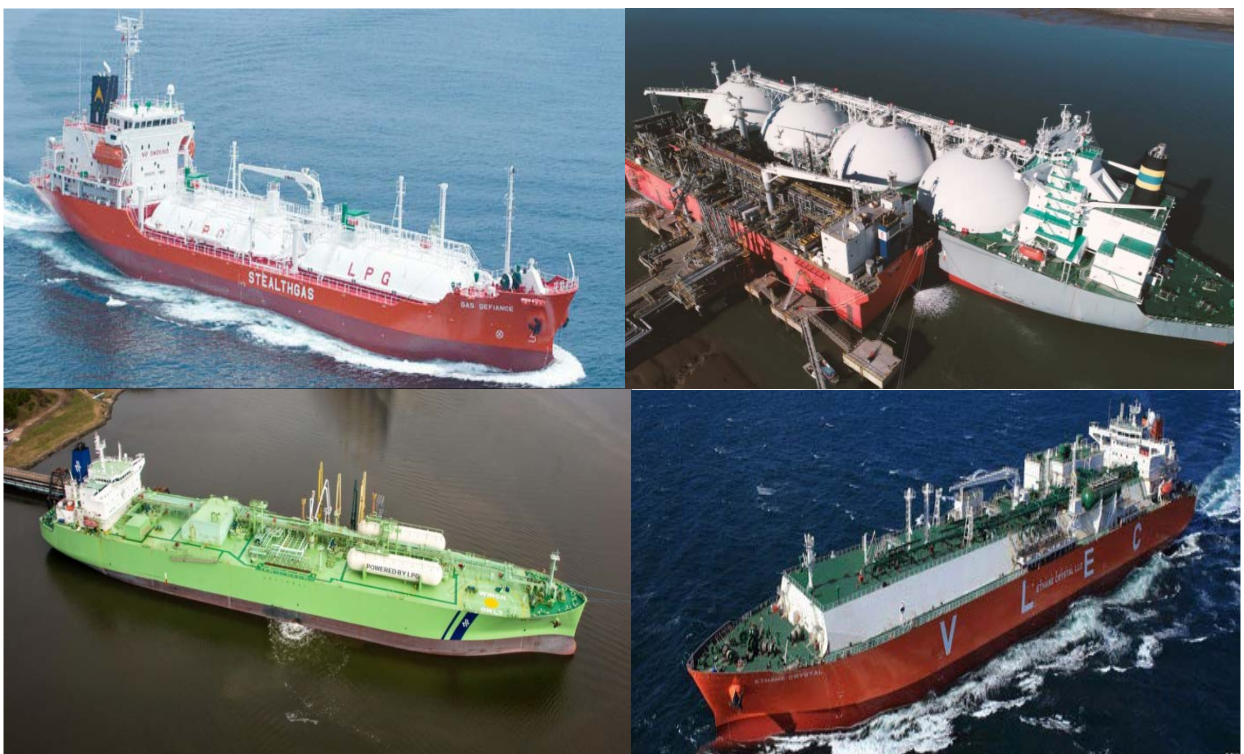


Fig 5: Example of few tank and dome type LPG Carrier [35,36,37,38,39]

During the loaded passage, the LPG cargo is warmed by heat input from sea water and atmosphere, causing the temperature and saturation pressure (cargo tank) to rise. It is therefore necessary to maintain strict control of the cargo temperature and pressure at all times during the loaded passage. On vessels other than pressurized LPG carriers this is achieved by re-liquefying the boil-off and returning it to the tanks. [40] Furthermore, there are regular instances where it becomes essential to lower the temperature of the cargo during transit, ensuring that the ship reaches the destination terminal with a cargo temperature lower than that of the shore tanks.Hence, minimizing the amount of flash gas discharged during the discharge operation. This is achieved by use of the re-liquefaction plant on board. It can often take several days to cool by 0.5° C, but this may be sufficient. Heavy weather can sometimes present problems as there is always a risk that slugs of liquid can be carried over into the compressor. Running the compressors during severe weather is not recommended for this reason.

Where weather conditions are calm, it is possible that, because of the small vapor space in the tank and the absence of liquid circulation in the tank, a cold layer of liquid can form at the surface when the condensate returns from the re-liquefaction plant through the top sprays. This, in turn, enables the compressors to reduce the vapor pressure after only a few hours running, when in fact the bulk of the liquid has not been cooled at all.In order to avoid this, full re-liquefaction plant capacity should be run on each tank separately and the condensate returned from the cargo condenser should be returned through the bottom connection to ensure circulation of the tank contents. After the cargo has been cooled, the re-liquefaction plant capacity can be reduced to a level sufficient to balance the heat flow through the tank insulation. Regularly checking and equalizing tank levels is of utmost importance. Throughout the loaded passage, regular checks must be made to ensure that there are no defects in the cargo equipment and no leaks in the nitrogen or air supply lines.

Handling of LPG fires

The highest priority of action must be given to stopping the gas flow to limit the amount of flammable material available and contain the fire in as small an area as possible. This may happen automatically with the operation of the emergency shutdown system. Fire fighters must wear protective clothing and self contained compressed air breathing apparatus. Tackling the fire requires the use of two media, water and dry powder.[41] Large quantities of water spray are to be used to protect fire fighters and those assisting the rescue of trapped personnel from spaces as well asto cool surfaces exposed to heat.[42] The normal extinguishing medium for LPG fires is dry powder, which is propelled by nitrogen. The best results are achieved by applying dry powder at a maximum rate by using as many guns as possible from upwind. The guns must sweep rapidly backwards and forwards over the fire area. If a liquid spillage is involved, the surface of the spillage must not be disturbed by direct impact. If it is judged preferable to allow a flame to burn from a controlled leak, such as a pipe fracture, water spray is to be used to contain the fire without extinguishing the flame. Fire incident of Gas Carrier [43] has been shown in fig 6 below.

Fig 6: Fire incident of Gas Carrie [44]

Brief Description and Operation of LNG Tanker

Typically a clear, colorless, and odorless liquid, natural gas is a blend of hydrocarbons that occurs in a liquefied state in nature. LNG is typically transported and stored at a temperature near its boiling point under atmospheric pressure, which is approximately -160o C. LNG, which stands for liquefied natural gas, is the chilled liquid state of natural gas, which serves as fuel for gas stoves, home heaters, and electric power plants. Upon warming up, LNG reverts back to its original form as natural gas.We can't liquefy natural gas without cooling. Few countries export and many countries import LNG by ship. Interesting to know that, the United States does both. LNG does not burn itself. LNG needs to be in vapor form and mixed with air to burn. It is combustible in the range of 5% to 15% volume concentrations in air. However, combustible mixtures in confined space will burn explosively. LNG is a cryogenic substance and physical contact or spillage constitutes a personnel and equipment hazard. Natural gas presents an asphyxiation hazard. It gasifies violently when directly introduced into a cargo tank at ambient temperature and rapidly increases the internal pressure of the cargo tank and makes the atmosphere into a flammable condition. In addition, the cargo tank is rapidly cooled and resulting tremendous thermal stress on cargo tank skins and cargo piping systems. To avoid such damages, some preparatory work for cargo loading after dry docking needs to be followed. During dry docking all the compartments of an LNG carrier are kept gas free. LNG compresses to a small fraction of its original volume (approximately 1/600) under liquefaction. Liquefaction reduces the volume of natural gas making it much more economical to transport. With the amount of flammable material that LNG contains, it has the potential to be an extremely dangerous chemical, if handled improperly.

LNG is not as dense as petroleum, requiring between double and triple the space for the fuel tank. To alleviate the loss of space, some Norwegian naval architects and designers locate the tanks under accommodation spaces, building protective coffers to hold the tanks. Others have placed tanks on deck, where they can vent into the atmosphere should a spill occur. IMO guidelines do not prohibit placement of LNG tanks under accommodation. The fleet of LNG carriers is witnessing significant expansion as the LNG market undergoes rapid growth. LNG is carried at very low temperature which can cause crack in the metal structure if cargo comes in contact with the ship's hull. Additionally, LNG carrier must have a cargo tank with double layer of insulation protection. Material used for tank must have very low coefficient of thermal expansion (invar) to be provided with vaporizer to meet its own vapors requirements. Re-gasification plant should be provided. A images of loading gas cargo of a LNG Carrier [45,46] has been shown in fig 7 below.

Fig 7: Two images of loading gas cargo of atypical LNG Carrier [47,48]

On January 25, 1959, the Methane Pioneer, the inaugural LNG carrier weighing 5034 DWT, departed from the Calcasieu River located on the Louisiana Gulf coast. It embarked on a journey to the United Kingdom, transporting the world's first-ever ocean cargo of LNG, which was successfully delivered upon arrival. As the trade continued to flourish, the fleet underwent significant growth, and today, enormous LNG vessels with a capacity of up to 266,000 m3 traverse the seas worldwide. In the late 1960s, opportunity arose to export LNG from Alaska to Japan, and in 1969 that trade with TEPCO and TOKYO Gas was initiated. Two ships, Polar Alaska and Arctic Tokyo, each with a capacity of 71500 m^3 were built in Sweden. During the early 1970s, the US government provided encouragement to US shipyards for the construction of LNG carriers, resulting in the creation of 16 such ships. As the late 1970s and early 1980s approached, the possibility of Arctic LNG ships emerged, leading to several projects under examination. To accommodate the growing cargo capacity of around 143,000 m3, novel tank designs were formulated. Recently, the size and capacity of LNG carriers has increased greatly. Since 2005, Qatar-gas has been at the forefront of introducing two innovative categories of LNG vessels known as Q-Flex and Q-Max.. Each ship has a cargo capacity of between 210000 and 266000 m^3 and is equipped with a re-liquefaction plant.[2,45,46] In 2017, an estimated 170 vessels are in use at any one time. At the end of 2018, the global LNG fleet was approximately 550 vessels. In 2018, the first LNG powered bulk carrier named Green Iris of South Korea has been began construction. In 2017, Daewoo Shipbuilding and Marine Engineering has constructed and delivered an icebreaking LNG tanker with capacity 172600 m^3 and 80200 DWT named Christophe de Margerie to Sweden.

An average LNG carrier is equipped with four to six tanks positioned along the center-line of the vessel. The tanks are surrounded by a combination of ballast tanks, cofferdams, and voids, effectively providing the vessel with a double-hull design. Each tank typically houses three submerged pumps. Among them, there are two main cargo pumps employed during cargo discharge operations, and a smaller pump known as the spray pump. The spray pump serves the purpose of pumping out liquid LNG for use as fuel via a vaporizer or for cooling down cargo tanks. It can also be utilized to remove the remaining cargo during discharge operations. All of these pumps are housed within a pump tower.. The pump tower also contains the tank gauging system and the tank filling line, all of which are located near the bottom of the tank. In membrane type vessels there is also an empty pipe with a spring loaded foot valve that can be opened by weight or pressure. This is the emergency pump tower. In the event both main cargo pumps fail the top can be removed from this pipe and an emergency cargo pump lowered down to the bottom of the pipe. The top is replaced on the column and then the pump is allowed to push down on the foot valve and open it. The cargo can then be pumped out. All cargo pumps discharge into a common pipe which runs along the deck of the vessel; it branches off to either side of the vessel to the cargo manifolds, which are used for loading or discharging. Example of few tank and dome type LNG Carrier has been shown in fig 8 below.[49,50,51] All cargo tank vapor spaces are linked via a vapor header which runs parallel to the cargo header. This also has connections to the sides of the ship next to the loading and discharging manifolds.

Fig 8: Example of few tank and dome type LNG Carrier [52,53,54,55]

Handling of LNG fire

LNG fire is mainly cold vapor fire. Ignition of a flammable mixture of natural gas vapor requires a spark of similar ignition energy as would ignite other hydrocarbon vapors. The auto ignition temperature of methane in air is 650° C and that is higher than other hydrocarbons. Electrostatic ignition of LNG is not a hazard during normal operations. This is because the permanent, positive pressure in LNG tanks maintained by gas boil-off prevents air entering these spaces to form flammable mixtures in tanks or lines. The velocity of propagation of a flame is lower in methane than almost all other hydrocarbons. Burning of LNG vapors produces a similar flame size and heat radiation to other hydrocarbon fires, but little smoke is produced. From a fire fighting viewpoint, LNG/cold vapor fires have the characteristics of both liquid and gaseous hydrocarbon fires. During any LNG fires, it need to isolate the source of leak, stop loading & discharging, and shut all manifold valves and raise the alarm. Vessel needs protection for adjacent equipment and for fire-fighters. Fire-fighters should attack fire with a maximum rate of application of dry powder. There should not be agitation to the surface of any pool of LNG. It should be remain on guard against possible re-ignition. During any LNG fires, use water spray systems or dry chemical powder or gas smothering systems is effective.

Spillage and Hazards on Gas Carriers

An analysis of several spherical carriers showed that the vessels can withstand a 90 degree side-on collision with another similar LNG carrier at 6.6 knots with no loss of LNG cargo integrity. HAZID performed a risk assessment of an LNG spill and they calculate that the likelihood of an LNG spill as approximately 1 in 100000 trips. In the event that the tank integrity of a LNG transport is compromised, there is a risk that the natural gas contained within could ignite, causing either an explosion or fire. Flameless explosions which result out of cold cargo liquid coming into sudden contact with water do not release much energy. Pool fires which is the result of a leaked pool of cargo liquid catching fire and jet fires which the result of the leak are catching fire are grave hazards. Flash fires occur when there is a leak and do not ignite immediately but after the vapors travel some distance downwind and getting ignited and is extremely dangerous. Vapor cloud explosions and boiling liquid expanding vapor explosions are the most grave flammability hazards on gas carriers. The cargoes are carried at extremely low temperatures from 0 to -163° C. Hence, frostbite due to exposure of skin to the cold vapors or liquid is a very real hazard. In sufficient concentrations any vapor may cause asphyxiation, whether toxic or not. A person affected may experience headache, dizziness and inability to concentrate, followed by loss of consciousness.

Global Shipbuilding Market

Usually shipbuilding market of merchant-ship has divided into few categories like, oil tankers, bulk carriers, container ships, general cargo ships, and passenger ships. Global shipbuilding market share by main ships types in 2020 has been shown in figure 9 below. The shipbuilding market in 2020 witnessed the dominance of the Bulk carrier sector, holding the largest market share. Bulk carriers, specifically designed for transporting vast quantities of loose cargo such as coal, ore, cement, steel coils, and food grains, took the forefront. These ships are known for their sturdy construction and high cargo density. Their design focuses on enhancing capacity, durability, and efficiency.. Again on the basis of end-use, the shipbuilding market is classified into transport and military. In 2020, the transport segment has dominated the shipbuilding market by acquiring the maximum revenue share.[56]

The forecast of future global shipbuilding market (both commercial and military together) by KBV research by size or value in billion USD has been shown in fig 10 below. It has expected that shipbuilding market will reach USD 176.1 billion within 2027. The average growth of shipbuilding markets is 3.4% (as CAGR) during the forecast period (2017-2027). However, 'main factors responsible for the growth of the shipbuilding market are seaborne trade, rising demand for cargo transportation, increasing agreements related to trade, advanced technologies adopted by the ships, and automation in ships'.[56] Today's modern specialized ships design and building is high-tech and complicated affair. As example, nuclear aircraft carrier can travel around globe with a mini airport and hundred aircraft for few decades without refueling; nuclear submarines are capable of attacking enemy territory from deep sea by in disguise and can stay underwater around six months. Modern cruise vessel, oil tanker or buikers are so colossal that those looks like a small city.

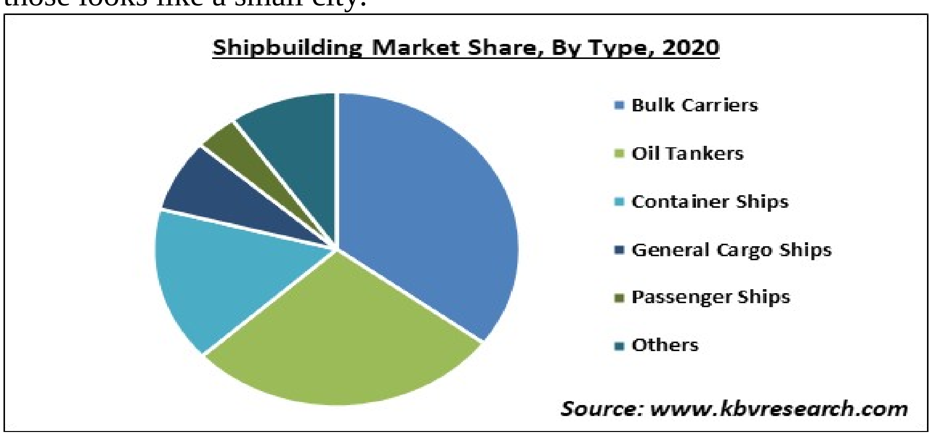


Fig 9: Global merchant shipbuilding market share by main ships types in 2020 [57]

Salient factors driving growth of the global shipbuilding market are ‘GDP, economic growth, global seaborne trade, incremental demand for cargo transportation through sea, trade-related agreements, technological advancements, market trend of EOL ships, marine rules and regulation, trend of automation in marine transport sector’.[57] However, variations in transportation and inventory costs, ecological concerns, and global financial or other unfortunate crisis like COVID-19 pandemic or Russian war on Ukraine; which affect globally are few significant trends that could hinder growth of such market.

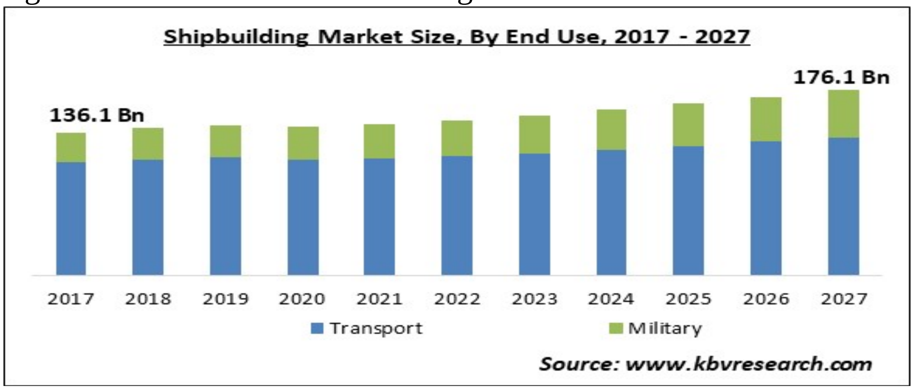


Fig 10: Forecast global shipbuilding market (commercial and military) in billion USD[57]

Trend Analysis of Global Shipbuilding New-Orders

Let’s see the trend of global shipbuilding industry. The two-thirds of global ship building were of dry bulk carriers and tankers. In 2020, ship deliveries declined by 12%, mainly due to lockdown induced labour shortages and that disrupted marine industrial activity. Table 1 below shows that in 2020, the majority of newly delivered ships consisted mainly of bulk carriers, followed by oil tankers and container ships.[58,59] Since 2015, an increasing proportion of shipbuilding has been taken place in four countries. Those are: China, South Korea, Japan, and Philippines.

Ships type	China	South Korea	Japan	Philippines	Rest of world	Total	Percentage (%)
Bulk Carries	15,051	1,442	9,383	551	311	26,738	46
Oil Tankers	2,702	7,071	1,901	1	478	12,152	21
Container ship	2,665	5,357	394	56	200	8,671	15
Gas carriers	869	4,046	353		7	5,275	9
Ferries and Cruise	251	64	76		1,208	1,600	3
Chemical Tankers	488	88	465		55	1,095	2
General cargo	390	1	142		360	893	2
Offshore	340	101	7		118	566	1
Other	501	4	107		162	775	1
Total	23,257	18,174	12,827	608	2,898	57,765	100
Percentage	40%	31%	22%	1%	5%	100	%

Table 1: Deliveries of new-building merchant ships (thousand gt) by the countries in 2020

Impact of COVID 19 and Geopolitical Situation

The COVID-19 pandemic has severely inflated the global economy, trade, social life, maritime transport and shipbuilding. However, “the outcome was less detrimental than initial anxiety. The pandemic shock in the first half of 2020 has caused maritime trade reduced by 3.8% and in the second half there was a recovery. But at the end of 2020 both containerized and dry bulk trade increased”.[59] But tanker shipping failed to recover. Again, Russian war on Ukraine and rise in oil price change the entire situation. However, in 2021 global trade and GDP has recovered and increased by 4.3% and that has been shown in figure 11. In 2020, international maritime trade by region by in % tonnage has been shown in figure 12 below. 'Over the past two decades, the compound annual growth in maritime trade has been found 2.9%. UNCTAD predicts that over the period 2022–2026, the rate will be slow and low as 2.4%'.[60,59]

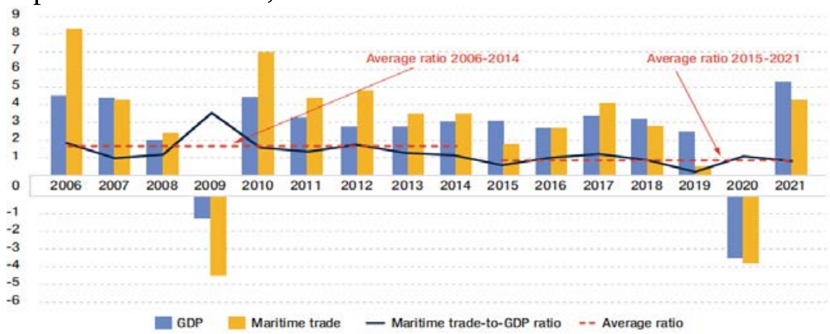


Fig 11: International maritime trade, world GDP and their ratio, (2006-2021 in %)[60,61]

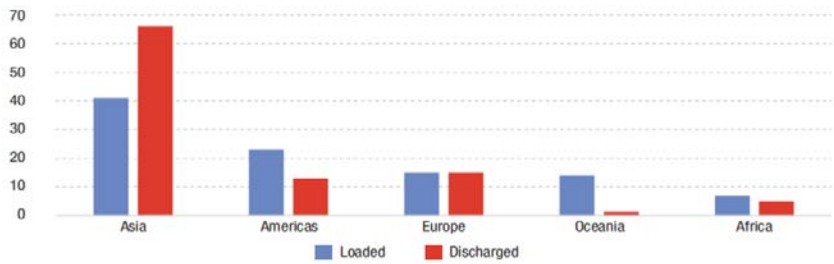


Fig 12: International maritime trade by region in 2020 (percentage share in tonnage)[59]

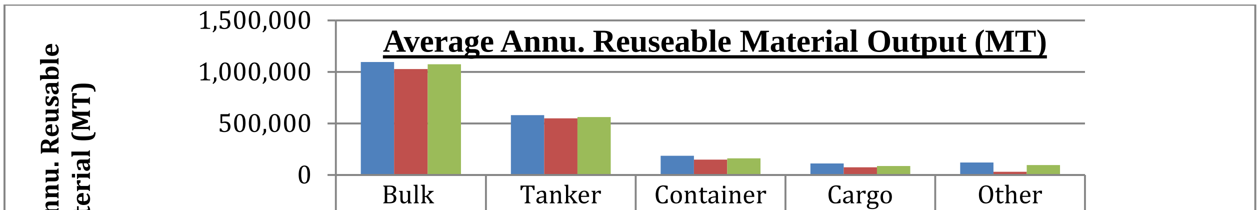
Global Ship Recycling State. Ships are generally removed from the fleet after end of life (EOL) through a process known as recycling. Ship owners and buyers negotiate scrap prices based on few factors; ship's empty weight or LDT and prices in the scrap metal or recycle market. In 1998 almost 700 ships went through the recycling process at ship breakers in places like Chottogram, Bangladesh, Alang, India and Karachi, Pakistan.[3,62] The world wide ship recycling industry dismantles around 1000 large ocean-going vessels annually, where more than 50% are tanker.[7,63] In 2020, 'almost half of the recycling was of bulk carriers, reflecting declining charter rates and following the trend of recycling ageing tonnage in LDT'.[64,61] Around two-thirds of reported tonnage (LDT) sold for recycling in 2020 was in Bangladesh and India. 'With Pakistan and Turkey, the share of the top four countries reached 93% and that has been shown in the table 2 below.[61] The highest increases in shares have observed for Pakistan, by 14.7%, and for India by 3.2%' (UNCTAD 2021d). However, there were visible reductions in Bangladesh, by 15% and in China by 2%. Market share of China has reduced due to ban on recycling international ships (in 2018). And, Bangladesh market share has declined due to local restriction by government regulation.

Ship Types	Bangladesh	India	Pakistan	Turkey	China	Rest of world	World Total	Percentage
Bulk Carries	5,254	1,317	1,718	34	125	61	8,509	48.9
Container ship	160	1,428	282	206		68	2,143	12.3
Oil Tankers	616	410	617	159	10	226	2,038	11.7
Offshore supply	125	257	4	308	3	273	969	5.6
Ferries/ passenger Ships	26	279		545	3	26	879	5.1
General cargo	176	219	175	203	47	29	848	4.9

LPG/ LNG	169	241		8		176	594	3.4
Chemical Tankers	12	125	94	1		10	241	1.4
Others	157	786		135	9	93	1,180	6.8
Total	6,694	5,061	2,890	1,598	195	962	17,401	100
Percentage	38.5	29.1	16.6	9.2	1.1	5.5	100	(%)

Table 2: Global ship recycles in LDT in thousand gross tonnes sold in 2020 [61]

In Bangladesh, average 200 different types of obsolete ships including LNG and LPG are recycled annually in different yards located in Chottogram.[65,66,67] In figure 13 below, total LDT of different types and size of ships including gas carrier recy
cled and reusable material output in Bangladeshi recycling yards between the years 2009 to 2015 has been shown. Bangladeshi recycling yards are dismantling around 30% of global EOL ships in term of DWT.



	Bulk	Tanker	Container	Cargo	Other
LDT	1,094,566	579,542	186,583	111,486	120,169
Min. Output	1,028,892	550,565	149,266	74,696	30,042
Max. Output	1,072,675	562,156	162,327	86,959	96,135

Figure 13: Average annual LDT vs average annual reusable material output (2009 to 2015).

Conclusion

Gas carriers range in capacity from the small pressurized tankers of between 500 and 6000 m^3 for shipment of propane, butane and the chemical gases at ambient temperature up to the fully insulated or refrigerated seagoing tankers of over 100000 m^3 capacity for the transport of LNG and LPG. Between those two distinct types is a third tanker type, semi-pressurized gas carrier. These very flexible tankers are able to carry many cargoes in a fully refrigerated condition at atmospheric pressure or at temperatures corresponding to carriage pressure of between five and nine bar. The movement of liquefied gases by waterways is now a mature industry, served by a fleet of many tankers, a network of export and import terminals and a wealth of knowledge and experience on the part of various people involved. Gas carriers have certain features common with other tankers used for the carriage of bulk liquids such as oil and chemical tankers. One notable characteristic found predominantly in gas carriers is the maintenance of positive pressure within the cargo system, which serves the purpose of preventing the entry of air into the cargo. This means that only cargo liquid and cargo vapor are present in the cargo tank and flammable atmospheres cannot develop. Furthermore all gas carriers utilize closed cargo systems when loading or discharging, with no venting of vapor being allowed to the atmosphere. In the LNG trade, provision is always made for the use of a vapor return line between tanker and shore to pass vapor displaced by the cargo transfer. In the LPG trade this is not always the case as, under normal circumstances during loading, re-liquefaction is used to retain vapor on board. By these means cargo release to the atmosphere is virtually eliminated and the risk of vapor ignition is minimized.

There is much variation in the design, construction and operation of gas carriers due to the variety of cargoes carried and the number of cargo containment systems utilized. LPG carriers are specifically designed to transport primarily butane, propane, butadiene, propylene, vinyl chloride monomer, and have the capacity to transport anhydrous ammonia. On the other hand, LNG carriers are designed to carry liquefied natural gas and that is mostly methane. Compared to oil, there is less public concern over spillage of LNG carrying vessels. The LNG sector is known to have a good safety record regarding cargo loss. There have been close to 80000 loaded port transits of LNG carriers with no loss of containment failure. Vinyl chloride commonly carried on gas carriers is a known as a human carcinogen, particularly liver cancer. It is not only dangerous when inhaled but can also be absorbed by the skin. Caution must be exerted while dealing with such cargoes, precautions such as use of chemical suits, self-contained breathing apparatus and gas tight goggles must be worn at all times to prevent exposure. Chlorine and ammonia are other toxic cargoes carried. Almost all cargo vapors are flammable. When ignition occurs, it is not the liquid which burns but the evolved vapor that burns.

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