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ΘΕΜΑ :

CONSTRUCTION OF LPG SHIPS

ΣΕΜΕΡΤΖΑΚΗΣ ΜΑΡΙΟΣ Α.Μ. 3252

Σύμβουλος καθηγήτρια:

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ΠΤΥΧΙΑΚΗ ΕΡΓΑΣΙΑ

ΕΠΙΒΛΕΠΩΝ ΚΑΘΗΓΗΤΗΣ: κ. ΞΕΝΙΤΙΔΟΥ ΕΛΛΗ

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Ο ΔΙΕΥΘΥΝΤΗΣ ΣΧΟΛΗΣ :

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INTRODUCTION

In this essay, there will be an examination ofthe construction of LPG ships.
First of all, there will be a reference to the history of LPG ship's construction andthe categories, on those ships construction methods, over time.The methods that are preferred nowadays will be reported and so their advantages against older ones and the needs that resulted us in these kind of methods.
After that, there will be a focus on LPG ships cargoes, cargo handling and their containment systems.
To continue, there will be an examination to the rules & methods a classification society uses in LPG ship building such us Germanischer Lloyd. There will be a detailed report on the rules they set, as a classification society, on some of the important matters in LPG Ships building and also their minimum standards.
Furthermore, we will study the hazards on LPG carriers and the health effects in some of their cargoes.
Those will be the main subjects which this essay is about.

A.CHAPTER ONE

i. HISTORY OF LPG CARRIERS CONSTRUCTION

The first LNG carrier *Methane Pioneer*

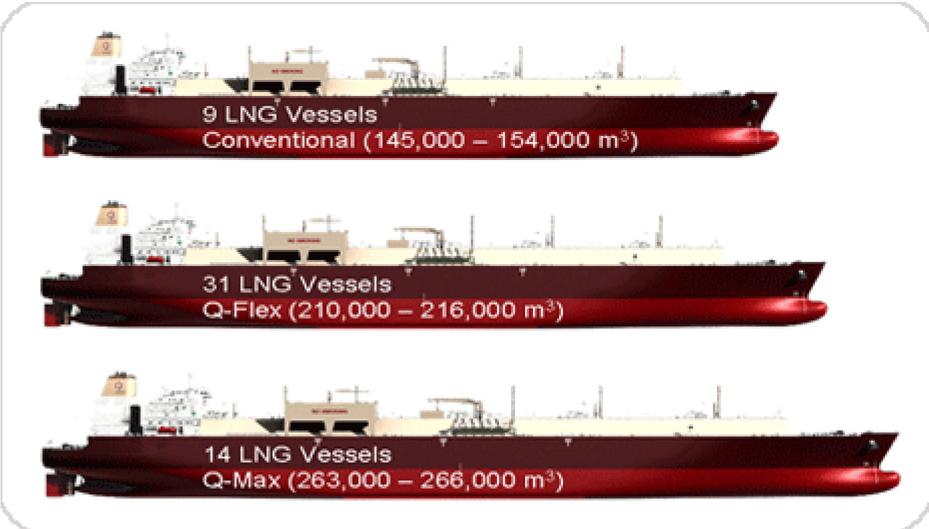
(dwt5034 tons) left the Calcasieu River on the Louisiana Gulf coast on 25 January 1959. Carrying the world's first ocean cargo of LNG, it sailed to the UK where the cargo was delivered. Subsequent expansion of that trade has brought on a large expansion of the fleet to today where giant LNG ships carrying up to 266,000 m^3 are sailing worldwide. At the end of 2005, a total of 203 vessels have been built, of which 193 are still in service.

The success of the specially modified C1-M-AV1-type standard ship *Normarti*, renamed *The Methane Pioneer*, caused the Gas Council and Conch International Methane Ltd. to order two purpose built LNG carriers to be constructed: the *Methane Princess* and the *Methane Progress*. The ships were fitted with Conch independent aluminum cargo tanks and entered the Algerian LNG trade in 1964. These ships had a capacity of 27,000 cubic meters.

In the late 1960s opportunity arose to export LNG from Alaska to Japan, and in 1969 that trade was initiated. Two ships, each with a capacity of 71,500 cubic meters, were built in Sweden. In the early 1970s, the US Government encouraged US shipyards to build LNG carriers, and a total of 16 LNG ships were built. The late 1970s and early 1980s brought the prospect of Arctic LNG ships with a number of projects being studied.

With the increase in cargo capacity to approximately 143,000 cubic meters, new tank designs were developed, from Moss Rosenberg to Technigaz Mark III and Gaztransport No.96.

In recent years, the size and capacity of LNG carriers has increased greatly. Since 2005, Qatargas has pioneered the development of two new classes of LNG carriers, referred to as Q-Flex and Q-Max



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Each ship has a cargo capacity of between 210,000 and 266,000 cubic meters and is equipped with a re-liquefaction plant.

ii. CATEGORIES ON LPG CARRIER CONSTRUCTION METHODS

Gas carriers range in capacity from the small pressurised tankers of between 500 and 6,000 m3 for shipment of propane, butane and the chemical gases at ambient temperature up to the fully insulated or refrigerated seagoing tankers of over 100,000 m3 capacity for the transport of LNG and LPG. Between those two distinct types is a third tanker type – semipressurised 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.

A feature almost unique to the gas carrier is that the cargo is kept under positive pressure to prevent air entering the cargo system. This means that only cargo liquid and cargo vapour are present in the cargo tank and flammable atmospheres cannot develop.

Furthermore all gas carriers utilise closed cargo systems when loading or discharging, with no venting of vapour being allowed to the atmosphere.

In the LNG trade, provision is always made for the use of a vapour return line between tanker and shore to pass vapour displaced by the cargo transfer. In the LPG trade this is not always the case as, under normal circumstances during loading, reliquefaction is used to retain vapour on board. By these means cargo release to the atmosphere is virtually eliminated and the risk of vapourignition is minimised.

Gas carriers are divided into two main groups.

Liquefied Petroleum Gas (LPG) Carriers, which are designed to carry mainly butane, propane, butadiene, propylene, vinyl chloride monomer (VCM) and are able to carry anhydrous ammonia.

Liquefied Natural Gas (LNG) Carriers, which are designed to carry liquefied natural gas (which is mostly methane).

Gas carriers are classed in three types based on hazard potential:

i) type 1G, designed to carry the most hazardous cargoes

ii) type 2G and 2PG, designed to carry cargoes having a lesser degree of hazard

iii) type 3G, designed to carry cargoes of the least hazardous nature.

Gas carrier types

All gas cargoes are transported in liquid form (ie they are not carried as a gas in its vapour form) and, 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 follows:

i) Fully Pressurised

ii) semi-pressurised and refrigerated

iii) fully refrigerated

Note. These grouping names are more prevalently used when discussing the classes and types of LPG carriers rather than LNG carriers.

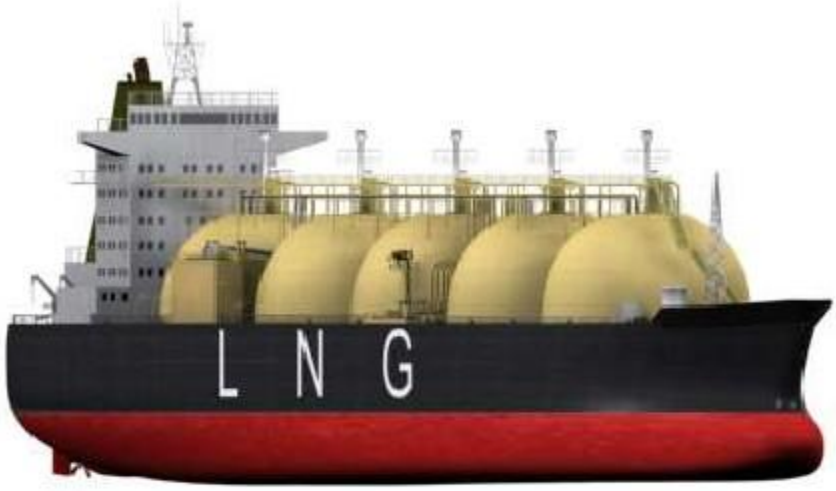
In principle, the design is ‘a box within a box that is separated by a void space’, similar in effect to the principle of a flask. Gas Carriers can be split into two distinct groups. One is the liquefied natural gas (LNG) carrier. The other is the liquefied petroleum gas (LPG) carrier.

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.

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.

The cargo tank construction of LNG and LPG ships can be of (a) prismatic design (b) membrane design or (c) spherical design. Materials used for these cargo tanks can be aluminium, 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 cost of these specialised 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 138000m3 of gas, their LBPs up to 280 m and their Br. Mld from 25 to 46 m. When fully loaded, their CB can be 0.660 up to 0.680 with service speed in the range of 16–20.75 kt. 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. The variation of equipment as fitted can make the gas carrier one of the most sophisticated tankers afloat today.

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. Cargo containment systems may be of the independent tanks (pressurized, semi-pressurized or fully refrigerated) or of the membrane type.

Fully pressurized tanks
The capacity of fully pressurized ships is usually less than 2000 m3 of propane, butane, or anhydrous ammonia carried in two to six uninsulated horizontal cylindrical pressure vessels arranged below or partly below deck. These independent tanks of Type C are normally designed for working pressures up to 17.5 kg/cm2, which corresponds to the vapor pressure of propane at 45 _C, the maximum ambient temperature the vessel is likely to operate in. The tanks can be constructed from ordinary grades of steel, are mounted in cradle-shaped foundations, and if below deck are fitted with domes protruding through the deck to which are fitted all connections. Wash bulkheads are fitted in very long tanks. The shape of the tanks generally prevents good utilization of the underdeck space.

Semi-pressurized (or semi-refrigerated) tanks

The capacity of semi-pressurized ships ranges up to about 5000 m3, the cargoes carried being similar to fully pressurized ships. The independent Type C tanks are generally constructed of ordinary grades of steel suitable for a temperature of -5 oC and are designed for a maximum pressure of about 8 kg/cm2. The outer surface of the tank is insulated and refrigeration or reliquefication plant cools the cargo and maintains the working pressure. Cargo tanks are often horizontal cylinders mounted on two saddle supports and many designs incorporate bio-lobe tanks to better utilize the underdeck space and improve payload.

Fully refrigerated tanks
The capacity of fully refrigerated ships ranges from 10,000 to 100,000 m3, the smaller ships in the range being multi-product carriers whilst the larger vessels tend to be single-product carriers on a permanent route. Tanks fall almost exclusively into the prismatic, independent Type A category with tops sloped to reduce free surface and bottom corners sloped to suit the bilge structure. In most cases they are subdivided along the center line by a liquid-tight bulkhead that extends to the underside of the dome projecting through the deck that is used for access and piping connections, etc. The tanks sit on insulated bearing blocks so that surfaces are accessible for inspection and are located by anti-roll and pitch keys in such a manner that expansion and contraction can take place relative to the ships structure. Antiflotation chocks are provided to prevent the tank floating off the bearings if the hold were flooded. Tanks are constructed of a notch ductile steel for the normal minimum operating temperature of _43 _C, the boiling point of propane.
The ship has a double hull extending over the bottom and bilge area, the secondary barrier being provided by low-temperature (notch ductile) steel at the inner bottom, sloping bilge tank, part side shell, and sloping bottom of topside tank. Transverse bulkheads may be single- or double-plate (cofferdam) type between cargo holds. Insulation can be either on the tank or the secondary barrier for this type of ship.

General arrangement of gas carriers
Gas carriers have a similar overall arrangement to tankers in that their machinery and accommodation are aft and the cargo containment is spread over the rest of the ship to forward where the forecastle is fitted.
Specific gravity of LPG cargoes can vary from 0.58 to 0.97, whilst LNG ships are often designed for a cargo specific gravity of 0.5 so that a characteristic of LNG ships in particular and most LPG ships is their low draft and high freeboards.
Water ballast cannot be carried in the cargo tanks so adequate provision is made for it within the
double-hull spaces, double-bottom, bilge tank, and upper wing tank spaces.
The double-hull feature of LNG carriers and many LPG ships is a required safety feature and the tanks of LPG ships that do not have this feature are required to be a minimum distance inboard of the shell.
Fore end and aft end structure is similar to that for other ships. The cargo section is transversely or longitudinally framed, depending primarily on size, in the same manner as other cargo ships, the inner hull receiving special consideration where it is required to support the containment system.
All gas ships have spaces around the tanks that are monitored for gas leaks and in many ships these spaces are also inerted, an inert gas system being fitted aboard the

ship. Liquid gas cargoes are carried under positive pressure at all times so that no air can enter the tanks and create a flammable mixture.
Liquefaction equipment is provided aboard LPG ships; ‘boil-off’ vapor from the tanks due to any heat ingress is drawn into the liquefaction plant and returned to the tank. Boil-off vapor from LNG ship tanks can be utilized as a boiler fuel in steam ships, otherwise it is vented to atmosphere, although this is not permitted in many ports, and several other solutions have been developed to overcome this problem.

B. CHAPTER TWO

i. LPG ships cargoes

The Gas Codes, developed by International Maritime Organization apply to all gas carriers regardless of size. There are three Gas Codes and these are described below.

Gas carriers built after June 1986 (the **IGC Code**)

The Code which applies to new gas carriers (built after 30 June 1986) is the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. In brief, this Code is known as the IGC Code. The IGC Code, under amendments to International Convention for the Safety of Life at Sea(SOLAS), is mandatory for all new ships. As proof that a ship complies with the Code, an International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk should be on board. In 1993, the IGC Code was amended and the new rules came into effect on 1 July 1994. Ships on which construction started on or after 1 October 1994 should apply the amended version of the Code but ships built earlier may comply with previous editions of the IGC Code.

Gas carriers built between 1976 and 1986 (the **GC Code**) The regulations covering gas carriers built after 1976 but before July 1986 are included in the Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. It is known as the Gas Carrier Code or GC Code in short. Since 1975, International Maritime OrganizationIMO has approved four sets of amendments to the GC Code. The latest was adopted in June 1993. All amendments are not necessarily agreed by every government. Although this Code is not mandatory, many countries have implemented it into national law. Accordingly, most charterers will expect such ships to meet with Code standards and, as proof of this, to have on board a Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

Gas carriers built before 1977 (the **Existing Ship Code**). The regulations covering gas carriers built before 1977 are contained in the Code for Existing Ships Carrying Liquefied Gases in Bulk. Its content is similar to the GC Code, though less extensive. The Existing Ship Code was completed in 1976 after the GC Code had been written. It therefore summarises current shipbuilding practice at that time. It remains as an International Maritime OrganizationIMO recommendation for all gas carriers in this older fleet of ships. The Code is not mandatory but is applied by some countries for ship registration and in other countries as a necessary fulfilment prior to port entry. Accordingly, many ships of this age are required by charterers to meet with Code standards and to have on board a Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

LPG is the name originally given by the oil industry to a mixture of petroleum hydrocarbons, principally propane and butane and mixtures of the two. LPG is used as a clean fuel for domestic and industrial purposes. These gases may be converted to the liquid form and transported in one of three conditions:

1. Solely under pressure at ambient temperature
2. Fully refrigerated at their boiling point (_30 to _48 _C)
3. Semi-refrigerated at reduced temperature and elevated pressure.

A number of other gases with similar physical properties, such as ammonia, propylene, and ethylene, are commonly shipped on LPG carriers. These gases are liquefied and transported in the same conditions as LPG except ethylene, which boils at a much lower temperature (_104 _C) and which is therefore carried in the fully refrigerated or semi-refrigerated condition.

Information about the LPG:

Liquefied petroleum gas or **liquid petroleum gas** (**LPG** or **LP gas**), also referred to as simply propane or butane, is a flammablemixture of hydrocarbon gases used as a fuel in heating appliances, cooking equipment, and vehicles.

It is increasingly used as an aerosol propellant and a refrigerant, replacing chlorofluorocarbons in an effort to reduce damage to the ozone layer. When specifically used as a vehicle fuel it is often referred to as autogas.

Varieties of LPG bought and sold include mixes that are primarily propane (C_3H_8), primarily butane (C_4H_{10}) and, most commonly, mixes including both propane and butane. In winter, the mixes contain more propane, while in summer, they contain more butane.[1][2] In theUnited States, primarily two grades of LPG are sold: commercial propane and HD-5. These specifications are published by the Gas Processors Association (GPA)[3] and the American Society of Testing and Materials (ASTM).[4] Propane/butane blends are also listed in these specifications.

Propylene, butylenes and various other hydrocarbons are usually also present in small concentrations. HD-5 limits the amount of propylene that can be placed in LPG to 5%, and is utilized as an autogas specification. A powerful odorant, ethanethiol, is added so that leaks can be detected easily. The international standard is EN 589. In the United States, tetrahydrothiophene (thiophane) or amyl mercaptan are also approved odorants,[5] although neither is currently being utilized.

LPG is prepared by refining petroleum or "wet" natural gas, and is almost entirely derived from fossil fuel sources, being manufactured during the refining of petroleum (crude oil), or extracted from petroleum or natural gas streams as they emerge from the ground. It was first produced in 1910 by Dr. Walter Snelling, and the first commercial products appeared in 1912. It currently provides about 3% of all energy consumed, and burns relatively cleanly with no soot and very few sulfur emissions. As it is a gas, it does not pose ground or water pollutionhazards, but it can cause air pollution. LPG has a typical specific calorific value of 46.1 MJ/kg compared with 42.5 MJ/kg for fuel oil and 43.5 MJ/kg for premium grade petrol (gasoline).[6] However, its energy density per volume unit of 26 MJ/L is lower than either that of petrol or fuel oil, as its relative density is lower (about 0.5–0.58, compared to 0.71–0.77 for gasoline).

As its boiling point is below room temperature, LPG will evaporate quickly at normal temperatures and pressures and is usually supplied in pressurised steel vessels. They are typically filled to 80–85% of their capacity to allow for thermal expansion of the contained liquid. The ratio between the volumes of the vaporized gas and the liquefied gas varies depending on composition, pressure, and temperature, but is typically around 250:1. The pressure at which LPG becomes liquid, called its vapour pressure, likewise varies depending on composition and temperature; for example, it is approximately 220 kilopascals (32 psi) for pure butane at 20 °C (68 °F), and approximately 2,200 kilopascals (320 psi) for pure propane at 55 °C (131 °F). LPG is heavier than air, unlike natural gas, and thus will flow along floors and tend to settle in low spots, such asbasements. There are two main dangers from this. The first is a possible explosion if the mixture of LPG and air is within the explosive limits and there is an ignition source. The second is suffocation due to LPG displacing air, causing a decrease in oxygen concentration.

Comparison with natural gas

LPG is composed primarily of propane and butane§, while natural gas is composed of the lighter methane and ethane. LPG, vaporised and at atmospheric pressure, has a highercalorific value (94 MJ/m^3 equivalent to 26.1kWh/m^3) than natural gas (methane) (38 MJ/m^3 equivalent to 10.6 kWh/m^3), which means that LPG cannot simply be substituted for natural gas. In order to allow the use of the same burner controls and to provide for similar combustion characteristics, LPG can be mixed with air to produce a synthetic natural gas (SNG) that can be easily substituted. LPG/air mixing ratios average 60/40, though this is widely variable based on the gases making up the LPG. The method for determining the mixing ratios is by calculating the Wobbe index of the mix. Gases having the same Wobbe index are held to be interchangeable.

LPG-based SNG is used in emergency backup systems for many public, industrial and military installations, and many utilities use LPG peak shaving plants in times of high demand to make up shortages in natural gas supplied to their distributions systems. LPG-SNG installations are also used during initial gas system introductions, when the distribution infrastructure is in place before gas supplies can be connected. Developing markets in India and China (among others) use LPG-SNG systems to build up customer bases prior to expanding existing natural gas systems.

LPG-based SNG or natural gas with localized storage and piping distribution network to the house holds for catering to each cluster of 5000 domestic consumers can be planned under initial phase of city gas network system. This would eliminate the last mile LPG cylinders road transport which is a cause of traffic and safety hurdles in Indian cities. These localized natural gas networks are successfully operating in Japan with feasibility to get connected to wider networks in both villages and cities.

ii. Cargo handling

Handling LPG - Safety & operational matters

A liquefied gas is the liquid form of a substance which, at ambient temperature and at atmospheric pressure, would be a gas.The same liquefied gas at the same temperature, in a closed container, will always have the same pressure. Therefore, 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 All are pressurised containers.

Most liquefied gases are hydrocarbons and the key property that makes hydrocarbons the world's primary energy source – combustibility – also makes them inherently hazardous. Because these gases are handled in large quantities, it is imperative that all practical steps are taken to minimize leakage and to limit all sources of ignition.

Gases are always liquefied for transportation in bulk simply because more cargo can be fitted in a given volume. Typically, but dependent upon the product, 1 volume of liquefied petroleum gas (LPG) is equivalent to over 250 volumes of vapour and 1 volume of liquefied natural gas (LNG) equivalent to 600 volumes of vapour.

Fig:Fully refrigerated LPG carrier at sea

The physical properties of a liquefied gas depend on its molecular structure. 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 for example N-BUTANE x ISO-BUTANE.

The single most important physical property of a liquefied gas is its saturated vapour pressure/temperature relationship. This property governs the design of the containment system suitable for each cargo.

Escape of LPG on deck

Whether a spillage of liquid or a leak of vapour, the priorities of the Emergency Party are to:

a) Stop the flow of gas

b) Prevent ignition

c) Disperse the vapour cloud

The flow of gas from a source which is between two valves on the Emergency Shut Down system will be limited. However, personnel advancing to close a valve manually close to the source of a spillage or leak must:

a) Wear breathing apparatus and protective clothing.
b) Be protected by a massive water wall
Care must be taken to avoid cargo coming into contact with the skin.
Any leak of LPG will produce a rapidly expanding cloud of explosive vapour, which must be prevented from coming into contact with a source of ignition. It is imperative therefore to isolate any source of ignition and ensure that no vapours enter the accommodation. Early consideration must be given to altering course and/or speed, and if necessary to stopping ventilation fans. Personnel who have to leave the accommodation to close vent intakes must wear breathing apparatus and protective clothing. If a vapour cloud approaches a known source of ignition, consideration must be given to attempting to "bend" its path by putting up a solid water wall.

The rate of dispersal of a vapour cloud will depend on climatic conditions. However, the use of liberal quantities of water in spray form will increase the rate of vaporisation, and, in the case of liquid spillage, reduce the risk of cold fractures of steel. Solid water jets must not be used on liquid spills, as they will result in splashing of cold liquid. Fixed water sprays may also assist in vapour dispersal if near enough to the cloud.

Sources of ignition

Smoking
There are frequently local regulations about smoking which must be rigidly observed. Smoking may be permitted but only under controlled conditions at times and in places specified by the Master. Personnel when working aboard the ship must not carry matches or more particularly lighters, and the risk of doing so is to be impressed on all.

Portable Electrical Equipment.
Only approved Safety torches or hand lamps are to be used. Portable Electric Equipment self contained or on extension cables are not to be used in a gas dangerous place or zone unless the equipment is intrinsically safe.
Portable domestic radios, electronic calculators, tape recorders and other non-approved battery equipment are not to be used in a gas dangerous place or zone.

Communication Equipment.
When berthed the ships normal communication equipment is not to be used unless certified safe. Main radio transmitters are not to be used during cargo operations. This does not apply to permanently and correctly installed VHF equipment or Satellite communication systems

Hot work, hammering, chipping and power tools
Before any hot work, hammering, chipping, or power tools including shot blasting are used the responsible officer is to examine the area to be worked and satisfy himself that such work can be safely undertaken and a hot work permit certificate issued. Non - sparking tools are not to be used as they do not significantly reduce the risk of igniting a flammable vapour. Aluminium paint is not to be smeared across steel. A heavy smear of aluminium on rusty, steel if struck can cause an incandescent spark.

Ship to Shore Bonding
On some jetties this may be required but it is considered to be of minimal benefit. Cargo hoses and loading arms are to be fitted with an insulating flange to ensure discontinuity between ship and shore.

Auto - Ignition
The vapours from flammable liquids including fuel and lubricating oil may ignite if the liquid comes into contact with any surface heated above the auto - ignition temperature e.g. steam lines, exhaust manifolds, over heated equipment. Immediate steps are to be taken to rectify any leakage and to remove any soaked rags on other material including lagging.

Static Electricity
Static Electricity can cause sparks capable of igniting a flammable gas. The cargo system of a gas carrier is electrically bonded to the ships hull to prevent any build up of charges, bonding connections must be maintained in good order.

Steam
A jet of steam may become charged in passing through a nozzle. Steam is not to be injected into a tank compartment or piping system which may contain a flammable mixture.

Carbon Dioxide
Liquid Carbon Dioxide when released under pressure may form particles of solid carbon dioxide these may become electrostatically charged. For this reason it must not be released into tanks or spaces which contain flammable mixture.

Principles of refrigeration
Cold liquid refrigerant (Liquid Gas Cargo) is evaporated in an evaporator coil (Cargo tank) which being cooler than its surroundings draws heat to provide the latent heat of vaporisation. The cool vapour is drawn off by a compressor which raises both the pressure and the temperature of the vapour and passes it to the condenser.

The pressure of the vapour having been increased the vapour now has a temperature of condensation greater than the temperature of the condenser cooling fluid (sea water). The vapour is condensed to a high pressure liquid and the sensible heat of desuperheating the vapour together with the latent heat of condensation is removed via the condenser coolant which is warmed up in the process.

The high pressure liquid then passes through an expansion valve to the low pressure side of the cycle, in doing so flash evaporates to a mixture of cold liquid and vapour. The mixture passes to the evaporator (cargo tank) to continue the cycle.

A typical LNG carrier has four to six tanks located along the center-line of the vessel. Surrounding the tanks is a combination of ballast tanks, cofferdams and voids; in effect, this gives the vessel a double-hull type design.

Inside each tank there are typically three submerged pumps. There are two main cargo pumps which are used in cargo discharge operations and a much smaller pump which is referred to as the spray pump. The spray pump is used for either pumping out liquid LNG to be used as fuel (via a vaporizer), or for cooling down cargo tanks. It can also be used for "stripping" out the last of the cargo in discharge operations. All of these pumps are contained within what is known as the pump tower which hangs from the top of the tank and runs the entire depth of the tank. 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.

All cargo tank vapour spaces are linked via a vapour 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.

iii. Containment systems

Cargo Containment Systems in Liquefied Gas Carriers

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

For cargoes carried at temperatures between –10 degree C and -55 degree C, the ship's hull may act as the secondary barrier and in such cases it may be a boundary of the hold space.

The basic cargo tank types utilized on board gas carriers are in accordance with the list below:-

Independent Type 'A': Some other types such as:

Independent Type 'B': Internal insulation Type '1'

Independent Type 'C': Internal insulation Type '2'

Membrane: Integral

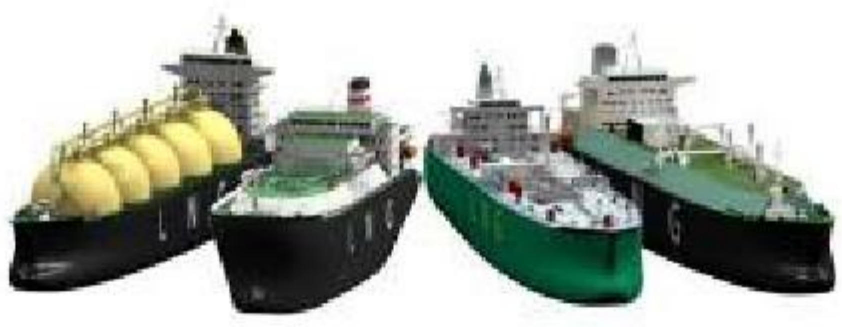


Fig:Various type LNG carrier

Independent Tanks
Independent tanks are completely self-supporting and do not form part of the ship's hull structure. Moreover, they do not contribute to the hull strength of a ship. As defined in the IGC Code, and depending mainly on the design pressure, there are three different types of independent tanks for gas carriers: these are known as Type 'A', "B' and 'C'.

Fig:LNG carrier membrane gaz transport

Type 'A' Tanks

Type 'A' tanks are constructed primarily of flat surfaces. The maximum allowable tank design pressure in the vapour space of for this type of system is 0.7 barg; this means cargoes must be carried in a fully refrigerated condition at or near atmospheric pressure (normally below 0.25 barg).

This type of tank as found on a fully refrigerated LPG carrier. This is a self-supporting prismatic tank which requires conventional internal stiffening. In this example the tanks is surrounded by a skin of foam insulation. Where perlite insulation is used, it would be found filling the whole of the hold space.

The material used for Type 'A' tanks is not crack propagation resistant. Therefore, in order to ensure safety, in the unlikely event of cargo tank leakage, a secondary containment system is required. This secondary containment system is known as a secondary barrier and is a feature of all ships with Type 'A' tanks capable of carrying cargoes below -10 degree C.

For a fully refrigerated LPG carrier (which will not carry cargoes below –55 degree C) the secondary barrier must be a complete barrier capable of containing the whole tank volume at a defined angle of heel and may form part of the ship's full, as shown in the figure.

In general, it is this design approach which is adopted. By this means 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 IGC Code stipulates that a secondary barrier must be able to contain tank leakage for a period of 15 days.

On such ships, the space between the cargo tank (sometimes referred to as the primary barrier) and the secondary barrier is known as the hold space. When flammable cargoes are being carried, these spaces must be filled with inert gas to prevent a flammable atmosphere being created in the event of primary barrier leakage.

Type 'B' Tanks

Type 'B' tanks can be constructed of flat surfaces or they may be of the spherical type. This type of containment system is the subject of much more detailed stress analysis compared to Type ‘A’ systems. These controls must include an investigation of fatigue life and a crack propagation analysis. The most common arrangement of Type ‘B’ tank is a spherical tank. This tank is of the Kvaerner Moss design.

Because of the enhanced design factors, a Type ‘B’ tank requires only a partial secondary barrier in the form of a drip tray. The Type ‘B’ spherical tank is almost exclusively applied to LNG ships; seldom featuring in the LPG trade. A type ‘B’ tank, however, need not be spherical.

There are Type ‘B’ tanks of prismatic shape in LNG service. The prismatic Type ‘B’ tank has the benefit of maximizing ship-deck. Where the prismatic shape is used, the maximum design vapour space pressure is, as for Type ‘A’ tanks, limited to 0.7 barg.

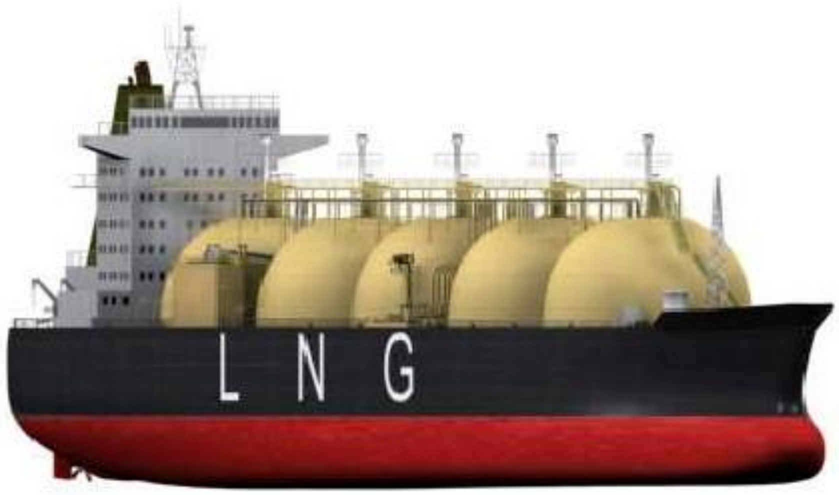


Fig:LNG carrier moss tanks

Type ‘C’ Tanks

Type ‘C’ tanks are normally spherical or cylindrical pressure vessels having design pressures higher than 2 barg. The cylindrical vessels may be vertically or horizontally mounted. This type of containment system is always used for semi-pressurized and fully pressurized gas carriers.

In the case of the semi-pressurized ships it can also be used for fully refrigerated carriage, provided appropriate low temperature steels are used in tank construction. Type ‘C’ tanks are designed and built to conventional pressure vessel codes and, as a result, can be subjected to accurate stress analysis. Furthermore, design stresses are kept low. Accordingly, no secondary barrier is required for Type ‘C’ tanks and the hold space can be filled with either inert gas or dry air.

In the case of a typical fully pressurized ship (where the cargo is carried at ambient temperature), the tanks may be designed for a maximum working pressure of about 18 barg. For a semi-pressurized ship the cargo tanks and associated equipment are designed for a working pressure of approximately 5 to 7 barg and a vacuum of 0.5 barg. Typically, the tank steels for the semi-pressurized ships are capable of withstanding carriage temperatures of -48 degree C for LPG or -104 degree C for ethylene. (Of course, an ethylene carrier may also be used to transport LPG.)

Type ‘C’ tanks as fitted in a typical fully pressurized gas carrier. With such an arrangement there is comparatively poor utilization of the hull volume; however, this can be improved by using intersecting pressure vessels or bi-lobe type tanks which may be designed with a taper at the forward end of the ship. This is a common arrangement in semi-pressurized ships.

Membrane Tanks (membrane – 0.7 to 1.5 mm thick)

The concept of the membrane containment system is based on a very thin primary barrier (membrane – 0.7 to 1.5 mm thick) which is supported through the insulation. Such tanks are not self-supporting like the independent tanks. An 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.

The membrane is designed in such a way that thermal expansion or contraction is compensated without over-stressing the membrane itself. There are two principal types of membrane system in common use – both named after the companies who developed them and both designed primarily for the carriage of LNG. These two companies have now combined into one.

Fig:Membrane type lng carrier

Semi-Membrane Tanks

The semi-membrane concept is a variation of membrane tank system. The primary barrier is much thicker than in the membrane system, having flat sides and large roundish corners. The tank is self-supporting when empty but not in the loaded condition. In this condition the liquid (hydrostatic) and vapour pressures acting on the primary barrier are transmitted through the insulation to the inner hull as is the case with the membrane system. The corners and edges are designed to accommodate expansion and contraction.

Although semi-membrane tanks were originally developed for the carriage of LNG, no commercial-size LNG carrier has yet been built to this design. The system has, however, been adopted for use in LPG ships and several Japanese-built fully refrigerated LPG carriers have been delivered to this design.

Integral Tanks

Integral tanks form a structural part of the ship’s hull and are influenced by the same loads which stress the hull structure. Integral tanks are not normally allowed for the carriage of liquefied gas if the cargo temperature is below -10 degree C. Certain tanks on a limited number of Japanese-built LPG carriers are of the integral type for the dedicated carriage of full refrigerated butane.

Internal Insulation Tanks

Internally insulated cargo tanks are similar to integral tanks. They utilize insulation materials to contain the cargo. The insulation is fixed inside ship’s inner hull or to an independent load-bearing surface. The non-self-supporting system obviates the need for an independent tank and permits the carriage of fully refrigerated cargoes at carriage temperatures as low as -55 degree C.

Internal insulation systems have been incorporated in a very limited number of fully refrigerated LPG carriers but, to date, the concept has not proved satisfactory in service.

TGZ Mark III

This design is originally by Technigaz and it is of the membrane type. The membrane consists of stainless steel with 'waffles' to absorb the thermal contraction when the tank is cooled down. The primary barrier, made of corrugated stainless steel of about 1.2 mm thickness is the one in direct contact with the cargo liquid (or vapour in empty tank condition). This is followed by a primary insulation which in turn is covered by a secondary barrier made of a material called "triplex" which is basically a metal foil sandwiched between glasswool sheets and compressed together. This is again covered by a secondary insulation which in turn is supported by the ship's hull structure from the outside.

So, going from the inside of the tank outwards, we haveLNG Primary barrier of 1.2 mm thick corrugated/waffled Stainless Steel Primary Insulation (also called the inter-barrier space) Secondary barrier of triplex membrane Secondary Insulation (also called the insulation space) Ship's hull structure.

GT96

This is Gaz Transport's tank design. The tanks consists of a primary and secondary thin membrane made of the material Invar which has almost no thermal contraction. The insulation is made out of plywood boxes filled with perlite and continuously flushed with nitrogen gas. The integrity of both membranes is permanently monitored by detection of hydrocarbon in the nitrogen. An evolution is proposed by NG2, with the replacement of nitrogen by argon as the flushed inert and insulation gas. Argon has a better insulation power than nitrogen, which could save 10% of boil-off gas.

CS1

CS1 stands for Combined System Number One. It was designed by the now merged Technigaz and GazTransport companies and consists of the best components of both MkIII and No96 systems. The primary barrier is made of invar 0.7 mm, and secondary from Triplex. The primary and secondary insulation consists of polyurethane foam panels.

Three vessels with CS1 technology have been built by one shipyard, but established shipyards have decided to maintain production of the MKIII and NO96.

C. CHAPTER THREE

Ship Arrangements

3.1 Segregation of the cargo area

3.1.1Hold spaces are to be segregated from machinery and boiler spaces, accommodation spaces, service spaces and control stations, chain lockers, drinking and domestic water tanks and from stores. Hold spaces should be located forward of machinery spaces of category A, other than those deemed necessary by the Society for the safety or navigation of the ship.

3.1.2 Where cargo is carried in a cargo containment system not requiring a secondary barrier, segregation of hold spaces from spaces referred to in 3.1.1 or spaces either below or outboard of the hold spaces may be effected by cofferdams, fuel oil tanks, or a single gastight bulkhead of all welded construction forming an A-60 class division. A gastight A-O class division is satisfactory if there is no source of ignition or fire hazard in the adjoining spaces.

3.1.3 Where cargo is carried in a cargo containment system requiring a secondary barrier, segregation of hold spaces from spaces referred to in 3.1.1 or spaces either below or outboard of the hold spaces which contain a source of ignition or fire hazard is to be effected by cofferdams or fuel oil tanks. If there is no source of ignition or fire hazard in the adjoining space, segregation may be by a single A-O class division which is gas-tight.

3.1.4 When cargo is carried in a cargo containment system requiring a secondary barrier:

.1 at temperatures below – 10 °C, hold spaces are to be segregated from the sea by a double bottom; and

.2 at temperatures below – 55 °C, the ship is also to have a longitudinal bulkhead forming side tanks.

3.1.5 Any piping system which may contain cargo or cargo vapour is:

.1 to be segregated from other piping systems, except where inter-connections are required for cargo related operations, such as purging, gas freeing or inerting. In such cases precautions are to be taken to ensure that cargo or cargo vapour cannot enter such other piping systems through the interconnections;

.2 not to pass through any accommodation space, service space or control station or through a machinery space other than a cargo pump room or cargo compressor space;

.3 to be connected into the cargo containment system directly from the open deck, except that pipes installed in a vertical trunkway or equivalent may be used to traverse void spaces above a cargo containment system and except that pipes for drainage, venting or purging may traverse cofferdams;

.4 except for bow or stern loading and unloading arrangements in accordance with 3.8, and emergency cargo jettisoning piping systems in accordance with 3.1.6, and except in accordance with Section 16, to be located in the cargo area above the open deck; and

.5 except for thwartship shore connection piping not subject to internal pressure at sea or emergency cargo jettisoning arrangements, to be located inboard of the transverse tank location requirement of 2.6.1.

3.1.6 Any emergency cargo jettisoning piping system should comply with 3.1.5 as appropriate and may be led aft externally to accommodation spaces, service spaces or control stations or machinery spaces, but are not to pass through them. If an emergency cargo jettisoning piping system is permanently installed a suitable means of isolation from the cargo piping is to be provided within the cargo area.

3.1.7 Arrangements are to be made for sealing the weather decks in way of openings for cargo containment systems.

3.1-0.1Hold spaces are to be separated from each other by single bulkheads. Due consideration is to be given to the steel selection of the bulkheads considering the lowest temperature they may be exposed to during service. Where cofferdams are used instead of single bulkheads, they may be used as ballast tanks subject to special approval by the Society.

3.2 Accommodation, service and machinery spaces and control stations

3.2.1No accommodation space, service space or control station is to be located within the cargo area. The bulkhead of accommodation spaces, service spaces or control stations which face the cargo area is to be located so as to avoid the entry of gas from the hold space to such spaces through a single failure of a deck or bulkhead on a ship having a containment system requiring a secondary barrier.
3.2.2 In order to guard against the danger of hazardous vapours, due consideration is to be given to the location of air intakes and openings into machinery spaces, accommodation spaces, service spaces and control stations in relation to cargo piping, cargo vent systems and machinery space exhausts from gas burning arrangements.
3.2.3 Access through doors, gastight or otherwise, is not permitted from a gas safe space to a gas dangerous space, except for access to service spaces forward of the cargo area through airlocks as per-mitted by 3.6.1 when accommodation spaces are aft.
3.2.4 Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and control stations shall not face the cargo area. They are to be located on the end bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse at a distance of at least Lc/25 but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5 m. Windows and side scuttles facing the cargo area and on the sides of the superstructures or deckhouses within the distance mentioned above are to be of the fixed (non-opening) type. Wheelhouse windows may be non-fixed and wheelhouse doors may be located within the above limits so long as they are so designed that a rapid and efficient gas and vapour tightening of the wheelhouse can be ensured. For ships dedicated to the carriage of cargoes which have neither flammable nor toxic hazards, the Society may approve relaxations from the above requirements.
3.2.5 Side scuttles in the shell below the uppermost continuous deck and in the first tier of a superstructure ordeckhousearetobeofthefixed(non-opening)type.
3.2.6 All air intakes and openings into the accommodation, service and control station spaces are to be fitted with closing devices. For toxic gases they are to be operated from inside the space.
3.2-0.1Compliance with other relevant paragraphs of the Code and in particular with paragraphs 3.2.4, 3.8, 8.2.10 and 12.1.6 where applicable would also ensure compliance with this paragraph.
3.2-0.2Air outlets are subject to the same require-ments as air inlets and air intakes. This interpretation also applies to paragraphs 3.2.2, 3.8.4and 8.2.10.
3.2-0.3 Doors facing the cargo area or located in prohibited zones in the sides are to be restricted to stores for cargo-related and safety equipment, cargo control stations as well as decontamination showers and eye wash.
3.2-0.4The requirement for fitting air intakes and openings with closing devices operable from inside the space in ships intended to carry toxic products shall apply to spaces which are used for ships' radio and main navigating equipment, cabins, mess rooms, toilets, hospitals, galleys, etc., but shall not apply to engine room casings, deck stores, steering gear compartments, work shops etc. The requirement does also not apply to forecastle stores and to cargo control rooms located within the cargo areas. When internal closing is required, this shall include both ventilation intakes and outlets. The closing devices shall give a reasonable degree of gas tightness. Ordinary steel fire-flaps without gaskets/seals shall normally not be considered satisfactory.
3.2-0.5 Access to forecastle spaces containing sources of ignition may be permitted through doors facingcargo area provided the doors are located outside hazardous areas as defined in IEC Publication 60092-502.
3.3 Cargo pump-rooms and cargo compressor rooms
3.3.1.1 Cargo pump rooms and cargo compressor rooms are to be situated above the weather deck and located within the cargo area unless specially approved by GL. Cargo compressor rooms are to be treated as cargo pump rooms for the purpose of fire protection according to Chapter 2 – Machinery Instal-lations, Section 12(SOLAS regulation II-2/9.2.4).
3.3.1.2 When cargo pump rooms and cargo com-pressor rooms are permitted to be fitted above or below the weather deck at the after end of the aftermost hold space or at the forward end of the foremost hold space, the limits of the cargo area as defined in Section 1, C.1.6 are to be extended to include the cargo pump rooms and cargo compressor rooms for the full breadth and depth of the ship and deck areas above those spaces.
3.3.1.3 Where the limits of the cargo area are extended by 3.3.1.2, the bulkhead which separates the

cargo pump rooms and cargo compressor rooms from accommodation and service spaces, control stations and machinery spaces of category A is to be so located as to avoid the entry of gas to these spaces through a single failure of a deck or bulkhead.

3.3.2 Where pumps and compressors are driven by shafting passing through a bulkhead or deck, gastight seals with efficient lubrication or other means of ensuring the permanence of the gas seal are to be fitted in way of the bulkhead or deck.

3.3.3 Arrangements of cargo pump rooms and cargo compressor rooms are to be such as to ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. All valves necessary for cargo handling are to be readily accessible to personnel wearing protective clothing. Suitable arrangements shall be made to deal with drainage of pump and compressor rooms. When cargo pump rooms or compressor rooms are permitted to be fitted at the after end of the aftermost hold space the bulkhead which separates the cargo pump rooms or compressor rooms from accommodation and service spaces and control stations and machinery spaces of category A are to be so located as to avoid the entry of gas to these spaces through a single failure of a deck or bulkhead. The same condition is also to be satisfied when cargo pump rooms and compressor rooms, fitted within the cargo area, have a bulkhead in common with accommodation and service spaces, control stations and machinery spaces of category A.

3.4 Cargo control rooms Any cargo control room is to be above the weather deck and may be located in the cargo area. The cargo control room may be located within the accommodation, service or control station spaces provided the following conditions are complied with:

.1 the cargo control room is a gas safe space and

.2.1 if the entrance complies with 3.2.4, the control room may have access to the spaces described above;

.2.2 if the entrance does not comply with 3.2.4, the control room shall have no access to the spaces described above and the boundaries to such spaces shall be insulated to "A-60" standard.

3.4.2 If the cargo control room is designed to be a gas safe space, instrumentation shall, as far as possible, be by indirect reading systems and shall in any case be designed to prevent any escape of gas into the atmosphere of that space. Location of the gas detector within the cargo control room will not violate the gas safe space if installed in accordance with 13.6.5.

3.4.3 If the cargo control room for ships carrying flammable products is a gas dangerous space, sources of ignition are to be excluded. Consideration is to be paid to the safety characteristics of any electrical installations.

3.5 Access to spaces in the cargo area

3.5.1 Visual inspection shall be possible of at least one side of the inner hull structure without the removal of any fixed structure or fitting. If such a visual inspection, whether combined with those inspections required in 3.5.2, 4.7.7 or 4.10.16 or not, is only possible at the outer face of the inner hull, the inner hull shall not be a fuel-oil tank boundary wall.

3.5.2 Inspection of one side of any insulation in hold spaces shall be possible. If the integrity of the insulation system can be verified by inspection of the outside of the hold space boundary when tanks are at service temperature, inspection of one side of the insulation in the hold space need not be required.

3.5.3 Arrangements for hold spaces, void spaces and other spaces that can be considered gas dangerous and cargo tanks are to be such as to allow entry and inspection of any such space by personnel wearing protective clothing and breathing apparatus and in the event of injury to allow unconscious personnel to be removed from the space and to comply with the following:

.1 access is to be provided:

.1.1 to the cargo tanks direct from the open deck;

.1.2 through horizontal openings, hatches or manholes the dimensions of which are to be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction, and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 mm by 600 mm and

.1.3 through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening of which is to be not less than 600 mm by 800 mm at a height of not more than 600 mm from the bottom plating unless gratings or other footholds are provided.

.2 The dimensions referred to in 3.5.3.1.2 and .1.3 may be decreased if the ability to transverse Where the surveyor does not require to passbetween the surface to be inspected and any part of the structure, for visibility reasons the distance between the free edge of that structural element and the surface to be inspected is to be at least 50 mm or half the breadth of the structure's face plate, whichever is the larger

.3If for inspection of a curved surface the surveyor requires to pass between that surface and another surface, flat or curved, to which no structural elements are fitted, the distance between both surfaces is to be at least 380 mm.Where the surveyor does not require to pass between a curved surface and another surface, a smaller distance than 380 mm may be accepted taking into account the shape of the curved surface.

.4 If for inspection of an approximately flat surface the surveyor requires to pass between two approximately flat and approximately parallel surfaces, to which no structural elements are fitted, the distance between those surfaces are to be at least 600 mm

.5 The minimum distances between a cargo tank sump and adjacent double bottom structure in way of a suction wells are not to be less than shown in Fig. 3.5. If there is no section well, the distance between the cargo tank sump and the inner bottom is not to be less than 50 mm.

.6 The distance between a cargo tank dome and deck structures is not to be less than 150 mm

.7 If necessary for inspection fixed or portable staging is to be installed. This staging is not to impair the distances required under .1 to .4.

.8If fixed or portable ventilation ducting has to be fitted in compliance with 12.2 such ducting is not to impair the distances required under .1 to .4.

3.5-0.3

For the purpose of subparagraph 3.5.3.1.2 and .1.3 the following applies:

.1 The term "minimum clear opening of not less than 600 ×600 mm" means that such openings mayhave corner radii up to 100 mm maximum.

.2 The term "minimum clear opening of not less than 600 ×800 mm

.3Circular access openings in type C cargo tanks are to have diameters of not less than 600 mm.

3.6 Airlocks

3.6.1 An airlock is permitted only between a gas dangerous zone on the open weather deck and a gas safe space and is to consist of two steel doors substantially gastight spaced at least 1,5 m but not more than 2,5 m apart.

3.6.2 The doors are to be self-closing and without any holding back arrangements.

3.6.3 An audible and visual alarm system to give a warning on both sides of the airlock is to be provided to indicate if more than one door is moved from the closed position.

3.6.4 In ships carrying flammable products electrical equipment which is not of the certified safe type in spaces protected by airlocks should be de-energized upon loss of over-pressure in the space (see also 10.1.4). Electrical equipment which is not of the certified safe type for maneuvering, anchoring and mooring equipment as well as the emergency fire pumps should not be located in spaces to be protected by airlocks.

3.6-0.1The following means for monitoring overpressure in spaces protected by airlocks are considered acceptable alternatives to differential pressure sensing devices in spaces having a ventilation rate not less than 30 air changes per hour:

.1monitoring of current or power in the electrical supply to the ventilation motors; or

.2air flow sensors in the ventilation ducts.

In spaces where the ventilation rate is less than 30 air changes per hour and where one of the above alternatives is fitted, in addition to the alarms required by 3.6.3, arrangements are to be made to de-energize electrical equipment which is not of the certified safe type, if more than one airlock door is moved from the closed position.

3.6.5 The airlock space is to be mechanicallyventilated from a gas safe space and maintained at an over-pressure to the gas dangerous zone on the open weather deck.

3.6.6 The airlock space is to be monitored for cargo vapor.

3.6.7 Subject to the requirements of the International Convention on Load Lines, 1966, the door sill is not to be less than 300 mm in height.
3.7 Bilge, ballast and fuel oil arrangements
3.7.1.1 Where cargo is carried in a cargo containment system not requiring a secondary barrier,
hold spaces are to be provided with suitable drainage arrangements not connected with the machinery space. Means of detecting such leakage are to be provided.
3.7.1.2 Where there is a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through adjacent ships structure are to be provided. The suction is not to be led to pumps inside the machinery space. Means of detecting such leakage are to be provided.
3.7.2 The hold orinterbarrier spaces of Type Aindependent tanks shall be provided with a drainage system suitable for handling liquid cargo in the event of cargo tank leakage or rupture. Such arrangements shall provide for the return of any cargo leakage to the liquid cargo piping. Such a system shall be provided with removable spool pieces.
3.7.3 In case of internal insulation tanks, means of detecting leakage and drainage arrangements arenot required for interbarrier spaces and spaces between the secondary barrier and the inner hull or independent tank structure which are completely filled by insulation material complying with 4.9.7.2.
3.7.4 Ballast spaces, including wet duct keels used as ballast piping, fuel-oil tanks and gas-safe spaces may be connected to pumps in the machinery spaces. Dry duct keels with ballast piping passing through, may be connected to pumps in the machinery spaces, provided the connections are led directly to the pumps and the discharge from the pumps lead directly overboard with no valves or manifolds in either line which could connect the line from the duct keel to lines serving gas-safe spaces. Pump vents shall not be open to machinery spaces.
3.8 Bow or stern loading and unloading arrangements
3.8.1Subject to the requirements of this Section, cargo piping may be arranged to permit bow or stern loading and unloading.
3.8.1.1 Bow or stern loading and unloading lines which are led past accommodation spaces, service spaces or control stations shall not be used for the transfer of products requiring a Type 1G ship. Bow or stern loading and unloading lines shall not be used for the transfer of toxic products as specified in C.37. unless specifically approved by GL.
3.8.2 Portable arrangements shall not be permitted.
3.8.3 In addition to the requirements of the following provisions apply to cargo piping and related piping equipment:
.1 Cargo piping and related piping equipment outside the cargo area are to have only welded
connections. The piping outside the cargo area shall run on the open deck and shall be at least
760 mm in board except for thwart ships shore connection piping. Such piping shall be clearly
identified and fitted with a shut-off valve at its connection to the cargo piping system within
the cargo area. At this location, it shall also be capable of being separated by means of a
removable spool piece and blank flanges when not in use.
.2 The piping is to be full penetration but welded, and fully radiographed regardless of pipe
diameter and design temperature. Flange connections in the piping are only permitted within the cargo area and at the shore connection.
.3 Arrangements are to be made to allow such piping to be purged and gas-freed after use.
When not in use, the spool pieces shall be removed and the pipe ends to be blank-flanged.
The vent pipes connected with the purge are to be located in the cargo area.
3.8.4 Entrances, air inlets and openings to accommodation spaces, service spaces, machinery
spaces and control stations shall not face the cargo shore connection location of bow or stern loading and unloading arrangements. They shall be located on the outboard side of the superstructure or
distance of at least Lc/25 but not less than 3 m from the end of the superstructure or deckhouse facing the cargo shore connection location of the bow or stern loading and unloading arrangements. This distance, however, need not exceed 5 m. Side scuttles facing the shore connection location and on the sides of the superstructure or deckhouse within the distance mentioned above shall be of the fixed (non-opening) type. In addition, during the use of the bow or stern loading and unloadingarrangements, all doors, ports and other openings on the corresponding superstructure or

decks and deck houses shall be closed. Where in case of small ships compliance with 3.2.4and this paragraph is not possible, the Society may approve relaxations from the above requirements.
3.8.5 Deck openings and air inlets to spaces within distances of 10 m from the cargo shore connection location shall be kept closed during the use of bow or stern loading or unloading arrangements.
3.8.6 Electrical equipment within a zone of 3 m from the cargo shore connection location.
3.8.7 Fire-fighting arrangements for the bow or stern loading and unloading areas are to be in accordance with 11.3.1.3 and 11.4.7.
3.8.8 Means of communication between the cargo control station and the shore
e connection location shall be provided and, if necessary, certified safe. Cargo Containment
4.1 General
4.1.1 With regard to this Section reference is made to the Unified Requirements G1 and G2 of the International Association of Classification Societies (IACS).
4.1.2
In addition to the definitions in Section 1, The definitions given in this Section apply throughout this Chapter.
4.2 Definitions
4.2.1 Integral tanks
4.2.1.1 Integral tanks form a structural part of the ship's hull and are influenced in the same manner and by the same loads which stress the adjacent hull structure.
4.2.1.2 The "design vapor pressure" P0 as defined in 4.2.6 is not normally to exceed 0,25 bar. If, however, the hull scantlings are increased accordingly, P0 may be increased to a higher value but less than 0,7 bar.
4.2.1.3 Integral tanks may be used for products pro-vided the boiling point of the cargo is not below - 10 °C. A lower temperature may be accepted by the Society subject to special consideration.
4.2.2 Membrane tanks
4.2.2.1 Membrane tanks are non-self-supporting tanks which consist of a thin layer (membrane) sup-ported through insulation by the adjacent hull structure. The membrane is designed in such a way that thermal and other expansion or contraction is compensated for without undue stressing of the membrane.
4.2.2.2 The design vapor pressure P0is not normally to exceed 0,25 bar. If, however, the hull scant-lings are increased accordingly, and consideration is given, where appropriate, to the strength of the sup-porting insulation, P0may be increased to a higher value but less than 0,7 bar.
4.2.2.3 The definition of membrane tanks does not exclude designs such as those in which non-metallic membranes are used or in which membranes are included or incorporated in the insulation. Such designs require, however, special consideration by the Society. In any case the thickness of the membranes should normally not exceed 10 mm.
4.2.3 Semi-membrane tanks
4.2.3.1 Semi-membrane tanks are non-self-supporting tanks in the loadedcondition and consist of a layer, parts of which are supported through insulation by the adjacent hull structure, whereas the rounded parts of this layer connecting the above mentioned supported parts are designed also to accommodate the thermal and other expansion or contraction.
4.2.3.2 The design vapor pressure P0is not normally to exceed 0,25 bar. If, however, the hull scant-lings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting insulation, P0may be increased to a higher value but less than 0,7 bar.
4.2.4 Independent tanks
4.2.4.1 Independent tanks are self-supporting; they do not form part of the ship's hull and are notessential to the hull strength. There are three categories of independent tanks referred to in 4.2.4.2 - 4.2.4.4.
4.2.4.2 Type A independent tanksare tanks which are designed primarily using classical ship-structural analysis procedures. Where such tanks are primarily constructed of plane surfaces (gravity tanks), the design vapor pressure P0is to be less than 0,7 bar.
4.2.4.3 Type B independent tanksare tanks which are designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (gravity tanks) the design vapor pressure P0is to be less than 0,7 bar.

4.2.4.4 Type C independent tanks(also referred to as pressure vessels) are tanks meeting pressure vessel criteria and having a design vapor pressure P0However, the Society may allocate a tank complying with the criterion of this sub-paragraph to type A or type B, dependent on the configuration of the tank and the arrangement of its supports and attachments.
4.2-0.1If the carriage of products not covered by Section 19is intended, the relative density of which exceeds 1,0, it is to be verified that the double amplitude of the primary membrane stress
created by the maximum dynamic pressure differential does not exceed the allowable double amplitude of the dynamic membrane stress
4.3.2.2. In order to evaluate the maximum pressure differential pressure differentials are to be evaluated over the full range of the acceleration ellipse.
4.2.5 Internal insulation tanks
4.2.5.1 Internal insulation tanks are non-self support-ing and consist of thermal insulation materials which contribute to the cargo containment and are supported by the structure of the adjacent inner hull or of an independent tank. The inner surface of the insulation is exposed to the cargo.
4.2.5.2 The two categories of internal insulation tanks are:
.1 Type 1 tanksare tanks in which the insulation or a combination of the insulation and one
or more liners function only as the primary barrier. The inner hull or an independent tank
structure should function as the secondary barrier when required.
.2 Type 2 tanksare tanks in which the insulation or a combination of the insulation and one
or more liners function as both the primary and thesecondary barrier and where these barriers areclearly distinguishable. The term "liner" means a thin, non-self-supporting, metallic, non-metallic or composite material which forms part of an internal insulation tank in order to enhance its fracture resistance or other mechanical properties. A liner differs from a membrane in that it alone is not intended to function as a liquid barrier.
4.2.5.3 Internal insulation tanks are to be of suitable materials enabling the cargo containment system to be designed using model tests and refined analytical methods as required in 4.4.7
4.2.5.4 The design vapor pressure P0shall not normally exceed 0,25bar. If, however, the cargo containment system is designed for a higher vapor pressure, P0 may be increased to such higher value, but not exceeding 0,7 bar if the internal insulation tanks are supported by the inner hull structure. However, a design vapor pressure of more than 0,7 bar may be accepted by the Society provided the internal insulation tanks are supported by suitable independent tank structures.

Cargo Containment

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4.2.6 Design vapor pressure
4.2.6.1 The design vapor pressure P0is the maximum gauge pressure at the top of the tank which has been used in the design of the tank.
4.2.6.2 For cargo tanks where there is no temperature control and where the pressure of the cargo is dictated only by the ambient temperature, P0is not to be less than the gauge vapor pressure of the cargo at a temperature of 45 °C. However, lesser values of this temperature may be accepted by the Society for ships operating in restricted areas or on voyages of restricted duration and account may be taken in such cases of any insulation of the tanks. Conversely, higher values of this temperature may be required for ships permanently operating in areas of high ambient temperature.
4.2.6.3 In all cases, including 4.2.6.2, Pis not to be less than MARVS.
4.2.6.4 Subject to special consideration by the Society and to the limitations given in 4.2.1to 4.2.5 for the various tank types, avapor pressure higher than P0may be accepted in harbor conditions, where dynamic loads are reduced.
4.2-0.2Higher vapor pressures in harbor conditions are to be specified in the operating instructions
for the ship's management.
4.2.7 Design temperature The design temperature for selection of materials is the minimum temperature at which cargo may be loaded or transported in the cargo tanks. Provisions to the satisfaction of the Society are to be made that the tank or cargo temperature cannot be lowered below

the design temperature.
4.3 Design loads
4.3.1 General
4.3.1.1 Tanks together with their supports and other fixtures are to be designed taking into account proper combinations of the various loads listed hereafter:
– Internal pressure
– External pressure
– Dynamic loads due to the motion of the ship
– Thermal loads
– Sloshing loads
– Loads corresponding to ship deflection
– Tank and cargo weight with the corresponding reactions in way of supports
– Insulation weight
– Loads in way of towers and other attachments.
The extent to which these loads are to be considered depends on the type of tank, and is more fully detailed in the following paragraphs.
4.3.1.2 Account is to be taken of the loads corresponding to the pressure test referred to in 4.10.
4.3.1.3 Account is to be taken of an increase of vapor pressure in harbor conditions referred to in 4.2.6.4.
4.3.1.4 The tanks are to be designed for the most unfavorable static heel angle within the range 0° to 30° without exceeding allowable stresses given in 4.5.1.
4.3.2 Internal pressure
4.3.2.1 The internal pressure Pin bar gauge resultingfrom the design vapor pressure P and the liquid pressureP defined in 4.3.2.2, but not includingeffects of liquid sloshing Equivalent calculation procedures may be applied.
4.3.2.2 The internal liquid pressures are those created by the resulting acceleration of the center of gravity of the cargo due to the motions of the ship referred to in
4.3.4.1. The value of the internal liquid pressure Pgdresulting from combined effects of gravity and dynamical accelerations. Dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamical loads, in an arbitrary direction largest liquid height [m] above the point where the pressure is to be determined measured from the tank shell in the direction .

Materials of Construction

6.1 General
6.1.1 With regard to this Section reference is made to the Unified Requirement W1 of the International Association of Classification Societies (IACS).
6.1.2 This Section gives the requirements for plates, sections, pipes, forgings, castings and weildments used in the construction of cargo tanks, cargo process pressure vessels, cargo and process piping, secondary barriers and contiguous hull structures associated with the transportation of the products. The requirements for rolled materials, forgings and castings are given in 6.2 and Tables 6.1to 6.5. The requirements for weildments are given in 6.3.
6.1.3 The manufacture, testing, inspection and documentation are to be in accordance with the Rules II - Materials and Welding, Part 1 – Metallic Materials, and the specific requirements given in this Section.
6.1.4.1 Acceptance tests are to include Charpy V-notch toughness tests, unless otherwise specified by the Society. The specified Charpy V-notch requirements are minimum average energy values for three full size (10 mm ×10 mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy V-notch specimens are to be in accordance with the Rules II - Materials and Welding, Part 1 – Metallic Materials. The testing and requirements for smaller than 5,0 mm size specimens are to be specially considered by the Society. Only one individual value may be below the specified average value, provided it is not less than 70 % of that value.
6.1.4.2 In all cases, the largest size Charpy specimens possible for the material thickness shall be machined with the specimens located as near as practicable to a point midway between the surface and the center of the thickness and the length of the notch perpendicular to the surface, (see Fig. 6.1).

If the average value of the three initial Charpy V-notch specimens fails to meet the stated requirements, or thevalue for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, three additional specimens from the same material may be tested and the results combined with those previously obtained to form a new average. If this new average complies with the requirements and if no more than two individual results are lower than the required average and no more than one result is lower than the required value for a single specimen, the piece or batch may be accepted. At the discretion of the Society other types of toughness tests such as a drop weight test may be used. These may be either in addition to or in lieu of the Charpy V-notch test.

6.1.5 Tensile strength, yield stress and elongation are to be approved by the Society. For carbon-manganese steel and other materials with definitive yield points consideration is to be given to the limitation of the yield to tensile ratio.

6.1.6 The bend test may be omitted as a material acceptance test, but is required for weld tests.

6.1.7 Materials with alternative chemical composition or mechanical properties may be accepted by the Society.

6.1.8 Where post weldheat treatment is specified or required the properties of the base material are be determined in the heat treated condition in accordance with the applicable Table of this Section and the weld properties are to be determined in the heat treated condition in accordance with

6.3. In cases where a post weld heat treatment is applied, the test requirements may be modified at the discretion of the Society.

6.1.9 Where reference is made in this Chapter to A, B, D, E, AH, DH and EH hull structural steels, these steel grades are hull structural steels according to the Rules II - Materials and Welding, Part 1 – Metallic Materials. Welding and non-destructive testing

6.3.1 General

The requirements of this Section are those generally employed for carbon, carbon-manganese, nickel alloy and stainless steels, and may form the basis for acceptance testing of other material. At the discretion of the Society impact testing of stainless steel and aluminumalloy weildments may be omitted and other tests be specially required for any material.

6.3.2 Welding consumables

Welding consumables intended for welding of cargo tanks process pressure vessels and secondary barriers are to be in accordance with the Rules II - Materials and Welding, Part 3 – Welding, unless otherwise agreed with the Society. Deposited weld metal tests and butt weld tests are to be required for all welding consumables, unless otherwise specially agreed with the Society. The results obtained from tensile and Charpy V-notch impact tests are to be in accordance with the Rules II - Materials and Welding, Part 3 – Welding. The chemical composition of the deposited weld metal is to be recorded for information and approval.

6.3.3 Welding procedure tests for cargo tanks, process pressure vessels and secondary barriers

6.3.3.1 Welding procedure tests for cargo tanks, process pressure vessels and secondary barriers are required for all butt welds and the test assemblies are to be representative of:

– each base material

– each type of consumable and welding process

– each welding position

For butt welds in plates, the test assemblies are to be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test is to be approved by the Society. Radiographic or ultrasonic testing may be performed at the option of the manufacturer or the Society. Fillet welding procedure tests are to be in accordance with the Society's practice. In such cases consumables are to be selected which exhibit satisfactory impact properties.

6.3.3.2 The following welding procedure tests are required from each test assembly:

.1 Cross-weld tensile tests

.2 Transverse bend tests:

These bend tests may be face, root or side bends at the discretion of the Society. How-ever, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.

.3 One set of three Charpy V-notch impact tests is to be made generally at each of the following locations, as shown in Figure 6.1: Centre line of the welds Fusion line (F.L.)

1 mm from the F.L.
3 mm from the F.L.
5 mm from the F.L.
.4 Macro section,micro section and hardness survey may also be required by the Society.
6.3.4 Test requirements
6.3.4.1 Tensile tests
Generally tensile strength is not to be less than the specified minimum tensile strength for the appropriate parent materials. The Society may also require that the transverse weld tensile strength is not to be less than the specified minimum tensile strength for the weld metal, where the weld metal has a lower tensile strength than that of the parent metal. In every case, the position of fracture is to be reported for information.
6.3.4.2 Bend tests
No fracture is acceptable after a 180° bend over a former of a diameter four times the thickness of the test pieces, unless otherwise specially required by or agreed with the Society.
6.3.4.3 Charpy V-notch impact tests
Charpy tests are to be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy (E), are to be not less than 27 J. The weld metal requirements for sub size specimens and single energy values are to be in accordance with 6.1.4. The results of fusion line and heat affected zone impact tests are to have a minimum average energy (E) in accordance with the transverse or longitudinal requirements of the base material, whichever is applicable, and for sub sizespecimens, the minimum average energy (E) is to be generally in accordance with 6.1.4. If the material thickness does not permit machining either full size or standard specimens, the testing procedure and acceptance standards are to be approved by the Society.
6.3.5 Welding procedure test for piping
Welding procedure tests for piping are to be carried out and are to be similar to those detailed for cargo tanks in 6.3.3. Unless otherwise specially agreed with the Society, the test requirements are to be in accordance with 6.3.4. Production weld tests
6.3.6.1 For all cargo tanks and process pressure vessels except integral and membrane tanks, production tests are generally to be performed for approximately each 50 m of butt weld joints and are to be representative of each welding position. For secondary barriers,
the same type production tests as required for primary tanks are to be performed except that the number of tests may be reduced subject to agreement with the Society. Tests, other than those specified in 6.3.6.2, .3 and .4 may be required for cargo tanks or secondary barriers at the discretion of the Society.
6.3.6.2 The production tests for independent tanks types A and B and semi-membrane tanks are to include the following tests:
.1 Bend tests, and where required for procedure tests one set of three Charpy V-notch tests is to be made for each 50 m of weld. The specimens having the notch alternately located in the center of the weld and in the heat affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches are to be in the center of the weld.
.2 The test requirements are the same as the applicable test requirements listed in 6.3.4except that impact tests that do not meet the prescribed energy requirements may still be accepted, upon special consideration of the Society by passing a drop weight test. In such cases, two drop weight specimens are to be tested for each set of Charpy specimens that failed and both must show "no break" performance at the temperature at which the Charpy tests were conducted.
6.3.6.3 In addition to those tests listed in 6.3.6.2.1 for type C independent tank and process pressure vessels, transverse weld tensile tests are required. The test requirements are listed in 6.3.4 except that impact tests that do not meet the prescribed energy requirements may still be accepted upon special consideration by the Society, by passing a drop weight test. In such cases, two drop weight specimens are to be tested for each set of Charpy specimens that failed, and both must show "no break" performance at the temperature at which the Charpy tests were conducted.
6.3.6.4 Production tests for integral and membrane tanks are to be specially agreed with the Society.
6.3.7 Non-destructive testing
6.3.7.1 For type A independent tanks and semi-membrane tanks where the design temperature is

- 20 °C or lower, and for independent tanks type B regardless of temperature, all full penetration butt welds of the shell plating of cargo tanks are to be subjected to 100 % radiographic inspection.
.1 Where the design temperature is higher than - 20 °C, all full penetration butt welds in way of intersections and at least 10 % of the remaining full penetration welds of tank structures are to be subjected to radiographic inspection.
.2 In each case the remaining tank structure including the welding of stiffeners and other fittings and attachments are to be examined by magnetic particle or dye penetrant methods as considered necessary by the Society.
.3 All testing procedures and acceptance standards are to be approved by the Society. The Society may accept an approved ultrasonic testing procedure in lieu of radiographic inspection, but may in addition require supplementary inspection by radiography at selected locations. Further, the Society may require ultrasonic testing in addition to normal radiographic inspection.
6.3.7.2 Inspection of independent tanks type C and process pressure vessels are to be carried out in accordance with Section 4.10.9.
6.3.7.3 For integral and membrane tanks, special weld inspection proceduresand acceptance criteria are to be submitted for approval by the Society.
6.3.7.4 The inspection and non-destructive testing of the inner hull or the independent tank structures supporting internal insulation tanks is to take into account the design criteria as given in 4.4.7. The schedule for inspection and non-destructive testing is to be to the satisfaction of the Society.
6.3.7.5 Inspection of piping is to be carried out in accordance with the requirements of .
6.3.7.6 The secondary barrier is to be radiographed as considered necessary by the Society. Where theouter shell of the hull is part of the secondary barrier, all sheer strake butts and the intersections of all butts and seams in the side shell are to be tested by radiography.

CHAPTER FOUR

i. Hazards and health effects on LPG carriers

Hazards on gas carriers

Toxicity

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. Skin irritation and watering of the eyes indicate dangerous levels of VCM may be present in the atmosphere. Caution must be exerted while dealing with such cargoes, precautions such as use of Chemical suits Self-contained Breathing Apparatus (SCBA's) and gas tight goggles must be worn at all times to prevent exposure. Chlorine and ammonia are other toxic cargoes carried.

Flammability

Almost all cargo vapors are flammable. When ignition occurs, it is not the liquid which burns but the evolved vapor that burns. Flameless explosions which result out of cold cargo liquid coming into sudden contact with water do not release much energy. Pool fires which are the result of a leaked pool of cargo liquid catching fire and jet fires which are the result of the leak catching fire are grave hazards. Flash fires occur when there is a leak and does not ignite immediately but after the vapors travel some distance downwind and getting ignited and are extremely dangerous. Vapor cloud explosions and Boiling liquid expanding vapor explosion are the most grave flammability hazards on gas carriers.

Frostbite

The cargoes are carried at extremely low temperatures, from 0 °C to −163 °C, and hence frostbite due to exposure of skin to the cold vapors or liquid is a very real hazard.

Asphyxia

Asphyxia occurs when the blood cannot take a sufficient supply of oxygen to the brain. A person affected may experience headache, dizziness and inability to concentrate, followed by loss of consciousness. In sufficient concentrations any vapor may cause asphyxiation, whether toxic or not.

Seeing it in more detail:

Flammability and explosion

Combustion is a chemical reaction, initiated by a source of ignition, in which a flammable vapor combines with oxygen in suitable proportions to produce carbon dioxide, water vapor and heat. Under ideal conditions the reaction for propane can be written as follows:

$C_3 H_8$ + 502 Combustion $3CO_2 + 4H_2O$ + Heat

propane oxygen Z carbon water

dioxidevapor

Under certain circumstances when, for example, the oxygen supply to the source of fuel is restricted, carbon monoxide or carbon can also be produced.

The three requirements for combustion to take place are fuel, oxygen and ignition. The proportions of flammable vapor to oxygen or to air must be within the flammable limits. The gases produced by combustion are heated by the combustion reaction. In open, unconfined spaces the consequent expansion of these gases is unrestricted and the combustion reaction may proceed smoothly without undue overpressures developing. If the free expansion of the hot gases is restricted in any way, pressures will rise and the speed of flame travel will increase, depending upon the degree of confinement encountered. Increased flame speed in turn gives rise to more rapid increase in pressure with the result that damaging overpressures may be produced and, even in the open, if the confinement resulting from surrounding pipework, plant and buildings is sufficient, the combustion can take on the nature of an explosion. In severely confined conditions, as within a building or ship's tank where the expanding gases cannot be adequately relieved, the internal pressure and its rate of increase may be such as to disrupt the containment. Here, the resultant explosion is not so much directly due to high combustion rates and flame speed as to the violent expulsion of the contained high pressure upon containmentrupture.

The boiling liquid expanding vapor explosion (BLEVE) is a phenomenon associated with the sudden and catastrophic failure of the pressurized containment of flammable liquids in the presence of a surrounding fire. Such incidents have occurred with damaged rail tank car or road tank vehicle pressure vessels subject to intense heat from surrounding fire. This heat has increased the internal pressure and, particularly at that part of the vessel not wetted by liquid product, the vessel's structure is weakened to the point of failure. The sudden release of the vessel's contents to atmosphere and the immediate ignition of the resultant rapidly expanding vapour cloud have produced destructive overpressures and heat radiation. There have been no instances of this kind, nor are they likely to occur, with the pressure cargo tanks on liquefied gas tankers where, by requirement, pressure relief valves are sized to cope with surrounding fire, tanks are provided with water sprays and general design greatly minimizes the possibilities of a surrounding fire occurring.

The term flammable range gives a measure of the proportions of flammable vapor to air necessary for combustion to be possible. The flammable range is the range between the minimum and maximum concentrations of vapor (per cent by volume) in air, which form a flammable mixture. These terms are usually abbreviated to LFL (lower flammable limit) and UFL (upper flammable limit). This concept is illustrated for propane in Figure 2.9.

All the liquefied gases, with the exception of chlorine, are flammable but the values of the flammable range are variable and depend on the particular vapor.. The flammable range of a particular vapor is broadened in the presence of oxygen in
excess of that normally in air; the lower flammable limit is not much affected whereas the upper flammable limit is considerably raised. All flammable vapors exhibit this property and as a result oxygen should not normally be introduced into an atmosphere where flammable vapor’s exist. The oxygen cylinders associated with oxyacetylene burners and oxygen resuscitators should only he introduced into hazardous areas under strictly controlled conditions.

The flash point of a liquid is the lowest temperature at which that liquid will evolve sufficient vapor to form a flammable mixture with air. High vapor pressure liquids such as liquefied gases have extremely low flash points. However, although liquefied
gases are never carried at temperatures below their flash point, the vapor spaces above such cargoes are non-flammable since they are virtually 100 per cent rich with cargo vapor and are thus far above the upper flammable limit. The auto-ignition temperature of a substance is the

temperature to which its vapor in air must be heated for it to ignite spontaneously. The auto-ignition temperature is not related to the vapor pressure or to the flash point of the substance and, since most ignition sources in practice are external flames or sparks, it is the flash point rather than the auto-ignition characteristics of a substance which is generally used for the flammability classification of hazardous materials. Nevertheless, in terms of the ignition of escaping vapor by steam pipes or other hot surfaces, the auto-ignition temperature of vapors of liquefied gases are worthy of note.

Should a liquefied gas be spilled in an open space, the liquid will rapidly evaporate to produce a vapor cloud which will be gradually dispersed downwind. The vapour cloud or plume would be flammable only over part of its downwind travel. The situation is illustrated in general terms. The region B immediately adjacent to the spill area A would be non-flammable because it is over-rich, i.e. it contains too low a percentage of oxygen to be flammable. Region D would also be non-flammable because it is too lean, i.e. it contains too little vapor to be flammable. The flammable zone would be between these two regions as indicated by C.

Liquid ammonia is a colorless alkaline liquid with a pungent odor. The vapors of ammonia are flammable and burn with a yellow flame forming water vapor and nitrogen, however, the vapor in air requires a high concentration (16-25 per cent) to be flammable, has a high ignition energy requirement (600 times that for propane) and burns with low combustion energy. For these reasons the IMO Codes, while requiring full attention to the avoidance of ignition sources, do not require flammable gas detection in the hold or interbarrier spaces of carrying ships. Nevertheless, ammonia must always be regarded as a flammable cargo.

Ammonia is also toxic and highly reactive. It can form explosive compounds with mercury, chlorine, iodine, bromine, calcium, silver oxide and silver hypochlorite. Ammonia vapour is extremely soluble in water and will be absorbed rapidly and exothermically to produce a strongly alkaline solution of ammonium hydroxide. One volume of water will absorb approximately 200 volumes of ammonia vapor. For this reason it is extremely undesirable to introduce water into a tank containing ammonia vapor as this can result in a vacuum condition rapidly developing within the tank.
Since ammonia is alkaline, ammonia vapor/air mixtures may cause stress corrosion. Because of its highly reactive nature copper alloys, aluminum alloys, galvanized surfaces, polyvinyl chloride, polyesters and Viton rubbers are unsuitable for ammonia service. Mild steel, stainless steel, neoprene rubber and polythene are, however, suitable.

Vinyl chloride monomer (VCM) is a colorless liquid with a characteristic sweet odor. It is highly reactive, though not with water, and may polymerizein the presence of oxygen, heat and light. Its vapors are both toxic and flammable. Aluminum alloys, copper, silver, mercury and magnesium are unsuitable for vinyl chloride service. Steels are, however, chemically compatible.

Ethylene oxide and propylene oxide are colorless liquids with an ether-like odor. They are flammable, toxic and highly reactive. Both polymerize, ethylene oxide more readily than propylene oxide, particularly in the presence of air or impurities. Both gases may react dangerously with ammonia. Cast iron, mercury, aluminum alloys, copper and alloys of copper, silver and its alloys, magnesium and some stainless steels are unsuitable for the handling of ethylene oxide. Mild steel and certain other stainless steels are suitable as materials of construction for both ethylene and propylene oxides.

Chlorine is a yellow liquid, which evolves a green vapor. It has a pungent and irritating odor. It is highly toxic but is non-flammable though it should be noted that chlorine can support combustion of other flammable materials in much the same way as oxygen. It is soluble in water forming a highly corrosive acid solution and can form dangerous reactions with all the other liquefied gases. In the moist condition, because of its corrosivity, it is difficult to contain. Dry chlorine is compatible with mild steel, stainless steel, monel and copper. Chlorine is very soluble in caustic soda solution, which can be used to absorb chlorine vapor.

Inherent Hazards/Potential Risks
The principal potential hazard with LP Gas is fire and explosion. This derives from its inherent quality of high flammability and in extreme cases may combine with another condition, i.e. high pressure, and lead to the BLEVE (Boiling Liquid Expanding Vapor Explosion) phenomenon. This is a type of explosion that can occur when a vessel containing a pressurized liquid is ruptured due to high temperature and pressure. Such explosions can be extremely hazardous. There are also hazards incidental to the various modes of transport for distribution and use.

An additional potential hazard may arise at the point of use if ventilation is inadequate and the products of combustion are not dispersed into the atmosphere. Carbon monoxide may be produced and reach dangerous levels. LP Gas 'sniffing' i.e. the intentional inhalation of LP Gas vapour seeking a narcotic effect can result in injury or in some cases, death.
The risk associated with such hazards (with the exception of sniffing) can be controlled using available, proven technology, i.e. the safety equipment and procedures normally used by the LP Gas industry.

Liquid LP Gas will cause cold burns if it comes into contact with the skin. Propane, with its low boiling point is more hazardous in this respect than Butane which, in cold conditions, is slower to vaporize and disperse. The eyes and body must be protected when handling all liquefied products.

LP Gas vapor, being heavier than air, may, in the event of a leak, accumulate in confined spaces and low-lying areas. The means of ventilation and meteorological conditions will influence the movement and dispersion of the LP Gas vapor.
Any uncontrolled release of LP Gas is inherently hazardous. A liquid LP Gas leak is considered more hazardous in that it will expand to vapor form with volume in excess of 200 times that of the original liquid volume leak. Being heavier than air, vapor will tend to lie, or drift, close to the ground with a risk that it will find a source of ignition while it remains within its flammable limits. The physical properties are given in the table shown earlier in this section.

Liquid LP Gas has a high co-efficient of volumetric expansion and therefore cylinders and tanks should never be completely filled. They should be filled with ullage (the unfilled space in a container of liquid) to allow for liquid expansion caused by an increase in temperature. The degree of ullage necessary will depend on the operating conditions, especially the maximum expected operating temperature. This potential risk is further controlled by a combination of safety devices and procedures and especially by control during product transfer operations. This potential risk explains why cylinders and tanks should only be filled under the supervision of competent persons and why illegal filling is dangerous because of the risk of overfilling.

Because of its much higher vapor pressure, tanks and cylinders containing Propane need to be stronger than those for Butane, and both should be protected against excessive pressure. This potential risk is controlled by safety devices and by segregating the products or, where LP Gas mixture is handled, ensuring that the Propane content does not exceed a specified upper limit. In cold weather, a tank storing Butane may be subjected to negative pressure and must be capable of withstanding this.

During the process of distribution, LP Gas will normally be transported in one or more modes. There will be hazards associated with the transport mode and with the consequences of traffic accidents and incidents. The risks will vary from country to country and with the transport mode. The control of transport-related risks is discussed in Chapters 6 and 9.
The majority of consumers will use LP Gas as a fuel in an appliance. The installation comprising the LP Gas supply and connection to the appliance may be simple or complex, large or small. Hazard scenarios and risk at the point of use are discussed in Chapter 10.
The products of complete LP Gas combustion - mainly water and carbon dioxide - are not inherently hazardous. Good installation practice specifies ventilation to supply the air required for combustion and to vent the products of combustion. This minimizes risk by preventing a build-up of carbon monoxide or a development of asphyxiating (i.e. oxygen-deficient) conditions.
LP Gas is a clear odorless liquid and is not readily visible in its gaseous phase. In the event of a leak it may be present, unseen, in hazardous concentrations. To minimize this risk, odorant with a distinctive, persistent and unpleasant smell is added to LP Gas prior to distribution. In special applications requiring odor-free LP Gas, such as aerosol propellant, or the chemical industry, alternative safety measures are adopted such as the use of gas detectors.
Accumulation of LP Gas vapor may result in the development of an oxygen-deficient atmosphere which carries a risk of asphyxiation. The visible cloud might be smaller or bigger than the actual gas cloud, depending on humidity in the air. An explosive-meter should be used to approach a gas cloud. No one should enter a gas cloud as the possible introduction of an ignition source creates a hazardous zone and possible fatal area. No one should enter a vessel which has been used for LP Gas storage without supervision and only when all appropriate safety measures are in place and the area has been determined as gas free.

Minimizing risk in any operation must be one of the foremost goals. Guidelines such as these allow for the management of LP Gas operations, and for its use, well within the parameters for individual and societal risks acceptable in a modern, industrialized society.

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