**INTRODUCTION**:

The marine transportation of liquefied gases is a very small part of the shipping industry. With slightly more than 1,000 ships of over one thousand cubic meter capacity, it does not stand comparison to the 3,000 chemical tankers, the 7,000 oil tankers and the 44,000 other types of ships of similar sizes. Compared to the rest of shipping, which is as old as the oldest civilization, the marine transportation of liquefied gases is very new. It is just over 60 years since the first attempt was made to transport LPG in bulk and it is but 40 years since “Methane Pioneer” carried the first cargo of LNG. LPG and LNG are among the least polluting of the energy sources known in the world today.

The marine transportation of liquefied gases is poised for rapid growth in future. The source of energy in 19th century was “Coal”, in 20th Century the “Oil”, and 21st Century will be known for “Gas” as main source of energy.

The reason for this is obvious; the oil reserves are depleting, natural gas is available in abundance as “Wet” natural gas, where during drilling for oil it emits out at first and continues. Also “dry” natural gas reserves have been identified around the world where oil is not likely to be found. The Gas is to be moved to the consumer. Of these gases methane carrier numbers have grown from 200 vessels to about 300. This fuel is very much environment friendly, on combustion leaving only carbon dioxide and water vapour, has high calorific value and hence extremely useful as domestic and industrial fuel.

Although transportation is very compact i.e. 1 volume of liquefied Gas can produce about 600 volumes of Gas in the state in which it is used as fuel, making marine transportation very convenient. Its density in liquid form is less than 1.0, which is an advantage during shipment. Of course, there are various hazards, in transportations by sea viz, Flammability / Explosivity, Toxicity, Pollution, Reactivity, Corrosivity, Low Temperature, High pressure and Cargo contamination. But all these can be duly taken care of by acquiring knowledge through specialized education and training. Therefore, training of personnel to man these specialized vessels; who should strictly follow do’s and don’t’ is vital. The design of these vessels as per code and subsequent relevant maintenance show that vessels have excellent record of safety worldwide.

The accidental release of a gas tanker’s cargo might result in a serious fire but little, if any, lasting environmental pollution. The safety record of the liquefied gas fleet is second to none and gas tankers are listed by all Port State Controls as the type of ship showing the least number of discrepancies.

**Synopsis**

Marine Transportation of Liquefied Gases though at present form a very small part of tonnage of the shipping industry, is poised for rapid growth in near future, as many such cargoes form a very important source of energy or source for chemical industry.

The transportation by sea is compact, convenient and commercially viable; however there are many hazards associated with the nature of such cargo viz, Flammability, Explosivity, Toxicity, Pollution, Reactivity, Corrosivity, low temperature, High pressure and Cargo contamination.

Although vessels are suitably designed keeping in view, the Hazards and comply with code of construction for such ships; however, in appropriate operations can result in hazardous situations developing, at any point during its transportation including from loading at Terminal; Transportation and Unloading at Consumer Terminal.

**HAZARDS AND RISKS**

Liquefied gases are classed as hazardous commodities and since the beginning of their transportation by ship; they have always generated a lot of controversy, particularly Liquid Natural Gas (LNG), of which large quantities are transported on the largest ships of the fleet of liquefied gas tankers.

In the liquefied gas industry, particular attention is focused on the reduction of the risk of an uncontrollable release of large quantities of combustible liquid or vapour, since such a release could have serious consequences. In a release situation, asphyxiation and frost burns may lead to injuries and fatalities among people at the release site. An ignition of the released gas would result in fire and / or explosion, considered to be the most serious incidents. Present technology, associated with the existing design, construction and operating standards imposed by nature of liquefied gases render the risk of spillage intrinsically low.

* 1. **Hazard**

A Hazard is a physical situation which has the potential to cause harm. The assessment of a hazard includes the identification of both the undesirable situation and its potential consequences.

* 1. **Risk**

Risk is the probability of hazard that may be realized in a given span of time, or the probability that a person or a group of persons, as a result of the hazard occurring may suffer a specified level of injury in a given time span.

**1.3 Liquefied Gases**

Defined in International Gas Carrier Codes published by International Maritime Organization.

“Products having a vapour pressure exceeding 2.8 bar absolute at a temperature of 37.80o C(100 o F), and other products shown in Chapter 19 of the Code, when carried in bulk.” - Reference:- IGC Code, International Maritime Organization.

**1.4 Liquefied Gas Tanker Cargoes**

1.4.1 LNG-Liquefied Natural Gas

Primarily Methane but also includes Ethane and other heavy components Methane CH4

Flammable, Colourless, Odour less; (may be stenched) with a faint odour Aspyxiant

Flash Point -175 0 C

Boiling Point (at atmospheric pressure) -1620 C

Relative Vapour Density 0.55

Uses of LNG

Mainly used as a fuel. It is a clean burning fuel with the high ratio of Hydrogen to Carbon.

**1.4.2 Natural Gas Liquid**

Natural Gas Liquids found in association with natural gas.

Ethane, Propane, Butane, Pentane and heavier hydrocarbons. Also include water, CO2, Nitrogen and other non hydrocarbon substances. Sometimes called Wet Gas.

1.4.2.1 Ethane

C2H6 Flammable, Colourless, odorless Asphyxiant

Flash Point -125 0 C

Boiling point (at atmospheric pressure) -89 0 C

Relative Vapour Density 1.05

1.4.2.2 Liquefied Petroleum Gas (LPG)

Propane and Butane comes from

1. Oil processing in refineries.

2. Natural gas or oil streams.

1.4.2.2.1 Propane

C3H8

Flammable, Colourless, odourless (may be stenched)

Asphyxiant

Flash point -105 0 C

Boiling Point (at atmospheric pressure) -42 0 C

Relative Vapour Density 1.55

1.4.2.2.2 Butane

C4H10

Flammable, Colourless, odourless (may be stenched)

Asphyxiant

Flash point -60 0 C

Boiling Point at atmospheric pressure) -0.50 C

Relative Vapour Density 2.0

Used as portable fuels and feed stocks in the petrochemical industry.

1.4.2.3 Liquefied Ethylene Gas (LEG)

Ethylene is not found naturally but is produced from the cracking of Naphtha, Ethane, or Propane

Ethylene

C2H4

Flammable, Colourless, faintly sweet odour

Asphyxiant

Flash Point -150 0 C

Boiling Point (at atmospheric pressure) -104 0 C

Relative Vapour Density 0.98

Used as a raw material in the production of plastics, polyethylene foam, styrene etc,

**1.4.3 Chemical Gases**

Not naturally occurring but produced by chemical process.

Examples of common cargoes are:

Ammonia

Vinyl Chloride Monomer

Butadiene

Propylene

**1.4.3.1 Ammonia**

NH3

Toxic

Colourless, pungent, and suffocating odour

Flash Point -75 0 C

Boiling point (at atmospheric pressure) -33 0 C

Relative Vapour Density 0.6

**1.4.3.2 Vinyl Chloride Monomer (VCM)**

C2H3Cl

Flammable and Toxic

Colourless, pleasant sweet odour

Flash Point -77 0 C

Boiling Point (at atmospheric pressure) -14 0 C

Relative Vapour Density 0.97

All of the above cargoes are carried as liquid by means of refrigeration, pressurization, or partial refrigeration and pressurization.

Table : Physical properties of some liquefied gases :

|  |  |  |
| --- | --- | --- |
| Liquefied gas | Vapour pressure at 37.8oC (bars absolute) | Boiling point at atmospheric pressure (oC) |
| Methane | Gas\* | -161.5 |
| Propane | 12.9 | -42.3 |
| n-Butane | 3.6 | -0.5 |
| Ammonia | 14.7 | -33.4 |
| Vinyl chloride | 5.7 | -13.8 |
| Butadiene | 4.0 | -5 |
| Ethylene oxide | 2.7 | +10.7 |

Reference:- Liquefied Gas Tanker Course – Library, LBS CAMSAR

|  |  |  |
| --- | --- | --- |
|  | Liquefied Petroleum Gas-LPG | Liquefied Natural Gas-LNG |
| Properties | Petroleum Hydrocarbon(C3+C4)  Flammable Gas  - Propane flammable limits in air-  2,2%-9.5%  - Butane flammable limits in air  1.8% -8.4%  - Floats and boils on water  - Flammable, visible vapour cloud  Vapour approximately 250 times of liquid.  Aquatic& Wildlife toxicity, food chain concentration potential -none | Petroleum Hydrocarbon(C1)  Flammable Gas  - Flammable limits in air  5.3% -14.0%    - Floats and boils on water  - Flammable, visible vapour cloud  Vapour approximately 600 times  Volume of liquid  Aquatic& Wildlife toxicity, food chain concentration potential -none |
| Major Hazards of  Liquefied Gases | The Major Hazard of liquefied Gases is not in liquefied form-it is  the vapour from a release.  The associated heat from a vapour cloud that is subsequently ignited  This could be remote from the point of liquid release  Detonation of a vapour cloud of LPG (has been simulated) | Detonation of LNG cloud has not been found to be possible |
| Hazards to the marine environ-ment | Not a water pollutant-neither toxic nor persistent  Explosion hazard   * Acutely lethal effects to marine organisms in the vicinity of underwater explosion * Less of a widespread, persistent, chronic environmental hazard than a crude oil spill   Contact with cold liquid LNG will damage tissues. |  |
| Other Hazards of LPG and LNG | BLEVE( Boiling Liquid Expanding Vapour Explosion) occurs when pressurized LPG containment becomes over pressured and fails catastrophically | RPT(Rapid Phase Transition) can occur with LNG when there is mixing with Water in correct proportion |
| Differences-LPG and LNG vapour | LPG  Vapour cloud is heavier than air, cloud dispersion is at low level and LFL and UFL is reached slowly | LNG  Vapour becomes rapidly (over temperatures of 1000C) lighter than air, increasing cloud dispersion and thus LFL and UFL is reached quickly |

**LNG/LPG Accidental Release Behaviour**

When liquefied gas is released, it vaporizes and is warmed by mixing with diluting air, cooling the surrounding air.

-Some distance before diluted below the flammable limits

-Spreads rapidly until vaporization is complete

-Vapour cloud of LNG, is generally visible due to air temperature being

lowered below ambient dew point.

On Land-vaporization initially is rapid until the ground cools; and can take hours to evaporate later

On Water-generally rapid throughout as water transmits heat.

**sEA tRANSPORT Of Liquefied Gas**

Gas Transport Development

Important stages in the transport of liquefied gas by ship :

Gas Shipping began in the late 1920

The earliest Ships were designed to carry liquefied gas in pressure vessels at ambient temperature. Butane and Propane were the first cargoes in the market. The subsequent development of refrigeration techniques and more particularly metal suitable to low temperature permitted the carriage of Cargoes at temperature below ambient.

In the late 1950s these gases began to be partially refrigerated commercially and ships were built with pressure vessels of low temperature material to carry the cargo.

By the mid 1960s fully refrigerated LPG Ships were in service carrying cargo at atmospheric pressure. Ethylene and LNG Ships had also entered service. In the meantime ammonia had become a common cargo and chemical gases such as butadiene had become commercially important.

Definition: Liquefied Gas Cargoes

1. LNG – liquefied Natural Gas, the Principal constituent of which is Methane.
2. LPG – Liquefied Petroleum Gas – Mainly Propane and Butane pentane and can be shipped separately or as a mixture.
3. LEG – Liquefied Ethane Gas or Liquefied Ethylene Gas – Also other saturated Hydro Carbons
4. Chemical Gases- Vinyl Chloride monomer, Ethylene Oxide, Propylene Oxide, Ammonia, and Chlorine are the Chemical Gases commonly transported in Liquefied Gas carriers. Their chemical properties vary as these gases do not belong to one particular family. (Generally C/H derivative & inorganic gases )

**2.1 Sea Transport of Liquefied Gas**

**2.1.1 Basic Principal of Gas Transport**

Gas Cargoes are carried in Liquefied State, because the liquid occupies up to 850 times less volume, which means that this much extra cargo can be carried, which makes the trade economically feasible. The liquid is at its boiling point, and will vaporize readily.

A gas can be liquefied either by increasing its pressure, reducing its temperature or both. The combination of pressurizing and cooling are fundamental to Gas carrier design. If the cargo is to be carried pressurized at ambient temp, the cargo tanks have to withstand the pressure of the cargo at the highest ambient temperature anticipated.

If the Cargo is to be carried at temperature below ambient, the cargo tanks have to withstand the pressure of the cargo, the tank material must be ductile at cargo temperature and be compatible with the cargo. The tanks also have to be insulated to prevent heat ingress.

Most of the commercially important gases have a specific gravity about half that of water, which means that the cargo tank can extend much higher above the water than is possible for oil tankers. The low specific gravity of the cargo is also the reason that the cargo capacity of a gas carrier is usually quoted in terms of volume (cubic meters) rather than dead weight. The tank volume is compartively higher than that of an oil tanker for a given dead weight, resulting in the molded depth becoming relatively large, this fact and the extent of free surface in cargo tanks necessitate particular attention to stability. The cargo specific gravity increases as the cargo temperature is reduced.

**Various types of ships carrying liquefied gas.**

**3.1 Fully pressurized ships**

As the name implies, these ships are designed to carry liquefied gas cargoes at the relevant pressure of the gas at the highest ambient temperature the ship is likely to experience. A Highest temperature of 450C is normally assumed with a design pressure of 17kg/cm2. This corresponds to the vapor pressure of propane, the most volatile cargo which can be carried at ambient temperature. However low design pressure can be used but this with restricted cargo requirements. Cylindrical or Spherical pressure vessels are used since they have a high degree of proven reliability and stress level for such vessels can be calculated easily and reliably backed by considerable experience with pressure vessels in water boilers and oil refineries. The simple design concept also means that the cargo requires little supervision during the voyage. However, building cost, tank size and weight, and poor utilization of hull space for this type of cargo containment vessel make the design impracticable for ships larger than small coastal ships. The ships tend to be up to the 2000 m3 range, although ships up to 6000 m3 are still being built to this design. These ships are usually fitted with double bottoms and topside ballast tanks, with the space around the pressure tanks normally air ventilated. Pressure vessels do not generally require internal or external stiffening members. However, perforated wash plates may be fitted athwart in long horizontal cylinders to reduce sloshing. External stiffening hoops may be fitted especially if the tank is designed to be placed under vacuum when purging or inerting.

The proportion of the hull volume used to contain cargo can be increased to an extent by the use of “Lobed” tanks; these are made from the elements of two cylinders, and are generally tapered to follow the hull contours, especially towards the bows.

Another way to make better use of hull volume is to extend the tanks above the main deck or install extra pressure vessel tanks above deck, protected by a water- tight cover. This capitalizes on the low specific gravity of the cargo. The limitation on this arrangement is the stability of the ship.

Even with the use of specially shaped tanks or extension of the system above the deck, there is still an appreciable amount of hull space unused for cargo, and the weight of the tanks themselves is relatively high. These disadvantages are, offset to some extent by the high degree of integrity of the containment system and advantages in cargo flexibility.

Pressure vessel systems are independent of the ships hull, but rest on supports or stools, built into the ship structure. The support system design has to take into consideration the deflection forces transmitted from the hull through the tank supports. The pressure vessel tank system is known as the “Independent Tank, Tank C

**3.2 Semi-pressurized / Refrigerated Ships**

To increase cargo capacity and reduce cargo tank building costs by way of thickness reduction, the semi-pressurized concept was adopted. This concept covers a wide range of ships but basically all have pressure vessels which are suitable for carrying cargo at temperature below ambient. The grade of steel used dictates the tank temperature limitation which can be as low as -500C. All have tank insulation and reliquefaction systems.

If the cargo is to be carried refrigerated (i.e. at temperature below ambient), the tank has to be made from special materials. Normal steels have reduced ductility at temperatures below 00C becoming brittle and less able to with stand the stress at low temperatures

For marine purpose, normal mild steel is suitable for cargo temperature down to 00C. Steel with fine grain structure and improved tensile properties can be used at lower temperature. The IMO Code recognize five grade of such steel, known as grade A, B, C, D and E. The steel can be used for independent cargo tanks, depending on thickness with a temperature limit of 00C for grade D, and - 250C for Grade E. For temperature down to -550C, an alloy-steel is necessary for cargo tanks, the most common one being fully-killed fine grain aluminum treated carbon manganese steel. For temperature as low as -1040C (ethylene) or -1630C(LNG) metals such as aluminum alloys or special alloys such as nickel steels or stainless (austenitic) steels are necessary for cargo tank construction.

While early ships were designed for temperature between -100C and -330C, newer semi pressurized ships are almost without exception designed for -480C to allow fully refrigerated carriage of LPG, ammonia and the commercial chemical gases such as butadiene, vinyl chloride and propylene. These ships are larger than the fully pressurized ships, mostly between 2- 15,000 m3, although some ships are upto 30,000 m3. They trade on both coastal and deep sea routes and tend to use the hull volume more efficiently (e.g. tapered cylinders, bi-lobed tanks, transverse tanks. The number of tanks varies from two for the smallest, up to six. While earlier designs had tanks penetrating the deck to utilize the hull volume, IMO requirements for damage stability have virtually ruled out that arrangements on newer ships.

The ships normally have a full double bottom, and some have topside ballast tanks. **No secondary barrier is required**. The hold space is normally ventilated with fresh or dry air. This type of ship often has a reliquefaction system with a very high capacity.

**3.3 Fully refrigerated ships**

The design pressure of the tank depends on the intended degree of refrigeration of the cargo. If the cargo is refrigerated so that its pressure is equal to atmospheric, the cargo tank need not be of a pressure vessel configuration, the cargo is said to be fully refrigerated, and the carriage temperature is the cargo’s atmospheric boiling point. If the cargo is below ambient temperature, it is necessary to insulate the cargo tanks to reduce the effects of heat from the atmospheric warming the cargo up, and to prevent the cargo cooling normal hull steels below their limiting temperature. It is also necessary to design some means that deals with cargo boil-off generated by any heat exchange through the tank insulation.

Full-refrigerated ships have special insulation tanks made from aluminum or carbon manganese steel and have a reliquefaction plant. Although spherical and cylindrical tanks are not uncommon the majority have internally stiffened rectangular flat walled tanks tailored to fit the available ships hold space. The cargo is carried fully refrigerated at slightly above atmospheric pressure.

Because the tanks are tailored to fit the hold space cargo capacity is optimized. The ships are normally 5000m3 to 100,000m3 carrying cargoes between 00C and -550C. Cargo tanks are fully insulated and supported on chocks keyed to the hull to permit its expansion and contraction. This type of tank may be fitted with center line bulkheads to improve stability and reduce sloshing. Due to the low cargo temperature, a secondary containment is provided with many designs, using special steel for the tank top and steel for the tank top and steel work surrounding the cargo tank. The space between the cargo tank insulation and the ballast tank / hull is usually inerted. Ballast is carried in the double bottom tanks and in the top side ballast tanks.

**3.4 Ethylene Ships**

Ethylene is usually carried fully refrigerated at -1040C but the ships are often capable of carrying boiling point cargoes such as LPG.

These ships are generally built with Cargo tanks designed for a saturation pressure of between 3 and 7 kg/cm2 and have a two stage cascade reliquefaction cycle with refrigerant gas R-22 as a secondary refrigerant. The sizes are typically between 2-12000m3, and the cargo tanks are independent pressure vessels type “C” tanks made from nickel-steel or stainless steel. For the Type “C” tanks no secondary barrier is required. Cargo tanks have a thicker insulation than on fully refrigerated ships

**3.5 Liquefied Natural Gas (LNG ) ships**

LNG Carriers are specialized types of gas carriers built to transport large volumes of LNG at its atmospheric boiling point of about -162 0 C. These ships are now typically of between 125000 and 135000 m3 capacity and are normally dedicated to a specific project. Here they often remain for their contract life, which may be between 20-25 years or more. Apart from a few notable exceptions during the early years of LNG transport, the containment system on these ships is mainly of four types

* Gaz Transport membrane
* Technigaz membrane
* Kvaerner Moss spherical-independent Type B and
* IHI SPB Tank-prismatic

All LNG ships have double hulls throughout their cargo length which provides adequate space for ballast. Ships fitted with the membrane systems have a full secondary barrier and tanks of the type B design have drip-pan type protection. A characteristic common to all LNG ships is that they burn cargo boil- off as fuel.

Hold spaces around the cargo tanks are continuously inerted, except in the case of spherical Type B containment where hold spaces may be filled with dry air provided that there is an adequate means for inerting such spaces in the event of cargo leakage. Continuously gas monitoring of all hold spaces is required.

In general, reliquefaction plants have been little used on LNG ships. Being much colder than LPG, the necessary equipment is much more costly and is currently more economic to burn the boil –off gas in the ships main boilers. Most LNG carriers have steam turbines propulsion plants. Few medium sized ships are equipped with low speed, low injection pressure, dual fuel diesel engines.

Methane / LNG is carried at atmosphere pressure at – 1630 C in cargo tanks made from aluminum, nickel-steel or stainless (austenitic) steel and insulated. Most LNG ships are correctly described as fully insulated since they usually have no reliquefaction plant, boil off gas is normally burnt in the main propulsion machinery. The ships are large, mainly from 40,000 to 1,35,000 m3 , with four or six cargo tanks of type A, B or membrane. The space between the primarily and secondary barriers is inerted. However, for Type D system with only a partial secondary barrier, the hold space is usually filled with dry air. A full double bottom and side ballast tanks are fitted. The arrangement of primary and secondary barrier varies widely from system to system. The common proprietary designs are described as :

* Prismatic – Free Standing tank.
* Prismatic – Type B Tanks – The IHI Type B (known as SPB) system has Self-

Supporting prismatic tank.

* Spherical - Type B Free Standing tank the Moss – Roseborg.
* Membrane System.

**Various type of cargo that are required to be carried out as Liquefied Gas**

The most significant cargoes in terms of tonnages moved are ammonia, LPG (butane, propane and mixture of these), and LNG. Other cargoes of commercial significance are butadiene, butane, ethylene, propylene, and vinyl chloride.

Apart from ethylene, and LNG, all of these cargoes are below their critical temperature at ambient temperature. They can therefore be liquefied by pressure and carried at ambient temperature. This is not possible for ethylene and LNG because the critical temperatures are low and pressure is too high. All of these cargoes can be liquefied by cooling and carried semi-or fully refrigerated, this being the only practical proposition for LNG and Ethylene.

These cargoes are generally non-corrosive to metals except for ammonia which attacks zinc and copper. For this reason copper alloys (eg Brass) and zinc need to be excluded from the cargo systems of ships that intend to carry ammonia. Similarly aluminum alloys have to be excluded from the cargo system of ships that intend to carry vinyl chloride.

**4.1 Liquefied Petroleum Gases LPG**

The liquefied petroleum gases comprise of propane, butane and mixture of the two. Butane stored in cylinders and bottled gas is used as a domestic fuel for heating and cooking/ industrious fuel as well.

Liquefied Petroleum Gases are also an important octane enhancer for motor gasoline and a key petrochemical feed stock. LPG is mainly used to power generation, for industrial purposes such as metal cutting and as a petrochemical feed stock. About 169 million tones of LPG are produced annually world wide, and 43.7 million tons are transported by sea. Ref: - Liquefied Gas Handling Principles on ships & terminals - McGuire & White (SIGTTO)

**4.2 Ammonia**

With increased pressure on the world’s food resources, demand for Nitrogen containing fertlisers, based on ammonia, expanded strongly during the 1970s and 1980s. Natural gases, is the raw material for Ammonia production. Ammonia is also an industrial refrigerant, used in the production of explosives and for numerous industrial chemicals such as urea. World wide consumption of this major inorganic base chemical in 1996 was 120 million tones. About 12 million tones of ammonia are shipped by sea each year in large parcels on fully refrigerated carriers and this accounts for the third largest sea borne trade in liquefied gases after LNG and LPG.

**4.3 Ethylene**

Ethylene is one of the primary petrochemical building blocks. It is used in the manufacture of polyethylene, plastics, ethyl alcohol, poly vinyl chloride (PVC), antifreeze, polystyrene and polyester fibers.

It is obtained by cracking either naphtha, ethane or LPG. Of the 85 million tones of ethylene produced worldwide annually, some 2.5 million tones are moved long distances by sea on semi-pressurised carrier.

**4.4 Propylene**

Propylene is a petrochemical intermediate used to make polypropylene and poly urethane plastics, acrylic fibers, and industrial solvents. About 2.7 millions tonnes of this total are being carried by semi-pressurised ships on deep sea routes.

**4.5 Butadiene**

Butadiene is a highly reactive petrochemical intermediate. It is used to produce styrene, acrylonitrile and polybutadiene synthetic rubbers. Butadiene is used in paints and binders, for non-woven fabrics, and acts as an intermediate in plastic and nylon production. About 800,000 tonnes of Butadiene is traded by sea each year.

**4.6 Vinyl Chloride**

Vinyl chloride is an easily liquefiable, chlorinated gas used in the manufacture of PVC, the second most important thermoplastic in the world in terms of output. Vinyl chloride not only has a relatively high boiling point at – 140C, but also with a specific gravity of 0.97, much denser than the other common gas cargoes. About 786000 tonnes of Vinyl Chloride were transported by sea in 1996.

**4.7 Liquefied Natural Gas LNG**

Natural gas is transported to either by pipe line as a gas or by sea in its liquefied form as LNG.

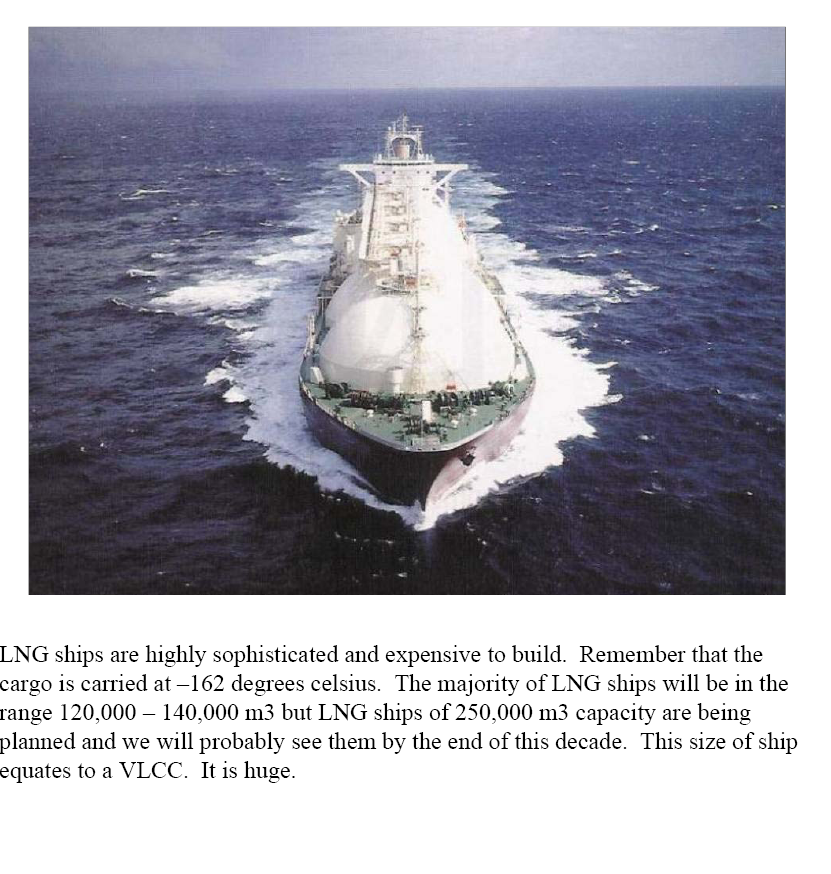
Natural gas comes from under-ground wells, which are mainly gas bearing (non-associate gas)

* Condensate reservoirs (Pentanes and heavier hydrocarbons)
* Large oil fields (associated gas)

Its composition varies according to where it is found, but methane is by far the predominant constituent, ranging from 70 percent to 99 percent. Natural gas is now a major commodity in the world energy market.

In 1997, almost 182 million cubic meters (or 82 million tones) of LNG were carried by sea and this is raised more than 100 million tones in 2005.

|  |
| --- |
| The world fleet of LNG ship is numbered 153 at the end of 2003.To meet the increase in global demand this number is expected to reach 200 by the end of 2006 and 240 by the end of 2010. Alone the US market will require an additional 68 large LNG ships by 2010. Currently over 65% of the world’s LNG Fleet has a carrying capacity in excess of 120,000 m3 equivalent to 72 million m3 of gas. That would be some vapour cloud . Traditionally LNG Ships have been constructed against specific long time contracts, but such is the expected growth in this trade it is predicted that a spot market for LNG ships should develop. |



**Environmental and Safety threats of Liquefied Gases**

The Liquefied Petroleum Gas and Liquefied Natural Gas are either flammable or toxic or both. Most are stored and handled at sub-zero temperature, or under pressure or by means of a combination of the two.

The Main Hazards relating to Environment, Health and Safety are:-

**6.1 Environment :-**

Construction and maintenance dredging, disposal of dredge spoil, construction of piers, wharves, breakwaters, and other water-side structures, and erosion may lead to short and long term impacts on aquatic and shoreline habitats. Additionally, the discharge of ballast water and sediment from ships during LNG terminal loading operations may result in the introduction of invasive aquatic species. For LNG facilities located near the coast (e.g. coastal terminals marine supply bases, loading / offloading terminals), guidance is provided in the Environment, Health and Safety Guidelines for Ports, Harbors, and Terminals.

**6.2 Hazardous Material Management**

Storage, transfer, and transport of LNG may result in leaks or accidental release from tanks, pipes, hoses, and pumps at land installations and on LNG transport vessels. The storage and transfer of LNG also poses a risk of fire and, if under pressure, explosion due to the flammable characteristics of its boil-off gas. In addition to the recommendations for hazardous materials and oil management discussed in the General EHS(Environmental, Health, and Safety) Guidelines, recommended measures to manage these types of hazards include:

* LNG storage tanks and components (e.g. pipes, valves, and pumps) should meet international standards for structural design integrity and operational performance to avoid catastrophic failures and to prevent fires and explosions during normal operations and during exposure to natural hazards. Applicable international standards may include provisions for overfill protection, secondary containment, metering and flow control, fire protection (including flame arresting devices), and grounding (to prevent electrostatic charge).
* Storage tanks and components (e.g. roofs and seals) should undergo periodic inspection for corrosion and structural integrity and be subject to regular maintenance and replacement of equipment (e.g. pipes, seals, connectors, and valves). A cathodic protection system should be installed to prevent or minimize corrosion, as necessary;
* Loading / unloading activities (e.g. transfer of cargo between LNG carriers and terminals) should be conducted by properly trained personnel according to pre-established formal procedures to prevent accidental releases and fire / explosion hazards. Procedures should include all aspects of the delivery or loading operation from arrival to departure, connection of grounding systems, verification of proper hose connection and disconnection, adherence to no-smoking and no-naked light policies for personnel and visitors.

**6.3 Spills :**

LNG is a cryogenic liquid (–162°C) that is not flammable in liquid form. However, boil-off gas (methane) forms as the LNG warms, and under certain conditions could result in a vapor cloud if released. Uncontrolled releases of LNG could lead to jet or pool fires if an ignition source is present, or a methane vapor cloud which is potentially flammable (flash fire) under unconfined or confined conditions if an ignition source is present. LNG spilled directly onto a warm surface (such as water) could result in a sudden phase change known as a Rapid Phase Transition (RPT)

In addition to recommendations for emergency preparedness and response provided in the General EHS(Environmental, Health, and Safety) Guidelines**,** recommended measures to prevent and respond to LNG spills include the following:

* Conduct a spill risk assessment for the facilities and related transport / shipping activities;
* Develop a formal spill prevention and control plan that addresses significant scenarios and magnitude of releases. The plan should be supported by the necessary resources and training. Spill response equipment should be conveniently available to address all types of spills, including small spills.
* Spill control response plans should be developed in coordination with the relevant local regulatory agencies;
* Facilities should be equipped with a system for the early detection of gas releases, designed to identify the existence of a gas release and to help pinpoint its source so that operator-initiated emergency shutdown devices ESD’s can be rapidly activated, thereby minimizing the quantity of gas releases.
* An Emergency Shutdown and Detection (ESD/D) system should be available to initiate automatic transfer shutdown actions in case of a significant LNG leak;
* For unloading / loading activities involving marine vessels and terminals, preparing and implementing spill prevention procedures for tanker loading and off-loading according to applicable international standards and guidelines which specifically address advance communications and planning with the receiving terminal;
* Ensuring that onshore LNG storage tanks are designed with adequate secondary containment (e.g., high nickel content welded steel inner tank and reinforced concrete outer tank; single wall tank with an external containment basin, full containment tank design) in the event of a sudden release;
* Facilities should provide grading, drainage, or impoundment for vaporization, process, or transfer areas able to contain the largest total quantity of LNG or other flammable liquid that could be released from a single transfer line in 10 minutes;
* Material selection for piping and equipment that can be exposed to cryogenic temperatures should follow international design standards;
* In case of a gas release, safe dispersion of the released gas should be allowed, maximizing ventilation of areas and minimizing the possibility that gas can accumulate in closed or partially closed spaces. Spilled LNG should be left to evaporate and evaporation rate should be reduced, if possible, e.g. covering with expanding foam;

**6.4 Waste water**

The **General Environment Health Safety ( EHS ) Guidelines** provide information on wastewater management, water conservation and reuse, along with wastewater and water quality monitoring programs. The guidance below is related to additional wastewater streams specific to LNG facilities.

***Cooling Water and Cold Water Streams***

The use of water for process cooling at LNG liquefaction facilities and for revaporization heating at LNG receiving terminals may result in significant water use and discharge streams.

Recommendations to control cooling and cold water use and discharge streams include the following:

* Water conservation opportunities should be considered for LNG facility cooling systems (e.g. air cooled heat exchangers in place of water cooled heat exchangers and opportunities for the integration of cold water discharges with other proximate industrial or power plant facilities).
* The selection of the preferred system should balance environmental benefits and safety implications.
* Cooling or cold water should be discharged to surface waters in a location that will allow maximum mixing and cooling of the thermal plume to ensure that the temperature is within 3 degrees Celsius of ambient temperature at the edge of the mixing zone or within 100 meters of the discharge point.
* If biocides / chemical use is necessary, carefully select chemical additives in terms of dose concentration, toxicity, biodegradability, bioavailability, and bioaccumulation potential. Consideration should be given to residual effects at discharge using techniques such as risk based assessment.

**6.5 Air emission:-**

Air emissions (continuous or non-continuous) from LNG facilities include combustion sources for power and heat generation (e.g. for dehydration and liquefaction activities at LNG liquefaction terminals, and regasification activities at LNG receiving terminals), in addition to the use of compressors, pumps, and reciprocating engines (e.g. boilers, turbines, and other engines).

Emissions resulting from flaring and venting, as well as from fugitive sources, may result from activities at both LNG liquefaction and regasification terminals. Principal gases from these sources typically include nitrogen oxides (NOX), carbon monoxide (CO), carbon dioxide (CO2), and, in case of sour gases, sulfur dioxide (SO2).

**6.6 Exhaust Gases**

Exhaust gas emissions produced by the combustion of natural gas or liquid hydrocarbons in turbines, boilers, compressors, pumps and other engines for power and heat generation, can be the most significant source of air emissions from LNG facilities. Air emission specifications should be considered during all equipment selection and procurement.

**6.7 Waste Management :-**

Non-hazardous and hazardous wastes routinely generated at LNG facilities include general office and packaging wastes, waste oils, oil contaminated rags, hydraulic fluids, used batteries, empty paint cans, waste chemicals and used chemical containers, used filters, spent sweetening and dehydration media (e.g. molecular sieves) and oily sludge from oil water separators, spent amine from acid gas removal units, scrap metals, and medical waste, among others. Waste materials should be segregated into non-hazardous and hazardous wastes and considered for re-use / recycling prior to disposal. A waste management plan should be developed that contains a waste tracking mechanism from the originating location to the final waste reception location. Storage, handling and disposal of hazardous and non-hazardous waste should be conducted in a way consistent with good EHS practice for waste management, as described in the General EHS Guidelines.

**6.8 Noise:-**

The main noise emission sources in LNG facilities include pumps, compressors, generators and drivers, compressor suction / discharge, recycle piping, air dryers, heaters, air coolers at liquefaction facilities, vaporizers used during regasification, and general loading / unloading operations of LNG carriers / vessels.

Atmospheric conditions that may affect noise levels include humidity, wind direction, and wind speed. Vegetation such as trees and walls can reduce noise levels. Installation of acoustic insulating barriers can be implemented, where necessary. Maximum allowable log equivalent ambient noise levels that should not be exceeded and general recommendations for prevention and control of noise are described in the General EHS(Environmental, Health, and Safety) Guidelines.

**6.9 LNG/LPG Transport:-**

Common environmental issues related to vessels and shipping (e.g. hazardous materials management, wastewater and other effluents, air emissions, and solid waste generation and management related to LNG tankers / carriers), and recommendations for their management are covered in the EHS Guidelines for Shipping. Emissions from tugs and LNG vessels, especially where the jetty is within close proximity to the coast, may represent an important source affecting air quality.

LNG vessel design, construction and operations should comply with international standards and codes relating to hull requirements (e.g. double hulls with separation distances between each layer), cargo containment, pressure / temperature controls, ballast tanks, safety systems, fire protection, crew training, among other issues.

Specific recommendations to mitigate Rapid Phase Transition (RPT) include the following:

* The pressure rating of the actual LNG cargo tanks should be maximized;
* The LNG cargo tanks pressure relief system should actuate as quickly as possible, in order to relieve the large volumes of vapor that can be generated by an RPT event.

**6.10 Security :-**

Unauthorized access to facilities should be avoided by perimeter fencing surrounding the facility and controlled access points (guarded gates). Public access control should be applied.

Adequate signs and closed areas should establish the areas where security controls begin at the property boundaries. Vehicular traffic signs should clearly designate the separate entrances for trucks / deliveries and visitor / employee vehicles. Means for detecting intrusion (for example, closed-circuit television) should be considered. To maximize opportunities for surveillance and minimize possibilities for trespassers, the facility should have adequate lighting.

**6.11 Health :-**

**6.11.1 Toxicity :-**

Toxicity is the ability of a substance to cause damage to living tissue, including impairment of the nervous system. Illness or in extreme cases, death may ccur when a dangerous gas or liquid is breathed, taken orally or absorbed through the skin. (In general, the terms ‘toxic’ and ‘poisonous’ can be considered synonymous.)

Many substances can act as poison and a person can be exposed to their effects by various routes. As a result toxicology has branched into several specialized areas, one of which is industrial toxicology. In this area the effects of chemicals in the air or on the body are evaluated.

Toxic substances are often ranked according to a system of toxicity ratings.

Threshold Limit Value (TLV)

Research into toxicity considers such factors as:-

- The length of exposure

* Whether contact is by inhalation, ingestion or through the skin
* The stress of the person and
* The toxicity of the product

**6.11.2 Asphyxia (suffocation**)

For survival, the human body requires air having a normal content of about 21% oxygen. Oxygen deficiency in an enclosed space can occur with any of the following conditions:-

* When large quantities of cargo vapour are present.
* When large quantities of inert gas or nitrogen are present
* Where rusting of internal tank surfaces has taken place.

A person affected may experience headache, dizziness and inability to concentrate, followed by loss of consciousness. In sufficient concentration, any Vapour may cause asphyxiate whether toxic or not.

Asphyxiation can be avoided by the use of Vapour and Oxygen detection equipment and breathing apparatus as necessary.

**6.11.3 Anesthesia:-**

Inhaling certain Vapour (eq. Ethylene Oxide) may cause loss of consciousness due to effect upon the nervous system. The unconscious person may react to sensory stimuli, but can only be roused with great difficulty. Anesthetic vapour hazards can be avoided by the use of Cargo Vapour detection equipment and breathing apparatus as necessary.

**6.11.4 Frost bite:-**

Many cargoes are either shipped at low temperature or are at low temperature during some stage of Cargo Operations. Direct contact with cold liquid or vapour or uninsulated pipes and equipment can cause cold burns or frostbite. Inhalation of cold vapour can permanently damage certain organs (e.g. Lungs).

Ice or frost may build up on uninsulated equipment under certain ambient conditions and this may act as insulation. Under certain conditions, however, little or no frost will form and in such cases contact can be particularly injurious.

Appropriate protective clothing should be worn to avoid frostbite, taking special care with drip trays on Deck which may contain cargo liquid.

**6.11.5 Chemical Burns :-**

Chemical burns can be caused by ammonia, chlorine, ethylene oxide and propylene oxide. The symptoms are similar to burns by fire, except that the product may be absorbed through the skin causing side effects. Chemical burn is particularly damaging to the eyes.

For the treatment of chemical burns, IMO Medical First Aid Guide must be referred. On Gas tankers authorized to transport these products, deck showers and eye baths are provided for water dousing; their locations should be clearly indicated.

**6.12 Safety :-**

**6.12.1 Flammability**

It is the vapour given off by a liquid and not the liquid itself which burns. A mixture of vapour and air lie between two concentrations known as Lower Flammable Limit (LFL) and the Upper Flammable Limit(UFL). The limits vary according to the cargo data sheets. Concentrations below the lower limit (too lean) or above the upper limit (too rich) cannot burn. However it is important to remember that concentrations above the upper limit can be made to burn by diluting them with air until the mixture is within a flammable range, and that pockets of air may exist in any system leading to the creation of a flammable mixture.

A liquid has to be at a temperature above its flash point before it evolves sufficient vapour to form a flammable mixture. Many liquefied gas cargoes are flammable, and since they are shipped at temperatures above their flash points flammable mixtures can be formed.

The source of flammable material may be vapour from the cargo, or from anything else that will burn. Oxygen normally is derived from the atmosphere which contains approximately 21% oxygen by volume. Ignition can be caused by anything capable of providing the necessary energy such as a naked flame, an electrical or electrostatic spark, or a hot metal surface.

Fire is prevented by ensuring that at least one of these three elements is excluded.

In the presence of a flammable substance, sources of ignition or oxygen should be excluded. Oxygen can be restricted to a safe level within the cargo system by keeping the pressure above atmospheric pressure with cargo vapour or inert gas. Many sources of ignition are eliminated during the design stage and care should be taken to ensure that design features are not impaired in any way. Other sources of ignition need to be excluded by correct operational practices.

Liquefied gas cargoes are usually carried either fully refrigerated or pressurised in order to avoid loss of cargo. Cargo vapour is evolved and treated in the following ways.

* During loading, vapour is displaced by cargo liquid; this vapour is either reliquified and returned to the tanks as a boiling liquid or returned to shore through a vapour return line.
* During the carriage, the cargo will boil off because of heat transfer through the insulation. In this case the vapour is either reliquefied or is (in the case of LNG only) burnt in Boilers or main engines. If the cargo system is fully pressurized any vapour will be retained within the cargo tank.
* During gas-freeing at sea, the vapour is normally a mixture of cargo vapour and inert gas or inert gas and air . It cannot be used as fuel or reliquefied, and is vented to atmosphere. During gas freeing in port, the vapour is returned through a shoreline.

Whatever methods are provided for handling vapour, it is essential to ensure that they function properly and are operated correctly. Failure to do so may create a hazard to the ship, the ship’s crew and the environment.

**6.12.2** **Protection against sources of ignition :**

* Smoking
* Portable Electrical Equipment
* Communication Equipment in Port
* Use Of tools
* Aluminum Equipment and paint
* Ship/Shore Insulating, Earthing and Bonding
* Auto Ignition
* Spontaneous Combustion
* Hot Work
* Static Electricity

**6.12.3 Fire-fighting and Fire Protection Equipment**

* Fire Fighting equipment should always be kept on good order, and should be available for use at all times.
* Flame Arrestors and Flame Gauge Screens should be maintained in good condition and replaced if they become defective.
* Inert Gas used in the cargo system (e.g. tanks, hold or interbarrier space) should be checked regularly to ensure that the oxygen concentration is below the required level and that the pressure is above atmosphere. All instruments and equipment in the system should be maintained in good condition.

**6.13 B L E V E :-**

A particular destructive form of vapour burn, associated with the storage of iquefied Gas in pressurized containers is the B L E V E (Boiling Liquid Expanding Vapour Explosion).

The BLEVE results from the catastrophic failure of vessel containing a liquid significantly above its boiling point at normal atmospheric pressure. The container may fail for any of the following reasons:- mechanical damages, corrosion, excessive internal pressure, flame impingement or metallurgical failure.

The most common cause of a BLEVE is probably when a fire increases the internal tank pressure of the vessels contents and flame impingement reduces its mechanical strength, particularly at those parts of the vessels still non cooled by internal fluid. As a result, the tanks suddenly splits, and pieces of the vessels shell can be thrown a considerable distance with concave sections such as end caps, being propelled like rockets if they contain liquids. Upon rupture, the sudden decompression produces a blast and the pressure immediately drops. At this time, the liquid temperature is well above its atmospheric boiling point and accordingly it spontaneously boils off, creating large quantities of vapour which are thrown upwards along with liquefied droplets.

Where the gas / air mixture is within its flammable limits, it will ignite from the red hot metal or the surrounding to create a fireball reaching gigantic proportions and the sudden release of gas provides further fuel for the rising fire ball. The rapidly expanding vapour produces further blast and intense heat radiation

Such BLEVE incidents have occurs with rail tank cars, road vehicles and in a number of terminal incidents. There have been no instances of this kind on Liquefied Gas carrier so far. Under the gas code, pressure relief valves are sized to cope with surrounding fire and this helps to limit this risk.

**6.14 Reactivity :-**

**With Itself (self reaction)**- The most common form of self reaction is polymerization which may be initiated by the presence of small quantities of other cargoes or by certain materials. Polymerization normally produces heat which may accelerate the reaction. Such cargoes which self react are to be carried under an inert gas blanket as per Code IMO. Ethylene Oxide, Propylene oxide are the examples

**With Air-** Some cargoes can react with air to form unstable oxygen compounds which could cause an explosion. Ethylene Oxide –reacts in air to form polymers. Air should be excluded from the cargo system before loading, and then excluded by maintaining a positive pressure of inert gas. The IMO Code requires these cargoes to be either inhibited or carried under nitrogen or other inert gas.

**With Other Cargoes-** Certain cargoes can react dangerously with one another. They should be prevented from mixing by using separate piping, and vent systems and separate refrigeration equipment for each cargo.

Positive segregation is to be maintained. Data Sheet for each cargo should be consulted to establish whether or not two cargoes will react dangerously. If outgoing cargo & incoming cargo are incompatible, Nitrogen should be used as intermediate atmosphere which is compatible with both of them.

**With Other Metal and Materials-**The data sheet list materials which should not be allowed to come into contact with the cargo. The materials used in the cargo systems must be compatible with the cargoes to be carried and care should be taken that no incompatible materials are used during maintenance (e.g gaskets).

Reaction can occur between cargo and purge vapours of poor quality: for instance, inert gas with high CO2 content can cause carbonate formation with ammonia. Reaction can also occur between compressor lubricating oils and some cargoes, resulting in blockage and damage.

**6.15 Corrosivity:-**

Some Cargoes and Inhibitors may be corrosive, and can attack human tissue. Appropriate data sheet to be referred and protective clothing should be observed.

**6.16 Low temperature effects :-**

As liquefied gas cargoes are often shipped at low temperatures it is important that temperature sensing equipment is well maintained and accurately calibrated.

**6.17 Brittle Fracture :-**

Hazards associated with low temperature include Brittle fracture. Most metals and alloys become stronger but less ductile at low temperature (ie the tensile and yield strength increase but the material becomes brittle and the impact resistance decreases) because the reduction in temperature changes the materials crystal structure.

Normal ship building steels, rapidly lose their ductility and impact strength below 00C. For this reason, care should be taken to prevent cold cargo from coming into contact with such steels, as the resultant rapid cooling would make the metal brittle and would cause stresses due to contraction. In this condition the metal would be liable to crack, the phenomenon occurs suddenly and is called brittle fracture.

However the ductility and impact resistance of material such as Aluminum, austenitic and special alloy steels and nickel improve at low temperature and these metals are used where direct contact with cargoes, at temperature below – 550C is involved.

**6.18 Spillage :-**

Care should be taken to prevent spillage of low temperature cargo because of the hazard to personnel and the danger of brittle fracture. If spill does occur, the source should first be isolated and the spilled liquid then dispersed. (The presence of vapour may necessitate the use of breathing apparatus). If there is a danger of brittle fracture, a water hose may be used to vapour the Liquid and to keep the steel warm. If the spillage is contained in a drip tray, the contents should be covered or protected to prevent accidental contact and allowed to evaporate. Liquefied gases quickly reach equilibrium and visible boiling ceases. This quiescent liquid could be mistaken for water and carelessness could be dangerous.

Suitable drip trays are arranged beneath manifold connections to control any spillage when transferring cargo or draining lines and connections. Care should be taken to ensure that unused manifold connections are isolated and that if blanks are to be fitted the flange surfaces are clean and frost free. Accidents have occurred because cargo escaped past incorrectly fitted blanks.

Liquefied gas spilt on to the sea will generate large quantities of vapour by the heating effect of water. This vapour may create a fire or health hazard or both. Great care should be taken to avoid such spillage, especially when disconnecting cargo hoses.

**6.19 Rollover:-**

Rollover is a spontaneous rapid mixing process which occurs in large tanks as a result of density, inversion. Stratification develops when the liquid large, adjacent to a liquid surface becomes more dense than the layers beneath, due to boil off of lighter fractions from the cargo. This obviously unstable situation relieves itself with a sudden mixing, which the name “roll over” aptly describes.

Liquid Hydrocarbons are most prone to rollover, especially cryogenic liquids. LNG is the most likely rollover by virtue of the impurities it contains and the extreme conditions of temperature under which it is stored,(close to the saturation temperatures, at storage pressures).

If the cargo is stored for any length of time and the boil-off is removed, evaporation can cause a slight increase in density and a reduction of temperature more cargoes is returned to one tank. In such circumstances, rollover may be prevented by returning condensate that is less dense, than the bulk liquid to the top of the tank, and condensate that is denser to the bottom of the tank.

No external intervention such as vibrations stirring or introducing new liquid is required to initiate rollover. The response to a small temperature difference within the liquid. (which will inevitably occur in the shipboard environment) is sufficient to provide the Kinetic energy to start rollover, and release the gravitational driving forces which will invert the tank contents. This inversion will be accompanied by violent evolution of large quantities of vapour and a very real risk of tank overpressure.

Rollover has been experienced ashore, and may happen on a ship that has been at anchorage for some time. If such circumstances are foreseen the tanks contents should be circulated by the cargo pumps to prevent rollover occurring.

Rollover can occur in smaller or compatible cargoes, if cargoes of different densities are put in the same tank. For example if tank pressure is maintained by boil-off reliquefaction, the condensate returned may be at slightly different temperature (and hence density) from the bulk liquid of the tank and likewise if condensate from two or more cargoes is returned to one tank. In such circumstances, rollover may be prevented by returning condensate that is less dense, than the bulk liquid to the top of the tank, and condensate that is denser to the bottom of the tank.

Rollover may also occur when two part cargoes are loaded into the same tank (e.g. propane and butane). In this case there will be a large boil-off (upto 3% in the total liquid volume) due to the heavy difference between the two. For this reason, the practice is considered unsafe unless a thorough thermo dynamic analysis of the process is undertaken and the loading takes place under strictly controlled conditions.

Rollover in a ship on passage is most unlikely. Essentially stratification and the subsequent rollover process are confined to shore LNG – Storage. However, of the use of LNG carriers for floating storage were to be introduced, personnel – manning such vessels would need to be aware of the problem and be vigilant to avoid rollover on their counterparts managing shore based storage.

**6.20 Pressure :-**

**High and Low pressure line failure effects:-**

Pressures above or below the design range can damage a system and operating personnel should be fully aware of any pressure limitation for each part of the cargo system; pressures should always be kept between the specified maximum and minimum.

**6.21 Pressure Surge :-**

High surge pressures ( shock pressures or ‘liquid hammers’) can be created if valves are opened or shut too quickly, and the pressure may be sufficient to cause hose or pipeline failure

**6.22 Pressurised Systems:-**

In pressurized systems, with the cargo at ambient temperature, there is normally no external frosting to indicate the presence of liquid or vapour anywhere in the system. Checks should be made for the presence of high pressure vapour or liquid by gauges and test cocks before opening valves etc.

It is possible for vapour trapped in a system to condense in cold weather, causing a slight reduction in pressure. If the cargo is inhibited, this condensed liquid will be uninhibited and the precautions should be observed.

**6.23 Reciprocating Compressors:-**

If vapour trapped in a reciprocating compressor condenses, it can dilute the lubricating oil in the crankcase which could cause bearing failure, overheating or possibly an explosion. The crankcase heating equipment, if fitted, should be used to reduce the possibility of cargo condensing and should be operated before the compressor is started. Liquid condensed in the compressor may also cause mechanical damage.

**6.24 Cargo Tank Pressures :-**

Cargo tank pressure should normally be maintained above atmospheric pressure to prevent the ingress of air and the possible formation of flammable mixtures. Positive pressures should be maintained if the tank contains any cargo vapour or inert gas. However, many pressure vessels are designed to withstand vaccum and it is possible to reduce tank pressure below atmospheric without drawing in air, for example during inerting and gas freeing

Cargo operations such as cooldown, warm up, loading and discharge may affect pressures in hold or interbarrier spaces. Pressures can also be affected by climatic changes and the variation in temperature between day and night.

Pressure in cargo tanks and hold or interbarrier spaces should be closely monitored, especially during cargo operations, and the equipment provided should be used to make the necessary adjustments. Particular care is necessary with membrane or semi membrane systems which are vulnerable to damage from vaccum or incorrect differential pressures because of the thin barrier material.

**6.25 Liquid Gas Samples:-**

Liquid gas samples should not be placed in containers which cannot withstand the pressure created by the sample at the highest ambient temperature expected. Sufficient ullage should be left in the container to ensure that it does not become full at the highest temperature anticipated. Liquid gas samples should be stored within the cargo area.

**6.26 Sloshing:-**

Within a range of tank filling levels, the pitching and rolling of the ship and the liquid free surface can create high impact pressure on the tank surface. This effect is called sloshing and can cause structural damage. Filling levels within this range must therefore be avoided.

**6.27 Pressure Relief Valve:-**

Pressure Relief Valves depend on accurate setting of opening and closing pressures for effective operation.

**6.28 Cargo Heat Exchangers :-**

Heat Exchangers should be pressure tested prior to use. This is especially important after a long period of idleness and before a ship is delivered on time charter. In addition to testing the tubes for tightness, the seawater low temperature cut-out must be tested to ensure that the cargo inlet valve to the heater closes, thereby avoiding damage to the tubes from freezing should the outlet temperature of the seawater fall below 5 degree centigrade.

In use, seawater flow through the heater must be established before product flow commences.

**Hazard Identification Techniques**

A comprehensive review of hazard identification techniques, as they apply directly to gas tankers and terminals, has been compiled by SIGTTO. Potentially hazardous events, typical prevention measures and further guidance is given on all operational aspects, including:

* Supply of liquefied gas to terminal
* Terminal export to land-based consumers
* Terminal storage
* Terminal refrigeration systems
* Loading system from terminal to ship
* Shore to ship connections from terminal to ship
* Ship reception systems for loading
* Ship off-loading to terminal
* Ship to shore connections for off-loading
* Terminal reception systems for off-Ioading
* Ship storage tanks and re-liquefaction systems
* Ship berthing
* Ship leaving berth
* Ship movement from sea to berth
* Ship movement from berth to sea
* Ship awaiting loading/off-loading offshore

**8.1 CONSEQUENCES OF CERTAIN TYPES OF ACCIDENT**

The main hazard identified in the marine transportation of liquefied gas is without doubt a large release or spillage of refrigerated gas and the subsequent vapour dispersion and/or combustion. Extensive studies have been conducted to understand these processes.

LNG and refrigerated LPG, as discussed are described as boiling liquids. They are stored at temperatures a few degrees above their boiling point, where their vapour pressure is slightly above that of ambient air pressure. If a release takes place to the atmosphere any of the following could occur simultaneously:

* Outflow of liquid into the surrounding environment
* Liquid spreading on the substrate to form a pool
* Evaporation or boiling to give a vapour which is heavier than air above the pool due to its temperature and /or its molecular weight.
* Dispersion of the Gas by the Wind and its subsequent dilution with air.

The first aspect to consider in the prediction of the consequences of any accidental release is the rate at which LNG or LPG would be released into the environment and what quantity would be released. Both answers will depend on parameters such as the size and shape of the tank, the position of the orifice, the nature of the product, pressures and temperatures inside and outside the tank and whether the leak occurs on land or in water.

**8.2.2 Frequency of Ship Incidents** — There are five main concerns with regard to ship operations.

* Collision, where two vessels under way run into each other.
* Striking, where a vessel moored in a port, alongside a berth, or a jetty is struck by a passing vessel.
* Impact ,where a vessel runs into a dock wall or jetty.
* Grounding, where a vessel runs onto shore or submerged rocks.
* Fire/explosion, where a fire on the vessel spreads to involve the cargo, or where an explosion is initiated in the cargo itself.

In addition to these main concerns ,following potential concerns are also considered in each case, but are usually found to be negligible when compared with other risks:

* Foundering/capsize — where the ship sinks in rough weather or because of leaks.
* Structural failure where the cargo tank cracks due to fatigue, wave load, vibration or adverse cargo load distribution.
* Aircraft strike — where an aero plane or helicopter crashes into the ship.
* Spontaneous failure where a manufacturing defect leads to an apparently spontaneous failure of the cargo tank.
* Refrigeration failure — where breakdown of the refrigeration plant on liquefied gas ship leads to the cargo boiling and escaping.
* Domino accident where an accident on one ship either causes or is caused by an accident on a nearby ship.

Data may be available for existing facilities from the Port Authority or from the

Operator’s own incident records. Where generic data is not appropriate for a particular situation, simulation methods may be adopted, to estimate ship incidents and release frequencies.

When assessing the critical speeds at which collisions and groundings would cause significant damage to a vessel, account should be taken of the following factors:

* The angle of approach and the location of impact on the struck ship.
* Whether the struck ship was moored alongside or floating free.
* The effect of added water mass on the dissipation of energy in the water.
* The draft and freeboard of the striking ship in relation to those of the struck ship.
* The apportionment of energy absorbed between the two ships, taking into account the form and stiffness of the striking ship’s bow.

0perational guide in ports, published by the International Chamber of Shipping. and others for example “The safety inspection guidelines and terminal safety check list for gas carriers” published by OCIMF (OIL