NYK-FIL
MARITIME E-TRAINING, INC.

ADVANCED TRAINING FOR SERVICE ON SHIPS SUBJECT TO THE IGF CODE

Introduction

Course Objective:

The course intends for safe operations of ships designed according to the IGF code and designed in accordance with the requirements for seafarers on ships using gases or other low-flashpoint fuels. The course is designed to meet the requirements of the STCW Convention amendments:

- Part A, Chapter V - *Special training requirements for personnel on certain types of ships*, required by regulation V/3, paragraph 8, in accordance with their capacity, duties and responsibilities as set out in table A-V/ 3-2 — *Specification of minimum standard of competence in advanced training for ships subject to the IGF Code*, and

- Part B, Section B-V/3 – *Guidance regarding the training and qualifications of masters, officers, ratings and other personnel on ships subject to the IGF Code*

Course Contents:

1. Familiarity with physical and chemical properties of fuels aboard ships subject to the IGF Code
2. Operate controls of fuel related to propulsion plant and engineering systems and services and safety devices on ships subject to the IGF Code
3. Ability to safely perform and monitor all operations related to the fuels used on board ships subject to the IGF Code
4. Plan and monitor safe bunkering, stowage and securing of the fuel on board ships subject to the IGF Code
5. Take precautions to prevent pollution of the environment from the release of fuels from ships subject to the IGF Code
6. Monitor and control compliance with legislative requirements
7. Take precautions to prevent hazards'
8. Apply occupational health and safety precautions and measures on board a ship subject to the IGF Code
9. Knowledge of the prevention, control and fire-fighting and extinguishing systems on board ships subject to the IGF Code

WHY TRAINING

$$\textit{Risk} = \frac{\text{Consequence * Probability}}{\text{Knowledge}}$$

Technology can reduce Consequence and Probability
Adding knowledge -> Reduce Risk!

- ***Design, construction and operation:*** INTERNATIONAL CODE OF SAFETY FOR SHIPS USING GASES OR OTHER LOW-FLASHPOINT FUELS (IGF CODE)"

- *Safety training:* STCW Chapter V- Special training requirements for seafarers on ships using gases or other Low-flashpoint fuels

- *Environment:* MARPOL 73/78, Annex VI outlines international requirements for vessel air emissions and shipboard air pollution prevention measures.

1. Simple chemistry and physics and relevant definition of related to safe bunkering and use of fuels used on board ships

1.1. Chemical structure of different fuels

.1 Explain the chemical structure of different fuels subject to the IGF Code

<u>HYDROGEN</u>

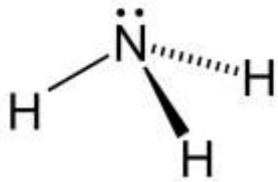
- It can be used as fuel under the IGF Code, even though detailed provisions are not yet developed (alternative design approach to be used).

- First element in the periodic table. In normal conditions it's a colorless, odorless and insipid gas, formed by diatomic molecules, H2. The hydrogen atom, symbol H, is formed by a nucleus with one unit of positive charge and one electron. Its atomic number is 1 and its atomic weight 1,00797 g/mol. It's one of the main compounds of water and of all organic matter, and it's widely spread not only in The Earth but also in the entire Universe. There are three hydrogen isotopes: protium, mass 1, found in more than 99,985% of the natural element; deuterium, mass 2, found in nature in 0.015% approximately, and tritium, mass 3, which appears in small quantities in nature, but can be artificially produced by various nuclear reactions.

  The cleanest fuel is hydrogen produced using renewable energy. Liquefied hydrogen could be used in future shipping applications. However, because of its very low energy density it requires large storage volumes, which may prevent hydrogen from being used directly in international deep-sea shipping. In a sustainable energy world where the entire energy demand is covered by renewable, CO2-free sources, hydrogen and CO2 will be the basic ingredients for fuel production, most likely in the form of methane or diesel-like fuels produced in a Sabatier/Fischer-Tropsch process. The Sabatier process is a reaction between hydrogen and carbon dioxide at elevated temperatures – optimally 300 to 400°C – and pressures in the presence of a nickel catalyst to produce methane and water. An alternative, the Fischer-Tropsch process converts a mixture of carbon monoxide and hydrogen into liquid hydrocarbons in a series of chemical reactions.

Looking ahead, LNG has already overcome the hurdles of international legislation, and methanol and biofuels will follow suit very soon. It will be a while before LPG and hydrogen are covered by appropriate new regulations within the IMO IGF Code as well. The existing and upcoming environmental restrictions can be met by all alternative fuels using existing technology.

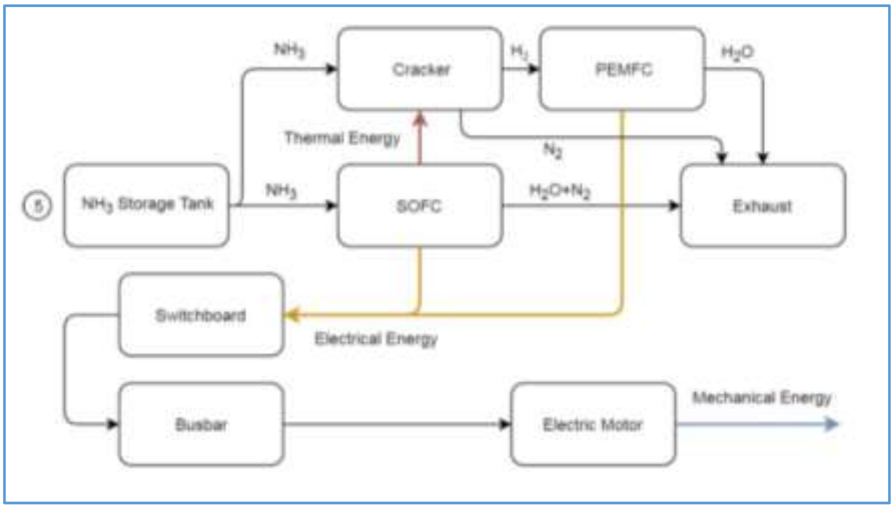
AMMONIA



- It can be used as fuel under the IGF Code, even though detailed provisions are not yet developed (alternative design approach to be used.

Ammonia fuel technologies and propulsion systems

The consortium will assess potential technologies and system configurations for using ammonia, both as a direct fuel and also as a hydrogen carrier. The technologies under consideration include internal combustion engines as well as two types of fuel cell, PEMFC (proton-exchange membrane fuel cell, which requires high-purity hydrogen fuel) and SOFC (solid oxide fuel cell, which can use ammonia fuel directly).



To illustrate the range of options under consideration, the slide on the right shows one potential configuration, the fifth pictured in de Vries's presentation. It shows a hybrid setup that combines both an SOFC, fueled with ammonia, and a PEMFC, fueled with hydrogen that is produced from ammonia, on-demand, using an on-board ammonia cracker.

The safety of ammonia as a maritime fuel

The project also includes an in-depth assessment of the safety of ammonia, which it will examine from four angles: bunkering, storage, consumption, and leakage / system failure. To ensure that the resulting analysis is relevant to the shipping sector, the consortium is working with a classification society from the outset.

Every fuel possesses safety challenges. For batteries, "their high energy density imposes additional risk management requirements." Hydrogen "would need careful risk management.

It has a very wide flammable range and very low minimum ignition energy, while embrittlement of metals might lead to leakages." And "widespread use of nuclear fuels is unlikely to be viewed as politically acceptable by the majority of governments, due to concerns about safety and security." With ammonia, the primary risk is clear: "Exposure to gaseous anhydrous ammonia can cause caustic burns, lung damage and death."

Physical properties, chemical properties and uses of ammonia

Physical Properties of Ammonia

- Ammonia is a colorless gas.
- It has a pungent odor with and an alkaline or soapy taste. When inhaled suddenly, it brings tears into the eyes.
- It is lighter than air and is therefore collected by the downward displacement of air.
- It is highly soluble in water: One volume of water dissolves about 1300 volumes of ammonia gas. It is due to its high solubility in water that the gas cannot be collected over water.
- It can be easily liquefied at room temperature by applying a pressure of about 8-10 atmosphere.
- Liquid ammonia boils at 239.6 K (- 33.5°C) under one atmosphere pressure. It has a high latent heat of vaporization (1370 J per gram) and is therefore used in refrigeration plants of ice making machines.
- Liquid ammonia freezes at 195.3 K (-77.8°C) to give a white crystalline solid.

Chemical Properties of Ammonia

Thermal stability

- Ammonia is highly stable. However, it can be decomposed into hydrogen and nitrogen by passing over heated metallic catalysts or when electric discharge is passed through it.

Combustibility

- Ammonia is combustible in air. However, it will burn in an atmosphere of oxygen

METHANOL

Methanol is a liquid chemical with the formula CH3OH (often abbreviated MeOH). It is colorless, volatile, flammable, and poisonous. Methanol is made from the destructive distillation of wood and is chiefly synthesized from carbon monoxide and hydrogen. Its principal uses are in organic synthesis, as a fuel, solvent, and antifreeze.

Toxicity

In humans, methanol has a high toxicity. As little as 10 mL can cause permanent blindness if ingested by destruction of the optic nerve. Only 30 ml can be fatal, although the typical fatal dose is 100-125 ml (4 fl oz). However, toxic effects take hours before they are evident and effective antidotes can often prevent permanent damage.

Methanol is a clear, colourless liquid that quickly dissolves in water and biodegrades rapidly. The environmental effects of a large methanol spill would be much lower than those from an equivalent oil spill.

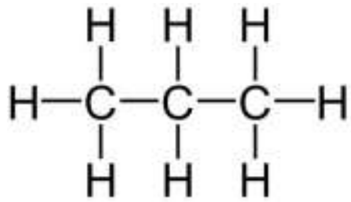
Methanol as Fuel

Methanol is a clean-burning fuel that produces fewer smog-causing emissions than conventional fuels — such as SOx, NOx and particulate matter. It can help ships meet environmental fuel regulations and improve air quality and related human health issues. Methanol marine fuel complies with the most stringent regulations in Emission Control Areas and would comply with even the most stringent future emissions regulations currently being considered.

.2 Identify the different examples of typical and low flash point fuels that are saturated hydrocarbons

Hydrocarbon is an organic compound made of nothing more than carbons and hydrogens. It is possible for double or triple bonds to form between carbon atoms and even for structures, such as rings, to form.

Components of Hydrocarbons



A compound composed mainly of C and H. They are part of our everyday life in the form of LPG, gasoline etc. There are a large number of hydrocarbon compounds. The structures of hydrocarbons vary with number of Carbon atoms and also with different bonding.

Hydrogen is the chemical element with the symbol H and atomic number 1. With a standard atomic weight of 1.008, hydrogen is the lightest element in the periodic table. Hydrogen is the most abundant chemical substance in the Universe, constituting roughly 75% of all baryonic mass.

Carbon is a chemical element, like hydrogen, oxygen, lead or any of the others in the periodic table. Carbon only becomes carbon dioxide when each atom of carbon joins with two atoms of oxygen (hence the chemical formula of carbon dioxide, CO2).

Properties of Hydrocarbon

Because the structure of different hydrocarbons can vary so drastically, the properties of each class of molecule vary greatly as well. In order to help categorize the properties of hydrocarbons, they are broken up into several basic types.

- Alkanes – These are referred to as saturated hydrocarbons. Saturated has a specific definition in terms of carbon-based molecules. Carbon can form up to four separate bonds with four separate other atoms. However, it is also possible for carbon to form multiple bonds with a single atom, even another carbon atom. When two carbon atoms in a hydrocarbon are linked together by two or more bonds rather than one, the molecule is termed unsaturated. All alkanes are saturated, which means they only contain single bonds between all carbon atoms. Alkanes are the basis of petroleum fuels and are found in linear and branched forms.

- Unsaturated Hydrocarbons – Those hydrocarbons that have one or more double bonds between carbon atoms are called alkenes. Those with one or more triple bonds between carbon atoms are called alkynes. These are mixed with alkanes in petroleum and contribute more carbon dioxide per pound than do saturated hydrocarbons.

- Cycloalkanes – Any hydrocarbon containing one or more ring structures. These are generally used for the same functions as the non-cyclic alkanes, though they have additional uses in creating certain plastics and in pharmaceutical bases.

- Aromatic Hydrocarbons – This class of molecules has specialized ring structures where bonds between carbon atoms are an intermediate between single and double bonds. Molecules in this class include the industrial solvent benzene.

The structure, hydrogen to carbon ratio, and the length of a particular hydrocarbon determine its properties. In general, small linear hydrocarbons will be gases while medium sized linear hydrocarbons will be liquids. Branched hydrocarbons of intermediate size tend to be waxes with low melting points. Long hydrocarbons tend to be semi-solid or solid. Unsaturated hydrocarbons are more likely to be solid than their saturated counterparts as are cyclic hydrocarbons.

Flash point

- The lowest temperature at which vapour of a volatile material can be ignited with an ignition source present

Saturated Hydrocarbon Examples

Name of saturated hydrocarbon	Structural formula
Methane	CH_4
Ethane	CH_3-CH_3
Propane	CH_3-CH_2-CH_3
Butane	CH_3-CH_2-CH_2-CH_3
Pentane	CH_3-CH_2-CH_2-CH_2-CH_3
Hexane	CH_3-CH_2-CH_2-CH_2-CH_2-CH_3
Heptane	CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3

Saturated Hydrocarbon vs Unsaturated Hydrocarbon

We know that saturated hydrocarbons contain only single bonds between carbon atoms of parent chain of molecule. Each carbon atom acquires tetravalency and connected with four other atoms in molecule. Since all are single covalent bonds which are sigma bonds, C-C bonds are very strong and difficult to cleave under normal conditions. It makes the saturated hydrocarbons least reaction hydrocarbons. On the other hand, unsaturated hydrocarbons have multiple covalent bonds like double or triple covalent bonds between carbon atoms of parent chain.

These hydrocarbons are called as unsaturated hydrocarbons. Alkenes, alkynes, cycloalkenes and cycloalkynes are examples of unsaturated hydrocarbons.
Unsaturated hydrocarbons have double or triple covalent bonds which have pi-bonds. Pi-bonds are weaker than sigma bonds so pi-bonds can easily cleave. Therefore, alkenes and alkynes can easily give addition reactions. Some common differences between saturated and unsaturated hydrocarbons are listed below;

Properties	Saturated hydrocarbons	Unsaturated hydrocarbons
Type of covalent bond	Single covalent bond	Double and triple covalent bond
Sigma / Pi bond	Sigma bond	Pi-bond
Chemical reactivity	Least reactive compound	Reactive hydrocarbons
Type of reactions	Substitution reactions	Addition reactions
Examples	Alkanes, cycloalkanes	Alkenes, alkynes, cycloalkenes and cycloalkynes

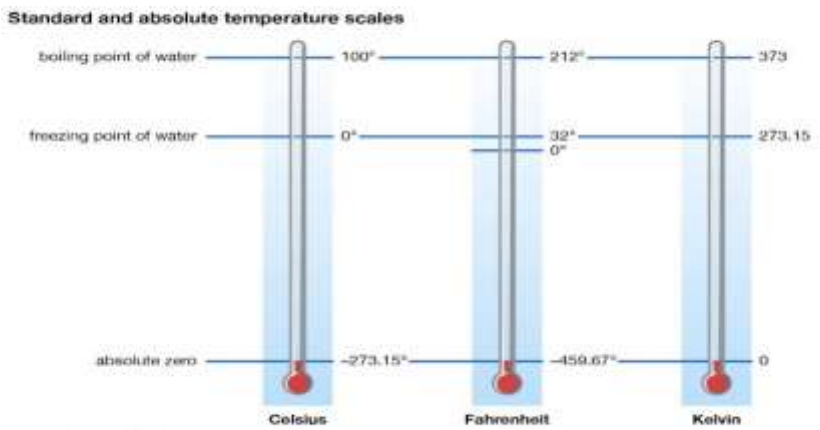
Saturated hydrocarbons, e.g. **methane, ethane, propane and butane,** are colorless and odorless. Alcohols like methanol and ethanol are relevant IGF Code fuels and their different chemical properties the vapor from methanol and ethanol are heavier than air.

1.2 THE PROPERTIES AND CHARACTERISTICS OF FUELS USED ON BOARD SHIPS SUBJECT TO THE IGF CODE

.1 Explain the properties and characteristics of low flash point fuels

Absolute Temperature

- is temperature measured using the Kelvin scale where zero is absolute zero. The zero point is the temperature at which particles of matter have their minimum motion and can become no colder (minimum energy).
- It's the temperature of a body in absolute units (ie. a scale that can have no negative value). The two most commonly used scales are the Kelvin (corresponding to the Celsius scale) and the Rankine (corresponding to the Fahrenheit scale).
- These scales are derived from kinetic theory by which a temperature of a gas is a function of its internal energy. Thus, at 0K, a body will have no energy. Needless to say, this is a conceptual situation. To bring a body down to absolute zero will require an infinite number of heat transfers, according to the third law of thermodynamics.



Absolute Temperature or Absolute Zero:

Since volume is directly proportional to its Kelvin temperature, the volume of the gas is theoretically zero at zero Kelvin or -273°C.

However, this is indeed hypothetical because all gases liquefy and then solidity before this low temperature reached. In fact, no substance exists as a gas at the temperature near Kelvin zero, through the straight-line plots can be extra plotted to zero volume. The temperature corresponds to zero volume is -273°C

Absolute Pressure

- Absolute pressure is measured relative to absolute zero on the pressure scale, which is a perfect vacuum. (Absolute pressure can never be negative.) Absolute pressure is indicated by p, and is identical to the familiar thermodynamic pressure.

Enthalphy

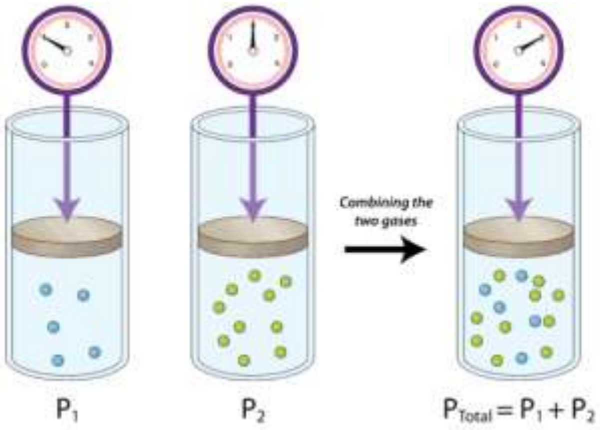
- Enthalpy, the sum of the internal energy and the product of the pressure and volume of a thermodynamic system. Enthalpy is an energy-like property or state function—it has the dimensions of energy (and is thus measured in units of joules or ergs), and its value is determined entirely by the temperature, pressure, and composition of the system and not by its history. In symbols, the enthalpy, H, equals the sum of the internal energy, E, and the product of the pressure, P, and volume, V, of the system: H = E + PV.

  convert S.I. units to other common units using a chart

Dalton's law of partial pressures

- Dalton's Law (also called Dalton's Law of Partial Pressures) states that the total pressure exerted by the mixture of non-reactive gases is equal to the sum of the partial pressures of individual gases. Mathematically, this can be stated as follows:

  Ptotal=P1+P2+...+Pn



Volume and temperature are constant

The principles of Joule's law in relation to the characteristics of fuels

Joule's second law

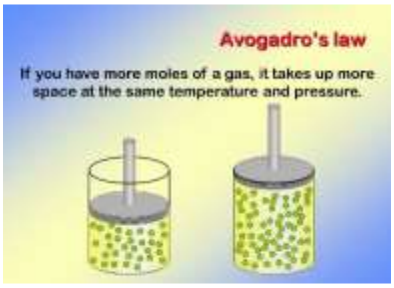
- For any gas whose equation of state is given exactly by pV = nRT (or pv = RT), the specific internal energy depends on temperature only. This rule was originally found in 1843 by an English physicist James Prescott Joule experimentally for real gases and is known as Joule's second law:

  The internal energy of a fixed mass of an ideal gas depends only on its temperature (not pressure or volume).

The principles of Avogadro's law in relation to the characteristics of fuels

Avogadro's law

- sometimes referred to as **Avogadro's hypothesis** or **Avogadro's principle** is an experimental gas law relating the volume of a gas to the amount of substance of gas present.
- Avogadro's law states that "equal volumes of all gases, at the same temperature and pressure, have the same number of molecules."



For a given mass of an ideal gas, the volume and amount (moles) of the gas are directly proportional if the temperature and pressure are constant. The law can be written as:

$$V \propto n$$

or

$$\frac{V}{n} = k$$

Where:

V is the volume of the gas;

n is the amount of substance of the gas (measured in moles);

k is a constant for a given temperature and pressure.

This law describes how, under the same condition of temperature and pressure, equal volumes of all gases contain the same number of molecules. For comparing the same substance under two different sets of conditions, the law can be usefully expressed as follows:

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

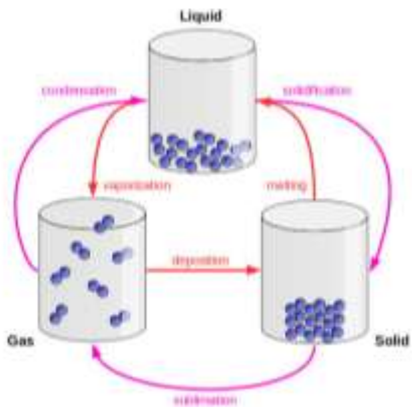
The equation shows that, as the number of moles of gas increases, the volume of the gas also increases in proportion. Similarly, if the number of moles of gas is decreased, then the volume also decreases. Thus, the number of molecules or atoms in a specific volume of ideal gas is independent of their size or the molar mass of the gas.

THE STATE OF MATTER IN RELATION TO SHIPS SUBJECT TO THE IGF CODE

Three States of Aggregation

There are three commonly recognized state of matter: **solid, liquid and gas.**

In addition to these three states of matter, scientists also distinguish three additional states - plasma and the Bose-Einstein and the fermionic condensates.



What is a state of aggregation?

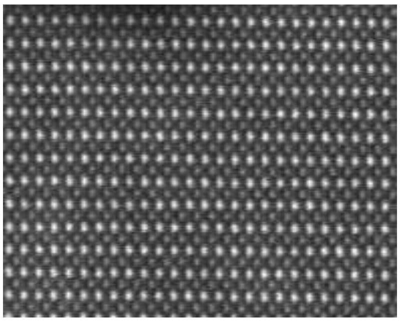
Every material in our environment is in a particular state, like liquid, solid or gaseous. Every material can be in every state. Sometimes it is quite difficult to imagine materials like iron in a gaseous state, but if a certain level of temperature is reached, also iron can be in a gaseous state.

How is the process from one state to the other state called?
The process, when a material changes its state by heating or cooling the material are differently called:

- From solid to liquid: melting
- From liquid to gaseous: evaporation
- From gaseous to solid: deposition
- From gaseous to liquid: condensation
- From liquid to solid: solidification
- From solid to gaseous: sublimation

A liquid boil at a temperature at which its vapor pressure is equal to the pressure of the gas above it. The lower the pressure of a gas above a liquid, the lower the temperature at which the liquid will boil.

States of Matter

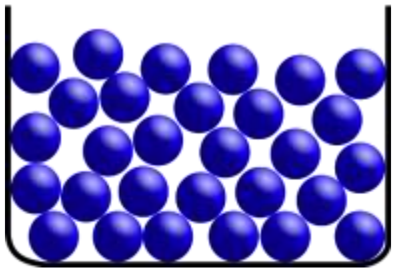


Solids A solid's particles are packed closely together. The forces between the particles are strong enough that the particles cannot move freely; they can only vibrate. As a result, a solid has a stable, definite shape and a definite volume. Solids can only change shape under force, as when broken or cut.

In crystalline solids, particles are packed in a regularly ordered, repeating pattern. There are many different crystal structures, and the same substance can have more than one structure. For example, iron has a body-centered cubic structure at temperatures below 912 °C and a face-centered cubic structure between 912 and 1394 °C. Ice has fifteen known crystal structures, each of which exists at a different temperature and pressure.

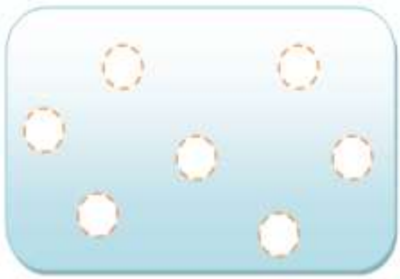
A solid can transform into a liquid through melting, and a liquid can transform into a solid through freezing. A solid can also change directly into a gas through a process called sublimation.

Liquids



A liquid is a fluid that conforms to the shape of its container but that retains a nearly constant volume independent of pressure. The volume is definite (does not change) if the temperature and pressure are constant. When a solid is heated above its melting point, it becomes liquid because the pressure is higher than the triple point of the substance. Intermolecular (or interatomic or interionic) forces are still important, but the molecules have enough energy to move around, which makes the structure mobile. This means that a liquid is not definite in shape but rather conforms to the shape of its container. Its volume is usually greater than that of its corresponding solid (water is a well-known exception to this rule). The highest temperature at which a particular liquid can exist is called its critical temperature.
A liquid can be converted to a gas through heating at constant pressure to the substance's boiling point or through reduction of pressure at constant temperature. This process of a liquid changing to a gas is called evaporation.

Gases



Gas molecules have either very weak bonds or no bonds at all, so they can move freely and quickly. Because of this, not only will a gas conform to the shape of its container, it will also expand to completely fill the container. Gas molecules have enough kinetic energy that the effect of intermolecular forces is small (or zero, for an ideal gas), and they are spaced very far apart from each other; the typical distance between neighboring molecules is much greater than the size of the molecules themselves.

A gas at a temperature below its critical temperature can also be called a vapor. A vapor can be liquefied through compression without cooling. It can also exist in equilibrium with a liquid (or solid), in which case the gas pressure equals the vapor pressure of the liquid (or solid).

A supercritical fluid (SCF) is a gas whose temperature and pressure are greater than the critical temperature and critical pressure. In this state, the distinction between liquid and gas disappears. A supercritical fluid has the physical properties of a gas, but its high density lends it the properties of a solvent in some cases. This can be useful in several applications. For example, supercritical carbon dioxide is used to extract caffeine in the manufacturing of decaffeinated coffee.

Liquid and vapour densities

the density of liquid gas and vapour of fuel subject to IGF code

Density of Liquid

Liquid density data are essential in process engineering design such as sizing of storage vessels that contain the basic raw materials and products for a plant, in process piping design involving either single-phase incompressible fluids, compressible fluids or two-phase flow mixtures. In distillation, absorption, or stripping, liquid density data are required in the determination of flooding and sizing of column diameter. Additionally, liquid density usage is encountered in various heat-, mass-, and momentum-transfer operations.

Density of Gas
As you know, density is defined as the mass per unit volume of a substance. Since gases all occupy the same volume on a per mole basis, the density of a particular gas is dependent on its molar mass. A gas with a small molar mass will have a lower density than a gas with a large molar mass. Gas densities are typically reported in g/L. Gas density can be calculated from molar mass and molar volume.

There are two (2) ways to look at density of gases:
1. The small-scale action of individual air molecules
2. The large-scale action of a large number of molecules

Gas Density examples based upon differences in molecular weight
Density of a gas with a constant number of molecules in a constant volume, varies according to the molecular weight. The higher the molecular weight the higher the density.

Gas Density based upon differences in temperature
The density of gases depends upon the temperature. The higher the temperature, the more the molecules are spread out and the lower the density as shown in the graphic on the left. The result is that warm gases rise and cool gases sink. The same concept helps to explain the weather resulting in high and low pressures. High pressure means high density, cooler, sinking air. Low pressure means low density, warmer, rising air.

Density of Vapours
Vapour density is the density of a vapour in relation to that of hydrogen. It may be defined as mass of a certain volume of a substance divided by mass of same volume of hydrogen.

Vapour density = mass of n molecules of gas / mass of n molecules of hydrogen.
Therefore: vapour density = molar mass of gas / molar mass of H_2

Variations of Density with Temperature
The density of a substance varies with temperature and pressure. Density is the ratio of mass to volume. When the temperature varies, the volume of the liquid changes. E.g. Liquids expand on heating. So due to this change is volume, the density varies with change in temperature.

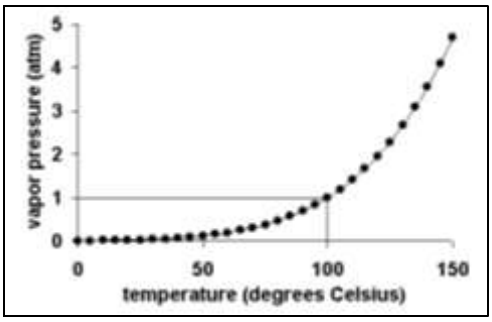
In simpler words, heating a substance causes molecules to speed up and spread slightly further apart, occupying a larger volume that results in a decrease in density. Also, cooling a substance causes molecules to slow down and get slightly closer together, occupying a smaller volume that results in an increase in density.

Vapour Pressure
The vapor pressure or equilibrium vapor pressure is defined as the pressure exerted by a vapor that is in thermodynamic equilibrium with the condensed phase (solid or liquid) at a given temperature in a closed system. The equilibrium vapor pressure is an indication of the

evaporation rate of a liquid. A substance with a high vapor pressure at normal temperatures is often referred to as volatile.

Variation of Vapor Pressure with Temperature

The vapor pressure of a liquid varies with its temperature, as the following graph shows for water. The line on the graph shows the boiling temperature for water.



As the temperature of a liquid or solid increases its vapor pressure also increases. Conversely, vapor pressure decreases as the temperature decreases.

Boil-off and weathering of cryogenic fuels

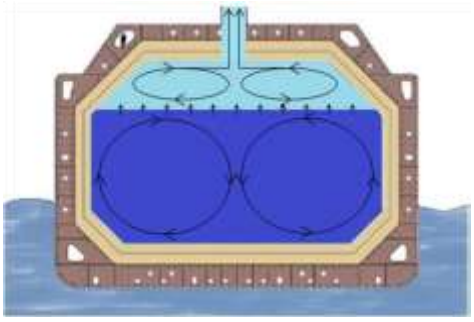
Explain how the boil-off occur

What are the main sources of Boil-Off?

There are several sources responsible for Boil-Off Gas generation: (1) heat ingress source, (2) sloshing of fuel, (3) cooling down of tanks, (4) LNG loading and unloading conditions and (5) the fuel tanks pressure.

(1) Heat ingress

The ingress of heat via the fuel tank insulation into fuel tanks is due to the difference between the temperature in the fuel tanks and the temperature of the environment surrounding it.



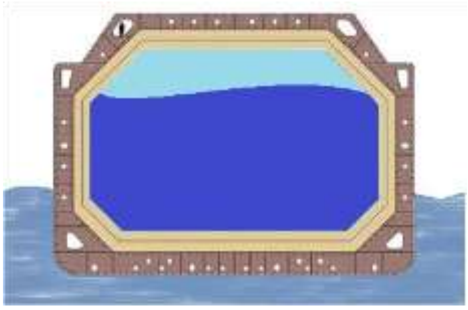
The liquid bulk receives the heat flux through the side and bottom walls of the tanks. A warm boundary layer is formed along the walls. The heat is evacuated by evaporation when the layer reaches the surface. Then, the cooled layer dives to the tank bottom.

Like the liquid area, the gaseous phase receives the heat flux by the side walls. A convection loop is formed which evacuates the evaporated flow from the liquid area and the warmed boundary layer by the gas dome.

As the fuel stays at its boiling point according to fuel tank pressure, any heat ingress causes evaporation (BOG).

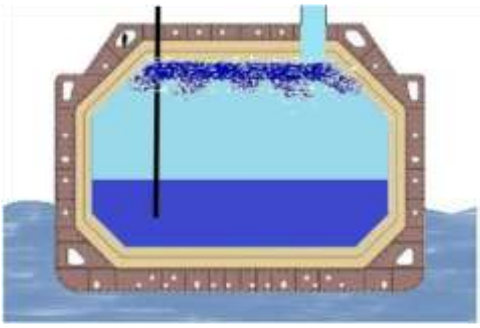
(2) The sloshing of fuel: Liquid Motion

The liquid movement inside the tanks (due to waves or navigation) brings mechanical energy to the system. It contributes to the evaporation (energy dissipation through turbulence), but it also acts as a spraying action and performs a partial cooling of the gas and the tank walls above the liquid level.



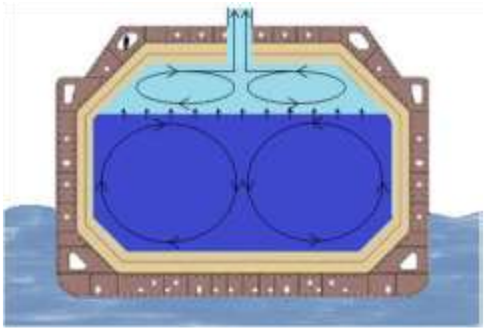
The cooling-down of tanks

During the tank cooling-down, the sprayed liquid natural gas undergoes a sudden change of pressure which leads to its evaporation, a decrease of the tank temperature and generates BOG.
Additional heat ingress might also occur following completion of the tank insulation cooling-down during the first 48 hours of the laden voyage as the insulation and surrounding structure's temperature normalizes.



(5) Tanks pressure decrease

Decreasing fuel tank pressure will modify the boiling point of the LNG. The LNG will then become superheated compared to this boiling point and will tend to evaporate at an increased rate until reaching the new boiling point.



The vessel loads its fuel at a given temperature imposed by the loading terminal and needs to deliver its fuel to a receiving terminal under specified conditions. The vessel has thus the "responsibility" to condition the fuel without having direct control on its characteristics.

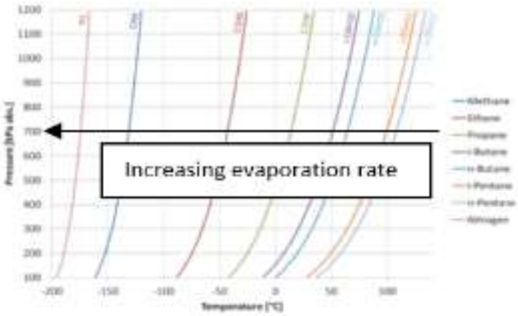
To do so, the vessel is equipped to provide effective BOG management within the maximum pressure allowable inside the tanks. In the case that "warm" LNG is loaded the associated BOR will be high, reducing fuel tanks pressure management flexibility.

As a consequence, it may be necessary to manage excess BOG via the Gas Combustion Unit (GCU) instead of retaining the LNG for sale, valued as fuel or reliquefied.

The LNG composition is a significant parameter / variable and could in specific conditions even dictate the BOG generated as detailed hereafter:
LNG is composed of several components of varying volatility, each having its own pure component boiling point at any given pressure. The presence of other volatile components in a mixture affects the boiling temperature of all the components in the mixtures.

During a voyage the most volatile (lightest) components like nitrogen will evaporate first. This phenomenon is called “ageing” and has some importance on the BOG generated as the voyage progresses.
Effect of ageing of a fuel can differ greatly based on the fuel composition and the duration. The boiling temperature of the fuel can increase significantly due to the presence of heavy components such as propane and ethane.

The evaporation rate of LNG depends not only on the composition of the product but also on the temperature of LNG when the fuel is loaded at the loading terminal. If the temperature of the fuel is too high according to the fuel tanks pressure it will evaporate more on voyage.



Another imposed constraint during the voyage concerns the temperature limitations of the LNG at the receiving terminal. While the fuel is mixed with a significant amount of heavy components, there are few options:

- Reliquefaction of BOG is one possibility but does consume energy.
- Ideally BOG is used for useful work.
- Last option consists in burning the gas by decreasing fuel tanks pressure to reach an acceptable temperature imposed by the receiving terminal.

What could be done to minimize BOG?

It is clear that composition, ageing and operating constraints imposed by the terminals are of a major importance to BOG generation during the laden voyage.
There is an efficient way to limit the BOG generated which requires further cooling of the LNG during loading, or in the fuel tanks during the loading operation but this supplementary energy consumption can be important for the value chain.

It would be possible to rank the quality of the loaded products. Based on this ranking, it would be fair to agree on an extra Boil-Off margin agreed in the charter party when typical conditions are not met.
Apart from loading LNG as cold as possible, there are also operational considerations which can be employed to improve and optimise the generation of Boil-Off Gas.

- Reducing the pressure inside the tanks at loading as far as possible (use of HD compressor to send gas to shore).

- The level of liquid motion inside the fuel tanks has an influence on the level of natural boil-off from the tanks.
- Define a route or heading to reduce ship motions.
- Anticipate slow or agitated passages by reducing fuel tank pressure when possible.
- Fuel Gas System set-up to avoid recirculation of warm fuel gas whilst maintaining a stable supply to consumers
- Monitor cofferdam temperatures and maintain the temperature at the desired value.
- Wherever operationally possible, arrive with tanks cold and ready to load at the loading terminal.

Weathering of cryogenic fuels occur

Ageing/Weathering

LNG ageing or weathering as it also can be named is a gradual change in the initial composition of the liquid over a period of time. The phenomenon occurs due to heat transfer from the surroundings which initiates evaporation of the stored liquid and hence gives boil-off gas. The composition of the liquid change in terms of an increased content of heavier components due to that the volatile components in the liquid evaporate. During the ageing process both quality and properties of the liquid are changed. This is known as ageing of fuel.

The impact of weathering in the engine performance

LNG with a high content of heavier hydrocarbons has a high tendency to age. Thus, ageing affects the composition of LNG but has only minor effect on the composition of the LPG. ***Ageing decreases the methane number and increases the heating value. It implies that the risk of damaging the engine is more probable when ageing has occurred i.e. has reduced the methane number outside the recommended range.*** In this report is it also stated that the original of LNG have a greater impact on methane number than the effects of ageing

The effect of boil-off and weathering of cryogenic fuels in relation to safety, environmental protection and ships operation

The boil-off gas (BOG) is a key issue for technical and economic reasons. **Evaporation of LNG causes increase of pressure in LNG storage tank.** It has an impact on storage process safety. Evaporation process changes conditions in storage tank, it has influence on compositions of liquefied natural gas and boil-off gas, also due to evaporation process thermodynamic properties of LNG and BOG can change.

For these reasons boil off problem in whole LNG supply chain is one of key important factors. The BOG quantity changes also depending on the changes in ambient temperature and pressure in the tank.

Compression and Expansion of Gases

The principles occurrence of compression and expansion of gases subject to the IGF Code

Internal energy is that thermodynamic energy which is attributed to the physical state of the gases. It is the sum of the kinetic and potential energies of the particles that form the system. The internal energy of a system can be understood by examining the simplest possible system: an ideal gas. Because the particles in an ideal gas do not interact, this system has no potential energy. The internal energy of an ideal gas is therefore the sum of the kinetic energies of the particles in the gas. Gas's internal energy change could result in thermal and/or pressure changes.

It is the change of enthalpy which is important in thermodynamic analysis of compression of gases in the reliquefaction cycle. A change in enthalpy expresses the total energy change in a gas as it passes through any thermodynamic process.

When compressing or expanding a gas, there is a significant relationship between pressure and density depends on the nature of the process. The process can be

- isothermal,
- isentropic (adiabatic)
- polytropic

The effect of compression and expansion of gases in relation to safety and ships operation

Isothermal Compression/Expansion Processes

If compression or expansion of gas takes place under **constant temperature** conditions - the process is said to be **isothermal.** The isothermal process can be expressed with the Ideal Gas Law.

Isentropic (or adiabatic) Compression/Expansion Processes

If compression or expansion of gas takes place with no flow of heat energy either into or out of the gas - the process is said to be isentropic or adiabatic.

Polytropic Compression/Expansion Process

An ideal isothermal process must occur very slowly to keep the gas temperature constant. An ideal adiabatic process must occur very rapidly without any flow of energy in or out of the system. In practice most expansion and compression processes are somewhere in between, or said to be polytropic.

Cryogenic liquids undergo large volume expansion upon transition to the gas phase, for example, one volume of liquid nitrogen vaporizes to 694 volumes of nitrogen gas. Consequently, the warming of a cryogenic liquid in a sealed container produces high pressure, which can rupture the container.

The expansion ratio of a liquefied and cryogenic substance is the volume of a given amount of that substance in liquid form compared to the volume of the same amount of substance in gaseous form, at room temperature and normal atmospheric pressure.

If a sufficient amount of liquid is vaporized within a closed container, it produces pressures that can rupture the pressure vessel. Hence the use of pressure relief valves and vent valves are important.

Critical pressure and temperature of gases

The importance of critical pressure and temperature of gases in terms of liquefaction of gases

Liquefication of Gasses

Critical Temperature And Pressure

Two important properties of gases are important in developing methods for their liquefaction: critical temperature and critical pressure. The critical temperature of a gas is the temperature at or above which no amount of pressure, however great, will cause the gas to liquefy. The minimum pressure required to liquefy the gas at the critical temperature is called the critical pressure.

For example, the critical temperature for carbon dioxide is 304K (87.8°F [31°C]). That means that no amount of pressure applied to a sample of carbon dioxide gas at or above 304K (87.8°F [31°C]) will cause the gas to liquefy. At or below that temperature, however, the gas can be liquefied provided sufficient pressure is applied. The corresponding critical pressure for carbon dioxide at 304K (87.8°F [31°C]) is 72.9 atmospheres. In other words, the application of a pressure of 72.9 atmospheres of pressure on a sample of carbon dioxide gas at 304K (87.8°F [31°C]) will cause the gas to liquefy.

Differences in critical temperatures among gases means that some gases are easier to liquify than are others. The critical temperature of carbon dioxide is high enough so that it can be liquified relatively easily at or near room temperature. By comparison, the critical temperature of nitrogen gas is 126K (-232.6°F [-147°C]) and that of helium is 5.3K (-449.9°F [-267.7°C]). Liquefying gases such as nitrogen and helium obviously present much greater difficulties than does the liquefaction of carbon dioxide.

Critical Temperature

Gases can be converted to liquids by compressing the gas at a suitable temperature. Gases become more difficult to liquefy as the temperature increases because the kinetic energies of the particles that make up the gas also increase.

The critical temperature of a substance is the temperature at and above which vapour of the substance cannot be liquefied, no matter how much pressure is applied.
Every substance has a critical temperature. Some examples are shown below.

Substance	critical temperature (°C)
NH_3	132
O_2	-119
CO_2	31.2
H_2O	374

Critical Pressure

The critical pressure of a substance is the pressure required to liquefy a gas at its critical temperature. Some examples are shown below.

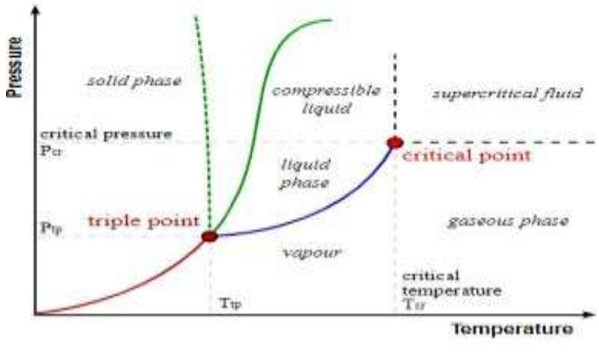
Substance	critical pressure (atm)
NH_3	111.5
O_2	49.7
CO_2	73.0
H_2O	217.7

Apart from LNG and LH2, all gas fuels are below their critical pressures at ambient temperatures

Interpret the critical pressure and temperature of gases with the aid of chart

At temperatures above the **critical temperature**, the substance in question (in its vapour/gaseous state) can no longer be liquefied, regardless of the amount pressure applied to it.

A graph describing the triple point (the point at which a substance can exist in all three states of matter) and the critical point of a substance is provided below. It can be noted that the graph is plotted with pressure on the Y-axis and temperature on the X-axis. Therefore, the critical temperature can be obtained from the X-axis value of the critical point. The corresponding Y-axis value of the critical point, which is the pressure required to liquefy a substance at its critical temperature, is known as the **critical pressure** of the substance.



The critical point of a liquid was discovered by the French physicist Charles Cagniard de la Tour in the year 1822. He observed that carbon dioxide could be liquified at a temperature of 31°C when 73 atm of pressure was applied, but it could not be liquified at higher temperatures, even when pressures above 3000 atm were applied. This maximum temperature at which substances could exist in the liquid phase was later named "Critical Temperature" by Dmitri Mendeleev in the year 1860.

Dangers in LNG Ships which may originate from critical pressure and temperature of fueles:

1. Explosion
Most severe risk generating danger of LNG ships is the explosion of LNG ships. The flames of LNG are very high and have greater lateral reach. The explosion not only damages the reputation of the ship but also causes non-recoverable loss i.e. the loss of lives of the crew of the vessel.

Major areas of risk: The three main areas of LNG ship are highly prone to the risk of explosion are – the engine room, motor rooms and fuel compressor rooms. These areas must be provided with CO_2 fire suppression systems. The fire systems should meet the requirements of ISO 14520 and also comply with PFEER codes.

2. Risk of vapour cloud explosion
LNG vaporizes very soon, so the volume of gaseous LNG becomes 625 times the earlier volume of liquid LNG. As soon as the LNG tank of LNG ship leaks, with the leakage of liquefied natural gas in air, its initial flash vaporization starts and generates a lot of steam instantaneously.
When this steam mixes with its surrounding air it forms cold steam fog and white smoke after condensation in the air. It then gets diluted and heated to form a flammable gas cloud with air and reaches explosive concentrations (5% 15%), which will lead to a vapour cloud explosion. This vapour cloud explosion changes into boiling liquid explosion and finally break out as fire risk.

Fire Risk: LNG is highly explosive and flammable when comes in contact with the atmosphere with the ignition point of 650. Its flames propagate rapidly and burn a large mass approximately doubles to that of gasoline or other oils. It has a property of recrudescence, re-explosion and it is difficult to stamp it out.
As the LNG in the tanker is stored at a lower temperature, excessive thermal stresses are produced due to local cooling, which results in loss of ductility of hull structure and produces brittle fractures in hull structure.

3. LNG Spills:
When LNG spills over the water it causes cryogenic burns, asphyxiation, dispersion, fires, and explosions. These all are the matter of major concern in regard to public safety. Necessary safety measures should be taken to make the voyage safer.
LNG spills were not considered dangerous until a ship having spill collides with another ship and results into explosion because without a source of ignition spilt LNG is not harmful as it vaporizes from water rapidly, causing no damage to the environment as well as to the aquatic lives.

4. Fumigation:
It is the process of mixing of liquefied natural gas from the engine room or other congested parts of the ship with the charged air so as to cause suffocation and make the environment poisonous. It is more commonly an outcome of LNG spills.

FLASHPOINT, UPPER AND LOWER FLAMMABLE LIMITS, AND AUTO-IGNITION TEMPERATURE

The flammable limits depend on oxygen concentration, the concentration of gases other than oxygen, the inert gas type and concentration, the size of the equipment, the direction of flame propagation, and the pressure, temperature, turbulence and composition of the mixture. The addition of inert gases to the atmosphere containing solvent is frequently used to reduce the probability of an explosion. It is generally assumed that if the concentration of oxygen is below 3%, no ignition will occur. The type of inert gas is also important. Carbon dioxide is more efficient inert gas than nitrogen. The size of equipment matters because of the uniformity of vapor concentration. A larger headspace tends to increase the risk of inhomogeneity. The cooling effect of the equipment walls influences the evaporation rate and the vapor temperature and should be used in risk assessment.

Lower Explosive Limit (LEL)

The minimum concentration of a particular combustible gas or vapor necessary to support its combustion in air is defined as the Lower Explosive Limit (LEL) for that gas. Below this level, the mixture is too “lean” to burn.

Upper Explosive Limits

The maximum concentration of a gas or vapor that will burn in air is defined as the Upper Explosive Limit (UEL). Above this level, the mixture is too “rich” to burn. The range between the LEL and UEL is known as the flammable range for that gas or vapor.

Autoignition Temperature

The auto-ignition temperature of a substance is the temperature to which its vapourin-air mixture must be heated to ignite spontaneously. The auto-ignition temperature is not related to the vapour pressure or to the flash point of the substance and, since the most likely ignition sources are external flames or sparks, it is the flash point rather than the auto-ignition temperature which is used for the flammability classification of hazardous materials. Nevertheless, when vapour escapes are considered in relation to adjacent steam pipes or other hot surfaces, the auto-ignition temperature is worthy of note.

The effect of flashpoint, upper and lower flammable limits, auto-ignition temperature in relation to safety, environmental and ships operation

LNG is highly flammable and explosive substance with ignition point of 650 , rapid flame propagation, large mass burning rate about 2 times more than gasoline, high flame temperature, so the burning is of strong radiant heat, easy to form large area of fire, with characteristics of recrudescence, re-explosion and difficult to stamp out. Liquefied natural gas in the ships are stored at low temperature (162) and atmospheric pressure. Liquid fuel of ultra-low temperature contacting with general hull, because local cooling produces excessive thermal stress, will make the hull brittle fractures spontaneously, and loses ductility, thereby endangering the entire ship's structure. LNG’s easy vaporization at room temperature makes the pressure and temperature inside the hold rise easily, thus damages the structure of the hold. Breakage in the combination of working pipeline and loading and unloading system, rupture in liquid hold, collision and other factors may lead to leakage of liquefied gas, which will result in fire accidents when encountering fire.

The measures to prevent flashpoint, upper and lower flammable limits, auto-ignition temperature

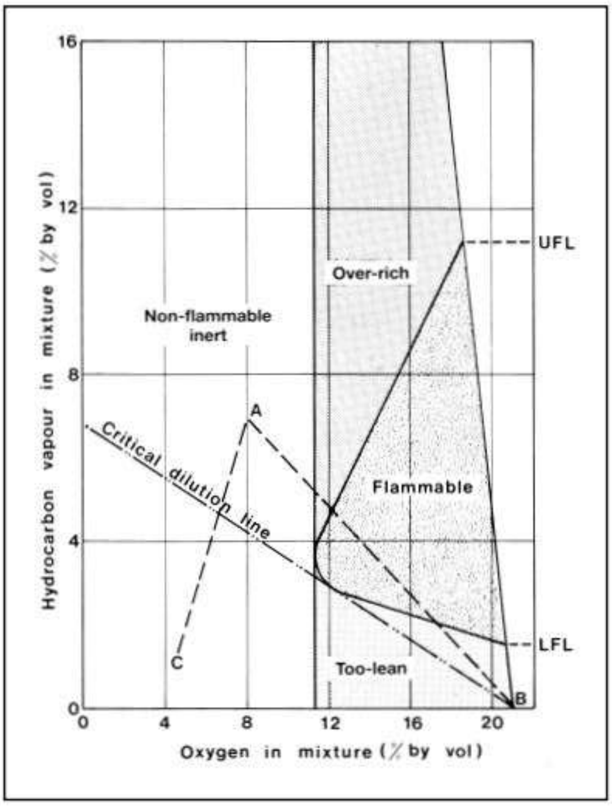


Figure 2.19 Flammable limits of gas mixtures in air and nitrogen

Whereas increasing the oxygen concentration in a flammable mixture causes a broadening of the flammable range and a lowering of the energy necessary for ignition, decreasing the oxygen causes the flammable range to be narrowed and the minimum ignition energy to be increased. If the oxygen availability is reduced to a sufficient extent, the mixture will become non-flammable no matter what the combustible vapour content may be. Figure 2.19 illustrates this concept for a typical hydrocarbon gas mixtures with air and nitrogen. The mixtures are represented on the horizontal axis by the percentage oxygen content in the total mixture. The diagram provides much useful information. The narrowing of the flammable range as the oxygen is reduced 52 LGHP Figure 2.19 Flammable limits of gas mixtures in air and nitrogen can be seen from the shape of the area labelled flammable. It is also clear that an oxygen content of less than that at the left hand extremity of the flammable envelope renders the mixture non-flammable. This value, for most hydrocarbon vapours, is around 10 to 12 per cent by volume. However, on a gas carrier for an atmosphere to be adequately non-flammable, less than 5 per cent (sometimes 2 per cent) by volume oxygen is needed. This allows for a degree of poor mixing and pockets of gas remaining in some areas of the tank. The diagram is also useful in illustrating proper inerting and gas-freeing procedures. For example, assume that a tank atmosphere is determined to be at point A. If the tank is then gas-freed directly with air, the composition of the tank atmosphere will move along the line AB to the fully gas-free condition at point B. In so doing, the atmosphere passes through the flammable envelope. This can be avoided by first inerting the tank along, say, the line AC to a point below the critical dilution line. Aerating to point B may then be undertaken without the tank atmosphere passing through the flammable envelope. This result can only be safely achieved if regular measurements are taken, using properly calibrated instruments to evaluate the atmosphere throughout the tank at the various stages. In this process, it is important to use reasonable margins of safety since the shape of the flammable envelope is ill-defined for mixtures and any non-homogeneity of the tank atmosphere must be allowed for. Also, the varying range of flammable limits for the different gases must be considered (see Table 2.8). The flammable envelope data, as given in Reference 2.1, can also be helpful on a grade by grade basis.

Saturated vapour pressure/reference temperature

The concepts of saturated vapour pressure/ reference

Vapour in the space above a liquid is in constant motion. Molecules near the liquid surface are constantly leaving to enter the vapour-phase and molecules in the vapour are returning to the liquid-phase. The vapour space is said to be unsaturated if it can accept more vapour from the liquid at its current temperature. A saturated vapour is a vapour in equilibrium with its liquid at that temperature. In that condition, the vapour space cannot accept any further ingress from the liquid without a continuous exchange of molecules taking place between vapour and liquid. The pressure exerted by a saturated vapour at a particular temperature is called the saturated vapour pressure of that substance at that temperature.

Various methods exist for the measurement of saturated vapour pressures and one is illustrated in Figure 2.11. This apparatus consists of a barometric tube (C) which is filled with mercury, inverted and immersed in a mercury reservoir (A). The space above the mercury is a virtual vacuum (B). The height of mercury (X) is a measure of atmospheric pressure. A small amount of the liquid under test is introduced into the mercury barometer and this rises to the vacuum space. Here it partially vaporises and exerts its saturated vapour pressure. This vapour pressure pushes the mercury down the barometer tube to a new level (Y). The saturated vapour pressure exerted by the test liquid is shown by the difference between the heights of the mercury column X and Y and, in this case, is usually expressed in millimetres of mercury. If the mercury column containing the liquid under test is heated, then the mercury level will fall further, indicating that the saturated vapour pressure has increased with increasing temperature. It is possible by this means to determine the saturated vapour pressure for the liquid under test at various temperatures.

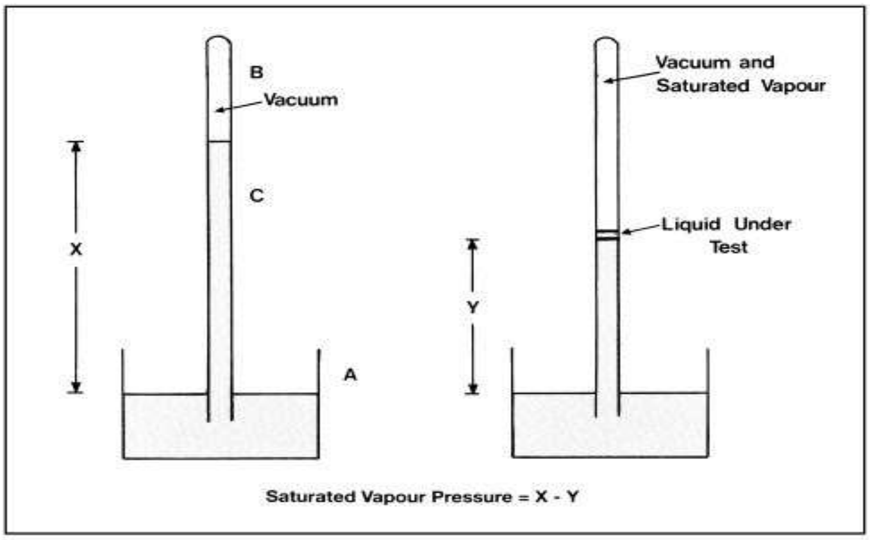
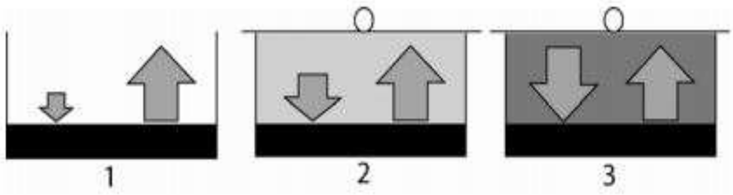


Figure 2.11 Barometric method for measuring saturated vapour pressure

Differentiate vapor pressure and saturated vapor pressure

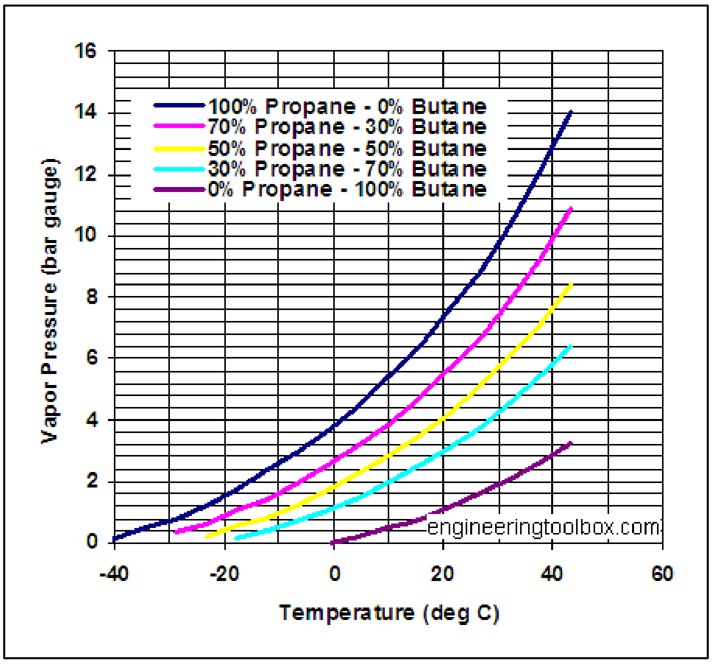
Above the surface of liquid water there always exists some amount of gaseous water and consequently there exists a vapor pressure. When a container containing water is open then the number of the escaping molecules is larger than the number of molecules coming back from the gaseous phase (Fig. 1). In this case vapor pressure is small and far from saturation. When the container is closed then the water vapor pressure above the surface increases (concentration of molecules increases) and therefore the number of molecules coming back increases too (Fig.2). After some time, the number of molecules escaping the liquid and that coming back becomes equal. Such situation is called by dynamic equilibrium between the escaping and returning molecules (Fig. 3). In this case, it is said that the water vapor pressure over the liquid water is saturated.



Dewpoint and bubble point

Explain the principles of dewpoint and bubble point

For a liquid mixture in equilibrium with its vapour, the bubble point and the dew point are at different temperatures. It is common to distribute a mixture of propane (C_3H_8) and butane (C_4H_{10}) (LPG) for combustion purposes. Propane is more suited to colder environments since it evaporates at -44oF (-42oC) at atmospheric pressure. Butane evaporates at 33oF (0.6 oC) at atmospheric pressure.



The two curves are the bubble points and dew points respectively of the mixture over the whole range from pure propane (zero of the less volatile component) to pure (100% of the less volatile component). It will be noted that at the two extremes, pure material, the bubble points and dew points become coincident.

Differentiate dewpoint and bubble point

In order to be able to predict the phase behavior of a mixture, scientists and engineers examine the limits of phase changes, and then utilize the laws of thermodynamics to determine what happens in between those limits. The limits in the case of gas-liquid phase changes are called the bubble point and the dew point.

The names imply which one is which:

The bubble point is the point at which the first drop of a liquid mixture begins to vaporize.

The dew point is the point at which the first drop of a gaseous mixture begins to condense.

Hydrate Formation

The principles of hydrate formation

Hydrate formation is a well-known risk in natural gas wells and pipelines and is managed by the injection of hydrate inhibitors, most commonly methanol, which lower the hydrate formation temperature to below the minimum expected operating temperature.
The dew point inside the fuel tank and hold spaces is to be lowered and controlled to avoid hydrate and carbonate formation. Long pipelines are constructed of carbon steel. Carbonic acid will corrode the iron in the pipeline wall, producing iron carbonate. This iron carbonate can precipitate in the production fluid and follow the gas and liquid flow, causing problems downstream.

The problems that may occur with hydrate and carbonate formation. Hydrate nuclei form from the films of water on the tubular walls. The subsequent crystallization can result in large plugs of hydrate tens or hundreds of meters long.

To prevent such hydrates, injecting a substance like mono ethylene glycol (MEG) will lower the freezing point of water by diluting the system, just like an anti-freeze agent. A lower freezing point ensures that solid structures of water cannot form and hence there will be no formation of hydrates

The causes of hydrate formation

Hydrate Formation is a formation that occurs due to the reaction of water with hydrocarbons present in the reservoirs. These hydrocarbons include methane, ethane, propane or hydrogen sulfide, nitrogen and carbon dioxide. Hydrates are solid shaped particles which can be compared to ice and can cause problems in the well operations. These hydrates are solids that are formed when natural gas and water combine at low temperature and high pressure. This may happen in both oil and gas wells.

Effect of hydrate formation in relation to safety, environmental and ships operation

It became apparent that hydrates were occasionally and unpredictably appearing in the fuel systems of refrigerated LPG carriers. **This resulted in damage to pumps and other plant machinery being damaged, as well as interference to fuel handling.** While the procedures used to produce LPG and its handling on ship and shore includes minimising the water content in the product, little information has been gathered that specifically deals with hydrates forming in commercially dry refrigerated LPG. As a result, a review of the processes and procedures commonly used in production, storage and transportation was required to identify how water can enter or remain within the fuel.

The measures to prevent hydrate formation

Certain fueles, notably LPGs, may contain traces of water when loaded. It may be permissible in such cases to prevent hydrate formation by adding small quantities of a suitable anti-freeze (e.g. methanol, ethanol) at strategic points in the system. It is emphasized that nothing whatsoever should be added to any fuel without the shipper's permission. For LPG mixtures a small dose of anti-freeze may be permissible, but for chemical fueles such as ethylene the addition of even one liter per two hundred tons could make the fuel commercially valueless. In the case of inhibited fueles the anti-freeze could adversely affect the inhibitor.

If the use of anti-freeze is permitted it should be introduced at places where expansion occurs because the resultant lowering of temperature and pressure promotes hydrate formation.

Anti-freeze additives are often flammable and toxic, and care should be taken in their storage and use.

Inhibitor: A substance used to prevent or retard fuel deterioration or a potentially hazardous chemical self-reaction, e.g. polymerization.

Combustion Properties: Heating Values

The importance of combustion properties in flashpoint fuels

Combustion is the scientific word for burning. In a combustion reaction, a substance reacts with oxygen from the air. Combustion reactions happen at **high** temperatures, and transfer energy to the surroundings as **light and heat**. This is why you see flames when things burn.
One important combustion reaction is that of methane. Methane reacts with oxygen from the air and produces either a hot blue or an orange flame. The energy that the reaction produces can be used to heat water, cook food, and generate electricity or even power vehicles.

The products of combustion reactions are compounds of oxygen, called oxides. Since methane is made up of atoms of carbon and hydrogen, the products of its combustion reaction are oxides of carbon and hydrogen. The names of these oxides are **carbon dioxide and water**.

Heating Values

The heating value depends on the source of gas that is used and the process that is used to liquefy the gas. The range of heating value can span +/- 10 to 15 percent. A typical value of the higher heating value of LNG is approximately 50 MJ/kg or 21,500 BTU/lb. A typical value of the lower heating value of LNG is 45 MJ/kg or 19,350 BTU/lb.

For the purpose of comparison of different fuels the heating value may be expressed in terms of energy per volume which is known as the energy density expressed in MJ/litre. The density of LNG is roughly 0.41 kg/litre to 0.5 kg/litre, depending on temperature, pressure, and composition, compared to water at 1.0 kg/litre. Using the median value of 0.45 kg/litre, the typical energy density values are 22.5 MJ/litre (based on higher heating value) or 20.3 MJ/litre (based on lower heating value).

The (volume-based) energy density of LNG is approximately 2.4 times that of CNG which makes it economical to transport natural gas by ship in the form of LNG. The energy density of LNG is comparable to propane and ethanol but is only 60 percent that of diesel and 70 percent that of gasoline.

Methane number/knocking

The principles of methane number/locking in flashpoint fuel

Knocking is the phenomena commonly occurring in a CI engine. You may know that in a CI engine the combustion occurs due to self-ignition of fuel at high temperature generated due to compression of air. When the fuel is sprayed in the cylinder, the very first few droplets take some time to ignite which is termed as ignition delay. During this delay next few droplets have also entered the cylinder and the piston has reached the TDC. At this point the pressure in the cylinder is maximum and thus is the temperature. This ignites the first droplets which further elevate the temperature. During this period the fuel supply is going on. The droplets which enter during this period get ignited rapidly due to high temperature generated. This leads to sudden ignition of a fuel mass which generates a loud sound or a ‘knock’.

Methane Number (MN) can differ based on LNG composition. Methane number of a gas provides an indication of the knock tendency of a fuel. It is a product of the different constituent gases within the natural gas, particularly the proportions of methane, ethane, propane and butane. Understanding the knock resistance is important when selecting an engine for a gas-powered combined heat and power plant.

Methane, which has a high knock resistance, is given an index value of 100. Hydrogen, which burns quickly relative to methane, has a low knock resistance and is given the index value of 0. If a gas mixture has a methane number of 80, its knock resistance is equivalent to that of a gas comprised of 80% methane and 20% hydrogen. There are gas constituents which have a higher methane number than 100 therefore it is also possible for a gas composite to have a higher methane number than 100. Biogas often has a methane number in excess of 100. Understanding the methane number of the natural gas fuel is an important factor when determining the appropriate engine version to select.

The methane number is comparable to octane number for petrol. Methane number calculation method should be taken from DIN EN 16726. The fuel methane number does not necessarily reflect what goes into the engine.

The methane number in indicating the knocking characteristics of a fuel gas

Knocking in pure gas and dual fuel engines is mostly related to pre-ignition of the gas inside the combustion chamber. This is a phenomenon that occurs in engines working under the Otto principle, where the fuel is injected into the chamber during the compression stroke. During pressurization, heat builds up in the cylinder which can cause components in the gas to self-ignite, subsequently causing premature ignition of the rest of the injected gas-air mixture. Diesel cycle engines, such as the gas-diesel which use high pressure gas injection, do not suffer from pre-ignition knocking issues.

Effect of methane number/knocking relation to safety, environmental and/or ships operation
Knocking can cause **erosion of the combustion chamber surface, and rough, inefficient operation**. It can be avoided by adjusting certain variables of engine design and operation, such as compression ratio and burning time; but the most common method is to burn gasoline of higher octane number.
The measures to prevent knocking
Knocking in dual fuel engines is avoided by proper air-fuel ratio control and individual cylinder balancing. Once knocking occurs the engine will, depending on its design criteria, either reduce its load to a safe level (typically for pure-gas engines or land based dual fuel engines) or maintain the load but switch over to liquid fuel (marine dual-fuel engines).

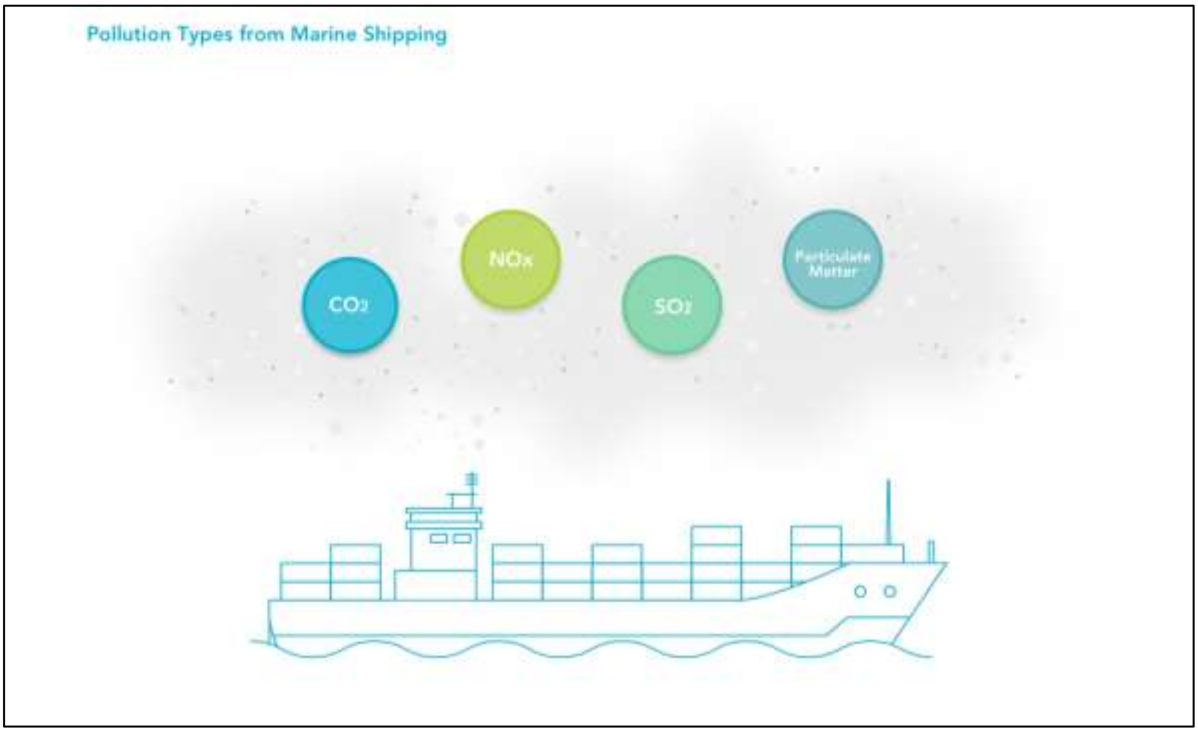
Pollutant characteristics of fuels addressed by the IGF Code

Determine the typical pollutants generated using marine fuels subject to the IGF Code:
- Sulphur oxides
- Nitrogen oxides
- Particulated matter
- CO_2
- Methane

Typical pollutants generated using marine fuels

1. Sulphur oxides (SOX)
2. Nitrogen oxides (NOX)
3. Particulate matter (PM)
4. Carbon dioxide (CO2)
5. Methane (CH4)

Methane is a greenhouse gas with a 100-year global warming factor of 25 compared with the 1 of CO2. There are two broad types of engine, two-stroke and four-stroke. Losses of methane can occur in four-stroke engines as fuel gas is pre-mixed outside the cylinders and then injected at low pressure. This is called methane slip.



Commercial ships burn fuel for energy and emit several types of air pollution as by-products. Ship-source pollutants most closely linked to climate change and public health impacts include carbon dioxide (CO2), nitrogen oxides (NOx), sulphur oxides (SOx) and particulate matter.

The global shipping fleet is rushing to meet a 2020 deadline imposed by the International Maritime Organization (IMO) to reduce air pollution by forcing vessels to use cleaner fuel with a lower sulphur content of 0.5%, compared with 3.5% as currently used.

Effect of pollutants in relation to safety and environmental
Carbon Dioxide (CO_2)

CO_2 contributes to widespread climate change by trapping the sun's heat. In Canada, these climate changes include increased average and extreme temperatures, shifting rainfall patterns, thawing permafrost, and increases in hazardous weather.

Climate change-induced extreme weather events such as heat waves, floods and major storms have a negative impact on human health and cause untimely deaths worldwide.
When CO_2 is absorbed by seawater, the water becomes more acidic. This increase in acidity has adverse effects on marine life and ecosystems.

Nitrogen Oxides (NO_x)

A collection of gases of various combinations of nitrogen and oxygen that:

- Cause lung inflammation when breathed, increasing susceptibility to harm from allergens in people with asthma. NO_x may enter the bloodstream and with long-term exposure lead to eventual heart and lung failures.
- Interact with volatile organic compounds (VOCs) to create ground-level ozone, which contributes to eye, nose and throat irritations; shortness of breath; worsening of respiratory conditions; chronic obstructive pulmonary disease; asthma and allergies; cardiovascular disease and untimely death.
- Cause acidification of soil and water (acid rain).
- Decrease crop and vegetation productivity due to ground-level ozone, threatening food security.
- Flood ecosystems with excess nitrogen nutrients, leading to toxic algal blooms in coastal waters and inland lakes.

Sulphur Oxides (SO_x)
A collection of gases of various combinations of sulphur and oxygen that:

- Cause lung inflammation when breathed, increasing susceptibility to allergens in people with asthma. SO_x and may enter the bloodstream and with long-term exposure lead to eventual heart and lung failures.
- Cause eye irritation, increased susceptibility to respiratory tract infections, and increased hospital admissions for cardiac disease.
- Cause acidification of soil and water (acid rain).

The measures to mitigate pollution
The shipping industry has at its disposal a wide range of options and techniques to reduce shipping's impact on air quality, most of which are already available on a large scale and easily implementable. These include:

- **Zero emission berth standard in ports.** Shore-side electricity can be used while ships are at the port, virtually eliminating ship-sourced SOx, NOx, PM, but also CO2. Alternatively ships could comply using alternative fuels such as hydrogen of ammonia.

- **Using low-sulphur fuels:** this is the easiest way of reducing ships' impact on air quality. Shipping fuels in use outside sulphur emission control areas contain up to 3,500 times the sulphur content of fuels used by road transport in Europe. Low-sulphur fuels can make the ship's engine run smoother and more efficiently with less operating problems and maintenance costs. Last but not least, using low-sulphur (non-residual) fuels reduces other pollutant emissions, such as black carbon, which is a potent global-warming agent.

- Scrubbers: an alternative compliance option to burning low-sulphur fuels approved by the IMO and the EU is for ships to install scrubbers. These could cut emissions of SO2 by 99% and considerably reduce emissions of other polluting particles. There are, however, concerns regarding wash-water discharges from open-loop scrubbers which deposit them in open seas and closed-water areas. This leads to higher pH levels in surrounding waters causing additional environmental concerns. Hence, open-loop scrubbers are not a sustainable alternative compliance method for marine sulphur standards.

- Internal engine modifications, such as water injection and exhaust gas recirculation (EGR – for 4-stroke engines): these are techniques to prevent NOx production during the combustion process. However, Tier III standard cannot be met by these methods alone.

- Humid air motor: adding water vapour to the combustion air can also reduce NOx emissions, however, not down to Tier III levels.

- Selective catalytic reduction (SCR): a system to treat exhaust gases after their production but before they are actually emitted. SCR is very effective in reducing NOx emissions far beyond Tier III. It's already used by many ships worldwide and works better with low-sulphur fuel

- Development of alternative energy sources such as battery electric propulsion, wind propulsion, hydrogen, ammonia, biofuels and fuel cells is ongoing and could be useful in the future.

- Hybridization and electrification can deliver emission savings regardless of the type of fuel used to generate electricity.

The environmental benefits of using IGF fuel against conventional fuels

The environmental benefits of using IGF fuels against conventional fuels.
The environmental benefits of using LNG as fuel or other Low flash point fuels are significant. Compared to the use of diesel fuel, use of LNG will reduce the NO x emission by approximately 90% on a lean burn gas fuelled engine, and the SOx and particle matters emissions are negligible without the need on any abatement technologies. The CO2 emissions are about 20% lower compared to diesel fuel because of the lower carbon content. However, the overall effect on GHG (Green House Gas) emissions needs further study.

The impact of using gas as fuel for transport can be regarded from 2 different perspectives:

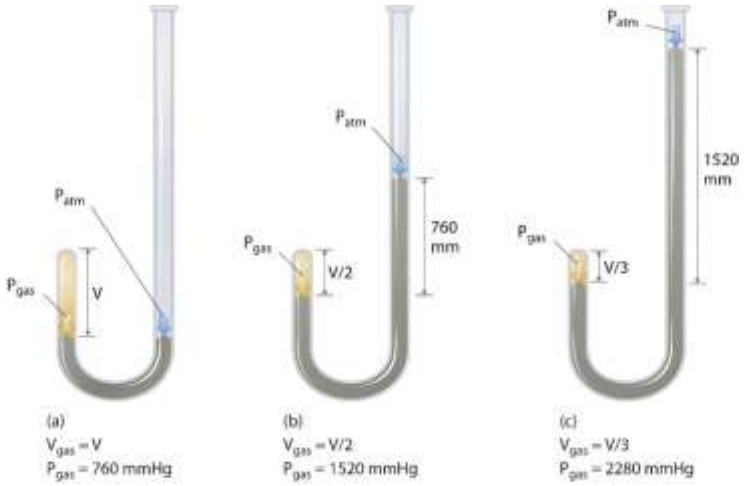
1. The net benefits of gas as a replacement of oil fuels, in terms of local air pollution (SOX, NOX and Particulate Matter); and

2. The higher GHG emission potential of methane (higher constituent of LNG).

.2 Identify the relationship between pressure, volume and temperature in handling low flash point fuels

The Relationship between Pressure and Volume

As the pressure on a gas increases, the volume of the gas decreases because the gas particles are forced closer together. Conversely, as the pressure on a gas decreases, the gas volume increases because the gas particles can now move farther apart. Weather balloons get larger as they rise through the atmosphere to regions of lower pressure because the volume of the gas has increased; that is, the atmospheric gas exerts less pressure on the surface of the balloon, so the interior gas expands until the internal and external pressures are equal.



The Relationship between Temperature and Volume

Hot air rises, which is why hot-air balloons ascend through the atmosphere and why warm air collects near the ceiling and cooler air collects at ground level. Because of this behavior, heating registers are placed on or near the floor, and vents for air-conditioning are placed on or near the ceiling. The fundamental reason for this behavior is that gases expand when they are heated. Because the same amount of substance now occupies a greater volume, hot air is less dense than cold air. The substance with the lower density—in this case hot air—rises through the substance with the higher density, the cooler air.

LNG is stored as a "boiling cryogen," that is, it is a very cold liquid at its boiling point for the pressure it is being stored. Stored LNG is analogous to boiling water, only 470°F [243°C] colder. The temperature of boiling water (212°F [100°C]) does not change, even with increased heat, as it is cooled by evaporation (steam generation). In much the same way, LNG will stay at near constant temperature if kept at constant pressure. This phenomenon is called "autorefrigeration". As long as the steam (LNG vapor boil off) is allowed to leave the tea kettle (tank), the temperature will remain constant.

If the vapor is not drawn off, then the pressure and temperature inside the vessel will rise. However, even at 100 psig [6.7 barg], the LNG temperature will still be only about -200°F [-129°C].

1.3 The properties of single liquids

.1 Explain the properties of a single liquids subject to the IGF Code

A liquid is a sample of matter that conforms to the shape of a container in which it is held, and which acquires a defined surface in the presence of gravity. The term liquid is also used in reference to the state, or condition, of matter having this property.

The atom s or molecule s of matter in the liquid state are compressed as tightly as those of matter in the solid state, but the atoms or molecules in a liquid can move freely among each other. Examples of liquids are water at room temperature (approximately 20 ºC or 68 ºF), oil at room temperature, and alcohol at room temperature.

When a liquid is heated, the atoms or molecules gain kinetic energy . If the temperature becomes sufficiently high, the liquid becomes a gas , or it may react with chemicals in the environment. Water is an example of a liquid that becomes gaseous when it is heated gradually. Alcohol will combust (combined with oxygen in the atmosphere) if heated suddenly and dramatically.
When a liquid is cooled, the atoms or molecules lose kinetic energy. If the temperature becomes low enough, the liquid becomes a solid. Water is a good example. If cooled down, it freezes into ice.

The different properties of a single liquids

The liquid state of matter is an intermediate phase between solid and gas. Like the particles of a solid, particles in a liquid are subject to intermolecular attraction; however, liquid particles have more space between them, so they are not fixed in position. The attraction between the particles in a liquid keeps the volume of the liquid constant.
The movement of the particles causes the liquid to be variable in shape. Liquids will flow and fill the lowest portion of a container, taking on the shape of the container but not changing in volume. The limited amount of space between particles means that liquids have only very limited compressibility.

Cohesion and adhesion

Cohesion is the tendency for the same kind of particles to be attracted to one another. This cohesive "stickiness" accounts for the surface tension of a liquid. Surface tension can be thought of as a very thin "skin" of particles that are more strongly attracted to each other than they are to the particles surrounding them. As long as these forces of attraction are undisturbed, they can be surprisingly strong. For example, the surface tension of water is great enough to support the weight of an insect such as a water skipper. Water is the most cohesive nonmetallic liquid, according to the U.S. Geological Survey.

Cohesive forces are greatest beneath the surface of the liquid, where the particles are attracted to each other on all sides. Particles at the surface are more strongly attracted to the identical particles within the liquid than they are to the surrounding air.

Adhesion is when forces of attraction exist between different types of particles. Particles of a liquid will not only be attracted to one another, but they are generally attracted to the particles that make up the container holding the liquid. Particles of the liquid are drawn up above the surface level of the liquid at the edges where they are in contact with the sides of the container.

The combination of cohesive and adhesive forces means that a slight concave curve, known as the meniscus, exists at the surface of most liquids. The most accurate measurement of the volume of a liquid in a graduated cylinder will be observed by looking at the volume marks closest to the bottom of this meniscus.

Adhesion also accounts for capillary action when a liquid is drawn up into a very narrow tube. One example of capillary action is when someone collects a sample of blood by touching a tiny glass tube to the blood droplet on the tip of a pricked finger.

Viscosity is a measure of how much a liquid resists flowing freely. A liquid that flows very slowly is said to be more viscous than a liquid that flows easily and quickly. A substance with low viscosity is considered to be thinner than a substance with higher viscosity, which is usually thought of as being thicker. For example, honey is more viscous than water. Honey is thicker than water and flows more slowly. Viscosity can usually be reduced by heating the liquid. When heated, the particles of the liquid move faster, allowing the liquid to flow more easily.

Evaporation

Because the particles of a liquid are in constant motion, they will collide with one another, and with the sides of the container. Such collisions transfer energy from one particle to another. When enough energy is transferred to a particle at the surface of the liquid, it will eventually overcome the surface tension holding it to the rest of the liquid. Evaporation occurs when surface particles gain enough kinetic energy to escape the system. As the faster particles escape, the remaining particles have lower average kinetic energy, and the temperature of the liquid cools. This phenomenon is known as evaporative cooling.

Volatility can be thought of as how likely a substance will be to vaporize at normal temperatures. Volatility is more often a property of liquids, but some highly volatile solids may sublime at normal room temperature. Sublimation happens when a substance passes directly from solid to gas without passing through the liquid state.

When a liquid evaporates inside a closed container, the particles cannot escape the system. Some of the evaporated particles will eventually come into contact with the remaining liquid and lose enough of their energy to condense back into the liquid. When the rate of evaporation and the rate of condensation are the same, there will be no net decrease in the amount of liquid.

The pressure exerted by the vapor/liquid equilibrium in the closed container is called the **vapor pressure**. Increasing the temperature of the closed system will increase the vapor pressure, according to Purdue University's department of chemistry. Substances with high vapor pressures can form a high concentration of gas particles above the liquid in a closed system. This can be a fire hazard if the vapor is flammable. Any small spark, even one occurring from the friction between the gas particles themselves, can be enough to cause a catastrophic fire or even an explosion. The U.S. Occupational Safety and Health Administration (OSHA) requires Material Safety and Data Sheets to give information about the volatility and flammability of liquids in order to help prevent accidents from occurring.

1.4 The nature and properties of solutions

.1 Explain the nature and properties of solutions in relation to IGF Code

A **solution** is a type of homogeneous mixture that is made up of two or more substances. A **homogeneous mixture** is a type of mixture with a uniform composition. This means that the substances cannot be distinguished easily from one another. Some examples of solutions are salt water, rubbing alcohol, and sugar dissolved in water. When you look closely, upon mixing salt with water, you can't see the salt particles anymore, making this a homogeneous mixture.

Solute: this is the substance that makes up the minority of the solution, or this is the part that is dissolved. In our example of salt water, the solute is the salt.

Solvent: this is the substance that makes up the majority of the solution. This is the part where the solute is dissolved. In our example of salt water, the solvent is water.

Nature and Properties of Solutions in Relation to the IGF Code

- The energy content of LNG ranges from 24 MJ/L to 21 MJ/L.
- The energy density of LNG is roughly 0.41 kg/L to 0.5 kg/L, depending mostly on temperature and pressure.
- The energy density of LNG is 2.4 times greater than CNG. This makes it economical to transport.
- The energy content of LNG is comparable to propane.
- There are a number of other gases that are separated from the raw natural gas before chilling, including propane, butane (n-butane) and isobutane (i-butane), as well as mixtures of these gases and are also referred to as natural gas liquids – NGL.
- Odourant is added, for safety, before the gas is piped to end users.
- Flammability Limits (in air by volume): 5.3% to 14%
- Auto Ignition Temperature: 595°C
- Liquid Density: 426kg/m3

- Gas Density (25°C): 0.656 kg/m3
- Specific Gravity (15°C): 0.554

1.5 Thermodynamic units

.1 Explain the thermodynamic units used in handling fuels subject to the IGF Code

Energy and power Equivalences The various forms of energy involved in energy transfer systems (such as potential energy, kinetic energy, internal energy, P-V energy, work and heat) may be measured in numerous basic units.

Below is a chart summarizing some energy units (joules, electron volts, calories, BTUs) and others that are closely related to energy:

work:	**joule**	J	work done by accelerating 1 g at 1 cm/sec^2 for 1 m	1000 J = 1 kJ 10^{18} J = 1 EJ (exajoule)
work	**electron volt**	eV	energy to accelerate 1 electron by 1 volt of potential difference	1 eV = 1.1602 x 10^{-19} J
heat:	**calorie**	cal	heat needed to raise the temperature of 1 g of H_2O by 1 deg C	1 cal = 4.184 J 1000 cal= 1 kcal
heat:	**British thermal unit**	BTU	heat needed to raise the temperature of 1 lb of H_2O by 1 deg F	1 BTU = 1.055 kJ
power:	**watt**	W	rate at which the energy, in joules, is delivered	1 W = 1 J/sec 1000 W = 1 kW

1.6 Basic Thermodynamic Laws and Diagrams

.1 Explain the principles of basic thermodynamic laws and diagrams

First law of thermodynamics: one of the most fundamental laws of nature is the conservation of energy principle. It simply states that during an interaction, energy can change from one form to another but the total amount of energy remains constant.

Second law of thermodynamics: energy has quality as well as quantity, and actual processes occur in the direction of decreasing quality of energy.

The third law of thermodynamics states that the entropy of a system approaches a constant value as the temperature approaches absolute zero. The entropy of a system at absolute zero is typically zero, and in all cases is determined only by the number of different ground states it has.

Specifically, the entropy of a pure crystalline substance (perfect order) at absolute zero temperature is zero. This statement holds true if the perfect crystal has only one state with minimum energy.

.2 Explain the general gas equation and its practical use

Thermodynamics Law Application

According to the Second law of thermodynamics, heat always flows from a body at a higher temperature to a body at the lower temperature. This law is applicable to all types of heat engine cycles including Otto, Diesel, etc. for all types of working fluids used in the engines. This law has led to the progress of present-day vehicles.

Another application of this law is refrigerators and heat pumps based on the Reversed Carnot Cycle. If you want to move heat from a body at a lower temperature to a body at a higher temperature, then you have to supply external work. In the original Carnot Cycle, heat produces work while in the Reversed Carnot Cycle work is provided to transfer heat from lower temperature reservoir to a higher temperature reservoir.

Removing heat from the food items in the refrigerator and throwing it away to the higher temperature atmosphere doesn't happen automatically. We need to supply external work via the compressor to make this happen in the refrigerator.

Air conditioner and heat pump follow the similar law of thermodynamics. The air conditioner removes heat from the room and maintains it at a lower temperature by throwing the absorbed heat into the atmosphere. The heat pump absorbs heat from the atmosphere and supplies it to the room which is cooler in winters.

Gas Laws

The three fundamental gas laws discover the relationship of pressure, temperature, volume and amount of gas. Boyle's Law tells us that the volume of gas increases as the pressure decreases. Charles' Law tells us that the volume of gas increases as the temperature increases. And Avogadro's Law tell us that the volume of gas increases as the amount of gas increases. The ideal gas law is the combination of the three simple gas laws.

Ideal Gases

Ideal gas, or perfect gas, is the theoretical substance that helps establish the relationship of four gas variables, pressure (P), volume (V), the amount of gas (n) and temperature (T). It has characters described as follow:

- The particles in the gas are extremely small, so the gas does not occupy any spaces.
- The ideal gas has constant, random and straight-line motion.
- No forces between the particles of the gas. Particles only collide elastically with each other and with the walls of container.

Real Gases

Real gas, in contrast, has real volume and the collision of the particles is not elastic, because there are attractive forces between particles. As a result, the volume of real gas is much larger than of the ideal gas, and the pressure of real gas is lower than of ideal gas. All real gases tend to perform ideal gas behaviour at low pressure and relatively high temperature

There are many laws which describe the behavior of gases. A gas which obeys them exactly is called a perfect gas. Typical fuel gas obeys these laws quite closely.
i) BOYLE'S LAW
ii) CHARLE'S LAW
iii) THE GENERAL GAS EQUATION is derived by combining the above laws and is stated as :

$$(P1.V1)/ T1= (P2.V2)/ T2$$

or

$$PV=nRT$$

Even at ordinary temperatures and pressures, real gases can deviate slightly from the ideal value.

- The effect is much greater under more extreme conditions;
- The non-ideal behavior gets worse at lower temperatures; and
- The non-ideal behavior gets worse at higher pressures.

When a gas is described under two different conditions, the ideal gas equation must be applied twice - to an initial condition and a final condition. This is:

Initial condition *(i)*	Final condition *(f)*
$PiVi=niRTi$	$PfVf=nfRTf$

Both equations can be rearranged to give:

$$R=\frac{PiVi}{niTi} \qquad R=\frac{PfVf}{nfTf}$$

The two equations are equal to each other since each is equal to the same constant R. Therefore, we have:

$$\frac{PiVi}{niTi} = \frac{PfVf}{nfTf}$$

The equation is called the general gas equation. The equation is particularly useful when one or two of the gas properties are held constant between the two conditions. In such cases, the equation can be simplified by eliminating these constant gas properties.

1.7 Properties of materials

.1 Identify the types of materials and design commonly used in handling and storage of fuels subject to the IGF Code

Table 1 – Typical Applications of Metals Used for LNG Systems

Alloy	TYPE	APPLICATION
9Ni	9% Ni steel	Storage tanks
304L	Stainless steel type AISI 304L	Piping; Small vessels. Some designs of large storage tanks.
36NiFe	Low expansion, 36%Ni-Fe alloy	Some large storage tank designs. Piping in critical applications.
Al	Aluminium alloy type 5083 (Al-4.5%Mg) Alloy 5154 (Al-3.5%Mg) Alloy 6000 (Al –Si)	Spherical or prismatic storage tanks for ship transportation of LNG. Tubing for the main cryogenic heat exchanger. Forgings such as flanges.

Material of the ships' structure and fuel tanks undergoes changes due to the properties of the fuel used. It should be noted that direct contact with LNG (as a cryogenic liquid) can result in serious freezing injuries. If LNG comes into contact with steel, the steel will embrittle due to the low temperature and a steel structure may fracture. Stainless steel retains its ductility at low temperatures and is therefore more resistant to contact with cryogenic liquids.

The types of materials used, and designs of containment systems is dependent upon the coefficient of thermal expansion, compatibility with fuel, ductility, strength and toughness of the material.The safety of the LNG fuel tank can be ensured by selecting the appropriate structural material, as well as by optimizing its structural design.

For instance, Figure 4 shows the schematic of the structural design concept of the type-B independent tank. The dimensions of the target structure are 21.85 m (length)×34.8 m (breadth)×17.4 m (height). As shown in Figure 4, the LNG fuel tank consists of the following three different parts:

(1) A primary barrier: It has direct contact with LNG and is made of AISI 304L stainless steel, which absorbs the thermal deformation caused by the cryogenic temperature.

(2) An insulation panel surrounding the primary barrier: It is composed of polyurethane foam (PUF), which is typically used as an insulation material for independent-type LNG fuel tanks.

(3) A support structure: It is the middle part, which is composed of compressed wood and functions as support. The properties of each material constituting the tank are summarized in Table 2.

Figure 4: Schematic presentation of the structural design and size of a type-B independent tank

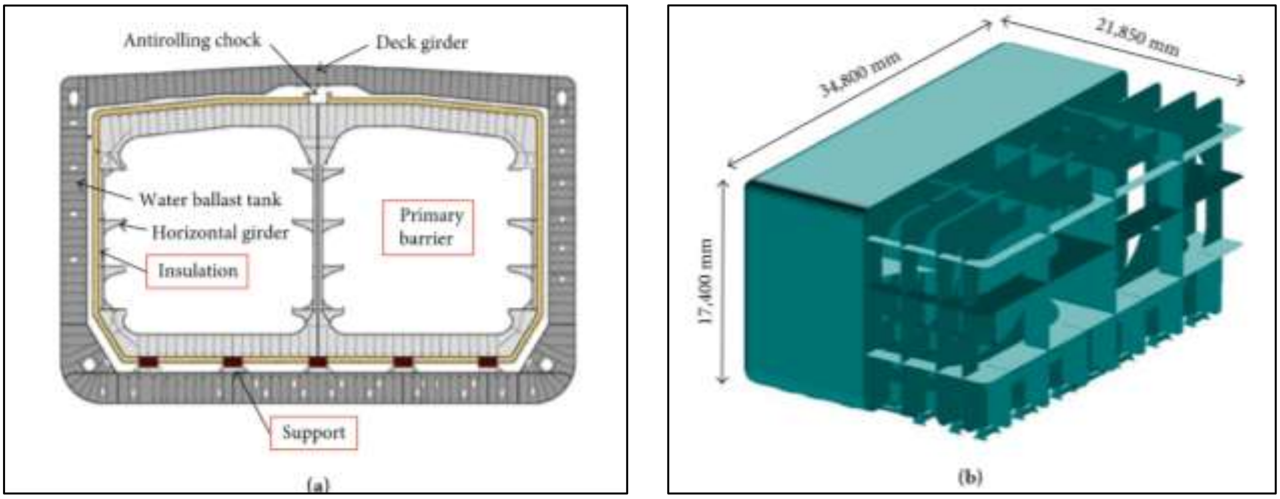


Table 2: Mechanical and thermal properties of materials of tank components.

	SUS304L	PUF	Wood
Poisson's ratio	0.3	0.4	0.024
Elastic modulus (MPa)	193×10^3	191	10,600
Density (tonnage/mm^3)	8×10^{-9}	3×10^{-11}	1.2×10^{-10}
Yield stress (MPa)	340.6 (20°C) 556.3 (−163°C)	2.7	63
Thermal conductivity (W/m^2 °C)	14	2.5×10^{-2}	4×10^{-2}
Specific heat (J/tonnage °C)	5×10^5	1.5×10^6	1.6×10^{-6}
Thermal expansion coefficient (mm/mm °C)	1.7×10^{-5}	8×10^{-5}	6.1×10^{-6}

The grade of plate and sections used in the hull structure, a temperature calculation shall be performed for all tank types. The materials of all hull structures for which the calculated temperature in thedesign condition is below 0°C, due to the influence of liquefied gas fuel temperature. This includes hull structure supporting the liquefied gas fuel tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

Metallic materials used in the construction of primary and secondary barriers not forming the hull, shall be suitable for the design loads that they may be subjected to. Where non-metallic materials, including composites, are used for or incorporated in the primary or secondary barriers, they shall be tested for the following properties, as applicable, to ensure that they are adequate for the intended service:

.1 compatibility with the liquefied gas fuels;
.2 ageing;
.3 mechanical properties;
.4 thermal expansion and contraction;

.5 abrasion;
.6 cohesion;
.7 resistance to vibrations;
.8 resistance to fire and flame spread; and
.9 resistance to fatigue failure and crack propagation

Fuel piping shall be capable of absorbing thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses. Provision shall be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to thermal movement and from movements of the fuel tank and hull structure.

.2 Explain the chemical properties of materials commonly used in handling and storage of fuels subject to the IGF Code

Table 2: Typical Chemical Compositions of Metals Used in LNG Systems.

		Element (Maximum weight%)											
Alloy	UNS	C	Si	Mn	S	P	Ni	Cr	Fe	Al	Cu	Mg	Zn
9Ni	K81340	0.13*	0.15-0.35	1.00	0.040	0.035	8.00-10.00	-	Bal	-	-	-	-
304L	S30403	0.03	1.00	2.00	0.030	0.040	8.0-12.0	18.0-20.0	Bal	-	-	-	-
36Ni	K93600	0.04	0.25	0.2-0.4	0.012	0.012	35-36.5	-	Bal	-	-	-	-
Al 5083	A95083	-	0.40	0.40-1.0	-	-	-	0.05-0.25	0.40	Bal	0.10	4.0-4.9	0.25
Al 6061	A96061	-	0.40-0.8	0.15 max.	-	-	-	0.04-0.35	0.7 max.	Bal	0.15-0.40	0.8-1.2	-

* lower carbon content, e.g. 0.04 - 0.08%, reduces the risk of excessive HAZ hardening.

1.8 Effect of low temperature, including brittle fracture, for liquid cryogenic fuels

.1 Explain the effect of low temperature on materials for fuel tanks, fuel lines and ship's hull subject to the IGF Code

Liquefied gas spilled onto constructional steel such as ships' decks not designed for low temperatures may cool this steel to temperatures where it becomes brittle. In the event of fuel system leaks & contact with LNG chilled to its temperatures of about –160 degree C will damage living tissue. Most metals lose their ductility at these temperatures; LNG may cause the brittle fracture of many materials. In case of LNG spillage on the ship's deck, the high thermal stresses generated can result in the fracture of the steel. Liquefied gas spilled onto constructional steel such as ships' decks not designed for low temperatures may cool this steel to temperatures where it becomes brittle.

.2 Explain the measures to mitigate the effect of low temperature

Care should be taken to prevent spillage of low temperature fuel because of the hazard to personnel and the danger of brittle fracture. Remember that a flammable or toxic cloud may not be visible. If spillage does occur, the source should first be isolated and the spilt liquid then dispersed. If these is a danger of brittle fracture, a water hose may be used both to vaporize 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. The resultant fractures are unlikely to propagate beyond the cooled areas.

Where cryogenic fuel is handled (tank connection spaces, fuel preparation rooms, bunkering station, etc. for cryogenic fuels) there should be barriers to prevent any leakage from reaching ship hull and deck (low temperature secondary barriers, drip trays etc.). Any such leakage should also be prevented from cooling down the surrounding ship steel due to cold bridges.

2. Information contained in Safety Data Sheet (SDS)

.1 Identify the sections contained in a Safety Data Sheet (SDS) on fuels subject to the IGF Cod

The information contained in the SDS is largely the same as the MSDS, except now the SDSs are required to be presented in a consistent user-friendly, 16-section format. The following can be used to help course attendant become familiar with the format and understand the contents of the SDSs.

The SDS includes information such as the properties of each chemical; the physical, health, and environmental health hazards; protective measures; and safety precautions for handling, storing, and transporting the chemical. The information contained in the SDS should be in English (although it may be in other languages as well).

Sections 1 through 8 contain general information about the chemical, identification, hazards, composition, safe handling practices, and emergency control measures (e.g., firefighting). This information should be helpful to those that need to get the information quickly. Sections 9 through 11 and 16 contain other technical and scientific information, such as physical and chemical properties, stability and reactivity information, toxicological information, exposure control information, and other information including the date of preparation or last revision. The SDS should also state that no applicable information was found no relevant information is found for any required element.

The SDS should also contain Sections 12 through 15, to be consistent with the UN Globally Harmonized System of Classification and Labeling of Chemicals (GHS).

.2 Use the information provided in the SDS

A description of all 16 sections of the SDS, along with their contents, is presented below:

Section 1: Identification This section identifies the chemical on the SDS as well as the recommended uses. It also provides the essential contact information of the supplier. The required information consists of:

- Product identifier used on the label and any other common names or synonyms by which the substance is known.
- Name, address, phone number of the manufacturer, importer, or other responsible party, and emergency phone number.

- Recommended use of the chemical (e.g., a brief description of what it actually does, such as flame retardant) and any restrictions on use (including recommendations given by the supplier).

Section 2: Hazard(s) Identification
This section identifies the hazards of the chemical presented on the SDS and the appropriate warning information associated with those hazards. The required information consists of:

- The hazard classification of the chemical (e.g., flammable liquid, category).
- Signal word.
- Hazard statement(s).
- Pictograms (the pictograms or hazard symbols may be presented as graphical reproductions of the symbols in black and white or be a description of the name of the symbol (e.g., skull and crossbones, flame).
- Precautionary statement(s).
- Description of any hazards not otherwise classified.
- For a mixture that contains an ingredient(s) with unknown toxicity, a statement describing how much (percentage) of the mixture consists of ingredient(s) with unknown acute toxicity. Please note that this is a total percentage of the mixture and not tied to the individual ingredient(s).

Section 3: Composition/Information on Ingredients
This section identifies the ingredient(s) contained in the product indicated on the SDS, including impurities and stabilizing additives. This section includes information on substances, mixtures, and all chemicals where a trade secret is claimed. The required information consists of:
Substances

- Chemical name.
- Common name and synonyms.
- Chemical Abstracts Service (CAS) number and other unique identifiers.
- Impurities and stabilizing additives, which are themselves classified and which contribute to the classification of the chemical.

Mixtures

- Same information required for substances.
- The chemical name and concentration (i.e., exact percentage) of all ingredients which are classified as health hazards and are:
    - o Present above their cut-off/concentration limits or
    - o Present a health risk below the cut-off/concentration limits.
- The concentration (exact percentages) of each ingredient should be specified except concentration ranges may be used in the following situations:
    - o A trade secret claim is made,
    - o There is batch-to-batch variation, or
    - o The SDS is used for a group of substantially similar mixtures.

Chemicals where a trade secret is claimed

- A statement that the specific chemical identity and/or exact percentage (concentration) of composition has been withheld as a trade secret is required.

Section 4: First-Aid Measures

This section describe the initial care that should be given by untrained responders to an individual who has been exposed to the chemical. The required information consists of:

- Necessary first-aid instructions by relevant routes of exposure (inhalation, skin and eye contact, and ingestion).
- Description of the most important symptoms or effects, and any symptoms that are acute or delayed.
- Recommendations for immediate medical care and special treatment needed, when necessary.

Section 5: Fire-Fighting Measures

This section provides recommendations for fighting a fire caused by the chemical. The required information consists of:

- Recommendations of suitable extinguishing equipment, and information about extinguishing equipment that is not appropriate for a particular situation.
- Advice on specific hazards that develop from the chemical during the fire, such as any hazardous combustion products created when the chemical burns.
- Recommendations on special protective equipment or precautions for firefighters.

Section 6: Accidental Release Measures

This section provides recommendations on the appropriate response to spills, leaks, or releases, including containment and clean up practices to prevent or minimize exposure to people, properties, or the environment. It may also include recommendations distinguishing between responses for large and small spills where the spill volume has a significant impact on the hazard. The required information may consist of recommendations for:

- Use of personal precautions (such as removal of ignition sources or providing sufficient ventilation) and protective equipment to prevent the contamination of skin, eyes, and clothing.
- Emergency procedures, including instructions for evacuations, consulting experts when needed, and appropriate protective clothing.
- Methods and materials used for containment (e.g. covering the drains and capping procedures).
- Clean-up procedures (e.g. appropriate techniques for neutralization, decontamination, cleaning or vacuuming; adsorbent materials; and/or equipment required for containment/clean up).

Section 7: Handling and Storage

This section provides guidance on the safe handling practices and conditions for safe storage of chemicals. The required information consists of:

- Precautions for safe handling, including recommendations for handling incompatible chemicals, minimizing the release of the chemical into the environment, and providing advice on general hygiene practices (e.g., eating, drinking, and smoking in work areas is prohibited).

- Recommendations on the conditions for safe storage, including any incompatibilities. Provide advice on specific storage requirements (e.g., ventilation requirements)

Section 8: Exposure Controls/Personal Protection

This section indicates the exposure limits, engineering controls, and personal protective measures that can be used to minimize worker exposure. The required information consists of:

- OSHA Permissible Exposure Limits (PELs), American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and any other exposure limit used or recommended by the chemical manufacturer, importer, or employer preparing the safety data sheet, where available.
- Appropriate engineering controls (e.g., use local exhaust ventilation, or use only in an enclosed system).
- Recommendations for personal protective measures to prevent illness or injury from exposure to chemicals, such as personal protective equipment (PPE) (e.g., appropriate types of eye, face, skin or respiratory protection needed based on hazards and potential exposure).
- Any special requirements for PPE, protective clothing or respirators (e.g., type of glove material, such as PVC or nitrile rubber gloves; and breakthrough time of the glove material).

Section 9: Physical and Chemical Properties

This section identifies physical and chemical properties associated with the substance or mixture. The minimum required information consists of:

- Appearance (physical state, colour, etc.);
- Upper/lower flammability or explosive limits;
- Odour;
- Vapour pressure;
- Odour threshold;
- Vapour density;
- pH;
- Relative density;
- Melting point/freezing point;
- Solubility(ies);
- Initial boiling point and boiling range;
- Flashpoint;
- Evaporation rate;

- Flammability (solid, gas);
- Partition coefficient: n-octanol/water;
- Auto-ignition temperature;
- Decomposition temperature; and
- Viscosity.

The SDS may not contain every item on the above list because information may not be relevant or is not available. When this occurs, a notation to that effect should be made for that chemical property. Manufacturers may also add other relevant properties, such as the dust deflagration index (Kst) for combustible dust, used to evaluate a dust's explosive potential

Section 10: Stability and Reactivity
This section describe the reactivity hazards of the chemical and the chemical stability information. This section is broken into three parts: reactivity, chemical stability, and other. The required information consists of:

Reactivity
- Description of the specific test data for the chemical(s). This data can be for a class or family of the chemical if such data adequately represent the anticipated hazard of the chemical(s), where available.

Chemical stability
- Indication of whether the chemical is stable or unstable under normal ambient temperature and conditions while in storage and being handled.
- Description of any stabilizers that may be needed to maintain chemical stability.
- Indication of any safety issues that may arise should the product change in physical appearance.

Other
- Indication of the possibility of hazardous reactions, including a statement whether the chemical will react or polymerize, which could release excess pressure or heat, or create other hazardous conditions. Also, a description of the conditions under which hazardous reactions may occur.
- List of all conditions that should be avoided (e.g., static discharge, shock, vibrations, or environmental conditions that may lead to hazardous conditions).
- List of all classes of incompatible materials (e.g., classes of chemicals or specific substances) with which the chemical could react to produce a hazardous situation.
- List of any known or anticipated hazardous decomposition products that could be produced because of use, storage, or heating. (Hazardous combustion products should also be included in Section 5 (Fire-Fighting Measures) of the SDS.)

Section 11: Toxicological Information

This section identifies toxicological and health effects information or indicates that such data are not available. The required information consists of:

- Information on the likely routes of exposure (inhalation, ingestion, skin and eye contact). The SDS should indicate if the information is unknown.
- Description of the delayed, immediate, or chronic effects from short- and long-term exposure.
- The numerical measures of toxicity (e.g., acute toxicity estimates such as the LD50 (median lethal dose)) - the estimated amount [of a substance] expected to kill 50% of test animals in a single dose.
- Description of the symptoms. This description includes the symptoms associated with exposure to the chemical including symptoms from the lowest to the most severe exposure.
- Indication of whether the chemical is listed in the National Toxicology Program (NTP) Report on Carcinogens (latest edition) or has been found to be a potential carcinogen in the International Agency for Research on Cancer (IARC) Monographs (latest editions) or found to be a potential carcinogen by OSHA.

Section 12: Ecological Information (non-mandatory)

This section provides information to evaluate the environmental impact of the chemical(s) if it were released to the environment. The information may include:

- Data from toxicity tests performed on aquatic and/or terrestrial organisms, where available (e.g., acute or chronic aquatic toxicity data for fish, algae, crustaceans, and other plants; toxicity data on birds, bees, plants).
- Whether there is a potential for the chemical to persist and degrade in the environment either through biodegradation or other processes, such as oxidation or hydrolysis.
- Results of tests of bioaccumulation potential, making reference to the octanol-water partition coefficient (Kow) and the bio concentration factor (BCF), where available.
- The potential for a substance to move from the soil to the groundwater (indicate results from adsorption studies or leaching studies).
- Other adverse effects (e.g., environmental fate, ozone layer depletion potential, photochemical ozone creation potential, endocrine disrupting potential, and/or global warming potential).

Section 13: Disposal Considerations (non-mandatory)

This section provides guidance on proper disposal practices, recycling or reclamation of the chemical(s) or its container, and safe handling practices. To minimize exposure, this section should also refer the reader to Section 8 (Exposure Controls/Personal Protection) of the SDS. The information may include:

- Description of appropriate disposal containers to use.

- Recommendations of appropriate disposal methods to employ.
- Description of the physical and chemical properties that may affect disposal activities.
- Language discouraging sewage disposal.
- Any special precautions for landfills or incineration activities.

Section 14: Transport Information (non-mandatory)

This section provides guidance on classification information for shipping and transporting of hazardous chemical(s) by road, air, rail, or sea. The information may include:

- UN number (i.e., four-figure identification number of the substance).1
- UN proper shipping name.1
- Transport hazard class(es).1
- Packing group number, if applicable, based on the degree of hazard.2
- Environmental hazards (e.g., identify if it is a marine pollutant according to the International Maritime Dangerous Goods Code (IMDG Code)).
- Guidance on transport in bulk (according to Annex II of MARPOL 73/783 and the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (International Bulk Chemical Code (IBC Code)).
- Any special precautions which an employee should be aware of or needs to comply with, in connection with transport or conveyance either within or outside their premises (indicate when information is not available).

Section 15: Regulatory Information (non-mandatory)

This section identifies the safety, health, and environmental regulations specific for the product that is not indicated anywhere else on the SDS. The information may include:

- Any national and/or regional regulatory information of the chemical or mixtures (including any OSHA, Department of Transportation, Environmental Protection Agency, or Consumer Product Safety Commission regulations)

Section 16: Other Information

This section indicates when the SDS was prepared or when the last known revision was made. The SDS may also state where the changes have been made to the previous version. You may wish to contact the supplier or an explanation of the changes. Other useful information also may be included here.

ConocoPhillips Alaska, Inc

Methane, Beluga River Unit

Safety Data Sheet

Section 1: Identification of the substance or mixture and of the supplier

Product Name:	Methane, Beluga River Unit
SDS Number:	790587
Intended Use:	Fuel
Manufacturer:	ConocoPhillips Alaska, Inc. A Subsidiary of ConocoPhillips P.O. Box 100360 700 G. Street Anchorage, AK 99510-0360
Emergency Health and Safety Number:	Chemtrec: 800-424-9300 (24 Hours)
Customer Service:	907-659-7812
Technical Information:	907-659-7812
SDS Information:	Phone: 855-244-0762 Email: SDS@conocophillips.com URL: www.conocophillips.com

Section 2: Hazard(s) Identification

<u>Classification</u>
H220 – Flammable gases – Category 1
H280 – Gases under pressure – Compressed gas

Label Elements

DANGER
Extremely flammable gas. (H220)*
Contains gas under pressure. May explode if heated. (H280)*
Gas may reduce oxygen in confined spaces.

<u>Precautionary Statement(s):</u>
Keep away from heat/sparks/open flames/hot surfaces. - No smoking. (P210)*
Leaking gas fire: Do not extinguish, unless leak can be stopped safely. (P377)*
Eliminate all ignition sources if safe to do so. (P381)*
Protect from sunlight. Store in a well ventilated place. (P410+P403)*

** (Applicable GHS hazard code.)*

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Section 3: Composition / Information on Ingredients

Component	CASRN	Concentration*
Methane	74-82-8	98-99
Propane	74-98-6	<1
Nitrogen	7727-37-9	<1
Carbon Dioxide	124-38-9	<1

* All concentrations are percent by weight unless ingredient is a gas. Gas concentrations are in percent by volume.

Section 4: First Aid Measures

Eye Contact: If irritation or redness develops from exposure, flush eyes with clean water. If symptoms persist, seek medical attention.

Skin Contact: First aid is not normally required. However, it is good practice to wash any chemical from the skin.

Inhalation (Breathing): If respiratory symptoms develop, move victim away from source of exposure and into fresh air in a position comfortable for breathing. If breathing is difficult, oxygen or artificial respiration should be administered by qualified personnel. If symptoms persist, seek medical attention.

Ingestion (Swallowing): This material is a gas under normal atmospheric conditions and ingestion is unlikely.

Most important symptoms and effects

Acute: Anesthetic effects at high concentrations.

Delayed: None known or anticipated. See Section 11 for information on effects from chronic exposure, if any.

Notes to Physician: Epinephrine and other sympathomimetic drugs may initiate cardiac arrhythmias in persons exposed to high concentrations of hydrocarbon solvents (e.g., in enclosed spaces or with deliberate abuse). The use of other drugs with less arrhythmogenic potential should be considered. If sympathomimetic drugs are administered, observe for the development of cardiac arrhythmias.

Section 5: Fire-Fighting Measures

NFPA 704 Hazard Class

Health: 2 **Flammability:** 4 **Instability:** 0 (0-Minimal, 1-Slight, 2-Moderate, 3-Serious, 4-Severe)

Unusual Fire & Explosion Hazards: Extremely flammable. Contents under pressure. This material can be ignited by heat, sparks, flames, or other sources of ignition (e.g., static electricity, pilot lights, mechanical/electrical equipment, and electronic devices such as cell phones, computers, calculators, and pagers which have not been certified as intrinsically safe). Vapors may travel considerable distances to a source of ignition where they can ignite, flash back, or explode. May create vapor/air explosion hazard indoors, in confined spaces, outdoors, or in sewers. If container is not properly cooled, it can rupture in the heat of a fire.

Extinguishing Media: Dry chemical or carbon dioxide is recommended. Carbon dioxide can displace oxygen. Use caution when applying carbon dioxide in confined spaces.

Fire Fighting Instructions: For fires beyond the initial stage, emergency responders in the immediate hazard area should wear protective clothing. When the potential chemical hazard is unknown, in enclosed or confined spaces, a self contained breathing apparatus should be worn. In addition, wear other appropriate protective equipment as conditions warrant (see Section 8).

Isolate immediate hazard area and keep unauthorized personnel out. Stop spill/release if it can be done safely. If this cannot be done, allow fire to burn. Move undamaged containers from immediate hazard area if it can be done safely. Stay away from ends of container. Water spray may be useful in minimizing or dispersing vapors and to protect personnel. Cool equipment exposed to fire with water, if it can be done safely.

3. Principles of marine power plants

3.1 Operating Principles of Different Types of Marine Power Plants Subject to the IGF Code

.1 Explain the operating principles of the following marine power:

- Pure gas engines
- Dual Fuel engines (with low/medium pressure injection)
- Gas Diesel engines (with high-pressure gas injection)
- Multi/Bi-Fuel engines
- Gas turbines
- Steam turbines
- Fuel cells

Pure Gas Engines

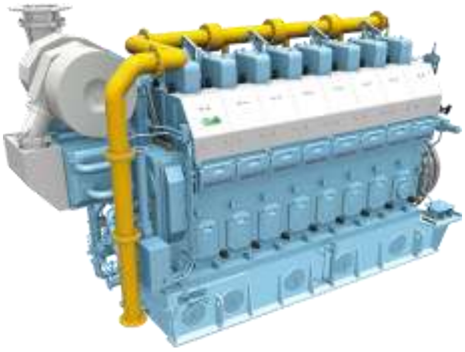
- Pure gas engines are really spark ignition engines; these can run on gaseous fuels which are mixed with air upon admission to the cylinder head. More volatile liquid fuels such as gasoline can be used in the engine if they are vaporized. The gas and air is mixed outside the combustion chamber and then admitted at low pressure into the cylinder prior to the compression stroke. In both cases the principle is the same, when compression has completed the fuel-air mixture ignition is initiated with a spark. This combustion process follows the Otto cycle.

Dual Fuel Engines

- Dual fuel engines are capable of running on gas or liquid fuel. When running on gas as fuel a small amount of liquid fuel, typically around 1-3% of the energy content at full power, is used as pilot fuel to ignite the gas, which is then burnt using the Otto cycle. The gas, and air are mixed outside the combustion chamber and then injected at low pressure into the cylinder. Liquid fuel is injected directly into the combustion chamber at high pressure. During the compression stroke the gas-liquid-air mixture warms until the liquid fuel ignites (Diesel process). The combusting liquid fuel burns first thus effectively igniting the majority gas-

air mixture (Otto cycle). Dual fuel engines with Otto principle are available as both 4-stroke and 2-stroke engines.

Gas Diesel Engines



- Similar to dual fuel engines these machines are capable of running on gas or liquid fuel. When running on gas as fuel a small amount of liquid fuel, typically aroun d 3-5% of the energy content at full power, is used as pilot fuel to ignite the gas on each combustion stroke. However, the operating principles for this technology are very different as the engine is operating on the diesel cycle. Both gas and liquid pilot fuel is injected at high pressure just as the compression stroke completes. This high-pressure injection results in effective mixing of fuel and air just before ignition commences therefore the possibility of pre-ignition/knocking is practically eliminated.

Multi/Bi-fuel engines

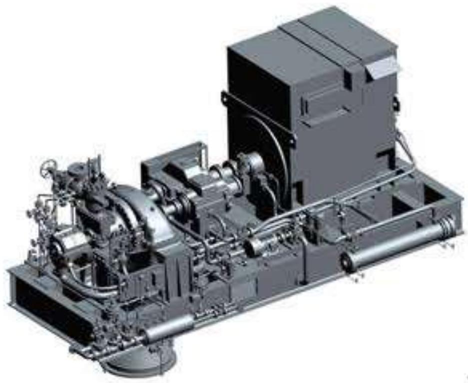
- A mixture of gas and liquid is burnt at the same time. Typically, the gas ratio can be between 30% and 70% of the energy content and the remaining energy needs to come from liquid fuel. This solution has been mostly used as a retrofit solution for high-speed engines.

Gas Turbines

- Aero-derivative gas turbines are used for marine propulsion with the heat en ergy of the exhaust used to drive a power turbine on a separate spool which in turn is connected to the propulsion unit, typically a water jet (via a gearbox) or directly. There are no reciprocating parts in the power or drive train and in high power applications modern recuperative units can achieve thermal efficiencies approaching reciprocating norms. Gas turbines can burn gas, marine distillate or diesel. They cannot normally burn a combination of fuels or switch easily between them.

Steam Turbines

Steam is raised in boilers by combusting fuel, gas, oil, or a mixture of these, in burners. The steam is used to drive a steam turbine connected to the propulsion system. Because of their low thermal efficiency, commercial steam turbine-powered ships are now very few in number worldwide, the majority being first generation LNG carriers. Steam systems utilize the Rankine cycle. Boilers for steam turbines are normally able to burn a wide range of gas compositions and so are largely insensitive to fuel composition changes.

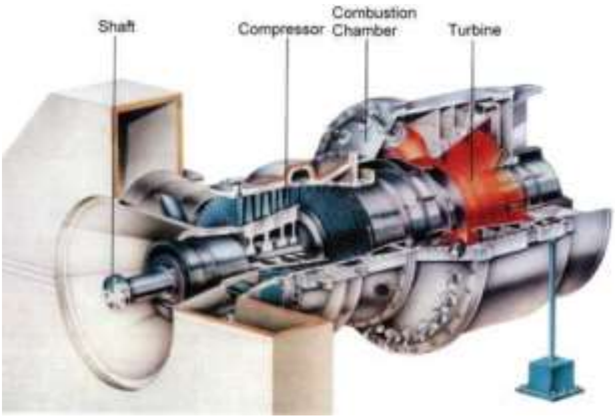


Gas Turbine for Power Generation

- The use of gas turbines for generating electricity dates back to 1939. Today, gas turbines are one of the most widely-used power generating technologies. Gas turbines are a type of internal combustion (IC) engine in which burning of an air-fuel mixture produces hot gases that spin a turbine to produce power. It is the production of hot gas during fuel combustion, not the fuel itself that the gives gas turbines the name. Gas turbines can utilize a variety of fuels, including natural gas, fuel oils, and synthetic fuels. Combustion occurs continuously in gas turbines, as opposed to reciprocating IC engines, in which combustion occurs intermittently.

How Do Gas Turbines Work?

- Gas turbines are comprised of three primary sections mounted on the same shaft: the compressor, the combustion chamber (or combustor) and the turbine. The compressor can be either axial flow or centrifugal flow. Axial flow compressors are more common in power generation because they have higher flow rates and efficiencies. Axial flow compressors are comprised of multiple stages of rotating and stationary blades (or stators) through which air is drawn in parallel to the axis of rotation and incrementally compressed as it passes through each stage. The acceleration of the air through the rotating blades and diffusion by the stators increases the pressure and reduces the volume of the air. Although no heat is added, the compression of the air also causes the temperature to increase.



- The compressed air is mixed with fuel injected through nozzles. The fuel and compressed air can be pre-mixed or the compressed air can be introduced directly into the combustor. The fuel-air mixture ignites under constant pressure conditions and the hot combustion products (gases) are directed through the turbine where it expands rapidly and imparts rotation to the shaft. The turbine is also comprised of stages, each with a row of stationary blades (or nozzles) to direct the expanding gases followed by a row of moving blades. The rotation of the shaft drives the compressor to draw in and compress more air to sustain continuous combustion. The remaining shaft power is used to drive a generator which produces electricity. Approximately 55 to 65 percent of the power produced by the turbine is used to drive the compressor. To optimize the transfer of kinetic energy from the combustion gases to shaft rotation, gas turbines can have multiple compressor and turbine stages.

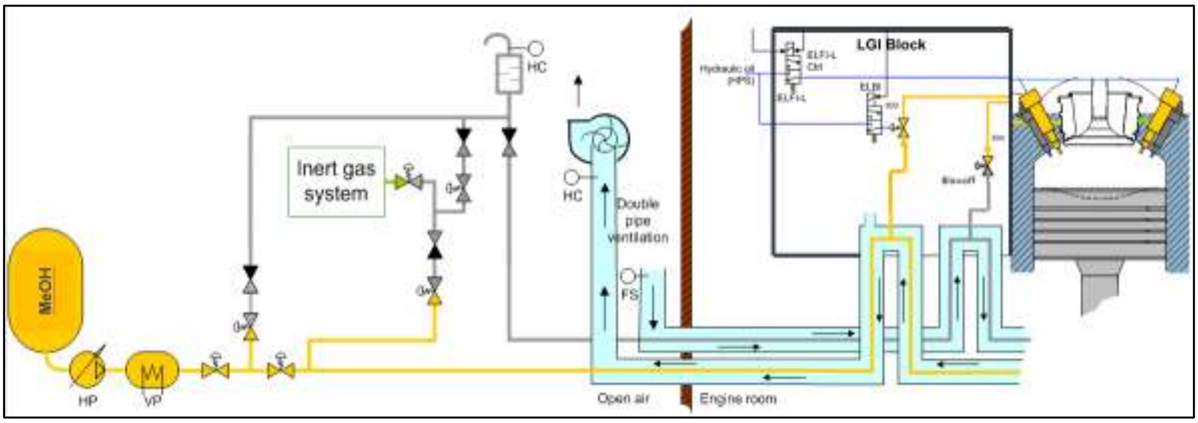
- Because the compressor must reach a certain speed before the combustion process is continuous – or self-sustaining – initial momentum is imparted to the turbine rotor from an external motor, static frequency converter, or the generator itself. The compressor must be smoothly accelerated and reach firing speed before fuel can be introduced and ignition can occur. Turbine speeds vary widely by manufacturer and design, ranging from 2,000 revolutions per minute (rpm) to 10,000 rpm. Initial ignition occurs from one or more spark plugs (depending on combustor design). Once the turbine reaches self-sustaining speed – above 50% of full speed – the power output is enough to drive the compressor, combustion is continuous, and the starter system can be disengaged.

.2 Operate marine power plant in accordance with technical specifications

Redundancy of Propulsion

It is to ensure the vessel can continue to operate after fuel supply shut down due to leakage in one gas/LEL fuel supply system. Redundant propulsion plants for hazardous fuel ships can be achieved by doubling the main engines, propellers and rudders. Hence, duplication of various machinery and systems forming a part of the propulsion system.

LNG shipping industry demands high reliability of the propulsion machinery and it can be achieved not only by the reliability of the equipment themselves, but also by installation of redundant system against unexpected failure of single equipment. The propulsion alternatives have been developed to secure redundancy concept and should be acceptable to LNG carriers. Very high reliability of gas turbine might interest operators and the dual fuel diesel electric propulsion system will provide better redundancy and flexibility with multi-engine installation.
For dual- and multi-fuel engines, an automatic fuel changeover system is required, which should operate on the failure of one fuel supply system. All gas components inside engine room are encapsulated and the duct is vented by a suction fan. HC sensors at the air outlet detects gas leakages and if the gas concentration becomes too high (<60LEL%) a gas shut down is released.

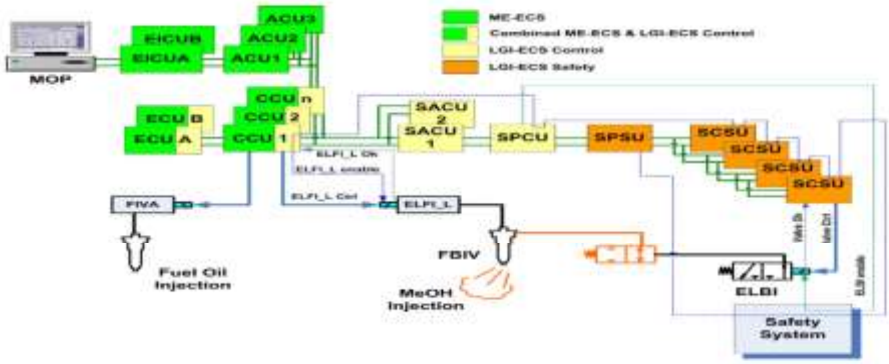


A single failure result in gas shut down or gas stop for safety reasons a detected single failure on a safety unit in results gas shutdown while a detected single failure on a control unit results in gas stop.

- Gas Shutdown: Immediately stop of gas injection - continued operation on fuel oil, handled by gas safety system (Followed by a gas blow off and inert gas purging sequence)
- Gas Stop: Normal changeover from gas mode to fuel oil mode – continued operation on fuel oil, handled by gas control system (Followed by a gas blow off and a inert gas purging sequence)

The Dual Fuel system must not affect the engine running on MDO/HFO. In case of gas shutdown, the Methanol injection is stopped immediately and the engine continues almost bump less on fuel without load reduction.

In case of gas stop the Methanol, injection is ramped down to minimum gas injection and then gas injection is stopped. Engine speed and load is maintained all the time during the changeover to fuel running.



Control and safety functionalities are separated on different hardware units. Some essential process information is monitored by having two sensors. One sensor is monitored by a control unit and the other sensor by a safety unit. Both sensors have to be operative to continue running on gas.

If the sensor send to the safety unit is failing a gas shutdown is carried out and if the sensor send to the control unit fails a normal gas stop is carried out. The gas injection is controlled from a control unit and the window valve is controlled from a safety unit.

4. Ship's auxiliary machinery
Nitrogen generation and distribution

.1 Explain the operating principles of nitrogen generation and distribution systems

Nitrogen generators
Nitrogen is generated onboard using a system called pressure swing absorption. The process is based on the use of an absorbent carbon bed, which acts as a molecular sieve, absorbing oxygen and leaving nitrogen as the unabsorbed product.
On exhaustion, the carbon beds are regenerated in a valve-operated sequential system, venting an oxygen rich waste. This type of system produces nitrogen gas of high purity, with less than 1% oxygen. Refrigerated drier (normally cooled by a Freon gas). Absorption drier.
Most LNG vessels are equipped with nitrogen generators, installed in the engine room, which produce gaseous nitrogen for:

- The pressurization of the barrier insulation spaces.
- As seal gas for the HD and LD compressors.
- For fire extinguishing in the vent mast risers.
- For purging the fuel gas system and various parts of the fuel piping.

Nitrogen is dry and non-combustible, and the nitrogen displacement of combustible gases will prevent an unstable and potentially ignitable atmosphere. Simply put, the use of nitrogen in oil and gas industry equipment effectively displaces moisture and oxygen and creates a more stable climate.
The goal of any nitrogen purging system is to "cleanse" pipes and other parts that contain contaminants. In doing so, you will significantly reduce any risk associated with hazardous elements, including oxygen. Depending on the method used, nitrogen may circulate at either high or low pressures.

Of course, the specific nitrogen displacement procedure used will depend on many factors, including some of the points we discussed above. Regardless of the method used, you will need access to a steady flow of nitrogen.

This is where a nitrogen generator comes into play, helping you achieve up to 99.9 percent purity levels.

The operating principle is based on the hollow fiber membranes through which compressed air flows and is separated into oxygen and nitrogen. The oxygen is vented to the atmosphere and the nitrogen is stored in a buffer tank.

It is important to appreciate that the exhaust from the nitrogen plant will be oxygen-rich compared to the surrounding atmosphere.

The testing of the nitrogen system should be included within the vessel's planned maintenance system along with maintenance routines recommended by the plant manufacturers. Any defects to the N2 Plant must be reported to the management office.

.2 Explain the operational arrangements of nitrogen injection and purging

The following requirements must be met to enable the nitrogen generator to perform at its rated capacity.

Air Supply

Air supplied to the generator must be between 100 °F / 38 °C and 33° F / 0.5 °C, with a water dew point of 40°F / 5°C or below. Air at temperatures higher or lower than this may cause damage not covered by warranty. Likewise, moisture content higher than that specified may damage the adsorbent material and void the warranty. Air pressure, air receiver and nitrogen receiver vessels must be compatible with the generator. Use of a correctly sized refrigerant dryer will ensure that air meets specified standards.

Additional Piping and Hoses

The air supply piping components must be capable of supplying the required amount of feed air at the required pressure measured at the generator inlet connection. If the length of piping from the air receiver is greater than 50 feet, an air supply line one size larger than the Nitrogen Generator inlet air nozzle size should be used.

Electrical Supply

Power supply must be 110 V or 220 V / 1 ph / 50 - 60 Hz as labeled on the unit. Power consumption is less than 0.1 kW.

Site Specifications

Select a non-hazardous area indoors for installation which remains above 33 °F / 0.5°C and below 100 °F / 38 °C. Adequate space should be provided around the generator for access and routine maintenance. Ensure that there is enough space for the air receiver and product receiver skid next to the unit. The exhaust piping from the nitrogen generator may be vented outside, but any additional piping used should be the same size as the exhaust piping supplied with the generator or larger depending on the length of the pipe. Exhaust piping should not have any restrictions or valves, and should be as short as possible.

.3 Explain the maximum allowable percentage of oxygen in the mix

The nitrogen generators are equipped with an oxygen analyzer, which continually monitors the oxygen content in the nitrogen output. If the level of oxygen rises above 1% of the design value, then an alarm is activated. If the level of oxygen rises further, the high high alarm operates, redirecting the flow to atmosphere and closing the discharge line to the buffer tank.

INERT GAS GENERATOR

.1 Explain the operating principles of inert gas systems

Main principles for operation of inert gas plant

Diesel is burned using atmospheric air in a combustion chamber and the exhaust gas collected, the resulting exhaust gas contains less than 5% oxygen, thereby creating "inert gas", which mainly consist of Nitrogen and partly Carbon Dioxide. The hot, dirty gas is then passed through a scrubbing tower which cleans and cools it using seawater. This gas is then delivered to fuel tanks to prevent explosion of flammable

.2 Explain the tank conditioning method "drying" and its importance

Preparation for loading LNG fuel - drying of fuel tanks

During dry docking or inspection, fuel tanks which have been opened and contained humid air, must be dried to avoid the formation of ice when they are cooled down and the formation of corrosive agents if the humidity combines with sulfur and nitrogen oxides which might be present in excess in the inert gas.

The drying operation need not be performed independently by using dry air, instead during inerting operation by supplying dry inert gas, drying operation can be achieved. During such operation special attention is required to the delivery temperature of inert gas to prevent condensation of humid air inside the tank.

Dry air, with a dew of -70ºC to -40ºC, can be produced by the onboard IGG system.

Operation procedures and precautions

i) It is essential that fuel tanks are thoroughly inspected for cleanliness, free of liquid, any loose objects and all fittings are properly secured. Once this inspection has been completed, the fuel tank should be securely closed and drying operation can be started

ii) During drying operation, measure the atmosphere at different levels at regular intervals. When the dew point of the fuel tank drops below than the planned temperature, finish the drying operation.

.3 Explain the tank conditioning method "inerting" and its importance

Inerting fuel tanks, fuel machinery and pipelines is undertaken primarily to ensure a non-flammable condition during subsequent gassing-up with gas. For this purpose, oxygen concentration must be reduced from 21 per cent to a maximum of five per cent by volume although lower values are often preferred.

5 Marine engineering terms

.1 Define marine engineering terms used onboard ships subject to the IGF Code

Unless otherwise stated below, definitions are as defined in SOLAS chapter II-2.

Accident means an uncontrolled event that may entail the loss of human life, personal injuries, environmental damage or the loss of assets and financial interests.

Breadth (B) means the greatest moulded breadth of the ship at or below the deepest draught (summer load line draught) (refer to SOLAS regulation II-1/2.8).

Bunkering means the transfer of liquid or gaseous fuel from land based or floating facilities into a ships' permanent tanks or connection of portable tanks to the fuel supply system.

Certified safe type means electrical equipment that is certified safe by the relevant authorities recognized by the Administration for operation in a flammable atmosphere based on a recognized standard.

CNG means compressed natural gas

Control station means those spaces defined in SOLAS chapter II-2 and additionally for this Code, the engine control room.

Design temperature for selection of materials is the minimum temperature at which liquefied gas fuel may be loaded or transported in the liquefied gas fuel tanks.

Design vapour pressure "P0" is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

Double block and bleed valve means a set of two valves in series in a pipe and a third valve enabling the pressure release from the pipe between those two valves. The arrangement may also consist of a two-way valve and a closing valve instead of three separate valves.

Dual fuel engines means engines that employ fuel covered by this Code (with pilot fuel) and oil fuel. Oil fuels may include distillate and residual fuels.

Enclosed space means any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally.

ESD means emergency shutdown.

Explosion means a deflagration event of uncontrolled combustion.

Explosion pressure relief means measures provided to prevent the explosion pressure in a container or an *enclosed* space exceeding the maximum overpressure the container or space is designed for, by releasing the overpressure through designated openings.

Fuel containment system is the arrangement for the storage of fuel including tank connections. It includes where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary, for the support of these elements. If the secondary barrier is part of the hull structure it may be a boundary of the fuel storage hold space.

The spaces around the fuel tank are defined as follows:

- *Fuel storage hold space* is the space enclosed by the ship's structure in which a fuel containment system is situated. If tank connections are located in the fuel storage hold space, it will also be a tank connection space;
- *Interbarrier s*pace is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material; and
- *Tank connection* space is a space surrounding all tank connections and tank valves that is required for tanks with such connections in enclosed spaces.

Filling limit (FL) means the maximum liquid volume in a fuel tank relative to the total tank volume when the liquid fuel has reached the reference temperature.

Fuel preparation room means any space containing pumps, compressors and/or vaporizers for fuel preparation purposes.

Gas means a fluid having a vapour pressure exceeding 0.28 MPa absolute at a temperature of 37.8°C.

Gas consumer means any unit within the ship using gas as a fuel.

Gas only engine means an engine capable of operating only on gas, and not able to switch over to operation on any other type of fuel.

Hazardous area means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment.

High pressure means a maximum working pressure greater than 1.0 MPa.

Independent tanks are self-supporting, do not form part of the ship's hull and are not essential to the hull strength.

LEL means the lower explosive limit.

Length (L) is the length as defined in the International Convention on Load Lines in force.

LNG means liquefied natural gas.

Loading limit (LL) means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded.

Low-flashpoint fuel means gaseous or liquid fuel having a flashpoint lower than otherwise permitted under paragraph 2.1.1 of SOLAS regulation II-2/4.

MARVS means the maximum allowable relief valve setting.

MAWP means the maximum allowable working pressure of a system component or tank.

Membrane tanks are non-self-supporting tanks that consist of a thin liquid and gas tight layer (membrane) supported through insulation by the adjacent hull structure.

Multi-fuel engines means engines that can use two or more different fuels that are separate from each other.

Non-hazardous area means an area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of equipment.

Open deck means a deck having no significant fire risk that at least is open on both ends/sides, or is open on one end and is provided with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side plating or deckhead.

Risk is an expression for the combination of the likelihood and the severity of the consequences.

Reference temperature means the temperature corresponding to the vapour pressure of the fuel in a fuel tank at the set pressure of the pressure relief valves (PRVs).

Secondary barrier is the liquid-resisting outer element of a fuel containment system designed to afford temporary containment of any envisaged leakage of liquid fuel through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level.

Semi-enclosed space means a space where the natural conditions of ventilation are notably different from those on open deck due to the presence of structure such as roofs, windbreaks and bulkheads and which are so arranged that dispersion of gas may not occur.

Source of release means a point or location from which a gas, vapour, mist or liquid may be released into the atmosphere so that an explosive atmosphere could be formed.

Unacceptable loss of power means that it is not possible to sustain or restore normal operation of the propulsion machinery in the event of one of the essential auxiliaries becoming inoperative, in accordance with SOLAS regulation II-1/26.3.

Vapour pressure is the equilibrium pressure of the saturated vapour above the liquid, expressed in MPa absolute at a specified temperature.

1. Design and characteristics of ships

.1 Explain the design and characteristics of ships subject to the IGF Code

Design and characteristics of ships subject to the IGF Code

The goal of the IGF Code is to provide for safe and environmentally-friendly design, construction and operation of ships and in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using gas or low-flashpoint fuel as fuel.

Main factors to be considered in designing a ship subject to the IGF Code

- protection of the fuel storage tank and fuel pipework from damage through collisions with other vessels or by dropped objects
- redundancy of fuel systems to ensure that the vessel can continue to navigate if one system has a shutdown due to a leakage or failure
- minimization of any hazards provided by the use of gas as fuel
- safety systems that provide a safe shut-down of hazardous systems and in worst case scenarios, removal of their inventories to prevent the build-up of potentially flammable atmospheres

2. **Ship design, systems and equipment**

7.1 Fuel system for different propulsion engine

.1 Identify the fuel system for different propulsion engines

When a cold liquefied fuel is used, the pipework should be allowed to contract without damage as it cools.

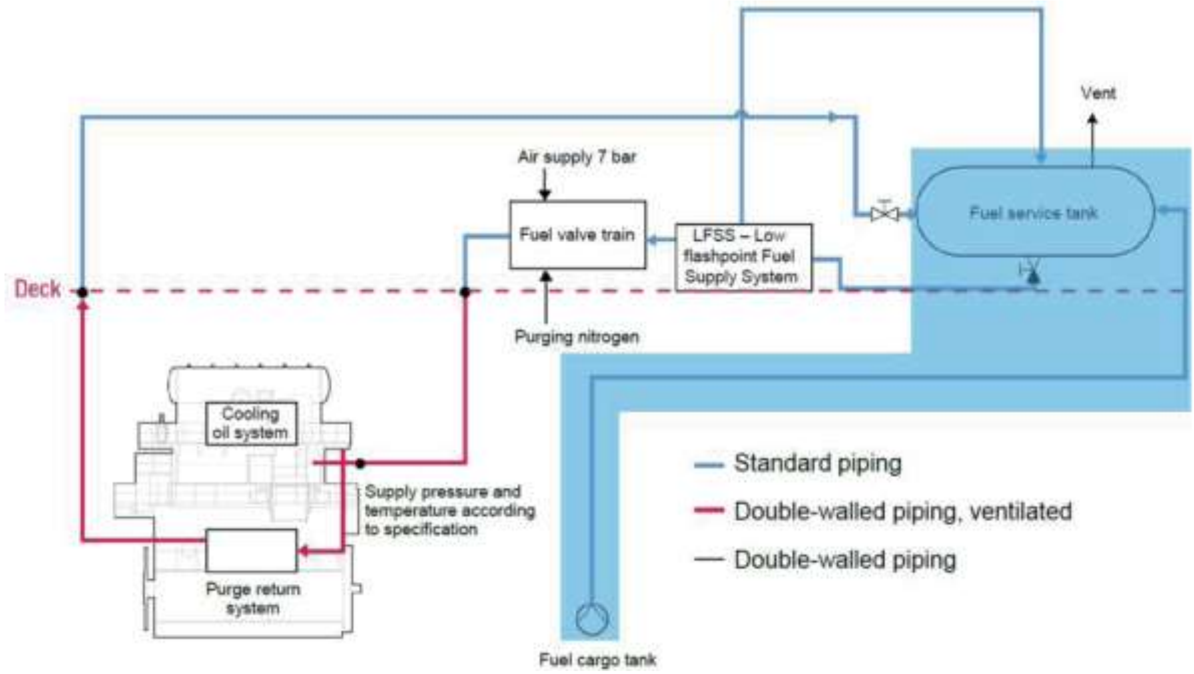
Provision must be made in the design and fitting of fuel pipelines to allow for thermal expansion and contraction. This is best achieved by the fitting of expansion loops or, by using the natural geometry of the pipework, as appropriate. In a few specific cases, expansion bellows may be fitted and, where this is planned, corrosion resistant materials should be used and Section 5.3.2.2 of the IGC Code should be considered. Where expansion bellows are fitted in vapour lines, it should be ensured that their pressure rating at least meets the liquid pipeline design criteria. Furthermore, expansion bellows are often subject to a considerable amount of wear and tear while a ship is in service — in particular, sea-water corrosion must be carefully avoided otherwise pin hole leaks are liable to develop.

It is also important not to alter or adjust adjacent pipeline supports once the ship has entered service since they form an integral part of the expansion arrangements.

Furthermore, it should also be noted that parts of pipeline systems are fitted with strong anchor points to resist lateral or vertical displacement from surge pressures. Similarly, when replacing parts such as bolts and restraining rods, care must be taken to ensure that the new parts are of the correct material for the service.

Removable spool pieces are taken in or out of pipelines to interconnect sections of line for special operational reasons such as using the inert gas plant or ensuring segregation of incompatible fueles. These spool pieces should not be left in position after use but should be removed and pipelines blanked to ensure positive segregation.

Valves should be included to isolate the fuel storage tank or any other significant volume of fuel.
Storage of methanol on board is outlined in the schematic overview of the methanol fuel system presented in Figure below. This part of the methanol fuel system consists of a fuel fuel tank in addition to a fuel service tank placed on deck. This is not the only possible solution regarding storage of methanol as fuel, but used as example in this study for illustration purposes.



Storage of methanol on board

Requirements regarding storage of methanol according to DNV GL rules/19/ are divided into location of fuel tanks, protection of fuel tanks, gas freeing, inerting, venting of fuel tanks and special concerns regarding tanks placed on weather decks.

Location of fuel tanks:

- Fuel shall not be stored within machinery spaces or accommodation spaces and the minimum horizontal distance between the fuel tank side and the ship's shell shall be at least 760 mm.
- The spaces forward of the collision bulkhead (forepeak) and aft of the aftermost bulkhead (afterpeak) shall not be arranged as fuel tanks.
- Two fuel service tanks for each type of fuel used on board necessary for propulsion and vital systems or equivalent arrangements shall be provided.

- Each tank shall have a capacity sufficient for continuous rating of the propulsion plant and normal operating load at sea of the generator plant for a period of not less than 8 hours, if only methanol is used as fuel.

Protection of fuel tanks located inside the ship hull:

- Where not bounded by bottom shell plating or fuel pump room, the fuel tanks for Low flashpoint Liquid (LFL) shall be surrounded by protective cofferdams.
- The protective cofferdam surrounding the LFL fuel tank shall be arranged with vapour and liquid leakage detection and possibility for water filling upon detection of leakage. The water filling shall be through a system without permanent connections to water systems in non-hazardous areas. Emptying shall be done with a separate system. Bilge ejectors serving hazardous spaces shall not be permanently connected to the drive water system.
  Fuel tanks on weather deck:
- LFL fuel tanks on open deck shall be protected against mechanical damage.
- LFL deck tanks on open deck shall be surrounded by coamings.
- Special considerations shall be taken to minimize any fire hazards adjacent to the fuel tanks on weather deck. Protection of the LFL fuel tanks from possible fires on board may be subject to a fire safety assessment in each particular case.

The requirements regarding placement and protection of tanks may imply that additional space must be allocated for storage of methanol on board. The requirements regarding gas freeing, inerting and venting of the tanks involve fitting of equipment, such as pressure/vacuum relief valves, shut-off valves, venting system and pressure sensors connected to alarms. These are all well-known systems and components and are usedall over the maritime industry, but may involve an increased installation cost. As opposed to fuel oil, methanol properties enable storage of methanol in double bottom tanks, since it is not considered harmful to the environment.

Pressure-relief valves should be provided to allow vapour to escape if pipes start to warm.

Liquefied gas fuel tanks shall be fitted with a minimum of 2 pressure relief valves (PRVs) allowing for disconnection of one PRV in case of malfunction or leakage.

The setting of the PRVs shall not be higher than the vapour pressure that has been used in the design of the tank. Valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS to allow sequential lifting, minimizing unnecessary release of vapour.

Importance of redundancy of the fuel system

Redundancy of the fuel system is considered essential. This is preferably based on multiple LNG tanks, each with its own fuel system providing fuel to multiple engines.

For single fuel installations the fuel supply system shall be arranged with full redundancy and segregation all the way from the fuel tanks to the consumer, so that a leakage in one system does not lead to an unacceptable loss of power.

For single fuel installations, fuel storage shall be divided between two or more tanks. The tanks shall be located in separate compartments.

For type C tank only, one tank may be accepted if two completely separate tank connection spaces are installed for the one tank.

7.2 General arrangement and construction

.1 Identify the different spaces and requirements for ship design subject to the IGF Code

Different spaces and requirements for ship design given in the IGF Code

- Access requirements to different spaces
  - The access or other openings to spaces containing fuel sources of release shall be so arranged that flammable, asphyxiating or toxic gas cannot escape to spaces that are not designed for the presence of such gases.
  - Direct access shall not be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock shall be provided.
  - If the fuel preparation room is approved located below deck, the room shall, as far as practicable, have an independent access direct from the open deck. Where a separate access from deck is not practicable, an airlock shall be provided.
  - Unless access to the tank connection space is independent and direct from open deck it shall be arranged as a bolted hatch. The space containing the bolted hatch will be a hazardous space.
  - If the access to an ESD-protected machinery space is from another enclosed space in the ship, the entrances shall be arranged with an airlock.
  - For inerted spaces access arrangements shall be such that unintended entry by personnel shall be prevented. If access to such spaces is not from an open deck, sealing arrangements shall ensure that leakages of inert gas to adjacent spaces are prevented.
  - For non-hazardous spaces with access from hazardous spaces below deck where the access is protected by an airlock, upon loss of underpressure in the hazardous space access to the space is to be restricted until the ventilation has been reinstated. Audible and visual alarms shall be given at a manned location to indicate both loss of pressure and opening of the airlock doors when pressure is lost.

- Limitations in engine-room arrangements

  In order to minimize the probability of a agas explosion in a machinery space with gas fuelled machinery on of these two alternative concepts may be applied:

  1. Gas safe machinery space: Arrangements in machinery spaces are such that spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e.

inherently gas safe. In a gas safe machinery space a single failure cannot lead to release of fuel gas into the machinery space.

2. ESD-protected machinery space: Arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous. In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of non-safe equipment (ignition sources) and machinery shall be automatically executed while equipment or machinery in use or active during these conditions shall be a certified safe type.

   In an ESD-protected machinery space a single failure may result in a gas release into the space. Venting is designed to accommodate a probable maximum leakage scenario due to technical failures.

   Failures leading to dangerous gas concentrations, i.e. gas pipe ruptures or blow out of gaskets are covered by explosion pressure relief devices and ESD arrangements.

- Limitations to tank locations with regard to
  a. Distance from ship side
  The fuel tank(s) shall be located in such a way that the probability for the tank(s) to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship.

  Fuel storage tanks shall be protected against mechanical damage. Fuel storage tanks and/or equipment located on open deck shall be located to ensure natural ventilation, so as to prevent accumulation of escaped gas.

  The fuel tank(s) shall be protected from external damage caused by collision or grounding in the following way:
  1. The fuel tanks shall be located at a minimum distance of B/5 or 11.5m, whichever is less, measured inboard from the ship side at right angles to the centerline at the level of the summer load lone draught;
     Where:
     B is the greatest moulded breadth of the ship at or below the deepest draught (summer load line draught) (refer to SOLAS regulation II-1/2.8).
  2. The boundaries of each fuel tank shall be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.
  3. For independent tanks the protective distance shall be measured ti the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance shall be measured to the bulkheads surrounding the tank insulation.
  4. In no case shall the boundary of the fuel tank be located closer to the shell piping or aft terminal of the ship than as follows:
     a. For passenger ships: B/10 but in no case less than 0.8m. However, this distance need not be greater than B/15 or 2m whichever is less where the shell plating is located inboard of B/5 or 11.5m, whichever is less.

b. For fuel ships:
   i. For Vc below or equal 1,000m^3, 0.8m;
   ii. For 1,000m^3 < Vc < 5,000m^3, 0.75 + Vc x 0.2/4,000m;
   iii. For 5,000m^3 $\leq$ Vc < 30,000m^3, 0.8 + Vc/25,000m; and
   iv. For Vc $\geq$ 30,000m^3, 2m
   Where:
   Vc corresponds to 100% of the gross design volume of the individual fuel tank at 20°C, including domes and appendages.
5. The lowermost boundary of the fuel tank (s) shall be located above the minimum distance of B/15 or 2.0m, whichever is less, measured from the moulded line of the bottom shell plating at the centerline.
6. For multihull ships, the value of B may be specially considered.
7. The fuel tank(s) shall be abaft a transverse plane 0.08L measured from the forward perpendicular in accordance with SOLAS regulation II-1/8.1 for passenger ships, and abaft the collision bulkhead for fuel ships.
   Where:
   L is the length as defined in the International Convention on Load Lines (refer SOLAS regulation II-1/2.5).
8. For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered.

b. Engine-rooms and other high fire risk spaces

The space containing fuel containment system shall be separated from the machinery spaces of category A or other rooms with high fire risks. The separation shall be done by a cofferdam of at least 900 mm with insulation of A-60 class. When determining the insulation of the space containing fuel containment system from other spaces with lower fire risks, the fuel containment system shall be considered as a machinery space of category A, in accordance with SOLAS regulation II-2/9. The boundary between spaces containing fuel containment systems shall be either a cofferdam of at least 900 mm or A-60 class division. For type C tanks, the fuel storage hold space may be considered as a cofferdam.

The fuel storage hold space shall not be used for machinery or equipment that may have a fire risk.

c. Fuel Operations

Fuel operations can increase the potential for uncontrolled sources of ignition. This is particularly of concern for fuel operations located near to or in the gas hazardous areas. Certain fuel operations present a greater chance for sources of ignition than others. For example, loading containers in a container bay adjacent to the ship's bunker station can provide a greater risk of producing sparks, which can be a source of ignition, than does loading passengers onto a ferry using a gangway on the opposite side of the ship from the bunker station.

The fuel tanks of LNG ships are thermally insulated and the fuel is carried at or near atmospheric pressure. Fuel tanks may be free standing spherical, of the membrane type, or prismatic in design. In the case of membrane tanks, the fuel is contained within thin-walled tanks of Invar or stainless steel. The tanks are anchored to the inner hull in appropriate locations and the fuel load is transmitted to the inner hull through the intervening thermal insulation.

d. Life-saving appliances and escape routes

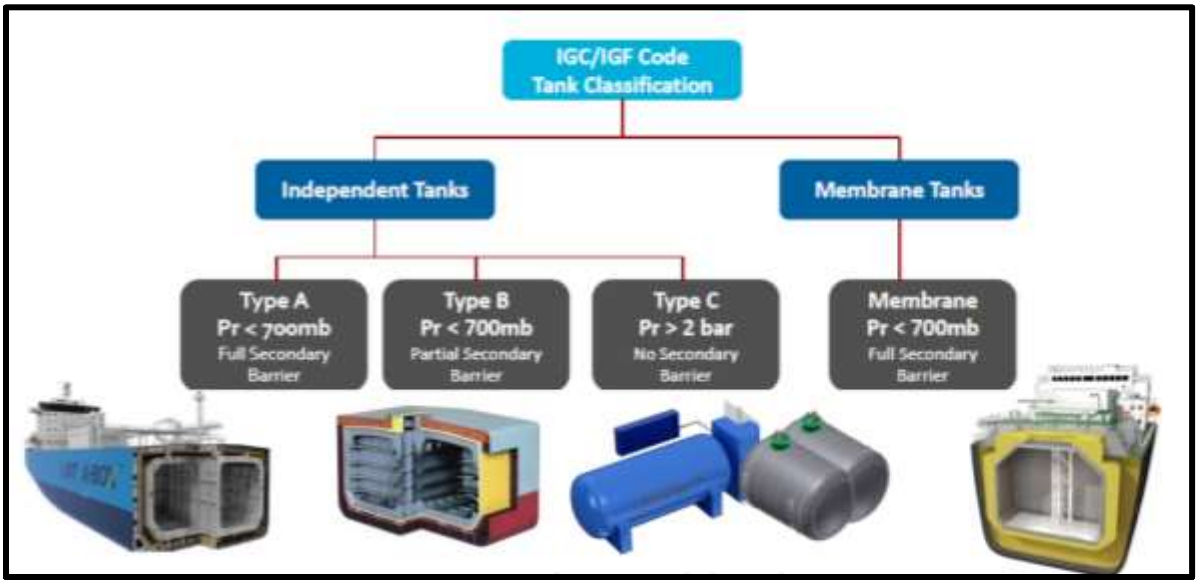
The fuel containment system shall be so designed that a leak from the tank or its connections does not endanger the ship, persons on board or the environment. Potential dangers to be avoided include:
.1 exposure of ship materials to temperatures below acceptable limits;
.2 flammable fuels spreading to locations with ignition sources;
.3 toxicity potential and risk of oxygen deficiency due to fuels and inert gases;
.4 restriction of access to muster stations, escape routes and life-saving appliances (LSA); and
.5 reduction in availability of LSA.

- limitations in location of ventilation inlets and other openings related to hazardous zones
  - Any ducting used for the ventilation of hazardous spaces shall be separate from that used for the ventilation of non-hazardous spaces. The ventilation shall function at all temperatures and environmental conditions the ship will be operating in.
  - Electric motors for ventilation fans shall not be located in ventilation ducts for hazardous spaces unless the motors are certified for the same hazard zone as the space served.
  - Air inlets for hazardous enclosed spaces shall be taken from areas that, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces shall be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct shall be gas-tight and have over-pressure relative to this space.
  - Air outlets from non-hazardous spaces shall be located outside hazardous areas.
  - Air outlets from hazardous enclosed spaces shall be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.
  - Non-hazardous spaces with entry openings to a hazardous area shall be arranged with an airlock and be maintained at overpressure relative to the external hazardous area.
  - Non-hazardous spaces with entry openings to a hazardous enclosed space shall be arranged with an airlock and the hazardous space shall be maintained at underpressure relative to the non-hazardous space. Operation of the extraction ventilation in the hazardous space shall be monitored.
  - Fuel storage tanks and or equipment located on open deck shall be located to ensure sufficient natural ventilation, so as to prevent accumulation of escaped gas.
  - The tank connection space shall be provided with an effective mechanical forced ventilation system of extraction type. A ventilation capacity of at least 30 air changes per hour shall be provided. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations shall be demonstrated by a risk assessment.
  - Approved automatic fail-safe fire dampers shall be fitted in the ventilation trunk for the tank connection space.

- location of gas outlets/ gas mast
  - During bunkering, Vent mast should not be near to any openings on the receiving ship, or if mobile tanks are used they should be positioned such that any leaks will vent away from critical locations or openings on the receiving ship. If this is unavoidable due to the arrangements of the receiving ship, then these openings should be secured while the bunker vessel is alongside the receiving ship.

7.3 Fuel storage systems on board, including materials of construction and insulation
.1 Identify the different tank types for low flashpoint fuels

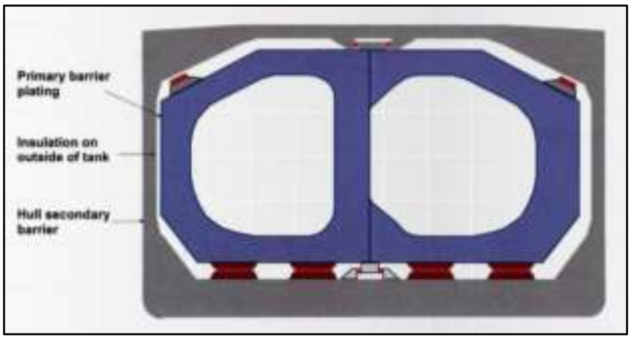
For the fuel tanks used on gas carriers, a distinction is generally made between non-self-supporting tanks (atmospheric membrane tanks) and self-supporting tanks (actual pressure tanks). The self-supporting fuel tanks are subdivided into three classes according to their strength. The same classification (IMO Classification) is used for LNG fuelled ships, to define the LNG fuel tanks.



For the current fleet of gas fuelled ships in operation only Type C tanks have been used. However, in accordance to the draft IGF Code, the use of membrane tanks will also be possible as fuel tanks for gas fuelled vessels. Additionally, the draft IG F Code opens for accepting use of portable tanks, i.e. tank containers.

1. Type A Independent Tanks (IMO Type A Tank)
   These are prismatic tanks with a low design pressure (< 0.7 barg). The material used in the construction of these tanks offers insufficient resistance to crack propagation, so that for safety reasons a second shell (tank wall) has to be provided to contain any leaks. This second shell can also

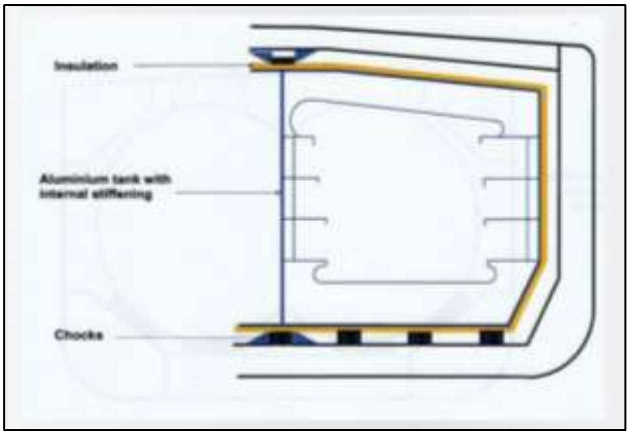
be formed by parts of the ship (e.g. inner hull) provided that these are capable of resisting the low temperature of the fuel.



- designed using classical ship-structural analysis procedure
- are required to have a full secondary barrier
- MAWP < 0.25 barg
- if the hull structure is of proper design MAWP < 0.7 barg
- capacity: 100 ÷ 20 000m3

2. Type B Independent Tanks (IMO Type B Tank)

   These are prismatic or spherical tanks with a low design pressure (< 0.7 barg), for which a great deal of attention has been paid in the design phase to detailed stress analyses (inter alia in relation to fatigue and crack propagation). Spherical Moss-Rosenberg tanks are the best known example of this type of tank. Because of the improved design, a type B tank only needs to have a partial second shell, fitted on the underside of the tank in the form of a drip tray.



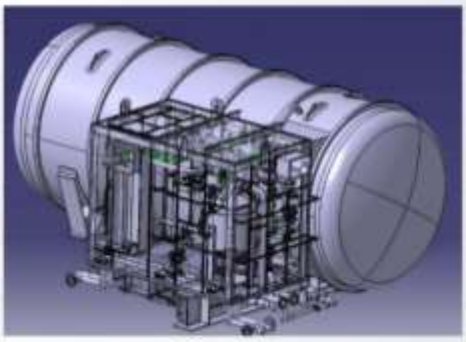
- similar to A-type tanks
- are designed using model tests, sophisticated analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics
- are required to have a partial secondary barrier

3. Type C Independent Tanks (IMO Type C Tank)

   These are spherical, cylindrical or bilobe pressure tanks with a design pressure greater than 2 barg. The tanks are designed and built according to the conventional pressure vessel codes and, as a result, can be subjected to accurate stress analyses. Moreover, in the design phase much attention is paid to eliminating possible stresses in the tank material. For these reasons, type C tanks do not require a second shell.

   For ships in which the fuel is transported in a cooled and partially pressurised state, the fuel tanks and associated apparatus are typically designed for a working pressure of 4 to 6 barg and a vacuum of 0.5

bar. The fuel tanks are typically insulated with polystyrene or polyurethane panels attached to the



tank wall.

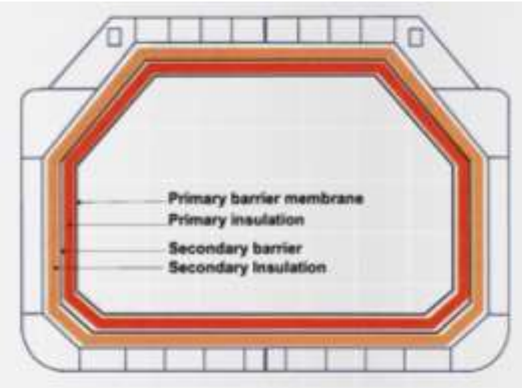
• MARVS <10 bar g
• 90% MARVS > MAWP > 0.7 bar g
• usually cylindrical shape
• presently capacity: up to 500-600 m^3

• future capacity: up to 2000 m^3
• relatively cheap
• small hull volume fulfillment ratio
• can be installed in the new-building and for upgraded existing ships

4. Membrane Tanks

The inner surface of the insulation is exposed to the fuel. Membrane tank – Membrane tanks are not-self-supporting tanks which consist of a thin layer (membrane) supported through insulation by the adjacent hull structure.

Despite the fact that membrane tanks are today widely used in LNG fuel tankers, the application of these technologies for LNG as Fuel is still without much expression.
Membrane tanks, as in Type A or B, optimize holding time by improved insulation.



• non-self-supporting
• consist of a thin layer (membrane) supported through insulation by the adjacent hull structure
• MAWP < 0.25 barg
• if the hull structure is of proper design MAWP < 0.7 barg
• capacity: 100 ÷ 20 000m3
• high production costs

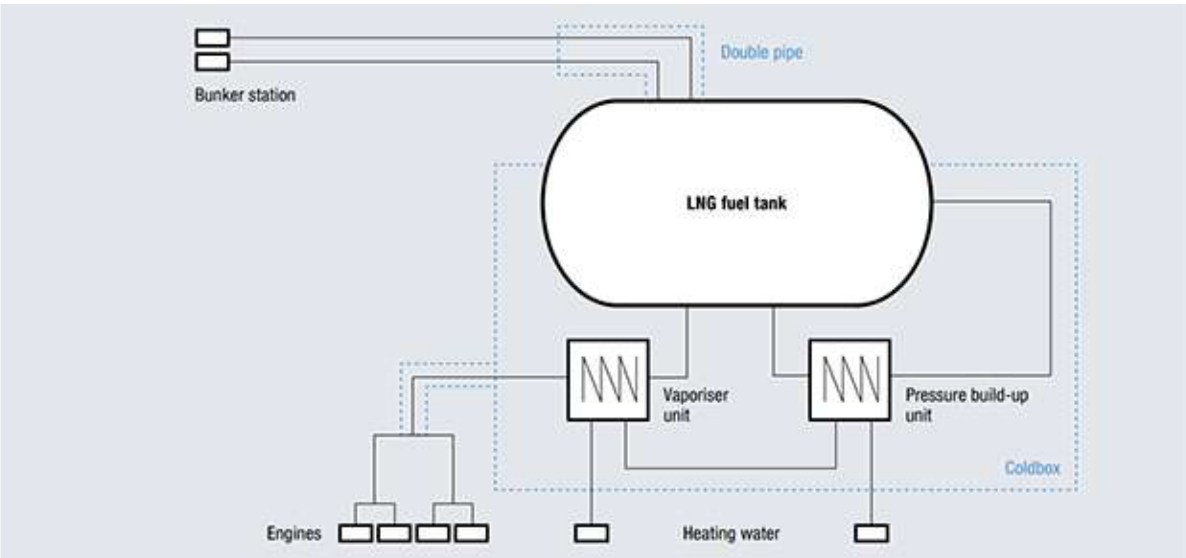
.2 Explain the importance of monitoring hold space atmosphere

Monitoring hold space atmosphere is important to detect the leakage of fuel from the tanks, the hold space is filled with inert gas or dry air. Sensors placed in the hold space can detect the change in composition of the inert gas or dry air due to fuel vapour, and leakages can hence be detected and prevented.

7.4 Fuel Handling Equipment and Instrumentations on board Ships:

.1 Explain the functions of different fuel-handling equipment and instrumentation onboard ships subject to the IGF Code

Fuel Pumps and Pumping Arrangements:



The purpose of the marine fuel gas system is to fill, store and vaporise LNG and to supply natural gas to engines on a ship. The system is designed for minimum heat in leakage to guarantee maximum holding time. The gas is fed to the engines using the tank pressure. Hence, no pumps are needed and the maintenance costs are low.

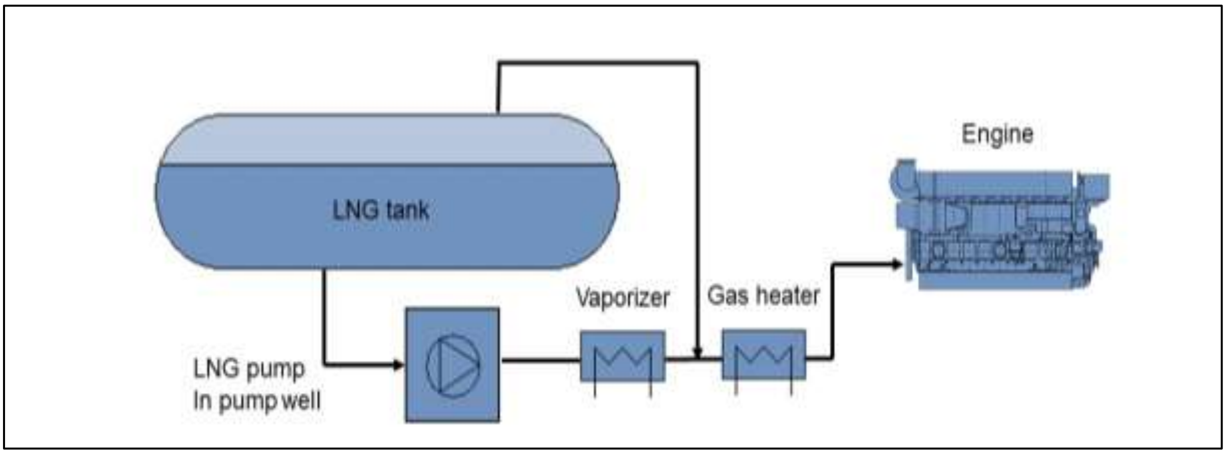
The system mainly includes:

- One or more LNG fuel tanks

- Water-heated vaporiser units for vaporisation of the LNG to gaseous natural gas
- Pressure build-up units for the increase of tank pressure
- Bunker stations
- Control system
- Piping for bunkering LNG and gas feed lines for supply of natural gas to the engines

In addition, there are three (3) design concept for gas fuel system:

1. Gas fuel system with pump

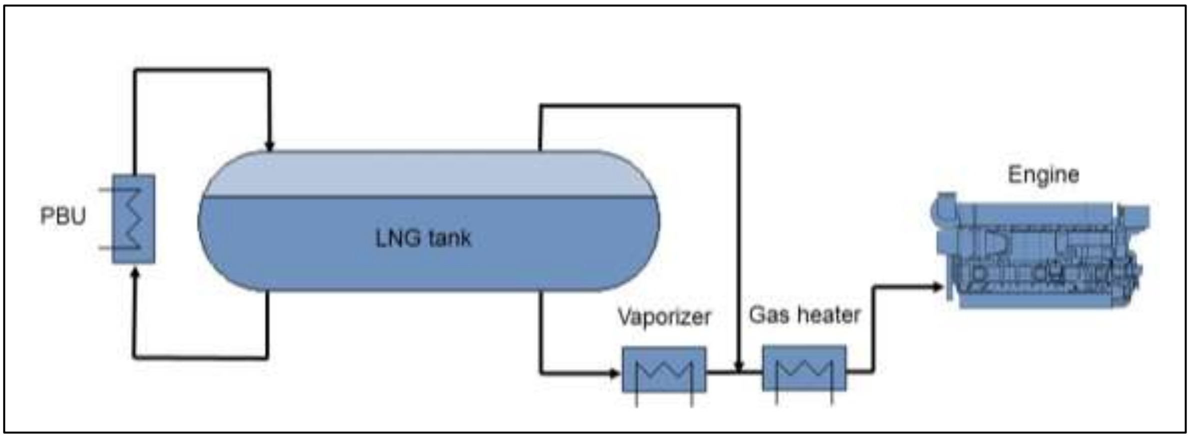


Features:

- Rigid design
- No time needed for pressure build up of the tank
- The pump deliveres the 8 bar working pressure needed for the dual-fuel main engine

This system uses a submerged pump to deliver the pressure required by the engines. For a dual fuel engine this is about 6 to 8 bar, for gas engines the pressure can be lower around 2 to 3 bar. By using a pump the tank itself can be maintained at a lower pressure, this is favorable for the holding time of the tank. The choice of a pump is determined by the amount of fuel consumed by the engines.

2. Gas Fuel System with pressure build-up

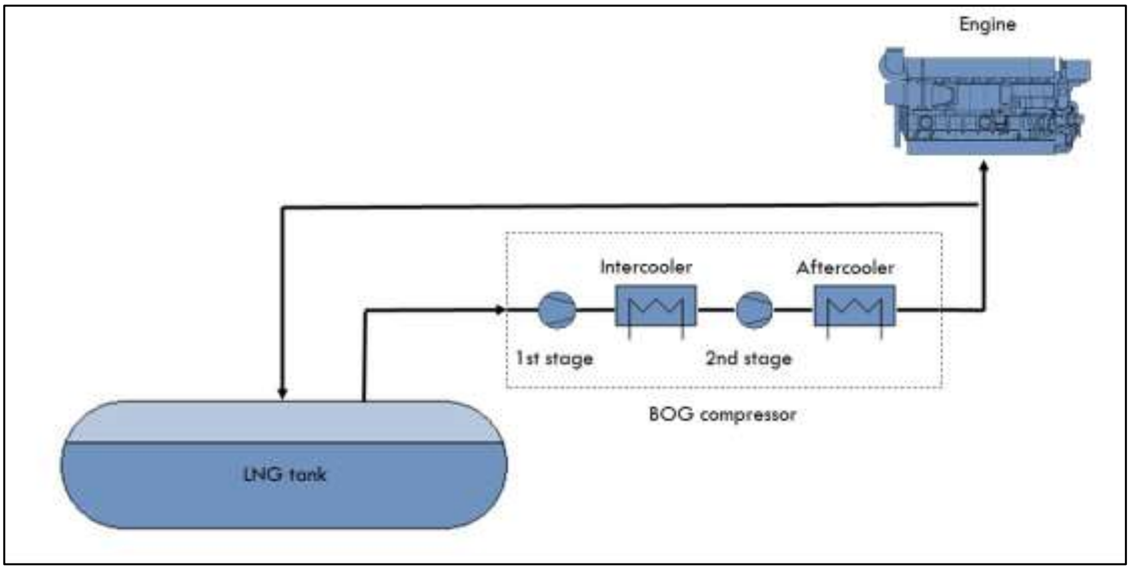


Features:

- Lower investment costs
- Requires longer time for pressure build up of the tanks

When using a pressure built up design concept the whole tank will be brought up to the pressure required by the engines. The PBU raises the pressure by vaporizing a small portion of LNG every time the pressure in the tank gets too low. The pressurized LNG is pushed through the vaporizer to the engines. This design is the simplest and cheapest to build which however, has the drawback that if no fuel is consumed, the pressure in the tank rapidly reached its maximum set pressure (MARVS). Because blowing off gas is usually not acceptable it is necessary to start the engine(s) to maintain the pressure in the tank at a pre-defined level.

3. Gas Fuel System with compressor



Features:

- This set-up is used a lot on LNG carriers where the BOG compressors are used for fuel gas also.

  Finally, there is the possibility of supplying the gas with a compressor to the engine. This kind of system is often used on LNG tankers. The design is very flexible in usage. A drawback is that compressors heat up the gas. Inter-coolers and after-coolers mounted on the compressors keep the temperature of the gas within acceptable limits.

There are four different LNG bunkering methods that either have been commonly used or have been idealized which are:

1. Truck-to-Ship (TTS): is the most common method used to support the LNG-fueled ship network, to date. It is the transfer of LNG from a truck's storage tank to a vessel moored to the dock or jetty. Typically, this is undertaken by connecting a flexible hose designed for cryogenic LNG service. A typical LNG tank truck can carry 13,000 gallons of LNG and transfer a complete load in approximately one hour.

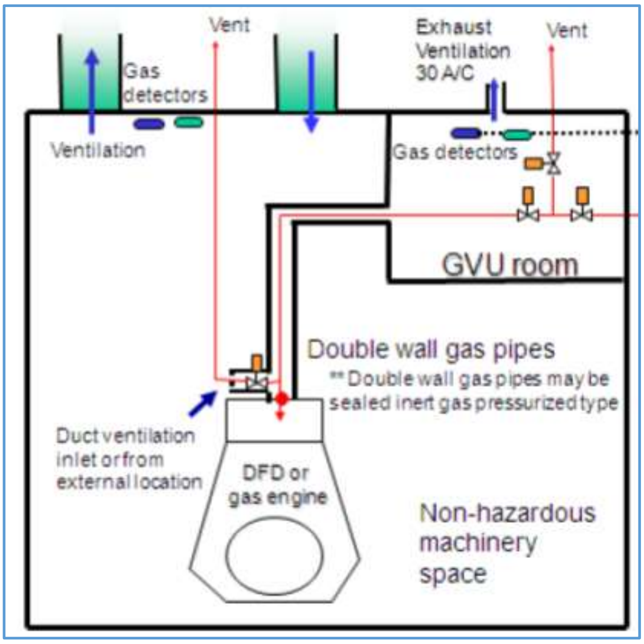
2. Shore/Pipeline-to-Ship (PTS): LNG is transferred from a fixed storage tank on land through a cryogenic pipeline with a flexible end piece or hose to a vessel moored to a nearby dock or jetty. These facilities have scalable onsite storage such that designs could be capable of performing bunkering of larger volumes than TTS or with portable tanks.


3. Ship-to-Ship (STS): It is the transfer of LNG from one vessel or barge, with LNG as fuel, to another vessel for use as fuel. STS offers a wide range of flexibility in location bunkering, and flexibility on quantity and transfer rate. There are two types of STS bunkering operations, one is performed at the port, and the other is carried out at sea. This has only been carried out at the Port of Stockholm for the new LNG-fueled ferry, Viking Grace.


4. Portable tanks: They can be used as portable fuel storage. They can be driven or lifted on and off a vessel for refueling. The quantity transferred is flexible and dependent on the number of portable tanks transferred. A 40-foot (ISO-scale) intermodal portable tank can hold approximately 13,000 gallons of LNG.

Fuel Pipelines

- Fuel pipes shall not be located less than 800 mm from the ship's side.
- Fuel piping shall not be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations as defined in the SOLAS Convention.
- Fuel pipes led through ro-ro spaces, special category spaces and on open decks shall be protected against mechanical damage.
- Gas fuel piping in ESD protected machinery spaces shall be located as far as practicable from the electrical installations and tanks containing flammable liquids.
- Gas fuel piping in ESD protected machinery spaces shall be protected against mechanical damage



Fuel tank technology is also available providing several options of fuel tank types. These tanks are double-wall for providing efficient insulation in different ways. LNG is stored in the tanks as a 'boiling cryogen' which is a very cold liquid at its boiling point. However, as efficient as the tank may be, it will not keep the LNG cold enough to remain liquid by itself. As heat is transferred, the pressure in the tank rises as LNG starts evaporating. Under this condition, the gas that boils off needs to be released from the tank in order to control the pressure rates within the tank

The figure shows the main parts of the engine room of a ship running on LNG. We can observe ventilation ducts and air flow channels in the machinery, fire and gas detectors and double walled pipes. In these tubes, there is space containing pressurized inert gas at a pressure higher than that of the gas. In case of loss of pressure of the inert gas due to leakage of gas safety systems are actuated.

Engine Room is designed and built according to inherently safe concept

- LNG in double wall piping, ventilated with fresh air
- Inerting system for maintenance and emergency with N2
- Normal ventilation in engine room
- Normal equipment in engine room
- Exhaust piping burst discs
- Normal fire fighting

Fuel Gas Supply System

- From Tank to tank room ('cold box') in liquid form
  - LNG gasification with heat from LT-circuit
  - Heat from AC-system, 'cold recovery'

- From tank room to GVUs in gaseous form
  - Double walled from tank room to Gas Valve
  - Units (GVU)
  - Tank room controls the pressure and
  - temperature according to need

- From GVUs to engines and boilers
  - Gas Valve Unit can be located in a room or be built into a module
  - GVU distance to engines limitation, max 10 meters
  - GVU regulates the gas pressure to the engine according to engine load
  - Boiler GVU regulates the gas pressure to boiler

Expansion devices
Purpose of expansion devices in IGF Code

Normally the gas on board the carriers is stored in cylindrical or spherical steel tanks. The vessels usually are designed with 4-6 tanks along the centreline of the vessel. A combination of ballast tanks, cofferdams and voids are surrounding the tanks. Pumps are installed inside the tanks. All the fuel pumps are discharged into a common pipe, which runs along the deck of the vessel. It branches of to either side of the vessel to the fuel manifolds used for loading or discharging.

On the carrier, each gas tank is mounted on an anchoring, which allows the gas tank to move. In order to absorb these movements, an expansion joint is installed at each anchoring. The tank is supported around its circumference by the equatorial ring, which is supported by a large circular skirt that takes the weight of the tank down to the hull structure. This skirt allows the tank to expand and contract during cool down and warm-up operations. During cool down or warm-up, the tank is able to elongate or compress (expand or contract) by 2 feet. Because of this expansion and contraction, all piping enters into the tank via the top and is connected to the ships' lines via flexible bellows that will result in movements in the tank settlements.

Expansion joints for gas carriers are customised solutions designed to it the application. They are available in all designs, all sizes and all materials. Due to the demanding design parameters and the severe consequences following a possible failure, the expansion joints used for such applications must also meet very high criteria.

Expansion joints
Where bellows and expansion joints are provided in accordance with the following apply:
1. if necessary, bellows shall be protected against icing;
2. slip joints shall not be used except within the liquefied gas fuel storage tanks; and
3. bellows shall normally not be arranged in enclosed spaces.

Expansion bellows
The following type tests shall be performed on each type of expansion bellows intended for use on fuel piping outside the fuel tank as found acceptable and where required by the Administration, on those installed within the fuel tanks:
1. Elements of the bellows, not pre-compressed, but axially restrained shall be pressure tested at not less than five times the design pressure without bursting. The duration of the test shall not be less than five minutes.
2. A pressure test shall be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation.
3. A cyclic test (thermal movements) shall be performed on a complete expansion joint, which shall withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature.
4. A cyclic fatigue test (ship deformation, ship accelerations and pipe vibrations) shall be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding

to a compensated pipe length, for at least 2,000,000 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.

Flame screens

Usage and importance of flame screens in IGF Code

A device incorporating corrosion-resistant wire meshes. It is used for preventing the inward passage of sparks (or, for a short period of time, the passage of flame), yet permitting the outward passage of gas.

- Controlled tank venting system – A system fitted with pressure/vacuum relief valves. Controlled venting systems are required to be fitted to all tanks carrying fueles which emit harmful or flammable vapours.

- Open tank venting system – A system which offers no restriction, except for friction losses and ***flame screens*** if fitted, to free flow of liquid vapour to or from the tank served during normal liquid transfer or ballasting operation. Open venting is specified for fueles which pose little or no flammable or toxic hazard.

Temperature monitoring systems

Equipment used for temperature monitoring equipment

Temperature detection is the foundation for all advanced forms of temperature control and compensation. The temperature detection circuit itself monitors ambient temperature. It can then notify the system either of the actual temperature or, if the detection circuit is more intelligent, when a temperature control event occurs. When a specific high temperature threshold is exceeded, preventative action can be taken by the system to lower the temperature.

Similarly, a temperature detection circuit can serve as the core of a temperature compensation function. Consider a system such as liquid measuring equipment. Temperature, in this case, directly affects the volume measured. By taking temperature into account, the system can compensate for changing environment factors, enabling it to operate reliably and consistently.

There are four commonly used temperature sensor types:

1. Negative Temperature Coefficient (NTC) thermistor

A thermistor is a thermally sensitive resistor that exhibits a large, predictable, and precise change in resistance correlated to variations in temperature. An NTC thermistor provides a very high resistance at low temperatures. As temperature increases, the resistance drops quickly. Because an NTC thermistor experiences such a large change in resistance per °C, small changes in temperature are reflected very fast and with high accuracy (0.05 to 1.5 °C). Because of its exponential nature, the output of an NTC thermistor requires linearization. The effective operating range is -50 to 250 °C for glass encapsulated thermistors or 150°C for standard.

2. Resistance Temperature Detector (RTD)

An RTD, also known as a resistance thermometer, measures temperature by correlating the resistance of the RTD element with temperature. An RTD consists of a film or, for greater accuracy, a wire wrapped around a ceramic or glass core. The most accurate RTDs are made using platinum but lower-cost RTDs can be made from nickel or copper. However, nickle and copper are not as stable or repeatable. Platinum RTDs offer a fairly linear output that is highly accurate (0.1 to 1 °C) across -200 to 600 °C. While providing the greatest accuracy, RTDs also tend to be the most expensive of temperature sensors.

3. Thermocouple

This temperature sensor type consists of two wires of different metals connected at two points. The varying voltage between these two points reflects proportional changes in temperature. Thermocouples are nonlinear, requiring conversion when used for temperature control and compensation, typically accomplished using a lookup table. Accuracy is low, from 0.5 °C to 5 °C. However, they operate across the widest temperature range, from -200 °C to 1750 °C.

4. Semiconductor-based sensors

A semiconductor-based temperature sensor is placed on integrated circuits (ICs). These sensors are effectively two identical diodes with temperature-sensitive voltage vs current characteristics that can be used to monitor changes in temperature. They offer a linear response but have the lowest accuracy of the basic sensor types at 1 °C to 5 °C. They also have the slowest responsiveness (5 s to 60 s) across the narrowest temperature range (-70 °C to 150 °C).

Gas code requires at least two devices for indicating fuel tank temperatures:

- One at bottom of tank.
- Second near the tank top, but below the highest allowable liquid level.
- Tanks requiring a secondary barrier at a temperature below -55°C.

Gas code recommends more thermometers be fitted to:

- At least one tank to monitor temperatures during warm-up/cooldown.
- To avoid thermal stress.

Gas code requires a temperature sensing device within the insulation or on the hull structure adjacent to the containment system:

- Thermo-couples set must provide ample warning alarm prior to the lowest temperature for the hull steel being approached.

Fuel Tank Level Gauging Systems

The IGF Code require that high level alarms and high-high level alarm are fitted, and that the high-high level alarm will lead to automatic stop of bunkering operations.

The hazards associated with an overfill vary greatly depending on the product, but any overfill costs money and resources to clean up, especially when surrounding equipment is at risk of damage.

If a tank contains hazardous liquids, such as chemicals, or petroleum products, then tank overfill prevention is required. The health and safety of employees and the community at large is at risk, not to mention that hazardous spills have many expenses, usually including big fines.

Liquefied gas fuel tank liquid level gauges may be of the following types:

- Indirect devices, which determine the amount of fuel by means such as weighing or in-line flow metering; or
  In-line flowmeters are indicators for flow rate. These flow meters are ideal for measurement of a range of compatible gases, oil, or water-based liquids. Applications include deionized water flow, pickling, compressed gases, harsh environments, coolant lines, and industrial applications.

- Closed devices, which do not penetrate the liquefied gas fuel tank, such as devices using radio-isotopes or ultrasonic devices;

Capacitive devices are widely used for measuring the level of both liquids and solids in powdered or granular form. They perform well in many applications, but become inaccurate if the measured substance is prone to contamination by agents that change the dielectric constant. Ingress of moisture into powders is one such example of this. They are also suitable for use in extreme conditions measuring liquid metals (high temperatures), liquid gases (low temperatures), corrosive liquids (acids, etc.), and high-pressure processes.

Ultrasonic level measurement is one of a number of noncontact techniques available. It is primarily used to measure the level of materials that are either in a highly viscous liquid form or in a solid (powder or granular) form. The principle of the ultrasonic level gauge is that energy from an ultrasonic source above the material is reflected back from the material surface into an ultrasonic energy detector.

Radar (Microwave) Sensors Level-measuring instruments using microwave radar are an alternative technique for noncontact measurement. Currently, they are still very expensive (w$4000), but prices are falling and usage is expanding rapidly. They are able to provide successful level measurement in applications that are otherwise very difficult, such as measurement in closed tanks, measurement where the liquid is turbulent, and measurement in the presence of obstructions and steam condensate. They can also be used for detecting the surface of solids in powder or particulate form. The technique involves directing a constant amplitude-, frequency-modulated microwave signal at the liquid surface.

Nucleonic, sometimes called **radiometric, sensors** are relatively expensive. They use a radiation source and detector system located outside a tank. The noninvasive nature of this technique in using a source and detector system outside the tank is particularly attractive. The absorption of both beta rays and gamma rays varies with the amount of material between the source and detector, and hence is a function of the level of the material in the tank.

Vibrating Level Sensor, the principle of the vibrating level sensor is illustrated in. The instrument consists of two piezoelectric oscillators fixed to the inside of a hollow probe that generate flexural vibrations in the probe at its resonant frequency. The resonant frequency of the probe varies according to the depth of its immersion in the liquid. A phase-locked loop circuit is used to track these changes in resonant frequency and adjust the excitation frequency applied to the probe by the piezoelectric oscillators. Liquid level measurement is therefore obtained in terms of the output frequency of the oscillator when the probe is resonating. The sensor operates reliably and is easy to clean. Its operation is also little affected by any buildup of material deposits on the probe.

Pressure Monitoring and Control Systems

Pressure Monitoring and Relief: Since LNG is a boiling liquid, the fuel tank pressure is to be controlled during transit, in port, and during bunkering in order to prevent the pressure in the tank from exceeding the tank design pressure. To monitor the pressure, pressure indicators are fitted in the vapor space of the tank. In addition, the tank must be fitted with two pressure relief valves that lead to a vent mast.

The Gas Codes call for pressure monitoring throughout the fuel system. Appropriate positions include fuel tanks, pump and compressor discharge lines, liquid crossovers and vapour crossovers. In addition, pressure switches are fitted to various systems to protect personnel and equipment by operating alarms and shut-down systems.

.2 Operate fuel fuel-handling equipment and instrumentation onboard ships subject to the IGF Code

Bunker Operations

It is important to note that LNG bunker procedures may vary greatly between projects, ships, and bunker facilities. The use of standardized procedures and checklists from existing projects may be helpful as guidance. However, vessel-specific procedures for the bunkering operation should be developed to include any characteristics or features that are unique to the particular bunkering facility and receiving vessel or location.

During Transfer:

1. Monitor tank levels.
2. Monitor tank pressures and temperatures.
3. Monitor pump transfer rates.
4. Adjust pump flow rates as necessary.

5. Adjust top spray and bottom fill rates as necessary to control tank pressure.
6. Adjust mooring lines and bunker hoses and arms as necessary.
7. Monitor that the integrity of security and safety zones is maintained. Monitor that weather and sea conditions remain within limits.

.3 Monitor the operations of fuel-handling equipment and instrumentation onboard ships subject to the IGF Code

Since LNG is a boiling liquid, the fuel tank pressure is to be controlled during transit, in port, and during bunkering in order to prevent the pressure in the tank from exceeding the tank design pressure. To monitor the pressure, pressure indicators are fitted in the vapor space of the tank. In addition, the tank must be fitted with two pressure relief valves that lead to a vent mast.

A piping system shall be arranged to enable each fuel storage tank to be safely gasfreed, and to be safely filled with fuel gas from a gas-free condition. The system shall be arranged to minimize the possibility of pockets of gas or air remaining after changing the atmosphere.

The system shall be designed to eliminate the possibility of a flammable mixture existing in the fuel tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.

Gas sampling points shall be provided for each fuel tank to monitor the progress of atmosphere change. Inert gas utilized for gas freeing of tanks may be provided externally to the ship.

7.5 Cryogenic fuel tanks temperature and pressure maintenance

.1 Explain the different methods of maintaining pressure and temperature in accordance with the prescribed procedures

With the exception of liquefied gas fuel tanks designed to withstand the full gauge vapour pressure of the fuel under conditions of the upper ambient design temperature, liquefied gas fuel tanks' pressure and temperature shall be maintained at all time within their design range by means acceptable to the Administration, e.g. by one of the following methods:

1. reliquefaction of vapours;
2. thermal oxidation of vapours;
3. pressure accumulation; or
4. liquefied gas fuel cooling.

"Liquefied gas fuel tanks' pressure and temperature should be controlled and maintained within the design range at all times including after activation of the safety system required for a period of minimum 15 days. The activation of the safety system alone is not deemed as an emergency situation."

IACS understands that some LNG fuel tanks that are unable to accumulate pressure for 15 days without opening of the pressure relief valves (PRVs) will need to accommodate the boil off gas by some other method. A safety action in any part of the gas fuel system shall not affect the capability of maintaining the tank pressure below the set pressure of the PRVs. IACS considers that to meet the IGF Code requirement for those tanks that are not able to accumulate pressure for 15 days, segregation and redundancy will be required in the fuel supply system; or some other means to maintain tank temperature and pressure within acceptable limits, such as a reliquefaction system, independent thermal oxidation unit, etc.

The boil off control should be capable of being maintained after the automatic safety action. This should be achieved by independent fuel supply lines all the way from the fuel tanks to the consumers and more than one means of consuming 100% of the boil off rate, or other equivalent means to control pressure and temperature.

To further clarify the above understanding and provide examples of acceptable arrangements, such as follows:

▪ Examples of acceptable arrangements are shown below:

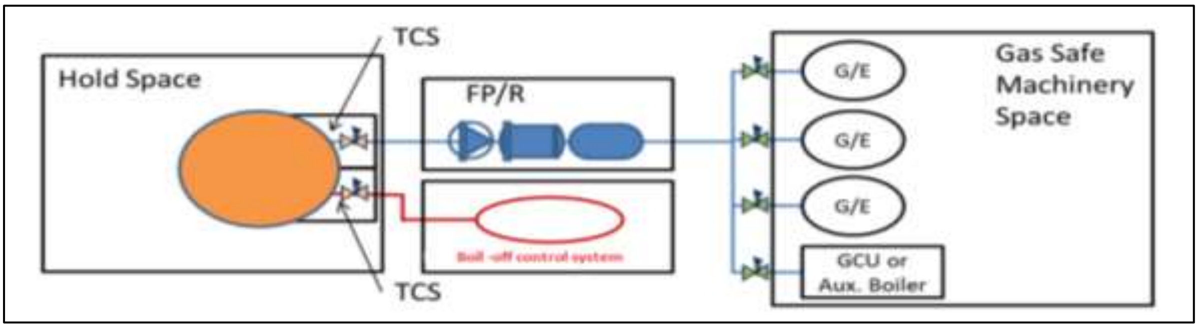


Figure 1: Fuel supply from two tank connection spaces and independent fuel supplies all the way from the fuel tank to the consumers, or other means to control pressure and temperature.

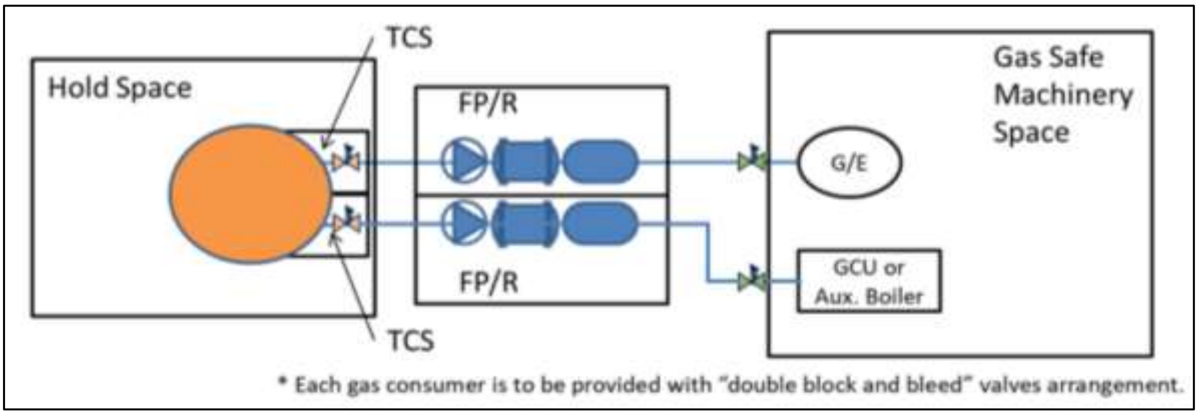


Figure 2: Fuel supply from two tank connection spaces and independent fuel supplies all the way from the fuel tank to the consumers.

7.6 Fuel system atmosphere control systems, including storage, generation and distribution

.1 Explain the process of controlling atmosphere during generation and distribution of fuel subject to the IGF Code

Inert gas used for atmosphere control should be suitable for the intended purpose, regardless of source. In particular it should:

- be chemically compatible with the fuel and the materials of construction throughout the full range of operating temperatures and pressures;
- have a sufficiently low dewpoint to prevent condensation, freezing, corrosion, damage to insulation etc. at the minimum operating temperature;
- have an oxygen concentration not exceeding 5%, but as low as 0.2% if the fuel can react to form peroxides;
- have a low concentration of CO_2 to prevent it freezing out at the anticipated service temperature;
- have minimal capacity for accumulating a static electrical charge.

Regulations on Inerting

Arrangements to prevent back-flow of fuel vapour into the inert gas system shall be provided to prevent the return of flammable gas to any non-hazardous spaces, the inert gas supply line shall be fitted with two valve in between (double block and bleed valves). In addition, a closable non-return valves shall be installed between the double block and bleed arrangement and the fuel system.

These valves shall be located outside non-hazardous spaces. Where the connections to the fuel piping systems are non-permanent, two non-return valves may be substituted for the valves required.

The arrangements shall be such that each space being inerted can be isolated and the necessary controls and relief valves, etc. shall be provided for controlling pressure in these spaces.

Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means shall be provided to monitor the quantity of gas being supplied to individual spaces.

Regulations on inert gas production and storage on board

- The equipment shall be capable of producing inert gas with oxygen content at no time greater than 5% by volume. A continuous-reading oxygen content meter shall be fitted to the inert gas supply from the equipment and shall be fitted with an alarm set at a maximum of 5% oxygen content by volume.
- An inert gas system shall have a pressure controls and monitoring arrangements appropriate to the fuel containment system.
- Where a nitrogen generator or nitrogen storage facilities are installed in a separate compartment outside of the engine-room, the separate compartment shall be fitted with independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour. A low oxygen alarm shall be fitted.
- Nitrogen pipes shall only be led through well-ventilated spaces. Nitrogen pipes in enclosed spaces shall:
  - be fully welded;
  - have only a minimum of flange connections as needed for fitting a valves; and
  - be as short as possible.

7.7 Toxic and flammable gas-detecting systems

.1 Identify the toxic and flammable materials on board ships subject to the IGF Code

Apart from the common occupational health and safety issues, risk remains high for people working onboard as they may be exposed to gases or vapors that are poisonous. In this respect, crew members working with dangerous goods should adhere strictly to basic safety precautions and be familiar with the conventional labeling of these goods which should never be stored in anything other than their original containers.

1. Carbon monoxide: it is often mild but may be chronic or frequently recurring; can occur when a person inhales smoke from a large fire or from poorly ventilated internal combustion engines, fuel stoves and heaters.

2. **Carbon dioxide:** it is nontoxic but displaces breathable air from enclosed spaces. It is heavier than air and accumulates at the bottom of enclosed spaces.

3. **Cyanide:** it is used to fumigate ships. Exposure can occur if fumigation is carried out carelessly or by untrained workers. Hydrogen cyanide is lighter than air, accumulates at the top of enclosed spaces, and is rapidly dispersed by adequate ventilation

4. **Irritant gases (phosgene, chlorine, ammonia):** These gases are heavier than air and accumulate at the bottom of enclosed spaces.

5. **Flammable liquid vapours** (incl. LPG and Calor gas, propane and butane, and most solvents are vapours heavier than air): These tend to accumulate at the bottom of holds and storage lockers, and although not directly toxic displace breathable air and can asphyxiate crew who enter these areas.

6. **Freons:** they are widely used as refrigerants. If a Freon is inhaled, it can cause severe cold injury (frostbite) of the respiratory tract. Heavy exposure can damage the heart, causing abnormal heart rhythm and sudden death.

7. **Hydrogen sulphide (“Rotten egg gas”, “Sewer gas”):** it is produced in oil refining, and from decomposition of organic matter, especially manure. It is heavier than air and accumulates at the bottom of holds. Hydrogen

sulphide is explosive and toxic. The smell is obvious at first, but the gas poisons the sense of smell so that after a few minutes the smell appears to have gone away even if concentrations are rising. Low concentrations irritate the nose, mouth and eyes. Higher concentrations cause poisoning identical to that of hydrogen cyanide.

.2 Explain the gas detection system on board ships subject to the IGF Code

A gas detector is a device that detects the presence of gases in an area, often as part of a safety system. This type of equipment is used to detect a gas leak or other emissions and can interface with a control system so a process can be automatically shut down. A gas detector can sound an alarm to operators in the area where the leak is occurring, giving them the opportunity to leave. This type of device is important because there are many gases that can be harmful to organic life, such as humans or animals.

Gas detection equipment shall be installed where gas may accumulate and on the ventilation inlets. A gas dispersion analysis or physical smoke test shall be used to determine the best possible arrangement. The number and location of gas detectors in each space and for the different parts of the bunkering system shall be considered, taking size, layout and ventilation into account.

Fixed gas detection is, indeed, a fundamental requirement to detect potential loss of containment. This functional requirement should be shared by the whole bunkering interface. Visual detection and temperature detection may however be the most effective control measures for detection of potential LNG leakage/release. Depending upon gas detector locations, under certain open-air dispersion characteristics36 visual and temperature detection may be more appropriate (i.e. faster) to detect leakage rather than gas detectors.

How do we detect gas or gas leak?
Human and mechanical:
- Visual, sound, smell (but not for LNG, odorless)
- Handheld measuring device
- Fixed measuring device

Gas analyzing equipment on board liquefied gas carriers
An instrument which alerts someone to the presence of gas, especially in spaces where gas is not normally expected. Gas analyzing equipment include oxygen monitors, detectors for combustible gases, compressed breathing air monitors, and systems for detection of an array of toxic gases. Available equipment ranges from single-gas and four-gas portables to multi-channel stationary gas detection systems.

Vapour detection equipment is required by IMO codes for a number of reasons.
- Fuel vapour in air, inert gas or the vapour of another fuel.
- Concentrations of gas in or near the flammable range.
- Concentrations of oxygen in inert gas, fuel vapour or enclosed spaces.

There are two types of gas detection system commonly used on board, a sampling system and a gas detection system incorporating remote heads.

The sampling system draws gas samples from each monitored location into a central analyzer located in a 'safe' area. Typically, samples will be drawn from fuel areas in a pre-programmed sampling sequence and will be passed through an infrared analyzer. The system alarms if pre-set limits are exceeded.

Remote detector heads may also be used to monitor gas concentrations. The signal from flameproof infrared gas detectors will be passed to a central control unit having visual and audible alarm functions.

7.8 Fuel Emergency Shut Down System (ESD)

.1 Explain the functions of Emergency Shutdown System (ESD)

- The control, monitoring and safety systems of the gas-fuelled installation shall be so arranged that the remaining power for propulsion and power generation in the event of single failure;
- a gas safety system shall be arranged to close down the gas supply system automatically, upon failure in systems and upon other fault conditions which may develop too fast for manual intervention;
- for ESD protected machinery configurations the safety system shall shutdown gas supply upon gas leakage and in addition disconnect all non-certified safe type electrical equipment in the machinery space;
- the safety functions shall be arranged in a dedicated gas safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signal;
- the safety systems including the field instrumentation shall be arranged to avoid spurious shutdown, e.g. as a result of a faulty gas detector or a wire break in a sensor loop; and
- where two or more gas supply systems are required to meet the regulations, each system shall be fitted with its own set of independent gas control and gas safety systems.

When the ESD System activates, it creates a pressure surge on the LNG Loading Lines, which may exceed the design pressure, therefore, it may lead to a failure of the Loading Lines. To overcome this pressure surge, the ESD system initiates several sequential actions to protect the line from severe surge pressure. Nevertheless, if the ESD system malfunctions, the resulting surge pressure has been found to be higher than the pipeline design pressure.

When the ESD malfunction, the loading pumps will not trip and the vent valves will not open. Therefore, the resulted surge pressure will increase quite high, exceeding the design-pressure, that may lead to the failure of the loading line.

.2 Explain the factors that triggers the IGF fuel safety system

Automatic safety shut down is initiated by leakage detection or stop of ventilation, and will trigger stop of fuel supply to the affected area

Manual remote triggering of emergency shutdown of fuel system will mean closing of master valve(s), double block and bleed valves, tank valve(s), and stop of relevant machinery, or for dual fuel solutions a switch to alternative fuel.

Manual remote triggering of emergency shutdown of bunkering operation can be done from the bunkering operation station and will stop the bunkering.

8 Fuel system theory and characteristics, including types of fuel system pumps and their safe operation

8.1 Lower pressure pumps

.1 Explain the operating principles of low pressure pumps subject to the IGF Code

The tank system with low pressure pump is using a Cryogenic Piston pump driven by a linear electric drive. The complete system including the electrical control unit was developed specifically for the HDGAS requirements. The pump is designed to realize a differential pressure of 12 bar with a mass flow of 75kg/h.

8.2 High pressure pumps

.1 Explain the operating principles of high pressure pumps subject to the IGF Code

At the heart of the fuel gas system is the high pressure pump. To achieve output pressures in excess of 300 bar, reciprocating piston type positive displacement pumps are utilized. A positive displacement pump is aptly called so because it creates fluid motion through the repeated increasing and decreasing of its internal volume.

In the case of a reciprocating piston pump, this increase and decrease in volume comes from the extension and retraction of a piston into and out of a cylinder. In operation, pump flow is dictated by the demand of the engine using pump discharge pressure as control feedback, and adjusted by managing the speed of the pump accordingly.

8.3 Vaporizers

.1 Explain the operating principles of vaporizers subject to the IGF Code

The vaporizer is used for regasification and fuel gas temperature control. If vapor is withdrawn from the tank to reduce the pressure, the vaporizer is used as a heater for the vapor.

The vaporiser is a shell and tube type heat exchanger that is used for vaporising fuel gas liquid for the following operations:

- Exceptionally, when discharging fuel tank at the design rate without the availability of a vapour return from the shore. If the shore is unable to supply vapour return, liquid LNG is fed to the vaporiser by using one stripping pump or by bleeding from the liquid header. The vapour produced leaves the vaporiser at approximately –140 degree C and is then supplied to fuel tanks through the vapour header.

- Vapour pressure in the fuel tanks will normally be maintained at 110kPa abs. (minimum 104 kpa) during the whole discharge operation. Additional vapour is generated by the tank sprayer rings, the LNG being supplied by the stripping/spray pump. If the back pressure in the discharge piping to shore is not sufficient to have a minimum of 300kPa at the inlet to the vaporiser, a stripping/spray pump will be used to supply liquid to the vaporiser.

- Purging of fuel tanks with vapour after inerting with inert gas and prior to cool down. LNG is supplied from the shore to the vaporiser via the stripping/spray line. The vapour produced at the required temperature of +20 degree C is then passed to the fuel tanks.

- Emergency forcing by manual operation. The LNG vaporiser can function as the forcing vaporiser when the forcing vaporiser has failed.

8.4 Heaters

.1 Explain the operating principles of heaters subject to the IGF Code

A fuel gas heater will be employed in order to provide vapour at the right temperature via fuel gas master valve to gas valve unit (GVU).

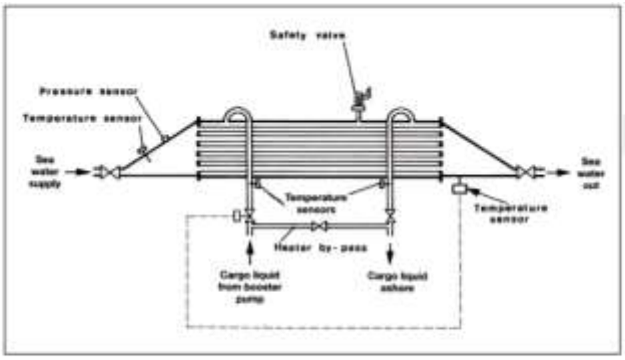
Steam heated fuel tank heaters are provided for the following functions:

- Heating the fuel gas vapour, delivered by the HD compressors, to the specified temperature for warming up the fuel tanks before gas freeing.
- Heating the boil-off gas, delivered by the LD compressors, or by free-flow, prior to supplying it to the boilers or venting to atmosphere.

The heaters are typically heat exchangers of the shell and tube type. The number of plugged tubes in fuel condensers, heaters or vaporizers should not exceed 25%.

When discharging refrigerated fueles into pressurized shore storage, it is usually necessary to heat the fuel so as to avoid low-temperature embrittlement of the shore tanks and pipelines.
Fuel heaters are normally of the conventional horizontal shell and tube type exchanger. Most often, they are mounted in the open air on the ship’s deck. Sea water is commonly used as the heating medium and this passes inside the tubes with the fuel passing around the tubes.

Figure below shows a typical heater arrangement; note the requirement for temperature controls and alarms to avoid freezing. This is a very real risk which always has to be guarded against.



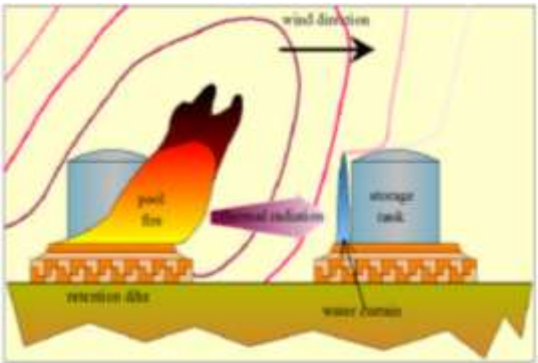
The heaters are typically designed to raise the temperature of fully refrigerated propane from –45°C to –5°C; however, it should be noted that the fuel flow rate at which this temperature rise may be achieved can be significantly reduced in cold sea water areas. Under such circumstances only very slow discharge rates may be possible and when sea water temperatures fall below 5°C it becomes increasingly difficult to use sea water as a heating medium.

8.5 Pressure build up equipment/units

.1 Explain the operating principles of pressure build up equipment/units subject to the IGF Code

When using a pressure built up design concept the whole tank will be brought up to the pressure required by the engines. This design is the simplest and cheapest to build but has the drawback that if no fuel is consumed, the pressure in the tank can rapidly increase to its maximum set pressure (MARVS). Because blowing off gas is usually not acceptable it is necessary to start the engine(s) to maintain the pressure in the tank at a pre-defined level.

Water curtain



It is also used as protection against heat radiation, in case of fighting vapour cloud fire. Water curtain has also been considered as one of the most economic and promising LNG vapour cloud control techniques. Water curtains are expected to enhance LNG vapour cloud dispersion mainly through mechanical effects, dilution, and thermal effects. The actual phenomena involved in LNG vapour and water curtain interaction were not clearly established from previous research

Water spray curtain is recognized as a useful technique to mitigate major industrial hazards. It combines attractive features such as simplicity of use, efficiency and adaptability to different types of risks. In case of accidental dangerous gas releases, the spray curtain may be used as a direct-contact reactor exchanging heat, mass and momentum with the gas phase

9 Safe procedures and checklists for taking fuel tanks in and out of service

.1 Identify the stages to follow in taking fuel tanks in and out of service

- Removal of remaining liquid. Pressure should be released with caution.
- Warming up with Hot Gas (Heating)
- Inerting
- Gas Freeing
- Inerting
- Cooling Down
- Pressure Control
- Initial Loading

.2 Explain the procedures in taking fuel tanks in and out of service

The procedure of removing dangerous and explosive gases from the interior of tanks (usually vapours originating in the fuel of oil tankers and chemical carriers). Gas freeing consists of a series of operations in which fuel vapour is replaced with inert gas which, in turn is purged with air to prevent explosion hazard.

To gas free a fuel tank the following procedures should be followed:
• Remove any remaining fuel liquid. Pressure should be released with caution.
• If the tank temperature is near fuel saturation temperature at atmospheric pressure, the tank atmosphere should be warmed up by circulating hot gas. This is a very time-consuming operation and it is essential that all the steel in the tank has reached a temperature above dew point. It will assist in evaporating any remaining liquid (including condensation on tank structures) and will reduce the quantity of inert gas required.
• Remove the fuel vapour in the system with inert gas. This stage may be omitted when gasfreeing after the carriage of ammonia.
• After inerting the system to a safe fuel vapour concentration, it may be necessary to ventilate the system with air to provide safe access for inspection or repairs. Venting with air should be continued until an oxygen content of 21% by volume is obtained. Samples should be taken at various levels, and sampling repeated sometime after the first acceptable readings are obtained, to allow possible pockets of inert gas to mix with the air, and the consequent

reduction in oxygen content to be detected before tanks are entered. When a tank and associated pipelines have been certified gas-free maintenance work may take place.

- Before starting gas freeing, the tank should be isolated from other tanks by means of closing valves or blanking off associated pipelines. When either portable fans or fixed fans connected to the fuel pipeline system are used to introduce air into the tank, the Inert gas inlet should be isolated. If the Inert gas system fan is employed to draw air into the tank, both the line back to the Inert gas source and the Inert gas Inlet into each tank that is being kept Inerted should be isolated.

Pressure control

Types of pressure gauges installed in LNG tanks, their accuracy limits

The vapour space of each fuel tank should be provided with a pressure gauge which should incorporate an indicator in the fuel control position. In addition, a high pressure alarm and, if vacuum protection is required, a low pressure alarm, should be provided on the bridge. Maximum and minimum allowable pressures should be marked on the indicators.

Each fuel pump discharge line and each liquid vapour fuel manifold should be provided with at least one pressure gauge.

Local reading manifold pressure gauges should be provided to indicate the pressure between stop valves and hose connections to the shore.

Hold spaces and interbarrier spaces without open connection to the atmosphere should be provided with pressure gauges.

Pressure and vacuum protection systems on LNG tanks

Instruments used to measure and display pressure in an integral unit are called pressure gauges or vacuum gauges.

Other methods of pressure measurement involve sensors that can transmit the pressure reading to a remote indicator or control system (telemetry).

In accordance with the IGF Code, chapter 6.7.1.2, fuel storage tanks which may be subject to external pressures above their design pressure should be fitted with vacuum protection systems.
There are many pressure control systems:

- spray lines in the top of the tank;
- vapour return;
- re-liquefaction;
- CNG storage; or
- vapour processing.

The used pressure control system should be exchanged and be agreed upon. It should be verified that re-liquefaction and boil off control systems, if required, are functioning correctly prior to commencement of operations.

Pressure control is one of the most critical processes during LNG bunker operations. It is important that such systems are fully operational and that back up is provided in case of a failure of the system.

Pressure measurement is the analysis of an applied force by a fluid (liquid or gas) on a surface. Pressure is typically measured in units of force per unit of surface area.

.3 Apply the procedures in and out of service in accordance with the established procedures

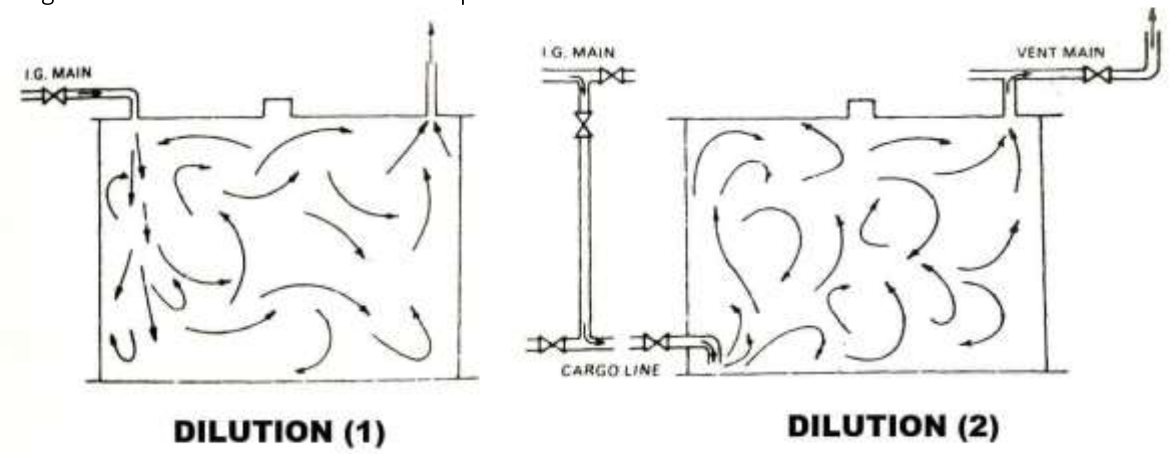
Principles of emptying system

If the entire tank atmosphere could be replaced by an equal volume of inert gas, the resulting tank atmosphere would have the same oxygen level as the incoming inert gas. In practice, this is impossible to achieve and a volume of inert gas equal to several tank volumes must be introduced into the tank before the desired result can be achieved.

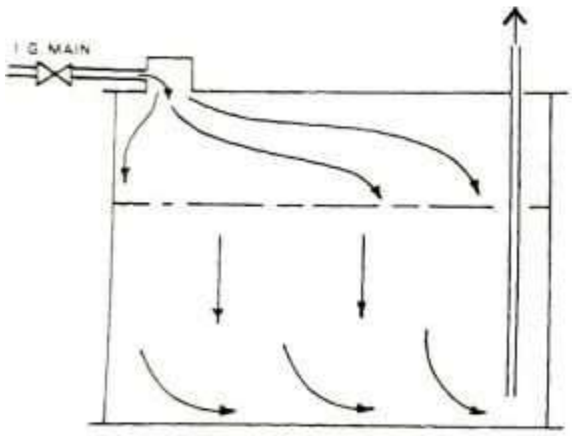
The replacement of a tank atmosphere by inert gas can be achieved by either inerting or purging. In each of this methods, one of two distinct processes, dilution or displacement, will predominate.

Resources, infrastructure and local conditions required for-gas freeing

Dilution takes place when the incoming inert gas mixes with the original tank atmosphere to form a homogeneous mixture throughout the tank so that, as the process continues, the concentration of the original gas decreases progressively. It is important that the incoming inert gas has sufficient entry velocity to penetrate to the bottom of the tank. To ensure this, a limit must be placed on the number of tanks that can be inerted simultaneously. Where this limit is not clearly stipulated in the operations manual, only one tank should be inerted or purged at a time when using the dilution method. Below is a representation of Dilution method onboard.



Displacement depends on the fact that inert gas is slightly lighter than hydrocarbon gas so that, while the inert gas enters at the top of the tank, the heavier hydrocarbon gas escapes from the bottom through suitable piping. When using this method, it is important that the inert gas has a very low velocity to enable a stable horizontal interface to be developed between the incoming and escaping gas. However, in practice, some dilution inevitably takes place owing to the turbulence caused by the inert gas flow. Displacement generally allows several tanks to be inerted or purged simultaneously. Below is a representation of Displacement method achieved onboard.



Displacement

10 Hazards and Control Measures Associated with Fuel System Operations

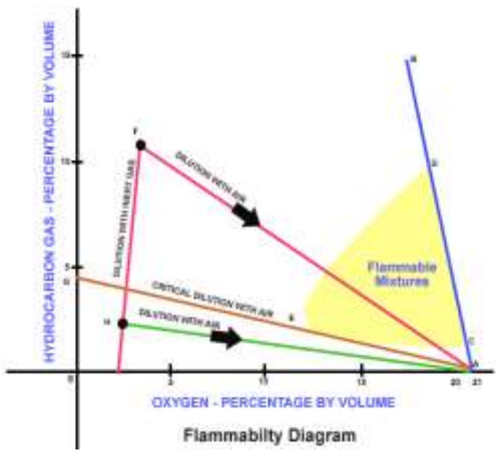
.1 Identify hazards associated with fuel system operations

Flammability

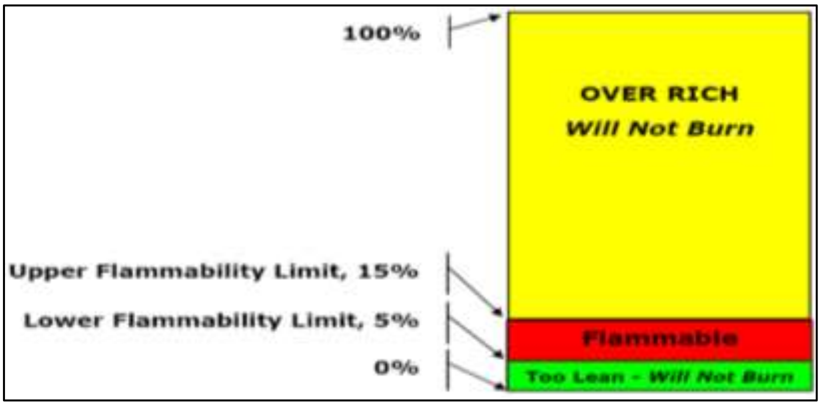
The ability of most liquefied gases and low flash point fuels to generate flammable vapour is a major factor for starting a fire.

The minimum and maximum concentrations of vapour in air which form flammable (explosive) mixtures are known as the lower explosive limit (LEL) and upper explosive limit (UEL) respectively.

The flammable range gives a measure of the proportions of flammable vapour to air for combustion to occur, in other words is the range between the minimum and maximum concentrations of vapour (per cent by volume) in air which form a flammable mixture. The lower and upper limits are usually abbreviated to LFL (lower flammable limit) and UFL (upper flammable limit).



Flammabilty Diagram



Explosion

Principles of stoichiometric point

Defined by the stoichiometric concentration of fuel in pure oxygen for the complete combustion of the fuel (all carbon in the fuel is converted to carbon dioxide). Moreover, the stoichiometric point is a term commonly used to describe the ideal fuel/air ratio in a combustion engine. The stoichiometric air-fuel ratio for gasoline is 14.7 to 1 by weight. Theoretically, at this ratio all of the fuel will be burned using all of the oxygen in the air.

The proportions of fuel and oxidizer that will result in optimal combustion are known as a stoichiometric ratio. The optimal ratio is determined by finding the amount of air that will result in the products of the combustion reaction containing only water and carbon dioxide with no left over oxygen.

Toxicity

A toxic substance is one which is liable to cause either harm to human health, serious injury or death. Toxic means the same as poisonous. Toxicity is an intrinsic property of a chemical, which man cannot modify, and its effect is a function of exposure. In some cases, correct response to its effects after exposure can diminish its consequences.

There are three common ways that a fuel can be toxic: swallowed (oral toxicity), absorbed through the skin, eyes and mucous membranes (dermal toxicity) or inhalation as a vapour or mist (inhalation toxicity).

TLV (Threshold Limit Value)

It is defined as a concentration of a gas which a person can be exposed to without any adverse effect. A TLV reflects the level of exposure that the typical worker can experience without an unreasonable risk of disease or injury. TLVs are not quantitative estimates of risk at different exposure levels or by different routes of exposure.

TWA (Time Weighted Average)

Time weighted average (TWA) is the average workplace exposure to any hazardous contaminant or agent using the baseline of an 8 hour per day or 40 hours per week work schedule. The TWA reflects the maximum average exposure to such hazardous contaminants to which workers may be exposed without experiencing significant adverse health effects over the standardized eight-hour work period.
The TWA is expressed in units of parts per million (ppm) or mg/m3.

STEL (Short Term Exposure Limit Value)

A Short-Term Exposure Limit (STEL) is defined by ACGIH as the concentration to which workers can be exposed continuously for a short period of time without suffering from:

- irritation
- chronic or irreversible tissue damage
- narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency.

Threshold Limit Value - Ceiling (TLV-C) mean?

The threshold limit value ceiling is a guideline to assist with the control of health hazards. It is the maximum level of exposure to a chemical substance day after day without suffering any adverse effects. This level must not be exceeded at any time. The threshold limit values are issued by the American Conference of Government Industrial Hygienists (ACGIH).

Reactivity

A liquefied gas cargo may react in a number of ways: with water to form hydrates, with itself, with air, with another cargo or with other materials.

Reaction with water (hydrate formation)

• Water for hydrate formation can come from:
– Purge vapors with incorrect dew point
– Water in the fuel system
– Sometimes: water dissolved in the fuel

Self Reaction

• Some self-react fuels (like ethylene oxide), which cannot be inhibited must be carried out under inert gas
• Most common form is polymerization initiated by the presence of small quantities of other fuels or certain metal

Reaction with Air

• Can cause explosion by forming unstable oxygen compounds
• Fuels must be either inhibited, carried under IG or N_2

Reaction with other Fuels

• Consult data sheet for each fuel
• If possible, separate reliquefaction systems to be used for each fuel
• If danger of chemical reaction exist than use of completely segregated systems is required, known as positive segregation (See specification of certain fuels in IMO Gas Carrier Code)
• If there is any doubt of the reactivity or compatibility of two fuels they must be treated as incompatible and 'positive segregation' provided

Reaction with other material

• Consult data sheet list of materials not allowed to come into contact with fuel
• ONLY compatible materials to be used in the fuel system

Corrosivity

Corrosion is the gradual decomposition or destruction of a material by oxidation or chemical actions, often due to an electrochemical reaction. Corrosion starts at the surface or a material and moves inward. Corrosion of iron or steel is commonly called rusting. A number of factors will accelerate corrosion, including:

- Acidity (low pH)
- High mineral concentrations
- Stray current electrolysis
- Galvanic corrosion caused by dissimilar metals
- Dissolved oxygen content
- Water temperatures

LNG is neither corrosive nor toxic. Natural gas is primarily methane, with low concentrations of other hydrocarbons, water, carbon dioxide, nitrogen, oxygen and some sulfur compounds.

Health Hazards

Gas / Fuel	Hazard
Liquefied Natural Gas / Methane	Liquefied gases may cause cryogenic burns or injury Light hydrocarbon gases are simple asphyxiants and can cause anesthetic effects at high concentrations. Gas can accumulate in confined spaces and limit oxygen available for breathing Continued exposure can lead to hypoxia (inadequate oxygen), rapid breathing, cyanosis (bluish discoloration of the skin), numbness of the extremities, unconsciousness and death.
Liquefied Petroleum Gas	Liquefied gases may cause cryogenic burns or injury Gas can accumulate in confined spaces and limit oxygen available for breathing Continued exposure can lead to hypoxia (inadequate oxygen), rapid breathing, cyanosis (bluish discoloration of the skin), numbness of the extremities, unconsciousness and death.
Propane	Contact with the liquefied or pressurized gas may cause momentary freezing followed by swelling and eye damage. Asphyxiant. High concentrations in confined spaces may limit oxygen available for breathing.
Butane	Contact with the liquefied or pressurized gas may cause frostbite. Light hydrocarbon gases are simple asphyxiants and can cause anesthetic effects at high concentrations
Ethane	Contact with the liquefied or pressurized gas may cause frostbite. Contact with the liquefied or pressurized gas may cause momentary freezing followed by swelling and eye damage. Light hydrocarbon gases are simple asphyxiants and can cause anesthetic effects at high concentrations
Methanol	Acute exposure of humans to methanol by inhalation or ingestion may result in visual disturbances, such as blurred or dimness of vision, leading to blindness. Neurological damage, specifically permanent motor dysfunction, may also result. Contact of skin with methanol can produce mild dermatitis

Inert gas composition

The International Convention for the Safety of Life at Sea (SOLAS) as amended, requires that IG systems be capable of delivering IG with an oxygen content of the IG main not more than 5% by volume at any required rate of flow; and of maintaining a positive pressure in the fuel tanks all times with an atmosphere having an oxygen content of not more than 8% by volume except when it is necessary for the tank to be gas free.

When an independent IG generator or a gas turbine plant with afterburner is fitted, the oxygen content can be automatically controlled within finer limits, usually within the range 1.5%-2.5% by volume.

It is absolutely essential to understand that with inert gases such as nitrogen, argon, helium, etc., asphyxia is insidious - there are no warning signs!

- Inert gases are odourless, colourless and tasteless. They are undetectable and can therefore be a great deal more dangerous than toxic gases such as chlorine, ammonia, or hydrogen sulphide, which can be detected by their odour at very low concentrations.
- The asphyxiating effect of inert gases occurs without any preliminary physiological sign that could alert the victim. Lack of oxygen may cause vertigo, headache or speech difficulties, but the victim is not capable of recognising these symptoms as asphyxiation. Asphyxiation leads rapidly to loss of consciousness – for very low oxygen concentrations this can occur within seconds.

- The situation is hazardous as soon as the oxygen concentration inhaled is less than 18 %. With no oxygen present, inhalation of only 1-2 breaths of nitrogen or other inert gas will cause sudden loss of consciousness and can cause death.

Electrostatic Hazards

Static electricity presents fire and explosion hazards during the handling of petroleum, and tanker operations. Certain operations can give rise to accumulations of electric charge which may be released suddenly in electrostatic discharges with sufficient energy to ignite flammable hydrocarbon gas/air mixtures; there is, of course, no risk of ignition unless a flammable mixture is present. There are three basic stages leading up to a potential static hazard: charge separation, charge accumulation and electrostatic discharge. All three of these stages are necessary for an electrostatic ignition.

Pressurised Gases

Gases expand with increase in temperature and if the space available is limited as in a tank or an isolated section of pipeline, the pressure will increase. This characteristic can lead to various hazards and makes monitoring of pressure very critical. It is very important that pressure sensors are well maintained and accurately calibrated.

Pressure surge or liquid hammer, as it is commonly known, is the result of a sudden change in liquid velocity. Liquid hammer usually occurs when a transfer system is quickly started, stopped or is forced to make a rapid change. Any of these events can lead to a catastrophic system component failure.

When the ESD System activates, it creates a pressure surge on the LNG Loading Lines, which may exceed the design pressure, therefore, it may lead to a failure of the Loading Lines. To overcome this pressure surge, the ESD system initiates several sequential actions to protect the line from severe surge pressure. Nevertheless, if the ESD system malfunctions, the resulting surge pressure has been found to be higher than the pipeline design pressure.

When the ESD malfunction, the loading pumps will not trip and the vent valves will not open. Therefore, the resulted surge pressure will increase quite high, exceeding the design-pressure, that may lead to the failure of the loading line.

Therefore, it was proposed to improve the existing surge protection by installing additional instrumentation as a sequential back-up when the existing protection system fails. As a result, in order to improve the reliability of the existing surge protection system, pressure switches were installed on the loading line, which function to trip the loading pumps and opens the vent valves at specified set pressure when the main surge protection fails.

Low temperature

In the event of fuel system leaks & contact with LNG chilled to its temperatures of about –160 degree C will damage living tissue. Most metals lose their ductility at these temperatures; LNG may cause the brittle fracture of many materials. In case of LNG spillage on the ship’s deck, the high thermal stresses generated can result in the fracture of the steel.

Low flashpoint liquids have a boiling temperature above zero, for instance 65°C is the boiling point of methanol. They also have flashpoint below normal ambient temperatures, methanol has a flashpoint of around 12°C. Low temperatures can cause burns which may damage skin and tissue when in direct contact with cold liquid or vapour.

Liquefied gases are boiling liquids and give off vapours readily, low flashpoint liquids also give off vapours due to flashing, vapour can be flammable, toxic or both, vapour in sufficient concentration will exclude oxygen and may cause asphyxiation whether the vapour is toxic or not, an explosive mixture may be produced when most vapours are mixed with air, gases are made up of molecules that are in constant motion and exert pressure when they collide with the walls of their container

.2 Identify control measures to mitigate hazards associated with fuel system operations

Flammability:

Control measures:

- Know the hazards. One major component of prevention is simply knowing the safety information for every liquid on your premises. This information is available on the material safety data sheet (MSDS) that comes with such products.
- Store fuel properly. Make sure all hazardous materials are stored according to procedures.
- Control all ignition sources. Except for when you're intentionally heating the flammable materials, keep ignition sources as far away from them as possible.
- Provide personal protective equipment. This is a must across all categories of fire hazards but especially when liquids and gasses are involved.

11 Dangers of non-compliance with relevant rules/regulations

.1 Explain the importance of complying with the international environment rules and regulations

Greenhouse Gases

Greenhouse gas, any gas that has the property of absorbing infrared radiation (net heat energy) emitted from Earth's surface and reradiating it back to Earth's surface, thus contributing to the greenhouse effect. Carbon dioxide, methane, and water vapour are the most important greenhouse gases. (To a lesser extent, surface-level ozone, nitrous oxides, and fluorinated gases also trap infrared radiation.)

Shipping is considered one of the most efficient modes of transport in terms of CO_2 emissions. However, it also represents a substantial and growing source of the overall greenhouse gas (GHG) emissions. Although CO_2 emissions from the shipping industry have been accounted for almost 3% of the global GHG values, without any further action, it is expected this to rise to 5% by 2050.

Influential Greenhouse Gases

• Carbon Dioxide (CO_2) is a colorless, odorless gas consisting of molecules made up of two oxygen atoms and one carbon atom. Carbon dioxide is produced when an organic carbon compound (such as wood) or fossilized organic matter, (such as coal, oil, or natural gas) is burned in the presence of oxygen. Carbon dioxide is removed from the atmosphere by carbon dioxide "sinks", such as absorption by seawater and photosynthesis by ocean-dwelling plankton and land plants, including forests and grasslands. However, seawater is also a source, of CO_2 to the atmosphere, along with land plants, animals, and soils, when CO_2 is released during respiration.

• Methane (CH_4) is a colorless, odorless non-toxic gas consisting of molecules made up of four hydrogen atoms and one carbon atom. Methane is combustible, and it is the main constituent of natural gas-a fossil fuel. Methane is released when organic matter decomposes in low oxygen environments. Natural sources include wetlands, swamps and marshes, termites, and oceans. Human sources include the mining of fossil fuels and transportation of natural gas, digestive processes in ruminant animals such as cattle, rice paddies and the buried waste in landfills. Most methane is broken down in the atmosphere by reacting with small very reactive molecules called hydroxyl (OH) radicals.

- **Nitrous oxide (N2O)** is a colorless, non-flammable gas with a sweetish odor, commonly known as "laughing gas", and sometimes used as an anesthetic. Nitrous oxide is naturally produced in the oceans and in rainforests. Man-made sources of nitrous oxide include the use of fertilizers in agriculture, nylon and nitric acid production, cars with catalytic converters and the burning of organic matter. Nitrous oxide is broken down in the atmosphere by chemical reactions driven by sunlight.

- **Sulfur hexafluoride (SF6)** is an extremely potent greenhouse gas. SF6 is very persistent, with an atmospheric lifetime of more than a thousand years. Thus, a relatively small amount of SF6 can have a significant long-term impact on global climate change. SF6 is human-made, and the primary user of SF6 is the electric power industry. Because of its inertness and dielectric properties, it is the industry's preferred gas for electrical insulation, current interruption, and arc quenching (to prevent fires) in the transmission and distribution of electricity. SF6 is used extensively in high voltage circuit breakers and switchgear, and in the magnesium metal casting industry.

Toxic Load
A toxin is a synthetic chemical or poison known to have harmful effects on the body. We expose ourselves to toxins every day via:
- cleaning products
- personal care products
- polluted air
- sprayed foods water

Our bodies process toxins through the liver and kidneys. These organs eliminate them in the form of sweat, urine and faeces. Some may question the need to detox on a daily basis. But, we can't ignore the tens of thousands of industrial chemicals that exist today. The record level of pollution and contaminants didn’t exist 50 years ago. And to top it off, the vast majority of these chemicals are not tested in health and safety studies.

Exposure to such environmental toxins and chemicals can cause toxic overload. Toxic overload is a heavy burden on your body. It interferes with fundamental organ and gland functions. The damage to your liver and kidneys reduces their ability to rid the body of toxins.

The toxins that aren't processed build up. They generate free radicals which do all sorts of damage, some of which is irreversible.

Effects of toxic overload include:
- allergies
- digestive sensitivities and problems like Irritable Bowel Syndrome
- weakened immune system

12 Risks assessment method analysis

.1 Explain risk assessment method in accordance with the established procedures

What is a Hazard?
Anything that has potential to cause harm or increase the severity of harm
Example: Slippery Surfaces, Damaged handrails, Presence of Toxic Gases, Lack of Oxygen, Damaged Tools, Damaged PPE, Naked flame, working aloft, Working on electrical Circuit.

A hazard is an agent which has the potential to cause harm to a vulnerable target. The terms "hazard" and "risk" are often used interchangeably. However, in terms of risk assessment, they are two very distinct terms. A hazard is any agent that can cause harm or damage to humans, property, or the environment. Risk is defined as the probability that exposure to a hazard will lead to a negative consequence, or more simply, a hazard poses no risk if there is no exposure to that hazard.

Hazards can be dormant or potential, with only a theoretical probability of harm. An event that is caused by interaction with a hazard is called an incident. The likely severity of the undesirable consequences of an incident associated with a hazard, combined with the probability of this occurring, constitute the associated risk. If there is no possibility of a hazard contributing towards an incident, there is no risk.

HAZID

Hazard identification (HazID) study is the method of identifying hazards to prevent and reduce any adverse impact that could cause injury to personnel, damage or loss of property, environment and production, or become a liability. HazID is a component of risk assessment and management. It is used to determine the adverse effects of exposure to hazards and plan necessary actions to mitigate such risks.

In addition, Hazard identification (HAZID) is the core of the risk assessment process. A HAZID study is normally carried out in a work-shop setting by a multidisciplinary team. Its primary function is to review possible hazardous events that may occur during the planned operation based on detailed engineering information, previous accident history, and judgment of the participants. Depending on the specific methodology used (e.g., what-if, failure modes and effects analysis), the team will document what can go wrong, potential causes and consequences of that event, and what safety measures can prevent or mitigate the event.

A full range of hazardous effects that could occur after a hazardous event should be considered. These include fire, explosion, injury to personnel, damage to equipment and structures, shutdown of nearby activities, and cryogenic hazards. The hazardous events and effects are normally placed into a risk matrix. Based on the risk matrix, risks can be ranked in terms of importance (from low probability, low consequence risks to high probability, high consequence risks). In the risk matrix, it can be highlighted which risks are unacceptable without countermeasures to reduce either the probability, consequence, or both. The focus of the risk matrix should be consequences that affect people, followed by damage to equipment or structure.

The principal objectives of the HAZID should identify:
- hazards and how they can be realized (i.e. the accident scenarios);
- the consequences that may result;
- existing measures/safeguards that minimize leaks, ignition and potential consequences, and maximize spill containment; and
- recommendations to eliminate or minimize risks.

As a minimum, the HAZID should include the scope as described in the ISO/TS 18683.

BUNKERING

Here are the example of the hazard identification during bunkering as the above figure show:
- Sub-standard hose
- Co-mingling of bunker due to incorrect line up
- Overfilling bunker tanks
- High H2S content
- Internal communication failure
- IAS failure
- Malfunctioning level & pressure gauges

- Crew & Officer fatigue
- Night time operation
- VHF/UHF interference
- Pressure surge
- Overflow due to valve mis-operation
- Inadequate ship-barge compatibility study
- Inexperienced Master
- Incorrect maneuvering
- Moorings parting
- Inadequate fendering
- Contact with barge
- Transfer of personnel
- Weather
- Improper line up
- Fuel piping leakage @ manifold
- Excessive loading rate
- Inadequate monitoring of tanks
- Hydraulic system failure

HAZOP

The HAZOP study is a structured and methodical examination of a planned process and all its operational failures or operation to identify causes and consequences from a deviation to ensure the ability of equipment to perform in accordance with the design intent. It aims to ensure that appropriate safeguards are in place to help prevent accidents. Guide words are used in combination with process conditions to systematically consider all credible deviations from normal conditions.

The HAZOP should be realized with a focus on the LNG bunkering, the transfer of fuel to the receiving ship. The operational modes for the receiving ship to be considered are:
- start-up;
- normal operations;
- normal shutdown; and
- emergency shutdown.

A HAZOP divides the process up into nodes. Each node is then examined by a series of guidewords, e.g. low-flow, high-flow, no flow and reverse flow which then cover the normal operational scenarios including startup and shutdown.

A hazard and operability study (HAZOP) is a structured and systematic examination of a complex planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment.

The intention of performing a HAZOP is to review the design to pick up design and engineering issues that may otherwise not have been found. The technique is based on breaking the overall complex design of the process into a number of simpler sections called 'nodes' which are then individually reviewed. It is carried out by a suitably experienced multi-disciplinary team (HAZOP) during a series of meetings.

The HAZOP technique is qualitative, and aims to stimulate the imagination of participants to identify potential hazards and operability problems. Structure and direction are given to the review process by applying standardised guide-word prompts to the review of each node. The relevant international standard [1] calls for team members to display 'intuition and good judgement' and for the meetings to be held in 'a climate of positive thinking and frank discussion'.

Quantitative Risk Assessments (QRA)

A Quantitative Risk Assessment (QRA) may be required where:
1. bunkering is not of a standard type;
2. design, arrangements and operations differ from the guidance given in this document; and
3. bunkering is undertaken alongside other transfer operations (SIMOPS).

A QRA is also appropriate where further insight is required: to judge the overall level of risk; to appraise design options and mitigation alternatives; and/or to support a reduced safety zone and/or security zone. For bunkering, it is the safety zone that is important here to identify and stop hazards reaching the safety zone from the monitoring and security area that surrounds it.

The requirement for a QRA is normally determined by the national legislation/regulation authority, port authority and/or National Administration based on the conclusions and outcomes HAZID and accepted by the concerned parties

A Quantitative Risk Assessment (QRA) is a formal and systematic risk analysis approach to quantifying the risks associated with the operation of an engineering process. A QRA is an essential tool to support the understanding of exposure of risk to employees, the environment, company assets and its reputation. A QRA also helps to make cost effective decisions and manages the risks for the entire asset lifecycle.

Quantitative Risk Analysis is proven as a valuable management tool in assessing the overall safety performance of a Chemical Process Industry.

Objective of QRA:
- To identify, quantify and assess the risk from the facility from the storage and handling of chemical products
- To identify, quantify and assess the risk to nearby facilities / installations.
- To suggest recommendations in order to reduce the risk to human life, assets, environment and business interruptions to as low as reasonably practicable.
- Risk Analysis techniques provide advanced quantitative means to supplement other hazard identification, analysis, assessment, control and management methods to identify the potential for such incidents and to evaluate control strategies.

QRA is widely used in assessing the risk in Oil & Gas Installations especially refineries, tank farms, cross country pipelines, bottling plants, terminals etc.

13 Elaboration and development of risks analysis related to risks on board ships

.1 Perform risk assessment in accordance with the established procedures

In a given scenario, apply the principles of risk assessment method analysis

Risk assessment for ships should be continual, flexible, reviewed regularly to improve safety and preventing pollution. Since ‘risk’ is never a constant or concrete entity, the divergence of the nature of perception and anticipation the level of danger from the risk undertaken is resolved by experience, training and disposition. Human behavior towards issues, general awareness, and constant vigilance of those involved, all play a vital role in the organization’s decision-making process in the risk assessment in ship operations.

The risk assessment process normally includes the following main steps:
- Assembly of a team of experts who can provide objective and knowledgeable input on identifying risks and hazards, evaluate their consequences, and suggest counter measures
- Identification of potential hazards

• Assessment of the likelihood that the hazard will occur
• Assessment of the potential consequences. Depending on the concerns of the owner or operator, the consequence assessment could consider a variety of impact types, including impacts to people (both onsite and offsite), impacts to the environment, property damage, business interruption and reputation
• Identification of risk reduction measures if the risk of a hazard is considered unacceptable

14 Elaboration and development of safety plans and safety instructions

.1 Explain the purpose of developing safety plans and instructions

Having safety plans and instructions can reduce the risk of health hazard exposures and accidents. It is not difficult to develop such a plan, it should address the types of accidents and health hazard exposures that could happen in your workplace. Since each workplace is different, it should address the specific needs and requirements.

.2 Analyze the existing safety plans and instructions in accordance with the established procedures

Things to consider in developing safety plans and instructions:

Management Commitment and Crew Involvement. The department head/responsible person leads the way by setting up the policy, assigning and supporting responsibility, setting a positive example, and involving crew.

Work area Analysis. The work location is continually analyzed to identify all existing risk and potential hazards.

Hazard Prevention and Control. Methods to prevent or control existing or potential hazards are administered and maintained.

Proper Training for the Crew. Team leader/responsible person and crew must be well-trained to understand and deal with work area risk and hazards.

.3 Recommend improvement based on the results of existing safety plans analysis

Behavior Based Safety System

In a safety management system based upon the hierarchy of hazard control, BBS may be applied to internalise hazard avoidance strategies or administrative controls (including use of personal protective equipment), but should not be used in preference to the implementation of reasonably practicable safety measures further up the hierarchy.

BBS is not based on assumptions, personal feeling, and/or common knowledge. To be successful, the BBS program used must be based on scientific knowledge.

Under this, all crewmembers are responsible for the safety of everyone including themselves, therefore creating a safety culture that encourages participation and fault finding to develop a safer plan of action.

15 Calibration and usage of monitoring and fuel detection systems, instruments and equipment

.1 Explain the calibration and test procedures of different gas measuring equipment in accordance with the manuals

Gas Detection Equipment

Gas detection equipment and instrumentation requirements are laid down in the IGF code.

Regulations for gas detection are as follows:

- Permanently installed gas detectors shall be fitted in:
  .1 the tank connection spaces;
  .2 all ducts around fuel pipes;
  .3 machinery spaces containing gas piping, gas equipment or gas consumers;
  .4 compressor rooms and fuel preparation rooms;
  .5 other enclosed spaces containing fuel piping or other fuel equipment without ducting;

.6 other enclosed or semi-enclosed spaces where fuel vapours may accumulate including interbarrier spaces and fuel storage hold spaces of independent tanks other than type C;
.7 airlocks;
.8 gas heating circuit expansion tanks;
.9 motor rooms associated with the fuel systems; and
.10 at ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required.

Gas Detector Bump Test
In simple terms, a bump test is a functional test of the gas monitor to ensure that the sensors will respond to their target gas and that the alarms will function. This is performed by briefly exposing the sensors to their target gas. Bump testing should be performed before each day's use. Bump tests check for sensor and alarm functionality but do not measure sensor accuracy and do not make adjustments to the instrument in the way that a calibration does.
OSHA defines a bump test as “a qualitative function check in which a challenge gas is passed over the sensor(s) at a concentration and exposure time sufficient to activate all alarm settings.”

In English, the bump test is the process that verifies “the performance of the gas detector and ensures that sensors are responding to their target gas.” For example, an H_2S sensor is exposed to H_2S gas to verify it can respond. Please note, a bump test does not calibrate the sensors.

Bump Test Frequency
OSHA suggests that a bump test “should be conducted before each day's use in accordance with the manufacturer's instructions.” Based on OSHA's suggestion, the matter of bump test frequency is to be decided by the manufacturer's instructions.

Gas Detector Calibration
A calibration of gas detectors is done using an internal menu within the gas detector. This requires an exact blend of calibration gas to re-establish accuracy of the sensor or sensors of the gas detector. Calibration of gas detectors ensures the gas detector works accurately. It is important to check the expiry date of the calibration gas before starting a calibration. Also, it is important to use a calibration gas with precisely the gas concentration or gas concentrations necessary for a particular brand and type of gas detector. Before calibration, the device should have a zero. Zeroing the sensor should take place in a room with clean air or by using a Zero Air cylinder. As a result of zeroing the gas detector, it can be calibrated. If the gas detector fails calibration, a service company or the manufacturer should be contacted.

3. Review Data
Almost all gas detectors in use today provide some form of data logging

Operational Testing and Inspection
Gas measuring instruments should be tested in accordance with the manufacturer's instructions before the commencement of operations requiring their use. Physical checks should include (if applicable):
- hand pump;
- extension tubes;
- tightness of connections;
- batteries; and
- housing and case.

.2 Calibrate Gas Detectors in Accordance with the Manufacturer's Manuals

Manual Bump Test:

Manual bump tests are performed simply by using a gas bottle, a regulator, tubing, a calibration cup (if using a diffusion instrument), and a gas detector. Users can put the instrument into bump test mode, then apply the gas. The gas detector will either cycle through each individual sensor or do them all at once, depending on instrument settings. After the test is complete, the instrument will display results, showing whether it was a passed or failed test. Alternatively, users can perform a manual bump test simply by applying gas to the instrument while it is on its main gas reading screen. If each sensor shows readings in response to the gas and the detector goes into alarm, then that instrument is good to go.

Span Gas Calibration:

1. At the AUTO CAL screen, press and release the POWER MODE button. A screen appears that displays the calibration gas concentrations that the GX-2009 expects you to use.
2. Use the sample tubing to connect the calibration adapter plate to the regulator. Attach the tubing to the adapter plate on the inlet side.
3. Confirm that the regulator on/off knob is turned all the way clockwise (closed) and screw the calibration gas cylinder onto the regulator
4. Push the adapter plate onto the GX-2009's sensor face. Make sure the adapter plate with the sensor names on the adapter plate matching up with the sensor names on the instrument.
5. Press and release the POWER MODE button. The LCD will display the current gas readings and "AUTO CAL" will flash.
6. Turn the regulator on/off knob counterclockwise to open it. Calibration gas will begin to flow.
7. Allow the gas to flow for two minutes.
8. Press and release the POWER button.
9. The GX-2009 will attempt to make a span adjustment on all channels.
10. If the span adjustment is successful, the LCD will show "PASS" before returning to the AUTO CAL screen.

16 Hot work, enclosed spaces and tank entry including permitting

.1 Explain the safety precautions in hot work, enclosed spaces and tank entry in accordance with the established procedures

Hot work

Work involving sources of ignition or temperatures sufficiently high to cause the ignition of a flammable gas mixture is termed as Hot Work. This includes any work requiring the use of welding, burning or soldering equipment, blow torches, some power-driven tools, portable electrical equipment which is not intrinsically safe or contained within an approved explosion-proof housing, and internal combustion engines.

Hot work in the vicinity of fuel tanks, fuel piping and insulation systems should only be undertaken after the area has been secured and proven safe for hot work and all approvals have been obtained

Hot work outside the main machinery spaces (and in the main machinery spaces when associated with fuel tanks and fuel pipelines) must take into account the possible presence of flammable vapours in the atmosphere, and the existence of potential ignition sources. Any hot work outside the designated hot work area in machinery room should be under SMS and permit control.

Hot work outside the main machinery spaces should only be permitted in accordance with prevailing national or international regulations and/or port/terminal requirements and should be subject to the restrictions of a shipboard hot work permit procedure of company's SMS (safety management system).

Hot work in dangerous and hazardous areas should be prohibited during bunkering, tank cleaning, gas freeing, purging or inerting operations.

Checks by officer responsible for safety
Head of Department (Chief Officer & Chief Engineer)
- Inspecting the work area and the equipment to be used for hot-work together with the person/s carrying out the job.
- Physically checking and filling-up the work permit jointly with the responsible officer and the person/s involved in the work.
- Testing the atmosphere of the work area where applicable
- Ensuring continuous effective ventilation of the work area.
- Determining that hot-work is safe to be carried out and signing the permit.
- Monitor the work is going on as per safety briefing.
- Inform the master to retract the permit if safe working conditions are breached.
- To continue monitoring the worked area for at least 30 minutes after completion of hot work or until the risk of fire no longer exists.

Enclosed space and tank entry
An enclosed space is a space which is not used for day to day activity and which has any of the following characteristics:
- Limited opening for entry and exit
- Inadequate ventilation
- Is not designed for continuous worker occupancy

The presence of any one of the characteristics as stated above can make space an enclosed space. A ship-specific list should be available to identify all enclosed spaces onboard and should be displayed in public spaces. The most common confined spaces onboard ships are fuel holds, chain lockers, cofferdams, water tanks, void spaces, duct keels, fuel tanks, engine crankcases, exhaust and scavenge receiver.

Any area on the ship that has been left closed for any length of time without ventilation must be considered dangerous. Changes in the environment of a space which is not labelled unsafe can also make space unsafe, for example, failure of fixed ventilation or from the migration of hazardous vapours from an adjacent hazardous space.

Personnel entering any space designated as a hazardous area should not introduce any potential source of ignition into the space unless it has been certified gas-free and maintained in that condition.

It is best practice to not to enter a dangerous space, however onboard crew members have to enter enclosed spaces for a number of reasons including routine inspection of tanks (ballast tanks, DB tanks), checking if a tank is dry before loading, cleaning of tanks or holds, maintenance including painting, repairing, etc

No person should open or enter an enclosed space unless authorized by the master or the nominated responsible person and unless the appropriate safety procedures laid down for the particular ship including permit to work have been followed. Only a tank or space declared gas-free can be entered by personnel without breathing apparatus and protective clothing.

In other words, Personnel should not enter enclosed spaces, unless the gas content of the atmosphere in such space is determined by means of fixed or portable equipment to ensure oxygen sufficiency and the absence of an explosive atmosphere. A gas-free tank or space may not be considered to remain gas-free unless regular measurements of the atmosphere prove so.

Procedure for Entering an Enclosed Space

The following are the points that need to be followed before entering an enclosed space:

1 Risk assessment to be carried out by a competent officer as enclosed or confined space entry is deficient in oxygen, making it a potential life hazard
2 A list of work to be done should be made for the ease of assessment for e.g. if welding to be carried out or some pipe replacement etc. This helps in carrying out the work quickly and easily
3 Opening and securing has to be done and precaution should be taken to check if the opening of enclosed space is pressurized or not
4 All fire hazard possibilities should be minimized if hot work is to be carried out. This can be done by emptying the fuel tank or chemical tank near the hot workplace
5 The confined space has to be well ventilated before entering. Enough time should be allowed to establish a ventilation system to ensure that air containing enough oxygen to sustain life is introduced. Ventilation can either be natural or mechanical using blowers.
6 Space has to be checked for oxygen content and other gas content with the help of oxygen analyzer and gas detector.
7 Permit to work has to be checked and permitted by the Master of the ship in order to work in confined space
8 Proper signs and Men at work signboards should be provided at required places so that person should not start any equipment, machinery or any operation in the confined space endangering the life of the people working
9 Duty officer has to be informed before entering the enclosed space
10 The checklist has to be signed by the person involved in entry and also by a competent officer
11 One person always has to be kept standby to communicate with the person inside the space. Effective communication between the people inside the space and the person standing by is vitally important.
12 The person should carry oxygen analyzer with him inside the enclosed space and it should be on all the time to monitor the oxygen content. As soon as level drops, the analyzer should sound alarmed and space should be evacuated quickly without any delay
13 The number of persons entering should be constrained to the adequate number of persons who are actually needed inside for work
14 The rescue and resuscitation equipment are to be present outside the confined space. Rescue equipment includes breathing air apparatus, spare charge bottles, stretchers, means of hoisting an incapacitated person from the space like a tripod, rescue harness, portable lighting, etc.
15 Means of hoisting an incapacitated person should be available
16 After finishing the work and when the person is out of the enclosed space, the after-work checklist has to be filled
17 The permit to work has to be closed after this

The use of appropriate PPE is mandatory to protect the crew against the various hazards

Monitoring and evaluation of spaces adjacent to fuel tanks for vapour content should be considered carried out at regular intervals. If gas concentrations are observed, repairs and maintenance work must be stopped when working in the concerned area. Additionally, the cause of the presence of gas concentration must be investigated into and the same eliminated. Other adjoining spaces must be checked for similar defects.

17 GENERAL KNOWLEDGE OF SHIPS SUBJECT TO THE IGF CODE

.1 Explain the general principles of fuel handling of ships subject to the IGF Code

IGF Code is an acronym for “International Code of Safety for Ships using gases or other Low-flashpoint fuels” developed by The International Maritime Organization’s Maritime Safety Committee. IGF Code aims to minimize the risk to the ship, its crew and the environment, it is mandatory under the International Convention for the Safety of Life at Sea (SOLAS).

Code includes regulations to meet the functional requirements for natural gas fuel. Regulations for other low-flashpoint fuels will be added to this Code as, and when, they are developed by the Organization. In the meantime, for other low-flashpoint fuels, compliance with the functional requirements of this Code must be demonstrated through alternative design.

18 Data available on board related to bunkering, storage and securing of fuels

.1 Explain the content of bunkering procedures in accordance with the fuel transfer manual

A typical bunkering procedure would contain the following elements:

- Scope of the procedure
- properties and potential hazards
- Operational bunkering procedures
    - General principles Safety Management System (SMS)
    - Ship and supplier compatibility and pre-agreements
  - Approval & information Responsibilities and qualifications requirements
  - General safety
  - General considerations for communication
  - Operations before bunkering Operations before transfer
  - Operations during bunkering
  - Operations after bunkering
- Bunker Checklist Truck to Ship Bunker delivery note
- Pre-agreement supply note

.2 Use the data available on board related to bunkering, storage and securing of fuels addressed by the IGF Code

Bunker Checklist

The implementation of LNG bunkering checklists is an important measure to ensure adequate documentation of important aspects of LNG bunkering operations.

Part of the LNG bunker operation includes the completion of checklists before and after bunkering by the persons-in-charge. The checklists serve to ensure that all requirements for bunkering have been completed in the correct order. Checklists should be specifically developed for each receiving vessel in accordance with the regulations and circumstances applicable to that vessel and the expected type of bunker supply and bunker location

LNG-BUNKER DELIVERY NOTE*
LNG AS FUEL FOR

SHIP NAME:__________________ IMO NO.:________

Date of delivery:

1. **LNG-Properties**

Methane number**	–	
Lower calorific (heating) value	MJ/kg	
Higher calorific (heating) value	MJ/kg	
Wobbe indices Ws / Wi	MJ/m³	
Density	kg/m³	
Pressure	MPa (abs)	
LNG temperature delivered	°C	
LNG temperature in storage tank(s)	°C	
Pressure in storage tank(s)	MPa (abs)	

2. **LNG-Composition**

Methane, CH_4	% (kg/kg)	
Ethane, C_2H_6	% (kg/kg)	
Propane, C_3H_8	% (kg/kg)	
Isobutane, i C_4H_{10}	% (kg/kg)	
N-Butane, n C_4H_{10}	% (kg/kg)	
Pentane, C_5H_{12}	% (kg/kg)	
Hexane, C_6H_{14}	% (kg/kg)	
Heptane, C_7H_{16}	% (kg/kg)	
Nitrogen, N_2	% (kg/kg)	
Sulphur, S	% (kg/kg)	
negligible<5ppm hydrogen sulphide, hydrogen, ammonia, chlorine, fluorine, water		

3. **Net Total delivered: __________t, ______________MJ __________m³**

Net Liquid delivery:___________GJ

4. **Signature(s):**

Supplier Company Name, contact details:___________________

Signature:____________Place/Port ________ date:____________

Receiver:____________________

* The LNG properties and composition allow the operator to act in accordance with the known properties of the gas and any operational limitations linked to that.

** Preferably above 70 and referring to the used methane number calculation method in DIN EN 16726. This does not necessarily reflect the methane number that goes into the engine.

Bunker delivery note – BDN

The bunker delivery note (BDN) is the official receipt stating the grade and quantity of bunkers supplied to the receiving ship. Regulation 18.5 of MARPOL Annex VI and appendix V of MARPOL Annex VI stipulates information to be included in the BDN.

Additional details, beyond the MARPOL requirements, may be included on the BDN according to local requirements and the commercial requirements of the supplier.

The BDN also states the composition of the fuel bunkered in this case-LNG. It will show the methane number which will help in determining the correct procedure in handling it in the fuel system.

19. Clear and concise communications and between the ship and the terminal, truck or the bunker-supply ship

.1 Explain the importance of clear and concise communications during bunkering operations

Clear communication between different parties during normal operations and emergency situations is one of the factors necessary to ensure safe operations. Clear communication rules have to be agreed on between the different parties before starting any activity. The language for communication should be agreed upon between all parties involved prior to any operation. Communication systems should be part of the compatibility assessment. Communications should be guaranteed between the supplier and receiver by at least two different communication means.

.2 Communicate clearly and concisely all matters related to bunker operations

A communication plan should be agreed between all parties involved prior to the start of operations. Communications equipment to be used within Hazardous Zones to be Ex-proof classified.

Items that communication protocols should address.

Ship bunkering source communications

- Communications shall be maintained between the ship PIC and the bunkering source PIC at all times during the bunkering operation. In the event that communications cannot be maintained, bunkering shall stop and not resume until communications are restored.
- Communication devices used in bunkering shall comply with recognized standards for such devices acceptable to the Administration.
- PIC's shall have direct and immediate communication with all personnel involved in the bunkering operation.
- The ship shore link (SSL) or equivalent means to a bunkering source provided for automatic ESD communications, shall be compatible with the receiving ship and the delivering facility ESD system

20. Safety and emergency procedures for operation of machinery, fuel- and control systems

.1 Explain the safety and emergency procedures in operating machinery, fuel and control systems

Safety Barriers

Safety barriers like redundant extraction ventilation systems, gas detection, shut downs are used for the IGF Code fuels.

Ventilation System: Proper ventilation of bunker stations is necessary to remove any vapors released during bunkering operations. For bunker stations located within the ship's hull or elsewhere that is not an open deck, a forced ventilation system may be required.

Gas Detection: Permanently installed gas detectors are provided for enclosed or semi-enclosed bunker stations in order to detect the release of methane vapors.

Emergency Shutdown System (ESD): The ESD system is critical to the safety of the vessel and is typically a hardwired system. The ESD system is to be fitted to stop bunker flow in the event of an emergency. Generally, the ESD system is activated by manual and automatic inputs. The ESD system is to be tested prior to each bunker operation.

The manuals and procedures should be readily available during bunker operations. Before beginning any bunker operations, both the supplier and the receiver should ensure that the receiving ship's procedure is compatible with the supplier's transfer procedure and the procedure to be followed is agreed by both parties.

Emergency Procedures

Emergency response planning and preparedness are critical to protect personnel, the environment, the public and assets during an incident. In addition to the typically required emergency response plans aboard the ship, specific plans relevant to an emergency involving the LNG system and bunkering operations also should be developed and implemented.

Emergency procedures can be classed as 'higher level' and 'lower level'. Higher level procedures are intended to provide general instruction to all relevant personnel, while lower level procedures are more specific to certain incidents, areas aboard the vessel, or equipment. The emergency procedures are intended to provide guidance and direction on how to carry out an organized and effective response to an incident, which may include LNG spill and/or gas release, fire or other hazardous situation. Some possible incidents that directly affect bunkering are loss of power by the supplier or receiver, non-LNG related fire near the bunkering, unexpected breakaway of one of the vessels, etc. Emergency procedures also should exist for other external incidents not directly related to the bunkering, such as a fire or gas release on a quay, pier or bunker vessel. Other emergency procedures should handle incidents relating to injury sustained by personnel involved in bunkering, such as frostbite induced by contact with extremely cold LNG or equipment.

It is important that personnel from both the supplier and the receiving ship are familiar with and trained in the emergency procedures and have access to them at all times. The training, drills, and exercises should ensure that all involved personnel understand the procedures, their role and responsibilities, and the use of the emergency response equipment available at the supplier and aboard the receiving ship.

The emergency procedures can be updated to reflect lessons learned from previous incidents or exercises or to reflect any modifications made by the supplier or receiving ship. SIGTTO and other agencies have developed numerous publications specifically related to the hazards of LNG which can be referenced when developing emergency response procedures.

.2 Operate the fuel machinery, fuel - and control systems in accordance with the established procedures

Procedures and Manuals

Operation manuals or procedures can be used for safe operation. Port state regulatory requirements will typically require operational procedures and manuals for bunkering gas-fueled ships such as:

• LNG Fuel Transfer Systems Operation Manual
• Emergency Manual
• Maintenance Manual

21. Operation of bunkering systems on board ships subject to the IGF Code

.1 Explain the operating principles of bunkering system subject to the IGF Code

- bunkering procedures
- emergency procedures
- ship-shore/ship-ship interface
- prevention of rollover

Bunkering Procedures

LNG Bunkering is the practice of providing liquefied natural gas fuel to a ship for its own consumption. The key advantage of LNG as a fuel is the vast reduction in pollutant caused by the more traditional method of fuelling ships such as heavy fuel oil, marine diesel fuel (MDO) and marine gas oil (MGO).

Emergency Procedures

Procedures to be followed in case leaks, fire or any emergency that happens while bunkering between ship and shore.

Ship-shore/ship-ship interface

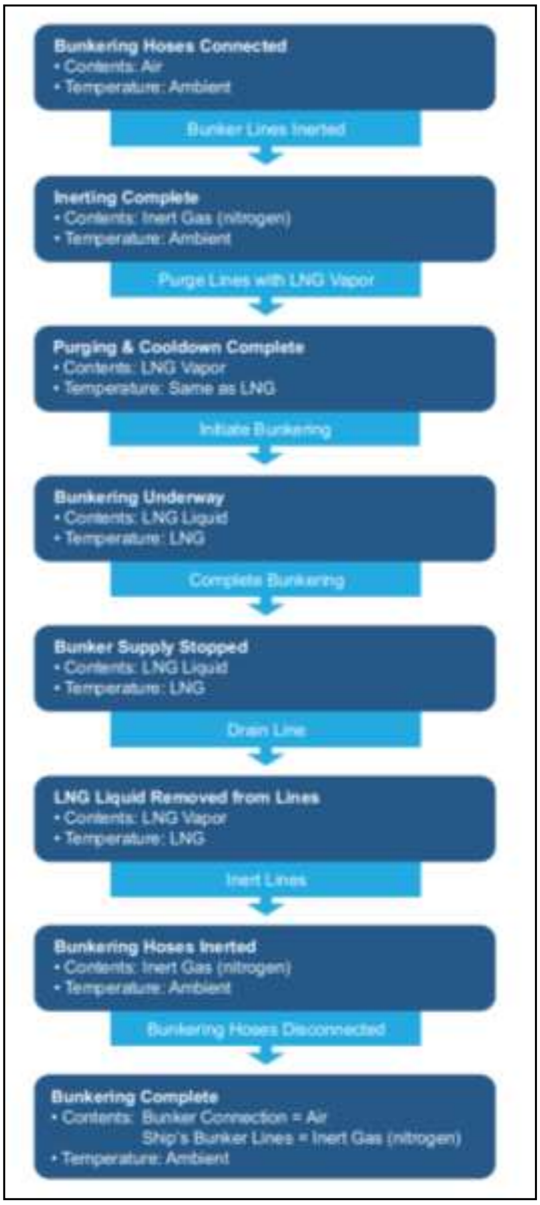
It is very important to maintain a clear interface while the two departments are working together, for any gap in communication can lead to inefficient operation, accidents, and even pollution. Both, ship and shore staff must be adequately trained about interface management so that the operation can be performed safely, efficiently and within the time limit. Ships visit various countries with different languages. Hence to maintain a standard for operational communication, training is required for both ship and shore staff under interface management. Such training is provided by several companies offering training courses for ship shore interface.

Prevention of rollover

LNG "rollover" refers to the rapid release of LNG vapours from a storage tank caused by stratification. The potential for rollover arises when two separate layers of different densities (due to different LNG compositions) exist in a tank. In the top layer, liquid warms up due to heat leakage into the tank, rises up to the surface, where it evaporates. Thus, light gases are preferentially evaporated and the liquid in the upper layer becomes denser. This phenomenon is called "weathering". In the bottom layer, the warmed liquid rises to the interface by free convection but does not evaporate due to the hydrostatic head exerted by the top layer. Thus, the lower layer becomes warmer and less dense. As the density of two layers approach each other, the two layers mix rapidly, and the lower layer which has been superheated gives off large amount of vapour as it rises to the surface of the tank.

.2 Operate bunkering systems in accordance with the fuel transfer manual

- bunkering procedures
- emergency procedures
- ship-shore/ship-ship interface
- prevention of rollover
- Monitor the operation of bunkering systems in accordance with established procedures



Bunkering Procedures

The following stages of a simplified bunkering process are considered:

1. Bunkering Hoses connection
2. Inerting (for oxygen depletion)
3. Purge and Cool-down with LNG Vapour
4. Start Bunkering transfer
5. Top-up
6. Stop Bunkering transfer
7. Drain Bunkering lines
8. Inerting (for natural gas purging)
9. Bunkering Hoses disconnection

Emergency procedures

The emergency procedures should include, but not be limited to:

- A description of the emergency lighting and emergency power systems.
- A description of the ESD systems.
- First aid procedures and, if there are first aid stations, the location of each station.
- Emergency fuel transfer system shutdown procedures.
- Procedures addressing natural gas leakage.
- Procedures addressing fire in or in the vicinity of the location where fuel is being transferred.
- Procedures for evacuation.
- The location of mustering areas.
- Information on alerting, communication with and the location of the local fire brigade, hospital and police.
- Procedures for the operation and location of active fire-fighting equipment.

Emergency Release Coupling

An important development in hard arm design has been the introduction of emergency disconnect arrangements for use in the event that the limits of the design operating envelope are approached or if some other emergency occurs.

The emergency release system (ERS) forms a second stage emergency shut-down system in addition to the first stage emergency shut-down system described in 6.8. Its purpose is to provide a means to quickly uncouple the hard arms with minimal spillage in an emergency. The system incorporates instrumentation to monitor the ship's position; it also includes alarm and control systems.

The ERS shall consist of an emergency release coupling (ERC), including interlocked isolating valves to minimise loss of LNG or NG when the ERC parts, and for transfer systems 4" or larger in diameter, sensors to monitor operating envelope The disconnection can be triggered manually or automatically. In either case, activation of the ERS system should trigger activation of the ESD (ESD1) before release of the ERC (ESD2). Following any breakaway event, the ERC should be able to ensure a zero-leak release.

A breakaway coupling or emergency release coupling (ERC) is a coupling located in the LNG transfer system (at one end of the transfer system, either the receiving ship end or the bunker facility end, or in the middle of the transfer system), which separates at a predetermined section when required, each separated section containing a self-closing shut-off valve, which seals automatically.

Care should be taken that, in the event of an ERS disconnection, the backlashing hoses do not harm people or equipment at the manifolds. During the bunker transfer operation personnel, should not be in the vicinity of the ERS in case of sudden activation.

Emergency Release or Dry Break Couplings

Bunkering hoses are important elements in the bunkering operation. Typically, in composite multi-layer thermoplastic, hoses for use with cryogenic fuels are to be designed and certified according to the following standards:

- EN 1474-2 – Design and testing of marine transfer systems. Design and testing of transfer hoses
- EN 13766:2010 – Thermoplastic multi-layer (non-vulcanized) hoses and hose assemblies for the transfer of liquid petroleum gas and liquefied natural gas – Specification

Emergency shutdown procedure between ship and shore

The ESD system is critical to the safety of the vessel and is typically a hardwired system. The ESD system is to be fitted to stop bunker flow in the event of an emergency. Generally, the ESD system is activated by manual and automatic inputs. The ESD system is to be tested prior to each bunker operation.

An Emergency Shutdown system is a protective measure to ensure the emergency stop of the transfer system through active isolation of the transfer line.

SIGTTO ESD definitions are:

- ESD-1 emergency shutdown stage 1 – shuts down the transfer operation in a quick controlled manner by closing the shutdown valves and stopping the transfer pumps and other relevant equipment in ship and shore systems. Activation of ESD-1 should set off visual and audible alarms.
- ESD-2 emergency shutdown stage 2 – shuts down the transfer operation (ESD-1) and uncouples the bunker hose/loading arms after closure of both the ERS isolation valves.

Emergency Shutdown (ESD): Having a means to quickly and safely shut down the bunkering operation by closing the manifold valves, stopping pumps, and closing tank filling valves is essential to ensure safety. The ESD should be capable of activation from both the bunker receiving ship and the bunker supplier, and the signal should simultaneously activate the ESD on both sides of the transfer operation. No release of gas or liquid shall take place as a result of ESD activation.

Typical reasons for activation of the ESD include the following:

- Gas detection
- Fire detection
- Manual activation from either the supplier or receiver
- Excessive ship movement
- Power failure
- High level in receiving tank
- Abnormal pressure in transfer system
- High tank pressure

• Other causes as determined by system designers and regulatory organizations

Emergency Breakout Operation of Shore Connections

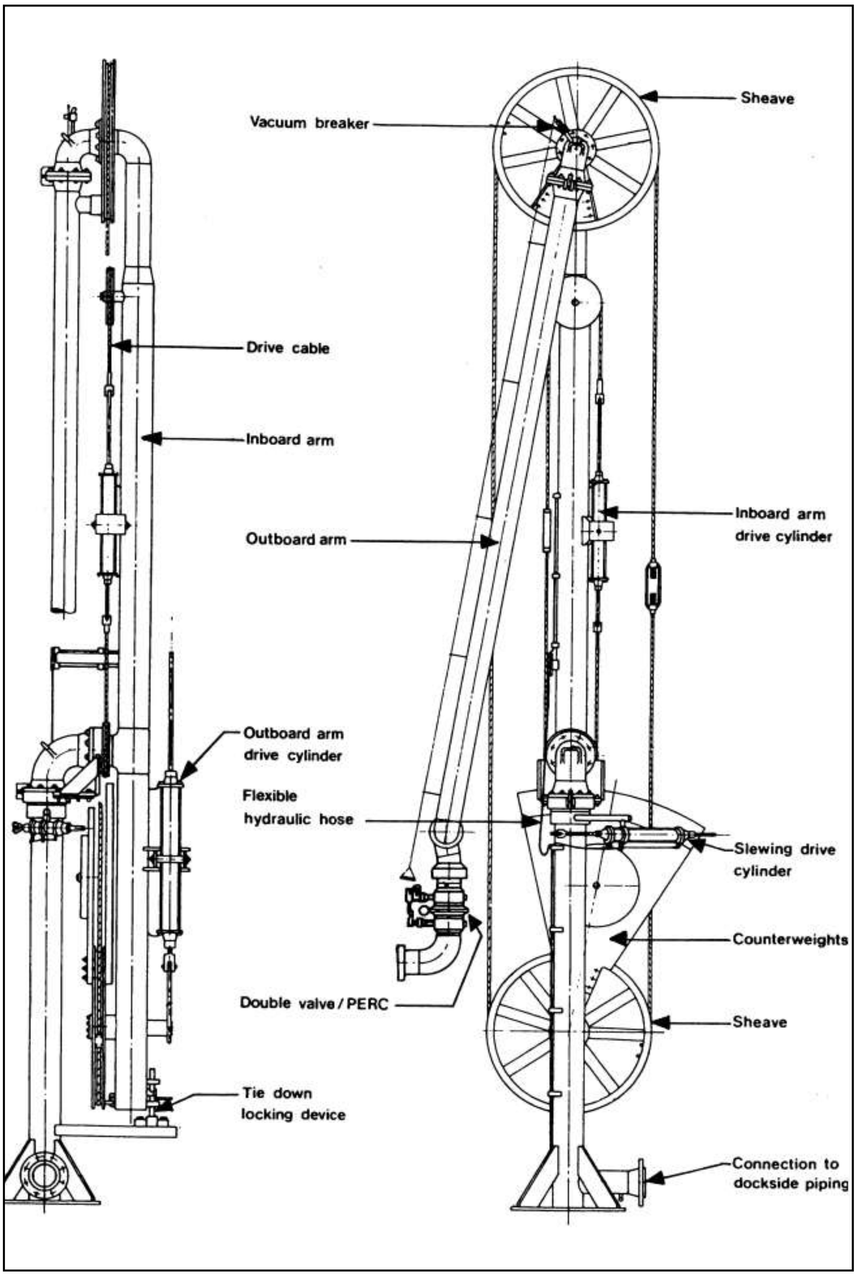
The function of the ERS (Emergency Release System) is to protect the transfer arms by disconnecting them, if the ship drifts out of the design envelope. The ERS may also be activated from the jetty by manual operation. The ERS consists of an ERC, interlocked isolating valves to minimize loss of product when the ERC parts, and sensors to monitor the transfer arm angle. The design of this system should consider possible ice build-up.

Initiation of the ERS should result in the simultaneous closing of interlocking ERS isolating valves, followed by activation of the ERC. The disconnected arm(s) should retract to a safe position away from the ship's manifold and should lock hydraulically. The design of the systems should be such that the ERS cannot be activated unless the functions of the ESD have commenced.

Precautions should be taken to prevent inadvertent or unauthorized manual operation of the ERS.

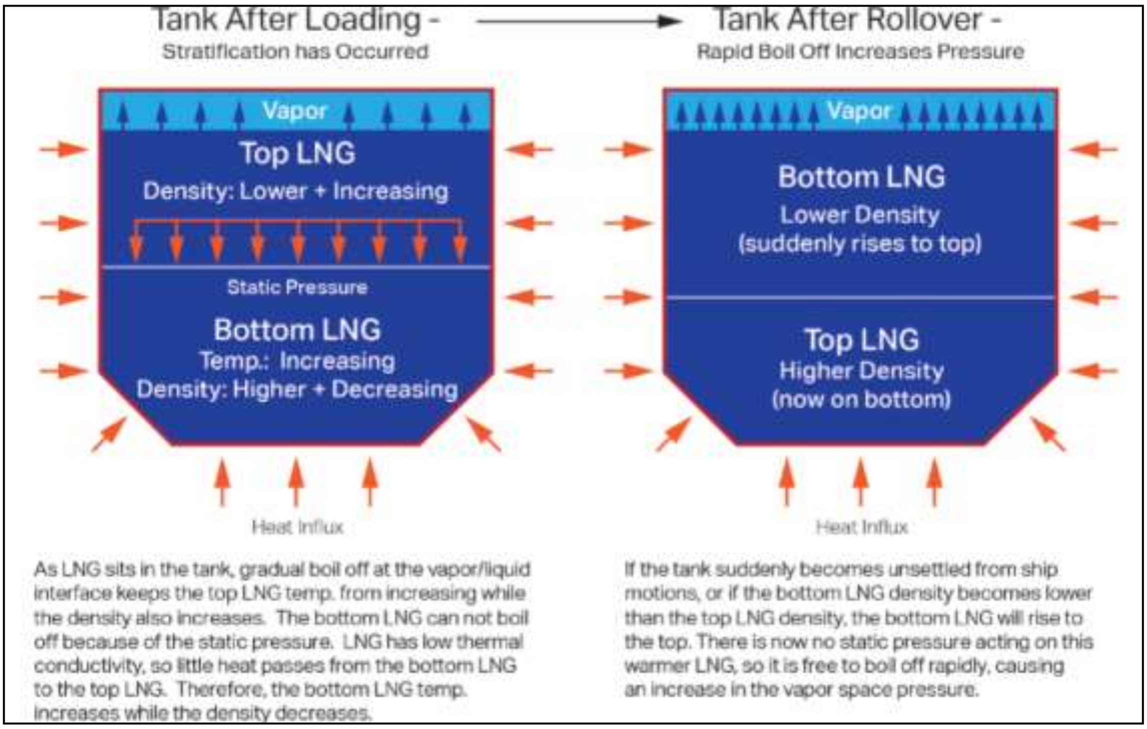
Ship-Shore/Ship-Ship Interface

Shore connections A typical marine loading arm used for the transfer of liquefied gas is shown in below. The arm is fitted with swivel joints to provide the required movement between the ship and the shore connections. A counter-balance is provided to reduce the deadweight of the arm on the ship’s manifold connection and to reduce the power required to manoeuvre the arms into position. The range or operating envelope of the hard arm is determined by the tidal variation and changes of ship’s freeboard whilst loading or discharging. In addition, an allowance is provided in case the ship ranges fore and aft along the jetty or drifts away from the berth.


Sheave
Vacuum breaker
Drive cable
Inboard arm
Inboard arm drive cylinder
Outboard arm
Outboard arm drive cylinder
Flexible hydraulic hose
Slewing drive cylinder
Counterweights
Double valve / PERC
Sheave
Tie down locking device
Connection to dockside piping

Prevention of Rollover

The main hazard arising out of a rollover accident is the rapid release of large amounts of vapour leading to potential over-pressurization of the tank. It is also possible that the tank relief system may not be able to handle the rapid boil-off rates, and as a result the storage tank will fail leading to the rapid release of large amounts of LNG to the atmosphere. It is important to emphasize the difference between stratification and rollover. Stratification is the phenomenon of stored LNG forming distinctive cells which is driven by density differences and can be manipulated for boil-off gas optimization; rollover is the rapid release of boil-off gas in an uncontrolled event which can have safety implications.



Stratification is managed by use of measurement devices upon the LNG storage tanks, of which, the types of instrumentation required are stipulated within design codes. Advances of rollover prediction models have also enabled operators to prevent and make informed decisions for the management of stratification within LNG storage tanks.

Potential stratification may be prevented during filling operations by loading the denser liquid above the heel of a lighter stored LNG or loading a lighter LNG into the bottom of the tank combined with proper filling rate and/or mixing nozzle so that the light grade does not float to the surface. This creates mixing of the unloaded product with the stored contents. If stratification is detected, product can be moved to prevent rollover from occurring. Product can be recirculated by moving it from the bottom of a particular tank to the top of that same tank. Alternatively, the product can be transferred from the bottom of one tank to the top or bottom of an adjacent tank. Top and bottom fill nozzles designed to promote mixing (in conjunction with the in-tank pumps) are used to move the product for loading, recirculation, and transfer operations. Not only does this move the product to areas with similar compositions, but it also serves to mix the product and release any trapped heat or vapour within the product being moved. Mixing may also be promoted with mechanical agitators such as jet mixing nozzles on the top-filling and mixing slots on the bottom-filling.

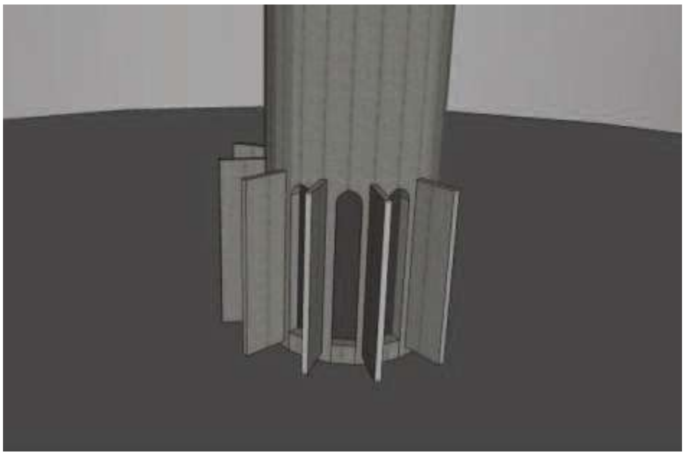
Informed LNG storage tank design combined with appropriate plant operational procedures can mitigate the risk of rollover. Mitigation measures that are used are:

- Stratification inside storage tanks is avoided by top or bottom filling according to heel and fill LNG densities, bottom/top recirculation, mixing the liquids by filling using jet nozzles and distributed fill systems
- Different compositions of LNG are stored in separate tanks
- Specify LNG with nitrogen content less than 1%
- Monitoring of LNG density and temperature over height of tank
- Monitoring of total boil-off and heat balance to detect superheating
- Use of software based on LNG tank thermodynamic modelling to predict potential for roll-over
- Ensure LNG residence period in tank is not too long
- Process relief systems and safety valves are designed to handle rollover effects

Out of all of these mitigation approaches, the direct measurement of density across the tanks' height is the primary means of detecting stratification. During stratified conditions the bottom layer often becomes superheated, but monitoring BOG rate is a better indication of potential stratification, rather than direct measurement of the temperature of superheated LNG.

Bottom Filling

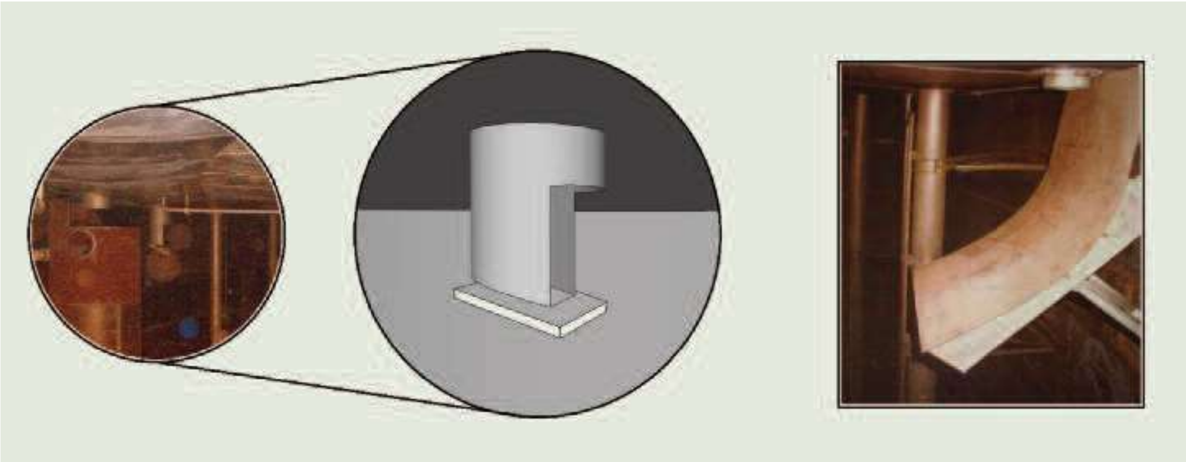
If the incoming LNG is lighter than the heel in the tank, a bottom filling operation will generally ensure a complete mixing of the two LNG grades, with little or no chance of stratification. The boil-off gas production, generated due to the temperature rise of the LNG during transfer from the LNG carrier to the filled tank, is limited by the hydrostatic pressure at the bottom of the tank. The bottom filling device (Figure 5.1) consists of a tube attached to the support of the tanks and goes down vertically from the top to the bottom of the tank. At the bottom of the tube, there are some slots that direct the incoming LNG into several directions to promote mixing with the LNG in the heel. The bottom filling device is positioned at the edge of the tank near the tank wall. The location, diameter, number and width of slots and other characteristics depend on the specific design.



Model drawing of a typical bottom filling device

Top Filling

If the incoming LNG is heavier than the stored LNG a tank top filling operation will avoid stratification and the risk of subsequent rollover, but this usually results in excessive vapour generation due to the flashing of the injected LNG into the tank's vapour space and subsequent increase in tank pressure which must be managed. A simple solution to this is to reduce the loading rate, but this may not always be commercially acceptable and other means may need to be adopted. Furthermore, top filling is not generally provided on LNG carriers, unless they have been modified for use as a floating storage regasification unit (FSRU) when they are often provided with top fill connections. Top-filling devices such as sprays or splash plates are common and appear to be fairly effective insofar as they cause large vapour evolution rates. However, it is thought that this type of device creates droplets that can be carried over into the vapour line, masking the effectiveness of the device and sometimes making the vapour evolution rate excessive.



Example of two types of top filling devices

One method of reducing overall vapour generation when top filling is to lower the tank pressure prior to filling the tank; this will create more boil-off and drop the temperature of the heel. Immediately before filling commences the tank pressure is raised to above normal operating pressure to limit the amount of LNG that flashes off when discharging into the tanks vapour space. This raised pressure is maintained throughout the loading process and when filling is complete the tank pressure is slowly returned to its normal level.

A top filling device is a pipe that enters into the top of the tank though the dome chamber Normally the device consists of a plate at 45° to the direction of flow. When incoming LNG comes into contact with the plate it produces droplets of LNG that fall down the tank into the heel.

.3 Monitor the operation of bunkering systems in accordance with established procedures

Method A: BDN and periodic stocktakes of fuel tanks

This method is based on the quantity and type of fuel as defined on the BDN combined with periodic stocktakes of fuel tanks based on tank readings. The fuel at the beginning of the period, plus deliveries, minus fuel available at the end of the period and de-bunkered fuel between the beginning of the period and the end of the period together constitute the fuel consumed over the period.
The period means the time between two port calls or time within a port. For the fuel used during a period, the fuel type and the Sulphur content need to be specified.

This method should not be used when BDN are not available on-board ships, especially when fuel is used as a fuel, for example, liquefied natural gas (LNG) boil-off.

Under existing MARPOL Annex VI regulations, the BDN is mandatory, is to be retained on board for three years after the delivery of the bunker fuel and is to be readily available. The periodic stocktake of fuel tanks on board is based on fuel tank readings. It uses tank tables relevant to each fuel tank to determine the volume at the time of the fuel tank reading. The uncertainty associated with the BDN should be specified in the monitoring plan. Fuel tank readings should be carried out by appropriate methods such as automated systems, soundings and dip tapes. The method for tank sounding and uncertainty associated should be specified in the monitoring plan.

Where the amount of fuel uplift or the amount of fuel remaining in the tanks is determined in units of volume, expressed in litres, the company should convert that amount from volume to mass by using actual density values. The company should determine the actual density by using one of the following:

1. onboard measurement systems;
2. the density measured by the fuel supplier at fuel uplift and recorded on the fuel invoice or BDN; and
3. the density measured in a test analysis conducted in an accredited fuel test laboratory, where available.

The actual density should be expressed in kg/l and determined for the applicable temperature for a specific measurement. In cases for which actual density values are not available, a standard density factor for the relevant fuel type should be applied once assessed by the verifier.

Method B: Bunker fuel tank monitoring on board

This method is based on fuel tank readings for all fuel tanks on board. The tank readings should occur daily when the ship is at sea and each time the ship is bunkering or de-bunkering.
The cumulative variations of the fuel tank level between two readings constitute the fuel consumed over the period.

The period means the time between two port calls or time within a port. For the fuel used during a period, the fuel type and the sulphur content need to be specified.

Fuel tank readings should be carried out by appropriate methods such as automated systems, soundings and dip tapes. The method for tank sounding and uncertainty associated should be specified in the monitoring plan.

Where the amount of fuel uplift or the amount of fuel remaining in the tanks is determined in units of volume, expressed in liters, the company should convert that amount from volume to mass by using actual density values. The company should determine the actual density by using one of the following:

1. onboard measurement systems;
2. the density measured by the fuel supplier at fuel uplift and recorded on the fuel invoice or BDN; or
3. the density measured in a test analysis conducted in an accredited fuel test laboratory, where available.

The actual density should be expressed in kg/l and determined for the applicable temperature for a specific measurement. In cases for which actual density values are not available, a standard density factor for the relevant fuel type should be applied once assessed by the verifier.

Method C: Flow meters for applicable combustion processes

This method is based on measured fuel flows on board. The data from all flow meters linked to relevant CO2 emission sources should be combined to determine all fuel consumption for a specific period.

The period means the time between two port calls or time within a port. For the fuel used during a period, the fuel type and the Sulphur content need to be monitored.

The calibration methods applied, and the uncertainty associated with flow meters used should be specified in the monitoring plan.

Where the amount of fuel consumed is determined in units of volume, expressed in liters, the company should convert that amount from volume to mass by using actual density values. The company should determine the actual density by using one of the following:

- onboard measurement systems; or
- the density measured by the fuel supplier at fuel uplift and recorded on the fuel invoice or BDN.

The actual density should be expressed in kg/l and determined for the applicable temperature for a specific measurement. In cases for which actual density values are not available, a standard density factor for the relevant fuel type should be applied once assessed by the verifier.

Method D: Direct CO2 emissions measurement

The direct CO2 emissions measurements may be used for voyages and for CO2 emissions occurring in ports with local emission regulations CO2 emitted should include CO2 emitted by main engines, auxiliary engines, gas turbines, boilers and inert gas generators. For ships for which reporting is based on this method, the fuel consumption should be calculated using the measured CO2 emissions and the applicable emission factor of the relevant fuels.

This method is based on the determination of CO_2 emission flows in exhaust gas stacks (funnels) by multiplying the CO_2 concentration of the exhaust gas with the exhaust gas flow.

The calibration methods applied, and the uncertainty associated with the devices used should be specified in the monitoring plan.

22. Fuel-system measurements and calculations, including:

.1 Explain the measurement and calculations principles of the following:

- **maximum fill quantity**
  - Filling limits: The filling limit of an LNG tank is the maximum allowable liquid volume in the tank, expressed as a percentage of the total tank volume. The filling limit is not the same as the loading limit. The maximum filling limit for LNG fuel tanks is 98 percent at the reference temperature. This same limit is expected to apply to LNG fuel tanks. A higher filling limit may be allowed on a case-by-case basis based on requirements from classification societies and regulatory bodies.

    Loading limit (LL) means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded.

    Filling limit (FL) means the maximum liquid volume in a fuel tank relative to the total tank volume when the liquid fuel has reached the reference temperature.

    Special considerations may be made to allow a higher loading limit than calculated using the reference temperature, but never above 95%. If the pressure can only be maintained / controlled by fuel consumers, the loading limit should be 98% at reference temperature.

- **On Board Quantity (OBQ)**

  Quantity Remaining on Board (ROB): All the measurable oil, water, sludge and sediment in the fuel tanks and associated lines & pumps on a ship after discharging a fuel has been completed, excluding vapour.

- **minimum Remain On Board (ROB)**

  The small amount of liquefied natural gas (LNG) remaining on board a vessel (or storage) after discharge of the regular LNG fuel, it is used to insulate the LNG storage tanks and is also available as fuel for carrier ship. The heel is considered to exist both before and after discharge, as the minimum quantity of LNG necessary to be retained in holding tanks, and also includes LNG that is consumed en route to the discharge destination as fuel.

- **Fuel Calculations**

LNG as fuel, unlike tradition HFO, is computed with regards to its Energy. Below is the sample calculation:

Where:

E_{LNG} = Energy of LNG..............................MJ
V_{LNG} = Volume of LNG (Transferred).....m^3
D_{LNG} = Density of LNG............................kg/m^3
H_{LNG} **=** Gross Heating Value of LNG**.......**MJ/kg

$E_{LNG} = V_{LNG} \times D_{LNG} \times H_{LNG}$

Sample:

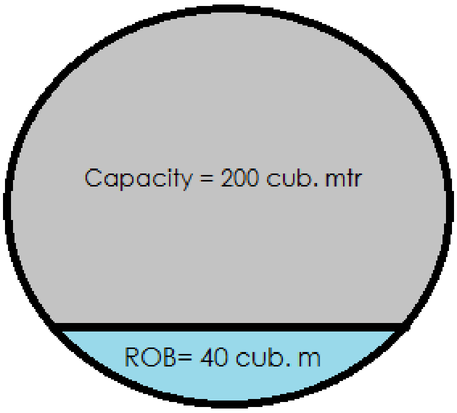
$E_{LNG} = 200m^3 \times 450kg/m^3 \times 53.6\ MJ/kg$
$= 482400\ MJ$

.2 Calculate the required bunker quantity

For computing the required bunker quantity. You need to consider the maximum fill quantity, onboard quantity, minimum remain on board, and fuel consumption calculations.

For example:

Computing for the Required Bunker Quantity:
Example Calculation: Given that the capacity of your tank is 200m^3, your target is to fill up your tank to 85% of its capacity. How much LNG in volume will you need if you have 40m^3 remaining in your tank?



Quantity to Bunker= (Capacity x % to load)- ROB
= (200m^3 x 0.85) – 40m^3
=130m^3

Fuel Consumption Calculations

Reference Temperature

The temperature corresponding to the vapour pressure of the fuel at the set pressure of the pressure relief valves when no fuel vapour pressure/temperature control or it is the temperature corresponding to the saturated vapor pressure of the LNG at the set pressure of the pressure relief valves. For example, if the LNG tank has a pressure relief valve set pressure of 0.7 barg (10.15 psig), then the reference temperature is -154.7°C (-246.4°F), which is the temperature that natural gas will remain a liquid at 0.7 barg (10.15 psig).

The temperature of the fuel upon termination of loading, during transport, or at unloading, whichever is the greatest, when a fuel vapour pressure/temperature control is provided. If this reference temperature would result in the fuel tank becoming liquid full before the fuel reaches a temperature corresponding to the vapour pressure of the fuel at the set pressure of the relief valves required, an additional pressure relief valve should be fitted.

23. Safe management of bunkering and other IGF Code fuel related operations concurrent with other onboard operations, both in port and at sea

.1 Explain the simultaneous bunkering operations concurrently with other onboard operations, both in port and at sea

SGMF expects SIMOPs during LNG bunkering to be the norm, as is the case for oil bunkering. SIMOPs will need to be reviewed to identify potential interactions and determine if any measures need to be implemented before the activity can proceed. In certain circumstances it may not be possible for a SIMOP to take place at the same time as bunkering.

SIMOPs can take place anywhere around the bunkering location, including on the receiving ship, on the bunker vessel, on the quayside, or in surrounding waters.

SGMF defines SIMOPs as:

LNG bunkering plus one, or more, other activity and/or operation conducted at the same time where their interaction may adversely impact safety, ship integrity and/or the environment

This can be broken down into the following elements:

i. LNG bunkering plus one, or more, other activities and/or operations
ii. where their interaction may adversely impact safety, ship integrity and/or the environment

.2 Explain the principles of safe management of bunkering and other IGF Code fuel related operations concurrent with other onboard operations, both in port and at sea

The following paragraphs go through each element in more detail.

i. LNG bunkering plus one, or more, other activities and/or operations

For this guidance, "LNG bunkering" as an operation includes: lifting and placing of the bunker hoses using a mechanical handling device; connecting and leak testing; transferring LNG and managing vapour return; monitoring LNG tank pressures and temperatures; and purging and disconnection.

Fuel handling (even if it is LNG on a LNG carrier), bunkering of other fuels, loading of stores, passenger movements, maintenance and testing are all operations independent of LNG bunkering.

Regular SIMOPs	Non-standard but planned
Operations that happen in the same or very similar way on a frequent basis, such as people/passenger/crew movements and cargo loading and unloading.	Operations that happen infrequently but are known and can be planned for. For example, maintenance or life boat drills.
Non-standard and unplanned	**External activities**
Operations that occur unexpectedly and infrequently and need immediate attention. For example, breakdowns.	Activities or events, normally short-term and irregular, that are beyond the control of the bunkering stakeholders and potentially the terminal/port. For example, security alerts or public festivals.

Below is a non-exhaustive list of regular and planned operations that might be considered as SIMOPs:
Planned SIMOPs (Regular & Non-standard)

- people/passenger/crew movements
  - passenger/vehicle embarking/disembarking near LNG bunkering
  - vehicle movements delivering passengers/crew/visitors
- fuel loading/unloading
  - lifting of fuel from/to dockside to/from ship
  - loading/unloading of heat generating or other hazardous fueles
  - operation of hatch covers
  - loading/unloading of pumped fueles and solid fueles using conveyor belts that may create static electricity
  - loading/unloading of fueles that create noise and airborne dust
- loading supplies and removing waste
  - service vessels/deliveries (for example, stores, port officials, oil bunkers, lube oils, crew change, laundry and garbage collection)
- port/terminal activities
  - construction and maintenance activities
  - operation of local generators (sparking engines)
  - hot work, welding, grinding or paint removal (using a blow torch)
  - disposal of waste and rubbish by burning
  - vehicle movements

- monitoring of mooring lines, particularly between bunker vessels and gas-fueled ships maintenance, inspection and cleaning of vessel areas andquipment
- use of non-intrinsically safe electric or sparking machinery or tools
- testing of stabilization systems
- testing of high-power radio and radar systems
- testing of ballast water systems
- maintenance and testing of power generation systems (black-out concerns)
- maintenance and testing of control systems (full functionality not available/spurious alarms distract)
- testing of fuel equipment (cranes, conveyors, pumps, and so on)
- control system software upgrades (local or centralized systems)
- hold cleaning
- inspection of hull using divers
- maintenance and testing of non-intrinsically safe electrical equipment
- hot work, welding, grinding or paint removal (using blow torch), use of sparking tools
- cabin/common area cleaning
- life boat drills
- ballasting operations simultaneous bunkering with other fuels
- Specialist operations
- Dynamic Positioning (DP) system operation and/or testing
- helicopter operations

All of these operations may have their own precautions and many may have similar risk management requirements to LNG bunkering, for example, prohibiting smoking.

Many of these processes may be routine but some, particularly periodic maintenance and inspection, may be infrequent or even one-off (nonstandard) operations.

All these SIMOPs need to be risk assessed and approved (or prohibited/ delayed, as necessary). The only difference is in the timescales; regular and planned SIMOPs can be evaluated significantly in advance of ship arrival. Unplanned and external events must be risk assessed immediately before bunkering. If the event occurs during LNG transfer, the flow of LNG should be halted until risk assessment has been completed and further mitigations, if any, agreed. Special attention should be given to unusual activities that might significantly increase the assessed consequences of an incident.

ii. where their interaction may adversely impact safety, ship integrity and/or the environment

The POAC/PIC controls the bunkering safety zone (SGMF FP02-01 “Recommendations of Controlled Zones during LNG bunkering”) and observes the monitoring and security area.

The key roles of the PIC/POAC are to:

- stop the transfer of LNG if an event, including a SIMOP, occurs which significantly increases risks or makes the process unsafe or they believe that such an event is imminent
- ensure that only authorised personnel (trained, required for their role and properly equipped) are within the safety zone
- ensure that any risk mitigations, including SIMOP restrictions, are in place and remain in place and uncompromised throughout bunkering
- communicate clearly, effectively and continuously with all parties involved

Additional responsibilities of the PIC/POAC are documented in SGMF's publication "FP07-1 gas as a marine fuel, safety guidelines, bunkering".

Risk Assessing SIMOPs

As discussed previously, SIMOPs can create additional risks by introducing additional hazards, increasing the likelihood of an LNG/gas leak, and/or escalating an event, should it occur, by increasing the severity of consequences.

With respect to SIMOPs, risk management and mitigation is all about placing barriers between threats and consequences.

Definitions:

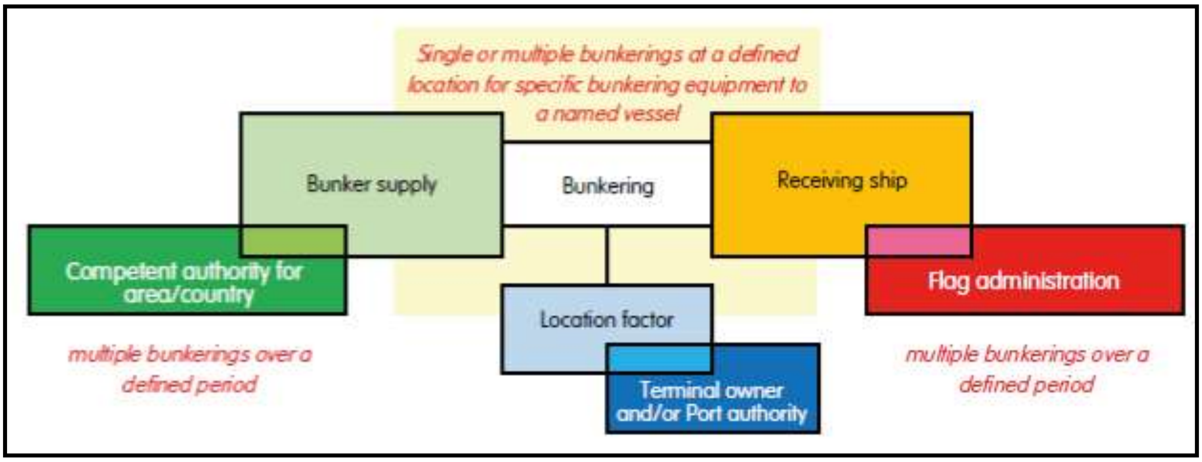
Threats	A threat is an event that has the potential to cause a hazard such as a release of LNG from the transfer hose. In this case it is only a threat when LNG is present in the hose. Also known as an Initiating Event
Hazards	hazard is an event that has the potential to cause harm or damage, for example, an LNG hose leak. Also known as an Unwanted Event
Consequences	Consequences are the potential outcomes if a hazard occurs. Again, actions can be included to prevent or mitigate these consequences, for example, no smoking in areas where flammable gases may be present.
Barrier	Barriers are actions, policies, physical design features and/or active and passive safety systems which stop a threat leading to a hazard or prevent/mitigate the consequences.

LNG bunkering, like any transfer of material from one place to another, may result in some of the LNG or the returning gas being lost in the process. There are many potential threats and several of these can be caused by SIMOPs. A non-exhaustive list is provided in Table.

Threats during bunkering

Independent of SIMOPs	SIMOPs related
LNG bunkering transfer system badly connected, causing leaks which were not identified during leak checking	Damage to the LNG bunkering transfer system from dropped objects, for example, cargo/container loading
LNG bunkering transfer system assembled or operated incorrectly, for example, removal without proper draining	Damage to the LNG bunkering transfer system from a collision by a road vehicle or another vessel either directly or through causing excessive movement
LNG bunkering transfer system badly supported leading to stress in specific components	Excessive movement such as testing stabilisation systems, poor ballast management or poor loading management (may overstress connectors allowing them to leak or even break away)
LNG bunkering transfer system or its components damaged or corroded through long-term poor operation and/or storage	If the LNG bunkering personnel become distracted by other SIMOPs then overfilling and venting of gas is more likely
	If there are activities like maintenance or testing that could trigger or disable control and monitoring (alarm) systems or result in power failure (Note: The IGF Code and Class rules require that power failures lead to a fail-to-safe mode but this could result in venting of gas)

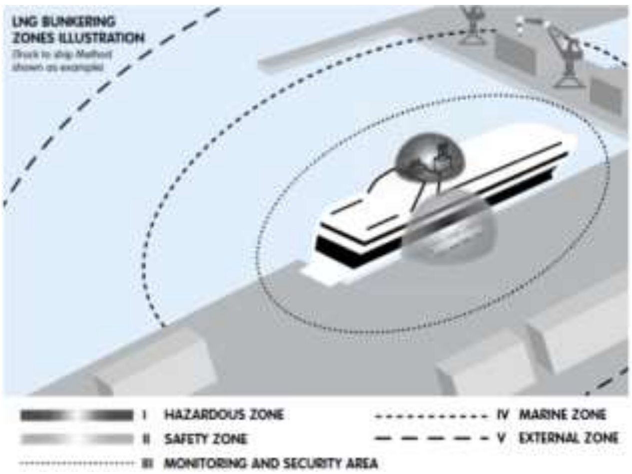
Example Bunkering Approval Process



Regular and non-standard but planned SIMOPs can be risk assessed and approved well in advance of the bunkering taking place. This is because the risks can be identified and applied to all supply situations envisaged in the bunkering contract via the bunker management plan.

Non-standard and unplanned operations need to be risk assessed and approved but this must happen before or on their occurrence. Competent authorities (port, local authority and/or flag administration, depending on the stakeholders involved) should provide general guidance to all ships about what they will require in these situations – for example, schemes of work, permit to work systems and/or specific formats of risk assessment – to streamline this process.

It is easy to envisage physical activities that can impact safety. It is more difficult, but equally important, to look at how human resources can impact safety. In many cases, it is a human making a mistake that leads to consequences, sometimes unforeseen. Having the right number of staff – properly trained and unimpaired by fatigue – to concentrate on their specific roles is crucial to safe bunkering. With SIMOPs the issues are magnified and additional competent staff will be required to manage additional operations.



The purpose of the safety zone is to minimize the risk of harm to people, impact on the environment and damage to equipment. This is achieved by controlling all activities that take place within the zone and observing and assessing the risks of activities within the monitoring and security area which, if left to continue without management, could subsequently impact the safety zone.

Typical control measures in the bunkering safety zone should include:

- excluding non-essential people and vehicle movements
- protecting staff through use of appropriate PPE

- avoiding (or controlling) ignition sources
- effective communication between the POAC/PIC(s) and all involved
- a method for quickly and effectively shutting down operations should an unplanned event occur
-

SIMOPs must not compromise these basic requirements for the safety zone. If additional personnel or activities are required, they must observe these control measures.

Each SIMOP may also have an area associated with it where any hazards associated with this task may occur, for example:

- areas of the deck where fuel will be loaded and where any fuel may be dropped
- hazardous zones around any non-intrinsically safe electrical equipment which may escalate another hazard
- the hazardous nature of some fueles
- areas where untrained people and vehicles congregate

If the bunkering safety zones can be demonstrated not to overlap with these SIMOPs risk areas, then it is likely there would be no interaction between the two activities. However, it should be noted that while the vast majority of LNG releases would not present a hazard outside the safety zone, there are credible but very low frequency events that could. In cases where there is vulnerability to high consequences, measures to assess SIMOPs may need to extend beyond the safety zone.

24. Effects of Pollution on human and environment

.1 Explain the causes and effects of pollution on human and environment

What is Pollution?

Pollution is the introduction of contaminants into the natural environment that cause adverse change. Pollution can take the form of chemical substances or energy, such as noise, heat or light. Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants. Pollution is often classed as point source or nonpoint source pollution. In 2015, pollution killed 9 million people in the world.

Major forms of pollution include: Air pollution, light pollution, littering, noise pollution, plastic pollution, soil contamination, radioactive contamination, thermal pollution, visual pollution, water pollution.

Marine Pollution

Marine pollution occurs when harmful effects result from the entry into the ocean of chemicals, particles, industrial, agricultural, and residential waste, noise, or the spread of invasive organisms. Eighty percent of marine pollution comes from land. Air pollution is also a contributing factor by carrying off pesticides or dirt into the ocean. Land and air pollution have proven to be harmful to marine life and its habitats.

As a result from different onboard combustion and energy transformation processes, remarkably for propulsion and energy production, ships represent sources of different substances to the atmosphere. Sulphur Oxides (SOx), nitrogen oxides (NOx), particulate matter (PM) and carbon dioxide (CO_2) are emitted to the atmosphere as a direct result. Collectively, ship generated emissions can be significant in areas subject to heavy marine traffic leading to concerns regarding air quality, bot at local level, in coastal areas, or in a more global level, regarding to CO_2 emissions leading to Greenhouse Gas emissions and contributing to global warming. Many actions have however been undertaken in recent years to significantly reduce air emissions from ships. Most of these actions have been taken through Annex VI of MARPOL, an international instrument developed through the International Maritime Organization (IMO) that establishes legally-binding international standards to regulate specific emissions and discharges generated by ships.

At the EU Level, the Sulphur Directive has been, in a consistent manner with that international instrument, the reference for control of sulphur oxide emissions from ships, regulating the sulphur content in fuels used onboard ships and, with regards to CO2 emissions from ships, the MRV Regulation sets the EU-wide legal framework for the monitoring, reporting and verification of CO2 emissions and other relevant information from maritime transport.

Emissions of air pollutants like sulphur dioxide can travel long distances. In recent years, emissions from maritime transport have increasingly affected air quality in the EU. Therefore, EU has developed dedicated legislation to deal with some of the most important air pollutants: Sulphur Oxide (SOx), Nitrogen Oxide (NOx), Ozone Depleting Substances (ODS) and Volatile Organic Compounds (VOC).

Air pollution from maritime transport including Sulphur Oxide (SOx), Nitrogen Oxide (NOx), Ozone Depleting Substances (ODS) or Volatile Organic Compounds (VOC), is high in the agenda both at global and European level. The reason for this is that Sulphur and Nitrogen Oxides emissions from shipping were increasing while those from land-based sources were actually decreasing.

Air pollution is an emergent problem for human health, since it is estimated that smokestack emissions from international shipping affect the health and contribute to the mortality of people living in Europe. Other problems associated to air pollution include eutrophication, acidification, forest damage or corrosion to old buildings, bridges, monuments, rock carvings etc.

.2 Explain the safety precautions to prevent pollution

In order to reduce atmospheric pollution caused by sulfur oxides (SOx) and particle matter (PM) found in vessel emissions as well as weather effects caused by GHG emissions, environmental regulations have been getting more strongly enforced. In theory, ships using alternative fuels such as LNG, LPG, and methyl/ethyl alcohol can reduce the amount of CO2 emissions by 10 to 20 percent compared to conventional oil fuels, and they do not contain sulfur. For this reason, alternative fuels are expected to be an effective solution for the regulations.

These alternative fuels have lower flashpoints compared to traditional fuels, therefore particular attention needs to be given to ensuring adequate safety precautions when using low-flashpoint fuels in order to decrease the potential risk of fire and explosions that may arise as a result of fuel leakage onboard the ship. International safety requirements for low-flashpoint fuels have been discussed at IMO and as a result, the International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code) has been adopted and enforced. The current code however, does not address specific regulations for alternative fuels other than LNG.

The industry has at its disposal a wide range of options and techniques to cut pollution, most of which are already available on a large scale and easily implementable. These include:

- Using low-sulphur fuels: this is the easiest way of reducing air pollutants from ships. Shipping fuels in use outside sulphur emission control areas contain up to 3,500 times the sulphur content of fuels used by road transport in Europe. Low-sulphur fuels can make the ship’s engine run smoother and more efficiently with less operating problems and maintenance costs. Last but not least, using low-sulphur (non-residual) fuels reduces other pollutant emissions, such as black carbon which is a potent global-warming agent.

- Scrubbers: an alternative compliance option to burning low-sulphur fuels approved by the IMO and the EU is for ships to install scrubbers. These could cut emissions of SO2 by 99% and considerably reduce emissions of other polluting particles. There are, however, concerns regarding wash-water discharges from open-loop scrubbers which deposit them in open seas and closed-water areas. This leads to higher pH levels in surrounding waters causing additional environmental concerns. Hence, open-loop scrubbers are not a sustainable alternative compliance method for marine sulphur standards.
- Internal engine modifications, such as water injection and exhaust gas recirculation (EGR – for 4-stroke engines): these are techniques to prevent NOx production during the combustion process. However, Tier III standard cannot be met by these methods alone.
- Humid air motor: adding water vapour to the combustion air can also reduce NOx emissions, however, not down to Tier III levels.
- Selective catalytic reduction (SCR): a system to treat exhaust gases after their production but before they are actually emitted. SCR is very effective in reducing NOx emissions far beyond Tier III. It's already used by many ships worldwide and works better with low-sulphur fuels.
- Gas or duel-fuel engines: ship engines can work with liquefied natural gas (LNG) which doesn't contain sulphur and therefore has SO2 emissions close to zero. Gas engines also dramatically reduce other PM and BC emissions. Although it's easier to fit new ships with such engines, a few conversions have already taken place. LNG can also reduce NOx emissions; it has been shown to reach Tier III levels, hence providing a good solution for ship air pollution.
- Shore-side electricity: can be used while ships are at the port, virtually eliminating ship-sourced SOx, NOx, PM, but also CO2.

Alternative energy sources: experiments with wind and solar power, biofuels and fuel cells are ongoing and could be useful in the future

25. Measures to be taken in the event of spillage / leakage / venting

.1 Explain the importance of awareness of shipboard spill/leakages/venting

The potential hazards of a large LNG spill over water includes asphyxiation, cryogenic burns, and cryogenic damage to the ship from the very cold LNG, dispersion, fires, and explosions.

Based on expert review, the most likely hazards to people and property would be thermal hazards from an LNG fire. Cryogenic and fire damage to an LNG ship were also identified as concerns that could cause additional damage to LNG fuel tanks following an initial fuel tank breach, though the additional impact on public safety would be limited.

Risks and hazards from a potential marine LNG spill can be reduced through a combination of approaches, including reducing the potential for a spill, reducing the consequences of a spill, or improving LNG transportation safety equipment, security, or operations to prevent or mitigate a spill.

Explosions in confined spaces, either combustion events or events of rapid phase transition, may have the potential for causing secondary damage that could lead to further spillage of LNG.

.2 Explain the safe working practices to prevent spill/leakages/venting

Other proactive risk management approaches can help reduce both the potential for and hazards of such events. These include:

i) improvements in ship and terminal safety/security systems including improved surveillance, tank and insulation upgrades, tanker standoff protection systems;

ii) modifications and improvements in LNG tanker escorts, extension of vessel movement control zones, and safety operations near ports and terminals;

iii) improved surveillance and searches of tugs, ship crews, and vessels;

iv) redundant or offshore mooring and offloading systems; and

v) improved emergency response systems to reduce fire and dispersion hazards and improved emergency response coordination and communication.

Risk prevention and mitigation techniques are especially useful in zones where the potential impact on public safety and property can be high. The hazards of brittle fracture, rapid phase transitions, and explosions in confined ship spaces, as well as cascading events that may result from the extreme fire exposure a ship would experience if a nominal 12,500 m3 spill on water around the ship was ignited, will require careful consideration. The definition of

The majority of liquefied gases are clean, non-polluting, products and create no danger to the marine environment. If however certain liquefied gases spill on to the sea you should be aware that they may:

- create large quantities of vapour ¬ sea water rapidly vapourises the liquid gas- which may cause a fire or explosion or a health hazard.
- generate toxic vapours, which can drift, sometimes over a considerable distance.
- dissolve in seawater and cause local pollution

The Data Sheets will give information on pollution, if any Pollution is most likely to occur during fuel or bunkering operations:

- if the operation is not correctly monitored
- if the fuel hose or loading arm connections are not properly made
- when disconnecting fuel lines that have not been drained.
- if moorings are not checked and excessive strain is placed on the fuel connections or the ship "breaks out" of the berth.
- if fuel equipment is not properly maintained

Any spillage of LNG on any steelwork, unless stainless steel or wood-sheathed, will cause stresses and it is most likely serious brittle fractures will occur.

As soon as any leak or spill of LNG is exposed to ambient temperatures, the liquid will vaporise or ‘boil-off’. This vaporisation will occur in two phases. Initially, for a period of from 20-30 seconds, there will normally be a high rate of boiling as the heat for vaporisation is taken from the liquid spill itself and the immediate surrounding areas. Secondly, the cold vaporised gas begins to insulate the liquid surface and the evaporation rate will level off at a lower steady rate depending on how quickly heat can be transferred to the LNG from the surrounding area. This vaporisation rate may be increased by:

- Continuing leakage, i.e. greater volume exposed to atmosphere.
- Wind.
- Application of water.
- Ignition, i.e. greater heat flow to the liquid.
- Agitation of the surface.

Thus, spraying an un-ignited spillage of LNG with water will speed up the vaporisation and reduce the hazards of cold fractures, fire or ignition. Alternatively, spraying with water on to LNG which has been ignited will increase the vaporisation rate and hence the burning rate. The use of solid water jets on LNG spills may cause splashing, leading to cold fractures or frost burns or, if ignited, may seriously aggravate the fire.

Immediately after vaporisation, natural gas is 1·4 times heavier than air. As the gas warms, its density will decrease, becoming the same as air at approximately –120°C and reaching the value of 0·55 at 15oC. There may, therefore, be a tendency for cold vapours to form a layer around the spill in a similar manner to other hydrocarbon gases. Fortunately, this layering will normally be visible due to the condensation of atmospheric moisture.

However, unlike other hydrocarbon gases, natural gas quickly becomes buoyant and, except in enclosed spaces, will rise and disperse rapidly as it warms. This dispersion is further aided by the very rapid diffusion properties of methane in air. Where spills may have entered enclosed spaces, it is important to recognise that gas pockets may become trapped near deckhead structures, etc.

In the case of a leakage or spillage of LNG, the following general procedure should be followed:

- Isolate source of LNG. If loading/discharging, the ESD system should be activated.
- Summon assistance.
- Protect the hull from risk of cold fracture.
- Speed vaporisation to minimise ignition risk.

The exact procedure will depend upon the nature of the incident, inclusive of size of spill, location, ambient conditions and ignition risks.
Where LNG spills onto water, Rapid Phase Transition may occur causing loud bangs similar to ones that may be heard during an explosion. However, there are no flames or explosion when this occurs.
Fuel system leaks - Emergency response for liquefied gas carriers

In the event of fuel system leaks & contact with LNG chilled to its temperatures of about –160 degree C will damage living tissue. Most metals lose their ductility at these temperatures; LNG may cause the brittle fracture of many materials. In case of LNG spillage on the ship’s deck, the high thermal stresses generated can result in the fracture of the steel.

Minor or major leaks from LNG tanks & dealing with vapour clouds

An emergency can occur at any time and in any situation. Effective action is only possible if pre-planned and practical procedures have been developed and are frequently exercised. The Contingency Plan provides guidelines and instructions that assist in making an efficient response to emergency situations onboard ships.

LNG bunkering
Major Leak from an LNG Tank- Not Ignited

If a major leak occurs and it can not be confined then jettisoning should be considered. Inerting of hold spaces shall be done same way as in case of minor leak.

i) Sound general alarm
ii) Stop fuel operation. Activate ESD
iii) Disconnect loading arms. PERC

iv) Leave jetty
v) As safety measure - Inert the hold space where leakage (Fuel Tank rupture) has been detected until the O2% is reduced to 2%. Continue blowing inert gas to hold space in order to keep temperature as high as possible. Remember to open the vent for hold space in order to avoid overpressure in the hold space
vi) Transfer fuel to other tanks in order to empty the tank.
vii) Consider - stability and stress factors.
viii) Consider - jettisoning. Remember two fuel pumps are required in order to have proper pressure in the nozzle.
ix) Consider - external assistance
x) Prepare fire fighting equipment
xi) Consider - abandonment. Prepare life-rafts, lifeboats

Minor Leaks from an LNG Tank- Not Ignited

If a small leak occurs the vessel will be able to handle the leak through the drip pan. The liquid will flow to the drip pan to be transferred by the eductor (by means of a spray pump), back to the tank. Driving liquid to the eductor is supplied by spray pump. Data to remember: The tank designer advises that if a fuel tank cracks an average of 8 Liter/hour will be released. The Drip pan will be able to contain this kind of leakage for 15 days without transferring fuel to another fuel tank.
i) Release pressure in order to avoid further damages

ii) Isolate the rest of the hold spaces

iii) Transfer fuel to other tanks, if possible. Note that this is not normally possible on a normally loaded voyage as all tanks are full.

Vapour clouds

If there is no immediate ignition of an LNG spill, a vapour cloud may form. The vapour cloud is long, thin, cigar shaped and, under certain meteorological conditions, may travel a considerable distance before its concentration falls below the lower flammable limit. This concentrate is important, for the cloud ignite and burn, with the flame travelling back towards the originating pool.

The cold vapour is denser that air and thus, at least initially, hugs the surface. Weather conditions largely determine the cloud dilution rate, with a thermal inversion greatly lengthening the distance travelled before the cloud becomes non-flammable.

The major danger from an LNG vapour cloud occurs when it is ignited. The heat from such a fire is a major problem. A deflagration (simple burning) is probably fatal to those within the cloud and outside buildings but is not a major threat to those beyond the cloud, though there will be burns from thermal radiations.

When loaded in the fuel tanks, the pressure of the vapour phase is maintained as substantially constant, slightly above atmospheric pressure.

The external heat passing through the tank insulation generates convection currents within the bulk fuel, heated LNG rises to the surface and boils.
The heat necessary for the vaporization comes from the LNG and long as the vapour is continuously removed by maintaining the pressure as substantially constant, the LNG remains at the boiling temperature

If the vapour pressure is reduced by removing more vapour than generated, the LNG temperature will decrease. In order to make up the equilibrium pressure corresponding to its temperature, the vaporization of LNG is accelerated, resulting in an increase heat transfer from LNG to vapour.

Risk of overfilling of fuel tank during loading onboard a liquefied gas carrier

Risk of Overfilling of Fuel Tanks only applies when vessel is alongside Terminal. The chances of overfilling a fuel tank are improbable as all LNG carrier fuel tanks are fitted with High and Very High level safety devices. The High level alarm will be activated when the loading level has reached 98.8% (typically) of tank capacity. The activation of the alarm immediately closes the filling valve of the tank in question, stopping fuel flowing into the tank.

The Very High (VH) alarm/Emergency Shut down (ESD) alarm will be activated if fuel reaches 99.5% tank capacity and will stop all fuel operations. The set point of the safety devices may vary from vessel to vessel. As general rule High level is 98.8% and Very High level is 99.5%. However, there are vessels that load more than 98.5% and then the safety devices are set with different values. In those cases High level may be 99.5% and Very High level at 99.7%.

Should the alarms fail, overfilling during loading cannot directly rupture a fuel tank as the tanks also contain safety valves that are designed to prevent the build up of excess vapour pressure. If the pressure increases beyond a preset level, a diaphragm in the safety valve ruptures and vents the excess fuel through the tank mast. When this happens, the main hazards are:

The risk of the vessel's hull or fuel tank covers cracking

The flammable gases present in the atmosphere may create an explosive environment.
Following actions recommended in an emergency:

i. Watch keeper patrolling flying passage to advise ECR as soon as fuel is seen overflowing, coming out from vent mast.

ii. Activate ESDS immediately. Stop fuel operations.

iii. Activate general alarm and advise by public address nature of incident and location

iv. Sound predefined signals in order to warn Terminal

v. Check for any injuries or fatalities

vi. Treat injured people, and evacuate them as necessary. Advise agent/terminal if external medical assistance is required

vii. Advise terminal the nature of incident and present situation

viii. Activate Spray system on tank domes, manifolds, accommodation, compressor house in order to protect steel and vaporise the liquid

ix. Prepare fixed Dry Powder Fire Extinguishing System in case fire occurs due to external ignition source or static electricity

x. Consider - transfer fuel in order to lower down level in overfilled tank

xi. Consider - disconnect loading arms. Activation of PERC

xii. Consider - leave the jetty / terminal. Tugs/pilot required

xiii. Once the situation has stabilised, consider - continue loading operations, keeping in mind that both fuel tank safety valves are leaking through

xiv. Inform Owners, Insurance, P&I, Local Authorities

BOG Venting Operation
It shall be remembered that, under normal operating conditions, the venting of LNG vapor (BOG) to atmosphere is prohibited. If in Emergency cases it is necessary to vent off excessive tank pressure, then strict safety countermeasures shall be in place. The Company shall be advised of any uncontrolled venting occurrence. The amount of LNG vapour released to atmosphere, which can be measured, shall be recorded onboard.
BOG Venting Procedure

Drifting Point
Safe drifting point shall be decided taking direction of current / wind into consideration. Special attention shall be paid to sign of weather change with strict watch on the navigation bridge.

Plan
Plan shall be drafted in consideration to refrain BOG venting during night time, since venting operation is performed under fire restriction.

Safety Countermeasures
Safety countermeasures, such as Ventilation Control / Fire Restriction / Access Control, shall be in places well as the time of fuel handling work.

Drainage from Vent Mast
Ensure to drain water from all vent mast, and drain valves shall be closed after drainage.

Ship's Heading
Ship's heading shall be adjusted in consideration of location of navigation lights and deck lights to prevent damage due to a large amount of BOG. The preferable ship's heading depends on the construction of each ship.

Opening Manual Valve
A manual valve on vapor header line shall be opened. All crew members shall stay inside of accommodation once the manual valve is opened. If the manual valve is located near the vent mast, venting operation shall be performed subject to no crew on deck.

Watch Keeping
Watch keeping on bridge shall be maintained strictly.

Recording
Record shall be maintained without fail as evidence which prove that the venting operation was performed safely.

Venting

Once tank pressure reach the planed level, BOG shall be vented through remote control valve. The remote-control valve shall be opened from crack gradually. At the time, vent mast shall be monitored with binoculars.

Monitoring

Monitor the direction and amount of BOG released from vent mast. Venting operation shall be suspended immediately if BOG tends to drift to unexpected direction, such as to accommodation house, and light post.

Awareness of shipboard spill/leakage/venting response procedures

The biggest risk of a fuel spill is during fuel handling operations, either because of equipment failure or improper handling procedures. Fuel spills are therefore most likely to happen in port. In the event of a spill, the following actions should be taken immediately:

- Activate the alarm.
- Stop all fuel operations and close valves and hatches.
- If alongside a berth, notify the terminal staff of the chemicals involved and possible risk posed to personnel.
- Notify local port authorities, usually through the terminal staff.
- Prohibit smoking and use of naked lights throughout the ship.
- Clear all non-essential personnel from the area.
- Close all accommodation access doors, and stop all non-closed-circuit ventilation.
- Arrange for main engines and steering gear to be brought to stand-by

Awareness of appropriate personal protection when responding to a spill/leakage of fuels addressed by the IGF Code

Because LNG is a cryogenic liquid, there is a risk of cold burns if it is in contact with skin. Therefore, LNG should be stored, transported and handled using cryogenic equipment compliant with applicable norms and regulations. To minimize the risks further, Personal Protective Equipment (PPE) should be worn by personnel conducting transfer activities (i.e., filling an LNG road tanker or truck). In this regard, the hazards of LNG handling are very similar to those of common industrial gasses like liquid Nitrogen (LIN), Argon (LAR) and Oxygen (LOX).

It is advised to use the following Personal Protective Equipment (PPE) when working with cryogenic gases and liquids:

- Overall with long sleeves
- Safety Goggle or Face shield
- Safety Shoes
- Cryogenic gloves
- Helmet
- Gas detector

Personal protective equipment

Breathing Apparatus: It is always preferable to achieve a gas free condition in a tank or enclosed space prior to entry. Where this is not possible, entry should only be permitted in exceptional circumstances and when there is no practical alternative. In this case breathing apparatus must be worn and if necessary protective clothing must be worn also. There are three types of respiratory protection.

Canister filter respirators :

These consist of a mask with a replaceable canister filter attached through which contaminated air is drawn by the normal breathing of the wearer. They are simple to operate and maintain, can be put on quickly and have been used extensively as personal protection for emergency escape purposes on ships certified for carrying toxic fueles.

They are, however, only suitable for relatively low concentrations of gas, once used there is no simple means of assessing the remaining capacity of the filter, filter materials are specific to a limited range of gases and, of course, the respirator gives no protection in atmospheres of reduced oxygen content. For these reasons, the IMO Code requirement for emergency escape protection is now met by lightweight portable package self-contained breathing apparatus.

Fresh air respirators :

These consist of a helmet or face mask linked by a flexible hose (maximum length 120 feet) to an uncontaminated atmosphere from which air is supplied by a manual bellow or rotary blower. The equipment is simple to operate and maintain and its operational duration is limited only by the stamina of the bellows or blower operators.

However, movement of the user is limited by the weight and length of hose and great care must be taken to ensure that the hose does not become trapped and kinked. While in general this respirator has been superseded by the self-contained or air line compressed air breathing apparatus, it will be found on many ships as an always available backup to that equipment.

Compressed air breathing apparatus :

In the self-contained version (SCBA), the wearer carries his air for breathing in a compressed air cylinder at an initial pressure of between 135 and 200 bars. The pressure is reduced at the outlet from the cylinder to about 5 bars and fed to the face mask as required through a demand valve providing a slight positive pressure within the mask. Working duration depends upon the capacity of the air cylinder and the respiratory demand. Indicator and alarm features are usually provided to warn of air supply depletion.

A typical set, providing approximately 30 minutes operation with physical exertion, may weigh about 13kg and the bulk of the cylinder on the back of the wearer imposes some restriction on his manoeuvrability in confined spaces. Although when properly adjusted, the SCBA is simple and automatic in operation, its maintenance requires care and skill. To ensure their serviceability when required, all such breathing sets must be checked monthly and worn and operated during appropriate exercises preferably using special exercise air cylinders in order to keep the operational cylinders always fully charged.

Although modern demand valves are designed to maintain a slight positive pressure within the face mask, it must not be assumed that this feature will prevent leaks from the contaminated atmosphere into an ill-fitting face mask. While face mask materials and contours are designed to accommodate a range of typical facial shapes and sizes, it is essential that, before entry to a dangerous space, the air tightness of the mask on the wearer's face be thoroughly checked in accordance with the manufacturer's instructions. Comprehensive practical tests have shown that it is virtually impossible to ensure continued leak tightness in operational conditions on a bearded face.

Most compressed air breathing sets may be used in the air line version (ALBA) whereby the compressed air cylinder and pressure reducing valve are placed outside the contaminated atmosphere and connected to the face mask and demand valve by a trailed air hose. At the expense of decreased range ability and the need for extra care in guiding the trailing air hose, the wearer is relieved of the weight and bulk of the air cylinder and his operational duration may be extended by the use of large air cylinders of continuous supply cylinder changeover arrangements.

Escape Breathing Sets

One short-duration escape breathing apparatus is useful for each person on board LPG ships. The total number of sets onboard is equal to the number of persona the ship is certified to carry.

The Master is to ensure that all personnel onboard are familiar with the operation and the limitations of these sets. In particular, newly joined personnel are to be instructed in the use of these sets when they sign on.

It is the responsibility of the Second Officer to ensure that the compressed air cylinders are full and that they are checked monthly or more frequently if required. On no account are these sets to be used for operation use, inspection, rescue or fire-fighting support. They have duration of 15 minutes and are to be used only to assist personnel escape from concentrations of toxic vapours.

Protective clothing

In addition to breathing apparatus full protective clothing should be worn when entering an area where contact with fuel is a possibility. Types of protective clothing vary from those providing protection against liquid splashes to a full positive pressure gas-tight suit which will normally incorporate helmet, gloves and boots. Such clothing is also to be resistant to low temperatures and solvents.

Full protective clothing is particularly important when entering a space which has contained toxic gas such as ammonia, chlorine, ethylene oxide, VCM or butadiene.

One complete set of protective clothing is to consist of:

- One self-contained air breathing apparatus not using stored oxygen having a capacity of at least 1200L of free air.
- Protective clothing, boots, gloves and tight-fitting goggles.
- Steel-covered rescue line with belt.
- Explosion proof lamp.
- At least 5 suits of protective clothing, are supplied to LPG ships and these should be stowed: Emergency Headquarters 3 nos & Fuel Control Room 2 nos

When wearing protective clothing it is important to ensure that neither the sleeves are tucked into the gloves, not the trousers into the boots. This is to avoid low temperature fuel falling into the gloves and boots of personnel working in areas where splashing of fuel of spillage is possible. Sleeves are to pass over gloves and trousers over the boots of all protective clothing.
Suitably marked decontamination showers and eyewash should be available on deck in convenient locations. The showers and eyewash should be operable in all ambient conditions.

26. Provisions of the International Convention for the Prevention of Pollution from Ships (MARPOL), as amended and other relevant IMO instruments, industry guidelines and port regulations

.1 Explain the relevant regulations of International Convention for the Prevention of Pollution from Ships (MARPOL) as amended and other relevant IMO instruments subject to the IGF Code

Most international regulations on marine pollution come from the 1973 International Convention for the Prevention of Pollution from Ships (MARPOL) and is aimed at preventing and minimizing pollution from ships – both accidental and from routine operations.

Compliance with all international, national, and local regulations as amended is an integral part of safe IGF Ship operations

IMO regulations to reduce sulphur oxides (SOx) emissions from ships first came into force in 2005, under Annex VI of the International Convention for the Prevention of Pollution from Ships (known as the MARPOL Convention). Since then, the limits on sulphur oxides have been progressively tightened.

From 1 January 2020, the limit for sulphur in fuel oil used on board ships operating outside designated emission control areas will be reduced to 0.50% m/m (mass by mass). This will significantly reduce the amount of sulphur oxides emanating from ships and should have major health and environmental benefits for the world, particularly for populations living close to ports and coasts.

The sulphur oxides regulation (MARPOL Annex VI, regulation 14) applies to all ships, whether they are on international voyages, between two or more countries; or domestic voyages, solely within the waters of a Party to the MARPOL Annex.

Shipping activities are of international concern and the international forum for maritime and, therefore, shipping matters is IMO.
IMO has drawn up conventions which affect ships. Conventions directly affecting ships and shipping activities are the 1974 SOLAS Convention,

MARPOL and the 1978 STCW Convention, as amended.
In MARPOL, a new chapter 4 on energy efficiency has been added to annex VI regulations on air pollution. It requires an Energy Efficiency Design Index (EEDI) to be stated for new vessels and a ship energy efficiency management plan to be maintained on all vessels. The EEDI is an indicator of the fuel efficiency of a ship, measured in gram of CO_2 emissions per deadweight ton per nautical mile: the lower the figure, the better the fuel efficiency. The ship energy efficiency management plan aims to improve the efficiency of a vessel by introducing various management of methods such as improved voyage planning to increase fuel efficiency.

.2 Explain the safe management and operation of ships and pollution prevention in accordance with ISM system

SGMF identifies safety and environmental issues facing gas fuelled ships and develops and publishes recommendations that are accepted as the industry standards
The Society for Gas as a Marine Fuel (SGMF) was established in 2013
It was set up to focus on the newly developing use of LNG as a fuel on non-LNG carrier vessels, and the bunkering process for these vessels

SGMF is only beginning to issue publications and best practices, but its importance to operators of LNG fueled vessels and bunkering is expected to grow rapidly as SGMF grows in membership and the number of LNG fueled vessels increases

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27. Use of the IGF Code and related documents

.1 Explain the importance of using IGF Code and related documents in handling and operating fuels

The International Code of Safety for Ships using Gas or Other Low Flashpoint Fuels (IGF Code) is currently being developed by IMO.
The IGF Code will replace the current IMO guidance document (MSC.285(86*)).*

.2 Use the IGF Code and related documents in handling and operating fuels

The International Code of Safety for Ships using Gas or Other Low Flashpoint Fuels (IGF Code) is currently being developed by IMO. The IGF Code will replace the current IMO guidance document (MSC.285(86)).

IMO's Maritime Safety Committee's 94th session, which met from 17 to 21 November 2014 approved, in principle, the IGF Code as well as two amendments to SOLAS Chapter II-1:
• One amendment introduces a new Part G which mandates the application of the IGF Code to fuel ships ≥ 500 gt and passenger ships using natural gas as fuel; and
• A second amendment revises Part F Regulation 55 to account for the IGF Code requirement that ships using other low-flashpoint fuels (methanol, propane, butane, ethanol, hydrogen, dimethyl ether, etc.) need to comply with the analysis. Operationally dependent alternatives are not permitted.

If adopted at MSC 95 in June 2015, it is expected that the mandatory provisions will enter into force on 1 January 2017 and will apply to new shipsfunctional requirements of the Code through the alternative design regulation based on an engineering

:

• With a building contract placed on or after 1 January 2017; or
• In the absence of a building contract, the keel of which is laid or which is at a similar stage of construction on or after 1 July 2017; or
• Regardless of the building contract or keel laying date, the delivery is on or after 1 January 2020.

Ships which commence a conversion on or after 1 January 2017 to use low-flashpoint fuels or use additional or different low-flashpoint fuels other than those for which it was originally certified will need to comply with the IGF Code. IMO plans to develop additional parts of the IGF Code to provide detailed requirements for other specific low flashpoint fuels, such as methanol, liquefied petroleum gas (LPG), etc., at a later date and as industry experience develops. For clarification, the IGF Code is not intended to apply to gas carriers.

28. Use of safety equipment and protective devices

Proper training should be undertaken for correct usage of PPE. The trainees should demonstrate the proper usage of PPE. All personnel involved directly with LNG handling operations should wear personal protective equipment (PPE) including gloves, face protection and other suitable clothing to protect against LNG drips, spray, spills, and leaks. PPE is also required to protect against skin damage caused by contact with the cold pipes, hoses, or equipment. Material Safety Data Sheets (MSDS) identify LNG health hazards and provide guidance for PPE, LNG handling, first aid, firefighting measures and firefighting equipment.

.1 Usage of the following safety equipment and protective devices:

Breathing Apparatus And Evacuating Equipment

In the self-contained version (SCBA), the wearer carries his air for breathing in a compressed air cylinder at an initial pressure of between 135 and 200 bars. The pressure is reduced at the outlet from the cylinder to about 5 bars and fed to the face mask as required through a demand valve providing a slight positive pressure within the mask. Working duration depends upon the capacity of the air cylinder and the respiratory demand. Indicator and alarm features are usually provided to warn of air supply depletion.

A typical set, providing approximately 30 minutes operation with physical exertion, may weigh about 13kg and the bulk of the cylinder on the back of the wearer imposes some restriction on his maneuverability in confined spaces. Although when properly adjusted, the SCBA is simple and automatic in operation, its maintenance requires care and skill. To ensure their serviceability when required, all such breathing sets must be checked monthly and worn and operated during appropriate exercises preferably using special exercise air cylinders in order to keep the operational cylinders always fully charged.

Although modern demand valves are designed to maintain a slight positive pressure within the face mask, it must not be assumed that this feature will prevent leaks from the contaminated atmosphere into an ill-fitting face mask. While face mask materials and contours are designed to accommodate a range of typical facial shapes and sizes, it is essential that, before entry to a dangerous space, the air tightness of the mask on the wearer's face be thoroughly checked in accordance with the manufacturer's instructions. Comprehensive practical tests have shown that it is virtually impossible to ensure continued leak tightness in operational conditions on a bearded face.

Protective Clothing And Equipment

In addition to breathing apparatus full protective clothing should be worn when entering an area where contact with fuel is a possibility. Types of protective clothing vary from those providing protection against liquid splashes to a full positive pressure gas-tight suit which will normally incorporate helmet, gloves and boots. Such clothing is also to be resistant to low temperatures and solvents.

Full protective clothing is particularly important when entering a space which has contained toxic gas such as ammonia, chlorine, ethylene oxide, VCM or butadiene.

One complete set of protective clothing is to consist of:

- One self-contained air breathing apparatus not using stored oxygen having a capacity of at least 1200L of free air.
- Protective clothing, boots, gloves and tight fitting goggles.
- Steel-covered rescue line with belt.
- Explosion proof lamp

At least 5 suits of protective clothing, are supplied to LPG ships and these should be stowed: Emergency Headquarters 3 nos & Fuel Control Room 2 nos.

Resuscitators Rescue And Escape Equipment

Arrangements for hoisting an injured person with a rescue line must be made and kept in readiness when persons are working in congested/ enclosed spaces. Stretchers and medical first-aid equipment must be provided on board

A resuscitator should not be used in toxic or reduced O2 atmosphere

Hand-operated resuscitator – Hand-operated resuscitators are used to maintain or restore respiration in an emergency situation; therefore, as a matter of principle, they must function independently of external sources of power especially in disaster situations

VORTRAN Automatic Resuscitator (VAR) – This is a unique single patient use, disposable resuscitator. It provides consistent, reliable, hands-free ventilator support via a mask or endotracheal tube using a continuous gas flow source. The VARs are to be used by properly trained personnel for the delivery of short term, constant flow pressure-cycled ventilator support in emergency and hospital environments. They are cost competitive and provide more consistent ventilation than manual resuscitators.

.2 Demonstrate the different safety equipment and protective devices in accordance with the established procedures

Breathing Apparatus And Evacuating Equipment

Most compressed air breathing sets may be used in the air line version (ALBA) whereby the compressed air cylinder and pressure reducing valve are placed outside the contaminated atmosphere and connected to the face mask and demand valve by a trailed air hose. At the expense of decreased range ability and the need for extra care in guiding the trailing air hose, the wearer is relieved of the weight and bulk of the air cylinder and his operational duration may be extended by the use of large air cylinders of continuous supply cylinder changeover arrangements.

Protective Clothing And Equipment

When wearing protective clothing it is important to ensure that neither the sleeves are tucked into the gloves, not the trousers into the boots.

This is to avoid low temperature fuel falling into the gloves and boots of personnel working in areas where splashing of fuel of spillage is possible. Sleeves are to pass over gloves and trousers over the boots of all protective clothing.

Resuscitators Rescue And Escape Equipment

One short-duration escape breathing apparatus is useful for each person on board ships. The total number of sets onboard is equal to the number of persons the ship is certified to carry.

The Master is to ensure that all personnel onboard are familiar with the operation and the limitations of these sets. In particular, newly joined personnel are to be instructed in the use of these sets when they sign on.

It is the responsibility of the Second Officer to ensure that the compressed air cylinders are full and that they are checked monthly or more frequently if required. On no account are these sets to be used for operation use, inspection, rescue or fire-fighting support. They have duration of

15 minutes and are to be used only to assist personnel escape from concentrations of toxic vapours.

29. Safe working practices and procedures in accordance with legislation and industry guidelines and personal shipboard safety

.1 Different safe working practices and procedures in accordance with legislation and industry guidelines and personal shipboard safety of the following:

Precautions to Be Taken Before, During And After Repair And Maintenance

Work Planning Meetings
Work planning meetings should be held prior to the commencement of any work, and on each subsequent work day. Before the start of any work or operation, the intended standard procedures must be thoroughly discussed at a meeting held between the responsible ship's personnel and/or the terminal.

The purpose of the meeting is primarily to draw up a suitable work plan and to check on safety issues. Furthermore, the meeting has the benefit of making both sides familiar with the essential characteristics of ship and shore operational systems. At the meeting, the envisaged operational and safety procedures and requirements should be covered. Finally, any limitations to be observed during the job should be noted in writing.

Permit to Work
A Permit to Work should be a simple formal system stating exactly what work is to be done, when it is being done and the safety controls that must be put in place to avoid injury or death. Permits are also a means of communication between those who carry out the work, the person responsible for their safety and someone who could introduce a hazard if they were unaware the work was taking place. It can also coordinate different work activities to avoid conflicts.

However, issuing a permit does not by itself, make a task safe. That can only be achieved by the thoroughness of those preparing, supervising and carrying out the work. Permits to Work come in different forms. All companies should prepare a format that is suitable for their ships, and their crews should be trained to use the permit system.

A safe work permit (also known as a “permit to work”) is a document that includes a description of the work to be performed, the hazards involved, the precautions to take, the required authorizations, and other elements. It is a written record authorizing a specific work at a specific location, and for a specific time.

It's important to note that a safe work permit does not reduce risks of incidents by itself. Rather, it specifies the hazards and the risk control measures that workers must be aware of, before they start work. A safe work permit is an effective vehicle for communicating critical safety information.

When repairs are to be carried out concurrent with bunkering operations, specific permission should be granted. Whenever practicable, a drill should be held prior to commencing repair work. Moreover, a dedicated safety officer should be appointed by the Master to coordinate the permit and certification processes associated with the repair period.

Electrical Safety

All electrical equipment employed should be carefully inspected before each occasion of use to ensure it is in good condition and correctly earthed.

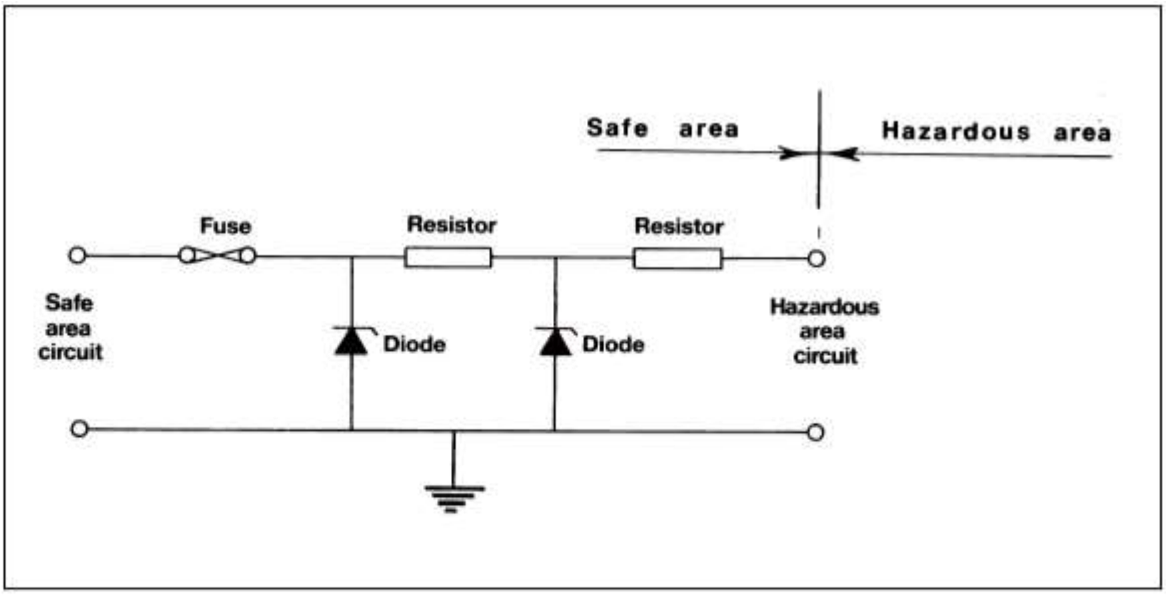
A common definition of area safety classification for electrical equipment is as follows:

Zone 0: An area with a flammable mixture continuously present
Zone 1: An area where flammable mixtures are likely during normal operations
Zone 2: An area where flammable mixtures are unlikely during normal operations

Electrical installations on gas carriers are subject to the requirements of the classification society and the Gas Codes. Zones and spaces on ships are classified as either gas-safe or gas-dangerous, depending on the risk of fuel vapour being present. For example, accommodation and machinery spaces are gas-safe, while compressor rooms, fuel tank areas and holds are gas-dangerous. In gas-dangerous spaces, only electrical equipment of an approved standard may be used; this applies to both fixed and portable electrical equipment. There are several types of electrical equipment certified as being safe for use on gas carriers and these are described in the following sections.

Intrinsically safe equipment
Intrinsically safe equipment can be defined as an electrical circuit in which a spark or thermal effect (under normal operation or specified fault conditions) is incapable of causing the ignition of a given explosive mixture.
Limitation of such energy may be achieved by placing a barrier, as shown in Figure in the electrical supply. This must be positioned in a safe area. Zener barriers are frequently used for this purpose and, in the circuit shown, the voltage is limited by the Zener diodes so that the maximum current flow to the hazardous area is restricted by the resistors. The uses of such intrinsically safe systems are normally limited to instrumentation and control circuitry in hazardous areas. Because of the very low energy levels to which they are restricted, intrinsically safe systems cannot be used in high-power circuits.

Intrinsic safety using Zener barriers



Flameproof equipment
A flameproof enclosure is one which can withstand the pressure developed during an internal ignition of a flammable mixture. Furthermore, the design is such that any flames, occurring within the enclosure, are cooled to below ignition temperatures before reaching the surrounding atmosphere.

Therefore, the gap through which hot gases are allowed to escape is critical and great care must be taken in assembly and maintenance of flameproof equipment to ensure that these gaps are well maintained. No bolts must be omitted or tightened incorrectly, while the gap must not be reduced by painting, corrosion or other obstructions.

Pressurized or purged equipment
The pressurization or purging of equipment is a technique used to ensure that an enclosure remains gas-free. In the case of pressurization, an over-pressure of about 0.5 bar, relative to the surrounding atmosphere, must be maintained. In the case of a purged enclosure, a continuous supply of purging gas must be provided to the enclosure. Air or inert gas can be used.

Increased safety equipment
The use of Increased Safety Equipment is appropriate for electrically powered light fittings and motors. This equipment has a greater than normal separation between electrical conductors and between electric terminals. Starters are designed to minimize both arcing at contactors and to limit the temperature of components. Increased safety motors, with flameproof enclosures, are frequently used on deck on gas carriers. Here they may be found driving deep well pumps or booster pumps. In such cases they must be protected by a suitable weatherproof covering.

Hazards associated with both current electricity and static electricity
As is the case with many other hydrocarbon liquids, a static electrical charge can be built up within a liquefied gas as it is being pumped. It has been found that the charge will increase as pumping velocity rises. This phenomenon occurs due to charge separation between layers within the fluid. The charge is then retained for some time within the liquid mass by its non-conducting property. The danger of such charges is that they can attain sufficient potential to create incendive sparks and, particularly in fuel tanks, electrical arcing is possible. It is, therefore, vital that the handling of gas fueles only takes place in spaces having atmospheres outside the flammable range. On gas carriers, such atmospheres are always maintained in the over-rich condition.

Problems with static electricity can also arise within vapour flows but only when the gas is contaminated with debris, dust particles or when a condensed mist is present. In such cases it is the debris (or the mist which forms as it exits to atmosphere) which attains a static charge. Vapours which can attain a static charge in this way include carbon dioxide (as a fire extinguishing agent) and steam.
Liquid hydrocarbons which are most prone to static build-up are called static accumulators.

Purpose of an insulating flange
Insulating flanges are needed to prevent electrical flow through a hard arm or hose. Such currents can be generated by electrolytic differences between ship and shore. It describes the recommended practice of inserting an insulating flange in the lower end of the outer hard arm to achieve this aim.
Fuel hoses are normally insulated by a similar flange but this is usually fitted onshore close to the shore presentation flange. Its position in the pipework should ensure that no supports to the jetty deck exist between the insulation flange and the point of hose connection.
The external surfaces of insulating flanges should be kept clean and unpainted and its insulating properties should be regularly tested by a 500-volt insulation resistance tester (such as a megger) and recorded in terminal maintenance documents.

CAUTION – The use of a ship-to-shore bonding cable is not only considered to be ineffective but can also be dangerous if it breaks in a flammable atmosphere (e.g. during ESD II). For further information the use and testing of insulating flanges.

Requirements for the use of electrical equipment in hazardous areas
All electrical equipment instrumentation in hazardous areas should be explosion-proof, intrinsically safe or of a certified safe type in accordance with recognized standards.

- Electrical equipment in hazardous areas require more inspection and maintenance than equipment in non-hazardous areas.
- Lack of inspection and maintenance introduce the risk of explosion.
- Where maintenance is subcontracted, they should be made aware of the rules.
- Competency control should be in place.

For the purposes of inspection and maintenance, up-to-date documentation of the following items shall be available:

- the classification of hazardous areas;
- apparatus group and temperature class;
- records sufficient to enable the explosion- protected equipment to be maintained in accordance with its type of protection

For example, list and location of apparatus, spares, technical information, manufacturer's instructions.

Definition of a place where a potentially explosive atmosphere may occur. The classification of an installation into distinct zones has two objectives:

- To define the categories of equipment used in the zones indicated, provided they are suitable for gases, vapours or mists and/or dusts.
- To classify hazardous places into zones to prevent ignition sources and be able to select the correct electrical and non-electrical equipment accordingly. The zones are defined on the basis of the occurrence of explosive gaseous or dusty atmospheres.

Hazardous areas are classified into three types:

- Zone 0: for areas where an explosive atmosphere is always present
- Zone 1: for areas where the risk of an explosive atmosphere exists during normal operation; and
- Zone 2: for areas where an explosive atmosphere can occur in the event of deviation from normal operation.

When the ship is moored, the ship's gas-dangerous space or zone may encroach into the shore's hazardous area. The possibility of uncontrolled sources of ignition from adjacent operations, particularly if these are not handling flammable or dangerous products, should be taken into account.

Earthing

If there is a fault in your electrical installation you could get an electric shock if you touch a live metal part. This is because the electricity may use your body as a path from the live part to the earth part.

Earthing is used to protect you from an electric shock. It does this by providing a path (a protective conductor) for a fault current to flow to earth. It also causes the protective device (either a circuit-breaker or fuse) to switch off the electric current to the circuit that has the fault.

For example, if a cooker has a fault, the fault current flows to earth through the protective (earthing) conductors. A protective device (fuse or circuit-breaker) in the consumer unit switches off the electrical supply to the cooker. The cooker is now safe from causing an electric shock to anyone who touches it.

Ship/Shore Safety Check List

When a ship is alongside, no fuel operations or inerting should commence until the international Ship/Shore Safety Check List has been completed by the ship and the terminal and it has been confirmed that such operations can be safely carried out. It is normal practice that this check list be presented to the ship by the terminal.

Recommendations on the Safe Transport of Dangerous Fueles and Related Activities in Port Areas were revised by IMO in 1995. They refer to a comprehensive Ship/Shore Safety Check List covering the handling of bulk liquid dangerous substances with a special section for liquefied gases. It also includes guidelines for its completion. This has since been updated and the current version is reproduced in Appendix 3.

The Ship/Shore Safety Check List consists of:
Part A (Bulk Liquids — General),
Part B (Additional Checks — Bulk Liquid Chemicals) — not included in this volume — and
Part C (Additional Checks — Bulk Liquefied Gases).
For gas carriers, Parts A and C should be fully completed.

A ship presenting itself to a loading or receiving terminal needs to check its own preparations and fitness for the safety of the intended operations. Additionally, the shipmaster has a responsibility to assure himself that the terminal operator has also made proper preparations for the safe operation of the terminal. Similarly, the terminal needs to check its own preparations and to be assured that the ship has carried out its checks and has made appropriate arrangements. The Ship/Shore Safety Check List, by its questions and its requirements for the exchange of various written agreements, is a minimum basis for performing such a mutual examination.

Some of the questions in the Ship/Shore Safety Check List are directed to considerations for which the gas carrier has prime responsibility. Others apply to both ship and terminal and the remainder to the terminal alone.

The importance of repetitive checks
Arrangements to carry out repetitive checks as necessary and agreed that those items with the letter 'R' in the column 'Code' should be re-checked at intervals not exceeding certain number of hours.
Repetitive checks as per checklists are very important, they provide regular checks on critical points during bunkering or fuel transfer.

The completed checklist is of no value if regarded as a paper exercise and should be physically used prior and during transfer of fuel

30 First aid with reference to a Safety Data Sheets (SDS)

.1 First aid do's and don'ts of occupational health and safety precautions and measures in accordance with Safety Data Sheets (SDS)

The vessel's operation manual for handling of the IGF fuel shall contain relevant operational instructions for safe fuel handling. Information about fuels to be handled is essential to the safety of the vessel and her crew. Information may also be found in Safety Data Sheets for each product, which includes all necessary data for the safe handling and use of the fuel. The properties of low flash point fuels used on ships subject to the IGF Code from a Safety Data Sheet (SDS).

The information is organized into sections. The specific names and content of these sections can vary from one supplier's to another but are often similar to the applicable industry Standard SDS.

Information should be on board and available to all concerned, giving the necessary data for the safe use of fuel. Such information should include for each product carried:
• A full description of the physical and chemical properties necessary for the safe containment of the fuel.

- Action to be taken in the event of spills or leaks.
- Counter-measures against accidental personal contact.
- Fire-fighting procedures and fire-fighting media.
- Procedures for fuel transfer, gas-freeing, ballasting, tank cleaning and changing fueles;
- Special equipment needed for the safe handling of the particular fuel;
- Minimum allowable inner hull steel temperatures; and
- Emergency procedures.

SDS gives detailed information about signs and symptoms, first aid and the administering of antidotes. The use of gas or low-flashpoint fuels poses health and environmental hazards.

Many liquefied gas contain components which are known to be hazardous to human health. In order to minimise the impact on personnel, information on liquefied gas constituents should be available during the gas transfer to enable the adoption of proper precautions. In addition, some port states require such information to be readily available during gas transfer and in the event of an accidental spill. The information provided should identify the constituents by chemical name, name in common usage, UN number and the maximum concentration expressed as a percentage by volume.

31. Methods and firefighting appliances to detect, control and extinguish fires

.1 Explain the firefighting agents and methods to be applied to control and extinguish fires of fuels addressed by the IGF Code

Safety and Firefighting: Sections 3/7 and 4/9 of the ABS Guide for Propulsion and Auxiliary Systems for Gas Fueled Ships (Gas Fueled Ships Guide) and SOLAS Chapter II-2 can be referenced for fire protection requirements for an LNG fueled vessel. A permanently installed fire extinguishing system will typically be fitted at the bunker station and drip trays. Manual release of the system should be easily possible from outside, but near, the bunker station. In addition, portable dry chemical fire extinguishers are typically located near the bunker station and in nearby areas with easy access by the crew. For enclosed or semi-enclosed bunker stations, a fixed fire and gas detecting system should be fitted.

A water curtain is frequently fitted wherever large quantities of cold LNG can leak and damage critical structural components, such as the ship's side shell directly below the LNG bunker station and bunker hoses and above the waterline.

Fighting LNG fires is not a simple task. Completely extinguishing an LNG fire could leave a pool of LNG which will continue to release gas that could reignite in a much more intensive fire. The most important first step is to cool any surrounding tanks or pipes that contain LNG, natural gas or other flammable substances, and to cool spaces that contain critical machinery and accommodations. This will help prevent the spread of the fire and reduce its consequential damage. Intensive heating of LNG tanks by an outside fire impinging on the tank can lead to excessive venting of the tanks. Spraying large quantities of water by a deluge system or from hoses or monitors is generally the recommended method of cooling. Medium or high-expansion foam sprayed on a liquid pool LNG fire also can reduce the intensity of the flames, reducing the potential for damage to surrounding areas, but will not stop the release of gas.

Dry chemicals also will work to extinguish LNG fires, but with the caution that extinguishing the flame without cutting off the source of the gas can be dangerous. It is important to stop the spread of released gas into confined spaces and other parts of the vessel to prevent an explosion due to the confined space. Firefighting should be one of the major sections of the bunkering operation emergency response plans and personnel involved with bunkering should have training on what to do if a fire is encountered.

One of the greatest safety hazards to the bunkering process is fire at or in the vicinity of the bunkering operations and piping systems. The reason fire is so dangerous is that natural gas is highly flammable and will readily fuel and expand a fire if it is released in the vicinity of the fire. In addition, the heat from fire can cause rapid boil-off of LNG in the vicinity of the fire, which can lead to system component rupture and feed gaseous fuel directly into the fire, greatly expanding the hazard from the fire.
The three elements of fire, which are heat, fuel, and air (oxidization). The three elements must be combined in the right proportions for a fire to occur. If any of the three elements is removed, the fire is extinguished. The fire triangle is used as a model for conveying the components of a fire.

Principles of Fire Prevention

For a fire to thrive and spread it requires three things:

• Fuel for the fire to burn
• Air for the fire to breathe
• Heat for the fire to continue burning

Removal of any one of the sides of this Fire Triangle will extinguish the fire.

Fuel

- If fuel is removed, the fire will starve and be extinguished. With bushfires this can be done through a number of pre-emptive methods, including prescribed burning or physical removal of the fuel.
- The removal of fuel can also be done through the lighting of small controlled fires to remove the fuel ahead of the fire.
- These fires, called burn-out fires, are lit from control lines and must only be done by experienced firefighters and well-supervised crews.

Air

- If air is removed, the fire will suffocate—because of a lack of oxygen—and go out. The removal of air from a bushfire is quite difficult as fires are normally quite big and encompass considerable area.
- Water-based foam sprayed on to the fire will act as a blanket between the fire and the air. Similarly, a layer of dirt shovelled onto the fire will act as a blanket.

Heat

- The removal of heat or the cooling of a fire is the most common form of suppression.
- In most cases water is used to essentially soak up the heat generated by the fire. This heat turns the water in to steam, thereby robbing the fire of the heat used.
- Without energy in the form of heat the fire cannot heat unburnt fuels to ignition temperature and the fire will eventually go out. In addition, the water can act to smother the flames and suffocate the fire.

Ignition sources and ways of excluding them

Ignition can occur when an ignition source with a temperature at or above the auto-ignition temperature of a fuel is contact with the vapour phase of the fuel. It is essential to cut off the source of fuel to control a (liquefied) gas fire. If the fuel source cannot be isolated, it is safer to let the gas fire burn, while cooling the surrounding areas with water.

The BLEVE

A BLEVE (Boiling-Liquid/Expanding-Vapour Explosion) is an explosion resulting from the catastrophic failure of a vessel containing a liquid significantly above its boiling point at normal atmospheric pressure. The container may fail for any of the following reasons: mechanical damage, 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 vessel's contents and flame impingement reduces its mechanical strength; particularly at that part of the vessel not cooled by internal liquid. As a result, the tank suddenly splits and pieces of the vessel's shell can be thrown a considerable distance with concave sections, such as end caps, being propelled like rockets if they contain liquid. 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 liquid droplets.

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

Such BLEVE incidents have occurred with rail tank cars, road vehicles and in a number of terminal incidents. There have been no instances of this kind on liquefied gas carriers. Under the Gas Codes, pressure relief valves are sized to cope with surrounding fire and, as for shore tanks, this helps to limit this risk. It must be said that the chance of a fire occurring in the enclosed space beneath a pressurised ship's tank is much smaller than on an equivalent tank situated on shore. This minimises the possibility of a surrounding fire occurring on a ship and almost excludes the possibility of a BLEVE occurring on a gas carrier.

Water-Spray System

A requirement is that a series of water spray nozzles are located at each tank liquid and vapour dome, at the amidships manifold, on the compressor house, on the forward bulkhead of the accommodation block and around the amidships fuel control room if applicable. The water for the operation of these nozzles is fed from a pump and line system independent from, but cross connected with, the ship's fire main. In addition to the above system, the sides of the accommodation block may be protected by spray nozzles supplied with water from the fire main via isolating valves.

Water is not a suitable medium of fighting an LNG fire directly as it will cause a massive expansion of the fire, through an increase in the rate of vaporization of the liquid to gaseous state. Water is however essential as a cooling medium for the surrounding area of an LNG fire and to protect personnel who may need to approach the site. Water is also essential for protecting steel work from the effects of extreme cold in the event of a liquid spill. It is necessary to avoid water running off adjacent structures and aggravating burning LNG, or splashing into spill trays which may contain LNG, thus causing it to overflow onto unprotected steelwork. Spill trays and areas under manifolds are in any case floodable with water to protect hull steelwork from damage due to exposure to the intense cold of LNG.

Gas tankers are fitted with a fixed water spray system for fire protection purposes. This covers areas such as:

Fuel tank domes

- Fuel tank areas above deck
- Fuel manifold areas
- The front of the accommodation including lifeboat boarding areas, and
- Control room bulkheads facing the fuel-deck

Minimum water flow rates of 10 litre/m2 per minute for horizontal surfaces and 4 litre/m2 per minute for vertical surfaces must be achieved.

Fixed Dry-Powder Extinguishing System

In addition to the fixed water spray systems, all gas tankers must be fitted with a fixed dry powder installation capable of fighting fires in the fuel area. Moreover, ships subject to the IGF Code are fitted with a fixed dry-powder extinguishing system in the bunkering station area to cover all possible leak points.

At least two hand hose lines should be provided to cover this area and on large ships there are two systems in each side covering the port and starboard manifold and 10-12 hose cabinets strategically situated around the deck. Each system consists of a tank containing sodium bicarbonate and cylinders containing N_2 gas under pressure. The system is operated by releasing the N_2 gas into the tank, which forces the mixture to the monitors and hose cabinets. When attempting to knock out the fire using a powder system, it is important to decide whether or not the water spray system should be cut off before the powder strike, because dry powders are normally soluble in water and a proportion may be eliminated if they have to pass through a water curtain. Irrespective of being the main extinguishing agent, it should be noted that dry powders doesn't provide cooling effect and may be ineffective since a fire extinguished by dry powder can easily reflash from the hot metal.

Water Dry Chemical Powder as a Fire-Fighting Agent

Water will not extinguish an LNG fire. Firefighting water does have its uses in an LNG fire such as keeping a vapor cloud away from a source of ignition, but the extinguishing agent used for LNG fires is Dry Chemical.

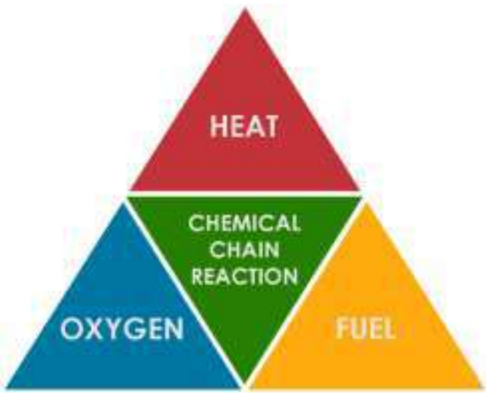
The only effective method for extinguishing an LNG fire is to use dry powder. Dry chemical (BC ones in the case of LNG facilities) is a proven firefighting agent whether it is used in portable extinguishers or in fixed pipe fire suppression systems.

Advantages of using dry chemical powder are several:

- Quick knockdown: dry powder, when correctly applied and at the required application rate, has the ability to ensure an initial quick knockdown of the fire.
- Good on running fuel fires: owing to its fires extinguishing action, dry powder, when used in conjunction with water/foam sprays, can be extremely effective when used in running fuel fires.
- Nonconductor of electricity: dry powder can be used at incidents where it is known (or suspected) that “live” electrical equipment is present.
- Creates no thermal shock: because the application of dry powder onto metal does not cause thermal shock, it is particularly useful for dealing with fires involving in confined area.

In addition for firefighting, all fire-fighting appliances should always be kept in good order and ready for use, and prior to commencing bunkering operations, the ship's fire-fighting equipment should be made ready, and the international shore connection should be at hand.

Extinguishing the fire by the following methods will break the “fire triangle” and “fire tetrahedron” and prevent the spread or continuation of the fire.



- Starvation – the fire will not sustain combustion if the source of the fuel is removed. Eliminate any inflammable materials from the fire area; turn the valves off.

- Smothering – reduce the oxygen around the fire boundaries. The extinguishing agent used here is CO_2, foam, sand, steam, or fire blankets.

- Cooling – the fire must be cooled down to a temperature below the ignition point. The most common agent here is water fog and foam is also used for this purpose.

- Chain Breaking – using dry powder can interrupt the chain reaction.

.2 Actions conforming with the emergency procedures for fuels addressed by the IGF Code

When you are prepared, even an emergency can be orchestrated well enough to avoid chaos. One of the first things we're told in a crisis is not to panic. Unfortunately, that's exactly what many people do.

Just saying "Remain calm!" is not enough–you need to be able to execute your emergency plan with a level of precision and decisiveness that tells your people that they can trust you and your preparedness.

Planning is critical. And, Practice is a must. Of course, we can't predict an emergency, and therefore plan, for absolutely everything. But there are a few steps to follow in an emergency to put your crew and employees at ease.

Step 1: Assess your risk

When designing an emergency plan, you have to know what you're dealing with when it comes to your assets and what could potentially happen to them. Your assets are your people, first and foremost. Other assets may include your facilities, equipment's, supplies, and etc. All of these assets are at risk when an emergency arises.

What are the emergencies that are most likely to occur? Weather-related events, power failures, and natural disasters are the most common. But each location where your company operates, may have its own variables and risks to assess. Consider the weather and geological events common in those areas, security and the nearest emergency response organizations, and the number of crew who may be affected.

Step 2: Survey your work environment

Each ship likely differs in design, evacuation routes, surrounding area and even your workmates.

Are there any stairs near to serve as an emergency route? Are there hazardous materials stored in that location? Each of these factors come into play in an emergency. We should also understand what emergency resources are available in each location, such as overhead sprinkler systems, fire extinguishers, and defibrillators that we can use in an event of an emergency.

Step 3: Identify Leaders

In an emergency, there needs to be leadership. Designate a specific people in each department to carry out different aspects of your plan and to keep people informed. Be sure every employee knows who these leaders are. Have a backup person named in case the designated one is absent. Equip this person with the necessary details and equipment's they need to send and receive information.

Step 4: Choose an emergency notification system

When seconds count, you want to be sure you have the latest information and can instantly and reliably send alerts and instructions to everyone involved.

Step 5: Design a plan

While it's good to prepare for specific contingencies, that's not enough to prepare for the myriad of possible threats to business continuity. Most emergencies can fall into one of four categories: weather or natural event; power or IT outage; security event; or health and safety incident. Your plan should be flexible enough to adapt to each of these different situations.

- Evacuation routes from the area
- Chain of command
- Nearest onsite resources
- Information dissemination for first responders

Step 6: Practice the plan

Once the plan is designed, it's time to practice. Your employees may bemoan of these drills, but when a critical event happens, they will be thanking you that they knew what to do, and they will be much less likely to panic. Remember, the goal is to avoid chaos and panic. The only real remedy is to have everyone fully aware of what they are to do in case of an emergency.

.3 The evacuation, emergency shutdown and isolation procedures involving fire of fuels addressed by the IGF Code

Emergency situations and events will vary widely and will require various levels of management to direct the handling of the emergency and subsequent restoration of operations and reporting.

Evacuation:

Evacuation routes are of prime importance for the safety of plant workers during an emergency. Two evacuation routes, which must be located as far apart as possible, should be provided from all hydrocarbon processes or normally occupied work areas.
Evacuation routes should also be generally straight and direct to points of safety or embarkation.

For ocean going vessels, ship's abandonment is to be conducted with totally enclosed lifeboats or free fall lifeboats and each of these demands different manipulations when the need of falling into the water arises. It is easy to understand that lifeboats are safety equipment which need the appropriate maintenance with periodical inspections and tests to ensure that they are properly working. Except from these precautions, IMO at its requirements regarding abandon ship operations (updated June 2017), requires additional measures aiming prevention of accidents with survival crafts. It focuses on the use of uniforms and also to the authorization, qualification and certification requirements to ensure reliable service is provided (requirements will enter into force on 1 January 2020).

Totally Enclosed Life Boats

This type ensures water tightness and also it gets upright on its own if an overturn have been caused by big waves. In case of an abandon ship operation, and a totally enclosed lifeboat is used, the crew should act as follows, before lowering of boat to the water:

- Sound abandon ship signal, MAYDAY signal and fix ship's position.
- Activate EPIRB and SART
- Stop main engine and propellers should be secured
- Muster at lifeboat stations with the appropriate life jackets and immersion suits

- If time permits, equip the lifeboats with extra blankets, water or food and remove painters from lifeboat (if any)

Free Fall Life Boats

Free fall is similar to an enclosed lifeboat, but it differs in the process of launching, as it is constructed in such way, so it can easily penetrate the water as it falls from the vessel without any rope support. When the crew uses a freefall lifeboat, should act same as for an enclosed lifeboat, but there are some additional measures to be taken, as the crew when board into the lifeboat should be prepared accordingly to experience a free fall situation which demands very careful preparations.

Emergency Shutdown

A safety system that is designed to minimize the consequence of an emergency situation such as; uncontrolled flooding, escape of hydrocarbons, or outbreak of fire. This also provides protection against possible harm to people, equipment and environment.

Here are some typical actions on ESD:

1. Shutdown of parts of the system and equipment
2. Isolate hydrocarbon areas
3. Isolate electrical equipment
4. Prevents the escalation of events
5. Stop the flow of hazardous fluids
6. Emergency controlled ventilations
7. Closing of watertight access and fire doors

The LNG fuelling station is provided with multiple emergency shutdown devices (ESD). ESD functions to generally shut off all pumps and closes off control valves along the piping so that LNG stays either on the ship or in the storage tank.

Isolation

Three elements – heat, fuel and oxygen – must be present to ignite a fire. "Combustion will take place if all three elements, in one form or another, are present, the gas/air mixture is within certain limits and the source of ignition has sufficient energy,"

The removal of one element is sufficient to prevent combustion as is the isolation or separation of the source of ignition from the gas/air mixture."

.4 Respond to fire emergency situations in accordance with the established procedures

Actions to be taken:

- As soon as a fire is detected, several actions should be taken to ensure the safety of the vessel and the personnel.
- General alarm should be sounded
- Bridge team should be informed
- Fire party should muster
- The fire should be isolated, by closing ventilation system, skylights, doors, boundary cooling, etc
- Before entering the fire space, crew should wear the appropriate PPE and use the proper fire extinguishing system, regarding the type of fire
- Interested parties should be notified