Basic LNG Training

Learning Based Outcomes

- Gas, Natural Gas, LNG
- Production of Natural Gas
- Properties of LNG and LPG, difference, pros and cons
- LNG – production, storage, liquefaction, transportation and re-gasifacation
- LNG Terminal – Vessel berthing, loading , unloading, storage and re-gasifaction
- Risks associated with LNG Cargo
- Hazards associated with LNG Cargo
- Permit to Work System

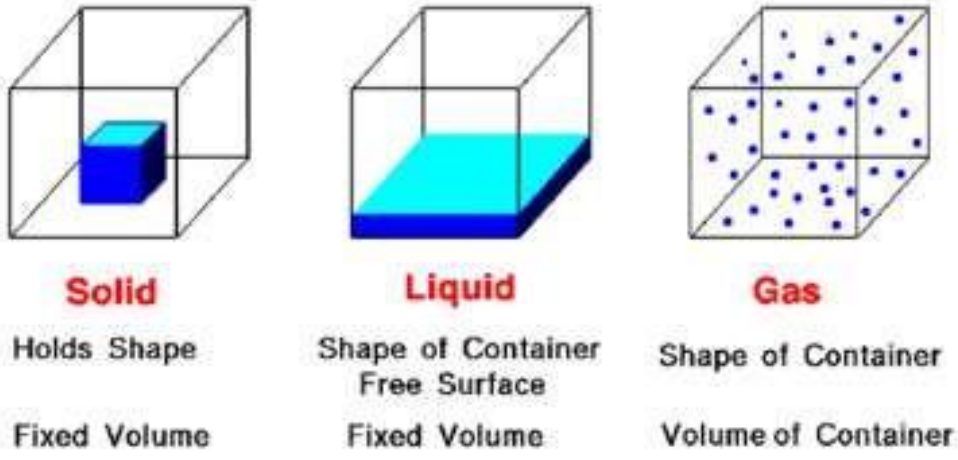
LNG (Liquefied Natural Gas)

- What is Gas ?
- What is Natural Gas ?
- What is Liquefied Natural Gas ?

What is Gas ?

States Of Matter

- What is Solid, Liquid and Gas?
- What is Plasma



States Of Matter

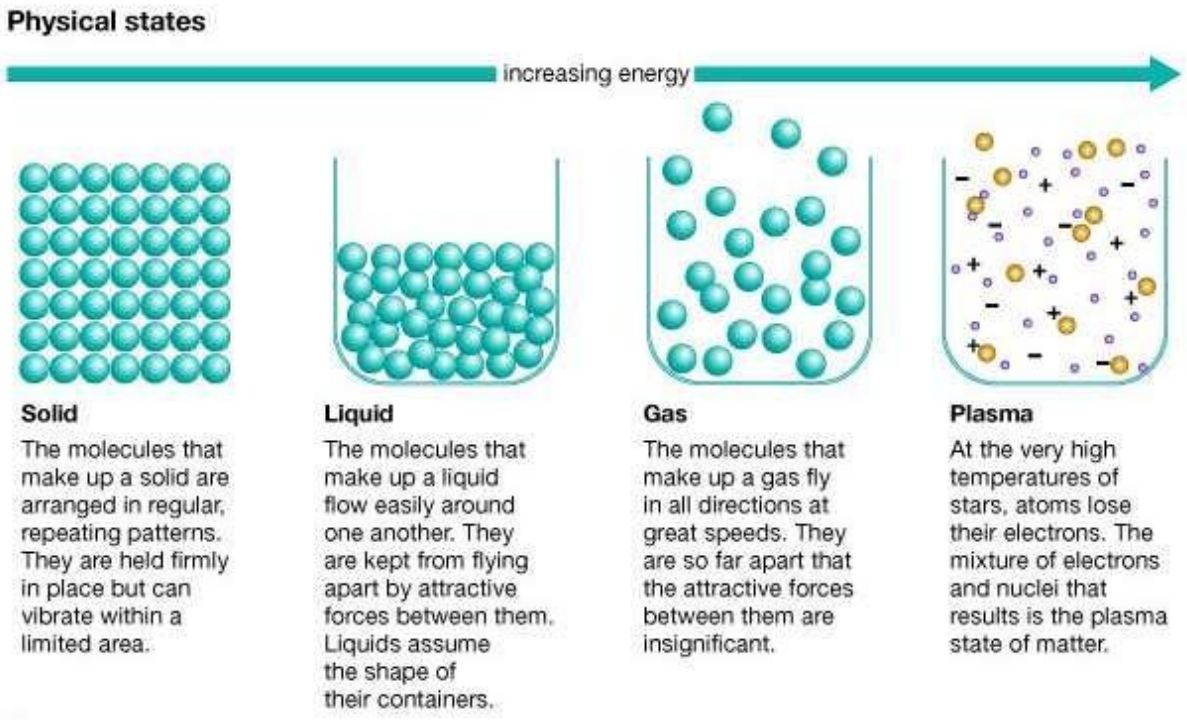
- **Plasma (Fourth State of Matter)**

A plasma is a **hot ionized gas** consisting of approximately equal numbers of positively charged ions and negatively charged electrons. The characteristics of plasmas are significantly different from those of ordinary neutral gases so that plasmas are considered a distinct "fourth state of matter."

States of Matter

- Conservation of **energy**.
  - In other words, this law means that **energy** can neither be **created nor destroyed**; rather, it can only be transformed from one form to another.

States Of Matter - Energy Levels



What is Natural Gas ?

Fossil Fuel

- What are Fossil Fuels?

Fossil fuels are natural resources, such as coal, oil and natural gas, containing hydrocarbons. These fuels are formed in the Earth over millions of years and produce carbon dioxide when burnt.

Fossil Fuel

- **Different Types of Fossil Fuels**

There are three types of fossil fuels which can all be used for energy are Coal, Oil, and Natural Gas.

Coal is a solid fossil fuel formed over millions of years by decay of land vegetation. When layers are compacted and heated over time, deposits are turned into coal. Coal is abundant compared to the other two fossil fuels.

Oil is a liquid fossil fuel that is formed from the remains of marine microorganisms that were left on the bottom of the sea floor. Oil is the most widely used fossil fuel.

Natural gas is a gaseous fossil fuel that is abundant and clean compared to coal and oil. Like oil, it is formed from the remains of marine microorganisms. It is a relatively new type of energy source.

Fossil Fuel

COAL

Formation:
•Peat is formed as dead plants build up in swamps
•Lignite is formed as layers of sand and mud cover peat
•After millions of years of heat and pressure, bitumen is formed
•Bitumen becomes anthracite under even more heat and pressure

Cool Stuff
•Most available fossil fuel
•At each stage of formation the amount of carbon increases

•Uses:
•electricity
•Plastics
•Fertilizer
•Chemicals
•Medicines
•Heating
•To make Steel

NATURAL GAS

Formation:
•Plants and animals die and settle to the bottom of oceans
•Sand and clay bury the plants and animals
•After thousands of years, heat and pressure decay the bodies into tiny bubbles of odorless, colorless gas.
•We find and drill gas out of rocks.

Cool Stuff:
•A smell is added to gas for safety
•When super cooled it becomes a liquid (LNG) and only takes up 1/600 as much space.

Uses:
•Gas Stove – cooking
•Heating
•Dry clothing

PETROLEUM

Formation:
•Plants and animals die and settle to the bottom of oceans
•Sand and clay bury the plants and animals
•After thousands of years, heat and pressure decay the bodies into oil
•We find and drill gas oil out of rocks.

Cool Stuff:
•Most widely used fossil fuel
•Easy to store and transport (liquid)

Uses:
•Transportation
•Plastics
•Chemicals (medicine, make-up, paint, plastic)
•Shoes, clothing
•Fertilizers
•Heating

Fossil Fuels - Advantages

Natural Gas

Types of Natural Gas

There are four basic types of natural gas used, which includes:

- Methane
- Ethane
- Propane
- Butane

Methane is the most prevalent, but each one can be used for different reasons around the house.

Natural Gas

- Natural gas is primarily composed of methane, but also contains ethane, propane and heavier hydrocarbons. It also contains **small** amounts of nitrogen, **carbon dioxide**, **hydrogen sulphide** and **trace** amounts of water.

Natural Gas - Composition

- Natural gas is primarily composed of **Methane**, but also contains ethane, propane and heavier hydrocarbons. It also contains small amounts of nitrogen, carbon dioxide, hydrogen sulphide and trace amounts of water.

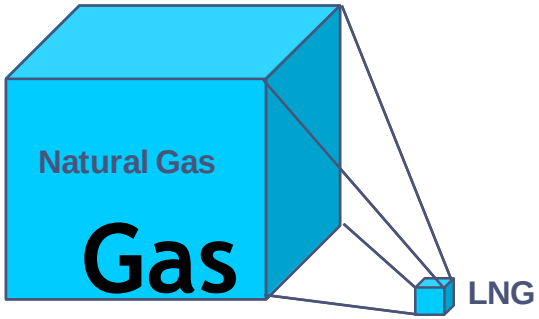
- Natural gas can be found by itself or in association with oil. It is both colourless and **odourless** and is in fact a mixture of hydrocarbons.

- It also contains small amounts of nitrogen, carbon dioxide, hydrogen sulphide and trace amounts of water.

- Methane - One carbon atom; chemical formula CH4. The principal use of methane is as a fuel. The natural gas that is delivered to your home is almost pure methane.

What is Liquefied Natural Gas (LNG)?

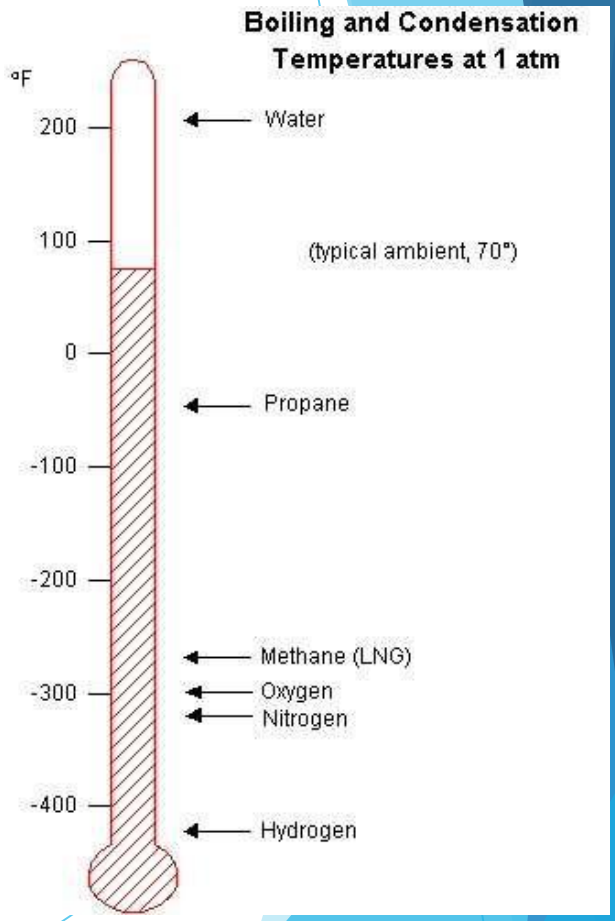
What is Liquefied Petroleum Gas (LPG) ?



Liquefied Natural

LNG is natural gas that has been cooled that it condenses to a liquid

- Temperature -256°F (-161°C)
- Atmospheric pressure.
- Volume is reduced 600 times
- Thus economical to transport locally and between continents in specially designed ocean vessels
- Liquefaction technology makes natural gas available throughout the world



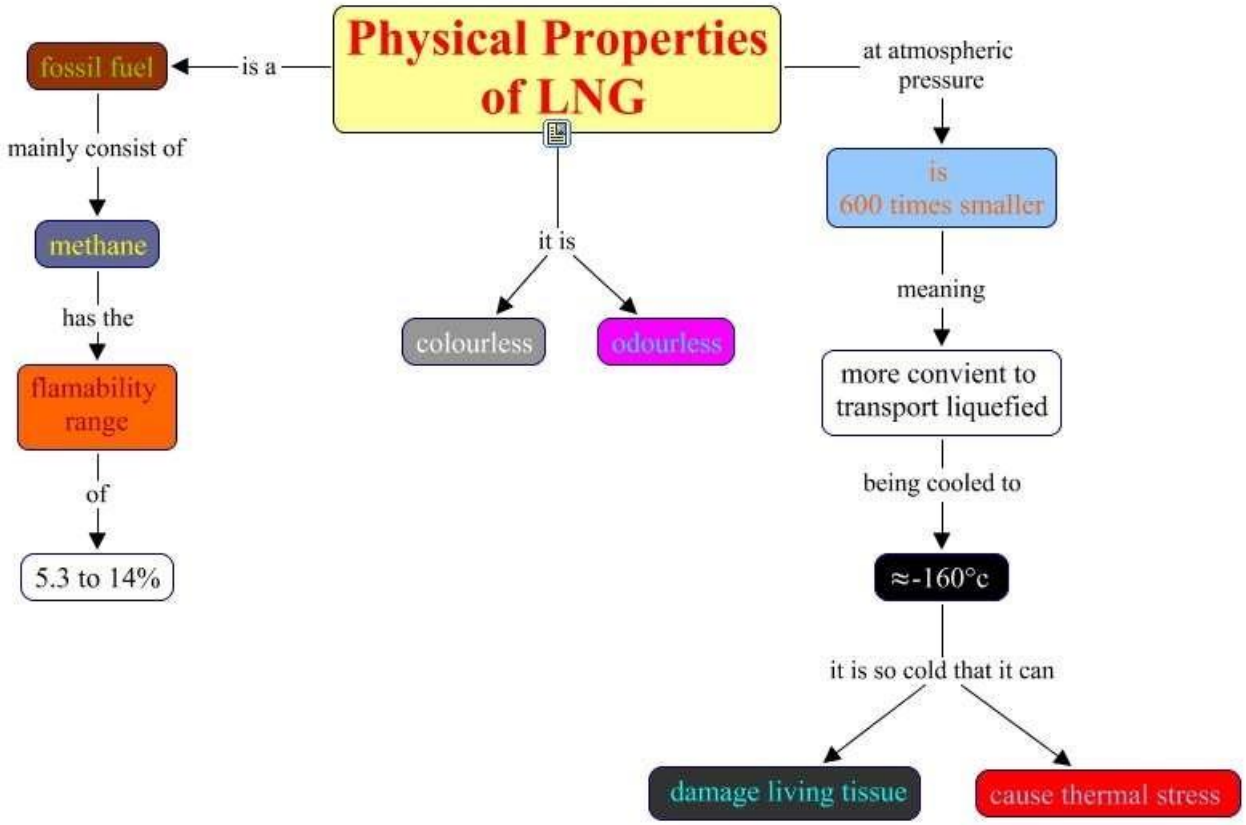
Liquefied Natural Gas (LNG)

- LNG – liquefied natural gas – is methane (CH_4) that is liquefied by chilling below -161°C.
- This the same natural gas that is piped to homes and businesses.
- As liquid, the volume of LNG reduce to 1/600 its gaseous state.
- This makes LNG transportable in **cryogenic** ships or trucks.

Properties of LNG

- Chemical formula: CH_4
- Boiling Point: -161°C
- Liquid Density: 426kg/m^3
- Gas Density (25°C): 0.656 kg/m^3
- Specific Gravity (15°C): 0.554
- Flammability Limits (in air by volume): 5.3% to 14% (5 % to 15 %)
- Auto Ignition Temperature: 595°C

Properties of LNG



Liquefied Petroleum Gas (LPG)

- Describes flammable hydrocarbon gases including propane, butane and mixtures of these gases.
- LPG, liquefied through pressurisation, comes from natural gas processing and oil refining.
- LPG is used as heating, cooking and auto fuel.
- LPG gases can all be compressed into liquid at relatively low pressures
- LPG is frequently used for fuel in heating, cooking, hot water and vehicles, as well as for refrigerants, aerosol propellants and petrochemical feedstock.

Properties of LPG

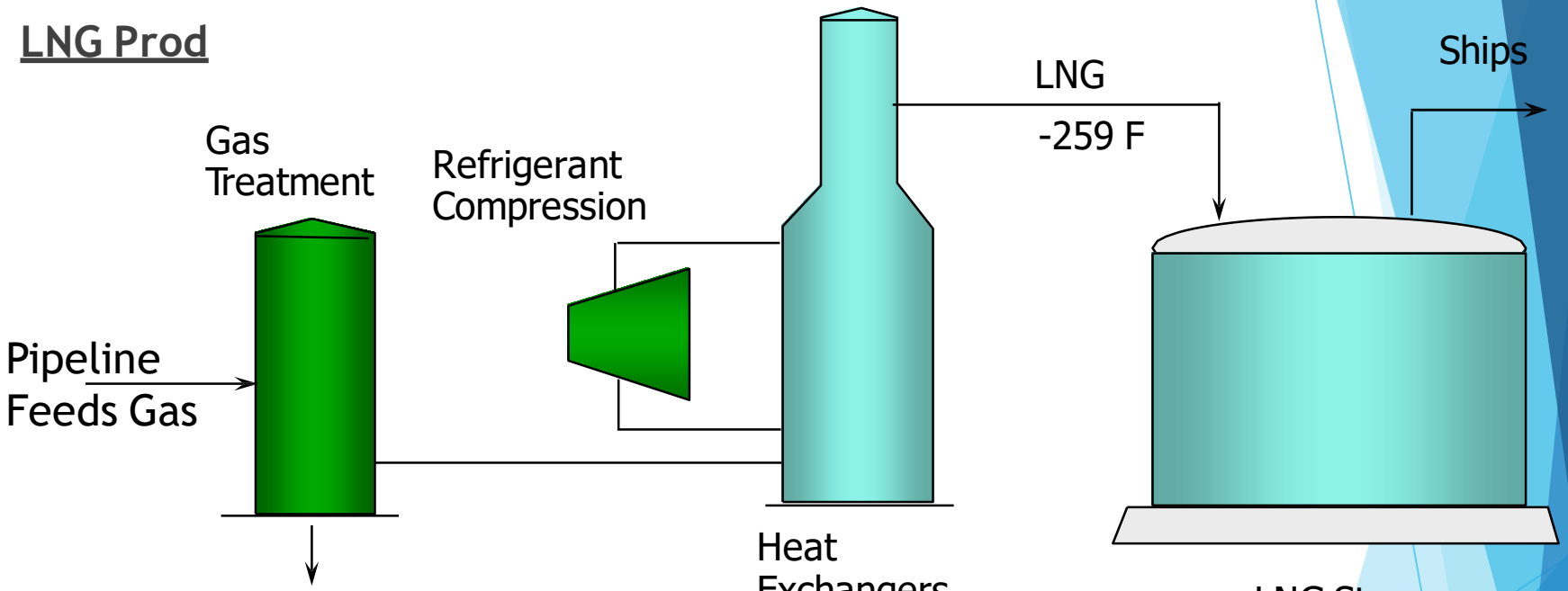
Propane vs Butane vs Isobutane - Properties ELGAS			
LPG Gases	Propane	Butane	Isobutane
Chemical Formula	C_3H_8	C_4H_{10}	C_4H_{10}
Energy Content: MJ/m^3	95.8	111.4	110.4
Energy Content: MJ/kg	49.58	47.39	45.59
Energy Content: MJ/L	25.3	27.5	25.0
Boiling Temperature: °C	-42	-0.4	-11.75
Vapour Pressure at 21°C: kPa	858.7	215.1	310.9
Flame Temperature w/Air	1967	1970	1975
Expansion: m^3/L	0.270	0.235	0.234
Gaseous Volume: m^3/kg	0.540	0.405	0.402
Relative density (water = 1)	0.51	0.58	0.60
Relative density (air = 1)	1.53	2.00	2.07
L/kg	1.96	1.724	1.669
kg/L	0.51	0.58	0.60
Gas Specific Gravity at 25°C	1.55	2.07	2.06
Gas density 15°C: kg/m^3	1.899	2.544	2.533

Comparison with other Fuels

Comparison of Properties of Liquid Fuels	LNG	Liquefied Petroleum Gas (LPG)	Gasoline	Fuel Oil
Toxic	No	No	Yes	Yes
Carcinogenic	No	No	Yes	Yes
Flammable Vapor	Yes	Yes	Yes	Yes
Form Vapor Clouds	Yes	Yes	Yes	No
Asphyxiant	Yes, but in a vapor cloud	Yes, same As LNG	No	No
Extreme Cold Temperature	Yes	Yes, if refrigerated	No	No
Other health hazards	None	None	Eye irritant, narcosis, nausea, others.	Same as gasoline
Flash point °F	-306	-156	-50	140
Boiling point °F	-256	-44	90	400
Flammability Range in air %	5-15	2.1-9.5	1.3-6	N/A
Stored Pressure	Atmospheric	Pressurized (atmospheric if refrigerated)	Atmospheric	Atmospheric
Behavior if spilled	Evaporates, forming visible "clouds". Portions of cloud could be flammable or explosive under certain conditions.	Evaporates, forming vapor clouds which could be flammable or explosive under certain conditions.	Evaporates, forms flammable pool; environmental clean up required.	Same as gasoline

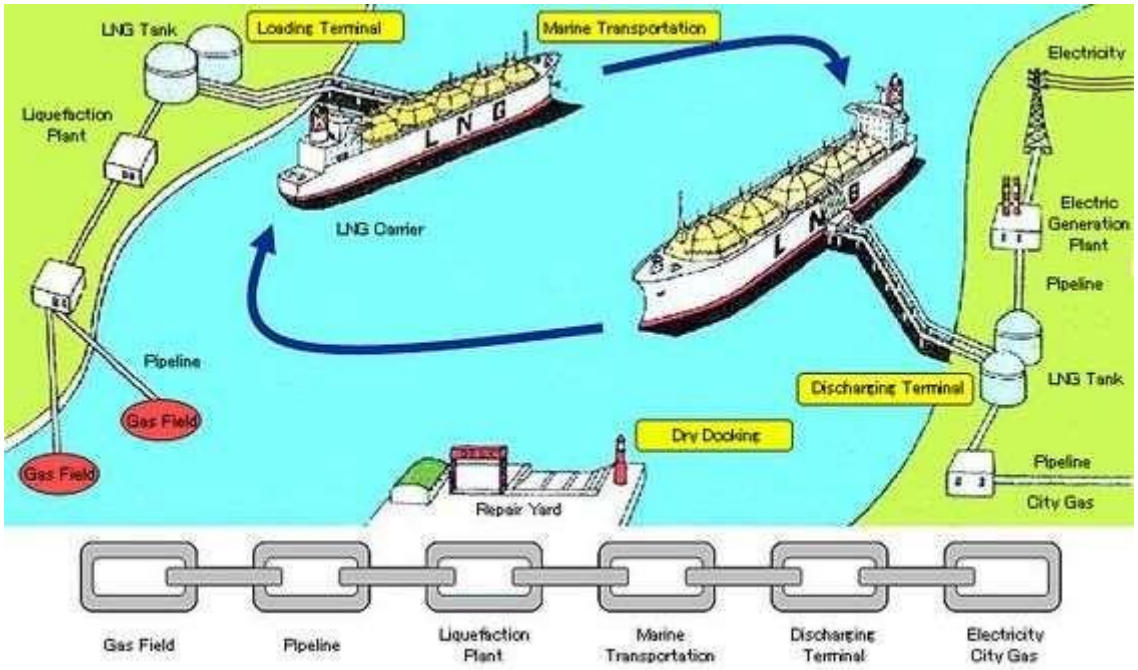
LNG Production

LNG - Production Process

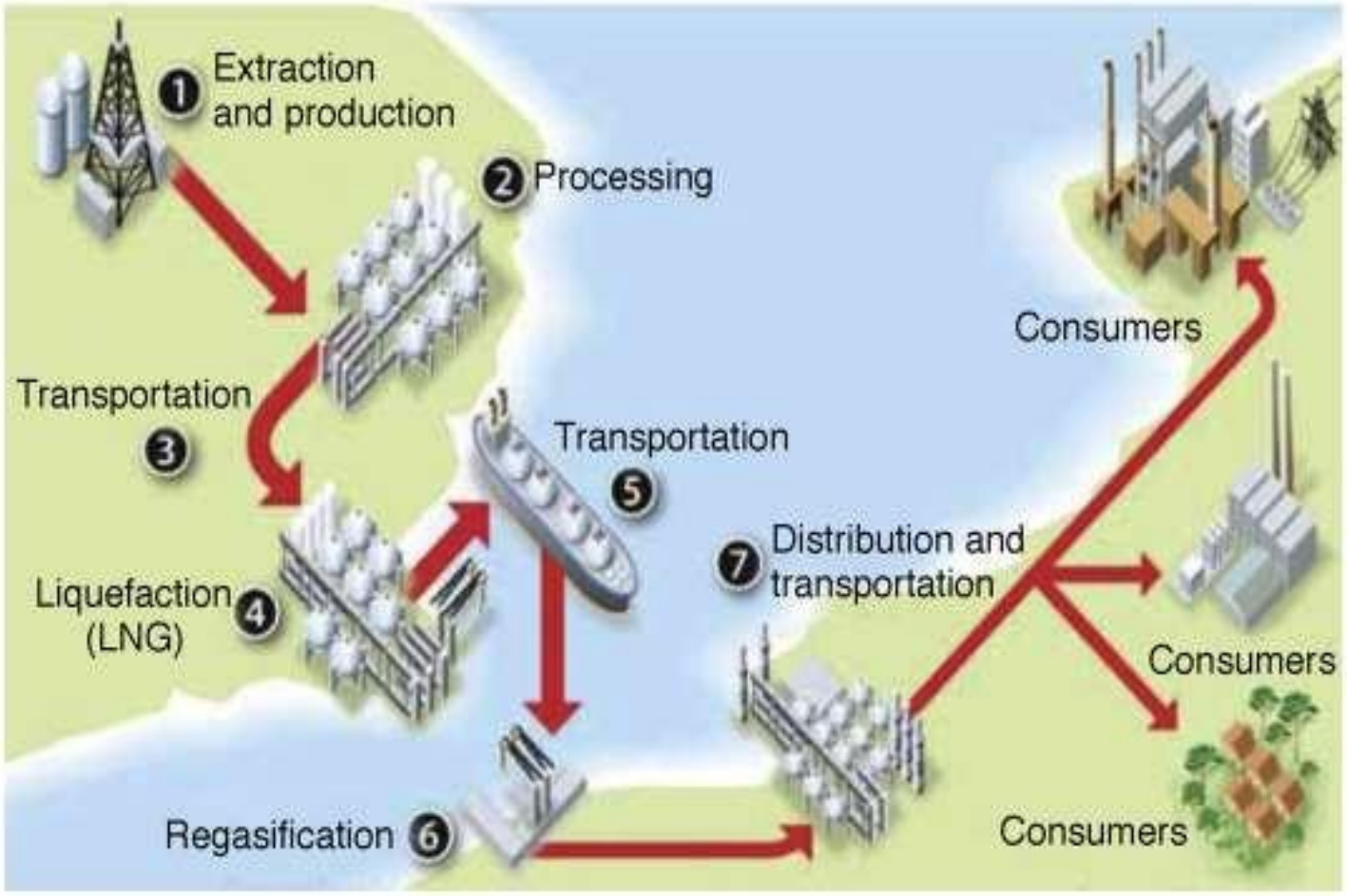


- Pentanes and heavier
- Condensates
- Impurities
  - -Carbon Dioxide
  - -Mercury
  - -Hydrogen Sulfide
  - -Water
  - -Nitrogen

LNG - Production and Transportation Process



LNG – Production and Transportation Process



LNG – Production and Transportation Process

- With **LNG**, **gas** is liquefied and transported internationally via tankers and then re-gasified into its original state for distribution and sale. Additionally, the hydrocarbon takes up significantly less space as a liquid than a **gas.**

LNG – Terminal

- *An LNG terminal is a facility for re-gasifyng the liquefied natural gas (LNG) shipped in by LNG tanker from the production zones.*

- **Functions**
  - A conventional terminal has four functions:
  - Berthing of LNG tankers and unloading or reloading of cargoes,
  - Storage of LNG in cryogenic tanks (-160°C),
  - Regasification of LNG,
  - Send-out of this gas into the transmission grid.

LNG – Terminal

- **Berthing and unloading**
  - On arrival at the terminal, LNG tankers (length 200 to 350 m) are moored to the unloading berth. Articulated arms are connected to the LNG carrier to unload its cargo and transfer LNG to the terminal storage tanks.
  - The LNG flows through pipes specially designed to withstand very low temperatures (-160°C). This operation takes at least 12 hours. A volume of boil-off gas is sent back from the terminal storage to the LNG tanker in order to maintain the pressure inside its cargo tanks.

LNG – Terminal

- **Storage**
  - LNG is stored in cryogenic tanks (designed for low temperatures) capable of withstanding temperatures of -160°C to maintain the gas in liquid form. The outer walls of the storage tanks are made of pre-stressed reinforced concrete.
  - They are insulated to limit evaporation. Despite the high-quality insulation, a small amount of heat still penetrates the LNG tanks.

LNG – Terminal

- This causes slight evaporation of the product. The resulting boil-off gas is captured and fed back into the LNG flow using compressor and recondensing systems.

- This process prevents the occurrence of venting natural gas from the terminal under normal operating conditions.

- During maintenance periods, boil off gas can no longer be recovered and is burnt off by the flare stack. It is preferable to burn the methane than to release it into the atmosphere (reduced impact on the greenhouse effect).

LNG – Terminal

- **Re-gasification**
  - The LNG is then extracted from the tanks, pressurised and re-gasified using heat exchangers.
  - Each tank is equipped with submerged pumps that transfer the LNG to high-pressure pumps.
  - The pressurised LNG (at around 80 times atmospheric pressure) is then turned back into a gaseous state in vaporisers.

Risks associated with LNG Cargo

- Is Liquefied Natural Gas Dangerous ??

Risks associated with LNG Cargo

- The historical reality is that **LNG** has the best safety record of all common fuel types and is completely non-toxic. Of course **natural gas** vapours are flammable and present safety hazards that must be managed, but these hazards are substantially less than for gasoline, diesel and other **liquid** fuels

Risks associated with LNG Cargo

- Can Liquefied Natural Gas Explode??

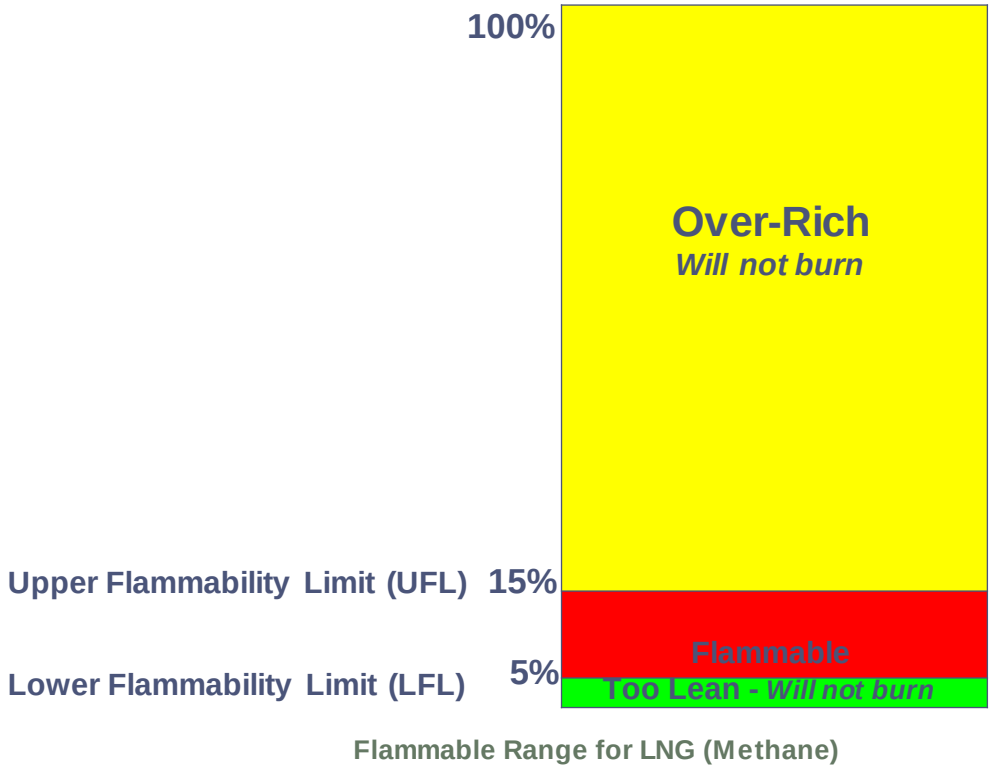
Risks associated with LNG Cargo

- As a **liquid**, **LNG** is not **explosive.**
- **LNG** vapour **will** only **explode** if in an enclosed space.
- **LNG** vapour is only **explosive** if within the flammable range of 5%-15% when mixed with air.

Hazards associated with LNG Cargo

- LNG is colourless, odourless, and non-toxic.
- When vaporized and mixed with air LNG is flammable.
- Cold methane vapour is denser than air and can settle in enclosed areas, while warm methane vapour is lighter than air and disperses.
- Methane is flammable in air in concentrations of 5% to 15%. Below 5% the mixture is too lean to burn. Above 15% the mixture to rich to burn.
- Potential for frostbite and freezing due to low temperatures. – Eyes especially vulnerable to sprayed or splashed LNG.
- Potential for asphyxiation due to displacement of oxygen, especially in enclosed areas.

Hazards associated with LNG Cargo



Occupational Hazard

- Occupational health and safety issues associated with LNG Facilities operations include the following :
  - Fires and explosions
  - Roll – Over
  - Contact with cold surface
  - Chemical hazards
  - Confined spaces

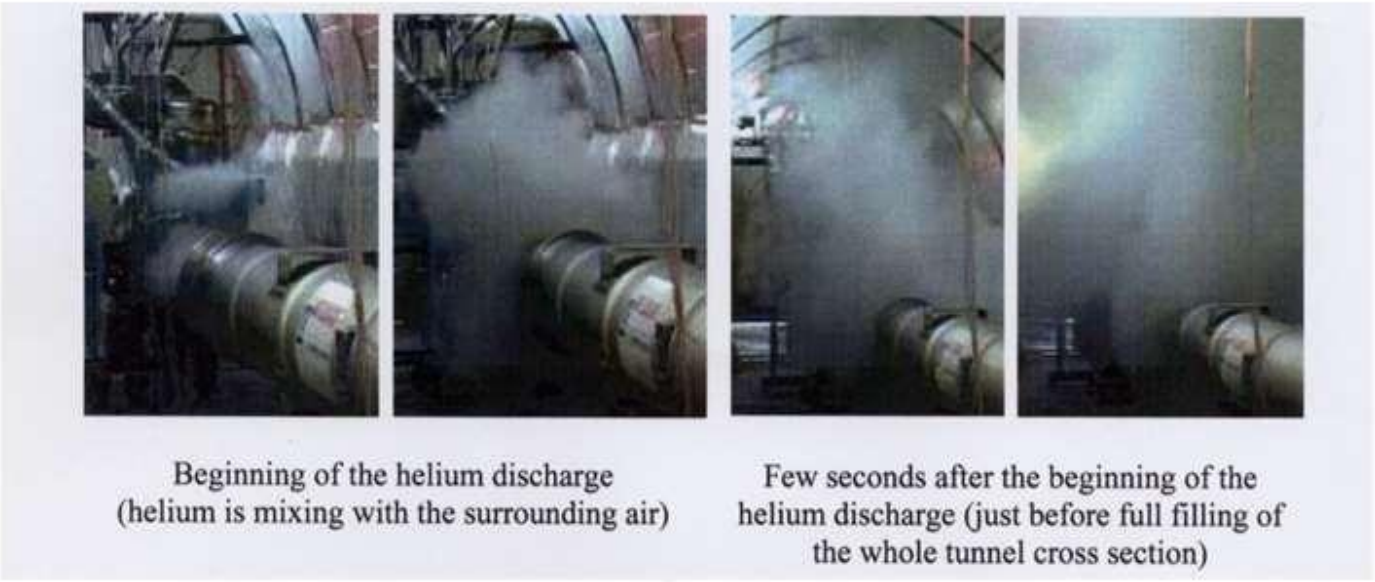
Hazard - Cryogenics

Hazard – Cold Burns

Preventive Measures

- Plant and equipment that can pose an occupational risk due to low temperatures should be adequately identified and protected.
- Training to educate workers for handling and dispensing LNG
- Proper PPE

Hazard – Asphyxiation



Beginning of the helium discharge (helium is mixing with the surrounding air)

Few seconds after the beginning of the helium discharge (just before full filling of the whole tunnel cross section)

Spill – What would you do ???

- A liquefied natural gas **(LNG) spill** can happen during an accident
- LNG is normally stored and transported in liquid form at a temperature of approximately −161 °C (−260 °F). If this cooled liquid is released from a storage facility, pipeline, or LNG transport ship, then it begins to warm. As LNG warms above its storage temperature, the liquid begins to vaporize. The resulting gas produced by this warming is typically methane, which is the major component (with some ethane) of natural gas.

- If a spill occurs and the vapour does not ignite, it would build to higher concentrations. At higher concentrations, the vaporized methane will cause an asphyxiation hazard to anyone exposed. If a spill or leak followed by a vaporization event were to occur in or near water, then water in contact with the spilled LNG can accelerate the vaporization process and increase the concentration of vapour in the immediate area. According to the 2004 Sandia report, this is of special concern to ship and pilot-boat crews, emergency response personnel or others who are exposed in a marine environment.

Hazard - Fire

- The risk of a fire or a blast at an LNG terminal is very small since the following three factors have to occur simultaneously to trigger such an event :

- A gas leak in a confined space,
- A gas/air mixture of between 5% and 15%,
- A source of ignition (spark or flame).

Fire Fighting

- **Water is not suitable for fighting LNG Fires**, as it increases the vaporization rate of LNG.
- Locate all fire protection systems in a safe areas of the facility, protected from the fire by distance or by fire walls
- Avoid explosive atmospheres in confined spaces by making them inert (removing oxygen)
- Implement safety procedures for loading and unloading of product to transport systems (ship, tankers, train , truck and vessels)
- When active fire protection systems are installed, they should be located to enable rapid and effective response.

Fire Fighting

- Burn out It self
- Dry Powder – Best Medium to tackle an fight LNG Fires
- Water Should not be used…..and if used should not be used directly. (accelerate vaporization and massive expansion)
- “ Cold Vapour Fire ” (Rapid Vaporization – prevents ignition)
- “ Lazy Flame ” (Spreading Characteristics)

Fire Fighting - Procedure

- Isolate the source of Leak, Stop all loading / discharging…
- Sound the Alarm
- Provide Protection for adjacent equip. and fire fighters.
- Attack – Dry Powder – Max. rate of Application
- Remain vigilant – Re ignition

Fire Fighting - Procedure

- Water – Water fog or spray – Cool adjacent areas
- If LNG Is not burning – Increase Evaporation rate by putting water
- Simultaneous attack and not one hose monitor attack
- Attack from Up Wind Direction (Disperses Away)
- DCP to be aimed at Vertical surface behind the seat of fire

Fire Fighting - Terminal

- A closed-loop fire water system will be provided to protect the LNG Terminal equipment, utilities, storage and unloading areas. The system will include main pumps and a standby mobile pump, along with hydrants and monitors. Fire water will also be provided to protect the berth.

LNG Fire – What would you do ??

- LNG does not Burn
- LNG does not Explode

BUT

- LNG Vapour Burns
- LNG Vapour can cause Explosion

LNG Fire

- **Types of LNG Fires:**
  - Flash Fire/Vapour Cloud Fire
  - Jet
  - Pool
  - BLEVE
  - Rapid Phase Transition?

LNG Fire

- **RPT (Rapid Phase Transition)**

- Is not a fire!
- Occurs when liquid comes in contact with water.
- LNG vaporizes violently.
- Rapid phase change from liquid to vapour.

LNG Fire

- **RPT (Rapid Phase Transition)**

- A physical or cold explosion.
- No combustion.
- Hugh amount of energy is transferred in the form of heat from the ambient temperature water to the cold LNG.

LNG Fire

- (Remaining) types of LNG Fires:

- Flash Fire/Vapour Cloud Fire
- Jet
- Pool
- BLEVE

LNG Fire

- Flash Fire/Vapour Cloud Fire.
- May happen if a cloud of gas burns without generating significant overpressure.
- Cloud must contain 5 to 15% concentration of methane in air.

LNG Fire

- Flash Fire/Vapour Cloud Fire:
- Cloud will be ignited at the edge as it disperses and meets source of ignition.
- Ignition sources include: open flames, sparks, internal combustion engines.
- Once ignited, a cloud will flash back along the flammable range

LNG Fire

- Flash Fire/Vapour Cloud Fire:
- The fire will continue to burn until the hydrocarbon is depleted.
- Relatively short in duration.
- Unconfined vapour does not explode.

LNG Fire

- Jet Fire:
- May be caused by vapour leaking from high pressure sources such as pumps, vent risers, or piping:
- Vapour must meet an ignition source.
- Vapour will not ignite spontaneously.
- RISK – vapour will ignite if it reaches ignition source.

LNG Fire

- If ignition occurs:

- In a flash, the flame will burn back to the source of the leak.
- Fire will continue until source of leak is secured.

LNG Fire

- Pool Fire:
- Accumulated liquid from spill
- Unlikely to occur on deck of ship.
- On shore, liquid can pool into large quantities.
- Contain the pool to prevent spreading.
- If vapour is present, it may ignite and create a pool fire.

LNG Fire

- BLEVE:
- Boiling Liquid Expanding Vapour Explosion
- Associated with storage of liquefied gas in pressurized containers (tanks)

LNG Fire Fighting

- When liquid gas fire is present, follow these procedures:

- Sound the alarm.
- Determine source of fire.
- Execute the emergency plan of action

LNG Fire Fighting

- A rough guide:
- Isolate and contain the source of the fire.
- Cool surfaces under radiation or encroaching flames with water.
- Control and extinguish fire with appropriate equipment.

LNG Fire Fighting

- Generally accepted fire extinguishing methods, if used appropriately:
- Water
- Dry chemical powders
- Foam
- Inert Gas and carbon dioxide

LNG Fire Fighting

- Water:
- Do Not use water on a burning liquefied gas pool.
- Use of water increases the vaporization of the liquid gas.
- Use of water increase the rate of burning.

LNG Fire Fighting

- Dry Chemicals:
- Very effective in suppressing small gas fires:
- Sodium bicarbonate
- Potassium bicarbonate
- Urea potassium bicarbonate

LNG Fire Fighting

- Dry Chemicals:
- Bring the fire under control by vapour dispersion then use dry chemicals to extinguish the flames.
- LNG carriers are required by the IGC to have fixed dry powder systems.
- The system should reach above-deck exposed cargo areas using hand hose lines a or combination monitor/hand hoses.

LNG Fire Fighting

- Dry Chemicals:
- Adjacent hot surfaces should be cooled with water before extinguishing the flame with dry chemicals.
- After extinguishing the fire, cool the adjacent surfaces with water.
- Customarily, jetty manifold spaces are protected by portable or fixed powder systems.

LNG Fire Fighting

- Foam:
- Foam systems suppress fire by separating the fuel from the air.
- Use high expansion foam to flood the surface of the burning pool (confined area) to suppress radiation and reduce rate of vaporization.
- After vapour is dispersed, use dry chemicals to extinguish flames.

LNG Fire Fighting

- Foam:
- Can reduce the horizontal range of the gas clouds of a confined pool.
- Increases the vapour's buoyancy due to heat input from the foam.
- May increase the vaporization rate as it diffuses into the liquid.

LNG Fire Fighting

- Foam will not extinguish a liquefied gas fire.
- For liquefied gases, foam should only be used in confined areas.
- Usually only found at terminals and is generally not provided on gas carriers.

LNG Fire Fighting

- Inert gas is a non-reactive gas under particular conditions used on gas carriers and in terminals to prevent explosions:

LNG Fire Fighting

- Cases of fire, especially those based on LNG, are obviously dangerous
- Any type of incident can be successfully managed/resolved if the basic principles are well understood.
- Prevention is crucial, with measures such as using the proper/right type of equipment and training in all available scenarios holding a pivotal role.

LNG Fire Fighting

- Display fire fighting plans and muster lists

- Training program should ensure that employees understand these procedures.

Accessing the Hazard

- LNG Vaporizes and causes condensation of atmospheric moisture - visible cloud
- As LNG Vapour cloud warms it lifts
- Water is a superior heat source compared to solids.
- Spills on water tend to vaporize rapidly creating a potentially combustible plume (cloud) that migrates until :

  a.) the LNG Source is exhausted.

  b.) dilution by air reduces the concentration below the lower flammability limit.

Accessing the Hazard

- An ignition source close to the origin of the spill (if any) is likely to cause ignition and result in result in rapid burn off of the natural gas vapours.

- Absence of an ignition source would result in a cloud that could migrate down wind for a long distance.

- A remote ignition of the cloud in the flammable portion of the vapour cloud would result in relatively slow burn back to the area of the spill.

PPE and Hazard Prevention

Recommended Personnel Protective Equipment:

- Cryogenic Gloves
- Face shield
- Closed shoes or boots
- Long sleeve shirt and long pants recommended.

Hazard Prevention:

- Follow recommended operating and maintenance procedures.
- Use Personnel Protective Equipment
- If there is a leak, avoid direct contact.
- Don’t handle cold hoses and piping without proposer gloves.
- Keep ignition sources away for tank and piping. No smoking.
- Perform vehicle maintenance in proper area.

Preventive Measures

- Proper grounding to avoid static electricity build up and lightening hazard (procedures to be in place for this)
- Use of intrinsically safe electrical installations and non – sparking tools
- Implementation of permit systems and formal procedures for conducting any hot work during any activities, including but not limited to tank cleaning, venting etc.
- Application of Hazardous areas zoning for electrical equipment in design.

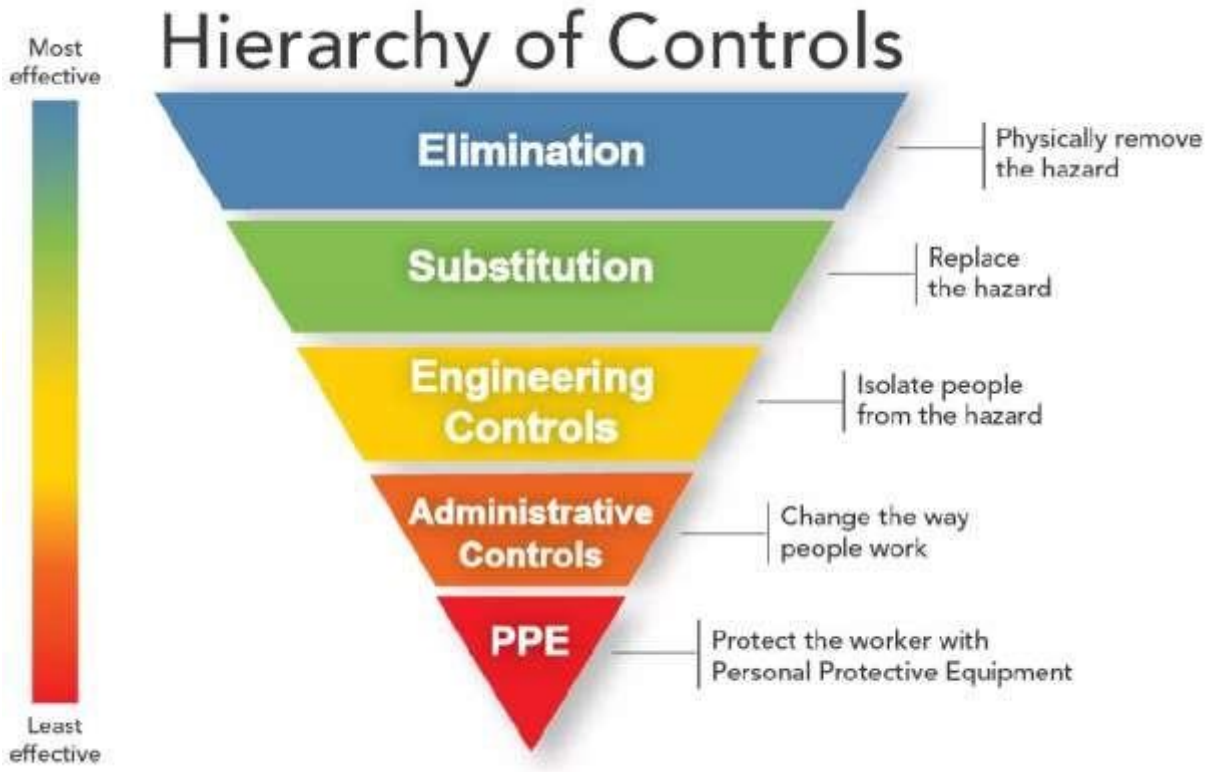
First Aid Measures

- **First Aid –**
  - Treat methane burns as other types of burns.
    - cool affected area, bandage if necessary, and seek medical assistance.
    - Treat frostbite by warming slowly (do not run) and seek medical assistance.
    - Treat asphyxia by providing fresh air, rescue breathing if necessary, and seek medical assistance.
    - Seek medical assistance for eye injury caused by LNG.

LNG – Safety System

- Emergency Shut Down System
- Manual reset only
- Fire Detectors
- Methane Detectors
- Emergency Stop Buttons
- Emergency Shutdown Valves
- Remove electrical power from all LNG equipment
- Auto dialler or fire alarm control panel
- Dispenser flow limits

SAFETY - What can we do.....




Thank
you!!