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on

LNG VALUE CHAIN & REGASIFICATION TERMINAL

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Abhay Pal

Ankit Singh Negi

STUDY OF LNG VALUE CHAIN AND RE-GASIFICATION TERMINAL

A dissertation submitted in partial fulfillment of the requirements for the Degree of

Bachelor of Technology

(Applied Petroleum Engineering)

By

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College of Engineering
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CERTIFICATE

This is to certify that the project work on **"LNG VALUE CHAIN AND RE-GASIFICATION TERMINAL"** submitted to the **University of Petroleum and Energy Studies**, Dehradun, by **Abhay Pal & Ankit Singh Negi** in partial fulfillment of the requirement for the award of degree of **Bachelor of Technology** in **Applied Petroleum Engineering**, (Academic session 2006-10) is a bonafide work carried out by them under my supervision and guidance. This work has not been submitted anywhere else for any other degree or diploma.

Mr. Uma Shankar

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ABSTRACT

In this project we'll be studying about the LNG value chain and about the LNG terminal, that is, we'll discuss about how natural gas is explored and produced and how its value increases at each step of the process till it reaches its consumers in the form of natural gas. The processes involved which are needed to be studied here are upstream exploration and production, liquefaction plant, LNG storage terminal, shipping, LNG re-gasification terminal and finally to the pipeline system from where it reaches the consumers.

Here we'll also discuss about various activities and the equipments (installations) which are present in the LNG re-gasification terminal. The various equipments and installations covered will be Pumps, Recondenser, Vaporizers, Compressor and the Storage tanks that form the part of a LNG terminal. While discussing the LNG terminal , main focus will be on the whole process that is carried out at the terminal from the time the vessel which is carrying the LNG comes , till the time LNG is re-gasified into natural gas and sent to customers via already existing pipeline system.

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Chapter 1: Introduction to Liquefied Natural Gas

1. Introduction to Liquefied Natural Gas

1.1 Basic Facts:

Liquefied natural gas or **LNG** is natural gas that has been converted to liquid form for ease of storage and transport.

LNG (Liquefied Natural Gas) is natural gas that has been extracted from subsurface reserves and then cooled. Natural gas has been used for very long time for both domestic and business purposes. Now LNG made it much more easier just because of its properties.

LNG offers an energy density comparable to petrol and diesel fuels and produces less pollution, but its relatively high cost of production and the need to store it in expensive cryogenic tanks have prevented its widespread use in commercial applications.

The liquefaction process involves removal of certain components (such as dust, helium, or impurities that could cause difficulty in downstream, e.g. water, and heavier hydrocarbons) and then condensed into a liquid at close to atmospheric pressure (1 atm) by cooling down it to approximately -161 ^{0}C. LNG is transported in specially designed cryogenic sea vessels or cryogenic road tankers; and stored in specially designed LNG tanks. When natural gas is cooled down to -161 ^{0}C, it condensed & turned into liquid. Due to phase change its volume is reduced to 600 times of its initial volume, making it much more cost-efficient to transport over long distances where pipelines do not exist.

Conditions required to condense natural gas depend on its precise composition and the requirement of the buyer but typically involve temperatures between −120 and −170 °C and pressures of between 101 and 6000 kPa.

The density of LNG is roughly 0.41 to 0.5 kg/L, depending on temperature, pressure and composition.

The heating value of LNG is estimated to be 24 MJ/L at -164^0C. The natural gas fed into the LNG plant will be treated to remove water, hydrogen sulfide, carbon di-oxide and other components that will freeze (e.g., benzene) under the low temperatures needed for storage or these will be destructive to the liquefaction facility. Purified LNG typically contains more than 90% methane. It also contains small amounts of ethane, propane, butane and some heavier alkanes. The purification process can be designed to give about 100% methane.

When regasified in a receiving terminal, LNG becomes a very clean and reliable natural gas source to meet consumer's growing need for low-emission energy. LNG is colourless, odourless, non-corrosive and non-toxic.

1.2 LNG Trade

Trading of LNG is done all-over in the world by shipping & these ships are specially designed to carry cryogenic liquid. The trade of LNG is completed by signing a sale and purchase agreement (SPA) between a supplier and receiving terminal, and by signing a gas sale agreement (GSA) between a receiving terminal and end-users. Most of the contract terms used to be DES or Ex Ship, which meant the seller, was responsible for the transportation, insurance and freight to the tankers. Another contract terms is FOB, under which the buyer is responsible for the transportation and insurance of the tanker.

The agreements for LNG trade used to be long-term and were relatively inflexible both in price and volume.

Exporters of Natural Gas:

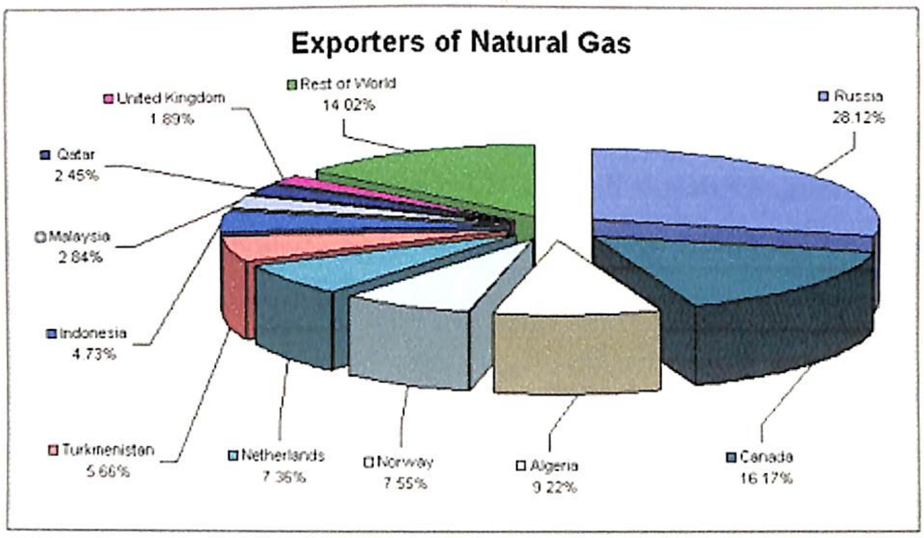


Fig.1.1:-Exporters of Natural gas.

Importers of Natural Gas:

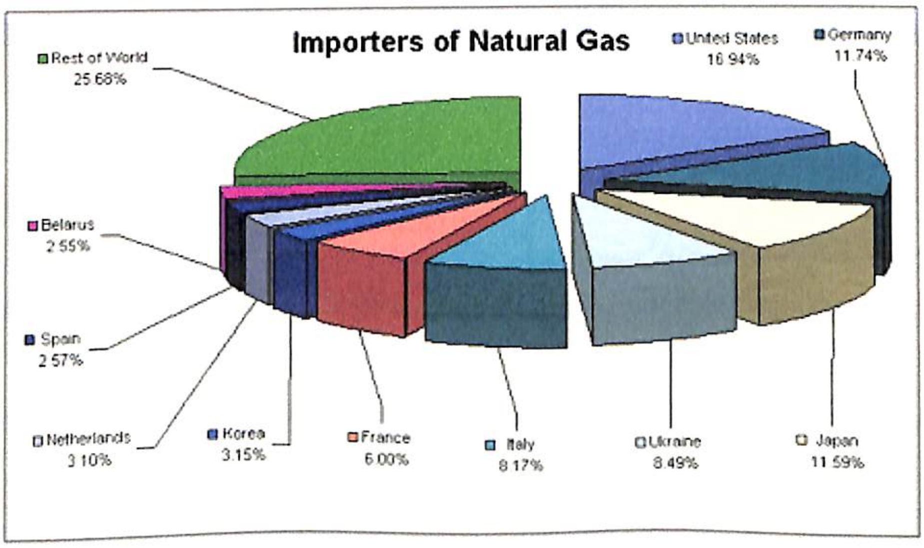


Fig.1.2:- Importers of Natural gas.

1.3 LNG: Environmental Concerns

Natural gas can be referred as the most eco-friendly fossil fuel in nature, because it emits lesser CO_2 unit of energy and also used in power generation. Because of the energy required to liquefy and to transport it, the environmental performance of LNG is inferior to that of natural gas, although in most cases LNG is still superior to alternatives such as fuel oil or coal. This is particularly so in the case where the source gas would otherwise be flared.

LNG is colourless, odourless, non-corrosive, non-toxic and clean fuel. It is beneficial among the other fossil fuels because of its properties. Coal and oil produces more harmful substances because of their complex molecular structure. They also emit carbon dioxide, nitrogen and sulphur oxides which are the primary source of pollution and these primary pollutants can arise secondary pollutants which will result in acid rain, ozone depletion which are harmful to people and the environment.

All around the world, natural gas is increasingly being used to generate electricity, in order to reduce the emission of harmful gases (such as CO2) and to improve air quality.

1.4 LNG: Safety and Accidents

LNG is a safe fuel and it is not explosive when it is in liquid state because of its very low temp (-161 ^{0}C). For explosions to occur with LNG, it must first vaporize, then mix with air in the proper proportions (the flammable range is 5% to 15%), and then is ignited.

When LNG is stored in the storage tanks, the tanks does not contain air because LNG ignited when come in contact with air. When LNG is released into open air and turns into a gas, it can burn because of the oxygen present in the air. Because of the evaporation dispersion characteristics, the gas is only flammable within certain limits.

Major LNG accidents:

- **20 October 1944, Cleveland, Ohio.** The East Ohio Natural Gas Company experienced a failure of an LNG. 128 people perished in the explosion and fire. The failure is because the tank did not have any bermed area or any dike wall. Tank steel contained less than 9% steel, due to which it made the tank brittle when exposed to the extreme cold of LNG and the tank damaged. More than 100 people affected by the spillage.
- **February 1973, Staten Island, New York.** No LNG is involved in this accident. This accident takes place during construction of LNG storage tank. During welding, fire started & increase the inside pressure of tank which leads the concrete dome to lifted up and then collapsed falling inside the tank and killing the 37 construction workers below.
- **October 1979, Lusby, Maryland.** In LNG plant a pump seal failed which results in the vapour deposition on an electrical conduit. When the circuit is switched-off, it igniting the gas vapours. Only one man is killed in that accident but that building id fully damaged. After the accident, National fire codes had been changed.
- **19 January 2004, Skikda, Algeria.** In this accident more than 20 people was killed & about 80 was injured. Yearly production was goes below 76%. Due to leaking of cold hydrocarbon, the gases were drawn into the combustion air for a high-pressure steam boiler and results in an explosion.

LNG ships and tankers have not had a major accident in over 47,000 voyages since maritime inception in 1959. Some tankers got little scratched but not results in any major accident.

Chapter 2: LNG Value Chain

2. LNG Value Chain

LNG value chain consists of four major parts beginning from exploration & production, secondly liquefaction of natural gas, followed by shipping of LNG & finally regasification and storage of LNG

The feed gas is come from gas field and then first passes through field processing unit (condenser), condensates are then removed. After that gas is treated in liquefaction plant in which pre-treatment is done and impurities is removed. Mainly acid gas is removerd. Then the gas is dehydrated and natural gas liquids are removed. In liquefaction process it is sent through three cooling processes until it reaches a final temperature of -163 ^{0}F.

LNG is then sent for storage in specially designed storage tanks. From there LNG is loaded on the ship tankers and sent to receiving terminals.

At the receiving terminals, LNG is offloaded to the storage then and then forwarded for regasification process.

Regasified LNG when comes to normal state then transported by pipelines and road tankers to consumers, power plants and industrial customers across the country.

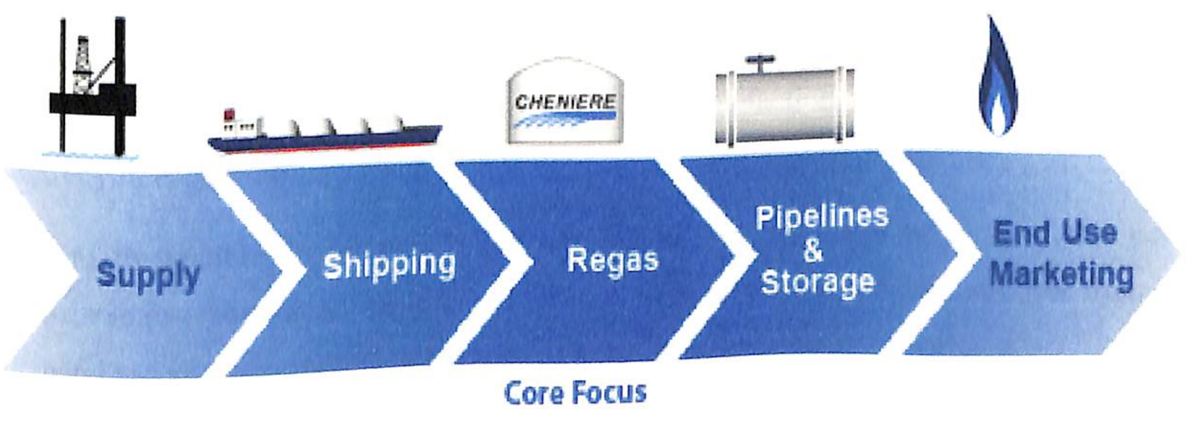


Fig.2.1:-LNG supply chain.

The various components of LNG value chain are:

- Gas Field
- Gas Treatment Plant
- Gas Liquefaction Plant
- Gas Transportation
- Re-gasification Terminal
- Re-gasification LNG In-land Terminal
- LNG In-land Transportation by Road Tankers

2.1 Gas Field

LNG liquefaction and regasification plant is established on a long term contract basis in which gas is reached the plant according to the contract and requirement, which then after liquefaction sent to the buyers. For a 5 MMTPA capacity LNG plant, a minimum 5 TCF proven gas reserves has to service the plant for 20 years as a thumb rule. The best design of the present time calls for a twin train LNG liquefaction plant from 5-8 MMTPA capacity of each train.

Due to fluctuations in oil prices, the production may vary and because of this non-associated gas reserves are priorities. LNG production remains constant and free from oil demand and its price variations because of long term agreement.

Gas supplied to the plants is costs according to its low value in upstream and does not depend on the current market value of gas.

2.1.1 Gas Reserves

Most of the proven gas reserves are situated in countries like Russia, Qatar, Saudi Arabia, and UAE. These reserves are much far from the consuming countries. LNG plays a vital role in upbringing of this natural gas to the consuming market. Since LNG is transported in liquid form makes it more economical in nature.

2.1.2 Rapid Growth: LNG

LNG gains its importance in gas market. The LNG market is globalizing very fast, and distinct regional markets are becoming interconnected. LNG growths depend on rising of compressed gas applications in market or natural gas dependent appliances. It is also been appreciated to make less dependent on oil lobbying countries.

Some major factors for the growth of LNG:

- Monetizing marginal gas fields which might be uneconomical to transport in gaseous state.
- Offshore source locations which might be uneconomical to transport in gaseous state.
- Technological development in processing of LNG.
- Secure long term market presence for Natural Gas.
- Environmental awareness.

2.2 Gas Treatment Plant

Gas treatment plant consists:

Dehydration, Water treatment & disposal, Gas sweetening, CO_2 removal, Mercury etc. removal, higher hydrocarbon removal and condensate treatment.

H_2S and Sulphur is removed from the gas to make it sweet. Carbon do oxide is removed from the gas. Water content from the gas has to be removed such that it causes difficulty and also cause corrosion. Heavier hydrocarbons also cause difficulty in downstream.

2.2.1 Technology

All above process gas sweetening, carbon di-oxide removal, dehydration applicable according to their need and availability. LNG cannot be specifically having any significance. Dehydration and CO2 removal is very much important because they form ice due to cooling of feed gas and creates problem.

2.2.2 LNG Liquefaction Plant

Successive cooling till liquefying all components of the feed gas produces LNG. The feed gas to LNG plant may be the non-associated gas (what is mostly the case) or a mixture of non-associated gas and associated gas.

Sulphur compound in excess of (30 ppm) total and H_2S alone up to 5 ppm may create corrosive components specially when coming across water vapours in the feed gas.

Nitrogen and other inert gas, though normally do not create any harmful effect on the process or equipment but they do not contribute any heat value to LNG. Therefore, the energy spent in cooling such components and again in re-gasifying goes as waste, thus making both liquefaction and re-gas process less cost effective.

All the components present in the feed gas have influence on liquefaction process. The solubility liquefaction temperature and other characteristics influence the liquefaction process.

Water vapour is another constraint in raw feed gas which needs be removed such that the water due point becomes more than (-) 80°C. Like CO_2, water vapour gets crystallized at much higher temperature than LNG final temperature, and creates possible chocking of the heat exchangers deployed in liquefaction process.

A trade off is therefore required to be worked out as to what extent these elements be removed from the raw feed gas. Normally 1% (max) by mole would be enough to limit such elements.

Mercury, even present in traces can cause corrosion of aluminium heat exchangers employed in liquefaction process, if it come across free water. Mercury removal is recommended to avoid corrosion.

Aromatics: The presence of Aromatics in LNG feed gas creates congealing of the heat exchangers due to solidification of the aromatic compounds. The permissible limit of aromatics is therefore very low to the extent ≤ 2 ppm in LNG feed gas. The MP & BP of important components of LNG feed is given in the table.

Amount of impurities allowed in LNG:

Impurity	**Allowable limit**	**Limiting criterion**
Carbon dioxide	< 50 ppm (vol)	Solubility
Water	< -73°C dew point	Solubility
Hydrogen Sulphide	< 5 ppm (max)	Product specifications
Mercury	< 5 mg (SM^3)	Corrosion
Aromatics	< 2 ppm (vol / max)	Solubility

Table 2.1:-Allowable limits of impurities in LNG.

LNG composition:

Constituent	Mol %	Boiling point (^0C)	NCV (Kcal/SCM)
Methane	94.5	-161.5	8092
Ethane	4.5	-88.6	14403
Propane	0.5	-42.2	20598
Butane	0.2	-10.0	26697
Heavier HC	0.2	-0.5	
Nitrogen	0.05	-195	0

Table 2.2:-Typical specification for LNG.

2.3 Liquefaction Technology

It includes the process used to convert the gas feed to liquid form under cryogenic temperature and pressure. It also includes the removal of impurities such as dust, acid gas mercury and others. Heavier hydrocarbons are also removed because they creates problem in downstream. They are:

1. Precooling cycle
2. Mixed refrigerants cycles or subcooling cycle

Since the end use of these technologies is production of LNG from the feed gas, all commercially available liquefaction processes therefore operate over the same temperature range i.e., from ambient to -163°C. The treatment of the feed gas is also same for all the processes.

The commercially developed technologies are described below:

2.3.1 APCI Technology

The treated feed gas enters the main pre-cooling section of the liquefaction train where the remaining hydrocarbons are removed in a scrubber column, which also provides sufficient LPG for refrigerant make up in addition to direct merchant sale. The separation column separates the ethane, propane, butane, pentane etc. In addition, the refrigerant (ethane and propane make up) is recovered as a separate sub-product. Each fractionation train has a de-ethanizer, de-propanizer and de-butanizer column.

The pre-cooling refrigeration is provided by multi-stage propane refrigeration system operating at minimum temperature of -37°C. The propane refrigeration is also used to partially condense the multi component refrigerant system and various cooling duties in the fractionating trains. Vapours from various stages of fractionation propane evaporation are compressed in a multi stage centrifugal compressor. The compressor discharges de-super heated and condensed using either seawater or air-cooling. The condensed refrigerant is then expanded to various pressures and temperature levels of refrigeration. The scrubber power overhead enriched in the C_2 + fraction is liquefied and sub-cooled in a heat exchanger with a circulated multi component refrigerant system consisting of nitrogen, methane, ethane and propane.

Heat transfer occurs in a single spiral wound heat exchanger called the main cryogenic heat exchanger (MCHX). This is the heart of the process and is supplied by APCI themselves. The mixed refrigerant system is pre-cooled to -34.5°C using propane refrigeration prior to entering MCHX. Low pressure mixed refrigerant leads the MCHX at about -37°C and is compressed to 44 Kg/Cm^2 in a multi stage compressor. Inter cooling is provided between various compression stages, a common driver is used for both stages of compression. Sub-cooled liquid natural gas leaving MCHX is flashed to storage tank pressure. The vapour and liquefaction fractions are separated. During pressure let down, nitrogen is preferentially rejected to the vapour ventures. The nitrogen enriched flashed vapours are compressed after refrigeration recovery and sent to plant fuel system.

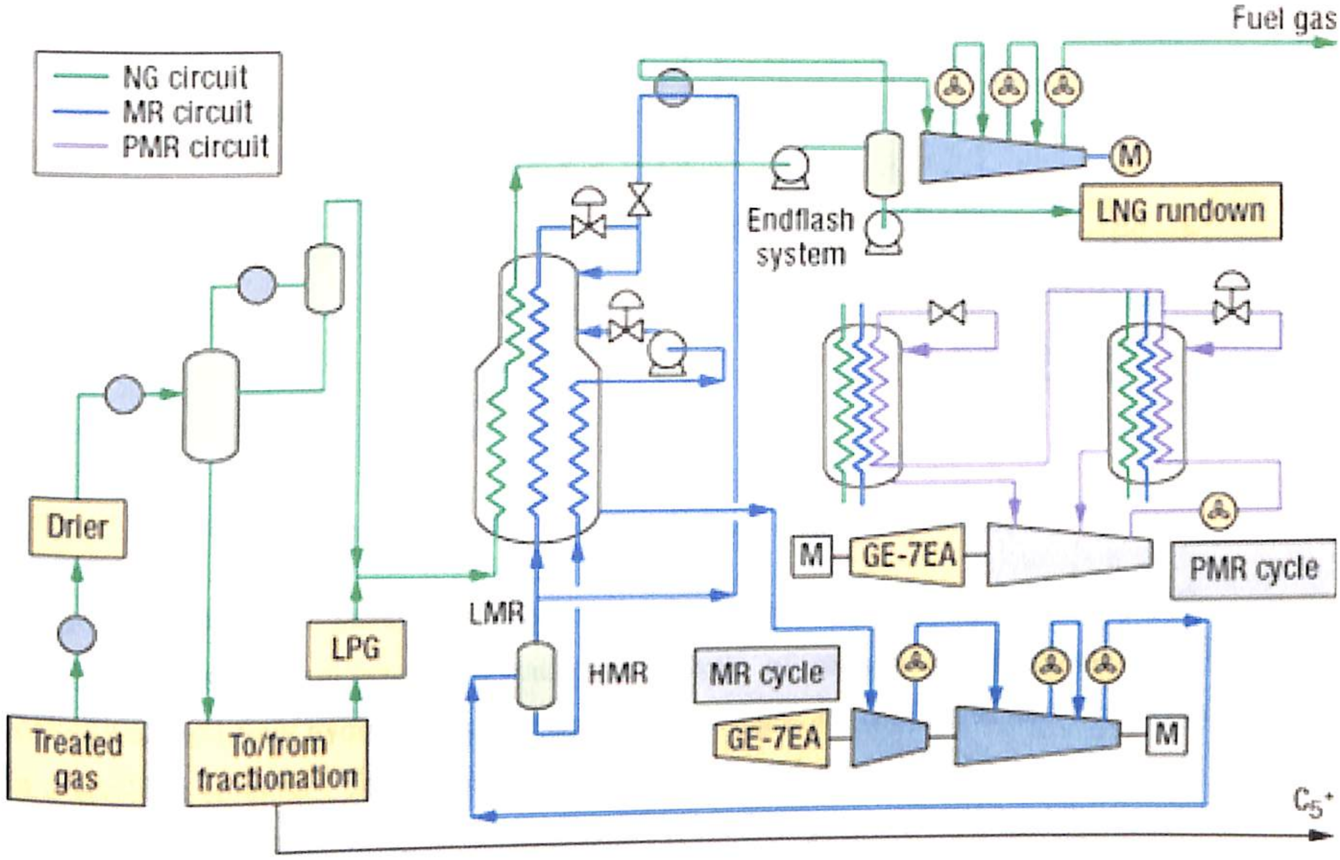


Fig.2.2:-Flow diagram for APCI propane cooled process.

2.3.2 Optimized Cascade Process - Phillips

In this process LNG is produced by cascade refrigeration system using propane, ethylene and methane as refrigerants. The propane and ethylene are closed loop refrigerant systems circulated a single component refrigerant. The methane refrigeration circuit is an open loop system with flushing of feed gas to successfully low pressure and re-compression and re-circulation of the flush and vapour. The process flow diagram is shown below with the simplification with methane circuit shown as closed loop.

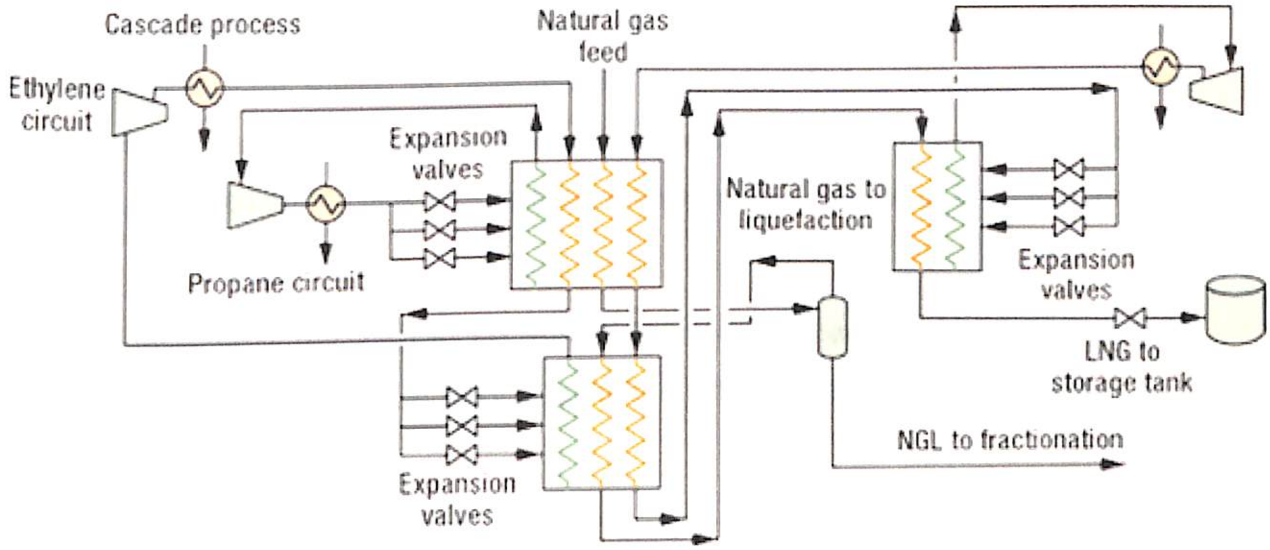


Fig.2.3:-Flow diagram for Phillips simplified cascade process.

The high pressure feed gas after treatment is cooled to a temperature of - 30°C to 35°C through successive heat exchange with three levels of propane refrigeration. The majority of the heavy hydrocarbons present in the feed gas are condensed and recovered in a scrubber column. The condensate is withdrawn and fractionated for recovery of higher hydrocarbons including LPG vapours or each of the propane vaporized flow back to propane compressor. After compression, the vapours are cooled and condensed with cooling water (sea or surface or air) before returning to feed cool circuit.

The feed gas leaving scrubber column is further coupled with ethylene refrigeration and there after it joins with methane rich re-cycle vapours from methane refrigeration system. The combined system is cooled and totally condensed in heat exchanger. Vapours from ethylene evaporators are re-heated to near ambient temperature and economizer heat exchangers before entering the ethylene compressor. High-pressure ethylene leaving compressor is coupled with cooling water / air and both high and intermediate level propane before being totally condensed using low-level propane refrigeration. The condensed feed gas methane re-cycle stream leaving the low stage ethylene evaporator is sub-cooled and economizer heat exchanger and flashed to reduced pressure. The nitrogen rich flashed vapours are re-heated and sent to plant fuel system. Liquid from the flush system is brought to atmospheric pressure in three successive stages. Vapours from the successive flash stages are re-heated in economizer before entering the methane refrigeration compressor. LNG produced from low stage flush is pumped to storage. Vapours produced due to tank heat leak are recovered and brought to low pressure flush circuit.

Re-cycle methane refrigerant vapours from discharge of the compressors are successfully cooled with cooling water; high stage propane and returning methane flush vapour

2.3.3 BHP's Expander Process:

This process utilizes the thermodynamic principle that the near isentropic expansion of fluid extracts work and in equivalent amount of heat from a closed system. Expander cycles for production of LNG have been successfully employed in a much smaller LNG peak saving type plants. The expansion cycle fluid either natural gas in an open cycle or nitrogen in a closed loop system is compressed cooled and expanded to near atmospheric pressure. The cold low-pressure expansion cools and liquefies the high pressure feed gas. The BHP process achieves improved thermo dynamic efficiency by using of a second cold expander to provide the lowest level of refrigeration in place of the Joule Thompson used in single stage process. Work recovered in their turbo expander is used to drive the boost, the second stage of expansions gas compression. The improved thermo dynamic efficiency with this turbo expander reduces the power consumption by 25%. The expander process is less efficient when compared to propane mixed refrigerant cycle to the extent of 15 – 35%. The process is similar to one used for air liquefaction where nitrogen and oxygen are separated in the liquid form.

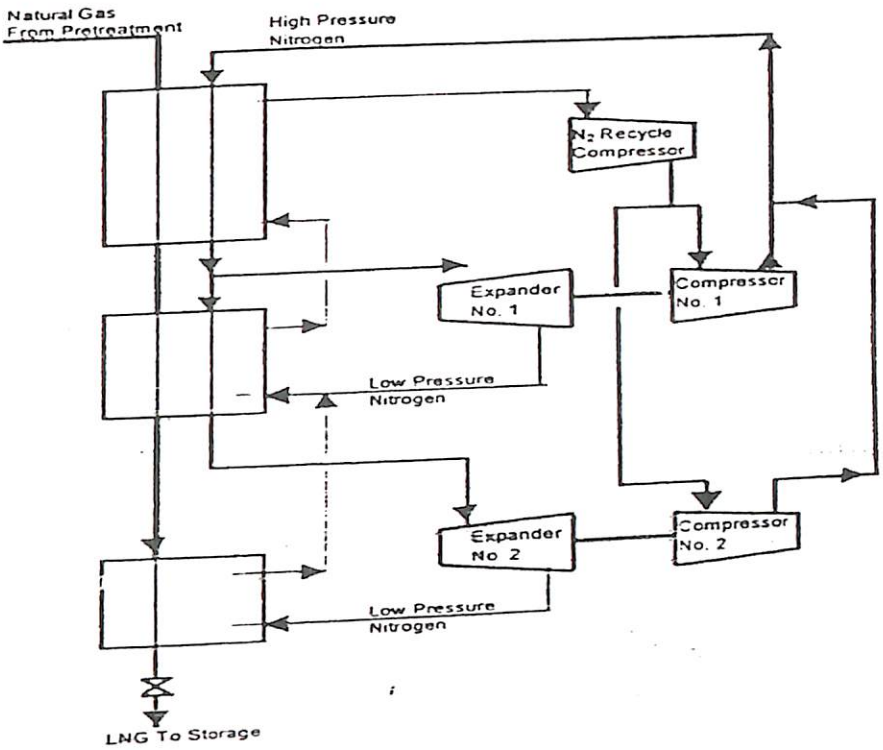


Fig.2.4:-Flow diagram for BHP nitrogen expander process.

2.3.4 Combined Mixed Refrigerant / Expander Process – Chiyoda

Chiyoda Corporation has recently patented a combined all mixed refrigerant expander LNG process. All heat transfer is accomplished in aluminium plate – fin heat exchangers. High pressure LNG leaves the MCHX at a relatively warm temperature compared to the pre-cooled mixed refrigerant processes. The high pressure LNG is reduced in pressure through to stages of liquid expansion. The first stage uses an axial type turbo expander followed by a second stage re-connection type hydraulic turbine. The large amount of flash gas produced on pressure let down is re-heated and re-compressed to incoming feed gas pressure using power generated by the turbo expanders.

2.3.5 Major Components of the LNG Liquefaction Plant:

1. **Heat Exchangers:** fin-plate, Shell type tube, spiral wound heat exchangers are used.
2. **Compressors / Steam Turbine Drivers:** centrifugal compressors are used for refrigeration process. Steam turbines are more efficient as it provide flexibility in design. Operation and maintenance cost is high.
3. **Gas Turbine Drivers:** It is simpler in design and has been preferred over any compressor. More fuel efficient and have low maintenance cost.

2.3.6 The recent trends in the development of technology based on high efficient equipments:

1. Economy of scale of liquefaction: With the initial LNG train of less than 1 MMTPA have successfully found switching to higher train size for achieving economy scale. Today, the train size of 5 MMTPA is very common and attempts have also been made to increase the train size up to 8 MMTPA.
2. Use of gas turbines for power generation reduces the cost of power per unit.
3. Refrigeration compressor drive changes to gas turbine improve efficiency of the refrigeration.
4. Improved equipment design time between schedule maintenance has increased thereby achieving higher on-stream days.
5. Changes from dual shaft gas turbine to single shaft gas turbine increase fuel efficiency by 10 – 15%.
6. Certain single shaft gas turbines could be directly coupled to the refrigerant compressor thereby eliminating the requirement for reduction gear which saves the power loss.

7. Change from large number of small gas turbines to less number of higher frame gas turbines to achieve better efficiency.

8. Instead of each compressor having a dedicated connected gas turbine; two compressors can be connected to a single gas turbine. This combination of single shaft turbine (replacing double shaft engine) improves efficiency by 15 – 25%. In mid 1990s, Air Products introduced split MR machinery configuration that allows two large frame, equal power, and single shaft gas turbine to be fully utilized and make more efficient use of the capital invested. The two MR compressor casings are connected to one turbine and a third is on the same shaft with the propane compressor connected to second turbine.

9. Improved compression technology resulting in the higher polytrophic efficiency requiring lower refrigeration power per unit of production.

10. Use of drive phase seal reduces compressor seal leakage.

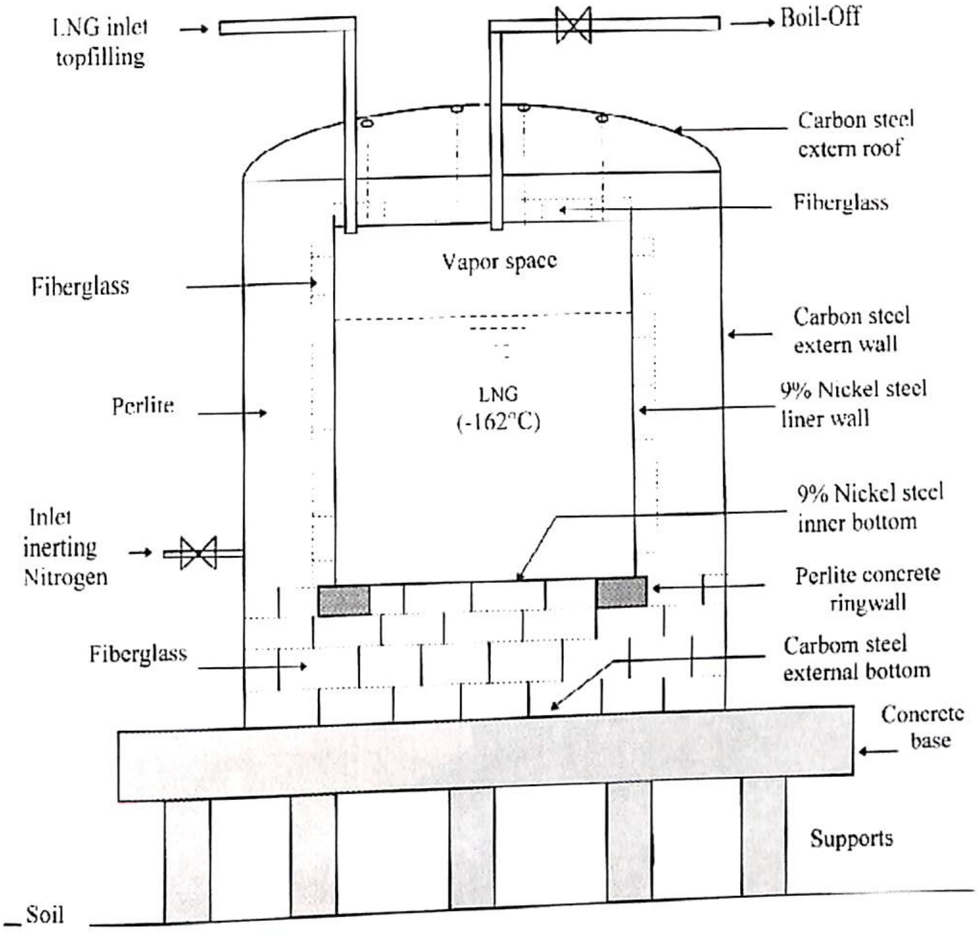
2.4 LNG Storage

LNG storage facilities are also another important part in the LNG value chain. Storage facilities are required at both the locations, i.e., at the LNG liquefaction plant as well as the re-gasification plant. Cost for LNG storage tanks are almost 10% of the total cost of the whole plant.

Basic types of LNG storage tanks:

1) Above ground
2) Underground.

Commonly all LNG plants have above ground storage tanks. The underground LNG storage tanks have been used in Korea & Japan because there required spaces for tanks are not



available.

Fig.2.5:-General view of a LNG storage tank.

2.4.1 Full Containment Tank:

It consists of two complete LNG storage tanks. The main inner tank & outer tank. The main inner tank is constructed of 9% nickel steel and is surrounded by an outer concrete wall. The annular space between the two tanks is filled with insulation & also controls venting of vapours. Roof of outer tank is provided with insulated suspended deck & it is fully insulated. Roof is made up of concrete & loosely filled with insulation so that it withstands high pressure & low temperature. If in any case inner tank is fail to contain liquid & gas, the outer tank is capable of containing both liquid and vapours. The outer wall may be pre-stressed concrete wall with liner. In this type of tank possibility of slippage of LNG is minimum.

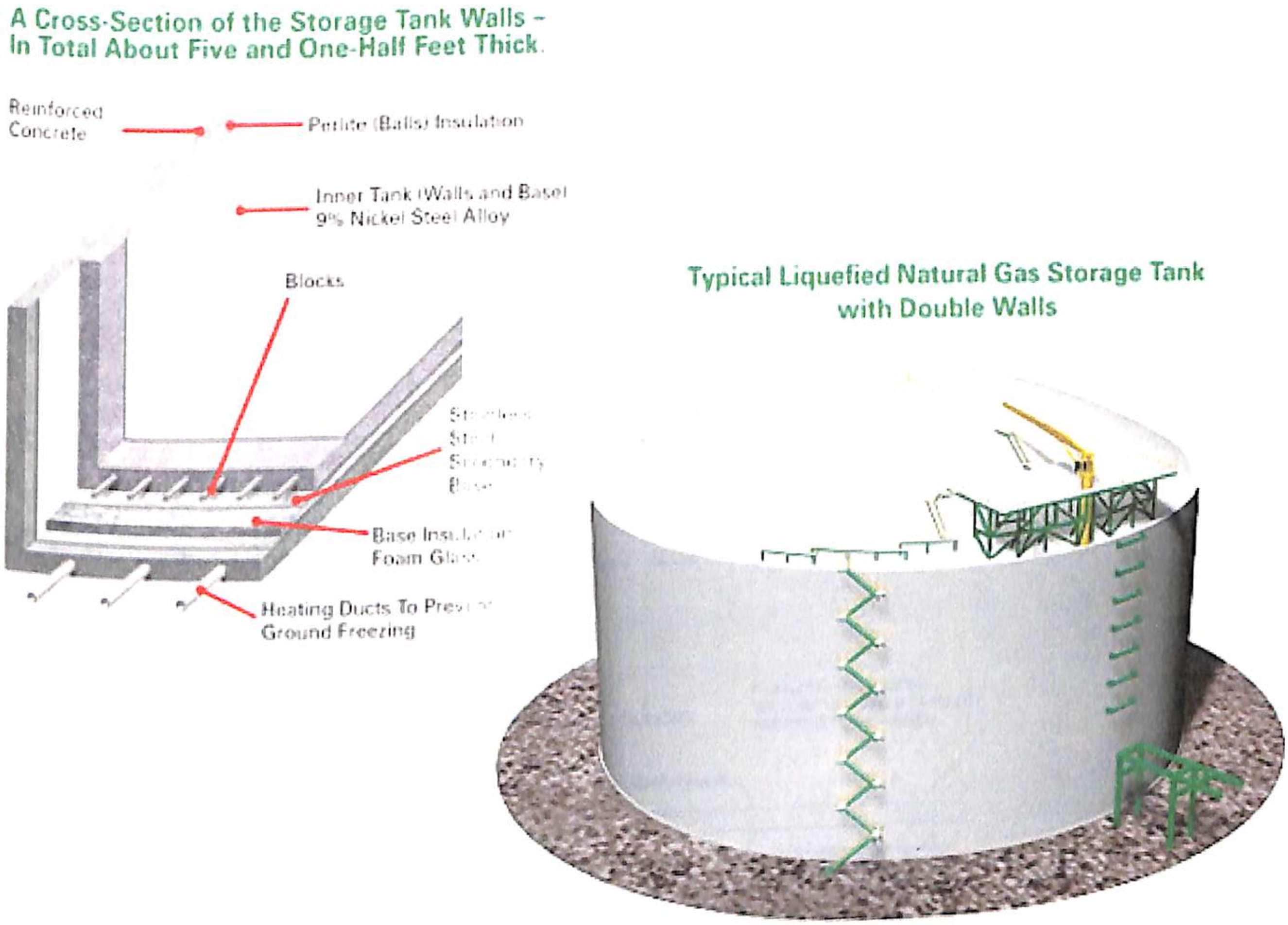


Fig.2.6:-View of cross section of walls of the LNG storage tank

2.4.2 Double Containment Tank:

This type is used when the land available is limited. These tanks are similar to full containment tanks. The inner tank structure is same but the outer tank is made up of pre-stressed reinforced concrete design. The annular space between the two tanks is filled with perlite insulation. Outer wall or dyke is capable of containing liquid in case of any failure of main tank but it cannot able to contain vapours. The roof of the outer tanks is of carbon steel and it is suspended insulated deck. A high degree of tank safety is achieved with this design, but with higher boil-off gas.

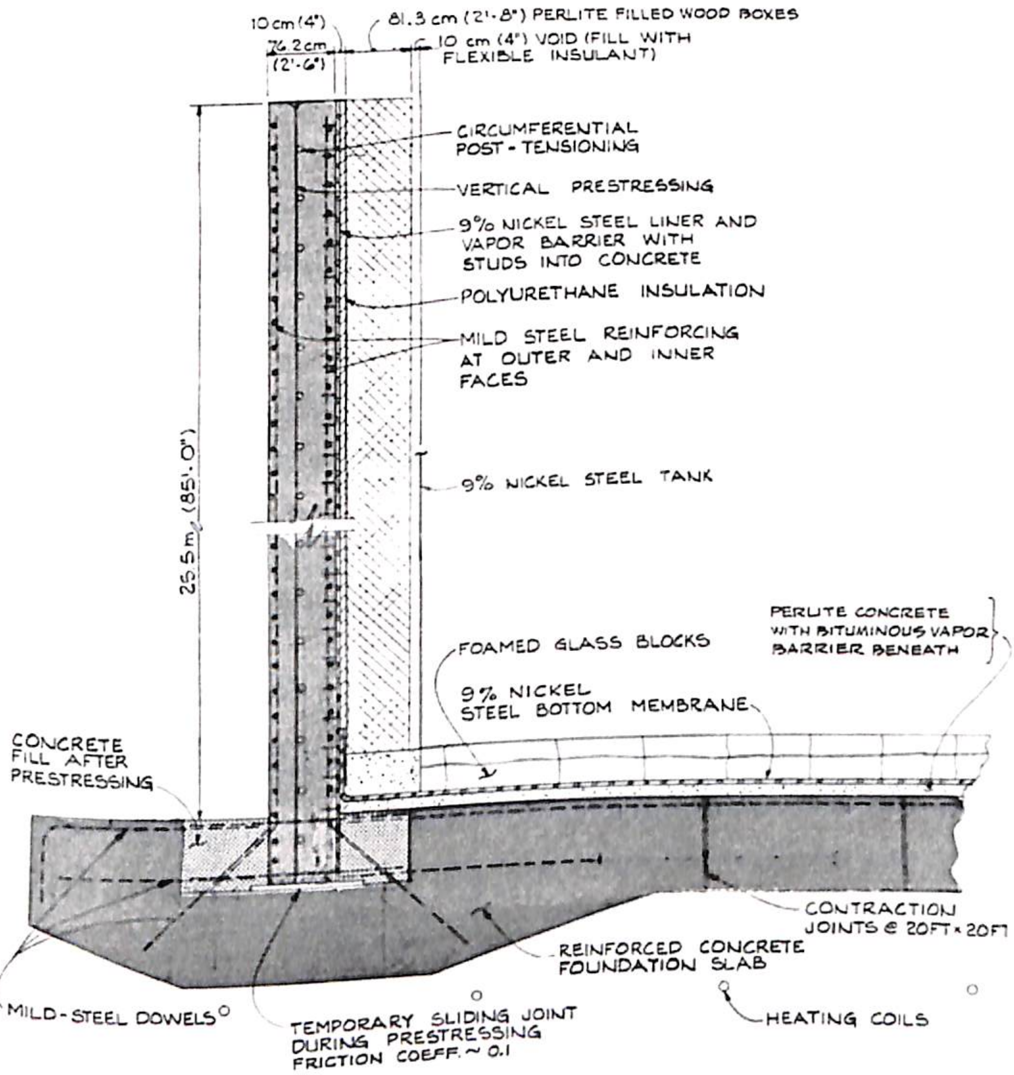


Fig.2.7:-Detailed design of LNG storage tank.

2.4.3 Single Containment Tanks:

Single containment refer to open top inner tank made of 9% nickel steel , with carbon steel outer tank. In this type of tank, the main inner tank is capable of containing the LNG. The carbon seal outer compressor protects the insulation around the outside of the cryogenic storage tank. In any case of the inner tank failure, the outer tank cannot contain the LNG and there will be liquid spillages to the area around the tank. This type of tank must have external secondary containment in the form of bermed area with sufficient capacity. The bermed area is so designed that it will contain at least the same amount of volume that is contained by the tank. The liquid is retained by that area in order to keep it safe from potential hazard of the burning liquid.

Cost-wise comparison of these three designs is 5: 8: 9 for single containment, double containment and full containment. Full containment tank costs double than single containment tank.

2.4.4 Storage Volume

The total volume of any LNG plant is determined by its daily production capacity & the number of storage tanks it has. However, the minimum LNG storage capacity is stated by the size of the ship or shell exported from liquefaction plant / imported to re-gasification plant.

LNG storage volume will also depends on the space availability on the plant, climatic condition in that area and most important, demand of LNG in that area. Size of tanks will also affect the total storage volume. LNG storage tank capacity varies from 75000 M^3 to 135000 M^3 to now 200000 M^3 capacities.

2.5 LNG Ship Transportation

Transportation of LNG is done by shipping. LNG transportation is a specialized job. The cryogenic tank design basically has two versions. The first one is a membrane design which utilizes the complete hull of the ship in a rectangular cryogenic storage tanks 36% nickel steel SS 304 corrugated membrane. The inner hull of the ship provides the structural strength that withstands the static and dynamic loads resulting from transportation of LNG. The load bearing insulation is mechanically attached with the inside surface of the inner hull. A thin liquid tight secondary barrier called the membrane covers the insulation, then, another layer of the insulation and finally a primary barrier. Both the primary and secondary membranes are designed and fabricated from materials operated at cryogenic temperatures without damage such as 9% nickel steel (SS 304 / 36% nickel). The membrane containment system provides a full liquid tide secondary barrier that will contain the LNG in the event of a leak in the primary barrier. The space between the secondary and primary barrier membranes is continuously purged with nitrogen exiting the inter barrier space is monitored by gas detection system for any evidence of leakage in the primary barrier.

Two primary membrane designs have evolved and are in the wide use both developed by French Gaz, Techni Gaz founded in 1963 and Gaz Transport founded in 1965 developed separate membrane technologies and competed vigorously for many years. In 1994, both the companies joined together to form Gaz Transport and Techni Gaz. Even after merger of both the companies in one entity, both membrane designs are available for commercial use.

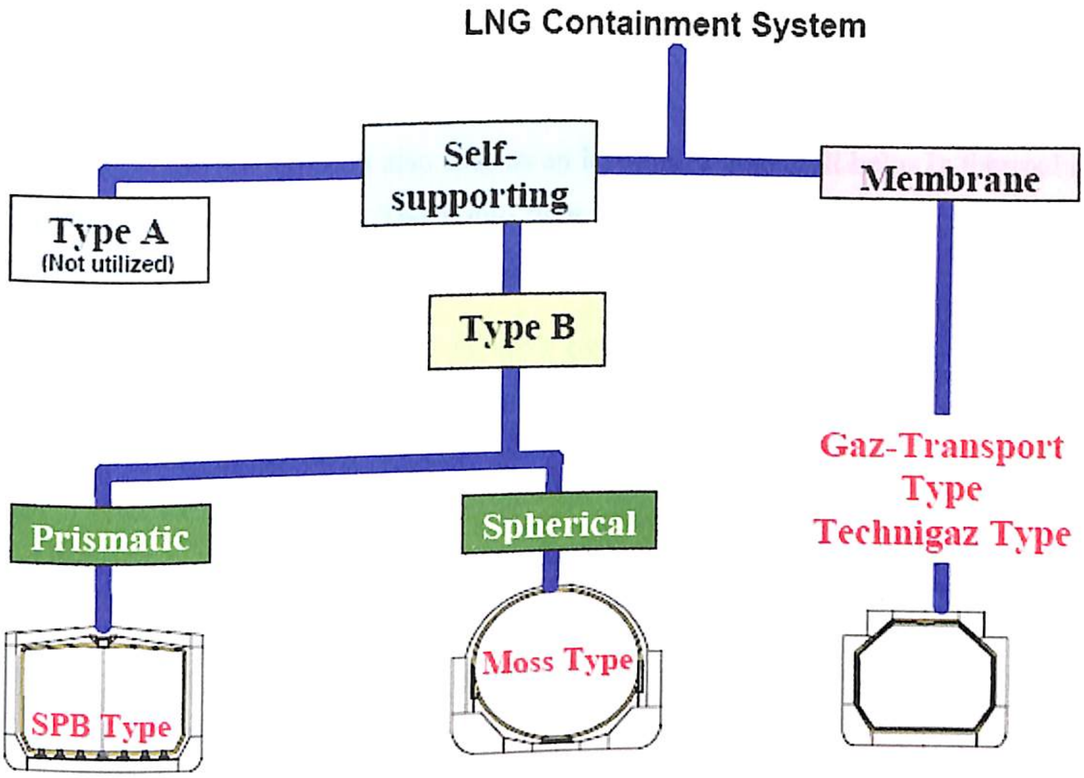


Fig.2.8:-Various types of LNG tankers used for transportation.

An LNG ship size varies from 20,000 to 135,000 m^3. Tanker having volume capacity less than 20,000 m^3 is termed as barges. Due to increase in LNG demand, price of LNG ships has been reduced.

2.5.1 Techni Gaz Tank Design:

The membrane is made of 1.2 mm thick SS-304 L with corrugations both longitudinally and transversely with a spacing of 0.5 metres apart. Because of sea temperature and pressure the hull experience an external force which will result in the breaking of membrane. These membranes thus cannot handle the mechanical pressure over them and due to thermal stress the LNG vessel will affected.

Original load bearing insulation consisting laminated balsa wood panels incorporated a plywood secondary liquid barrier. The inner hull of the ship is also covered with plywood and also used as load bearing agent in the tankers that will provide proper strength & base to the tanks. It also uses as an insulator which will helps in thermal losses due to transportation of ships. The liquid tight secondary barrier is a bounded composite aluminium foil and two layers of glass cloth.

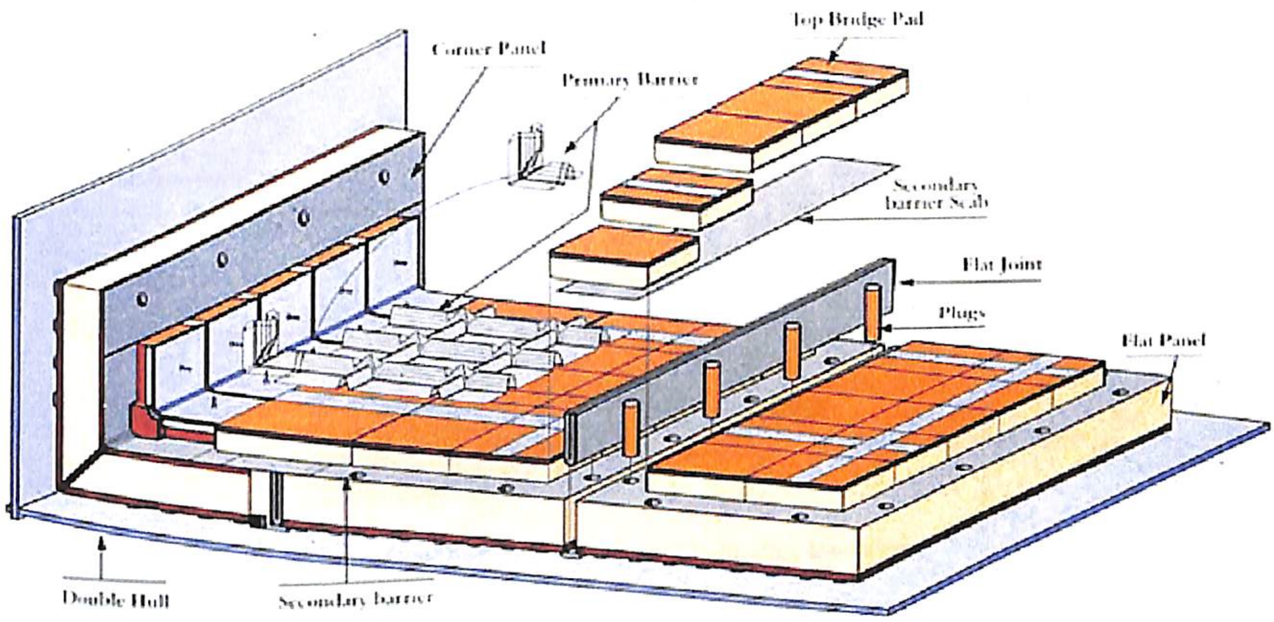


Fig.2.9:-Inside view of the hull of LNG transportation vessel.

2.5.2 Gaz Transport Tank Design:

This design uses 0.7 mm thin ship of invr (36% nickel steel alloy) for both the primary and secondary barrier. LNG vessel having 3-4 tanks on it and they have separately designed pumping as well as insulation system.

Invr strips 500 mm wide are rolled out in single pieces over the entire length of the cargo tank, adjoining strips are welded to invr tongue, i.e., fixed to the underline installation using automatic resistance welding technique. The load bearing insulation will support the primary and secondary barriers consist of plywood boxes filled with perlite insulation material. The boxes are strong enough to absorb high impact pressure resulting from slashing of the LNG cargo when the ship is at sea. Insulation boxes are mechanically fixed to the inner hull. The thickness of the insulation boxes varies depending upon desired boil-off rate, which can be utilized by the ship for its propelling power. Normally the thickness is about 200 – 250 mm

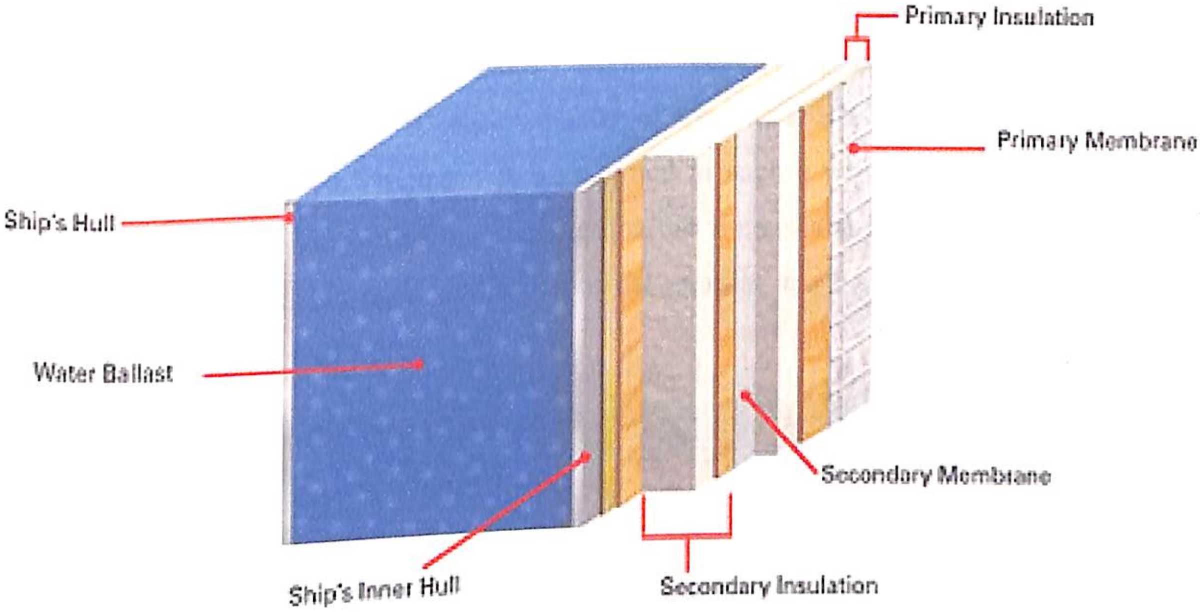


Fig.2.10:-Cross sectional view of LNG transportation vessels hull and containment system.

2.5.3 Spherical Tank System Design – LNG Ship:

The self-supporting tanks are constructed independent of the hull structure and are designed with inherent strength to withstand all the loads of the tank.

1. All static loads of the tank and insulation weight, cargo weight and vapour pressure of cargo.
2. Dynamic loads resulting from ship motion, hull deflection and cargo slashing.

Types of spherical tank:

2.5.3.1 Kvaerner Moss Spherical Tank Design:

These tanks are spherical fabricated with Al alloy. A cylindrical skirt supports each tanks, i.e., welded by a "specially shaved equatorial ring". The bottom of the skirt is welded to the inner bottom of the ship. Pipe tower is used for the support to the structure from the dome to the bottom. A structural transition joint where the transition from aluminium alloys used in the tank to SS is made and SS thermal break to reduce conduction of heat from inner hull to the cargo. LNG tank capacity of approx. 135000 M^3 have minimum internal diameter 37.5 to 40.5 metres. It is designed in such a way that if there is any crack in the tank, it will be notified and reported before if causes any damage. Insulation is of polyurethane foam. Nitrogen exiting from the annular space between the tanks is monitored for any leakage of LNG.

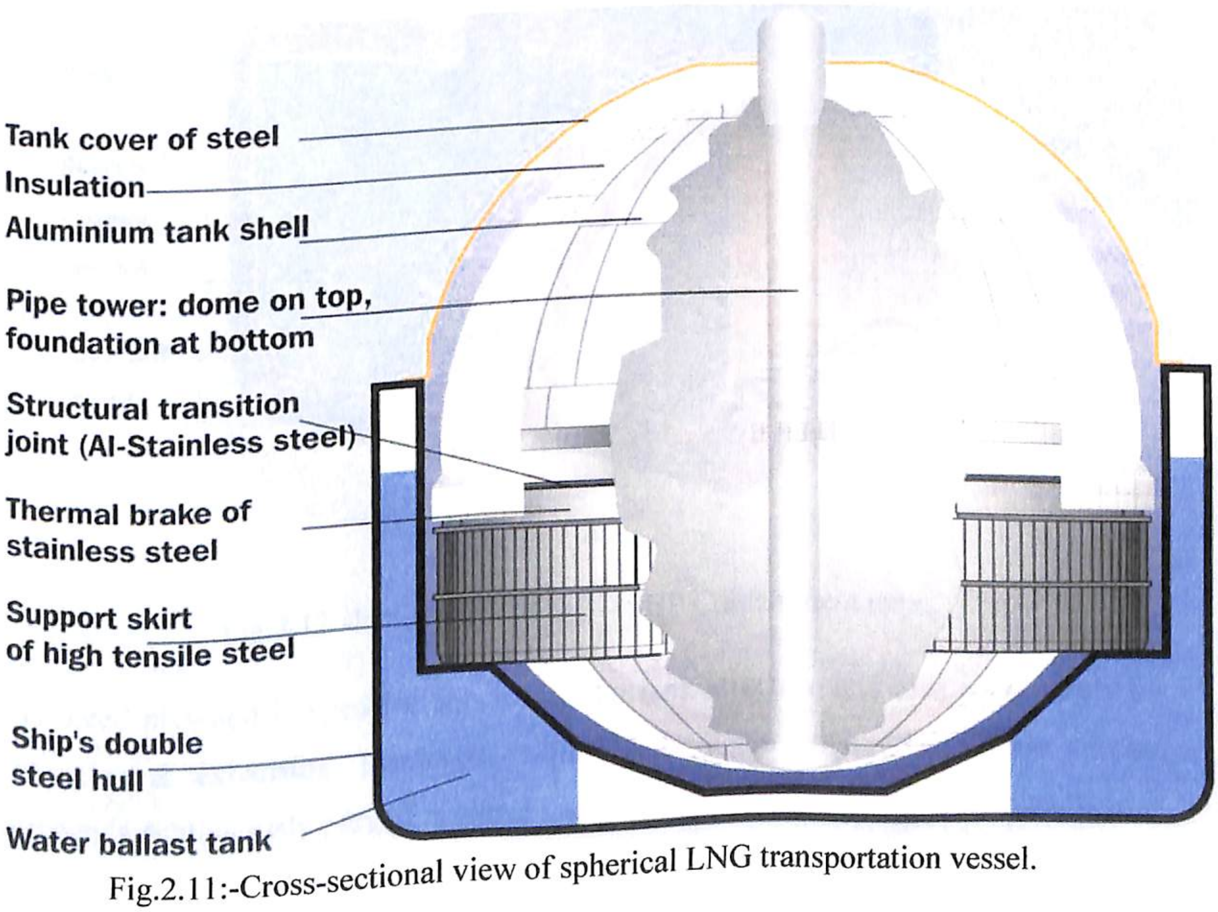


Fig.2.11:-Cross-sectional view of spherical LNG transportation vessel.

2.5.3.2 IHI – SBP Containment System:

This design is called as self-supporting prismatic independent type-B tank was developed by IHI (Ishikwajama – Harima – Heavy Industries). This is an improved and modernized version of Karneh design used in 1960s. The stress analysis when combined with crack and fatigue studies allows the design to predict with confidence that no crack in the shell can be detected before growing to a critical length and thus the tank is classified has IMO – dependent type-B. The prismatic shape aluminium alloy tanks are designed to fit the dimensions of the ship hull to utilize the space efficiently. The cargo tanks are internally stiffened with webs and girdens, in addition, a liquid tight longitudinal bulkhead divides each tank and transfers swash bulkhead, which effectively damp in liquid slashing.

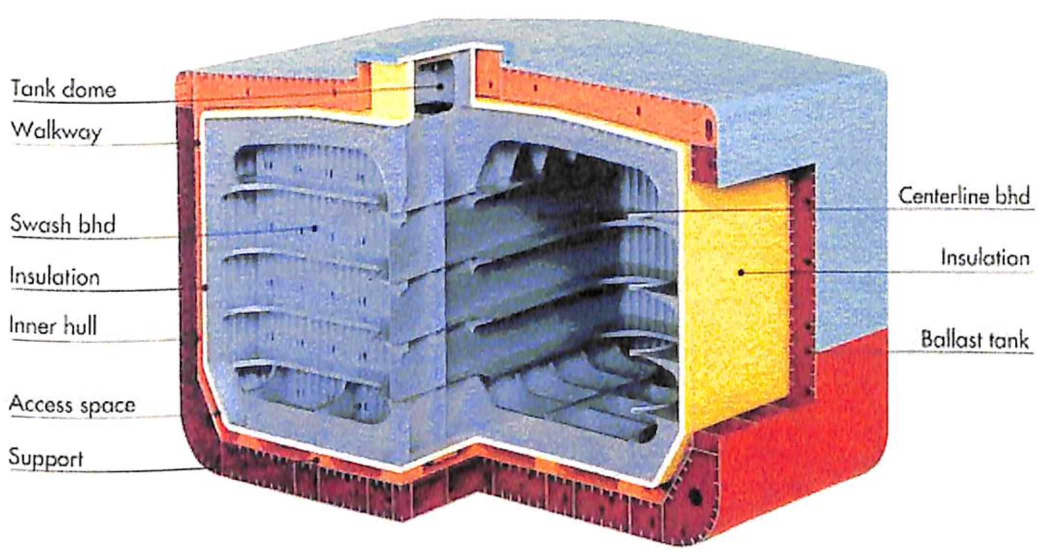


Fig.2.12:-Inside view of IHI – SBP Containment tank.

Reinforced plywood is used for supporting the tank structure and also gives space for contraction & expansion. Insulation is provided by the polyurethane foam blocks. Nitrogen is continuously purged between insulation of the tank to the existing nitrogen is monitored for LNG leaks.

2.6 LNG Re-gasification

LNG re-gasification termed as re-gasification of LNG to its natural state so that it can be delivered to the consumers and uses a fuel. Vaporiser helps in re-gasification of LNG after that it is then transported through pipelines & tankers. Re-gasification terminal is like liquefaction plant but does different work.

The terminal consists of:

· LNG unloading system, including jetty and berth.

· LNG storage tanks, LNG vaporizers..

· In-tank and external LNG pumps.

· Vapour handling system.

· Supporting utilities, piping, valves, control systems, and safety systems required for the terminals' safe operation.

· Infrastructure (roads, fencing and buildings).

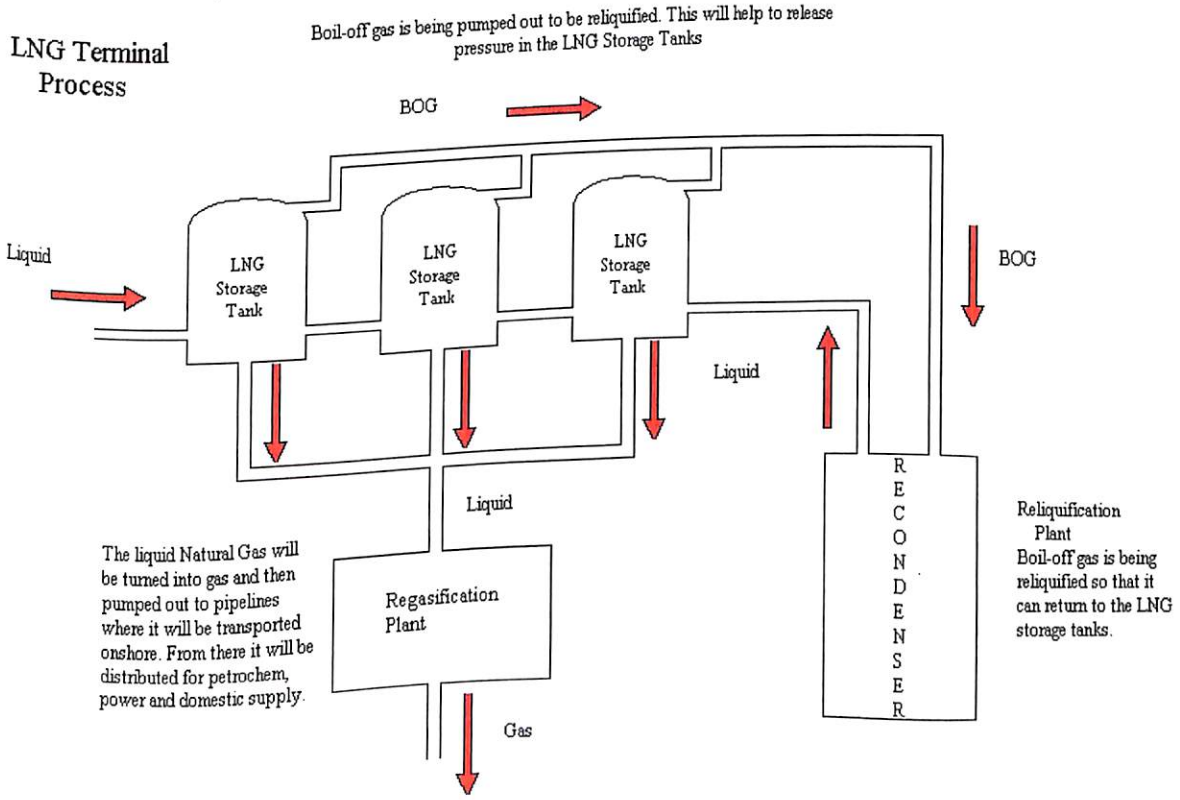


Fig.2.13:-General view of LNG re-gasification terminal.

Certain marine facilities to be included at the terminal are:

S.NO.	Facility	Use and Dimension
1	Shipping Channel	A 15 meter depth of water in the shipping channel required to allow in the LNG tankers.
2	Turning Basin	A basin of 15 meter water depth required to provide a turning circle for an LNG tanker (up to 950 meters diameter)
3	Jetty	If the jetty is unprotected a breakwater is required to provide protection from waves. There may be tradeoff between the jetty length and the dredging, required to provide a channel. The requirements for a breakwater depend on wave conditions, wave heights and the 100 year wave size.
4	Harbor	The key issues relating to the harbor depend on whether it is dedicated to LNG use or is established remote. LNG ships require immediate access on arrival and isolation from other shipping and cargo handling.
5	Terminal Site	The size required depends on the quantity of storage required and the need for back-up liquid fuel storage. The site should be seismically and geodetically secure.
9	Break water	Breakwaters are structures constructed on coasts as part of coastal defense or to protect an anchorage from the effects of weather and long shore drift.

10	Tug Boats:	The deployment of the tugboats should be such that they can independently handle ship movement in the channel under all adverse sea conditions involving high tides, strong waves and severe wind conditions.
11	Navigational Aids	To identify the approach channel, adequate number of buoys to be provided to assist navigation of the LNG ship.

Table 2.3:- Various facilities at LNG re-gasification terminal.

2.6.1 LNG Ship Unloading

For unloading LNG from the ships unloading arms are cooled down to maintain pressure, then LNG is transferred to the onshore LNG tanks by the ship pumps. Ship can be unloaded in 14-16 hrs but it takes almost 24 hr for LNG to unload because it also includes the mooring time and other time needed for safe unloading of LNG. The unloading is done with the 8 pumps situated in the tankers.

Following ship berthing and cool-down of the unloading arms, LNG is transferred to the onshore LNG tanks by the ship pumps. The unloading facility is often designed to accommodate a wide range of tanker sizes from 87,000 m^3 to 145,000 m^3.

Due to pressure difference in between tank & ship, some vapours are generated in the storage tanks which have to be unloading return back to ship tankers to normalize pressure difference. Sometimes blowers are also needed.

Any LNG plant has to be a minimum of 2 liquid unloading arms & 1 vapour return arm. Normally LNG plants have 3 liquid unloading arms & 1 vapour return arm. LNG ships already include vaporisers to enable the cargo to be used as fuel when gas is less costly. Vapours in the ship tankers will attain boil-off if there is any change in temperature, which becomes a safety issue.

2.6.2 LNG Storage

Storage tanks are designed in such a way that they store maximum volume of LNG without increasing the number of tanks. Generally a LNG plant contains 2 or 3 storage tanks.

The main tank types are

1. Single containment.
2. Double containment.
3. Full containment.
4. Membrane type.

2.6.3 Vapour Handling

During normal operation, boil-off vapour is produced in the tanks and liquid-filled lines by heat transfer from the surroundings. This vapour is collected in the boil-off header that ties into the boil-off compressor suction drum. An in-line de-superheater, located upstream of the drum will inject LNG into the gas stream if the temperature rises above -80°C (LNG temperature is approximately -162°C). Boil-off vapours generated during by heat leak into the storage tank and piping are compressed and liquefied in a recondenser. During ship unloading, the quantity of vapour in the tank outlet increases significantly. These additional vapours are a combination of volume displaced in the tanks by the incoming LNG, vapour resulting from the release of energy input by the ships pumps, flash vapour due to the pressure difference between the ship and the storage tanks and vaporisation from heat leak through the unloading arms and transfer lines.

Boil off gas compressor vendors are addressing the need to allow operation with warm inlet gas and thus avoid the need for LNG injection and hence the requirement for a compressor suction drum.

From the compressor suction drum, vapour can be routed to the boil-off gas blowers for vapour return to the ship or to the boil-off gas compressors. The vapour that is not returned to the ship is compressed and directed to the recondenser. The amount of vapour that can be recondensed depends on the amount of LNG send-out. If there is not enough LNG send-out to absorb the boil off vapour then the vapour must be compressed to pipeline pressure, or flared or vented. Thus the priority for handling vapour is in the following order of preference:

· Make up displacement in ship and storage tanks.

· Recondense into send-out LNG.

· Compress to pipeline pressure and send to pipeline.

· Flare or vent to atmosphere.

Installation of a pipeline compressor can usually be avoided by analyzing the send out rates in terms of the frequency of low send out rates and the value of the gas saved compared to the installed cost of the equipment.

2.6.4 First Stage LNG Send-Out Pumps

These pumps are situated inside the LNG storage tank fully immersed in LNG. They are placed in order to pump the LNG from the storage tanks to the recondenser. It also maintains the vapour return line cold so that to normalize pressure difference during unloading of LNG from the ships.

They are placed with easy access to pumps in case of any technical failure in pumps.

The first stage pumps usually have a discharge pressure of approximately 11 bars, and since the saturation pressure is approximately 1 bar, the LNG is effectively sub-cooled by 10 bars.

This sub-cooling provides the thermal capacity needed for recondensing boil-off vapour in the next processing step.

2.6.5 Recondenser

LNG from the in-tank pumps is routed directly to the recondenser vessel. The boil-off vapours generated during normal operations are routed to this vessel and mixed with the subcooled LNG to be condensed. This will avoid flaring or venting for most operating conditions. The recondenser houses a packed bed that creates a large surface area for vapour-liquid contact.

2.6.6 Second Stage LNG Send-Out Pumps

The send-out gas is usually injected into a high pressure gas distribution system of approximately 80 barg. To achieve this pressure multi-staged high head send-out pumps are required. The pumps take LNG from the recondenser and supply it to the vaporisers at a pressure suitable for the pipeline.

2.6.7 LNG Vaporisers

Vaporisers are used in re-gasification process to evaporate LNG and to gain its natural state. This helps in taking out of LNG from tank. The commercially available LNG vaporization process takes care of the three distinct designs of the evaporizer.

1. Open rack vaporiser (ORV).
2. Gas fired vaporizer.
3. Intermediate vaporiser

2.6.7.1 Open rack type sea water vaporizer: ORV takes sea water and flow it down the outside of hollow panels and heating it up the LNG that is flowing up through the interior of the panels.Currently this is the most commonly used LNG vaporizer. They does not depend on fuel gas as a fuel, they use electricity for circulation pump. Since they are stable and have low turn down capability, they are preferred.

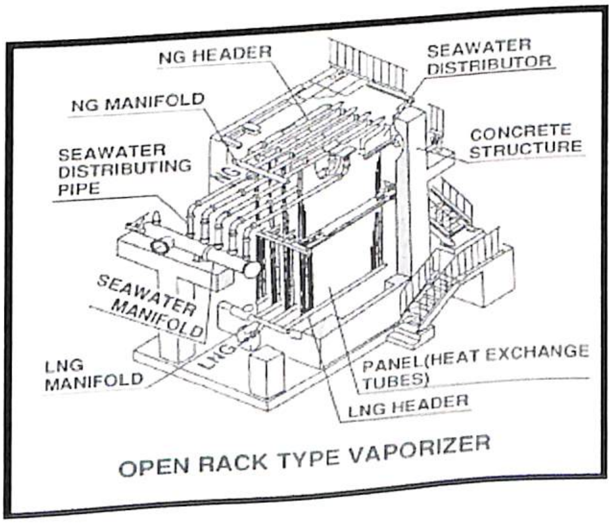


Fig.2.14:-General view of ORV.

2.6.7.2 **Gas fired vaporizer**: Submerged combustion type vaporiser use natural gas to heat the LNG. These are indirect fired heaters, consisting of a combustor system and water bath section. Flue gas from combustor section is directed through water bath, in which exchanger tube bundle is submerged. Around 30% of the vaporizers installed work on this principle. SCV use more energy than ORV but it creates no water discharge since it uses natural gas. SBV uses 1.5%-2%of their throughput as fuel.

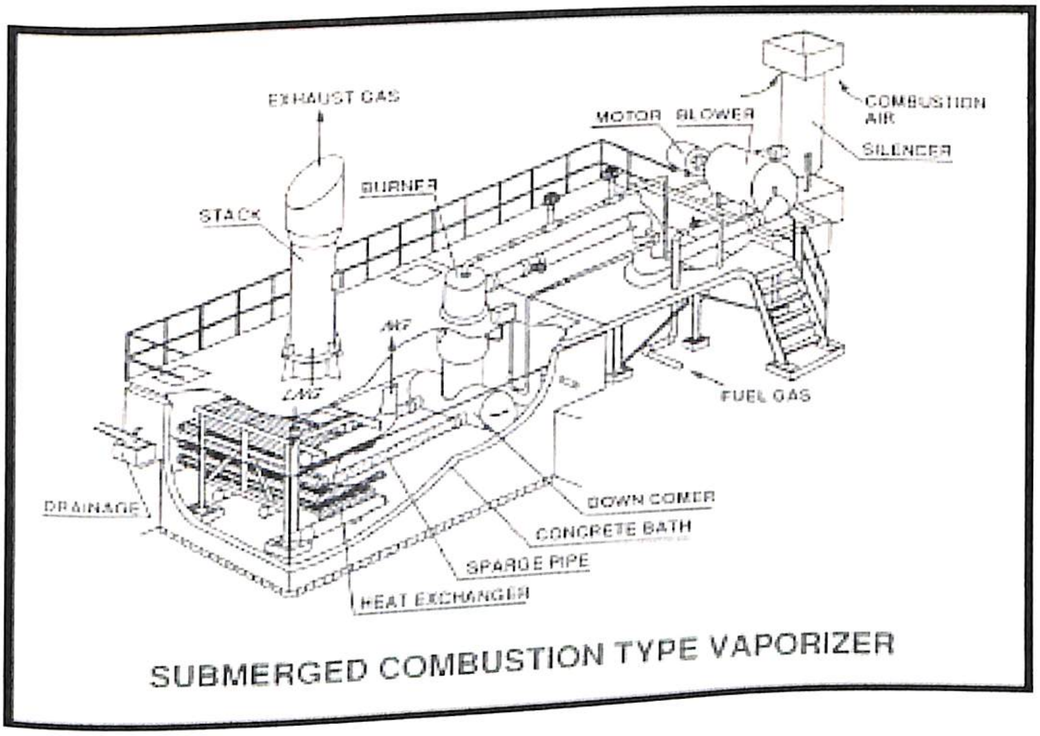


Fig.2.15:-General view of Gas fired Vaporizer.

2.6.7.3 Indirect vaporizers: A tube filled with intermediate fluid mainly propane is passed through LNG which will heat up the LNG to its natural form. An intermediate fluid between heat source and vaporizer will be used. STV have similar fuel consumption as SCVs but their air emissions are easier to control.The intermediate fluid evaporizers are also well suited for integration into cold recovery scheme.

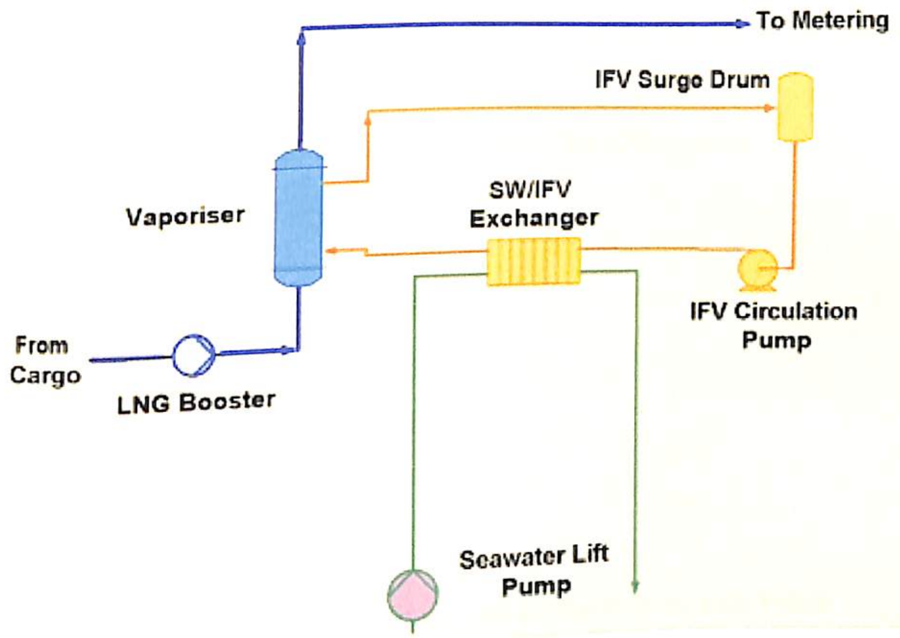


Fig.2.16:-General view of Intermediate Vaporizer.

Selection of LNG vaporiser is based on the availability of fuel and environmental condition. It is also selected to keep in mind that LNG remains cheaper.

2.6.8 Vent System or Flare

Vent system or flare is used for safe disposal of vapours when generated during vapour loading to LNG ships and during boil-off gas, vapours may be generated within the terminal that exceeds the capacity of the recondenser and pipeline compressor.

Burning the gas is the most preferable method. Venting of gas is effective but it is done with some special consideration. Since flare of gas is easily visible to local people, it is only used in extreme emergency situation. Venting is preferred because it is less visible to local residents.

Cold gases cannot be vented into atmosphere because of their adverse effect on environment. They are necessary to be burnt. For example cold methane affects 21 times more than carbon di-oxide does in global warming.

The tank system is fully equipped with overpressure relief valves which can operate automatically in emergency conditions.

2.6.9 Utilities

The following facilities are required to provide utilities to the LNG receiving terminal and support its operation:

- Seawater intake, outfall and pumping system for ORV units.
- Electric power.
- Firewater.
- Foam system.
- Plant water/fresh water/ tempered water.
- Plant and instrument air.
- Nitrogen (storage and vaporiser).
- Emergency power generation.
- Effluent treatment, including sanitary and contaminated rain water.
- Diesel oil supply for firewater pumps and emergency generator.
- Control Room, Substations, Maintenance, Warehouse, Administration and Guardhouse.

2.7 Re-gasification Off-shore/On-board Terminal

Off-shore re-gasification terminals are now considered as another option for LNG terminals. They are been recommended in those countries where land area is in issue or problem. Due to some environmental problems also it has been advised.

Off-shore LNG terminals:

- Off-shore gravity based structure (GBS)
- Off-shore floating storage and re-gasification unit (FSRU)

2.7.1. Gravity Based Structure (GBS): The concept of gravity based structure for use as LNG storage and re-gasification terminal has been developed in Techni Gaz. It constitutes of a large concrete structure, which houses two self-supporting prismatic storage tanks, and includes a regasification plant on the deck with open rack vaporizers. Storage tank technology is of the self supporting prismatic with a storage volume of 2*125000 (m^3).

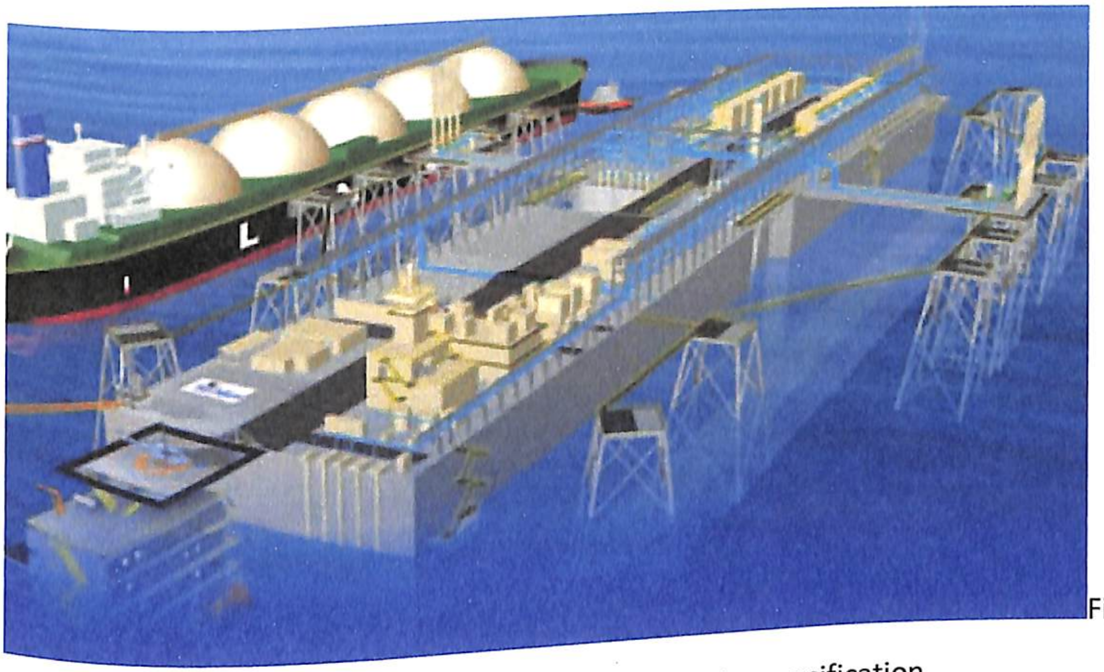


Fig.2.1

7:-Artists impression of GBS for LNG re-gasification.

2.7.2. Floating Storage and Re-gasification Units (FSRU): Several projects concerning this set-up are currently under design. For this terminal Moss sphere tanks and intermediate fluid vaporizers are considered in the present study, although membrane storages may also be used. Storage tanks technologies are Kvaerner/Moss-Rosenberg with the storage capacity of 4*35,000 (m^3). Intermediate fluid vaporizers are used on re-gasification terminal. One of the advantages is the independence from the sea bed, which provides an increased operational flexibility.

Some installation in regasification terminal such as turret mooring system, thrusters compartment foundation of loading arms, other equipments & cranes are also determined in the conversion of the Liquefied Natural Gas (LNG) carrier.

The project also involves the installation of a side by side berthing mooring system for the LNG carrier, a loading system (i.e. loading arms), LNG transfer system to regasification plant, a process plant for regasification, utilities including power generation and sea water systems, control, automation and communications systems.

Fig. 2.18:- Artists impression of FSRU for LNG re-gasification.

2.8 LNG by Road Tankers

LNG is also transported by the road tankers in the cases where pipeline facilities are not available or under construction. Mainly transportation of LNG is done by the pipelines. The road tankers are able to retain LNG for some time since they are doubled walled vessel which can handle cryogenic liquid like LNG. Transportation through road tankers are also depends on the area of demand or customer. The boil-off gas produced is used for refrigeration purpose. LNG transportation by road tankers in India are very common. A normal transport carrier can take 18 tonnes of LNG which translates into 36 X 600 = 216000 M^3.

Unit 3: LNG re-gasification terminal equipments designing

3. LNG re-gasification terminal equipments designing

3.1 LNG pump:

Flow rate, Q = 8.2 m^3/min

= $8.2*10^3$ l/min =51 bbl/min

= 2166 gpm

Specific speed, N_s = (rpm * gpm $^{0.5}$) / H $^{0.75}$

= (3600 * 2166 $^{0.5}$) / 726 $^{0.75}$

= 1197

Power, P = pgQh / 1000

= (480 * 9.81 * 0.12 * 240) / 1000

= 180 KW

D_2 = (1840 * 1.075 * 726 $^{0.5}$) / 3600

= 15"

Km_2 = 1.25

Cm_2 = Km_2 * (2gh) $^{0.5}$

= 15.1 ft/sec

Constant, b = gpm * 0.321 / (Cm_2 * (D_2 * 3.14 – Z * Su))

No. Of blades, Z = 6

Su = 0.5"

$b = 2166 * 0.321 / (8.2 * (15 * 3.14 - 6 * 0.5)$

$= 1.92$

Eye diameter

$D_1 / D_2 = 0.47$

$D_1 = 15 * 0.47 = 7.05"$

Shaft dia. = 3"

Eye area = $38.46^{2} * 7.05^{2}$

$= 31 \text{ in}^2$

$Cm_1 = (\text{gpm} * 0.321) / \text{area}$

$= (2166 * 0.321) / 31$

$= 23$ ft/sec

$Ut = (\text{dia} * \text{rpm}) / 229$

$= (7.05 * 3600) / 229$

$= 110$ ft/sec

Therefore, NPSH required = 42 ft

Specific Speed, $N_{ss} = (3600 * (2166)^{0.5}) / 42^{0.75}$

$= 10272$

3.2 LNG Pipeline:

The LNG pipeline at the terminal is required to transfer the LNG from the LNG carrying vessel to the tank farm.

This system comprises of two pipelines which transfer the LNG to the tank farm and one return vapour line.

$P_1 = 6$ barg

$P_2 =?$

$L = 2.5$ km

$Q = 10000\ m^3/hr$

$D = 30"$

$H_f = flV^2 / 2gD$

$= (0.032 * 2.5 * 1000 * 6.17^2) / (2 * 9.81 * 0.76^{1.33})$

$= 204$

Applying Bernoulli's theorem and assuming no elevation or velocity change:

$(7 * 10^5) / (480 * 9.81) - P_2 / (480 * 9.81) = 204$

$P_2 = 2.6 * 10^5$ Pa

LNG is loaded from top

$Z = pgH$

$= 480 * 9.81 * 34$

$= 1.6 * 10^5$ Pa

Therefore, pressure at the top is 1 barg.

3.3 Shell and tube type heat exchanger:

Shell and tube type heat exchangers are of great use at the LNG re-gasification terminal. The LNG that is being imported is converted into natural gas with the help of this equipment.

Total flow, Q = 21mmscfd

7 exchangers

Flow through one exchanger, Q = 3mmscfd

Specific gravity = 0.65

$T_1 = 200\ ^0R$

$T_2 = 420\ ^0R$

Number of tubes = q / (U*A*LMTD*L)

Heat duty, q

$T_1 = 200\ ^0R$ $\quad$ $P_1 = 1473$ psia

$T_2 = 420\ ^0R$ $\quad$ $P_2 = 1400$ psia

$P_{PC} = 671.43$ $\quad$ $T_{PC} = 370.26$

$P_{PR} = 1473/671.43$ $\quad$ $T_{PR} = 200/370.26$

$P_{PR} = 2.2$ $\quad$ $T_{PR} = 0.54$

$q = 41.7*T_{diff}*C_g*Q$

$C_g = 2.64*(29*Sp.\ Gr.*C + (C_{p1}-C_{p2}))$

$C = 0.39$ Btu/lb °F

$C_{p1} - C_{p2} = 40$

$C_g = 2.64*(29*0.65*0.39+40) = 125$

Heat duty, $q = 41.7*220*125*3*36.1$

$q = 124.2*10^6$ Btu/hr

Gas

$T_1 = -260\ ^0F$

$T_2 = -40\ ^0F$

Water

$T_1 = 203\ ^0F$

$T_2 = 71\ ^0F$

LMTD = (463 – 37) / ln (463 / 37) = 168.6

Correction factor = 0.95

Therefore, corrected LMTD = 160.2

Tube size = 5 / 8"   16BWG

$U = 100$ Btu/hr ft^2 ^0F

Assume, L = 60 ft

$N = 124.2*10^6 / (100 * 0.2618 * 160.2 * 60)$

= 494 tubes

$Area = 124.2*10^6 / (134 * 160.2 * 6.2)$

= 928 ft^2

Water required, $Q_w = q / (14.6* T_{diff})$

$= 124.2*10^6 / (14.6 * 126)$

$= 67515$ bwpd.

3.4 Ambient air heat exchanger:

Q = 20 mmscmd

= 722 mmscfd

Specific gravity = 0.65

$T_1 = 200\ ^0R$

$T_2 = 420\ ^0R$

Number of tubes, N = q / (U*A*LMTD*L)

$T_1 = 200\ ^0R$

$T_2 = 420\ ^0R$

$P_1 = 1473$ psia

$P_2 = 1400$ psia

$P_{PC} = 671.43$

$P_{PR} = 1400/671.43$

$P_{PR} = 2.1$

$T_{PC} = 370.26$

$T_{PR} = 420/370.26$

$T_{PR} = 1.13$

Heat duty, $q = 41.7*T_{diff}*C_g*Q$

$C_g = 2.64*(29*Sp.\ Gr.*C + (C_{p1}-C_{p2}))$

$C = 0.39$ Btu/lb ^{o}F

$C_{p1}-C_{p2} = 40$

$C_g = 2.64*(29*0.65*0.39+40) = 30$

Heat duty, $q = 41.7*100*30*722$

$q = 90*10^6$ Btu/hr

Gas	Water
$T_1 = -40\ ^0F$	$T_1 = 95\ ^0F$
$T_2 = 60\ ^0F$	$T_2 = 70\ ^0F$

LMTD = (135-10) / ln (13.5) = 48

Correction factor = 0.95

Therefore, corrected LMTD = 46

Tube size = 5 / 8" 16BWG

U = 70 Btu/hr $ft^2\ ^0F$

Assume, L = 100 ft

$N = 90*10^6 / (70 * 0.2618 * 46 * 100)$

$= 1067$ tubes

$Area = 90*10^6 / (4 * 46 * 134)$

$= 15249.8\ ft^2$

Unit 4: Conclusion

4. Conclusion

India is a growing giant facing the critical challenge of meeting a rapidly increasing demand for energy. With over a billion people, a fifth of the world population, India ranks sixth in the world in terms of energy demand. While India has significant reserves of coal, it is relatively poor in oil and gas resources. Its oil reserves amount to 5.9 billion barrels, (0.5% of global reserves) with total proven, probable, and possible reserves of close to 11 billion barrels.

India will be a major importer of natural gas and LNG over the next few decades. The cheapest way to supply India with gas would be through pipelines from Central Asia and the Middle East, through Pakistan, but due to tense relations with Pakistan the two countries have not been cooperating on energy schemes and such pipelines are politically infeasible. On the eastern coast, imports of small amount of natural gas from Bangladesh may be feasible. However, Bangladesh's internal party politics does not allow it to take a decision in favour of New Delhi. Consequently, India is focusing on costlier LNG imports especially from Oman and Qatar. This would require construction of LNG terminals which pose security risks and are attractive targets for terrorists.

Based on the literature survey and calculations, a LNG plant for India should be as per the given specifications. These specifications are general in nature and may be required to be changed for specific cases.

The re-gasification terminal should consist of two storage tanks of 135000 M^3; these should be full containment tank because if there is failure of tank in India, then due to severe weather conditions boil-off rate would be much higher in case of single and double containment tank.

The port facilities should be fully developed to handle large cargo ships.

The jetty should be around 1km in length, and the unloading pipeline should be around 2.5 kms and its diameter should be around 30".

There should be three unloading arms of these one should be used as vapour return line.

The LNG send out pump placed inside the storage tank with specific speed of around 10000 rpm.

The gas should then be sent to LNG vaporiser, as there are no environmental regulations in India we can use open rack type vaporiser. LNG vaporisation is done in two stages; in 1st stage we use 7 shell and tube type heat exchangers. In 2nd stage we use an ambient air exchanger.

This gas then should be metered and transferred to the pipeline from where it reaches the customer.

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