# Planning and feasibility study of LNG terminal for Visakhapatnam Port Trust

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## I. ABSTRACT

To meet India's growing energy demands, it is proposed to establish a LNG terminal at east coast for Visakhapatnam port trust. Its location is found to be feasible near the newly proposed Satellite Port and at proposed fishing harbour at Mullakuddu, Bheemunipatnam. This work comprises of the preliminary study and feasibility report along with plant process and basic requirements for setting up of LNG terminal for handling, storage and evacuation at Bheemunipatnam for Visakhapatnam Port Trust.

The proposed LNG terminal facility at Bheemunipatnam is planned with the following infrastructural facilities for the smooth handling of LNG, which consists of a Jetty, LNG Tanks, Vaporisation plant, Fire control mechanism, Maintenance workshops, Administration Building, Guard houses, Utility area & Control rooms. As the first phase, the planned LNG terminal capacity is 2mmtpa with two LNG storage tanks of 85,000 $m^3$ capacity, with a provision to increase it to 5mmtpa in future.

## INTRODUCTION

Visakhapatnam port trust is on its way to develop into a most-preferred port of South East Asia and become a fully automated port within a couple of years to handle 2,00,000 DWT vessels in the Outer Harbour. As LNG is relatively clean fuel with immense potential for future energy needs, its handling also would be a part of its expansion plans. Keeping in view to decongest traffic at the main harbour and huge land requirement to build LNG terminal, its location is found to be feasible near the newly proposed Satellite Port & Fishing harbour at Mullakuddu, Bheemunipatnam.

History of the location: Bheemunipatnam is supposed to have originated in the days of the mahabharatha (named after Bheema) as per legends. Most probably its origins were around the 3rd century BCE related to early Buddhism in Andhra Pradesh. It was one among the major Dutch settlements in the 17th century. Bheemunipatnam is located at 17.53N latitude & 83.26E longitude. It lies at the mouth of river Gosthani joining the Bay of Bengal. Bheemunipatnam tahsil had an area of 540 square km. with 117 villages; it is located 25km from Visakhapatnam city. It was the second municipality in Indian mainland, established on 9th February 1861. 150-Years of its formation has been celebrated in 2011. It has lot of potential for major developments.

Location of the proposed LNG terminal at Bheemunipatnam is shown in the figure below:


Figure I.

Globally around 200 million tonnes per annum of LNG is produced and exported by some 17 countries. Of the total LNG produced globally, around 70-75 percent is consumed in the Asia-Pacific region. The five major importing countries in the Asia Pacific region are Japan, South Korea, Taiwan, China and India. The balance 25 per cent volume of LNG is consumed in 22 other countries, mostly in Western Europe, including Spain, France, UK and Belgium. Re-gasification capacity in the world is around 560 mtpa with the US alone having re-gasification infrastructure of about 140 mtpa. India is the 13th largest gas consumer in the world. It is also the sixth largest LNG importer, importing 16 out of 70 bcm of natural gas that it consumes. LNG in India is mostly used for complementing domestic gas usage. To fuel its growing economy, the increase in India's energy consumption will lead to the rise in the share of natural gas in the Indian energy basket from 11% today to 20% in 2025. In 2005, gas constituted only 8% of India's total energy consumption. India has expanded its domestic gas production in order to address this increase in demand. Although it has taken efforts to develop its pipeline network into a national grid, it also relies heavily on imported gas. India's growing energy demand is marked by a greater dependency on imported natural gas. It is projected that India's gas demand of 243.34 mmscmd will be used to generate power between 2014-2015, as compared to 87.71 mmscmd between 2010-2011. Most of the gas demand will come from industries, refineries, base-load power and new fertilizer plants. India is the third largest fertilizer producer in the world. Its fertilizer capacity is expected to expand by approximately 35%. Current LNG re-gasification capacity in the country is 15 mtpa. Other than the forthcoming Gangavaram and Kakinada LNG terminals, there are no terminals on the east coast line of India.

## II. LNG LITERATURE

When natural gas is cooled to a temperature of approximately -160°C at atmospheric pressure, it condenses to a liquid called "liquefied natural gas "(LNG). One volume of this liquid takes up about 1/600th the volume of natural gas at a stove burner tip. LNG weighs less than one-half that of water, actually about 45% as much. LNG is odorless, colorless, non-corrosive, and non-toxic. When vaporized, it burns in concentrations of 5% to 15% on being mixed with air. LNG or its vapour is not explosive in an unconfined space.

Gas is typically cooled by successive cycles of refrigeration using giant compressors and heat exchangers. The liquefaction process removes the oxygen, carbon dioxide, sulfur compounds, and water. In its liquid form, natural gas is stored more efficiently and is economical to transport in dedicated LNG carriers to the receiving terminals. Indeed, converting natural gas into LNG is the only viable way to transport natural gas to places that are beyond the reach of pipeline systems. When LNG reaches its destination, it is returned to a gaseous state at regasification facilities. It is then piped to homes, businesses and industries. LNG has proved to be a cheaper, clean and efficient replacement to liquid fuels being deployed by many industries for their power requirements. The power costs can be reduced substantially when LNG replaces liquid fuel such as naphtha. Consequently, there has been increased appreciation of the reduction in costs on deployment of LNG replacing any other fuel in the energy basket.

The chemical composition of typical LNG and NG is shown in table I below:

TABLE I.

| Constituent | Chemical Formula | Typical Pipeline Natural Gas | Typical Liquefied Natural Gas |
|---|---|---|---|
| Methane | $CH_4$ | 88.90% | 94.70% |
| Ethane | $C_2H_6$ | 5.34% | 4.80% |
| Propane | $C_3H_8$ | 0.46% | 0.40% |
| Butane | $C_4H_{10}$ | 0.05% | 0.06% |
| Pentane | $C_5H_{12}$ | 0.03% | 0.01% |
| Hexane | $C_6H_{14}$ | 0.02% | 0.01% |
| Helium | He | 0.20% | - |
| Nitrogen | $N_2$ | 5.50% | 0.02% |
| Carbon Dioxide | $CO_2$ | 0.50% | - |

*Source: American Gas Association*

If LNG is spilled on the ground or on water and the resulting flammable gas vapour does not encounter an ignition source (a flame or spark or a source of heat of 1000°F (540°C) or greater), the vapour will generally dissipate into the atmosphere, and no fire will take place.

When compared to other liquid fuels, LNG vapour (methane) requires the highest temperature for auto-ignition, as shown in the table II below: TABLE II

| Fuel | Auto-ignition Temperature, °C |
|---|---|
| LNG (primarily methane) | 540°C |
| LPG | 455°C to 510°C |
| Ethanol | 423°C |
| Methanol | 464°C |
| Gasoline | 257°C |
| Diesel Fuel | Approx. 315°C |

*Source: New York Energy Planning Board, Report on issues regarding the existing New*

*York Liquefied Natural Gas Moratorium, November 1998*

LNG has a strong safety record technically and operationally: evolved to ensure safe and secure operations. These include everything from the engineering that underlies LNG facilities to operational procedures to technical competency of personnel.

Physical and chemical properties: of LNG are such that risks and hazards are easily defined and incorporated into technology and operations.

Standards, codes and regulations: applies to the LNG industry to further ensure safety.

It is concluded that LNG can continue to be transported, stored and used safely and securely, as long as safety and security standards and protocols developed by the industry are maintained and implemented with regulatory supervision.

## III. PLANT CONTENTS AND PROCESS

The proposed LNG terminal at Bheemunipatnam consists of Jetty, unloading arms, LNG Tanks, vaporisation(Re-gasification) area, maintenance workshops, administration building, guard houses, utility area & control rooms. At LNG terminal LNG is unloaded by cargo pumps via jetty unloading arms and the main unloading lines on the jetty to the LNG storage tanks. The size of the arms depends on the unloading flow rate. The terminal is designed for 1,67,000 $m^3$ capacity LNG tankers so, 16" dia. 3 nos. liquid arms and one vapour arm are provided. Boil-off gas generated in storage tanks is partly sent back to the ship via the return gas piping by pressure of these tanks to compensate the space produced by displacement of unloaded LNG. Surplus boil-off gas is routed to the BOG compressors where it is compressed for recondensation in the re-condenser, this re-condensation is achieved by mixing compressed gas with sub-cooled LNG pumped by in-tank low-pressure pumps. LNG including condensed BOG from the re-condenser, is directed to the high-pressure pumps (HP pumps - 8MPa and 4MPa), which boost LNG pressure slightly above that of the natural gas transmission pipelines to be connected to prior to entering the vaporizing section. LNG is then vaporized in the vaporizers, which operate at the various send-out pressures. NG will go through a metering system and eventually be sent out from the LNG terminal into the transmission pipelines. The plant consists of receiving section, storage section & send out section. In addition to the above, the terminal consists of various utilities, flare system, fire fighting facilities and other associated infrastructures.

LNG receiving terminal simplified process flow diagram is shown below in figure II.

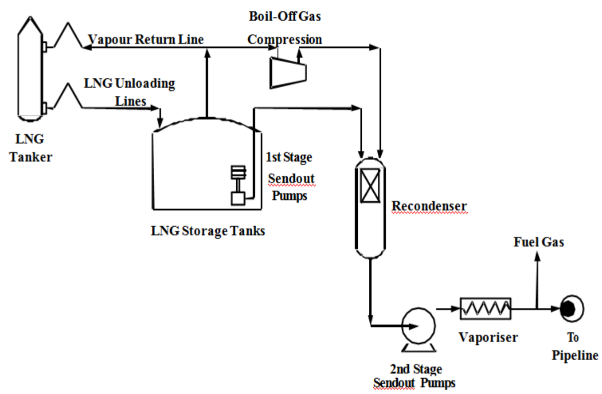


Figure II.

In the first phase, two numbers of storage tanks each of 85,000 m³ capacity are provided expecting only two LNG carriers to arrive in a month(vessel capacity ranging from 70,000 to 1,65,000 m³ i.e., approx. 30,000 to 80,000 Dwt) which arrives to plant capacity of 2.0 mmtpa.

The soil under the LNG storage tank shall not be allowed to become cold. If the soil becomes too cold, frost penetrates into the ground, ice lenses form in the soil (mainly in clay types of soil) and the growth of these ice lenses results in high expansion forces which lift and damage the tank or parts of the tank. To prevent such occurrence heating system needs to operate in the foundation. An automatic on/off switch system activates the electrical heating system and ensure that the tank foundation at its coldest location is within acceptable temperature range i.e. +5°C to +10°C.

As an alternative to electrical bottom heating system free ventilated tank bottom by elevated structure is also used.

Preferred LNG Storage tank is of Full containment with Raft type foundation design made of piles with a depth at which the dense earth strata is found at each location including two meters above the surface.

Insulation & material of construction: The storage tanks for LNG shall be adequately insulated in order to minimise the boil off gas generation due to heat leak from ambient. The extent of insulation depends on boil-off considerations for which the storage tank is designed. Normally boil-off rate of 0.06 to 0.1 % of hold up liquid volume per day is considered. Proper insulation shall be ensured in tank base, tank shell, tank roof, suspended deck etc.

Inner tank consisting of 9% Ni steel with insulating materials as resilient glass fibre blankets with aluminium foils and perlite concrete for the side walls and cellular glass layers and perlite concrete at the bottom of the slab.

The outer container consists of an entirely closed monolithic concrete structure - bottom slab, wall ring beam and roof. The concrete containment is designed for all possible combinations of normal and emergency loads which may occur during construction, testing, commissioning, operating and maintenance of the tank.

The Liquid unloading rate from similar dwt vessels taken is 1750m³/hr. each with 8 pumps with 2 pumps located in each of 4 tanks on board which takes around 12hrs. to unload a vessel, which is preferred considering safety aspect. The re-liquefaction system is intended to cool and liquefy boil-off gas through heat exchange between BOG pressurized to 0.5 to 1 MPa, and LNG supplied to a vaporizer. In send-out section, LNG is pumped and brought to a pressure slightly higher than the network pressure through secondary pumps and vaporised & warmed to a temperature above 0°C and metered before it is sent for distribution. Secondary pumps used for pumping the LNG from the intermediate pressure to the network pressure through vaporisers are submersible pumps. In-tank pumps are generally of Centrifugal Cryogenic Pumps with Net positive suction head (NPSH) of 2.0m.

LNG Boils at -162°C which is achieved through vapourisers effectively. The two types of vapourisers used are Open rack and submerged combustion vapourisers. Two ORVs (Open rack Vaporizer) of 180t/h each will be sufficient to evacuate 80,000t in 15days expecting two vessels to berth in a month. Single SCV(Submerged combustion vapouriser) unit is installed for a gas send-out rate of approximately 120 t/h. Vent systems in the plant is taken care of. During upset, extreme turndown or emergency conditions, vapours may be generated within the terminal that exceeds the capacity of the recondenser. If this occurs, the vapour is vented to the atmosphere through an elevated vent stack or a flare for safe disposal. The preferred method of disposal is generally to flare the gas to avoid accidental ignition by lightning. Also, the global warming potential of methane is approximately 21 times that of $CO_2$, so each methane molecule would be 21 times better burnt than just vented.

## IV. NATURAL GAS TRANSMISSION

The receiving station for the sent out gas is assumed to be planned by HPCL petro park, through transmission pipeline from the proposed LNG site. Three alternative routes have been considered for laying of pipeline. One with 52.0 km. length along the beach road, the second one with 54.50 km. length passing through Madhurawada and the third one with 57.3 km. length via Anandapuram-Simhachalam road. Among the above three alternatives, the third option is preferred as the major alignment of the first and second are passing through fully developed and densely populated areas where it is not feasible to get the permits and in aspects of safety considerations and availability of right of way. Transmission pipelines operate at pressures ranging from 500 to 1,400 pounds per square inch gauge (psig). Pipeline diameter is selected as 24 inches. The pressure drop in the pipeline from the source to the destination is calculated. The natural gas after passing through the metering stations is compressed to maintain the sent out pressure of 725psi. to reach the destination with 600 psi. pressure after the pressure drop of approximately 125psi in-between.

Velocity of the high pressure gas flow lines is taken as 40 m/s and the flow rate calculated is 10.752 $m^3/s$, the pipe grade for high pressure transmission pipeline for carrying natural gas is *API 5L, SAW, BS 31.8 Grade X52.* There are special construction procedures for pipe laying which are to be followed as per norms and directions of Gas transmission pipeline codes. Double submerged-arc-welding is adopted. Pipes are often protected with a fusion-bond epoxy (40 to 100 microns thick) or extruded polyethylene, both of which give the pipes a noticeable light yellow color. In addition, cathodic protection is often used, which is a technique that involves inducing an electric current through the pipe to ward off corrosion and rusting.

Chemical composition for high pressure transmission pipelines of alloy steel for carrying natural gas is given below:

| The Element | Max (%) |
|---|---|
| C (carbon) | - 0.26 % |
| Ti (titanium) | - 0.04 % |
| Mn (manganese) | - 1.40 % |
| P (phosphorus) | - 0.03 % |
| S (sulphur) | - 0.03 % |

and rest is Iron (Fe)

Regarding LNG carrying pipe lines inside plant, Vacuum insulation is the most reliable and proven method of transferring LNG with the minimum Boil-Off Gas. (Vacuum insulation pipe lines was first invented by Sir James Dewar in 1892 has been used for decades in industries where the transfer of cryogenic liquefied gases is used). Vacuum Insulated Piping out-performs conventional mechanically insulated piping with 1/10th the steady state heat leak and other Pipe-in-Pipe “powder insulation” methods by 1/5th the steady state heat leak.

It is simply constructed of an inner carrier pipe, normally stainless steel, which is wrapped with multiple, separated layers of a reflective material such as aluminized Mylar to insulate from radiant heat transfer. A jacket pipe is centered over the carrier line, also stainless steel or a coated carbon steel material, using low heat conductive 'spacers' and sealed at each end with a low heat conductive end closure. The jacket pipe also contains a convoluted/ complex ‘expansion joint' in each straight section to compensate for the contraction of the carrier pipe when LNG is being transferred.

## V. JETTY DESIGN

A jetty is a civil engineering marine structure projecting out into the waterway and with facilities for mooring ships at its head or along its flank. Jetties are normally used at major hazard plants for the loading and/or offloading of hazardous substances in bulk quantities between ship and land based storage facilities. Jetty is designed to meet the requirements of the appropriate design codes and standards, to sound engineering principles and to be fit for purpose. It should be of sound construction, preferably made of non-combustible materials, and be of sufficient strength to withstand normal berthing forces.

The jetty is designed for LNG carriers of capacity ranging from 70,000 to 1,65,000 m3 i.e. approximately 30,000 to 80,000 Dwt vessels, it is designed to the maximum capacity of 80,000 Dwt for the length of 280m. The jetty consists of a service platform flanked by four numbers of berthing and six numbers mooring dolphins. The service platform is connected to the shore by an approach trestle. The service platform is planned to accommodate three unloading arms and one vapour return arm for handling LNG. The approach trestle is about 500 m long which accommodates a single lane carriageway of 4.25 m and pipelines for LNG, firewater, fresh water and electrical cables. Jetty layout is shown below in fig. III

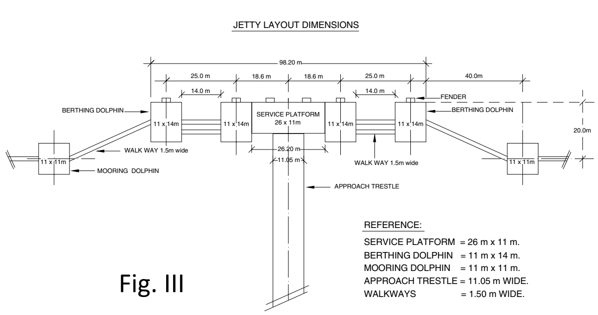

Fig. III

Various jetty loads are considered and calculations are carried out as per respective code standards for service platform, berthing dolphins & mooring dolphins. The size of the service platform is designed for length 26m and breadth 11m. with 36nos. cast-in-situ RCC M30 piles of 900mm diameter with design draught of -14m and overall depth of pile up to -29m. to the weathered rock strata. Berthing dolphins are designed for length 11m and breadth 14m. with 20 nos. piles of 1000mm. dia. Mooring dolphin is designed for mooring forces with dimensions of length and breadth as 11m. consisting of 16 nos. of 900mm. dia piles. The width of the approach trestle is arrived as 11.05m which is the standard bridge drawing and has an overall length of 500 m to obtain the desired draught and for safety considerations. BRIDGESTONE make – Super cell fenders are selected to withstand the berthing forces on to the jetty. The terminals safe operations, fire safety internal road connectivity's, securities, and several port terminal rules and regulations are also to be taken care of for the effective and efficient running of the plant.

## VI. LNG - SITE VARIABLES

The cost of an LNG receiving terminal is highly dependent on the selected site, but a typical cost distribution is provided in the table III below:

TABLE III

| Area | Percentage |
|---|---|
| Jetty | 11 |
| Tanks | 45 |
| Process | 24 |
| Utilities | 16 |
| General Facilities | 4 |
| Total= | 100 |

*Source : Technical paper in " LNG IMPORT TERMINALS- RECENT DEVELOPMENTS" - Janusz Tarlowski,John Sheffield,M. W. Kellogg Ltd United Kingdom.*

Factors that change the above breakdown are many and include: Marine conditions, On shore oil conditions, Storage tanks type, Power generation & Labour.

## VII. CONCLUSION

Keeping in view to decongest traffic at the main harbour and huge land requirement to build LNG terminal, its location is found to be feasible near the newly proposed Satellite Port and proposed fishing harbour at Mullakuddu, Bheemunipatnam. Various other factors which favours the proposed site are large navigational connectivity and wide scope for future expansion. The present work describes the mechanism for smooth handling of LNG and natural gas transmission pipeline to HPCL Petro-park.

This work has been taken up based on the demand of clean energy needs of our country. In this context, there is lot of potential for LNG in reducing the gap between demand- supply of our energy requirements. The in-house handling capacity of the country has to expand in the early stages to meet the tremendous future demand. It is necessary to find, develop and supply energy with low carbon intensity to decrease the impacts of climate change on our planet. LNG being a clean fuel is a source of energy that emits far less $CO_2$ for power generation than coal or fuel oil over the extraction to combustion lifespan. So it is a challenge to Visakhapatnam port, being one of the major ports of our country to take-up huge projects like LNG handling as part of its expansion and also contribute to the country's economy as a whole.

## VIII. ACKNOWLEDGMENTS

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