CSCanada
Advances in Natural Science
Vol. 8, No. 4, 2015, pp. 17-22
DOI:10.3968/7861

ISSN 1715-7862 [PRINT]
ISSN 1715-7870 [ONLINE]
www.cscanada.net
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The Prospect and Process of LNG

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Supported by Graduate Education Innovation Project in Heilongjiang Province (JGXM_HLJ_2014027).

Received 29 August 2015; accepted 15 November 2015
Published online 26 December 2015

Abstract

This report primarily addresses the issues surrounding a conventional onshore LNG receiving terminal and gives an overview of its chief components which include LNG unloading facilities, storage tanks, LNG (William, 1995) regasification system and vapor handling system. Report chiefly aims to the regasification process and infrastructures used in LNG receiving terminals, especially different types of vaporizers and storage tanks which being illustrated respectively in report. This report will be helpful in understanding the various technological aspects of conventional LNG receiving terminals.

Key words: LNG; Terminal; Regasification; Infrastructure

Bai, M. X., & Sun, J. P., Song, K. P., & Liang, J. W. (2015). The Prospect and Process of LNG. *Advances in Natural Science*, *8*(4), 17-22. Available from: http://www.cscanada.net/index.php/ans/article/view/7861
DOI: http://dx.doi.org/10.3968/7861

INTRODUCTION

LNG is abbreviation for Liquefied Natural Gas. It is natural gas that has been cooled to about −163℃ at normal pressure and condenses to liquid. LNG can be significant and economical for transportation between different continents in specially designed ocean vessels, since liquefaction reduces the volume of natural gas by approximately 600 times. LNG technology makes natural gas more available throughout the world.

The following figure shows a typical LNG value chain. LNG delivery is a multistep process. First, the liquefaction plants near the natural gas production sites transform the processed natural gas into liquefied natural gas. Next, the LNG is loaded into LNG tankers from the storage tanks located in liquefaction plants and transported to import terminals in consumer countries, where it is unloaded in storage tanks to undergo regasification. Once returned to its gaseous state, the natural gas is distributed to customers through pipelines (Christian, Begazo, & Erica, 2007).

1. CHARACTERS OF LNG

When we talk about a receiving terminal, we must know the characters of LNG that the terminal is going to handle. LNG is a mixture therefore its characters are decided by its components. However, depending on place of origin, the components of LNG are different which causes characters of LNG from different localities have a little bit difference between each other. The density of typically LNG is roughly 0.41 to 0.5 kg/L, depending on temperature, pressure and composition, compared to water at 1.0 kg/L. LNG is natural gas in liquid form, so LNG typically contains approximately or more than 90% methane which is same with natural gas. It also contains small amounts of ethane, propane, butane and some heavier alkalizes. Other impurities like H_2S, CO_2, H_2O and heavy hydrocarbon have been removed from natural gas in the prepossessing before liquefaction. The following table shows components of different LNG produced by some exporters over the world (Maclean, Lave, & Hendrickson, 2000).

1.1 Vaporization

1.1.1 Boil-Off Gas (BOG)

LNG is boiling in insulated tanks in transportation period. Boil-Off Gas (BOG) is boiled gas which generated in a storage tank of a ship transporting cryogenic liquefied natural gas. Its composition depends on LNG's composition. BOG is nearly pure methane at a lower temperature than -113℃C, while at -85℃; the component of BOG is approximately 80% methane, 20% nitrogen and a slight amount of ethane. The density of BOG is higher than air in both these two situations, which is about 60% of air in standard situation (Mokhatab & Economides, 2006).

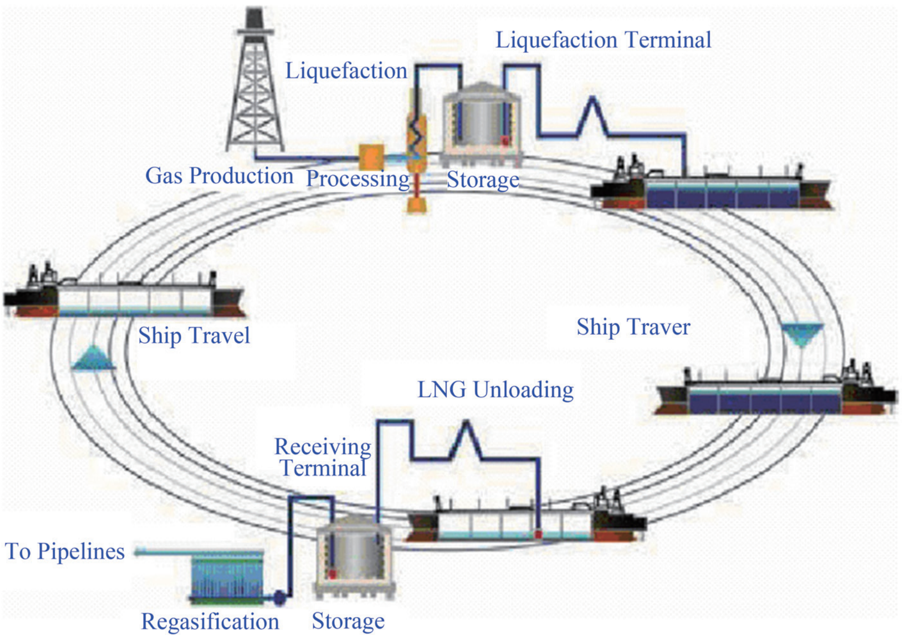

Figure 1
LNG Value Chain

1.1.2 Flash Vaporization

Besides normal vaporization, LNG has some other features like flash (or partial) evaporation, which is the partial vaporization process that occurs when a pressurized saturated liquid undergoes a reduction in pressure. A part of the liquid immediately "flashes" into vapor. Both the vapor and the residual liquid are cooled to the saturation temperature of the liquid at the reduced pressure.

LNG is a multi-component liquid; therefore, the component of flash gas is different from LNG. To calculate the component of flash gas and its corresponding liquid is very difficult which have to support from computer (Shukri & Foster, 2005)

1.2 Rollover

LNG "rollover" refers to the rapid release of LNG vapors from a storage tank caused by stratification. The potential for rollover arises when two separate layers of different densities (due to different LNG compositions) exist in a tank. In the top layer, liquid warms up due to heat transferred into the tank, rises up to the surface, where it evaporates. Thus light gases are preferentially evaporated and the liquid in the upper layer becomes denser. This phenomenon is called "weathering". In the bottom layer, the warmed liquid rises towards the interface by free convection but does not evaporate due to the hydro-static head exerted by the top layer (Barclay, Denton, & Foster, 2005). Thus the lower layer becomes warmer and less dense. As the densities of two layers approach each other, the two layers mix rapidly, and the lower layer which has been super-heated gives off large amounts of vapor as it rises to the surface of the tank. This phenomenon is called rollover.

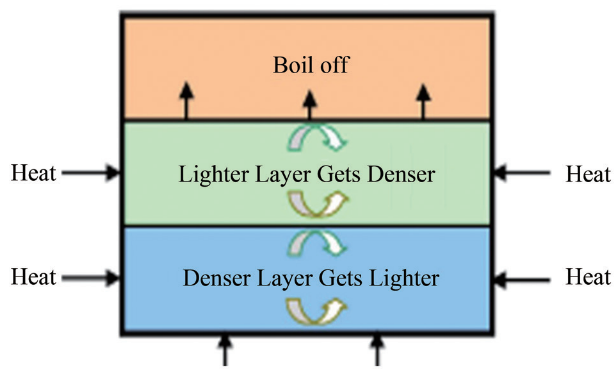

Figure 2
An NG Storage Tank With the Liquid Stratified

While rollover happens, the pressure in storage will increase rapidly even breakout through safety valves. To reduce the probability of rollover, there are several methods available. One method for an example is to practice proper transfer procedures to assist in deterring fill-induced stratification. When transferring product into a LNG tank of a different product density, it is prudent to bottom filled the lighter LNG while top-filling heavier product. This procedure will promote a natural mixing of the two product densities. Flashing the vapors prior to transfer will reduce significant amounts of heat present during transit and transfer. Another possible deterrent to rollover is to constantly run the re-circulation pumps to maintain a homogeneous density and temperature profile (Arteconi & Polonara, 2013).

2. INFRASTRUCTURES

The receiving terminals are made up by several systems. These infrastructures which mean unloading, storage, regasification & send-out, BOG handling and blow-down guarantee receiving, vaporize LNG and delivery natural gas to end customers safely and efficiently.

2.1 Unloading Equipment

Unloading system is used to unload LNG from ships to storage tanks in the receiving terminals. It is made up by unloading arms, unloading line, loading arm, BOG blower and vapor-return line. Following diagram gives an overview of facilities at a receiving terminal's dock.

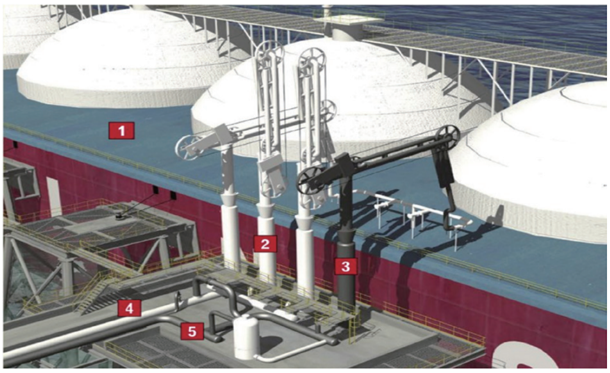

Figure 3
3 Diagram of an LNG Unloading Facility

Symbol List: 1: LNG Ship, 2: Unloading Arms, 3: Vapor Loading Arm, 4: Unloading Line, 5: Vapor Return Line

LNG is unloaded from the ship's tanks by pumps inside those tanks after the ship is docked and moored safely. Special coupling devices which called unloading / loading arms connect the vessel to the terminal's pipelines system which includes unloading line and loading line. Before unloading operations begin, those un-insulated unloading / loading arms are gradually chilled to the -162℃ LNG temperature. After this pre-refrigeration, unloading rate could be raised up to normal one. The ship pumps produce pressure enough to overcome piping losses and elevation changes to deliver LNG to the terminal's LNG storage tanks (Vatani, Mehrpooya, & Tirandazi, 2013).

Sometime, unloading pipeline is designed as double lines for security. Once unloading, each pipe undertakes 50% of the delivery value. Therefore, when one pipe breakdown, the other one could be full load operated to continue unloading work. Moreover, in no-operating period, double lines build up a cycle. This makes sense for maintain low temperature in pipes to decrease LNG evaporation caused by thermal leak through pipes. Normally, pipes' low temperature is maintained by LNG which comes from onshore storage tanks, and this LNG will go back into those tanks after traveling in the circulated unloading pipeline. And on the unloading pipeline, there is a sample applicator to collect LNG before unloading operation to analyze LNG's properties such as composition, density and heat value (Goto, 2002).

One of the key design considerations during operation of the LNG terminal is the management of LNG vapors arising during both unloading and while LNG is stored in tanks between carriers discharging LNG. The vapor is produced as a result of the heat leak of the system during these operations and the LNG displacement during ship unloading. The management of this vapor is critical due to both the value of the vapor and the elimination of any venting or flaring of the vapor that may be prohibited by environmental regulations. Normal method is re-inject this vapor back into the ship's tanks with the vapor return line and loading arm which shown in the 3D diagram above. It avoids either air pollution or negative pressure in ship's tanks (Beale, 2003).

Figure 4
An LNG Unloading Facility at Guangdong LNG Terminal China

Marine LNG unloading facility like shown above is a major cost item which can have a significant impact on the overall economics of the LNG. The key design variables of the unloading system are:

a) Distance from ship to tanks,
b) Ship discharge pump capacity (typically 3-5 bar),
c) Elevation of tanks,
d) Desired discharge rate,
e) Top versus bottom fill of LNG tanks,
f) Number of lines desired for reliability,
g) Hydraulic design of the line (water hammer),
h) Structure design of the lines (bowing).

Sometime around the marine unloading dock, a breakwater may be required depending upon the wave environment for the area. The unloading facilities capable of providing shelter from waves can easily be the most expensive part of a LNG terminal, and can cost up to

$200 million, depending on whether or not a breakwater is required. The requirement for a breakwater will depend upon the ocean meteorology criteria, wave simulations and the availability of the availability of the unloading berth that is desired. The necessity for a breakwater should be a key design issue an appropriate time and resources allocated to confirm the requirement and the effect on facility availability.

2.2 LNG Send-Out Pump

Natural gas is sent out by send-out pumps to takeaway pipelines after metering.LNG send-out pumps can be distinguished into two types: First stage type (in-tank type) and second stage type (pot type). Their structures are shown in Figure 5 following:

a) First stage send-out pumps (in-tank type) – Several low-head LNG send-out pumps are installed in each LNG storage tank. These pumps are similar to the loading pumps at the LNG liquefaction facility, except the send-out rate is much lower than the loading rate therefore the pumps are smaller. A very large receiving terminal will have a send-out rate of 50-60 million standard cubic meters per day (MSCMD) while the ship unloading rate is closer to 150 MSCMD. The discharge pressure of the first stage send-out pumps is around 8 bar (Zietsman, Ehsanul Bari, & Aaron, 2008).

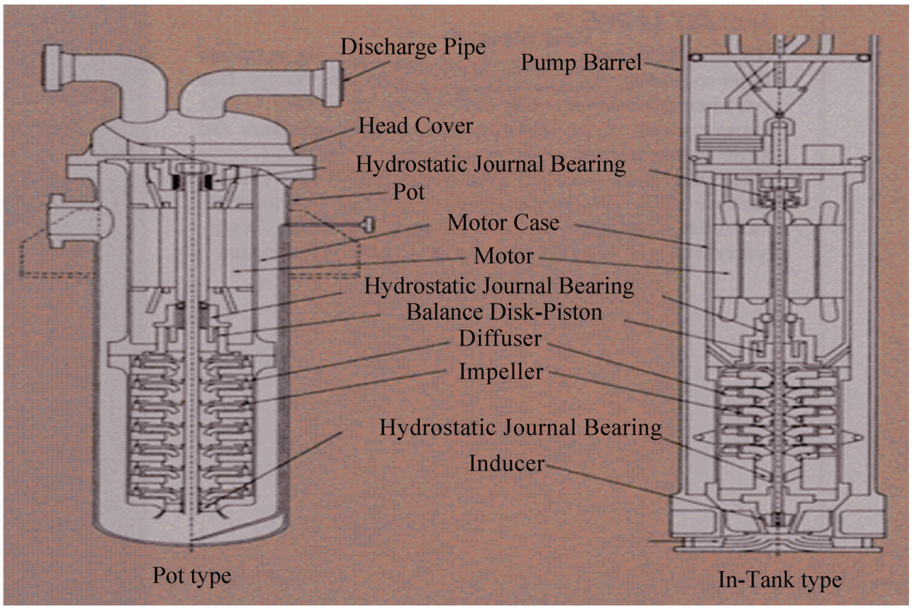

Figure 5
Structure of LNG Pumps

b) Second stage send-out pumps (pot type) – The send-out gas is usually injected into a high pressure gas transportation pipeline of approximately 80 bar. For this pressure, multistage send-out pumps are required. The pumps are high-head and take LNG from the first stage pump discharge and boost up the pressure to the vaporizers at the required pipeline pressure. Additional, to ensure pumps' regular operation, there are by-pass pipes to discharge section of pumps to construct some loops. With these loops, flow rate can be regulated.

3. LNG STORAGE TANK

From Figure 2 in chapter one, we can see there is LNG storage tank in receiving terminal. When discharged, LNG is either stored or immediately pumped to the regasification plant prior to entering the transportation or distribution system in the consuming area. But even immediately pump LNG to regasification can not match unloading rate because regasification rate is lower than unloading rate. Especially in the case of peak-shaving LNG projects, the LNG is stored to be re-vaporized only during periods when gas supply from other sources cannot fully meet the seasonal requirements of the distribution system.

This is why we need LNG storage tanks. LNG tanks are specially designed to storage LNG at its cryogenic temperature of approximately -161 C at atmospheric pressure. The receiving terminals are intended to store two to three LNG carrier volumes (up to 300,000 m 3 of LNG) in order to compensate for shipment delays, managing supply and demand variations for smooth send-out and for limiting demur-rage of carriers.

LNG inner tanks are primarily constructed with 9% Nickel steel inner tanks due to the cold temperature that they must withstand, or can also be constructed using stainless steel or aluminum. The outer tank can be either concrete or steel, depending upon owner preferences and Regulatory Authority requirements. The LNG tanks have a top entry point for both the loading and unloading operations. Submerged send-out pumps will be suspended from the top of the tank and pump the LNG out of the tanks (Kuz'menko, Dovbish, & Darbinyan, 2003). All tanks will be designed to simultaneously send out (to the regasification units) and to receive LNG (from-unloading LNG carriers). The tanks will be fitted with a low-pressure vent, which will provide storage tank over-pressure protection if the tank pressure exceeds the maximum operating limit of the LNG storage tank design pressure. Generally, a LNG tank is one of the following four types:

a) Single containment,
b) Double containment,
c) Full containment,
d) Membrane containment.

3.1 Single Containment Tank

Single containment tanks have only a single shell and use a secondary bound or earthen dike around each tank to limit the spread of a LNG spill. A single containment tank has a cylindrical wall and a flat and insulated bottom. It consists of a liquid-containing, self-supporting inner wall of 9% nickel steel which is surrounded by a thick insulation fill. Design considerations for this inner tank also include the hydro-static head of the LNG stored. The outer wall which is made up of concrete or carbon steel holds insulation but does not contain any cryogenic liquid leakage from the inner tank. It merely functions as the insulation holder. The secondary containment in this case is provided by a surrounding LNG Chain Regasification at Receiving Terminal 24 dikes as described above. Single containment which is shown in following Figure 3 is the most economical of the three basic types of containment (Bubger & Loerbroks, 1998).

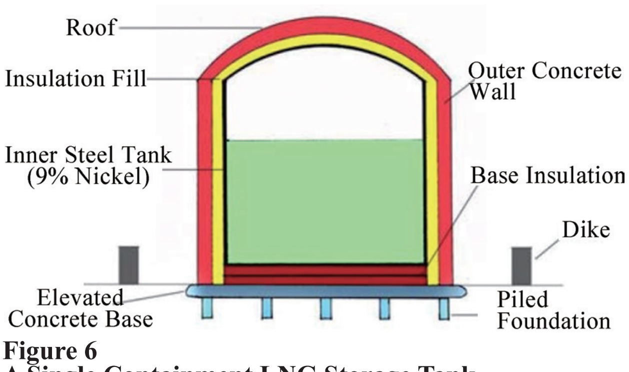

Figure 6
A Single Containment LNG Storage Tank

SUMMARY

Natural gas is believed by many to be the most important energy source for the future. LNG is recognized as the best form of natural gas transfer from remote continents to the consumers worldwide. The natural gas is liquefied and shipped to receive terminals. LNG receiving terminals are not a new phenomenon, with over 50 in existence worldwide, the oldest being nearly 40 years old. Currently, there are at least 50 proposed new receiving terminals in various stages worldwide. Due to the increased demand for clean burning energy and an abundance of natural gas worldwide, it is significant to research for LNG regasification at receiving terminals.

Setting up a LNG receiving terminal anywhere in the world is a difficult task in terms of local governmental policies, obtaining regulatory approvals and the associated initial investments. Many factors will influence the design and cost of a LNG receiving terminal. Some will relate to the owner's preferences and some will be mandated by the regulatory authorities and applicable design codes.

In technique, both LNG regasification technology and infrastructures are relative simple and proven to be widespread used. Compare those two regasification processes, the only optimum situation for directly compression process is consumers located around not far from receiving terminal and could receive a big quantity of low pressure BOG, so that not only re-condenser but also the pipeline compressor and second stage send-out pump can be eliminated.

Otherwise, as we see until now, BOG re-condensation process has been used mostly all over the world and also will be a chiefly option in future. For infrastructures, it is more likely to develop facilities' security, efficiency and reliability; meanwhile, decrease their capital and / or operation expenditure as possible in further study. As an example, storage technology which can we see that the development of it from single containment to full containment is a security enhancement process.

LNG receiving terminals have been using specialized equipment for years, but there are clearly opportunities ahead to further develop the technology. The interest in moving facilities offshore is high and improving process efficiency is also becoming a high priority. To date, all LNG import terminals have been constructed onshore. The cryogenic tank based near-shore LNG receiving terminals have been in safe and reliable LNG service for many decades. Although most of the LNG receiving projects which have been approved or are in the various stages of approval are to be located onshore. Due to local opposition, lack of undeveloped land remote from population, cost of land, and general permitting obstacles, now with the recent trend, the new terminals under consideration will be constructed offshore.

ACKNOWLEDGMENTS

The authors would like to thank all members of the research team.

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