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Engineering Considerations in Siting and Design of Offshore LNG Terminals

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Engineering considerations in siting and design of offshore LNG Terminals

National Petroleum Council (NPC) report [1] on "Balancing natural gas policy – Fueling the demands of a growing economy" in September 2003 forecast that the traditional North American producing area will provide only 75% of the long term U.S. gas needs. The current higher gas prices are the result of a fundamental shift in supply and demand balance. Even with greater fuel efficiency, conservation, and streamlining permitting process to allow increased drilling and development activity in Rocky Mountains; new large scale resources such as LNG and arctic gas, will be required to balance the increased gas demand and price volatility. At present approximately 2% of the total U.S. natural gas demand is met by imported LNG. Over the next 20 years, supply from the imported LNG is expected to grow, and it will make up approximately 15% of the total U.S. gas demand.

While the traditional land based LNG terminals in the U.S. and around the world have an excellent safety record, many local communities have been quite hostile to the idea of having an LNG terminal with large LNG storage nearby. Average Americans do not wish to have anything containing large hydrocarbon storage in their back yard, commonly known as NIMBY, due to perceived safety, security and environmental concerns. The intensive and well organized public opposition to the land based terminals has lead to the cancellation or delaying of several land based LNG terminal projects planned by major oil and gas companies in the Northeast and the Gulf Coast regions.

With the growing market demand and rising price of natural gas, LNG terminals have moved offshore which allows the siting of the LNG receiving terminals away from population centers. By moving terminals to the open sea, the problems associated with locating suitable coastal sites for bringing large LNG carriers through a narrow channel or other restrictions are avoided. Offshore LNG terminals promise to be the next best step forward in the process of supplying natural gas to the growing U.S. market.

At this time, the major areas of interest for offshore LNG terminals are the U.S. Gulf of Mexico and the Pacific coast, but it will not be long before considerations are given to the Northeast Atlantic coast. This paper highlights some of the major considerations associated with the siting and design of offshore LNG terminals.

Type of offshore terminal configurations

In general, there are three basic configurations of LNG terminals being considered today for siting at U.S. offshore locations. They are Gravity Based Structure (GBS) supported firmly from the sea bottom, permanently moored floating facility (usually a specially fitted LNG tanker with regasification equipment), and conventional fixed platform based facility supported firmly on a jacket from the sea bottom. In some cases fixed platforms are considered where the existing platform at a depleted oil field can be utilized. Fixed platforms also have been considered in combination with GBS based facilities.

Figure 1 below describes major types of LNG containment systems utilized for LNG storage offshore. There are two main options for LNG containment systems, described in Lloyds register energy and transportation [(2)], that are suitable for the LNG carriage. One is self supporting Type B, and the other one is a membrane tank system. Within option 1, there are two approved systems and they are Moss spherical tank system and IHI Self supporting Prismatic Type B tank system (IHI-SPB). Option 2 is the Gas Transport & Technigaz membrane tank system.

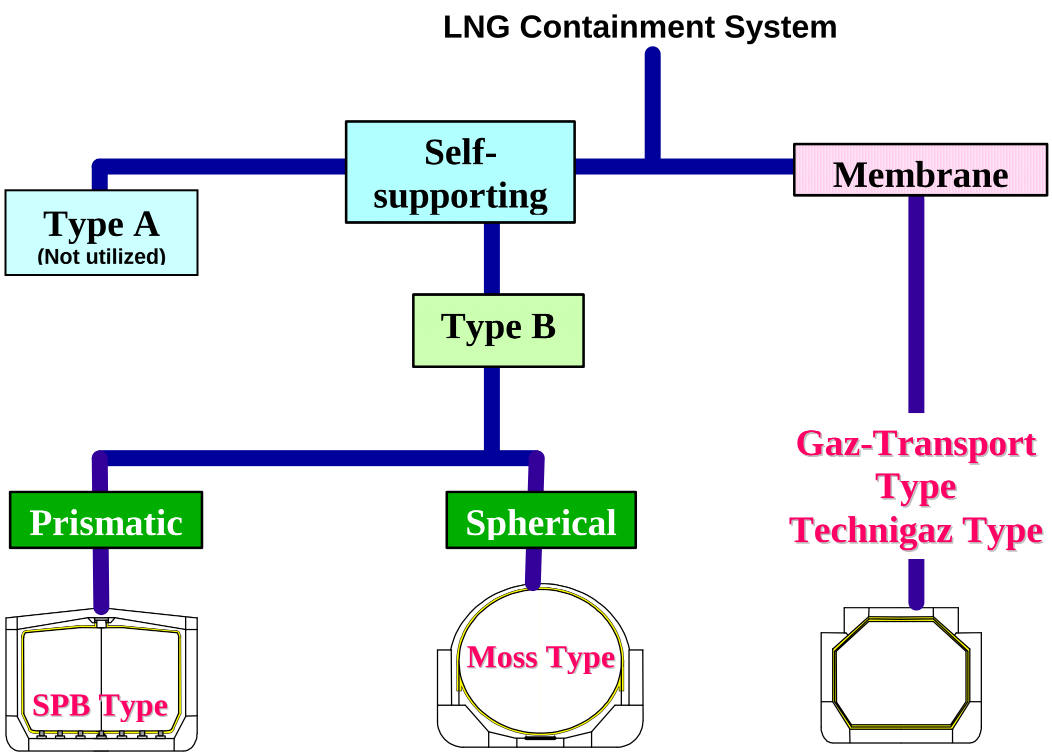

Figure 1-Types of LNG containment systems [(3)] utilized in various offshore vessels.

The above configurations are generally considered for LNG storage in various offshore based terminal configurations. The GBS based configurations can also be utilized with cylindrical configurations, similar to the onshore LNG storage tanks.

Figure 2 below shows the GBS based terminal. The GBS based terminals are ideal for shallow water where the IHI-SPB LNG storage tanks are integrated inside the concrete GBS, and where both vapor and liquid are contained within the GBS base, and the regasification and other essential facilities are located on top. The storage tanks can be IHI-SPB or rectangular shaped membrane tanks. Figure 2 shows two basic GBS terminal configurations. The one on the left has side by side IHI-SPB type tank arrangement within a single GBS, and the one on the right shows end to end configuration with one IHI-SPB tank in each GBS. The GBS terminal firmly rests on the sea bottom and provides a location similar to land based terminals for LNG ship unloading, storage and regasification.

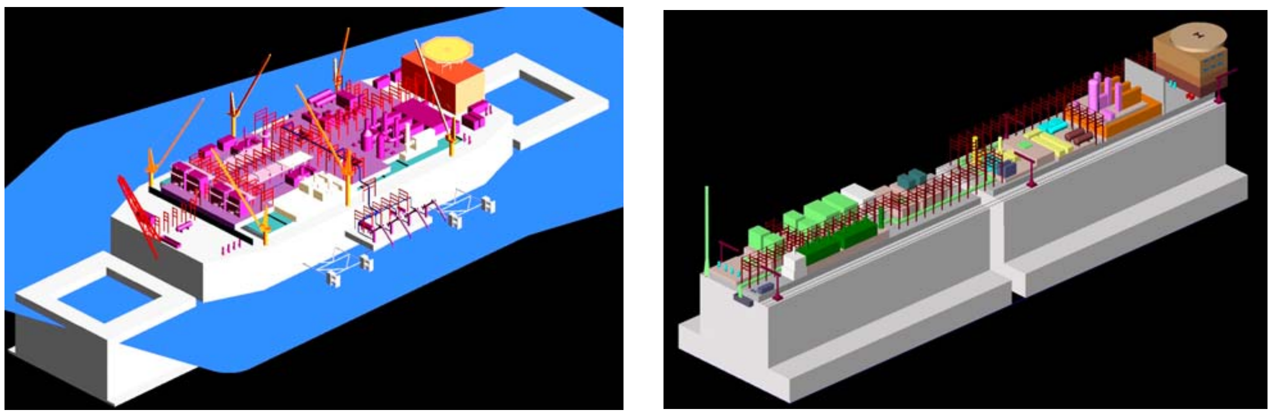

Figure 2 - GBS based terminals with LNG storage tanks inside the GBS.

Figure 3 below shows the floating type terminal. The floating terminal is ideal for deeper water. The LNG storage tanks can be IHI-SPB, Moss spherical storage tanks or the GAZ transport membrane tanks. The IHI-SPB or membrane tanks offer a flat main vessel deck which eases installation of regasification facilities. The Moss spherical tanks will occupy some of the vessel space and in principal require larger vessel dimensions, but the sloshing problems are less severe compared to the other types.

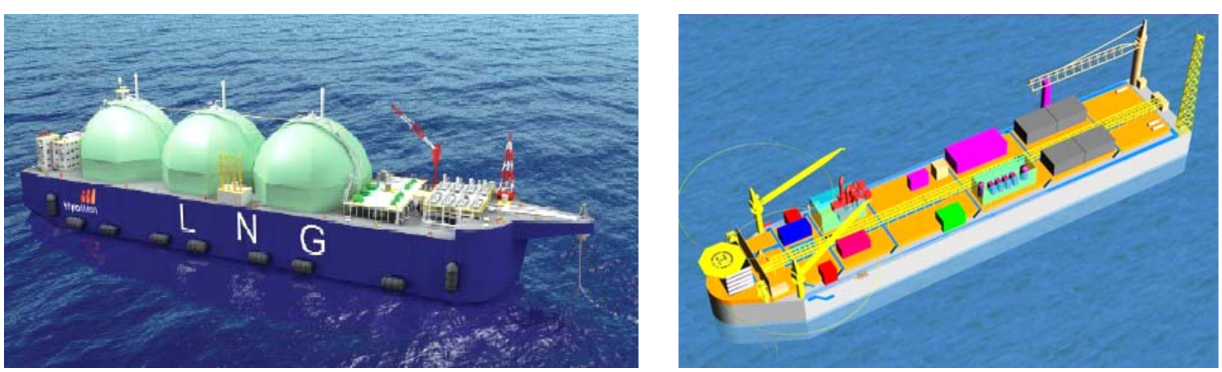

Figure 3 – Floating type LNG terminal with Spherical LNG storage tanks proposed by BHP Billiton for Cabrillo Port on the left and conceptual floating hull with IHI-SPB type tank inside on the right.

Sloshing is the most severe problem for the GAZ transport membrane system due to the lack of internal tank structure, particularly when the tanks are partially filled. The ship LNG offloading for floating terminals can be side by side using standard LNG unloading equipment or specially designed LNG arms (for example; stern to bow, FMC-Boom to Tanker, APL type flexible insulated hose, SBM offloading, Moss articulated system, etc.) for vessels moored in tandem. Both of these systems must be designed for movement during wave, wind and current conditions, as well as the size of ships to be unloaded. The design of side by side and tandem LNG offloading systems is one of the most challenging aspects in the design of the floating LNG terminals. The mooring design normally consists of either an external cantilevered turret system or internal turret system.

Figure 4 below shows the fixed platform based terminal. This terminal design utilizes various existing and new platforms to provide segregation of LNG storage, regasification and other support facilities. This platform utilizes a number of modular IHI -SPB type LNG storage tanks to spread the weight across the platform and to provide the maximum storage capacity in the confined space of the platform. Another approach would be to utilize Moss spherical tanks. The LNG ship unloading arms are similar to a land based system, but targeting the ship berthing is more complex and creates design challenges due to wave, current and wind conditions in the open sea. The offloading system is not protected due to open water, requiring special design considerations.

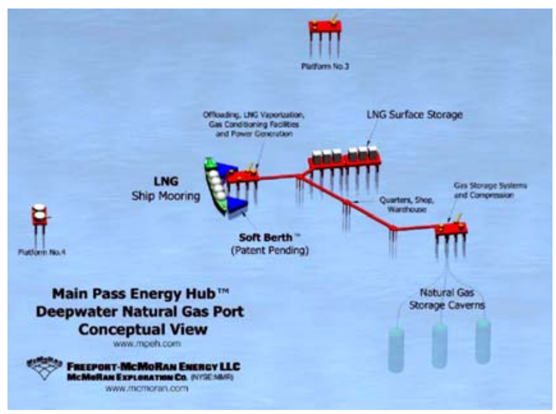

Figure 4 – Fixed existing platform proposed conversion to LNG terminal - Freeport - McMoRan's Main Pass Energy Hub™ located offshore, Louisiana

Siting Considerations

<u>Gas Export</u>

One of the primary design considerations in the siting of the offshore terminal is the proximity to existing infrastructure for receiving the export gas from the terminal. This factor explains the large activity for proposed offshore LNG terminals in the Gulf of Mexico, where a significant gas pipeline infrastructure exists. There is also considerable interest in the Atlantic Coast including offshore Canada which are in proximity to several major gas pipelines supplying gas to the Northeast U.S. region.

Siting of an offshore LNG terminal in remote locations away from existing infrastructure or in deeper water, can incur significant development costs for the export gas pipeline.

Water Depth

Water depth is a factor which normally determines the type of configuration that is likely to be utilized for offshore LNG terminals. Generally there is a draft requirement of around 40’ to 44’ for the LNG carrier. So generally speaking, 50’ water depth is a minimum requirement for any of the above (described) structures. The concrete GBS based terminal configuration described above is ideal for 25’ to 75’ water depth. As the water depth increases above 100’, economic evaluations must be carried out based on the type and size of the structure, local soil and seismic conditions, and met-ocean data. GBS based LNG terminals have been considered for a water depth as much as 120’, but current designs have generally shown unfavorable economics at greater water depths. In addition, a suitable location for a graving dock must be considered for GBS construction.

The floating type LNG terminal, for all practical purposes, can be considered for water depths beyond 150’. The ideal water depth for the floating LNG terminal is around 250’ to 300’, where there is reasonable flexibility for utilizing internal or external turret design depending on whether the environment is mild, moderate or harsh. Water depths below 200’ would require some type of Yoke system, unless the environmental conditions are very mild. There is no real limit as to how deep the water can be for siting the floating LNG terminal except deeper water depths requires additional cost and economic considerations for risers and mooring. Deepwater pipeline technology has matured to water depths below 2500’ and, thus, floating terminals have been considered at these water depths.

Fixed structure platform based LNG terminals can be considered for water depth of 50’ to above 200’. The general limit for the design of fixed structure platforms can be as great as 1000’, but the suggested practical water depth limit for fixed platforms is 200’ to 300’. The cost of supporting the LNG storage tanks, which starts becoming a big factor with greater depth, may limit the consideration of deeper water fixed platform.

Soil and Seismic Conditions (Geotechnical Factors)

The feasibility of siting GBS based and fixed structure platform based LNG terminals requires special considerations for soil and seismic conditions since they are supported from the sea bottom. Extensive site and design specific geotechnical evaluations are required. Once the detailed geotechnical evaluations are available, the detailed structural engineering design for the GBS or fixed structure platform can be carried out in a similar way as it would be for the seismically active land based terminals. In some locations, the underwater seismic and soil conditions evaluations are more difficult compared to onshore sites.

The floating LNG terminal has an advantage in seismically active sites since it is generally not affected by the seismic forces. The mooring and riser system is attached at the sea bottom, but it is normally designed for adequate flexibility to provide isolation from the main floating structure.

Marine and Weather Conditions

When considering offshore LNG terminals, marine and weather conditions are one of the major siting criteria that may determine the type of LNG terminal configuration for operational reliability. The wind, waves and currents in many locations can be severe, and it can affect marine operations depending on the type of terminal design configuration selected. The connection of the sub sea pipeline is more reliable when coupled to a GBS or other fixed structure due to the rigid connection at the sea bottom making it more stable in the marine environment.

The GBS based as well as the fixed platform based terminal offers similar advantages for topside operations over the floating type due to motion effect on the equipment. The marine offloading operation of GBS based terminal is the most reliable of all the configurations discussed above. In the fixed platform design the platform is fixed, but targeting an offloading ship can be difficult at times due to wave, wind and current in the open sea. In contrast, both the floating terminal and the LNG carrier will move due to wind, wave and current, creating large motion effects, which makes both the LNG tanker berthing operation and unloading more difficult. The design must consider these severe marine and weather conditions carefully to minimize berthing and unloading related reliability and availability problems. The effect on the flexible riser design for the gas pipeline due to motions in different directions must be considered for floating terminals.

Environmental and Safety

Generally, the environmental impact during terminal construction is not a major issue. In most cases, the major structures for all of the above configurations will be constructed away from the site and generally floated to the site. Bottom supported structures generally will have slightly more disturbance to marine life due to their attachments requiring greater area at the sea bottom compared to the floating type, requiring minimum attachment.

The impact related to the use of seawater for vaporizers or any other seawater requirements for the terminal, which might impact small fish and ithyoplankton, will be dependent on the specific design aspect of the regasification equipment.

Specific safety exclusion zones around the terminal site are all similar in nature regardless of the type of terminal being considered. All the offshore terminals considered above are unique in design and they require a detailed safety analysis and quantitative risk assessment on a case by case basis. The current codes, such as, NFPA 59A and EN1473, are primarily developed for land based terminals, where space is usually less of an issue. These codes must be scrutinized for offshore based terminals. The equipment lay-out, segregation of process and utility facilities from living quarters, escape evacuation and rescue analysis and consideration of inherent safety in design are some of the factors in the design of these facilities. The higher degree of automation to detect LNG spills and leak is another important consideration. These factors, along with the structured safety analysis for fire and explosion potential and hazard and operability (HAZOP) analysis of the facility design, reduce the risk and hazards in the facility and safety of the personnel.

Additional Design Considerations

The major design considerations are dependent on the type of terminal configuration described above. Many of these considerations have been discussed previously. Some additional design considerations are summarized below:

- Floating terminals usually require U.S. Coast Guard certification and periodic inspection. These factors must be thought through during the initial feasibility and selection of the terminal configuration.
- The factors affecting reliability in marine operations for LNG offloading system for various configurations are described above. Floating or fixed platform structure terminal operations may provide lower reliability than GBS based terminal. The initial project feasibility must consider these factors.
- Floating LNG terminals limit the use of Open Rack Vaporizers (ORV) due to motion effect. If sea water use is desirable to offer operating cost advantages, intermediate fluid vaporizer system, utilizing shell and tube exchangers, should be considered in the design. Floating terminals also require special attention in the design of Submerged Combustion Vaporizers (SCV) due to their sensitivity in maintaining water bath levels.
- In general, the floating terminal requires special design considerations for all unit operations requiring level controls in the equipment due to the terminal motion effect.

Conclusions

The market reality associated with the growing natural gas demand and rising prices, combined with local community safety, security and environmental concerns is causing the LNG industry to site terminals offshore. While there are challenges, various configurations discussed above provide unique solutions for siting and design of LNG terminals offshore. Offshore terminals promise to be part of the solution in supplying the natural gas to the growing U.S. market.

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