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Research Article

LNG bunkering pontoons on inland waters in China☆,☆☆

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Abstract

LNG bunkering pontoons are presented to solve the fueling difficulty of LNG ships on inland waterways with a great variation of water height and channel width by seasonal change. First, the background of this concept was analyzed as well as the demand of LNG bunkering pontoons, and the involved idea of levels management. Then, from the safety barrier perspective, safety design principles were discussed, the safety principles and implement measures of LNG storage were provided, LNG tanks for the pontoon were analyzed in detail in terms of their types, design pressure, material selection and leakage protection principles. Also, the safety concerns of LNG supply and bunkering process were raised, and an improved handy bunkering arm & hose, lighter and more flexible than ever before, was introduced. Berthing and unberthing are related to the survival of the pontoon so that the key points of such design were highlighted. It is concluded that (1) based on the levels management, the pontoon equipped with IMO Type C tanks, with reasonable berthing/unberthing and safety designs adopted, is proved to be safe and reliable by practices; (2) by 2025, nearly 30 such improved LNG bunkering pontoons with a fueling capacity of 500 m^3 each will be required on Yangtze and Pearl Rivers; and (3) the pontoon's safety and reliability has been verified by practices and its fourth generation has been developed.

Keywords: LNG bunkering pontoon; Floating fueling station; LNG fuel; Storage; IMO type C tanks; Bunkering arm & hose; Technical security; Levels management

In December 2015, the Ministry of Transport of China (MOT) printed and distributed the *Implementation Program for Ship Emission Control Areas in the Pearl River Delta, the Yangtze River Delta and around the Bohai Sea (Beijing, Tianjin and Hebei)*. This program, for the first time, defines the atmospheric pollutant emission regions of ships, and highlights the popularization of LNG as a marine fuel. In February 2016, the National Development and Reform Commission (NDRC), together with the Ministry of Environmental Protection (MEP), jointly issued the *Guiding Opinions on Strengthening the Control and Treatment of Environmental Pollution in the Yangtze River Waterway*, which particularly proposes to popularize the application of clean fuels like LNG. Under the guidance of the policies, the demands for LNG as a marine fuel have been increasing in coastal areas and inland water areas of China. The initial investment for LNG-fueled vessels is 15−20% higher than that for traditional ships, and oil price has fallen in recent years. In view of this, to economically encourage the application of LNG in ships as a fuel, the Ministry of Finance (MOF) stipulates the latest capital subsidy for LNG-fueled vessels in the *Supplementary Notice on the Regulations of Ship Abandonment & Disassemble and Ship Type Standardization Subsidy,* which was issued in 2016.

Thanks to the boosting of policies, 99 LNG-fueled vessels had been constructed or modified completely by the end of

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2016. A total of 1495 LNG-fueled vessels were approved by the MOT for construction or modification, among which 400 vessels are being constructed. The construction of LNG bunkering infrastructures is the prerequisite for the development of LNG-fueled vessels. Feasible LNG bunkering infrastructures includes shore-based LNG bunkering station, floating LNG bunkering station, LNG bunkering vessel and LNG tank truck [1–6].

1. Concept of and demands for LNG bunkering pontoons

1.1. The concept of an LNG bunkering pontoon

Natural rivers, like the Yangtze River and the Pearl River, vary greatly in channel width and seasonal water level (the maximum water level difference in the Yangtze River: about 18 m at the Chongqing section, 14 m at the Wuhan section and 8 m at the Nanjing section), so the shore-based LNG bunkering station is not suitable. An LNG bunkering vessel is classified as a dangerous cargo shipping vessel, and due to its feature, it shall be berthed frequently close to LNG-fueled vessels with LNG operation conducted, so its inland river navigation management is complex [7]. In view of this, Chinese industrial circles and the classification societies jointly put forward a new concept which is intermediate between a shore-based bunkering station and a bunkering vessel, i.e., an LNG bunkering pontoon, which can be also called “an inland water floating LNG bunkering station”. It is suitable for inland waters, and it is fixed close to the coastline or in specific water areas by anchors or cables to fill the LNG fuel to other vessels without navigation operation. An LNG bunkering pontoon is characterized by the following advantages. It doesn't need many coastline resources and its examination and approval is relatively simple; it can be moved conveniently and be recharged not only by LNG carriers on the water (at present, however, LNG bunkering pontoons can only be recharged by LNG bunkering vessels) but by LNG tankers on the shore.

The supply chain of an LNG bunkering pontoon is shown in Fig. 1. LNG is transported from a terminal to an LNG bunkering pontoon through a tank truck or a sub-line carrier, and then the LNG bunkering pontoon replenish LNG to an LNG-fueled vessel.

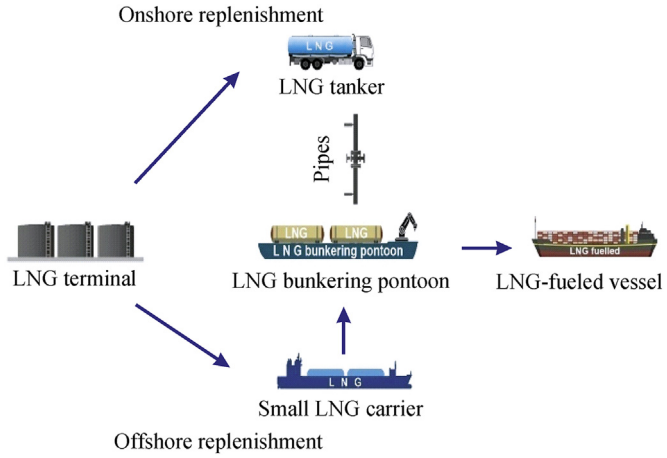

Fig. 1. Replenishment chain of an LNG bunkering pontoon.

1.2. Analysis on the demands

In China, there are more than 200 thousand ships on inland waters. It is conservatively estimated that by the year of 2025, there will be about 2800 LNG-fueled vessels in the Yangtze River area, 700 vessels in the Pearl River area, 3500 vessels in the Beijing–Hangzhou Canal and 150 vessels in coastal areas. LNG bunkering pontoon is an optimal choice for LNG filling in the Yangtze River and the Pearl River, demands calculation of which is shown in Table 1.

Table 1
Calculation of demands for LNG bunkering pontoons in the Yangtze and Pearl river areas.

Item	Yangtze River area	Pearl River area
Number of LNG-fueled vessels	2800	700
Average power per ship (in the general operational mode)/kW	400	300
Fuel consumption[a]/[g·(kWh)$^{-1}$]	190	190
Yearly working hours per ship/(h·ship^{-1})	3000	3000
Total LNG consumption per year/10^4 t	64	12
Storage capacity of each LNG bunkering pontoon[b]/tons	225	225
Days of one turnover per ship[c]/days	3	3
Yearly bunkering capacity of each LNG bunkering pontoon/10 thousand tons	27450	27450
Number of LNG bunkering pontoons	24	5

[a] It is estimated conservatively according to the measured data of domestic existing natural gas engines.

[b] It is calculated based on the LNG storage capacity of 500 m^3 per ship and LNG density of 450 kg/m.^{3}.

[c] The method for calculating the days of one turnover is as follows. The volume of LNG storage tank on each LNG-fueled vessel is set as 25 m^3, and according to the data of the actual project, the filling rate of LNG bunkering vessel is about 50 m^3/h, so one LNG storage tank can be filled in 0.5 h. Considering the preparatory and the subsequent operations take about 0.5 h, the filling time of each ship is assumed to be 1 h. The filling operation is carried out in the daytime (12 h), and the maintenance time is deducted, so it is assumed that 10 ships can be filled each day. Thus, the tanks on one LNG bunkering pontoon can be emptied in 2 days and be replenished in 1 day, so its turnover period is 3 days.

It can be inferred from the calculations of Table 1 that the demanded numbers for LNG bunkering pontoons will be 24 on the Yangtze River and 5 on the Pearl River, totally 29 by the year of 2025, if the storage capacity per LNG bunkering pontoon is 500 m^3. At present, the construction cost of one LNG bunkering pontoon with the capacity of 500 m^3 is CNY 35–50 million, which varies depending on the configurations of equipment. Table 2 lists the construction cost for a certain LNG bunkering pontoon. And it is shown that except for the hull structure, LNG storage tank, bunkering system and bunkering arms & hoses account for a substantial investment.

The statistics of LNG bunkering pontoons that have been built or are being built in China is shown in Table 3.