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Analysis of handling and storage of liquefied natural gas tank container

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Abstract

With the continuation of the policy of "Replacing Coal with Natural Gas" and " Blue Sky Protection Campaign ", natural gas consumption continues to grow. LNG tank containers are not only suitable for storage, but also have the characteristics of sea and road transport. With the help of multi-modal transport of containers, once transported in large quantities, they will become a new development direction of LNG production, supply, storage and sales system. To our knowledge, the research work on LNG tank containers has been carried out, but the laws and regulations are lacking, and the existing standard system can be poorly referenced. Meanwhile the accumulation of safety production experience, simulation of accident consequences and safety risk analysis will become the main auxiliary means to guarantee the safe operation conditions of LNG tank containers.

Keywords: LNG, LNG tank container

1. Introduction

Natural gas consumption continues to grow as the policy of "Replacing Coal with Natural Gas" and "Blue Sky Protection Campaign" continues. In April 2018, the National Development and Reform Commission and the National Energy Administration jointly issued the Opinions on Accelerating the Construction of Gas Storage Facilities and Improving the Market Mechanism of Gas Storage and Peak-shaving Auxiliary Services, providing a path guidance for accelerating the construction of natural gas production-supply-storage-sales. Nowadays, the construction of gas storage facilities such as LNG receiving terminal, LNG peak-shaving station is in full swing [1]. However, LNG receiving terminal have long construction cycle, uneven distribution and huge investment; The natural gas pipelines in LNG peak-shaving station cannot cover the small and medium-sized areas, so that the use and development of natural gas are restricted [2,3]. At present, liquefied natural gas tank containers are commonly used for transportation. LNG tank containers are not only suitable for storage but also for sea and road transport. Furthermore, liquefied natural gas tank container can realize direct docking between point supply and use terminals by means of container multimodal transport, benefiting the enterprises and people in the wider middle and small areas. However, the loading and unloading, storage and transportation of LNG tank containers are restricted by standards and industry cognition, until now, they have not been effectively applied yet.

2. Introduction of LNG and LNG Tank Container

Liquefied Natural Gas (referred to as LNG) is mainly composed of methane, a small amount of ethane and propane. It is colorless, odorless, non-toxic and non-corrosive. The gas-liquid critical temperature is about -160℃, the ignition point is about 650℃, the explosion limit is 5%~15% and the gasification ratio of 1:600 [4]. What's more, it is also an important clean energy. It is classified as category 2.1 flammable

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gas by the United Nations, whose UN number is 1972 [5], due to its wide explosion limit range, high gasification ratio and serious accident consequences.

Liquefied natural gas tank containers (referred to as LNG tank containers) are a kind of transportation equipment consisting of two parts: frame and tank. The tank consists of vacuum multi-layer adiabatic cryogenic liquid storage tank, and one end is equipped with valves, instruments and safety accessories [6]. LNG tank containers are a kind of portable tank, its design, materials, manufacturing, inspection and other aspects all comply with the requirements of international conventions and rules. Such as the International Container for Safe Containers (CSC)、UN Model Regulations, IMDG Code. Like ordinary container [7], LNG tank containers are easy to load and discharge and transport.

LNG tank containers come in three sizes: 20 feet, 30 feet, and 40 feet. The single containment tank volume is smaller than the main tank, the largest of which is less than 40m^3. LNG tank containers have good vacuum insulation performance [8], which greatly reduce the static evaporation rate, so that the tank can be maintained for 90 days without damage, up to 180 days. In this way, it can guarantee the LNG from evaporation and diffusion during transportation. In addition, LNG tank containers are equipped with safety instrumentation systems, emergency cut-off devices and other safety facilities, which inherently guarantees safety.

In summary, LNG tank container is relatively safe to transport as packaged goods although LNG is dangerous. It's flexible, safe and adaptable to a wide range. It can be widely used in vessel, railway and road transportation. It breaks the traditional storage and transportation forms of pipelines, tank trucks and storage tanks, breaks through the barrier that the pipeline must be consistent, and realizes the "door-to-door" terminal supply of natural gas. In the inland, LNG tank container stations can also become an important way of reserving natural gas. We believe that the promotion and application of LNG tank containers will change the distribution of energy supply and form a new production supply, storage and sales supply chain.

3. Development Status of LNG Tank Container

3.1. International development status

In 1999, Japan built a 30-foot container to transport LNG [9]. In 2010, Norwegian began shipping 40-foot cans in roll-on ships to Denmark. In 2014, Portuguese Gaslink company began to use 40-foot LNG tank container to transport to the satellite storage gasification station in Madeira, 1,900km away within a week. In 2015, Carib Energy of Florida, USA, designed a vessel capable of carrying more than 100 LNG tank containers. Normally, it would carry 15 40-foot LNG tank containers to the Caribbean region 2000 kilometers away each time. Then the tank containers were stevedored at port and transported by land to small local gasification stations.

In short, it can be clearly seen that foreign LNG tank container has entered the practical application stage. However, the quantity and storage scale of LNG tank containers are relatively small, which is difficult to meet the needs of industrial production or dwellers gas consumption.

3.2. Domestic development status

Our country's LNG tank containers transport started relatively early, but it is only in the research stage and has not yet been applied on a large scale. In 2003, Xinjiang Guanghui Group promoted the birth of first LNG tank container standard in order to carry out 1.8 km of LNG railway transportation. In July 2003, Zhangjiagang CIMC Sanctum Cryogenic Equipment Co., Ltd. conducted a 25-day road test of LNG tank container with a journey of 8,000 kilometers. In 2006 and 2012, Scientific Research Institute of the Ministry of Communications, Dalian Maritime University and other institutions carried out the sea transportation tests of LNG tank. In 2018, CNOOC carried out tests on LNG tank container filling, road transportation, storage and tank quality [10]. With its efforts, 130 40-foot LNG tank containers were transported by vessel from Yangpu Port in Hainan to Longkou Port in Shandong Province. It’s the first time that China has realized large-scale ocean transportation.

The research of LNG tank containers in China is in full swing, both water and land transportation of LNG tank containers can be implemented, which shows that China is confident about the application prospect of LNG tank containers. With the advancement of the research, the relevant standards and regulations of LNG tank containers for whole ship transportation and inland storage are expected to be promulgated in the year.

4. Analysis of Loading and Discharging, Storage and Transportation of LNG Tank Containers

The application of LNG tank containers transport is restricted by many aspects, including LNG design, manufacture and inspection, LNG loading and discharging, storage and LNG transportation process. The control system is also divided into three levels: international conventions, rules, national and regional laws, regulations, norms and standards.

4.1. LNG tank containers

The design and manufacture of LNG tank containers must comply with the requirements of international conventions and meet the requirements of Frozen Liquefied Gas Tank Containers (NB/ t47059-2017) and other standards. As pressure vessel, special equipment inspection should be carried out; Safety valve, emergency cut-off device and pressure gauge, shall be subject to mandatory verification; Lightning and static electricity protection devices should be tested.

4.2. LNG tank filling and discharging

Compared with the LNG tank truck, the LNG tank containers have a relatively high filling position. The LNG loading arms in LNG loading station is too short to be directly connected, the impact of loading load on LNG loading arms should be considered when adding short arm. During the transportation process, The LNG will slowly evaporate to form BOG gas due to the absorption of external heat, which will lead to an increase in the pressure inside the tank. Once the designed pressure of the relief valve is exceeded, BOG discharge may occur, causing accidents [11]. In order to ensure the safety of long-term transportation, the filling rate of LNG tank containers should be strictly controlled. During filling, the temperature and density of LNG must be monitored. The actual maintenance time of LNG tank containers should be determined comprehensively by the filling amount and LNG physical property parameters. It is worth noting that the conventional maintenance time of the LNG tank containers specification cannot be considered as the storage and transportation time. The maintenance time shall be considered for all the time of filling, storage and transportation to the user. When unloading LNG tank containers, external pumps will draw liquid from the tank. If excessive pumping occurs, LNG tank containers collapse or instrument failure may occur, so the tank containers should not be completely emptied. Daily monitoring should also be carried out for the small amount of LNG remaining in the tank after unloading.

4.3. Loading and unloading LNG tank containers

The LNG tank containers outer frame is an international standard container frame, and the ship can use the shore type container bridge transporter. The car can adopt the shore type container gantry crane with topside extension; the rail type or the belt type gantry crane, the front hoist; the train loading and unloading can use the track or wheeled gantry cranes, front hoists. Appropriate handling equipment should be selected according to the site form. Relatively speaking, the front hoist is more flexible when loading and unloading by cars or by trains. In order to carry out LNG tank containers handling operation, it is necessary to obtain the corresponding qualifications for dangerous goods operations and comply with the relevant provisions on operational safety management. For instance, the enterprises work in the dock shall obtain the qualifications for the operation of Class 2 dangerous goods and implement the Safety Regulations for Port Operations of Dangerous Goods Containers.

4.4. Storage of LNG tank containers

Relative to the loading and unloading operations, the danger is greatly increased due to the

accumulation of dangerous goods.

At present, there are many standards related to the construction of international and domestic LNG stations, LNG receiving terminal, LNG vaporizing station, etc., but there are few applicable LNG tank containers. Such as Code for Fire Protection Design of Oil and Gas Engineering (GB50183-2004), Code for Fire Protection Design of LNG Receiving Station Project (GB 51156-2015), Design of LNG Equipment and Installation of Onshore Equipment (GB/T 22724-2008), Liquid Natural Gas (LNG) Production, Storage and Shipment (GB/T20368-2012). All the storage containers mentioned above are LNG storage tanks, whether it is single containment tank, double containment tank, full containment tank, all refrigerated tanks, full-pressure tanks, and tanks are different from LNG tank containers. Hence, the storage and transportation methods and safety measures of tanks are also quite different. As far as we know, the standards that can be used for reference are currently only the port industry's Safety Regulations for Dangerous Goods Container Port Operations (JT397-2007). The standard stipulates that when LNG tank containers are loaded and unloaded at the port, they should be stored within a limited time. LNG tank containers should not be stacked during storage. LNG tank containers can be stacked without any spacing and other related safety requirements, but LNG tank containers yards are lacking. The fire-proof spacing requirements of enterprises and facilities in surrounding conditions, lack of professional requirements such as lightning protection grounding and fire protection.

Therefore, when constructing the LNG tank containers yard, there is no standard norm to be able to design the surrounding protection distance and the distance between the facilities in the plant. At the same time, there is no suitable reference or reference clause, and the design can only be borrowed from the relevant terms. In addition, the implementation of existing regulations also requires consideration of security in conjunction with practice. For example, the storage spacing between LNG tank containers, although there is no spacing requirement, should also leave at least safety inspection, inspection, and other working channels. In addition to the conventional fire separation distance, the external safety protection distance of the LNG tank containers yard should be determined in combination with the personal acceptable risk standard and the socially acceptable risk standard.

4.5. The transportation of LNG tank containers

4.5.1. Vessel

LNG tank containers is transported internationally and is subject to the international convention on the Transport of Dangerous Goods. For example, LNG tank containers are used as dangerous goods, so the UN Model Regulations on the carriage of dangerous goods should are executed. Ships carrying LNG tank containers shall comply with the requirements of Article 19 of Chapter II-2 of the International Convention for the SOLAS Convention [12]. LNG tank containers shipping shall comply with the mandatory provisions of the IMDG Code on the transport of packaged dangerous goods [13].

It is stipulated in IMDG that LNG packaging transportation are P203 for the package guide, T75 and TP95 for the tank guide [14]. P203, T75, T95 are the requirements for the design, manufacture, inspection, and testing of tank containers. Stowage and isolation as Class D. Class D representatives are limited to the cabin area and need to avoid living and living spaces. IMDG does not impose restrictions on the number of stacking layers. Due to the inability of the cabin to be stacked, the number of LNG tank containers shipped is limited, and the stacking height on deck also needs to consider the ship's draught, navigation stability and other factors [15]. In addition, the LNG tank containers should also consider BOG emission control issues when transporting large-scale vessels.

4.5.2. Road

LNG tank containers transported by road are similar to those transported by tanker. The difference is that the LNG tank containers can be loaded and unloaded, so the stability of their fixation is more important [16]. In addition, according to the statistics of LNG road transportation accidents from 2001 to 2011, vehicle traffic accidents and LNG leakage are the main safety risks of LNG road transportation. LNG tanks are mostly 40 feet long, the vehicles are relatively large, driving is more difficult, and traffic

accident risks should be paid extra attention.

4.5.3. Railway

Compared with road transportation, railway transportation roads have high reliability and low traffic accident incidence [17]. However, the railway transportation transition, loading apron are relatively complex, and the requirements for handling equipment and yard are high. In addition, the tunneling of the train may result in external overpressure, which has higher requirements on the material and stability of the tank containers.

5. Conclusions and Recommendations

LNG tank containers will become a new development direction of LNG production, supply, storage and sales system once large-scale transportation is realized through multimodal transport. At present, the application and research of LNG tank containers have been carried out, but laws and regulations are relatively lacking, and the existing standard system can be poorly referenced, so accident consequence and risk analysis should be the main auxiliary means for safety assessment [18]. To ensure the safety of LNG tank containers transport, multiple departments or enterprises should cooperate with each other in manufacturing, use and inspection. Let production-supply-storage-sales be integrated to jointly promote the coordinated and stable development of LNG tank containers.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Jian Guo and Haiqi Tang analyzed the data and wrote the paper, Hui Song undertook the literature review, Guoqing Sun had input valuable ideas to the realisation to the article, all authers had approved the final version.

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