TRANSPORTATION OF LIQUEFIED FUEL GAS IN CONTAINERS

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Abstract: Transportation from receiving terminals and condensed fuel gas production plants is accomplished by sea, railway and road transport using the standard (ISO) tank-containers, dedicated tanks and cryogenic semi-trailers.

Recently, the 20 ft and 40 ft tank containers, optimally adapted for multimodal transport have become commonplace. The use of cryogenic semi-trailers with vacuum-perlite, polyurethane, multi-layer and combined insulation with a capacity of up to 54,000 liters of condensed fuel gas allows for creating a flexible and elastic delivery system to the market.

KEY WORDS: LAND TRANSPORT, SEA TRANSPORT, GAZ CARRIER, EXPLOSION SAFETY.

1. Introduction

Liquefied Natural Gas (LNG) represents the main alternative to pipeline supplies of gas. In liquefied form, natural gas (methane) can be stored and transported across long distances, contributing to diversification of supply and enhancing energy security in Europe. The gas market in the EU is characterised by gradually declining domestic consumption and more rapidly declining domestic production. Import needs are likely to increase in the short and medium term, and remain broadly stable in the longer term.

The International Energy Agency and the European Commission expect this trend to continue in the coming years. Major new LNG suppliers are emerging and the prospect of US shale gas being exported as LNG could further reshape global gas markets. The European Commission is developing an EU strategy for LNG and gas storage, one of several measures under the Energy Union package to improve energy security and diversify sources of supply. Infrastructure projects, often with EU funding, are helping several Member States to access LNG supplies, while others have sufficient import capacity to meet expected future needs. A strategic emphasis on LNG is consistent with the recommendations of the European Council and the European Parliament.

Transportation from receiving terminals and condensed fuel gas production plants is accomplished by sea, railway and road transport using the standard (ISO) tank-containers, dedicated tanks and cryogenic semi-trailers.

The first automobile transportsations of liquefied natural gas in the United States dates back to the mid-1960s. In this time period there were not created the special designs of road tankers intended for transportation of liquid gases. Transportation were mostly of an experimental nature and were carried out in modernized vessels engineered for transportation of liquid hydrogen and nitrogen.

A huge increase in the number of consumers and the volume of deliveries of liquefied gas raised the question of creating specially engineered road tankers for transportation of large quantities of liquid gas. When developing the design of tanks, it was necessary to take into account a number of conditions, for example, to fit within the established dimensions for a trailer coupled with a towing vehicle. In this regard, the maximum length of a truck with a trailer was required to be less than 12.2 m, and the width - 2.44 m. The type of transportation was also taken into account. In this case, the trace route was taken into account, as well as whether the supplies are transit or they are intended for a single consumer. In addition to that, the design of a vehicle for transportation of liquefied gas must be approved by the Ministry of Transport. The first road-tankers for transportation of liquefied gas were limited both by the dimensions and weight [1].

Since the limitations on the dimensions and of road-tankers for transportation of liquid gases were established, the tanks with the increased working pressure (more than 2.8 kg/cm²) had been considered to be the preferred option. The use of these tanks has enabled to produce pouring the liquid gas without the use of the special-purpose discharge pumps. However, automobile transportation of liquefied gas remained low-efficient, since the highly flammable and explosive cryogens required installing expensive equipment, as well as the availability of fire-fighting equipment.

One of the main factors that need to be resolved is the determination of the optimal working pressure in the tank. In the light of the accumulated operating experience, the pressure of about 4.9 kg/cm² proved to be a most appropriate.

Liquefied gas is used for both covering the peaks in uneven gas consumption, and as the buffer fuel and raw materials in the event of temporary shutdown of gas pipeline.

In road transport of liquefied gas, great attention is paid to ensuring their explosion safety and control systems during discharge, loading and gas shipment. Two pressure gauges are installed on the tank, by which the driver controls the pressure in the tank during transport. A liquid level sensor, of the type of a differential pressure gauge, is calibrated in inches of water gauge. On the pipelines block, there is a table of conversion of readings of a differential pressure gauge into gallons. A remote-control system for the filling and emptying of tanks is provided.

When discharging liquid gas, part of it is skipped through the regasifier, after which it is returned into the tank. The operator maintains a constant control over the pressure in the tank, brings it to a specified value, and then turns on the taps and discharges the liquid gas.

A number of companies widely introduce computer engineering in supply maintenance practice. In particular, a program has been developed for calculating the operating schedule for preventive maintenance of vehicles for transportation of liquefied gas.

When designing the road-tankers, it is advisable to take into account the experience acquired with designing tanks for transport of other liquid gases - hydrogen, nitrogen, oxygen, and argon. The reliable thermal insulation of vehicles for fuel gas from the environment is due to the fact that the ambient temperature is 200 °C higher than the temperature of the liquid to be carried. The thermal insulation reduces evaporative losses. Besides, according to standards for occupational safety, the uncontrolled evaporation of gas during transport is unacceptable. Good insulation is the key to the economically optimal conditions for transportation of cryogenic liquids.

Insulation of the first transport tanks was carried out by filling the insulating space with powder, such as diatomite or magnesium carbonate. There is a way to insulate the container with powder under vacuum. The effectiveness of insulation by virtue of the provision of vacuum in the insulation cavity between the outer shell and the inner wall of the tank has increased 10 times. The thermal conductivity of this insulation is about 10⁻³ kcal/m·hr·°C. In addition, the vacuum insulation has the following advantages: the thickness of thermal insulation is reduced; at the set maximum diameter of the tank, the capacity of the latter increases due to the increase in the diameter of its internal tank, the wall thickness of the internal tank might be small due to a slight rise in pressure during transportation in the tank vapor space above the liquid to be carried.
2. Preconditions and means for resolving the problem

The outer shell of the tank is designed on the atmospheric pressure. The dimensions of this shell, which is a cylindrical tank with a big moment of resistance, allow for using it as a chassis of self-supporting semi-trailer.

Experience shows that the price of the tank with the vacuum powder insulation is only slightly higher, and sometimes is even lower than the price of the tank insulated only with powder. For the life time support of the vacuum powder insulation, it is necessary to exercise the pilot-testing in the manufacture of the tank shell. The pilot-testing includes the ultrasonic test of the cylinder and the bottoms, the X-ray examination of the weld seams and leakage detection using helium by means of a mass-spectrometer of both the inner and outer walls of the tank, as well as the pipelines mounted between both tanks.

Switching of partial flow of cargo into the tank-containers is considered to be a promising option for improving the rail transport economy. This is a relatively new vehicle for transportation of liquefied fuel gas. The tank-containers represent a modern and effective way to transport liquefied fuel gases.

Advantages of transportation of fuel gases in tank-containers are as follows:
- improvement of the rail transport economy;
- solving the problem of rolling stock deficit;
- shortening the time of transportation (time require for decanting of cargo, car detention due to the limited power capacity of the decanting stations);
- reducing dependence on the monopolized systems of storage and transfer;- exclusion of losses of product in evaporation and maintaining its chemical properties, owing to the exclusion of repeated decanting of cargo (in places of transfer, along the joint of a change of transport mode or the width of the railroad gauge);
- the geographical expansion of sales (door-to-door delivery to consumers, even in the absence of traditional infrastructure for transportation of fuel gases);
- additional opportunities to increase the number of fuel gas retail outlets, since the tank-containers can be used as repository and reservoirs.

Considering world practice and tendencies of market development, experts regard as inevitable the development of tank-container transportations. This view is supported by the fact that in the world transportation containerization is a driving force behind the development of logistics services. It should also be borne in mind that a growth factor in demand for this means of transportation through the South Caucasus transport corridor may be the implementation of the gas program of Azerbaijan, Kazakhstan and Turkmenistan.

Tank-containers meet precisely all the requirements imposed on them from the part of suppliers and consumers of liquefied fuel gas. First of all, the tank-containers are designed to operate at low temperatures. The temperature range, at which products retain their properties makes up from - 500C to + 500C. Another advantage of the modern container is the use of shut-off equipment, which reduces the cost of products, and makes them maintainable.

Maritime shipping

Tank-container is a tank for transportation of liquid bulk and gaseous cargo. Modules of this type are optimal for multimodal transportation, because when changing the type of transport, they do not require technically challenging repacking of contents. They are in demand in the field of transportation and sale of fuel and energy resources.

Structurally, the tank-container is a cylindrical metal cargo block in a rectangular frame. Its capacity is 25-35 m³. The discharge mechanism of the tank-container can be made either as a simple gravitational discharge or as a system for pumping the contents under pressure using the pumps. Their bodies are made of chemically resistant stainless steel. The hardness of the frames meets the ISO requirements. The combination of these parameters ensures safe transshipment and stacking of loaded equipment.

The tank container has unique advantages over the advanced standard block:
- It guarantees 100% safety of transportation of highly combustible and explosive cargo, including different types of fuel;
- The original discharge system allows for unloading the containers quickly and minimizing losses of the contents;
- The tank-container fits 60% more liquid or gaseous substances, compared to the similar standard block, and therefore provides savings in logistics more than twice and increases the profitability of business-projects.

The 20-foot tank-containers fall under the category of fast-payback equipment with high profitability.

Transport of tank-containers is carried out on the railway platforms, on decks and under decks of ships, by motor transport.
- Maritime transport of containers is carried out on decks of ships of an ordinary type and on decks and in the container cells of specialized the container carriers.
- During transport of tank-containers by public roads, there are used the container-carriers and semi-trailers equipped with the container mounting devices.

Tank containers are divided into several types, which in turn mean suitability for transportation of goods of a certain kind, in accordance with the specification in various categories, ranging from IMO0 (food products) to IMO7 (cryogenic gases).

The IMO7 category covers tanks for transportation of liquefied or pressurized gas, which typically has the operating pressure more than 7 bar. The variety of gas transported in such tanks is numerous, and there is no “standard” specification for such tanks for the operating pressure. The type of tank will depend on the technical characteristics of transported product. In all cases, the exact nature of product to be transported must be known in advance in order to determine the required operating pressures. These tanks are used for products such as butane, propane, liquefied petroleum gas.

Tank-containers, being a multimodal vehicle for international transportations, comply with international and national requirements for vehicles carrying dangerous goods, and tank-containers, should not be offered for carriage, if [2]:
- In an ullage, the movement of liquid within the tank may produce an unacceptable hydraulic force;
- Tank is unpressurized;
- Failures are such that the integrity of tank-container and its lifting and mounting devices can be compromised;
- Service equipment has not been examined and it has not been established whether it is in proper operating conditions.

In the process of transportation, tank containers should be adequately protected from lateral and longitudinal impacts and from overturning. If the hull and service equipment have such design, which is able to withstand impacts or overturning, but such protection is not required.

The examples for the protection of hull at collision:
- side impact protection may consist, for example, of longitudinal beams protecting the hull on both sides at the centerline level;
- the protection of hull from overturning may consist, for example, of reinforcing rings or beams, fixed across the frame;
- back impact protection may consist of a collision bumper or frame;
- the external nozzles must be so designed or protected so that they can prevent the release of contents on impact or if tank was overturned onto the nozzles.
Untreated and non-degassed empty tank-containers must meet the same requirements as tank-containers filled with relevant transported substances.

Displacement of container-tanks during an overload should be made smoothly, without jolts. The collision of tank-containers with vehicles, containers or other items shall be prohibited.

**The carriage of tank-containers by motor transport** is increasingly demanded in the intermodal traffic, when different types of transport interact with each other, when changing the rail gauges, or when delivering to hard-to-reach areas, where there is no railway line and where this container can be delivered by car.

**Transportation in tank-containers** is economically beneficial for exporters and importers, since cargo is not overflown either when changing gauge or in ports when transshipping onto a vessel, which rules out losses of cargo that inevitably occur from spillover, and besides, transportation of containers by rail is considerably cheaper than transportation by car.

The dimensions and coupling sizes of ISO-standard tank-container fully coincide with the sizes of a dry cargo container. Due to the aging of the rail car-tank fleet for transportation of dangerous goods and the minimum production of new rolling stock, the percentage of dangerous goods transported in tank-containers will increase in the future.

Given the lack of the necessity of intermediate cargo transshipment in multimodal transportation, tank containers are the most economical and practical.

Advantages of tank-containers:

1. Tank-container – the means for safe transportation of liquefied gases. Safety of international transport is provided by a well-developed world system of certification of tank-containers, inspection, repairing, testing, and insurance of containers and cargo;
2. The absence of additional overflow operations in the case of combined carriage by several types of transport from the manufacturer of cargo to the consumer, which makes it possible to exclude operations transshipment of product when changing the type of transport or crossing borders, in order to maintain the product’s factory quality;
3. The possibility of international transportation under the customs seals, applied during cargo shipping anywhere on Earth crossing any number of state borders;
4. The possibility of warehousing and temporary storage of goods in tank-containers without immediate unloading;
5. The solid structure of tank-containers that allows for stacking in several tiers;
6. No need for special tracks leading to the places of discharge and filling of product;
7. The possibility of direct inclusion in the technological cycles of chemical, oil- and gas-processing enterprises and so on.

Maritime transport of containers is carried out on decks of ships of an ordinary type and on decks and in the container cells of specialized the container carriers. The rules for the carriage of tank-containers by sea, as well as the requirements for tank-containers are regulated by the International Maritime Dangerous Goods Code in maritime transportation, there are mostly used the ISO series containers having a width of 2438 mm. Containers with a height of 2438 mm have designations 1C, 1B, 1A, 1D; containers with a height of 2591 mm - 1CC, 1BB, 1AA; containers with a height of 2896 mm - 1BBB, 1AAA; and containers with a height less than 2438 mm have designations - 1CX, 1BX, 1AX и 1DX.

According to ISO standards, tank-containers are divided into a number of classes, the most common of which is IMO class 1 - for transportation of dangerous chemical goods.

Fastening the tank to the frame elements or supporting elements of container must withstand the inertia forces of the tank itself and its load, arising during the movement of vehicle.

To prevent an increase in the internal pressure, each tank or compartment is equipped with the pressure control devices. If necessary, tanks are insulated, and also, there may be installed the means of cargo heating or cooling. This includes the measures to ensure safety of tank and its contents in the event of an excessive rise in temperature and stresses.

**3. Conclusion**

Today, in international practice, the use of tank-containers having a number of design features (for example, small capacity for transportation of viscous chemical goods, with a special inner lining for transportation of acids and hydrogen peroxide), refrigerated, heated for high-melting bituminous products, as well as for bulk and powder cargo.

The general requirements for the design and operation of tank-containers for maritime transportation are as follows [3]:

- The bodies of tank-containers should be made of metal suitable for profiling. For the welded bodies, it is allowed to use only material whose weldability has been fully proven.
- The coating material should not be significantly affected by contents, be homogeneous, non-porous, and be no less plastic than material of the pipelines of tank, and should have the same coefficients of thermal expansion.
- Use of aluminum as a construction material should be restricted for tank-containers intended for land transport, but its use is allowed for maritime transport if there is a special permit on Part II of the UN Recommendations for certain goods.
- The coating of each tank, nozzles and pipelines must be continuous and must cover the surface of any flange. The coating material should not be significantly affected by contents, be homogeneous, non-porous, and be no less plastic than material of the pipelines of tank, and should have the same coefficients of thermal expansion.
- Tank materials, including any devices, gaskets and equipment, must not be exposed to the harmful effects of contents.
- Tank-containers should be designed and manufactured with a frame that provides reliable support during transportation, as well as with the appropriate lifting and fastening device.
- Tank-containers for dangerous goods of classes from 3 to 9 must be designed and manufactured so as to withstand a test pressure exceeding at least 1.5 times the maximum allowable working pressure. However, the test pressure should never be less than 150 kPa (1.5 bar).

Tank-containers without a vacuum safety valve must be designed in such a way as to withstand, without permanent deformation, the external pressure exceeding at least 40 kPa (0.4 bar) the internal pressure. Tanks equipped with a vacuum safety valve must be designed to withstand, without permanent deformation, an external pressure greater than the internal pressure by 21 kPa (0.21 bar) or more; the valve must be adjusted to operate at a gauge pressure of -21 kPa (-0.21 bar).

**4. References**

2. [https://www.trajectus.ru/zheleznodorozhnye-perevozki](https://www.trajectus.ru/zheleznodorozhnye-perevozki)

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