



ANALYSIS OF THE OPERATING TECHNOLOGY OF LOADING AND UNLOADING FACILITIES FOR HAZARDOUS LIQUID CARGOES AND FILLING STANDARDS

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***ANNOTATION** Despite the diversity of proposals and transportation methods offered by different modes of transport for the carriage of dangerous liquid cargoes, transportation by rail remains highly relevant. This article analyzes the operating technology of loading and unloading facilities for dangerous liquid cargoes, as well as the standards for filling tank cars. In addition, innovative technologies adapted to modern requirements and aimed at preventing environmental risks in the transportation of dangerous liquid cargoes have been developed.*

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***АННОТАЦИЯ** Несмотря на разнообразие предложений и способов перевозки, используемых различными видами транспорта при транспортировании опасных наливных грузов, перевозка их железнодорожным транспортом остается актуальной. В данной статье проанализированы технология функционирования пунктов налива и слива опасных наливных грузов, а также нормы налива в цистерны. Кроме того, разработаны инновационные технологии, направленные на предотвращение экологических рисков при*

перевозке опасных наливных грузов и адаптированные к современным требованиям.

Ключевые слова: опасные наливные грузы, нефть, цистерна, налив, слив, объемное расширение.

Liquid bulk cargoes transported by rail include liquids carried in tank cars, containers, and semi-open hoppers. Over 90% of liquid bulk cargoes consist of petroleum products (kerosene, gasoline, diesel fuel, ligroin, fuel oils, mineral oils, etc.), while the remaining portion is crude oil, which is primarily transported through pipelines. In addition, the category of liquid bulk cargoes includes products of the food industry (vegetable oils, alcohol, molasses, animal fats, lard, etc.), as well as chemical cargoes (acids, alkalis, paints, varnishes, liquefied gases, etc.).

Liquid bulk cargoes are classified into non-hazardous cargoes, general cargoes, and hazardous cargoes.

Alongside the development of pipeline transport, the transportation of crude oil and petroleum products by rail showed continuous growth up until 1975. By 1989, the share of rail transport in the total volume of petroleum product shipments across all modes of transport was approximately 36%, while pipelines accounted for 52%, and maritime and river transport accounted for around 12%. However, in recent years, due to a slowdown in oil production and further development of pipeline transport, a decline in rail transport volumes has been observed.

All petroleum products can be classified into five groups:

- Crude oil;
- Dark-colored petroleum products (fuel oil and motor fuel);

- Light-colored petroleum products (diesel fuel, kerosene, and jet fuel); gasoline (for automotive and aviation use);
- Oils (ranging from lubricating oils to transformer oils).

Petroleum products possess specific properties that determine their behavior during loading, transportation, and storage, including density, viscosity, the ability to solidify at both negative and positive temperatures, ease of flammability and vaporization, explosion hazards, electrostatic accumulation (the buildup of hazardous static charges), and toxicity. The load-bearing capacity of tank cars, containers, and semi-open hoppers depends on the temperature and density of the liquid bulk cargo during loading. The highest densities are observed in fuel oil (935 kg/m³) and automotive/tractor oils (930 kg/m³).

For the transportation of liquid bulk cargoes by rail, the following types of tank cars are used:

- Tank cars equipped with a universal bottom discharge device, allowing for the unloading of liquid cargoes;
- Tank cars without a bottom discharge device, where cargo is loaded into or unloaded from the car through the top hatch using pump equipment (for light-colored petroleum products such as gasoline, ligroin, etc.);
- Tank cars specifically adapted for the transportation of chemical cargoes (acids, liquefied gases, etc.);
- Tank cars specifically adapted for the transportation of food products.

Loading and unloading facilities for hazardous liquid cargoes are classified into mechanized (cargo is loaded using pumps or allowed to

flow from storage tanks) and non-mechanized types (cargo is loaded manually using hand pumps).

Certain hazardous liquid cargoes are loaded into tank cars in a cooled state to make efficient use of the tank capacity and load-bearing capability. This is because some cargoes contract when cooled, creating additional space in the tank and allowing a larger quantity of cargo to be loaded.

Volume variation of petroleum products as a result of thermal expansion

$$W = V_q \cdot \beta (T_{\max} - T_H)$$

here

V_q — T_H the volume of petroleum products at the loading temperature, m³;

β — coefficient of volumetric expansion, °C⁻¹;

$T_{\max}$ — maximum allowable temperature, °C;

T_H — starting loading temperature, °C.

Studies have shown that fuel oil loaded into tank cars in a cooled state contains approximately 2.5 tons more per car compared to conventional loading. This implies that when transporting 1 million tons of fuel oil, the number of tank cars required can be reduced by over 1,000. Furthermore, it has been determined that the temperature of fuel oil should be +25 °C during the warm season and +5 °C during the cold season.

The processing capacity of a loading (or unloading) front refers to the number of tank cars that can be filled (or emptied) within a 24-hour period using the available equipment. This capacity depends on the

performance of the loading (or unloading) system, the time the front is occupied during each delivery cycle, and the number of cars handled per delivery.

Total occupancy time of the loading front

$$T_T^F = t_B + t_L + t_P + t_C$$

bu yerda

t_B — time for bringing and positioning tank cars at the loading front (depending on the station layout and the arrangement of transfer tracks), min;

t_L — loading duration, min;

t_P — duration of preparatory and final (auxiliary) operations, min;

t_C — time for cleaning tank cars (releasing the loading front) depending on the distance and mass of the group of cars being cleaned, min.

The time spent on auxiliary operations includes the following: inspection of tank cars, preparation of loading hoses, waiting for foam to settle after loading, measurement of the loaded product, removal of hoses from the tank cars, closing and sealing of tank hatches.

The duration of tank car delivery, removal, and auxiliary operations is determined individually for each station and oil depot, based on local conditions and practical observations.

Time spent on direct loading using pumps

$$t_L = \frac{Q_L}{60 \cdot f \cdot v_a \cdot \gamma \cdot n_C}$$

bu yerda Q_L — mass of petroleum products loaded per delivery cycle, t;

f — cross-sectional area of the collector, m²;

v_a — average movement speed of products along the collector, m/s;

γ — density of the product being loaded, t/m³;

n_c — number of collectors.

The flow velocity depends on the type of product and the type of pump, ranging from 1 to 2.65 m/s. The lowest velocities are observed for fuel oil and certain types of lubricating oils, while the highest velocities are characteristic of kerosene and gasoline.

Knowing the time required to occupy the loading front for a single delivery of tank cars, it is possible to determine the daily processing capacity of the front.

$$n_D = \frac{1440 \cdot \eta \cdot n_D^n}{t_B + t_L + t_P + t_C}$$

here η — coefficient accounting for breaks in the operation of the loading front over a 24-hour period (0,95–0,97).

n_D^n — number of tank cars per single delivery.

The processing capacity of unloading equipment is determined in a similar manner. The unloading time depends on the type and capacity of the technical equipment, ambient air temperature, as well as the type and mass of the product being discharged.

$$t_{dis}^L = \frac{60 \cdot Q_{dis}}{q_E \cdot \gamma}$$

bu yerda Q_{dis} — mass of the discharged petroleum product, t;

q_E — pump efficiency, m³/s.

Time required for direct gravity discharge of cargo from a single tank car.

$$t_{dis}^C = \frac{Q_t}{60 \cdot \psi \cdot v_a \cdot \gamma \cdot F}$$

Here Q_t — mass of product in a single tank car, t;

ψ — flow contraction coefficient (assumed to be 0.6);

v_a — average flow rate of the petroleum product, m/s;

F — cross-sectional area of the discharge orifice, m².

In turn

$$v_{CP} = q \cdot \frac{\sqrt{2gh}}{2}$$

here q — velocity coefficient: 0.97, and 0.95 for heated cargo;

g — acceleration due to gravity ($g = 9,81 \text{ m/s}^2$);

h — height of cargo in the tank car.

few tank cars are unloaded per day, with a maximum of 25–30 tank cars handling hazardous liquid cargoes. Approximately 60–65% of the total

CONCLUSION

Given the complexity of transporting hazardous liquid cargoes and the diversity of their types, it is critical to establish precise operational conditions for their handling and transport. Moreover, it is essential that the procedures for loading and preparing hazardous liquid cargoes for shipment conform to international regulatory standards. Based on research findings, the optimal loading temperatures and standardized transportation requirements for hazardous liquid cargoes have been defined, ensuring both operational efficiency and compliance with safety and environmental regulations.

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