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# Technical and Legal Aspects of Ensuring Safety of Transportation of Dangerous Goods of Hazard Classes 2 and 3 in Tank Cars

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## ABSTRACT

*The study has considered technical, organisational, and regulatory aspects of ensuring safety of transportation of dangerous goods by rail from the very beginnings of operation of domestic rolling stock to the present.*

*The main type of rolling stock for transportation of dangerous goods are special tank cars, the reliability and safety of which depends on the quality of design, the level of technology development in production of components, and the perfection of interconnected structural elements.*

*The study suggests a retrospective analysis of the most significant technological improvements in the design of tank cars and their most critical elements and considers in detail the experience of creating interdepartmental working groups with the participation of representatives of scientific organisations, design bureaus, developers, and operators of tank cars, which were engaged in an independent expert assessment of structures and units, manufacturing technologies, operation, monitoring issues, elimination of emergency situations with the subsequent development of recommendations and solutions aimed at preventing their occurrence.*

*The paper highlights the relevance and necessity of taking appropriate organisational measures related to the design, manufacture, operation, and control of tank cars for the transportation of dangerous goods, monitoring and elimination of emergency situations, processing and amending regulatory documents, based on positive historical experience.*

*It is proposed to consider the creation of a new generation of tank cars, a national or interstate standard in the field of monitoring the technical condition of tank cars for the transportation of dangerous goods, a permanent working group, a promising set of technical means of technical diagnostics, and a number of other possible solutions aimed at improving the safety of transportation of dangerous goods.*

*Keywords: railways, transportation of dangerous goods, technical and regulatory solutions, improvement of safety of transportation of dangerous goods, organisational solutions.*

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## INTRODUCTION

Ensuring transport security is a priority state task and the main condition for transportation of passengers and goods. Railway transport in the Russian Federation occupies a leading place in the overall transportation process, therefore, safety of life and health of people, safety of the environment, cargo, rolling stock, and infrastructure facilities largely depend on the effectiveness of functioning of its traffic safety management system.

According to experts, up to a quarter of the total volume of cargo transportation carried out by rail consists of dangerous goods that require special care and can cause significant harm to humans, the environment, property of individuals and legal entities [1]. Most emergencies with dangerous goods in transport occur during movement, transshipment and storage, at a considerable distance from the places of loading, which complicates the work to eliminate their consequences. Therefore, it is necessary to pay due attention not only to the technical condition of vehicles and transportation technology, but also to the regulatory, technical and legal framework. Reforming and improving transport legislation, according to a number of modern researchers, should be aimed at consolidating in one document more than 20 recently adopted legal acts, some of the provisions of which duplicate, and in some situations even contradict each other [2–4]. Moreover, this legal document should have the status of a federal law or technical regulation, which will eliminate the disunity of existing documents and have a positive impact on organisation of the entire transport process and on implementation of state control and supervision [5].

Systematic improvement of safety in transportation of dangerous goods is an urgent task for economically, scientifically and technically developed countries.

The international transportation of dangerous goods by rail is subject to strict regulations. In Europe and many other countries in North Africa, the Middle East and Central Asia, these rules are called RID and are developed by the intergovernmental OTIF organisation. In accordance with them, carriers are obliged, before accepting dangerous goods, to check tank cars that are approved and suitable for transportation of the relevant substances, have markings to ensure their safe transportation.

In 2009, the European Railway Agency approved the Common Safety Method (CSM) as a basic model for risk management in railway transport. According to its estimates, the systemic sources of risks in transportation of dangerous goods can be: transport infrastructure, vehicles and technologies, control and information systems, human resources, repair facilities. The influence of random factors and events can also lead to an accident leading to the release of hazardous substances. Such incidents threaten not only safety of railway transport, but also human life, the environment and property. It is extremely important to recognise all potential threats and eliminate them to an acceptable level to ensure safety and efficiency of railway transport in general [6].

To assess the risk of accidents with hazardous goods more accurately, American experts used reports from the Federal Railway Administration on accidents. To make appropriate management decisions, including complex risk assessment methods and effective route plans, they developed an assessment methodology using the Bayes total probability theorem and logical diagrams, considering the distinctive features of trains, car placement and characteristics of a railway accident [7, 8].

However, the regulations adopted in these countries are not always effective in specific places and the tasks for supervision of dangerous goods cannot be performed properly due to the lack of the necessary technical means and infrastructure [9].

The development of specific technical, organisational and regulatory solutions that ensure the guaranteed safety of transportation of dangerous goods on the railways of the Russian Federation should be based on an analysis of the accumulated historical experience.

The *objective* of the research was to study technical, organisational and regulatory aspects of ensuring safety of transportation of dangerous goods by rail with the use of retrospective analysis and to develop suggestions on possible directions of improvement of organisational and regulatory mechanisms.

## RESULTS

### From the History of the Topic: 19th century

The development and operation of domestic rolling stock began with the purchase in 1837 of English equipment: 6 steam locomotives, 44 passenger cars, 19 cargo cars, for the first

Russian railway between St.Petersburg and Tsarskoe Selo, the construction of which began on May 1, 1836 and official opening took place on October 30, 1837. The train was supposed to move at a speed of 40 versts per hour (42,6 km/h) and carry up to 300 passengers. However, already in 1838, on this section, which was then rather an attraction site, the first incident occurred, which can be classified as a crash, the cause of which was a break in the axle neck [10].

For development of the economy of the Russian state during this period, a radical renewal and expansion of the transport network was required, due to the natural extended geographical position and uneven distribution of industrial facilities, consumers and exporters. Thus, at the beginning of the 19th century Russia had an area of 17 million km$^2$ with a population of about 40 million people who lived, according to 1825 data, in 415 cities and settlements, concentrated mainly around large mining, processing, agricultural plants and manufactories, provincial, regional administrative centres scattered over large distances from each other and unevenly [11]. Therefore, in 1825–1830, the construction of railways connecting the territorial regions of the country with the system-forming conglomerations became a priority, economically profitable and expedient state task.

To ensure effective management of the railway system, in 1835 the Institute of the Corps of Railway Engineers was established, and in 1842 the Department of Railways of Russia became part of the main department [12]. Moreover, construction, operation, supervision and control over the railway transport network, except for Tsarskoye Selo railway, was carried out by state bodies and at the expense of the state treasury.

The result of the transformations was the start of a large-scale construction of the Trans-Siberian Railway to Vladivostok, the first laying of which took place on May 19, 1891. The total length of the world's longest railway line, the Trans-Siberian, connecting the European part of Russia with the largest East Siberian and Far Eastern cities, was 8,3 thousand km [13]. The economic and technical feasibility of such a solution has not lost its relevance at the present time.

The most important result of administrative reforms was formation of a state structure responsible for the technical design, manufacture and operation of devices and structures, as well as preparation of rolling stock, which later became the basis for creation of the Ministry of Railways (MPS), which existed until the early 2000s.

**Modern History: 20th Century – First Years of 21st century**

The technical policy of the Ministry of Railways was carried out by specialised organisations, while the main research enterprises responsible for unification of the design and manufacturing technology of railway transport products, including rolling stock, were identified. The main priority of the created organisational structure was to ensure safety of railway transport under the conditions of great length, various climatic and geological conditions and constantly changing operating parameters, including axle loads, speeds, train weights, etc.

It should be noted that over a hundred-year period of operation of domestic railways, axle loads increased from 14 t/axle to 23,5; 25; 27; 30 t/axle, the speed of cargo trains from 25 km/h to 120 km/h, and their weight began to reach 8–10 thousand tons.

Taking into account the rapidly changing operating conditions and the structure of cargo turnover, special-purpose cars were created to transport goods of varying degrees of danger. Tanks for flammable liquids of the hazard class 3 and tank cars for liquefied gases of the hazard class 2 started to be widely used.

It should be noted that during transportation of dangerous goods, the risk of emergencies and incidents increases significantly: fires, explosions, releases of hazardous chemical and radioactive substances, which can pose a threat to human health and damage to the environment.

In the 50–60s of 20th century, attempts were made to improve rolling stock in order to increase its efficiency and «economic» feasibility. Such attempts include an experiment to increase the carrying capacity of existing cargo cars and reduce the delivery time of goods by increasing the dimensions (T, $T_{pr}$, $T_c$) and speed.

However, since the mid-80s of the last century, there has been an increase in incidents, accidents and crashes with tank cars intended for transportation of liquefied hydrocarbon gases (hazard class 2) and tanks for transportation of oil and oil products (hazard class 3), which led to the death of people and severe environmental consequences.

In this connection, in 1993, the Government of the Russian Federation adopted a resolution «On creation of a single state system of environmental monitoring (EGESM)». The resolution fixes the distribution of functions of the EGESM System between central federal and executive authorities responsible for natural resources, and also provides for involvement of ministries, departments and subordinate organisations, and carriers of dangerous goods that are potential environmental pollutants in the process of creating the EGESM. Information support for environmental management involves the use of both sanitary and environmental criteria and standards.

Due to the fact that, as a rule, multi-departmental organisations are engaged in design, manufacture and operation of rolling stock, until the early 2000s there were head design bureaus, pilot production and testing centres for specific types of cars, including tanks for transportation of hazardous cargoes that carried out development, implementation and technical support of new developments, and were also responsible for their results. The composition of such working groups included competent specialists from relevant organisations, research institutes and enterprises: department of traffic safety of the Ministry of Railways, Federal Mining and Industrial Supervision Body (Gosgortechnadzor, existed in 1992–2004), MIIT (now Russian University of Transport) together with several other domestic organisations, and a number of foreign enterprises and companies: KAMAKS, Kawasaki, Hitachi, Svidnitsa Carriage Factory (Poland). The activities of all involved organisations were regulated by the Decrees of the Government, the State Planning Commission, and the Ministry of Foreign Trade. Control over design, manufacture and operation of tanks for transportation of dangerous goods was carried out by Gosgortekhnadzor, an administrative body independent of the Ministry of Railways, designers and manufacturers.

Based on the collected and analysed statistical data on incidents, members of the working group developed scenarios of past development of emergency situations, which were later used in mathematical models to study dynamic and traction processes, which made it possible to determine the ideology of development of both the design of tank boilers and technical means to minimise severe consequences in emergency situations.

The regulatory and legal documentation in force at that time, including the Norms for Calculation and Design of Cars,[1] technical operation rules (PTE), did not imply the occurrence of emergency situations during operation, therefore, did not contribute to the scientific and technical work to improve parts and assemblies of cars that increase safety of transporting dangerous goods.

However, the constant growth in the number and range of transported oily cargoes required modernisation of the filling fittings of tanks, which must meet the following requirements:

– «they should consist of three sequentially located locking units;

– ensure the strength and tightness of the vessel shell under all operating conditions, including emergency ones;

– have simple controls, layout and colouring that do not allow different interpretations of the operations performed;

– have the minimum possible height of elements protruding beyond the contour formed along the outer surface of the vessel shell;

– in case of going beyond the contour along the outer surface of the vessel shell, have additional shut-off devices located inside the circuit and ensuring the tightness of the vessel (boiler) in case of damage or failure of the main valve element in emergency mode;

– controls for taps and valves must have locking devices that prevent their loosening and spontaneous opening and depressurisation of the vessel (boiler) under all operating conditions, including emergency ones;

– safety devices (safety and high-speed valves, bursting discs, fusible plugs) of vessels (boilers) of tanks must ensure controlled discharge of the product from the vessel (boiler) at a pressure that excludes destruction of the vessel (boiler), in accordance with the calculated emergency heat gains and taking into account thermal insulation or fire-retardant coatings» [14].

Based on the results of R&D and their analysis by the members of the working group,

[1] Norms for calculation and design of cars of railways of MPS of 1520 mm gauge (non self-propelled). Approved by MPS RF, 1996, in force since 01.07.1996. Moscow, GosNIIV, VNIIZhT, 1996, 317 p.

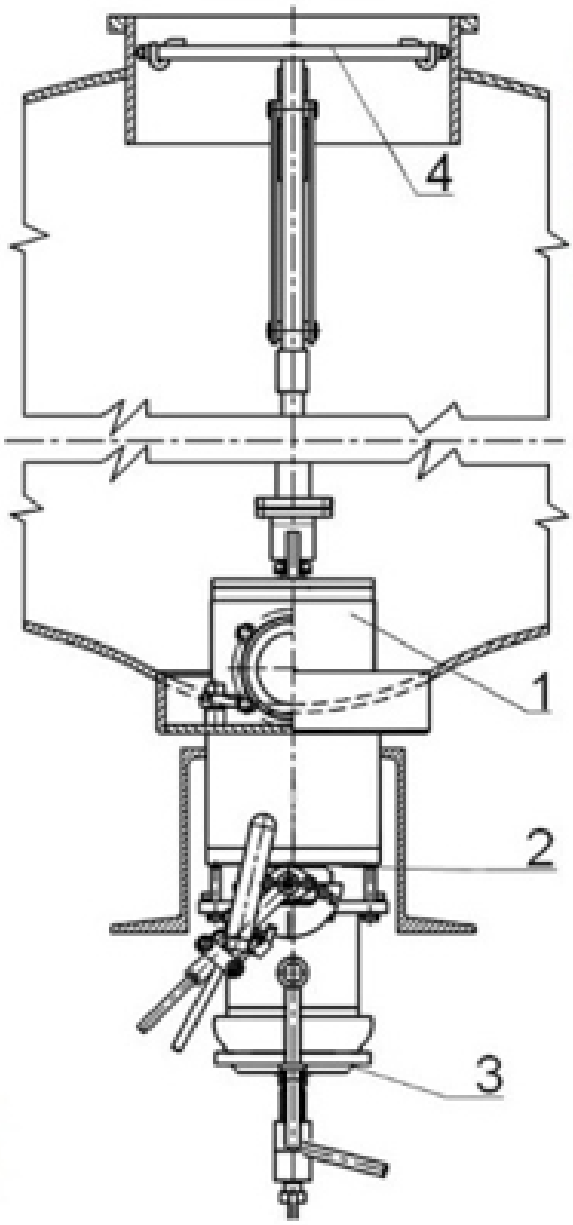

*Pic. 1. A serial tank car for liquefied hydrocarbon gases with technical means of protecting the boiler in emergency conditions (photo of the Department of Wagons and Wagon Facilities of RUT).*

it was found that tanks for liquefied hydrocarbon gases built before 1975 should be withdrawn from service due to defects in welds in the boiler. From now on, 100 % control of welded seams of tanks transporting cargo of hazard class 2 and 3 is envisaged. It was also noted that the parameters of safety valves did not correspond to the conditional calculated emergency modes, leading to explosions of boilers at the stage of emergency recovery work. In this regard, subsequently, parameters and designs of safety valves with large flow sections were developed to enable the product to be discharged during emergency thermal exposure, which practically eliminates the likelihood of a boiler explosion.

To increase the time spent by the tank in the fire before the explosion, Moscow MIT research institute and NPO Mashinostroeniya recommended the use of special fire-retardant coatings or thermal insulation. To protect the bottom of tanker boilers from breakdown during collisions, limiters preventing self-uncoupling of automatic couplers, protective screens and highly efficient elastomeric draft gears were developed. A general view of the tank, developed taking into account all the recommendations, is shown in Pic. 1

The safety of tanks for transportation of dangerous goods is determined by a combination of factors that depend on quality of design, the level of development of technologies in production of components, infrastructure elements interconnected with the transportation process: loading and unloading racks, washing and steaming stations, car repair enterprises, as well as reliability of unloading and filling fittings, safety valves, grounding systems.

Therefore, in parallel with improvement of design of the boiler, the tasks of creating drain-filling, control and safety fittings for both gas tanks and oil tanks were solved. At the same time, Atom ArmProject ball valves [15, 16], control valves with bellows instead of stuffing box valves were developed as the main shut-off devices, and stainless steel springs with stable stiffness characteristics for the entire period of operation began to be used in safety valves. Equipment tests were carried out in comparison with samples of foreign companies, the results of which confirmed the advantage of domestic options, as well as full compliance with the requirements of explosion safety standards; as well as biological, mechanical, fire, industrial, thermal, chemical, electrical, nuclear and radiation safety.




*Pic. 2. Drain device KPLV.494729.001 TU for installation on railway tank cars transporting oil and oil products [17].*
*The composition of the drain device:*
*1 – ball valve – the main shut-off element;*
*2 – disk lock – the first additional locking element;*
*3 – plug – the second additional locking element;*
*4 – ball valve control handle.*

Thus, one of the promising developments of domestic specialists was a new drain device KPLV.494729.001 TU (Pic. 2) [17] for railway tanks transporting oil and oil products, which ensures the unloading of contents of the tank and complete tightness during transportation and storage, which has confirmed its effectiveness and safety based on the results of operational and acceptance tests on three experimental tank cars loaded with oil products, which became the basis for making a decision on their installation and further operation on all types of tanks transporting oil products. Checking the tightness of new drain devices in the conditions of car repair enterprises is carried out in accordance with

the developed instructions for the checked drain device.

Subsequently, a prototype of such a device was developed, containing the main shutter with a drive mechanism in the upper part and an additional shutter in the form of a cover with a seal and a clamping screw in the lower part of the body on a swivel bracket. In this case, during an emergency, only the lower shutter can be damaged or cut along the safety ring, and the upper part will not be subject to external force action [18].

Many emergencies are caused by a weak or ineffective lightning protection system, which leads to fires and explosions. Therefore, the search for ways to improve the protection of railway tanks during transportation of oil products from the effects of lightning and static electricity is currently a very urgent task [19].

**Modern Situation: 21st century**

Given the fact that the list of dangerous goods transported by Russian railways is constantly expanding, it is necessary to dwell on the regulatory and legal aspects of ensuring traffic safety while performing these transportations.

Among the entire range of goods transported in Russia, the share of dangerous goods is about 20 %, and railway transport accounts for 35 % of this volume. These are mainly oil products, compressed, liquefied or dissolved gases under pressure. Thus, in 2022, from January to September, 160 million tons of oil and oil products were transported out of the total loading volume – 922,5 million tons (17,4 %).[2]

All dangerous goods are transported under special conditions, which are established by separate provisions of the Rules for Transportation of Dangerous Goods by Railways in Russia and 10 CIS countries (as of 2022, these are the Russian Federation, the Republic of Belarus, Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan, Kazakhstan, Armenia, Azerbaijan, Moldova),[3] the rules for technical operation of railways of the Russian Federation (PTE)[4] and the Instructions for movement of trains and shunting work (IDP) on the railways of the Russian Federation.[5]

A number of requirements for implementation of safety measures and elimination of the consequences of emergency situations with dangerous goods are set out in the Rules for Safety and the Procedure for Elimination of Emergency Situations with Dangerous Goods during their Transportation by Rail.[6]

Ensuring traffic safety is a complex process based on technical means and the human factor. In this connection, it is necessary to constantly improve the technical level and competence of the personnel, to require and monitor compliance with all the above rules. The list of such requirements is determined by a specific type of dangerous goods in accordance with classification of the interstate standard GOST 19433–88 «Dangerous goods. Classification and labelling»,[7] as well as international requirements established by the UN Model Regulations (Recommendations on the Transport of Dangerous Goods),[8] under which, according to the nature of hazardous properties, substances and products are divided into nine classes and subclasses, including explosives, gases, flammable liquids and solids, poisonous (toxic) substances, radioactive materials, etc.

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[2] Ministry of Transport of the Russian Federation. Mintrans of Russia. Statistics [Electronic resource]: https://mintrans.gov.ru/ministry/results/180/documents. Last accessed 10.03.2023.

[3] Rules for Transportation of Dangerous Goods by Railways. Approved by the Council for Railway Transport of the CIS on April 5, 1996, No. 15, put into effect on January 1, 1997 (with amendments and additions). [Electronic resource]: https://docs.cntd.ru/document/902165571. Last accessed 10.03.2023.

[4] Rules for technical operation of railways of the Russian Federation, approved by MPS of Russia on May 26, 2000, No. CRB-756. [Electronic resource]: https://files.stroyinf.ru/Data2/1/4293853/4293853142.pdf?ysclid=ll6i1t024y447803472. Last accessed 10.03.2023.

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[6] Rules for Safety and the Procedure for Elimination of Emergency Situations with Dangerous Goods during Their Transportation by Rail (appr. Ministry of Emergencies of Russia 31.10.1996, No. 9/733/3–2, MPS RF 25.11.1996, No. CM-407). [Electronic resource]: https://legalacts.ru/doc/pravila-bezopasnosti-i-porjadok-likvidatsii-avariinykh-situatsii/. Last accessed 10.03.2023.

[7] GOST 19433–88. Dangerous goods. Classification and labeling (appr. by the Resolution of Gosstandard USSR dated 19.08.1988, No. 2957) (amend. on 01.09.1992 г.). Moscow, IPK Izdatelstvo standartov, 1988, 47 p. [Electronic resource]: https://ufa-promtara.ru/wp-content/uploads/2019/04/GOST-19433–88.pdf. Last accessed 10.03.2023.

[8] Recommendations on the Transport of Dangerous Goods. Model regulations. Twentieth revised edition, United Nations, New York and Geneva, 2017. [Electronic resource]: https://unece.org/ru/rev-20–2017. Last accessed 10.03.2023.

The scale of transportation of dangerous goods currently determines the high potential level of risks of transport accidents. The task of the bodies of all levels of executive power, as well as of carriers, is to reduce this threat to the level of residual risks acceptable to ensure an accident-free transportation process.

The 2000 version of the PTE provided for control of technical documentation for the purchased rolling stock with the procedure for coordinating the interested departments of the Ministry of Railways.

However, after privatisation of the car fleet and its transfer to private transport companies (operators), the responsibility for its technical condition and re-equipment fell on the owners (transport companies), who are not able to influence the technical policy in the field of design, manufacture and repair. Recently, they have been actively acquiring new rolling stock, which, according to the law on technical regulation, must comply with the requirements of the technical regulation TR TS 001.[9] However, it only contains general requirements and a procedure for confirming compliance with them. Compliance with the requirements of the technical regulation TR CU 001 in relation to tank cars, including methods for their research (testing) and measurements, is provided on a voluntary basis by GOST R 51659–2000 «Tank cars of 1520 mm gauge main railways. General technical conditions»,[10] which also contains only general, rather outdated, requirements for all types of tanks without taking into account the cargo transported in them. Currently, a number of regulatory documents related to transportation of dangerous goods have been adopted, which must be taken into account when designing and operating tank cars. For example, these are the requirements of the Federal norms and rules in the field of industrial safety «Industrial safety rules when using equipment operating under excessive pressure», introduced by order of the Federal Service for Environmental, Technological and Nuclear Supervision of December 15, 2020, No. 536, and relating to tanks for compressed, liquefied gases, liquids and loose bodies operating under excessive pressure. At the same time, all regulatory and technical requirements for tank cars intended for transportation of dangerous goods apply both to private fleet cars that do not belong to the carrier on the basis of ownership, and to inventory fleet cars owned by railways.

Article 21 of the Federal Law of April 1, 2020, No. 69-FZ «On Railway Transport»[11] states that «responsibility for safety of transportation, loading and unloading of dangerous goods is borne by consignors and consignees, who are required to have the appropriate means and mobile units necessary to eliminate emergency situations and their consequences». At the same time, there are recovery and fire trains on the railway network subordinate to JSC Russian Railways, which are directly involved in elimination of emergency situations. However, the procedure and methods for eliminating emergency situations are developed and approved, among other things, by specialists from the Ministry of Emergency Situations of the Russian Federation, who have the appropriate means and mobile units throughout Russia, and not only at the places of dispatch and unloading of dangerous goods.

## CONCLUSIONS

Based on the study of previous experience of transportation of dangerous goods in tank cars and regulations, it is possible to formulate a set of proposals to ensure safe transportation of dangerous goods by rail:

– to finalise and to adopt the Federal Law on Transportation of Dangerous Goods, to prepare a draft Decree of the Government of the Russian Federation on the competent authority of the Russian Federation in the field of rail transportation of dangerous cargo to ensure legal regulation in the field of transportation of dangerous goods and improve the rules for transportation of dangerous goods in Russia;

[9] Technical Regulations of the Customs Union «On safety of railway rolling stock» (TR TS 001/2011). Approved by the Decision of the Commission of the Customs Union dated July 15, 2011, No. 710. [Electronic resource]: https://legalacts.ru/doc/reshenie-komissii-tamozhennogo-soiuza-ot-15072011-n/. Last accessed 10.03.2023.

[10] GOST R 51659–2000 «Tank cars of 1520 mm gauge main railways. General technical conditions» (appr. by the Resolution of Gosstandard of Russia dated 31.10.2000 № 282-st).Moscow, Gosstandard of Russia, 2000, 10 p. [Electronic resource]: https://www.reglament.by/wp-content/uploads/docs/gost-r/GOST-R-51659–2000.pdf?ysclid=ll6iw9g8fg230281240. Last accessed 10.03.2023.

[11] Federal law «On railway transport in the Russian Federation» dated 10.01.2003, No. 17-FZ (amend. on 19.12.2022), adopted by the State Duma on December 24, 2002, approved by the Federation Council on December 27, 2002. [Electronic resource]: https://docs.cntd.ru/document/901838120. Last accessed 10.03.2023.


https://www.miit.ru/content/393738.jpg?id_wm=393738&SWidth=1920

– to create designs of new generation tank cars and other cars with improved characteristics of reliability and physical protection in emergency situations;

– to develop a national or an interstate standard containing the requirements and control methods for tank cars for transportation of dangerous goods;

– to create a permanent working group consisting of competent specialists from specialised organisations – JSC Russian Railways, the Ministry of Emergency Situations of the Russian Federation, etc., research institutes and enterprises, the functions of which will comprise expert evaluation of new designs, assemblies of tank cars for transportation of dangerous goods, technologies for their manufacture, methods of operation, monitoring and elimination of emergencies for implementation on the railway network;

– to develop a promising set of automated technical means for diagnosing the condition of boilers of tank cars and tank containers for repair enterprises, as well as for checking the condition of tanks by shippers before loading and before transferring them to the railway for transportation;

– to ensure interaction and strict compliance with the requirements of the Ministry of Emergency Situations of the Russian Federation regarding elimination of emergencies with dangerous goods;

– to create a non-departmental supervision body and legally invest it with the authority to control compliance with the requirements of the regulatory framework and guidelines related to operation and repair;

– to introduce additions to the new Rules for technical operation of railways of the Russian Federation (PTE) [21] adopted and approved by Order of the Ministry of Transport of Russia dated June 23, 2022, No. 250, in terms of control and supervision by non-departmental organisations over design and operation of tank cars intended not only for transportation of dangerous goods, as well as over carrying out scheduled types of repairs, maintenance and liquidation of the consequences of emergency situations;

– to create economic levers of safety management of transportation of dangerous cargo.

The adoption of the proposed measures is now becoming especially relevant in connection with the proposed expansion of the range of trains running in the sparsely populated Northern and Arctic regions (NAR), Western and Eastern Siberia with harsh climatic conditions.

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