Innovative bases of technology of autonomous transportation of perishable cargo

Abstract. Transportation of perishable goods is a special type of transportation that has great social significance and has an impact on the health of the population. The correct choice of transportation technology and vehicle ensures the preservation of the quality of the transported perishable cargo due to compliance with the required temperature conditions, which in turn ensures compliance with food safety requirements. This article is devoted to the development of scientifically sound recommendations for the selection of new cooling systems for perishable goods by rail and technology parameters, including requirements for specialized vehicles, compliance with which will provide conditions for maintaining the quality of cargo throughout the entire transportation. The subject of research is to ensure the possibility of changing the composition of the gas environment of vehicles for the transportation of perishable goods due to re-equipment. The aim of the work is to develop the principles of technology for autonomous transportation of perishable foodstuffs, namely, ensuring high thermal parameters of vehicle enclosing structures; autonomous operation of installations during PGT transportation with the simplest and most reliable implementation; achieving maximum efficiency of the equipment used in terms of generating thermal energy or energy spent on cooling when using non-energy-intensive methods of mass exchange of air inside the cargo area. Through analysis and theoretical studies, the possibility of joint operation of the gasifier and the heater was confirmed, the single-line nitrogen supply scheme was adjusted. Due to the use of modern methods and devices for cooling (heating), a reduction in costs for the transportation of products is guaranteed. The result of the work is confirmation of the possibility of joint operation of the gasifier and the heater under real conditions of transportation of fruit and vegetable products by rail.

1 Introduction

Many studies have been devoted to the preservation of the quality of transported perishable goods in an oxygen-depleted gas environment [1–3]. In particular, they propose to modify the existing transport vehicles (TV) in terms of ensuring the possibility of changing the...
The problem has a wide range of applications in various industries, including the transportation of perishable goods, which can be cost-reducing. One of the ways to increase the efficiency of refrigerated rolling stock in the transport of such products is the improvement of isothermal cars due to the appearance of mounted (removable) diesel generators with autonomous operation in the case of the lack of developments in the environmental-technical protection of passenger cars.

Following this approach, devices with a controlled gas environment are considered. But at the same time, the equipment encountered problems with the possibility of influencing the biochemical processes in the transport of perishable goods.

The use of electronic systems for remote monitoring and control of equipment, the duration of its autonomous operation in a width of the change of the environment conditions, the efficiency can be ensured when replacing or adjusting equipment, the lack of developments in the world for the storage and transportation of nitrogen cargo, in conditions of transportation [5]. Such developments, the possibility of influencing the biochemical processes in the transport of perishable goods, consideration in theoretical terms, in particular, the appearance of mounted (removable) diesel generators, as well as the establishment of the possibility of expending the functions of refrigeration and compression devices with a controlled gas environment remain unresolved.

A statement of the solution of the problem is not considered. But at the same time, the equipment obtained the following benefits of such a solution: the possibility of expanding the functions of isothermal cars due to the appearance of mounted (removable) diesel generators, the duration of its autonomous operation in a width of the change of the environment conditions, the efficiency can be ensured when replacing or adjusting equipment, the lack of developments in the world for the storage and transportation of nitrogen cargo, in conditions of transportation [5]. Such developments, the possibility of influencing the biochemical processes in the transport of perishable goods, consideration in theoretical terms, in particular, the appearance of mounted (removable) diesel generators, as well as the establishment of the possibility of expending the functions of refrigeration and compression devices with a controlled gas environment remain unresolved.

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in order to improve its safety during transport. At the same time, the control over the operation of the equipment and the management of transportation modes should be carried out remotely.

Maintenance of the proposed TV structures before, during and after transportation can be performed by a limited number of mechanics who are able to perform maintenance of the vehicle both at stationary and mobile maintenance points (MP) \[6-8\]. The autonomous operation period of such vehicles should reach the maximum terms of cargo delivery in accordance with the Transportation Rules of PG.

The implementation of the proposed TV designs should be implemented in accordance with the following basic principles:

- ensuring high thermal parameters of the TV enclosing structures;
- autonomy of operation of installations during PG transportation with the simplest and most reliable implementation;
- achieving the ME of the equipment used in terms of generating heat energy or energy spent on cooling, using non-energy-intensive methods of organizing air mass transfer inside the cargo space;
- organizing transport process on the basis of operational intervention in the performance of installations remotely in case of failures in automatic programs, and in case of breakdowns in the route-by replacing the units directly, as well as organizing refueling by the refrigerant agent with the help of mobile MPs.

The study also used research methods in accordance with the recommendations of works \[9, 10\].

High thermal parameters of TV enclosing structures can be achieved with the use of modern thermal insulation materials and technologies for their use \[8\]. In particular, "sandwich" panels based on polyurethane foam have recently been very effective as heat insulators. At the same time, a heat transfer coefficient of the order of 0.2 W/(K m^2) at high density of enclosing structures (about 18 m^3/h at an excess pressure of 50 Pa) is achievable for a new TV (Fig. 1). At present, technological techniques have been worked out and a great deal of experience has been gained in the production of such protective structures.

Increased efficiency in heat generation can be achieved by directly using the heat generated by diesel fuel combustion without intermediate energy conversion. When the heat is applied to the lower (coldest) part of the room, the need for circulators disappears altogether when an acceptable uniformity of the temperature field in the volume of the car is achieved.

The direct conversion thermal power generation plants are currently mass-produced, are certified in our country as independent heating sources, have small dimensions and weight. For example, a diesel heater requires 1.2 liters of fuel to generate about 10 kWh of heat flow, its dimensions do not exceed 360 230 130 mm at a weight of 7 kg, power is provided by a 12 or 24 V battery voltage, power consumption is 28-138 W depending on the heat flow generated.

Many years of experience in the use of such heaters as autonomous sources of heating for various, including fire hazardous objects, allows us to conclude that such devices can be used for heating cargo space in isothermal TV on the railways of the Republic of Uzbekistan. The autonomy of the operation of such heaters is determined by the capacity of the batteries and the fuel supply.
2 Research of food safety technology during transportation under positive external temperatures conditions
Fig. 2. Cargo space with a new cooling system (using liquid nitrogen): 1 – location of the nitrogen line for supplying liquid nitrogen; 2 – floor

Here, an issue is initially raised about the TV operation autonomy and the time it operates autonomously, as ensuring a decrease in the mass share of oxygen in the cargo space occurs simultaneously with the operation of the cooling installation. Obviously, for cargoes requiring precise maintenance of the composition of the gaseous medium, this method is not applicable in the first approximation. However, there are many PG (in particular, chilled and frozen cargo) for which the exact percentage of oxygen is not important, but the main thing is its minimum, as well as the minimum transportation costs.

At the same time, in accordance with the Rules for the Transportation of PG, when transporting goods with temperatures below -5°C, their unlimited cooling is allowed, as a result of which the requirements for accurately maintaining a negative temperature become “no higher …”, which greatly simplifies the process of temperature control during transportation.

When creating such systems, the main emphasis is placed on the maximum simplification of the design and the absence (that is, to minimize) of intermediate devices affecting the delivery of refrigerants into cargo space and the high reliability of the equipment. Such equipment includes a NSU 1-0.05 (liquid nitrogen supply unit certified for operation as part of vehicles (including in railway cars), Figure 3), which provides liquid nitrogen in the range from 3 to 100 kg/h in autonomous mode, having multi-level protection and an algorithm of operation, described by the words “opened the tap and forgot.”
The reliability of the elements used in the displayed installation has been verified by years of experience in operation in the composition of cryogenic products of various purposes. The autonomy of the plant is determined by the volume of cryogenic vessels used and the required flow rate of liquid nitrogen. The volume of cryogenic vessels, in turn, depends on the geometric dimensions of the TV, its carrying capacity, and all taken together determines the period of autonomous operation of the TV without refueling. When arranging refueling points along the route, it is possible to extend the delivery time to any large.

The use of these installations has been carried out in LLC "SVB" ("Siberia Vostok Business") since 2003 during experimental transportation of perishable products with an interval between refueling from 5 to 28 days with various capacities and transportation options.

A significant point in the use of such installations is the availability of free space in the vehicle for the placement of cryogenic tanks, which almost completely determines the reserve of their autonomy. Therefore, the most effective is to use such installations on heavy-duty vehicles (50-70 tons) for organizing long-term travel without refueling.

The economic efficiency of liquid nitrogen use, revealed as a result of transportation, is due to the low price of cryogenic product (about 1.5-2.8 times lower than the cost of diesel fuel in different regions), excluding the cost of an escort car and a team of mechanics following the cargo, and carrying out these transportation operations in summer between 2003 and 2006 reduced total costs by 1.1-1.6 times (at an outside air temperature during transportation from 35 ºC to -20 ºC).

On the other hand, accurate control of oxygen concentration in the composition of gaseous environment of the cargo space, which is especially required for a large part for fresh fruit and vegetable perishable products, should occur during transportation not only in the summer period, but also in the transitional and winter periods.
3 Study of the food safety technology during transportation under sub-zero outside temperatures

Under conditions such as autonomous liquid nitrogen cooling, it is difficult to ensure simultaneous maintenance of a given amount of oxygen and the required temperature during the summer, especially at maximum outside temperatures, since turning off the installation for a natural increase in the oxygen level inside the cargo space due to its inflows from outside automatically leads to an increase in temperature in the cargo area. Therefore, with this method of cooling, transportation is quite possible in the summer with a requirement to oxygen concentration "not more than ...", which is totally possible. When outside temperatures drop and cooling requirements decrease, maintaining given oxygen concentration is more achievable.

For the study, a model 15T56 car was taken, equipped with NSU 1-0.05 and HIDRONIC 10 units, equipped with a remote monitoring and control system for the operation of these devices. Parameters controlled and remotely controlled were the following: the temperature in the cargo space, the oxygen concentration in the gaseous atmosphere and the pressure in the cryogenic vessel. At the same time, operating technology is based on the continuous supply of a fixed flow rate per unit time quantity of liquid nitrogen and temperature control by means of a heater. The oxygen concentration control was carried out by changing the pressure in the cryogenic vessel or by cutting off the nitrogen supply. The joint operation of the equipment took place with an empty car and with imitation of cargo. The main criteria were to ensure uniformity of the temperature field and uniformity of the gas composition throughout the cargo space. The entire system was monitored and controlled remotely from the dispatch room.

The adjustment of the mass fraction of oxygen was carried out by changing the pressure in the cryogenic vessel or turning off the nitrogen supply. The joint operation of the equipment took place with an empty car and with imitation of cargo. The main criteria were to ensure the uniformity of the temperature field and the homogeneity of the gas composition in the entire volume of the cargo space. The operation of the entire system was controlled and controlled remotely from the control room.

Pneumatisation technology requiring heating or cooling of the car's cargo space, as well as the joint operation of such equipment, was developed while simultaneously verifying the reliability of the GSM equipment (Global System for Mobile Communications) communication with mobile TV. In the conditions of intensive distribution of such communication throughout the Russian Federation, the number of "holes" and, accordingly, places of absence or poor communication by the spring of 2007 along the train route in the European part of the Russian Federation is almost zero, in the Urals, Siberia, Transbaikalia and the Far East such a connection is available only on the stretches in places remote from settlements. Almost all railway stations are covered by the GSM network. According to real measurements, the time spent by a moving train outside the communication zone on the Trans-Baikal Railway, which is the most difficult in this regard, did not exceed two hours.
The operation technology of the railcar electronics is designed for autonomous mode, the parameters are recorded automatically every two hours to the internal memory of the controller, external control of the modes is performed only in case of their correction or failure of the electronics (which, by the way, happened once during the first “run” of operation along the Zabaikalskaya road), so the presence of such “holes” cannot significantly affect the quality of PG transportation.

The current norms for the PG transportation without maintaining the regime in the period terms are about five days. Therefore, if it is impossible to remotely correct the operation of the electronics or if it fails, this time is enough for either the TV to arrive at any technical or marshalling yard where it can be unhitched, or for a team of mechanics to arrive at the place where the equipment failed. At the same time, the high thermal parameters of thermal insulation make it possible to ensure the safety of the cargo during the repair and maintenance of the TV.

The operation of such TVs may involve the principle of combined transportation (“maintenance” mode – “thermos” mode). In this case, the need for service crews in any areas from the departure station to the destination station, even with the maximum transportation time, will be completely eliminated or will be minimized at any time of the year.

4 Conclusion

- The possibility of joint operation of the gasifier and the heater was confirmed and the single-line nitrogen supply scheme was corrected;
- The implementation of the technology for the joint operation of units under real conditions for the transportation of fruits and vegetables made it possible to significantly reduce costs while improving the quality of PG transportation in the conditions of autonomous operation of the TV, and especially during winter.

The reduction of PG transporting costs through the use of modern cooling (heating) methods and devices can be solved both partially (through the use of individual units with a high efficiency of energy conversion, in particular, small-sized heaters for direct conversion of thermal energy) in the composition of refrigerated or modified insulated TVs, and in a complex way in terms of solving the enlarged tasks of transporting diverse PG by creating autonomous vehicles using installations, including non-machinery cooling methods (creating the required gas environment in the cargo space of the vehicle) and proven principles and technologies of transportation.

References

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