On the issue of the usage of sealed containers for cooling the refrigerant in refrigerated trucks

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Abstract. The paper deals with the problem of using machine-free cooling in refrigerated trucks for intercity transportation in order to ensure environmental safety and to eliminate noise from a working refrigeration machine when unloading refrigerated products from refrigerated trucks to the distribution network. A machineless method for cooling the body of a refrigerator truck with cold accumulators without direct contact with a cooling medium due to the usage of frozen sealed containers is proposed. The accumulation of cold (AC) is carried out, as a rule, due to the heat of the phase transition at the melting point or crystallization of individual substances or there mixtures. The research of water-salt systems, which are widely used for temperature stabilization in refrigeration, for storage and transportation of medicines and food products, is presented. The results of the melting and freezing of three cold storage substances, which are H₂O and water-salt solutions with NaCl concentrations of 8 and 13 % are presented. According to the results of studies, the usage of pressurized containers in refrigerated trucks with machine-free cooling is beneficial and opens up great opportunities for cooling the air in various destinations.

1. Introduction

Accumulation of cold allows one to increase the cooling capacity of the existing cooling system, energy efficiency, resource and reliability of the equipment.

An approximate classification of cold accumulators is given in Fig 1 [1]. Accumulation of cold is carried out with a phase transition with direct contact of the storage substance with or without refrigerant.

Nowadays cooling devices filled with eutectic solutions are widely used for urban transport of perishable foodstuffs by refrigerated vehicles. The eutectic solution is frozen by the refrigeration machine in the parking lot, generally at night, when Q fare for electricity is applied. During the route, the desired temperature is maintained as a result of eutectic solution melting in the truck body. This type of cooling is widely used abroad (Carrier Transicold, FIC s.p.a., etc.). The use of machine-free cooling in refrigerated trucks allows to maintain an environmentally friendly environment and eliminate noise when unloading products to supermarkets with a working refrigeration machine, especially in stores which are located in residential areas, avoiding noise for residents [2].
Thermal pollution is a factor which should be avoided, in particular, the energy spent on the operation of the refrigeration system is a source of environmental pollution. In some cases, the refrigeration system is a source of carbon dioxide. To recommend substances as cold storage materials, it is necessary that they satisfy the following requirements: have the necessary melting temperature, high specific heat of phase transition, insignificant amount of supercooling during crystallization, maintaining the stability of qualities during multiple melting and crystallization cycles, insignificant toxicity, explosion safety, availability and low cost.

An analysis of the scientific and technical literature showed that many water-salt systems are potentially productive substances as AC. However, the absence of important physical and chemical characteristics for many systems precludes the possibility of using them as an AC without conducting special studies.

2. **Object of research**

The authors have developed a method of accumulating cold without direct contact of the cold storage substance with a cooling and cooled medium. It is possible due to the usage of sealed containers of various shapes, which are filled up to 80–90% of their volume to ensure free expansion of the solution when it freezes. In fig. 2, a, you can see the air pocket in the capsule before freezing. Sealed containers are a system of spherical elements with diameters from 40 to 75 mm. Sealed containers can also have a different shape depending on the purpose. The tanks are filled with cold storage solution [3].

Hermetic containers are frozen in the air of the refrigerating chamber with their subsequent transfer to the truck body and their location in the supporting frame. Also, freezing of sealed elements can be carried out by immersing them in a coolant, which accelerates the process of freezing cold-storage substance in capsules.

While the process of melting a frozen solution in the truck body, an intensive absorption of heat occurs, due to which the temperature set by the technological conditions is maintained. The duration of the action of cold accumulators depends on the diameter of the sealed elements, which in turn affects the intensity of heat absorption. While reducing the diameter of the balls, using the same volume of eutectic solution, the area of the heat transfer surface between the cold storage substance and the cooled medium increases.
Figure 2. Capsules of the experimental installation for cold accumulation: a – before freezing; b – after freezing

3. The results of the research

The results of experimental studies of the process of charging balls are presented in Fig. 3.

Figure 3. Temperature changing of a cold storage substance inside a sealed container during charging: 1 – H₂O; 2 – 8 % NaCl solution, 13 % NaCl solution

Distilled water (H₂O) and saline solutions (H₂O + NaCl) are presented as cold storage substances. As can be seen from fig. 3 the batteries were charged to a temperature of −18 °C.

While freezing water, the water was cooled for 1.5 hours and then 8 hours and a phase transition was observed at 0 °C, then the ice was cooled for 2 hours to an air temperature of −18 °C in the chamber.

When freezing an 8 % NaCl solution (curve 2), the liquid cooling process lasts 2 hours, after which we observe a phase transition, which begins at a solution temperature of −6 °C.
When freezing a 13 % NaCl solution (curve 3), the liquid cooling process lasts 4 hours, after which we also observe the beginning of a phase transition, but at a lower temperature of $-11 \, ^\circ C$.

The freezing process of solutions differs from crystallization of water. After the first ice crystals are formed in the solution, the strength of the solution increases and the temperature of the phase transition decreases. The process occurs until the solution becomes saturated and the whole freezes. Therefore, the charging of cold accumulators with saline solutions extends over a large temperature range. A frozen salt solution consists of ice crystals and salt, which can be seen by examining the frozen element of the cold accumulator through a transparent sealed shell.

It should also be noted a slight hypothermia of 0.5–1 $^\circ C$ of saline solutions before the start of the phase transition.

Figure 4 shows the temperature change of the cooled medium, by the same elements of the cold accumulator filled with various cold storage substances $H_2O$, 8 % aqueous solution of NaCl and 13 % aqueous solution of NaCl.

![Figure 4. Temperature change by cooled medium: 1 – $H_2O$; 2 – 8 % NaCl aqueous solution, 13 % NaCl aqueous solution](image)

As it can be seen from fig. 4 when using $H_2O$, the temperature of the medium decreases by 14 $^\circ C$ in 35–45 minutes, when using an 8 % solution of $H_2O + NaCl$, the temperature of the medium decreases by 11 $^\circ C$ in 55–80 minutes, when using a 13 % solution of $H_2O + NaCl$, the temperature of the cooled medium changes by 8 $^\circ C$ for 120–130 min.

Using $H_2O$ under these conditions is more efficient than using 8 and 13 % aqueous NaCl solutions. This is because the cooling effect is based on the usage of latent heat of fusion of eutectic ice. When the eutectic melts, the temperature remains constant, in contrast to the melting of ice when it is mixed with salt. And, since the cryohydrate point for the ice-salt mixture with NaCl is $-21.2 \, ^\circ C$, at a NaCl concentration in the solution of 23.1 %, to obtain a solid eutectic NaCl solution, it is necessary to charge the elements of the cold accumulator with a NaCl concentration in the solution of 23.1 % at temperature below cryohydrate, which is not always possible.

4. Conclusion
As the operating experience of machine cooling systems of refrigerated trucks, they have a number of drawbacks, in particular, the environment is polluted with carbon dioxide emissions, when the
refrigeration machine is operating while food delivery to retail chains located in residential neighborhoods, there is increased noise that adversely affects people's health.

The results of the experimental studies show the benefits of using sealed containers of various diameters with various cold storage substances for cooling of working environments. When using H_2O, an effective decrease in the temperature of the medium occurs in a shorter period of time than when using aqueous 8 % and aqueous 13 % NaCl solutions frozen to a temperature above the eutectic temperature.

References
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