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THERMOELECTRIC REFRIGERATOR FOR SLEEPING CAR COMPARTMENTS

In this work, a thermoelectric refrigerator was designed, the cooling unit of which is built into a corner cabinet in the sleeping compartment of a PKP Intercity model 308A car. The design of the cooling unit provides for several execution options. The modernization of the car is carried out by PESA Bydgoszcz. The refrigerator has an innovative two-level power supply system, which allows reducing energy consumption. The refrigerator cabinet is divided into two chambers "serving" two adjacent compartments. The thermoelectric unit of the refrigerator cools both chambers simultaneously. The application of the invention allows increasing the comfort level of travelers. Bibl. 15, Fig. 4, Table 7.

Key words: thermoelectric transport refrigerator, two-level power supply system, thermoelectric unit.

Introduction

This work is aimed at improving the comfort of passengers travelling in sleeping cars, as a rule, in the period from April to October. For several years, we have been observing a significant warming of the climate [1]. This leads to higher temperatures during warm periods, which means that train passengers need space to store chilled drinks or food, flowers or temperature-sensitive medicines. This will increase the comfort of passengers traveling on longer routes, and will contribute to raising the standards of passenger transportation in these compartments. Modern trends in the developent of the use of thermoelectric coolers in transport are described in detail in the literature [2], [3]. Among the new applications, it is worth noting the bar with a thermoelectric coolers installed on board the Boeing-747 (Fig. 1).

A thermoelectric cooler is the most rational solution due to the numerous advantages of this method of cooling, especially in vehicles [4]. An additional advantage is the possibility of simple adjustment of the power supply voltage of the thermoelectric unit to the voltage used in networks of railway cars, and the use of modern methods of two-level temperature regulation in thermoelectric coolers [5]. All this allows avoiding the use of complex, unreliable and expensive energy systems [4].

Fig. 1. Thermoelectric cooler in the bar of the Boeing-747 aircraft [2]

A particularly advantageous place for locating a refrigerator in a compartment is a cabinet (ordinary or corner), placed above the sink (Fig. 2).

Fig.2. Triple sleeping compartments for cars 305Ab (left) and 308A (right)

A cooler designed in this way, as compared to the solution of installing refrigerators standing in the compartment separately, i.e. without a specially allocated place [6], does not reduce the usable area, is characterized by a lower cost of implementation and a lower energy consumption.

General information about sleeping cars manufactured in Poland

The sleeping compartment for a 305Ab car, manufactured at the *Zakłady Cegielskiego* factory in Poznan since 2004 року, as well as sleeping compartments of other modifications, are equipped, among other things, with three beds, a wash basin and a single-door cabinet with a wooden housing (Fig. 2). This cabinet has internal dimensions 49 x 17.5 x 59 mm, is equipped with a lock with a ball latch, in the middle of the back wall there is a mirror, on the top wall – a lighting lamp, on the side wall there is an electric socket for connecting a rasor. The interior space of the cabinet is divided by a horizontal shelf. The use of this cabient during the trip comes down to the fact that the conductor, before the start of the trip, puts uncooled mineral water (usually a 0.5 l PET bottle for each), a roll and a hygiene kit (towel + soap) into it. There is no refrigerator in the compartment, the only refrigerator in the car is in the conductor's compartment and is not available for direct use by passengers. The same applies to restaurant cars, where the refrigerator is built into the kitchen section [7].

A more modern sleeping car, for which the refrigerator project was developed, is a sleeping car with the designation 308A. In 2013, the PKP Intercity company signed a contract for the implementation of the project called «Upgrading of PKP Intercity rolling stock Przemyśl – Szczecin - Stage II». Modernization of 10 cars was ordered, and the execution was entrusted to company PESA from the city of Bydgoszcz. The first car was put on the test tracks in 2015 (Fig. 3).

Fig.3. Sleeping car 308A at the railway station Szczecin Główny

Cars manufactured in 1977-1981 were sent for modernization. This tender also included the installation of new bogies for the cars. New strollers of the type 39AN were without pneumatic cushion on flexible springs. In addition, a sliding door was installed at one end of the car. The car has 9 public compartments and one compartment for the conductor. Each compartment has 3 (folding) beds, located horizontally, one above the other [8]. This is a typical range of the middle class. 3 passenger seats in a space of about 8 m^3 is a high density which causes an additional increase in temperature in the compartment. However, this is still not the density we see in other means of transport. Such a comparison is presented in Table 1.

Table 1

The density of people per cubic meter of the car

Transport means	Type (model)	Number of persons in a cabin (incl.crew)	Interior dimensions (approximate), m	Interior volume, m^3	Density of persons/m^3
Aircraft	Boeing 737-700	126 (4)	20×5×1.8	200	0.722
Autocar	Setra 500	69 (2)	13.5×2.4×2.8	90.7	0.783
Railway	308A Entire car	28 (2)	24.5×2.9×4.2	298.41	0.09
	Triple compartment	3	1.66×1.94×2.5	8.051	0.372

As can be seen from Table 1, the density of people per cubic meter in a fully equipped compartment of a railway car is almost ten times lower for the whole car, and for a single sleeping compartment is almost half that of air or bus transport, which brings additional advantages, namely: greater safety during the coronavirus pandemic. A samller number of people per cubic meter accordingly reduces the probability of infection, for example, with the Covid-19 virus or any other virus.

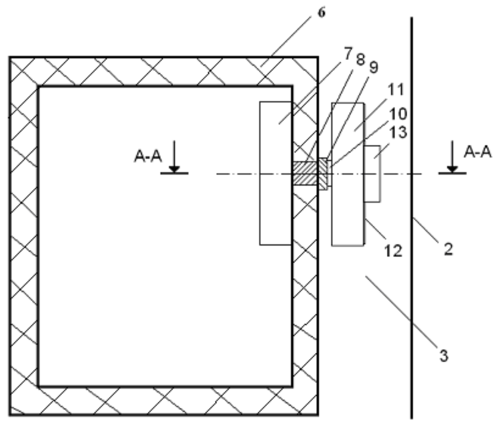
Another fact is in favour of the railway: CO_2 emissions per passenger are only 24.0 kg. [9] This is more than 3 times less than a car (87.4 kg) and 8 times less than an airplane (209.1 kg).

The modernization of a car 308A consists, among other things, in the fact that the car is adapted for the transportation of people with disabilities and has one special compartment for two people with a toilet adapted for wheelchailr users. There is a manual ramp on the side of this compartment that allows a wheelchair to enter a car 308A.

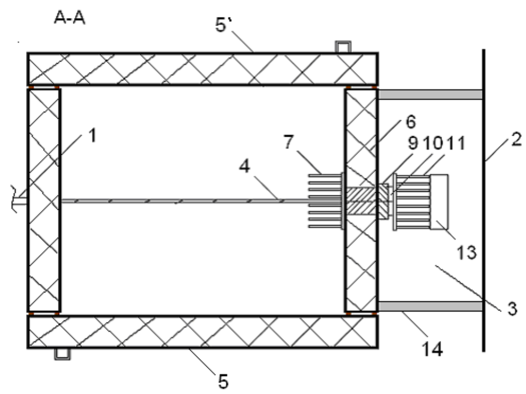
Description of the refrigerator and choice of the design option

The two-chamber thermoelectric refrigerator for a car 305Ab was developed in several versions, which differed in the location of the unit (on the side or on top) and the orientation of the partition (longitudinal, that is, parallel to the wall separating the two compartments of the car, or transverse – perpendicular to this wall).

In the first version, the refrigerator is placed in the opening of wall 1 that separates the compartment of the car, near the outer wall 2 of the car, from which it is separated by an air duct 3 (Fig. 4a). Inside the refrigerator there is a partition 3-4 mm thick, made of plastic, located along wall 1, which divides the compartment. Partition 4 divides the internal space of the refrigerator into two chambers of equal volume. Access to separate chambers is possible thanks to doors 5 and 5' for each compartment of the car. Walls 6 of the refrigerator contain heat-insulating material inside. The cooling unit consists of a cold heat sink 7, transitional elements 8 and 9 made of aluminium, a thermoelectric module 10, a hot heat sink 11 with a cover 12 and a fan 13. The unit and, in particular, heat sink 7, are located symmetrically in relation to the plane of partition 4, which ensures cooling of both chambers with the same cooling capacity. On the one hand, partition 4 is placed between the fins of the cold heat sink (as shown in Fig. 4), which provides additional rigidity of its position and facilitates the assembly of the refrigerator.



a)



b)

Fig.4. Schematic of a two-chamber thermoelectric refrigerator for a car 305Ab [10] with a lateral arrangement of the unit and a longitudinal partition: 1 – intercompartment wall, 2 – outer wall of the car, 3 – air duct, 4 - partition, 5, 5` - doors, 6 – fixed walls of the refrigerator, 7 – cold heat sink, 8, 9 – transition element, 10 - module, 11 – hot heat sink, 12 - cover, 13 - fan, 14 – duct wall.

In another version of the refrigerator, the unit is placed in the upper wall of the housing (Fig. 5).

The partition 4 is installed perpendicular to wall 1, which divides the compartment of the car, owing to which two chambers are created. Partition 4 has a thickness of 2-3 mm and is mirrored on both sides. The dimensions of the doors are adapted to the dimensions of the chambers. In this version, heat dissipates from the hot heat sink into the space above the refrigerator, which is isolated from the compartment of the car and connects to the ventilation channel of the car passing under its ceiling. To increase the useful capacity of the chambers and protect the user from damage to the fingers when inserting or removing products, the fins of the heat sink 7 are "sunk" in the recess made in the upper wall, as shown in Fig. 5.

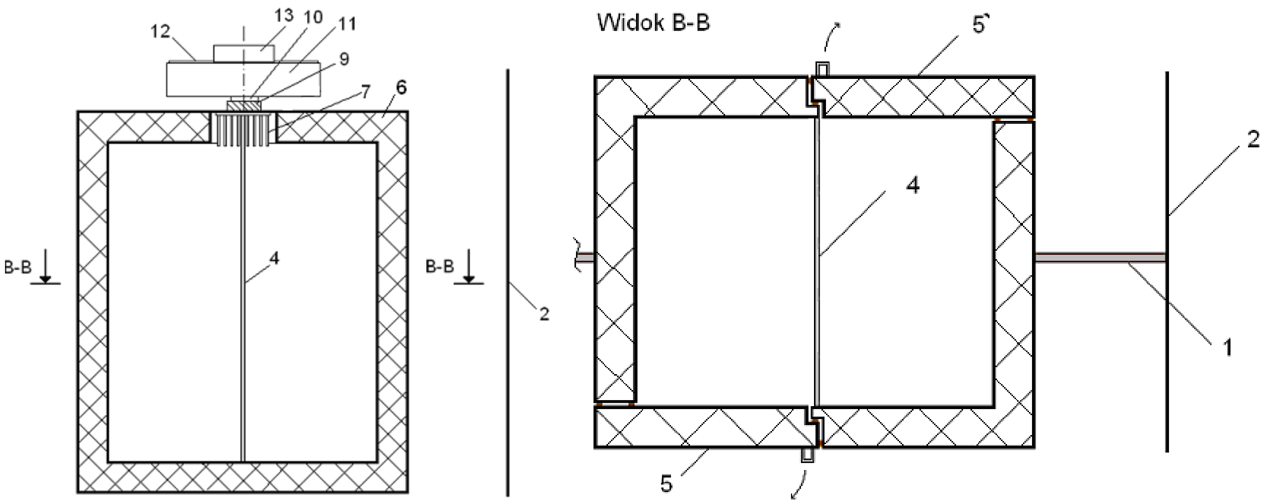


Fig. 5. Schematic of a two-chamber thermoelectric refrigerator for a car 305Ab [10] with the upper arrangement of the unit and a longitudinal partition. Positions as in Fig. 4.

The corner cabinet in the sleeping compartment of a car 308A has 3 shelves. After removing the upper shelf (Fig. 6, arrow), the space formed between the ceiling and the lower shelf can be used as a chamber for thermoelectric cooling.

Fig.6. Corner cabinet in a compartment of a car 308A

When placing the unit near the partition of the compartment at the level of the luggage shelf, it is necessary to isolate it from the luggage and thus provide additional protection of the unit. This problem can be avoided if you remove the middle shelf instead of the top one. Then the hot side of the unit will be placed in the space between the upper shelf and the ceiling of the cabinet.

The corner cabinet after inserting the partition and making the structural changes shown in Fig. 7, has the following internal dimensions:

- Width: 260 mm (obtained by adding a replaceable partition);
- Height: 340 mm (after removing the middle shelf and raising the upper one);
- Depth: 200 mm (averaged from the two bases of the trapezoid).

The cabinet designed in this way can accommodate a 1.5-liter bottle.

By replacing the wall between the compartments with the chosen one, we get an increase in the volume of the refrigerating chamber. This is shown in the following graphic comparison (Fig. 7). Due to the very low probability of opening both doors of the refrigerator at the same time, the proposed solution does not impair the sound isolation between adjacent car compartments.

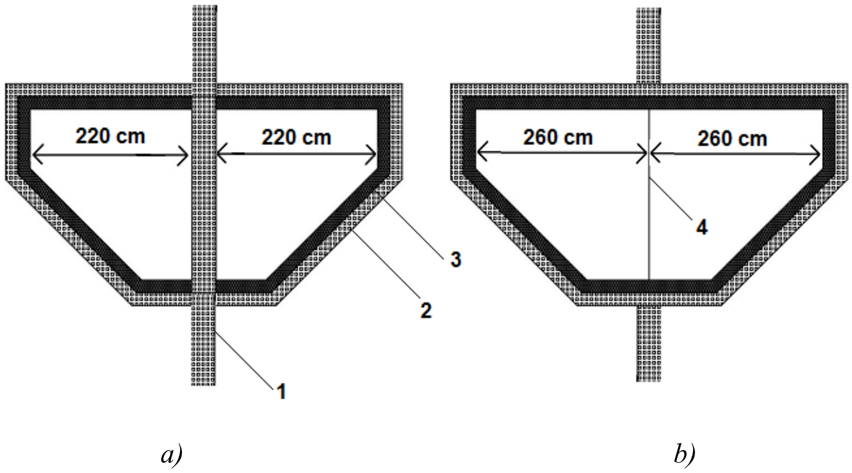


Fig.7. Comparison of the width of the refrigerating chamber: a – without a window cutout in the intercompartment wall of the car, b – with the use of intercompartment partition: 1 - partition, 2 – furniture board, 3 – thermal insulation, 4 – intercompartment partition.

If the thermoelectric unit will be located on the upper shelf of the corner cabinet, it is necessary to reduce the height of the cabinet doors, in order to obtain better air circulation that cools the hot heat sink of the unit.

Figs. 8 and 9 present structural fragments of a thermoelectric refrigerator for the compartment of a car 308A. The calculated value of the thermal load of one refrigerating chamber in this version was 11.5 W. Within the framework of the project [11], the type of thermoelectric module was chosen, the necessary heat exchange surfaces of heat exchangers were calculated under the accepted operating conditions of the refrigerator.

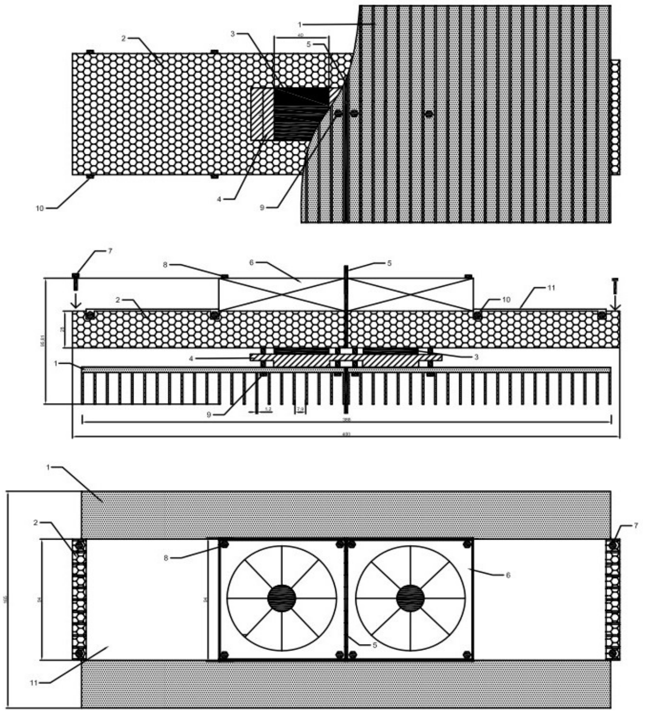


*Fig.8. Unit of a two-chamber thermoelectric refrigerator for a car 308A [11]:
1 – cold side heat exchanger, 2 – hot side heat exchanger, 3 – thermoelectric module; 4 – transition element, 5 –partition, 6 – fan, 7, 8, 9 – screws, 10 – thermal insulation, 11 – cabinet wall.*

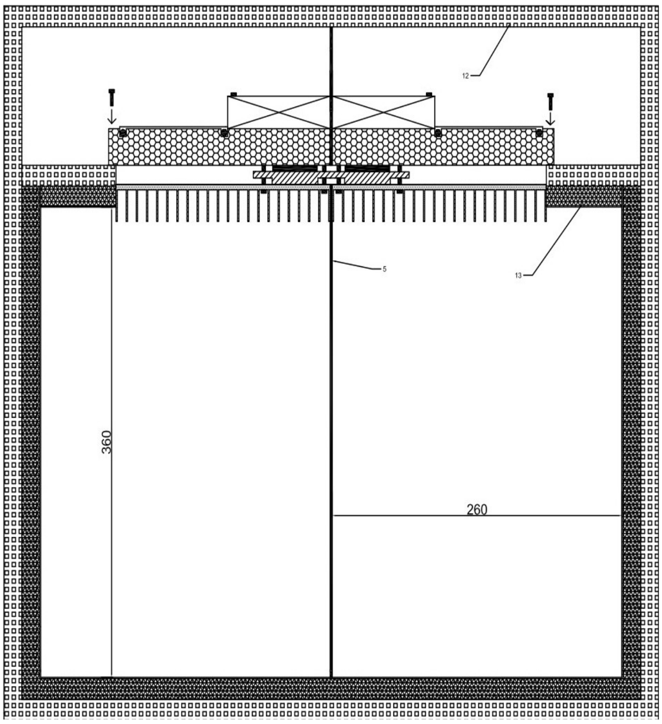


Fig. 9. Vertical section of the refrigerator for a car 308A. Positions as in Fig. 8.

Conclusions

1. A method of constructing theoretical models of ordered *Pb-Bi-Te* alloys using the geometric properties of a triangle is proposed.
2. The diagram of the distribution of phase regions and isothermal sections in the *Bi-Pb-Te* ternary systems has been constructed.
3. Calculations of effective radii, effective charges, dissociation energies in the *Bi-Pb-Te* ternary systems have been carried out.
4. The results obtained are consistent with the results of calculations of chemical bond parameters by the methods of microscopic theory [3 – 5], [7] and can be used in the development of technological modes for obtaining new materials based on *Bi-Pb-Te*.

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ТЕРМОЕЛЕКТРИЧНИЙ ХОЛОДИЛЬНИК ДЛЯ КУПЕ СПАЛЬНИХ ВАГОНІВ

У даній роботі розроблено термоелектричний охолоджувач, агрегат якого вбудований в кутову шафу спального купе вагона PKP Intercity моделі 308A. Конструкція холодильного агрегату передбачає кілька варіантів виконання. Модернізацію вагону проводить фабрика PESA Bydgoszcz. Холодильник має інноваційну дворівневу систему живлення, що дозволяє зменшити споживання енергії. Холодильна шафа розділена на два відділення, які «обслуговують» два сусідніх купе. Термоелектричний блок холодильника охолоджує обидві камери одночасно. Застосування винаходу дозволяє підвищити рівень комфорту подорожуючих.
Бібл. 11, рис. 9, табл. 1.
Ключові слова: *транспортний термоелектричний охолоджувач, дворівнева система живлення, термоелектрична установка*

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