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THERMAL INERTIALITY OF THE AIR IN THE PUBLIC TRANSPORT CABIN WITH CONDITIONING SYSTEM

In modern conditions, energy efficiency contributes to increasing competitiveness in the domestic and international markets of transport services. For Ukraine, the efficient use of fuel and energy resources is one of the most essential tasks that ensure the country's energy security and energy independence. The specifics of the operating conditions of rolling stock on urban bus routes in the warm season with air conditioning determine the number of requirements for the design parameters of the vehicle itself and for systems that provide the proper microclimate during the transport process. A characteristic feature of the microclimate in the interiors of city buses is the instability of its parameters since the temperature of the air and facing structures during the day can vary up to 10 C or more. It was presented in the work the decision with regards to the check-up of thermal inertiality of the city bus cabin air for determining the relevance of reviewing the usage of the certain power conditioner as a factor of power consumption reduction. When choosing temperature control systems in the passenger compartment, the real heat inertia of the indirect flow, which is passed through the passenger compartment of the bus by air conditioning, is taken into account. On purpose of increasing energy efficiency of the public transport in the warm season of the year while working with the conditioner it was considered the method of energy saving via reviewing the construction of the cabin interior and predicted speed of its cooling. It was obtained the results of the conducted exploitation tests of the microclimate in the public transport on the city routes at the temperature of the environment from +25 up to +34˚C. It was established that absorption of solar energy and thermal conductivity are the dominant factors of the bus construction, and thermal inertiality of the air is the important parameter of comfort and it favors loading reduction while warming and cooling.

Key words: city bus, bus cabin, thermal inertiality, thermal balance, comfortable conditions, temperature environment.

INTRODUCTION

One of the most important factors of the transportation process by the public two-wheeled transport is the micro-climate formed under the influence of the heat income of different sorts in the cabin and favours the additional heating the air in the warm season of the year by 8…15˚C.

The issue of regulation and management of the air parameters in the cabin of the passenger transport means is getting especially topical while introducing modern monitoring of the buses performance via GPS-navigation at the automotive companies.

The microclimate in the bus cabin depends on the peculiarities of the systems of heating, ventilation, conditioning, and also the range of the construction parameters of the bus itself (cabin tightness, engine location, its thermal insulation, thermal conductivity of lining and filling materials of the side walls, passenger presence, the degree and the type of windows glazing, conditioner management) [1].

Car air conditioners refer to the class of energy consumers which, in the presence of internal combustion engines, directly depends on fuel consumption. One of the key peculiarities of this approach lies in the fact that there are still not enough data in the technical description of the suppliers or main characteristics of the transport means, and it requires conducting additional experimental tests.

Reducing accumulation of the excess heat in the cabins of the transport means, and providing corresponding levels of the temperature environment may favour increasing fuel saving, power reserve, reliability, durability, comfort of the passengers and the driver, and transportation safety [2]. Improvement in managing the temperature in the motor vehicle remain crucial as the new technologies cause consumer demand, and the social problems as well as the state norms as for transportation process perfection are developing.

The amount of heat lost by the bus cabin in the cold season of the year and incoming into it in the warm season depends on thermophysical properties of the lining constructions of the cabin. The cabin consists of construction elements and constructions dividing internal environment of the cabin with non-regulated temperature from the external environment. Due to this the cabin zone plays the main part in providing common thermal comfort of the passengers and the driver. Thermal inertiality in the cabin of the public transport as the factor of heat input in the warm season of the year is determining for calculating productivity and conditioning system.

ANALYSIS OF LITERATURE DATA AND FORMULATION OF THE PROBLEM

The tasks of the complex microclimate management in the city bus cabin can be divided into the following subtasks according to their priority: maintaining quality air gas composition, providing comfort of transportation and energy saving. The analysis of approaches to the optimal microclimate management [3] shows that the contemporary tendency in this sphere is the development of management systems as to energy expenditures and comfort.

The mainstream intuitive thought that the temperature of the air inside the space (including the space inside the passenger transport cabin) practically always coincides with the temperature of the fencing constructions of this space. Under the conditions of the active air conditioning of the passenger cabin such a statement remains not always correct [4]. It can be explained, first of all, by the fact that in the city transport the air coming into the cabin through the open doors at the stops has the temperature different from the temperature established in the cabin. The duration of leaving the doors in the open state at the stop in average does not exceed 15-20 seconds [5]. The temperature of the cabin walls and seats remains practically unchanged within this period. Therefore, while choosing the air conditioning system in the cabin of city transport means, it is necessary to consider real heat inertiality of the cooled air in the conditioner coming through the cabin. It is shown in the works [4, 6] that it turns out to be much lower than the thermal inertiality of fencing constructions of the railway passenger carriage and it is calculated in minutes, not in hours that is characteristic for building constructions.

In the works [7, 8] it was presented experimentally proved peculiarities of the thermal state of the carriage and simplified mathematical micromodel of the non-stationary heat mode. It was introduced the assumptions that the temperature fluctuations between the air and the walls inside of the carriage may be neglected as it does not exceed 5-10% from the temperature fluctuations in the heat insulation layer of the outer walls of the carriage. The temperature air field of the internal partitions at all the stages is close to uniform, the heat capacity of finely dispersed insulation of the carriage comprises a small part from the heat capacity of the internal partitions and it influence may be calculated simplistically, in the form of assumption.

While assessing the heat comfort in the motor car vehicles, as a rule, subjective and objective measurements are used. In the works [9,10] there was a try to prove an important role to increase the comfort of the car seats via the temperature in different seasons of the year. According to the measurements results it was proved that all the materials of the seats have the equal level of the heat comfort.

The analysis of the heat loading carried out at the researched minibus showed that the solar energy influences sufficiently the heat characteristic of the cabin as it gets directly through the glass into the internal environment and, in its turn, cools the air. While solar energy penetration from 18% till 31% the need in cooling the cabin occurs. It was proved that reducing the coefficient of glazing transmission by coefficient 0,2 may lead to decreasing the set cooling power by 3,3% [11].

Heat loadings by the solar energy of transport means with the paint coating of different colours have an excellent absorption feature of the non-transparent bodywork elements. It potentially decreases the supporting loading of the transport means and reduces the fuel consumption enabling the use of the conditioner of the lower power [12, 13, 14].

The experimental comparison of black and silver compact sedans showed that increasing solar reflection of the car body bodywork approximately by 0,5% decreased the temperature by 5-6 °C. It was needed 30 min for cooling the air up to 25˚C in the silver car, that is 13% less than in the black car. The measurements proved that the colours have a much lower solar spectral reflective ability than the light tones.

A significant influence on the heat exchange between the cabin and the outer temperature is provided also due to the massiveness of bus design, due to this the temperature fluctuations on their internal surface are decreasing [1].

PURPOSE AND OBJECTIVES OF THE STUDY

The Aim of the work lies in creating technological decisions in terms of providing energy efficiency while managing the microclimate in the cabin of public on-land transport with the conditioner.

Principal difficulties occur while solving provision of microclimate quality in the public transport. They are connected, in particular, with the lack of clarity in the question of thermal inertiality of the air in the cabins of the city bus, trolleybus or a tram, when at the stops at the door open a certain mass of the outer air with higher or lower temperature gets into the cabin than it is regulated by the normative documents. It influences on technically and economically reasoned choice of the air conditioning system in the cabin of the transport means, and also the rational management of the air parameters in it.

The first step in anticipating the usage of the conditioner is determining the thermal state of the transport means with the consideration of the environment and the operation conditions. Working compressor of the system of air conditioning is the largest auxiliary load on the strength unit of the car compared to the generator and hydraulic drive of the steering. The conditioner compressor may add up to 5-6 kWt of the peak power of the car engine that approximately has the same loading as the conditioner of the small residence [15].

Meanwhile, the heat balance method in the bus cabin is applied for assessment of the loading on the conditioner according to the duration of its work and consequently on the extra fuel consumption by the power unit [1].

Unfortunately, work capacity and energy efficiency of all the conditioners that implement the reverse Carnot cycle principally depend on the temperature of the inner and outer air. As the desired parameters (temperature and relative humidity) of the inner air lay in comparatively narrow limits, practically the only parameter determining work capacity and energy efficiency of the conditioner, is the temperature of the outer air.

RESEARCH RESULT

The optimal energy consumption and the heat comfort in the cabin for the passengers can be calculated and modelled via the theory of the heat transfer, the heat balance method and the heat transfer coefficient [16].

The heat transfer is a complex exchange consisting of its separate kinds. Based on the theory of heat transfer there are three mechanisms of heat transfer: conductivity, convection, radiation. The heat transfer into the bus cabin in the warm season of the year is the dominating process due to the difficulty of the transport means construction (windows, sides of different layers, floor, roof and doors) as all the criteria of the heat transfer are present. The heat inertiality may be considered as the material property to accumulate the heat and retard its transfer into the outer environment, that is it is the level of slowness of reaching the temperature of the outer environment. Therefore, the heat inertiality is an important parameter of the heat comfort in the bus cabin and it favours loadings reduction while cooling the cabin with the conditioner in the warm season of the year within the certain time.

The heat inertiality (J $^{m-2}$K^{-2} s$^{-1/2}$) of the certain material may be calculated by the formula:

$$I_м = \sqrt{\lambda\, p\, c}\ , \qquad (1)$$

where λ – material thermal conductivity, W/(m K);

p – material density, kg/m^3;

c – relative heat capacity, J/kg ·°C.

Multitude *pc* represents bulk heat capacity. The heat capacity λ is the physical parameter of the substance. In general, it depends on temperature, pressure and type of the substance. Heat transmission from the hot heat transfer agent to the wall is carried out via convective heat exchange. The heat is transmitted via heat conductivity inside of the wall [17, 18].

Convection in the buses takes place at the contact between the surfaces of the construction panels (side walls, roof, floor) and the air inside the bus and the air outside the bus. Meanwhile inside the bus convection has low fluctuations, it is strengthened outside at increasing the bus speed.

Radiation, radiative solar loading on the bus, and its influence depending on the weather conditions and the season of the year may have an important contribution into the heat loading.

Heat inertiality of the air in the transport means cabin was considered at the example of the city bus MAZ – 206 with the conditioning system in the warm season of the year.

The equation of the heat balance in the passenger bus cabin as the demonstration of the saving and transformation energy law, is formed with the consideration of the special form of energy transmission. This equation is composed with the consideration heat incoming into the salon and coming out from it. While setting the heat balance between them (steady exchange mode) the heat balance equation looks in the following way [19]:

$$Q_{fc} + Q_{is} + Q_{pas} + Q_h = Q_{cs}\ , \qquad (2)$$

where Q_{fc} – the heat incoming into the cabin via fencing constructions, W;

Q_{is} – the heat incoming from the internal bus sources, W;

Q_{pas} – the heat releasing from the present passengers, W;

Q_h – the heat incoming into the cabin with tidal air, including the air through the open doors, at passengers boarding and disembarking at the technological stops and heat filtration air (due to the looseness of the bodywork), W;

Q_{cs} – heat compensated by the air conditioning system of the bus cabin, W.

Heat Q_{cs} in the passenger transport cabin is compensated with the certain amount of the cooled air $G_{x,}$ that is served by the autonomous conditioner.

Different categories of the heat influence on the public transport cabin (on the example of MAZ-206) are shown in Figure 1.

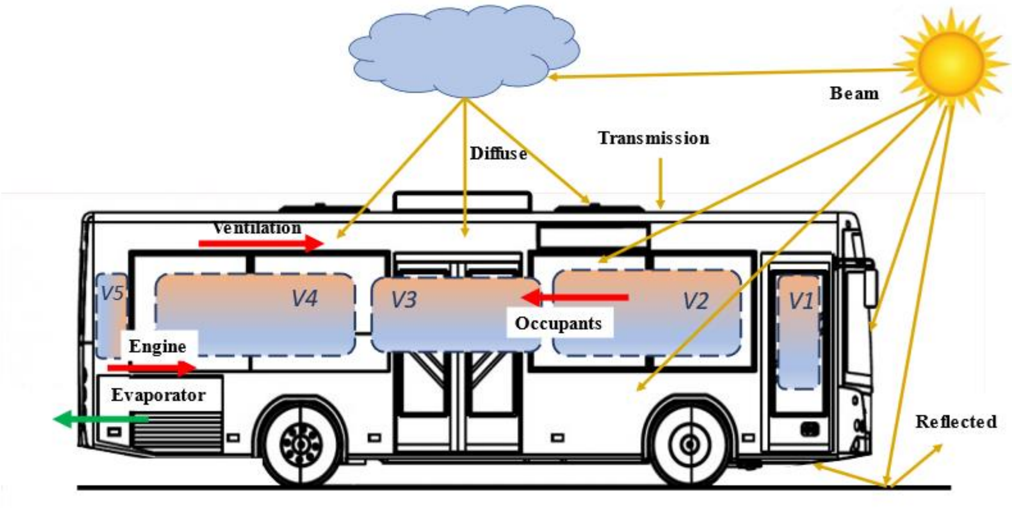

Figure 1 - Schematic picture of influences and mechanisms of heat transfer to the bus MAZ-206 and classification of the cabin into five zones

Heat transfer into the bus cabin by the solar radiation is conducted via absorption and permeation and it is the domineering part of the internal loading for cooling by the conditioner. Meanwhile the glass practically does not absorb the solar energy.

As the equivalent temperature of the solar radiation is connected with the thermal and physical properties of the outer source of the cabin side wall, we will use for the simplified analysis the model of the fencing construction of the bus cabin in the form of flat one-layer sheet panel (Figure 2).

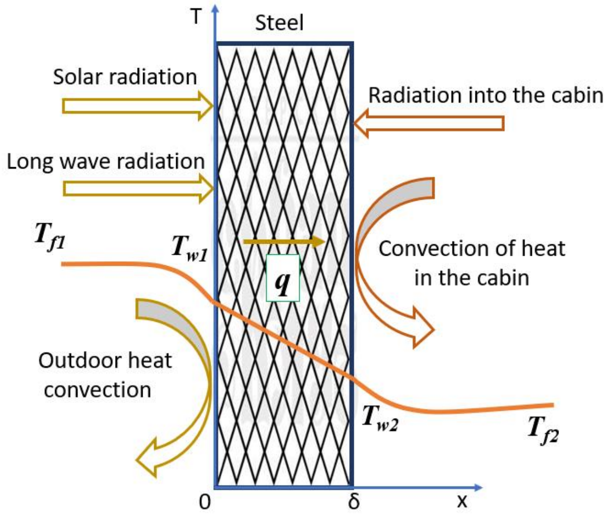

Figure 2 - Heat transfer processes of the outer panel of the transport means cabin: T_{f1}, T_{f2} – temperature values of the environment; T_{w1}, T_{w2} – temperature values of the bodywork panel surface

We calculate the coefficient of heat transfer K_δ (W/m^2 K) as for the flat bodywork panel by the formula:

$$K_\delta = \frac{1}{R_t} = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta}{\lambda_w} + \frac{1}{\alpha_2}}\ , \tag{3}$$

where R_t – complete heat resistance, K/W;
a_1, a_2 – coefficients of the convectional heat release, W/(m²·K);
δ, λ_w – thickness and heat conductivity of the metal panel accordingly.

The main loading on cooling inside of the bus originate from heat incoming through external fencing constructions. In the central zone of the cabin due to the forced convection created by the conditioner, the temperature field of the air remains close to the uniform due to low air heat conductivity. Therefore, while analyzing the regularities of the heat exchange of the cabin air with its walls, it may be done the assumption about the existence of some zone with relatively constant temperature (isothermal zone). Hence thermal and temperature modes of the air inside the cabin at the established thermal mode, should yield integral equation of the thermal balance that may be noted according to the approach [6]:

$$c_p \cdot G_x\, [t_{(\tau)} - t_x] + c_p \cdot \rho \cdot V \cdot \frac{dt}{d\tau} = \alpha \cdot F_{gen}\, [\, t_w - t_{(\tau)}\,] + Q_{tot}\ , \tag{4}$$

where c_p – relative isobaric heat capacity of the cold air (incoming into the cabin from the conditioner), J/(kg·°C);
G_x – consumption of the cold air coming through the cabin, kg/s;
$t_{(\tau)}$ – average temperature of the air in the cabin for the analyzed period of time, °C;
t_x – temperature of the cold air incoming into the cabin, °C; a
ρ – air density (at certain temperature), kg/m^3;
V – air volume in the cabin, м^3;
$\frac{dt}{d\tau}$ – temperature within the certain time limit, °C;
α – average coefficient of heat transfer of the cabin panels, W/(m^2 ·°C);
F_{gen} – general surface of structure-borne bus cabin (side walls, floor, ceiling, passenger seats, m^2 ;
T_w – average temperature of the walls, floor, ceiling, passenger seats in the cabin, °C;
Q_{tot} – total power of the internal heat sources incoming into the cabin (passengers, engine, electrical equipment), W.

It is accepted in the equation (4) that the air temperature removed from the cabin in the steady mode (at the city route) practically coincides with the average temperature of the air in the bus cabin. Meanwhile it is necessary to take into account that the bus bodywork and the bodywork walls as well have a higher thermal inertiality than the air in this cabin. Therefore, in the equation (4) while analyzing the transmission stage occurring while opening the doors at the stops and the outer infiltration air incoming into the cabin, the possible temperature change of the surrounding internal surfaces of the cabin (panels of the sidewalls, floor, ceiling, passenger seats).

The assumption concerning conditionally constant air temperature of the fencing side walls of the bus cabin (t_{cab}) enables to apply the notion of the steady stationary air temperature in the bus cabin (t_{cab}).
It may be used, for its calculating, the equation of the fixed thermal mode of the bus cabin with the outer environment according to the approach [6]:

$$c_p \cdot G_x \cdot [t_{cab} - t_x] = \beta \cdot F_{ext} \cdot [\, t_{ext} - t_{ext}\,] + Q_{tot}\ , \tag{5}$$

where t_{cab} – a constant air temperature in the bus cabin, ^{0} C; it is set with the working conditioner, and it is agreed with it the air consumption G_x and the air temperature at the outlet of the conditioner t_x;
β – relative heat conductivity of the bus bodywork walls, W/(m^2 ·^{0} C);
F_{ext} – surface of external fencing panels of the cabin, m^2 ;
T_{ext} - temperature of the external environment, ^{0} C.

we have from the equation (5):

$$t_{cab} = \frac{Cp \cdot Gx \cdot tx + \cdot\beta \cdot Fext \cdot tcp + Qtot}{Cp \cdot G + \beta \cdot Fext}\ . \tag{6}$$

The air temperature in the cabin should approximate to its stationary value (t_{cab}) at the steady temperature values of the bodywork side constructions (t_s), cold air temperature (t_x), air temperture in the cabin for the period analyzed ($t_{(\tau)}$) and consumption of the cold air via the cabin (G_x) according to equation (4).

Therefore, the equation in the stationary stage looks in the following way:

$$c_p \cdot G_x \cdot (t_{cab} - t_x) = \alpha \cdot F_{gen} \cdot (t_s - t_{cab}) + Q_{tot} . \qquad (7)$$

Under the conditions of passenger transport work on the city route in the warm season of the year the air parameters in the cabin are a bit different from the stationary ones (1, 9, 11, 20). It is conditioned by warmer air incoming into the cabin through the open doors at the technological stops [19], and also infiltration air due to the looseness in fencing constructions of the cabin while motion. The amount of infiltration air can be defined by the formula [21]:

$$V_{inf} = \frac{a \cdot g \cdot l}{\rho} , \qquad (8)$$

where a – coefficient characterizing the surface of the external surfaces of the bus bodywork, $a = 1$;
g – relative air consumption per unit of looseness length, $g = 17 kg/h$;
l - looseness length (for the bus being operated up to 6 years, l = 11,2 m);
ρ - air density, kg/m^3.

DIN 8959 Standard – "Transport Means of Germany with heat insulation" implies the coefficient of heat aging 1,4 – within 6 years and 1,5 – within 9 years of exploitation [22].

The side walls panels of the bus researched MAZ-206 are manufactured from galvanized sheet steel 0,9 mm thick and stuck to the frame according to the modern European technology. The angle panels (front and back) are made of glass fiber reinforced plastic 4 mm thick. On purpose of proper noise insulation of the bodywork the space between the panels of external and internal tiling, is, in general, filled with thermal noise insulation material 40 mm thick. All the doors (we have 2) have the plane-parallel type of opening. The doors are firmed with the rubber profiles. Composite materials made of plastic and padding materials are applied for the internal cabin, roof and side walls upholstery.

Heat transfer is estimated with the consideration of conductivity via solid materials, convection between the external air and external surfaces of the bus. According to the research [23], the equivalent temperature of the solar radiation is connected with thermal and physical properties of the external bodywork panels of the bus. The model of the three-layer side of the bus bodywork side is presented in Figure 3.

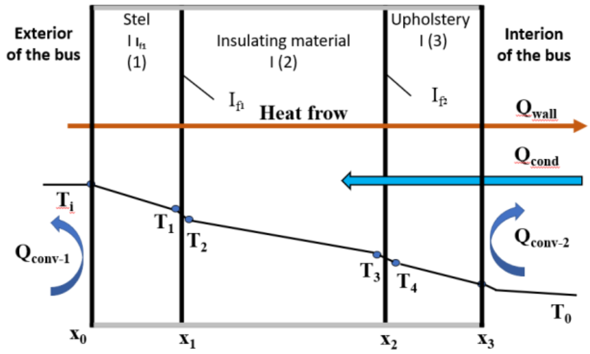

Figure 3 - Principal scheme of the three-layer sidewall of the cabin [23]: T_i — external temperature, °C; T_o — internal temperature, °C

The general coefficient of heat transfer for the three-layer bodywork sidewall is calculated according to the approach [23]:

$$\frac{1}{U_{wall}} = \frac{1}{h_i} + \left(\frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{L_3}{k_3}\right) + \frac{1}{h_0} + r_{cwall} \text{ , K/m}^2\text{W}. \qquad (9)$$

The sum of the heat resistance of both interfaces I_{f1} and I_{f2} is the heat contact resistance for the three-layer bodywork sidewall (Figure 3).

Taken into consideration all the stated above, it may be stated about the non-stationary mode of air parameters in the transport means cabin.

At the non-stationary modes temperature value ($t_{(\tau)}$) varies from temperature t_{cab} by the value $\vartheta(\tau)$ for the warm season:

$$t_{(\tau)} = t_{cab} - \vartheta_{(\tau)} . \tag{10}$$

The temperature $\vartheta_{(\tau)}$ is influenced by: heat incoming into the cabin with the air through the open doors at the stops, volume V_d and heat incoming with the infiltration air, volume V_{inf} .

After introduction the expression (10) into the equation (4) and subtracting from the right and left relevant members from (7), the equation (4) will look in the following way:

$$\mathcal{E} \cdot \frac{dt}{d\tau} + \vartheta_{(\tau)} = 0 , \tag{11}$$

Where it was introduced the marking according to the approach [7, 6]:

$$\mathcal{E} = \frac{cp \cdot \rho \cdot V}{\alpha \cdot Fgen + cp \cdot Gx} = const. \tag{12}$$

Considering the volume of the incoming air into the cabin, V_d (m^3/c) та V_{inf} (m^3/c) the equation (12) for the non-stationery mode will look in the following way:

$$\mathcal{E} = \frac{cp \cdot \rho \cdot (V + Vd + Vinf)}{\alpha \cdot Fgen + cp \cdot Gx} = const. \tag{13}$$

The equation (13) characterizes internal thermal inertiality of the air in the bus cabin. Parameter $\mathcal{E}$ in the theory of heat exchange is referred to as inertiality index. Common duration of the transient processes at technical calculations are assessed by the value $\tilde{\imath} \geq 3\mathcal{E}$ [7].

Its value depends on the complete air heat capacity that is in the cabin, and the air incoming through the open doors and bodywork looseness (infiltration), heat transfer α, general area of lining (fencing) constructions of the cabin and passenger seats F_{gen}, and also air consumption G_x, that is forcibly supplied into the cabin by the conditioner.

As an example, we will use the formula (13) for determining heat inertiality of the air in the cabin of the passenger bus MAZ – 206 with the conditioning system at the steady city route [5, 19].

We accept: V = 40,8 m^3; F_{gen} = 82 m^2; isobaric air heat capacity c_p = 1005 J/($m^{3}\cdot{}^0$C); air density ρ = 1,2 kg/m^3; air volume incoming into the cabin and removed from it through the door V_d = 0,125 m^3/s (450 m^3/h); the volume of the infiltration air is V_{inf} = 0,044 m^3/s (159m^3/h); the average coefficient of the cabin walls heat transfer via the conditioner is G_x = 0,55 m^3/c (2000m^3/h).

Resulting the calculations we obtain: $\mathcal{E}$ = 24 s. Taking into account the transitional process ($\tilde{\imath} \geq 3\mathcal{E}$), air inertiality does not exceed 2 minutes after closing the doors at the stop and the air temperature gets a steady value t_{cab}.

Full-scale experimental research of the thermal loading of the passenger bus MAZ-206 cabin were conducted while its motion on the route. The conditioner Revo 25 with the maximum volume of the air flow 4,640 m^3/h and the two-channel conditioning system [24] was installed in the bus. It was determined the temperature parameters of the outer air and the air inside of the cabin:

-temperature, t_{ext}, t_{cab} ,°C;

-motion speed, v_{ext}, v_{cab}, m/s;

-relative air humidity, φ_{ext}, φ_{cab}, %.

Control measurements of the air parameters were conducted in 1 minute before the stop and in 1 minute after the beginning of the bus motion from the stop. The scheme of measurement amount location is stated in Drawing 1. The measurement points were located in the zone of the sitting passenger head in the volumes *V2*, *V3*, *V4*.

The results of the microclimate parameters research in the bus cabin at the route in 1 minute before the technological stop are presented in Figure 1.

The research of the heat loading was conducted on the passenger bus cabin only, as the motor compartment (zone V5, Figure 1) provides heat insulation with the thermal and noise insulation material and padding by the perforated zinc-coated sheet, and the driver's stall (zone V1, Figure 1) is not adjacent with the present bus conditioning system and is not the subject to consider in this work.

Table 1. Microclimate in the bus cabin in 1 minute before the technological stop (with the working conditioner)

Place of measurements conducting	Air temperature, ˚C		Air speed, *v*, м/с		Relative air humidity, φ %	
	external, t_e,˚C	in the cabin, t_c,˚C	external, v_e, m/s	in the cabin, v_c, m/s	external, $φ_e$, %	in the cabin, $φ_c$, %
Volume *V2*	30,0	25,7	0,8 – 1,0	0,3	54	45
Volume *V3*	30,0	25,6	0,8 – 1,0	0,5	54	47
Volume *V4*	30,0	25,8	0,8 – 1,0	0,4	54	47

Graphic interpretation of the temperature change in the bus MAZ-206 cabin per relevant time of the conditioner work on the route is presented in Figure 4.

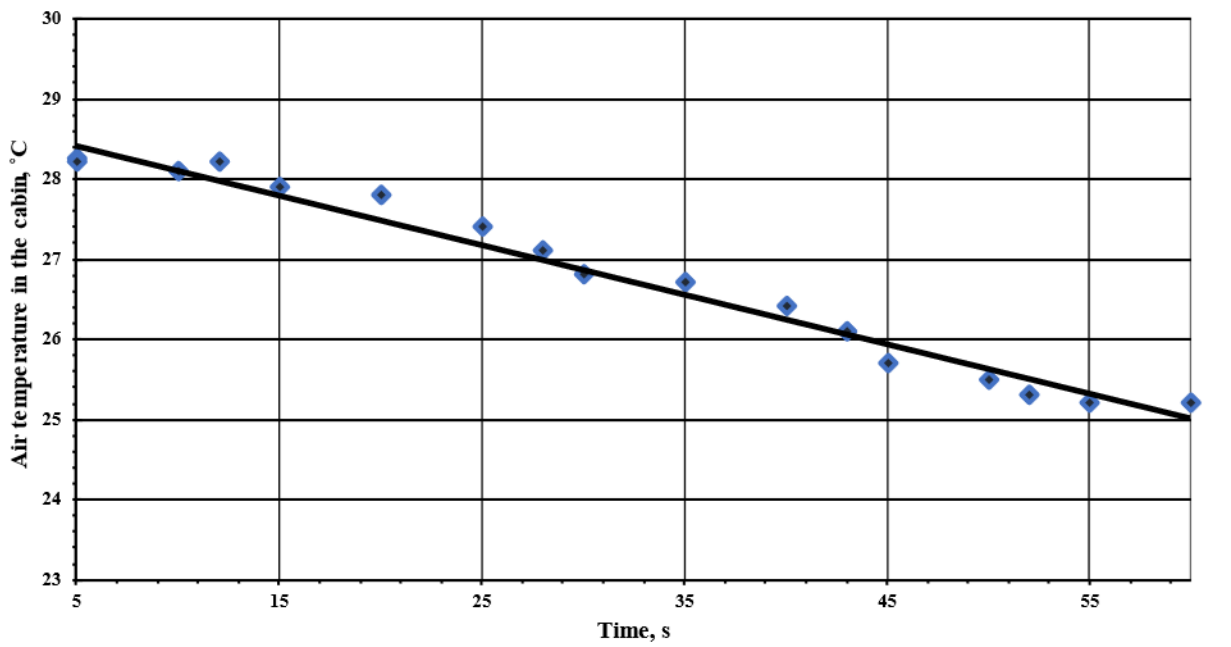

Figure 4 - Theoretical (▬▬) and experimental (◆) dependencies of air cooling velocity at the time of leaving the stopping point (at the external air temperature +31˚C)

Constructional panels of the outer opaque bus bodywork elements undergo absorption of the part of the solar radiation and their temperature increases. Inside the three-layer side wall the heat is transferred via heat conductivity from a more heated to the less heated element. At the need of reducing heat transfer intensiveness, it is necessary to increase heat resistance that is reached via applying the insulation layer with low heat conductivity on the internal part of the bodywork and heat-absorbing excipients are used. Increasing heat resistance of heat transfer of the constituents thermal inertiality of the air in the cabin decreases.

It may be seen from the graph of temperature decreasing in the bus to the optimal values (Figure 4) that it takes place by the linear dynamics of the climate stability reproduction and it explains inertia of the air in the cabin.

The research conducted prove mathematical calculations of the reproduction duration of the relevant temperature mode in the bus cabin, meanwhile air inertia does not exceed 2 minutes after closing the doors at the stop. It demonstrates that even at increasing heat inertiality of the air under certain conditions twice, thermal comfort will not influence the common microclimate in the bus cabin and it will decrease the loading on the conditioner.

It follows from the ratios (8) – (11) that it is possible to decrease thermal inertiality practically due to dramatic increase of the air amount that is supplied to the cabin. It is possible via increasing the power of the ventilation or the conditioner that supplies already cooled air. Accordingly, in some short time there is no need in supplying such an additional portion of the air. The solution of the problem is seen in preliminary cooling in the bus cabin at the end stop before the route performance.

It, in its turn, gives the opportunity to use the conditioner of the lower power as providing the proper microclimate is already possible taking into account short thermal inertiality that is experimentally proved.

DISCUSSION OF THE STUDY RESULTS

The main problem in reducing energy consumption of the transportation process by the busses with the conditioners for providing a comfortable division of the air in conditioner selection and agreement of the operational parameters with the heat-protective properties of the cabin. The phenomenon of thermal conductivity has a great significance while providing a proper microclimate in the public transport cabin.

Thermal inertiality of the bus cabin occurs while motion of the bus at the route. A proper work of the ventilation and conditioning system allows to reduce loading on the conditioner without additional energy consumption and keep the comfortable conditions at the bus stops while passengers onboarding and disembarking. At the same time there occurs a need in improving thermal-protective properties and bus bodywork sealing that will allow to use the conditioner of the lower power.

There occurs the need in revision of heat exchange of the cabin with the outer environment while working on the route with the conditioner turned on for agreement the work of all the conditioning system elements and reaching the highest efficiency of the system functioning with a possible need of correction in the conditioner compressor management.

Maintaining the necessary temperature in the bus cabin is conducted via management of the conditioner compressor work. It is worthy to note that outer thermal loadings depending on the season of the year and the time of the day may positive and negative.

CONCLUSIONS

It is obvious that in the warm season of the year the temperature medium of the bus cabins of the city routes may not correspond to the normative values, especially while staying at the end stop. It is necessary to take measures in reducing thermal inertiality of the cabin while performing the route for it.

The solution of this problem is seen in the preliminary cooling of the bus cabin at the end stop before performing the route. This, in its turn gives the opportunity to use the conditioner of the lower power as providing the proper microclimate is already possible considering short thermal inertiality.

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Чуйко С.П., Кравченко О.П. **Теплова інерційність повітря в салоні міського громадського транспорту з системою кондиціювання.**

У сучасних умовах енергетична ефективність сприяє підвищенню конкурентоздатності на внутрішньому і міжнародному ринках транспортних послуг. Для України ефективне використання паливно-енергетичних ресурсів є однією із найважливіших задач, що забезпечує енергетичну безпеку і енергонезалежність країни. Специфіка умов експлуатації рухомого складу на міських маршрутах автобусних перевезень У теплу пору року з кондиціонером визначає ряд вимог до конструктивних параметрів самого транспортного засобу і до систем, які забезпечують належний мікроклімат при виконанні транспортного процесу. Характерною особливістю мікроклімату в салонах міських автобусів є нестабільність його параметрів, оскільки температура повітря і облицювальних конструкцій протягом дня може змінюватись до 10˚С і більше. У роботі представлено рішення по перевірці теплової інерції повітря салону міського автобуса для визначення доцільності перегляду використання кондиціонера певної потужності як фактору зниженню енергоємності. При виборі системи управління температурою у салоні слід враховувати реальну теплову інерційність повітряного потоку, який проганяється через салон автобуса кондиціонером. З метою підвищення енергоефективності громадського транспорту у теплу пору року, при роботі з кондиціонером, розглянуто метод економії енергії шляхом перегляду конструкції інтер'єру салону та передбачувану швидкість його охолодження. Отримано результати проведених експлуатаційних випробовувань мікроклімату в громадському транспорті на міських маршрутах при температурі навколишнього середовища від +25 до 34˚С. Встановлено, що поглинання сонячної енергії та теплопровідність є домінуючими факторами конструкцій автобуса, а теплова інерція повітря важливим параметром комфорту та сприяє зменшенню навантаження при нагріванні та охолодженні.

Ключові слова: міський автобус, салон автобуса, теплова інерційність, тепловий баланс, комфортні умови, температурне середовищ.

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