Вісник Тернопільського національного технічного університету
https://doi.org/10.33108/visnyk_tntu
Scientific Journal of the Ternopil National Technical University
2024, № 2 (114) https://doi.org/10.33108/visnyk_tntu2024.02
ISSN 2522-4433. Web: ***visnyk.tntu.edu.ua***

UDC 629.113

STUDY OF MICROCLIMATE INDICATORS OF A BUS DRIVER'S WORKPLACE IN THE WARM SEASON OF THE YEAR

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Summary. *On the basis of the developed methodology for the working conditions of a city bus driver, experimental studies of the microclimate in a bus of the Electron A18501 model were carried out. After analyzing the rolling stock of bus fleets in a number of Ukrainian cities, the city of Lviv was selected for research. Using a specially designed set of measuring equipment, the temperature, humidity, and air volume, as well as the level of CO_2 at the bus driver's workplace were measured. The obtained results of the experiment can be further used in theoretical studies, and they can also serve as a basis for determining the capacity of refrigeration units for the buses under study.*

Key words: *city bus, air temperature, air humidity, microclimate, bus driver's cabin, ventilation.*

https://doi.org/10.33108/visnyk_tntu2024.02.011 *Received 02.01.2024*

Statement of the problem. The microclimate in the cabin of a public transport vehicle that carries a large number of passengers, especially city buses, should be given important attention, both in terms of the environment and the driver's working conditions. When operating a bus on a route, the driver must be comfortable at his or her workplace, because if microclimatic indicators and other comfort parameters are violated, undesirable reactions of the driver's body are possible, namely increased drowsiness, irritability, fatigue, etc. All this can cause an accident. This paper shows a methodology for the experimental study of the microclimate of the workplace of the driver of the Electron A185 city bus in the warm season.

Analyzing the transport fleets of Ukrainian cities, in particular the city of Lviv, we can conclude that a significant number of buses do not have air conditioning (Fig. 1).

Figure 1. Buses of the city of Lviv, which are not equipped with air conditioning

These buses (Fig. 1) are widely operated on the streets of Lviv and cities of Ukraine. In connection with the lack of refrigeration units in such vehicles, in hot weather, significant

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overheating is possible in the middle of the cabin. Accordingly, passengers and the driver will feel discomfort.

Analysis of the available investigations. To date, the issue of research in the field of microclimate in vehicles does not stand still, both in the scientific and in the industrial world. Many scientists from all over the world are working on the issue of improving comfortable transportation conditions, so we will consider their work further.

In [1, 2], the methodology for analyzing the thermal balance of a bus and its calculation based on the coefficient of thermal conductivity of the body common to all city buses is given. In [3, 4], the methodology of experimental studies of the interior microclimate of the MAZ – 206 bus with further analysis of fuel efficiency is given. In [5], the method of studying the interior of a city bus using CFD modeling is given.

To date, many scientists from all over the world are engaged in this topic of research. Next, we will consider some of their works in more detail.

In [6–8], Turkish scientists study temperature regimes in bus cabins, taking into account the peculiarities of Turkey's climate. In their works, the concept of exergy and methods of analyzing the operation of the air conditioner in the cabin of an intercity bus are widely used. [9] shows the method of researching the microclimate of the vehicle and the analysis of possible parameters for improving its condition.

The study of the microclimate of an electric bus (taking into account its features) using computer analysis is shown in [10]. The method is based on the CFD analysis of the water level and temperature in the cabin of an electric bus in a steady state without taking passengers into account.

The Objective of the work is experimental studies of microclimate parameters of the driver's cabin of a city bus. Among the parameters that should be investigated are air temperature, humidity, air volume and level of CO_2 pollution.

Statement of the task. To investigate temperature indicators at the workplace of the driver of the Electron A185 bus. Analyze the measured parameters and determine the level of harmful substances.

Bus selection and experimental methodology. Having conducted an overview of buses operating on the roads of Europe, it can be stated that the most [11] running model is a bus with an engine located in the rear overhang. Some models of such buses, which are manufactured and are popular in the countries of Eastern Europe, are shown in fig. 2.

Figure 2. Low-floor type city buses

The Ukrainian-made Electron A185 bus (Fig. 3), which can be found on masse on the routes of the city of Lviv, was chosen for research in this work. Some technical characteristics of the bus are given in the table. 1.

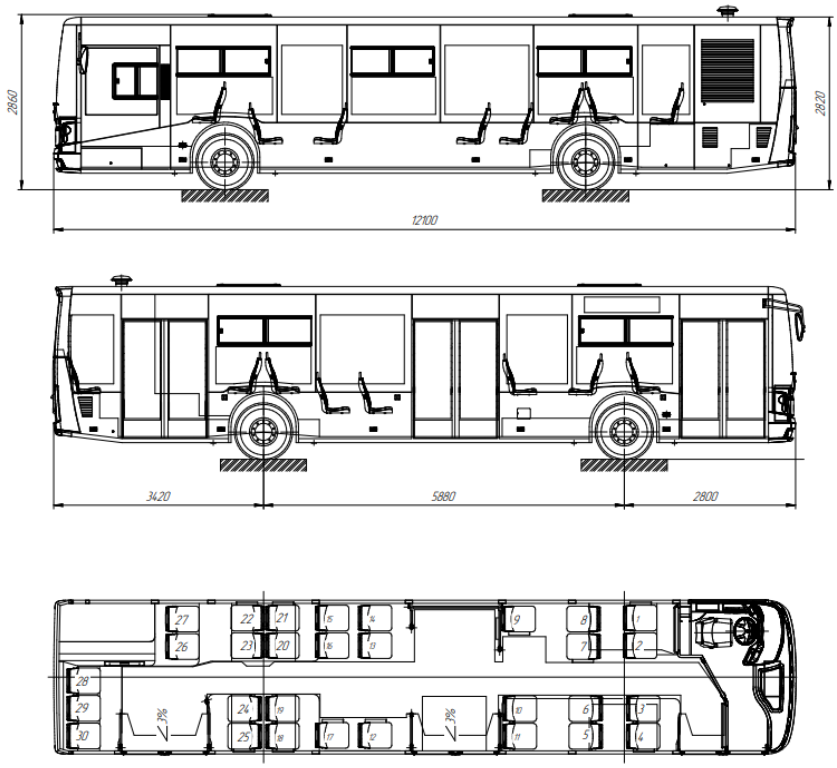

Figure 3. General view of the bus Electron A18501

Table 1

Main parameters and sizes of the bus Electron A18501

№	Characteristic	Unit	Value
1	Passenger capacity: - number of seats - total passenger capacity, based on 8 pas. per 1 m^2	 - -	 30 102
2	The empty weight of the bus in the equipped condition	kg	11 160
3	Technically permissible maximum mass of the bus		18 100
4	Technically permissible maximum masses falling on: - front axle - rear axle		 6 600 11 500
5	Overall dimensions: - length (over the body) - width (by body dimensions) - height - wheel base	mm	 12 100 2 550 2 990 5 880

The bus has a load-bearing body of a wagon layout, the main load-bearing element of which is a rigid frame, on which all nodes and aggregates are attached. The frame of the bus is made of high-strength steel with a full anti-corrosion coating. The bus is equipped with a Cummins diesel engine with a volume of 6.7 liters with a capacity of 205 kW, the engine complies with the Euro-5 standard and a ZF EcoLife automatic transmission. Suspension of front wheels – independent pneumatic, rear – dependent, pneumatic [12].

Having analyzed the route system of the city of Lviv, we can come to the conclusion that this type of bus is used quite a lot on long routes (Table 2, Fig. 4), which connect large sleeping areas and satellite small towns with the city center and key transport hubs of the city. In this regard, buses on such routes may be overloaded, especially at peak times. Accordingly, the state of the microclimate in the bus cabin will deteriorate due to a significant number of passengers.

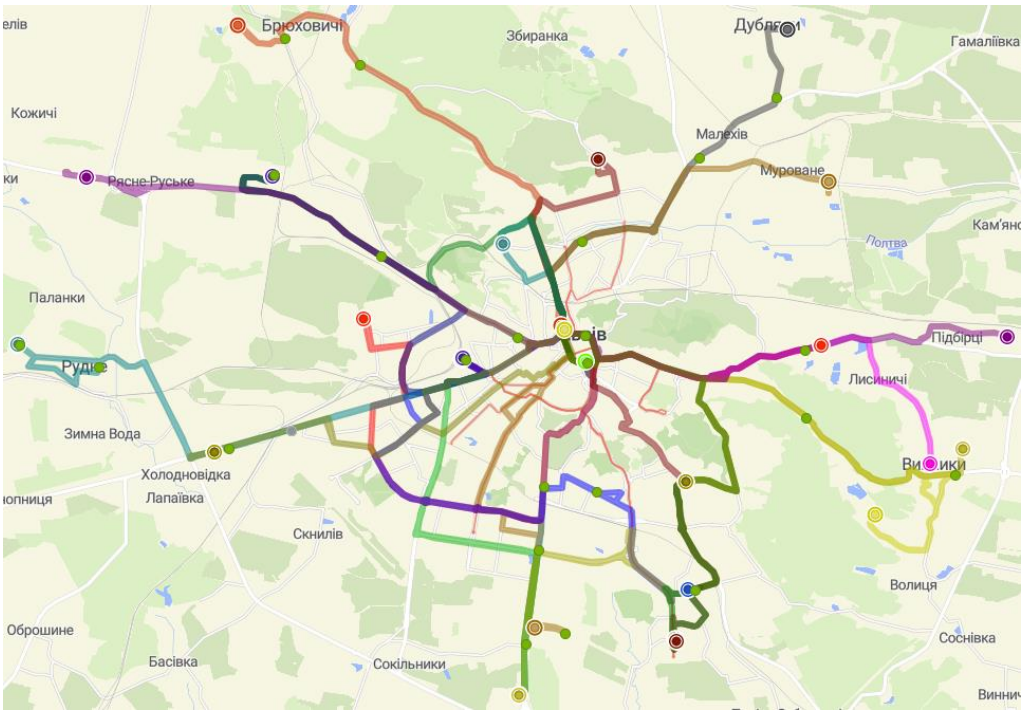

Figure 4. Map of the routes operated by Electron A18501 buses as of December 2023

Table 2

List of routes on which Electron A18501 buses run

№	Tracking route	The length of the route in one direction, km
1A	City center – Dublyany	11.5
3A	City center – KingCross	10
6A	City center – Ryasne 2	10
8A	City center – Bryukhovychi	12
9	Bus station – City center – Murovane	18.5
10	Railway station – KingCross	12
16	Railway station – Sykhiv	15
18	Levandivka – City center – Hlynyany road	19
29	Railway station – City center – Lysynychi	14
40	KingCross – Sykhiv – Vynnyky	23
46	Sykhiv – City center – The main city hospital	16.5
47A	Sykhiv – City center – Ryasne 2	25
49A	Railway station – Ryasne 2	12
52	Psdholosko – City center – Rudno	18.5
61	Pidryasne – City center – Pidbirtsi	23
92	West bus station – City center – Washington st.	17

As we can see from Table 3, the length of the routes is quite long, so in the warm season, with a large crowd of people, thermal discomfort is possible, both in the bus compartment and in the driver's cabin. For a more detailed analysis, experimental studies should be conducted.

As can be seen in fig. 3 (plan of the bus) in the bus we are investigating, the driver's cabin is tightly separated from the passenger cabin. That is, it turns out to some extent that the bus interior has two compartments that are minimally interconnected from the point of view of thermodynamics, since cold or heat can enter the driver's cabin only through an opened small window in the driver's cabin door.

Microclimate indicators were measured during the warm season at an external temperature of +25–26^{0}C using natural ventilation. The bus was driven in urban conditions along the route Ryasne 1 (Electronmash Plant)-Levandivka-Sknyliv (Bus Park No. 1) in Lviv. This route is approximately 10–11 km long and takes approximately 30–40 minutes, so it can be considered equivalent to a real city bus route.

Fig. 4 shows us the location of measuring devices in the bus driver's cabin.

Figure 5. Location of measuring equipment in the driver's cabin of the bus

As we can see in fig. 5 temperature and humidity sensors are located at the following points [13, 14]: at the level of the driver's legs, waist and head, as well as at the point of cold air intake, i.e. near the driver's cabin, where air can blow during the bus movement (natural ventilation) (Fig. 6).

The air quantity sensor also measured the amount of air entering the driver's breathing zone. The CO_2 level sensor was used to determine the level of pollution in the bus driver's cabin while driving.

To determine the parameters of the microclimate in the bus cabin, a measuring unit was created based on the Arduino microcontroller. From the microcontroller, data is transferred to a PC with an operating system not lower than Windows 10. For temperature and humidity measurements, a DHT11 sensor was chosen, which is a humidity and temperature sensor that generates a calibrated digital output. It can be connected to microcontrollers such as Arduino or Raspberry Pi and get instant results. The DHT11 is a relatively inexpensive humidity and temperature sensor that, however, provides high reliability and long-term stability.

To determine the speed of movement of air masses, the DFRobot F1031V model was selected, which allows you to determine the speed of flow in a gas medium, more precisely in the flow channel, using the thermodynamic principle. This model has high accuracy and good repeatability of measurement results due to calibration together with the temperature sensor. The housing for both sensors is common. The F1031V airflow sensor provides a linear analog voltage output for easy interpretation of results. Such sensors are used in a number of fans, air purifiers, in the management of industrial processes and environmental protection.

Air quality analysis was performed by the CCS811, which is a digital gas sensor module that detects a wide range of total volatile organic compounds (TVOCs), including equivalent levels of carbon dioxide (eCO2) and eCO. This sensor is designed to monitor indoor air quality in devices such as watches and phones, but this sensor module is designed to be used as a regular I2C device.

Results and discussion. The results of experimental studies are presented in fig. 5. Designation of zones according to the indices: 1 – leg zone, 2 – waist zone, 3 – head zone, 4 – cold air intake zone.

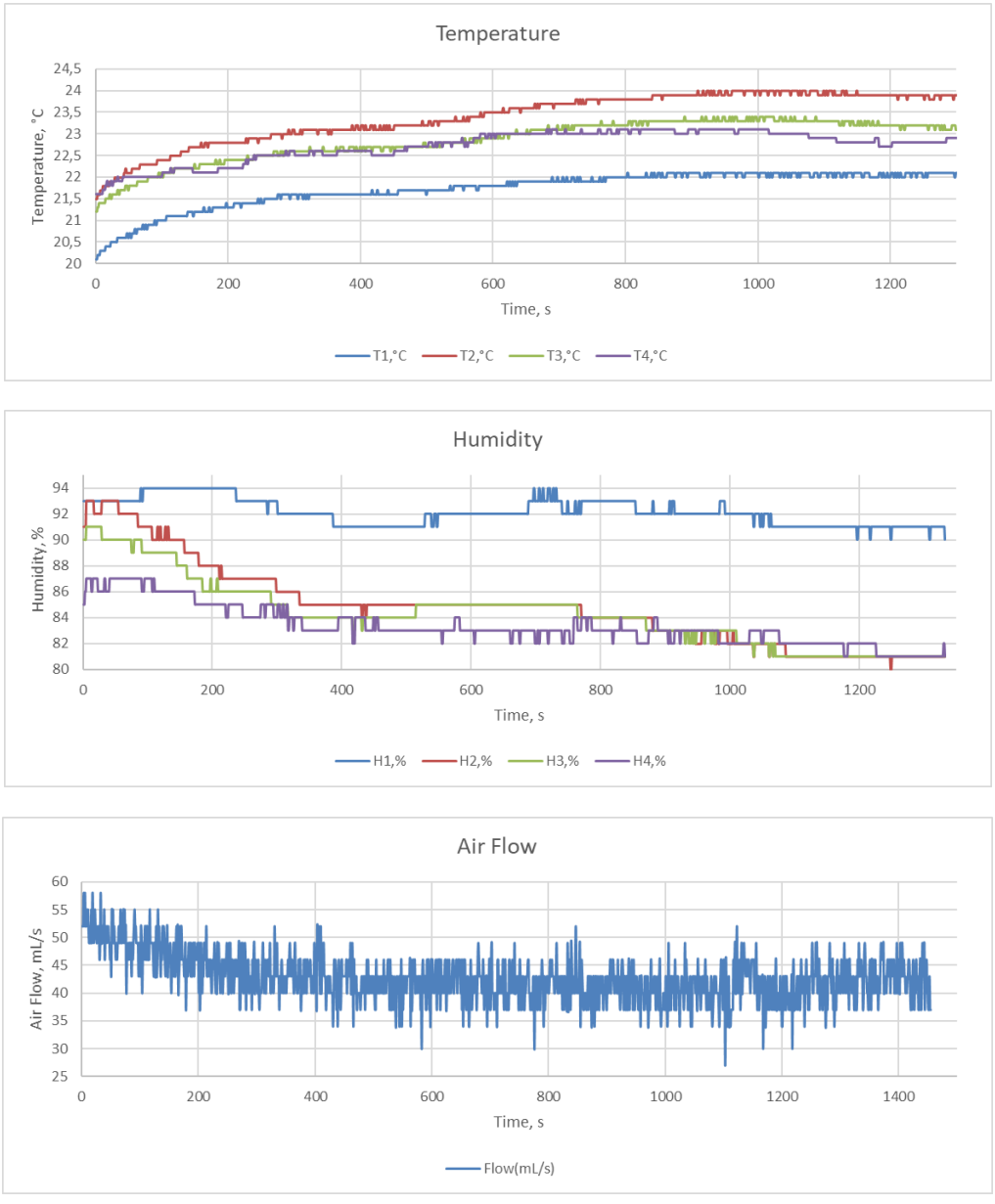

Figure 6. Results of the experiment

It can be seen that the temperature range in the driver's cabin corresponds to most of the norms [13, 14] (21–22^{0}C), only in the belt zone the temperature is slightly elevated (±23–23.5^{0}C), that is, it follows that the driver's cabin has enough good natural ventilation, because without the use of an air conditioner, given that the outside temperature was ±25^{0}C, the air temperature in the bus driver's cabin remains constant.

As for humidity, we can see that the values of air humidity at the measurement points exceed the normative values (80–90%) at an external air humidity of ±85%. Only in the area of the driver's feet is the humidity value overestimated at 92–94%.

According to the amount of air, we can see that it mostly remains constant within the range of approximately 40–55 ml/s.

We will estimate the CO_2 level according to [15, 16] (table 3).

Table 3

CO_2 concentration levels

Microclimate conditions	CO_2 concentration levels, ppm	
	Range	Value
Increased optimal	≤ 400	350
Optimal	**400-600**	**500**
Acceptable	600-1000	800
Limited admissible	≥ 1000	1200

The amount of CO_2 level per unit volume in air is 400 ppm. The measurement results showed that the CO_2 level at the driver's workplace is within the optimal norm.

Conclusions:

1. Ensuring comfortable transportation conditions is an important problem facing design engineers in the bus and coach industry today. One of the factors that creates comfortable transportation is to ensure that the temperature in the vehicle interior is only within a certain range.

2. Experimental studies have shown that the air temperature in the bus driver's cab is 21–23.5ºC, air humidity is 80–90%, air flow is 40–55 ml/s, and the level of air pollution is 400 ppm.

3. The results of the experiment can be used for further modeling of the movement of thermal masses in the vehicle interior, as well as for determining the capacity of refrigeration units for the buses under study.

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УДК 629.113

ДОСЛІДЖЕННЯ МІКРОКЛІМАТИЧНИХ ПОКАЗНИКІВ РОБОЧОГО МІСЦЯ ВОДІЯ АВТОБУСА В ТЕПЛУ ПОРУ РОКУ

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Резюме. *Мікроклімат салону автобуса є важливою складовою формування комфорту на робочому місці, адже при пасажирських перевезеннях є дуже важливо, щоб водій комфортно себе почував під час поїздки, за рахунок чого залежить безпека пасажирів. Показано розроблену автором методику експериментального дослідження кабіни водія міського автобуса Електрон А18501. Дослідження проводились у питанні мікроклімату та аналізу комфортності його параметрів. Проаналізовано рухомий склад автобусних парків міст України, зокрема Львова, наведено типові моделі автобусів, які експлуатуються на міських маршрутах, які не обладнані кондиціонерами. Значна частина автобусів виготовлена в Україні. Встановлено, що більшість рухомого складу в містах України не є укомплектована кондиціонерами. В літературному огляді наведено деякі роботи у галузі досліджень мікроклімату як в Україні, так і за кордоном. Проаналізувавши літературний огляд, можна побачити, що дана тематика активно розвивається у світі як в науковому, так і в промисловому світі. З певних джерел літератури та при візуальному спостереженні можна констатувати, що найбільш ходовою моделлю міського автобуса за кордоном і в нас є 12-метровий автобус з низьким рівнем підлоги. Серед автобусів, які експлуатуються у Львові, вибрано автобус українського виробництва Електрон А 18501. За допомогою спеціальної вимірювальної апаратури проведено виміри температури, вологості (в зонах ніг, поясу та голови водія, а також у зоні задуву холодного повітря) та кількості повітря, а також рівень CO_2 (в зоні дихання) на робочому місці водія автобуса. Результати вимірів порівняно з нормативними значеннями. Встановлено, що рівень забруднення повітря відповідає оптимальним значенням згідно з Д.Б.Н. Використовуючи результати проведеного експерименту, можна проводити подальші теоретичні дослідження, а також вони можуть слугувати базою для визначення потужності холодильних установок для досліджуваних автобусів подібного типу.*

Ключові слова: *міський автобус, температура повітря, вологість повітря, мікроклімат, кабіна водія, вентиляція.*

https://doi.org/10.33108/visnyk_tntu2024.02.011 *Отримано 02.01.2024*