DEVELOPMENT OF TECHNOLOGY AND A CONVERTER FOR NEUTRALIZING GREENHOUSE GASES EMITTED FROM AUTOMOBILES

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Abstract: *The article touches upon the issues of global warming associated with carbon dioxide (CO_2) emissions into the atmosphere from vehicle internal combustion engines (ICE). To neutralize existing greenhouse gases emitted by ICE, in particular CO_2, the interaction of the latter with various chemicals has been studied. The dynamics of exhaust gas emissions from ICE cylinders were observed. The experimental research was conducted to develop a greenhouse gas neutralization technology. Carbon dioxide neutralization converter with three neutralization batteries and a homogenization device is presented. This converter can guarantee CO_2 neutralization of up to 92%. The formation of CO_2 in the cylinders of modern petrol engines is due to the final combustion of the air-petrol fuel mixture. The combustion of the latter in the cylinder can be heterogeneous and diffusive. In addition, CO_2 is generated in large quantities during diffusion combustion. The most effective method of diffusive combustion was chosen by the constructors of modern ICE, which is the formation of an artificial turbulent gas-dynamic condition for the fuel mixture due to the increase in the temperature of the air adsorbed in the cylinder, which ensures the engine's thermal energy efficiency coefficient of up to 35%. The CO_2 volume in the exhaust gases of such engines reaches up to 16%. Thus, considering the perfection of modern ICE design for providing a high-efficiency reaction for the hydrocarbon oxidation in the fuel mixture in the combustion chamber, it becomes apparent that the presence of about 16% CO_2 in the fractional composition of emitted dissolved gases is a serious problem in terms of increasing the volume of greenhouse gases in the atmosphere. Therefore, the goal of this article is to develop a reduction technology.*

Keywords: *greenhouse gases, absorption, converter, molecular network effect, activator, zeolite, ion exchange, mass exchange, ecology, diffusion combustion.*

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Introduction

The problem of global warming is in the limelight of the member states of the United Nations. In December 2015, the leaders of around 190 countries of the Paris Framework Convention on Climate Change, organized by the United Nations, adopted an agreement aimed at reducing greenhouse gases (mainly CO_2) of anthropogenic origin, which are the primary reason for global warming. The same issue was discussed within the framework of the G-20 in Buenos Aires in December 2018 and in Glasgow in November 2021 [1,2,10,11,13]. Global warming is causing climate change, resulting in more frequent natural and climate disasters. The annual emissions of greenhouse gases into the atmosphere are about 15.0 billion tons. The total CO_2 volume emitted into the atmosphere is approximately 25%, or 6.7, of which 75% are greenhouse gases emitted by vehicles [3,4,7,8]. The volume of CO_2 in the exhaust gases emitted from automobile internal combustion engines (ICE) is 14 ÷ 16% [4].

Worldwide, over 1.1 billion automobiles are in operation, and this number grows annually, thus contributing to the growth in the volume of greenhouse gases released.

This means that CO_2 neutralization in the gases emitted from the ICE is an important environmental issue. For the mentioned problem solution, scientific research with the development of relevant technologies and devices is required, the use of which in automobile structures, more precisely in the exhaust gas emission system, will enable the neutralization of greenhouse gases, particularly carbon dioxide.

Therefore, research aimed at reducing CO_2 levels in the atmosphere and the development of new technologies are of vital ecological significance.

Literature review and problem statement

It is known that CO_2 emissions during different fuel combustions are particularly: 1.85 tons/thousand cubic meter of natural gas (methane), 3.15 ton/ton of diesel fuel, and 3.0 ton/ton of petrol. The neutralization of carbon dioxide is possible in several ways, mainly through absorption processes, where the CO_2 is absorbed by an absorbent, which then converts into other substances. There is another way for CO_2 to be neutralized, namely through platinum-palladium and aluminum-copper chloride catalysts. The high cost, the pair blocking phenomenon that occurs when several organic chemicals are absorbed, the poisoning of the catalyst with lead compounds, and the lack of heat resistance are the disadvantages of this method.

Another method for neutralizing greenhouse gases involves the exhaust gas passage emitted from ICE through anode sludge, which is formed through the electrolytic treatment of zinc-reducing solutions. The essence of this method is that the gases emitted from the ICE pass through the vortical device, acquire rotational motion, and contacting with the catalyst, where the greenhouse gases are released into the atmosphere. The following compounds represent the fractional composition of the catalyst: MnO_2 - more than 50%, PbO_2 - up to 15%, AgO_2 - up to 0.15%, and other mixtures.

Various neutralization reactions are possible, as with potassium hydroxide, calcium oxide, magnesium, etc. [4]. According to the fundamentals of classical chemistry [8], the main reaction for neutralizing CO_2 gas is the reaction with calcium hydroxide, which results in formation of calcium carbonate and water. But, the rate of this reaction is slow and does not provide the needed CO_2 neutralization productivity in the exhaust gases released from the ICE.

The choice of high-speed and high-performance CO_2 neutralization technology and the development of devices, the converter structural design, manufacturing, testing, correction, and installation in the removal system of exhaust gases emitted from ICE will make it possible to reduce the emissions from the automobiles into the atmosphere, particularly CO_2, which is the main requirement of the decision of the 2015 Paris Framework Convention.

The aim and objectives of the study

The aim of the study is to develop a technology that will enable to reduce the amount of CO_2 in the fractional composition of the exhaust gases emitted from the ICE, accepting the condition that the more improved the ICE structure, it's supply and fuel system, the design of the combustion chamber (volume and surface area ratio coefficient), and other factors, the greater is the volume of CO_2 formation. The opposite solution to the problem is to reduce the amount of CO_2 in the exhaust gases emitted from the ICE, which leads first to the engine's efficiency coefficient decreasing and an increase in fuel consumption, and secondly to an increase in carbon monoxide (CO), which is a toxic gas, and for its neutralization, petrol-engine automobiles are equipped with platinum-palladium catalysts. Therefore, the primary method of reducing the greenhouse gases included in the fractional composition of the exhaust gases emitted from the ICE before they are released into the atmosphere is the installation of a device (a unit) using neutralization technology in the pipeline for the removal of dissolved gases.

To achieve this aim, the following objectives are accomplished:

- to ensure high efficiency and productivity of CO_2 absorption and neutralization reactions by choosing the optimal fractional composition of the materials used and structural improvements to the converter.
- to ensure high productivity of neutralization reactions, availability of used materials, a simple preparation method.

Materials and Methods

Numerous tests of the neutralization absorbent's fractional composition in the converter have shown that CO_2 mass and ion exchange significantly change the temperature of the emitted gases, the number of crankshaft revolutions, and the absorbent.

In particular:

1. Absorbent based on the following chemical reaction:

$$Na_2CO_3 + H_2O + CO_2 \rightarrow 2NaHCO_3,$$

when the temperature of the absorbent is ÷ 80º ÷ 95ºC, the engine revolutions are:

$$Nmin = 1800\frac{rpm.}{min}, \quad Nmax = 4000\frac{rpm}{min}\ .$$

CO_2 absorption ranges from 62% to 37% depending on min and max rpm.

2. CO_2 absorption in the medium of Mg, CaO, $Ca(OH)_2$, KOH is formed through the following reactions:

$$\begin{aligned} &\text{a. } 2Mg + CO_2 \rightarrow 2MgO + C, \\ &\text{b. } CaO + CO_2 \rightarrow CaCO_3, \\ &\text{c. } \mathrm{Ca}(OH)_2 + CO_2 \rightarrow CaCO_3 \downarrow + H_2O, \\ &\text{d. } KOH + CO_2 \rightarrow KHCO_3. \end{aligned} \tag{1}$$

The temperature of the exhaust gases was 80º ÷ 95ºC during testing, and the engine rpm:

$$Nmin = 1800\frac{rpm}{min},\ Nmax = 4000\frac{rpm}{min}\ .$$

A homogenization device with three neutralizing batteries is installed in one container, composed of the gas neutralization converter (Fig.1). A homogenizing device is located at the converter input. Next is the first stage of the three-stage battery. The fractional composition of the first-stage battery is calcium hydroxide $Ca(OH)_2$ (93.5%) and sodium hydroxide NaOH (6.5%), which acts as an activator, i.e., accelerates ion exchange [4,8,14]. The exhaust gases pass from the first-stage battery to the second, where the fractional composition is primarily composed of natural clay powder (88%, SiO_2-47%, Al_2O_3-33%, H_2O-14%), Na_2O (8%), and KOH (4%). Finally, the third battery has the following fractional composition: SiO_2-25%, Al_2O3-1%, Fe_2O_3-4%, CaO-30% (powdered), volcanic slag grains with an average diameter of 5 mm, 40% [5,12,13,15].

The chemical reactions and material exchange in the first battery are based on the well-known reaction between calcium hydroxide and carbon dioxide, as given in (1). According to the developed method, the experiment resulted in a mass exchange in the first battery from 72 % to 80%, at a 4000 rpm to 1800 rpm interval.

In the second and third batteries of the converter, the process of CO_2 absorption of the exhaust gases continues. According to the experimental results, the neutralization process proceeds in the second battery according to the following interaction reactions:

$$Na_2O + CO_2 \rightarrow Na_2CO_3, \tag{2}$$

$$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O. \tag{3}$$

Powdered mineral clay containing $(AlSi_2)O_4$ is used as an absorbent for neutralization.

The final process of CO_2 gas neutralization occurs in the third battery of the converter, which is a mineral with high catalytic activity - zeolite.

Zeolite is characterized by the following main features [3,6]:

- catalytic - property of accelerating chemical reactions,
- ion exchange - ability for cation exchange,
- absorption - ability to absorb, and form other substances.

The mentioned features lead to the carbon dioxide neutralization in the exhaust gases emitted from the ICE. In addition, it has been proven [6,14] that (AlSi2) O4 present in the zeolite open cavity has a negative charge, which counteracts and compensates the counter-ions (ion exchange mechanism) [14].

The CO_2 absorption process is based on the molecular-network principle of interacting substances [14]. Granulated mineral zeolite separates CO_2 from other gases, making the absorption process more effective. The Republic of Armenia is rich in natural zeolite reserves (Noyemberyan region). It has the following fractional composition: SiO_2, TiO_2, Al_2O_3, Fe, O_3, M_2O, CaO, K_2O.

It should be noted that $(AlSi_2)\ O_4$ was also used in the third battery of the converter.

The fractional compositions of the absorbents in the converter three batteries were determined experimentally (around 150 experiments). The data were stored on the PC in the form of a graph.

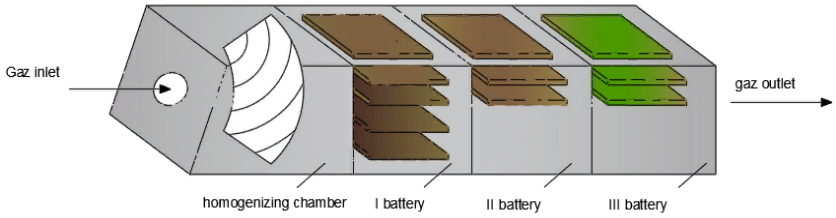


Fig. 1. *General structure of the converter*



Fig. 2. *General image of the converter*



Fig. 3. *Infrakar 1-M 1 gas analyzer*



Fig. 4. *Lifan-170B single-cylinder, four-stroke gasoline engine*

The diagram of the converter structure for the neutralization of greenhouse gases, especially CO_2, present in the exhaust gases from ICE is shown in Fig.1, and the general image is presented in Fig.2.

Having CO_2 neutralization technique and a converter for exhaust gases from the ICE, scientific and experimental studies were conducted.

The research was carried out with a special Infrakar 1-M 1 gas analyzer (Fig.3), which transmits the measured data in digital form and with a special program to the PC, which records the indicators to be measured every 2 seconds and draws the diagrams of the changes.

The tests were carried out with a four-stroke petrol single - cylinder air - cooled engine, Lifan-170 B, with a working volume of 245 cm^3 and 7 horsepower (Fig.4).

These diagrams are presented in the next section, in the discussion of results.

Results

The chemical compounds and minerals used in the converter are non-toxic

A method has been developed for conducting scientific research, which regulates the technical-technological data of scientific experiments, the duration of the experiments, the method for recording the results, the types according to the change of engine's rotation numbers *n*, the fractional composition of

absorbent materials in the three batteries of the converter, the temperature, humidity, and atmospheric pressure (altitude above sea level) in the environment, as well as the octane number of petrol used for engine operation (determined by the SX-100 k octameter).

The results of the scientific research were measured and recorded in diagrams. In the PC, they are given in Figs. 5, 6. The numerical data are shown in Table 1.

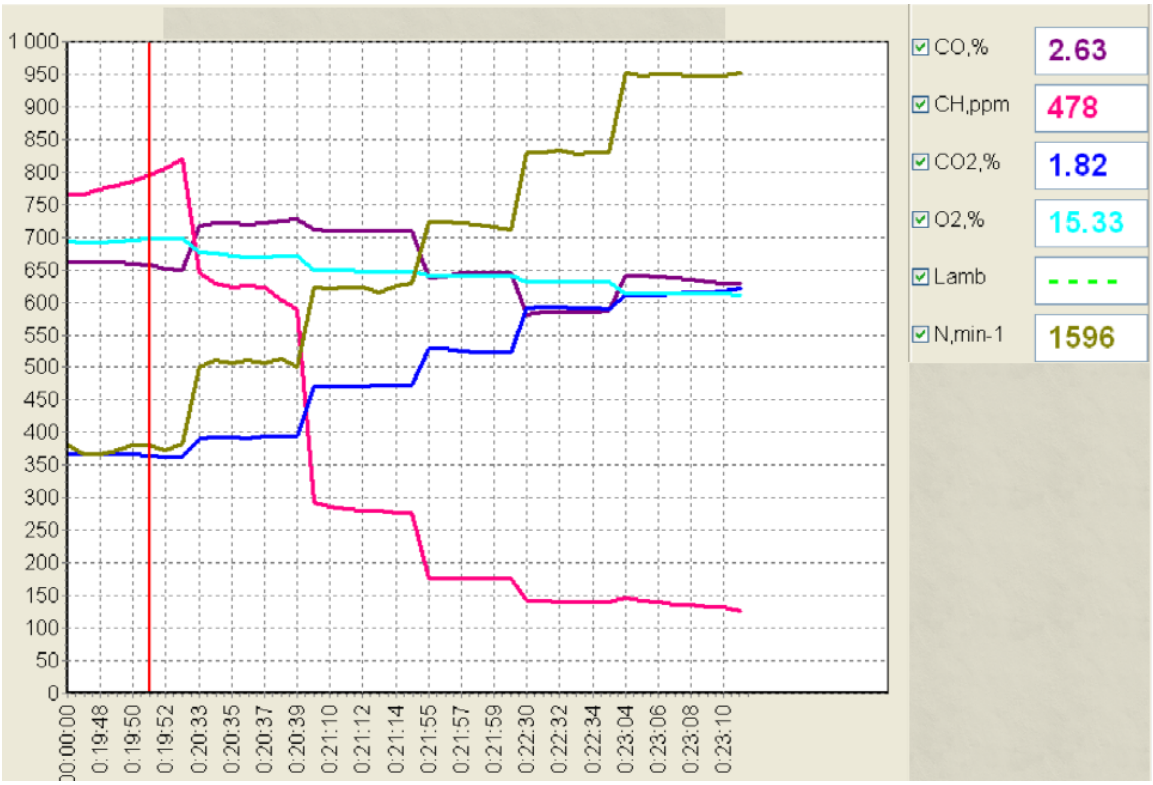


Fig. 5. *CO_2 emissions from ICE exhaust gases at different rotation numbers*

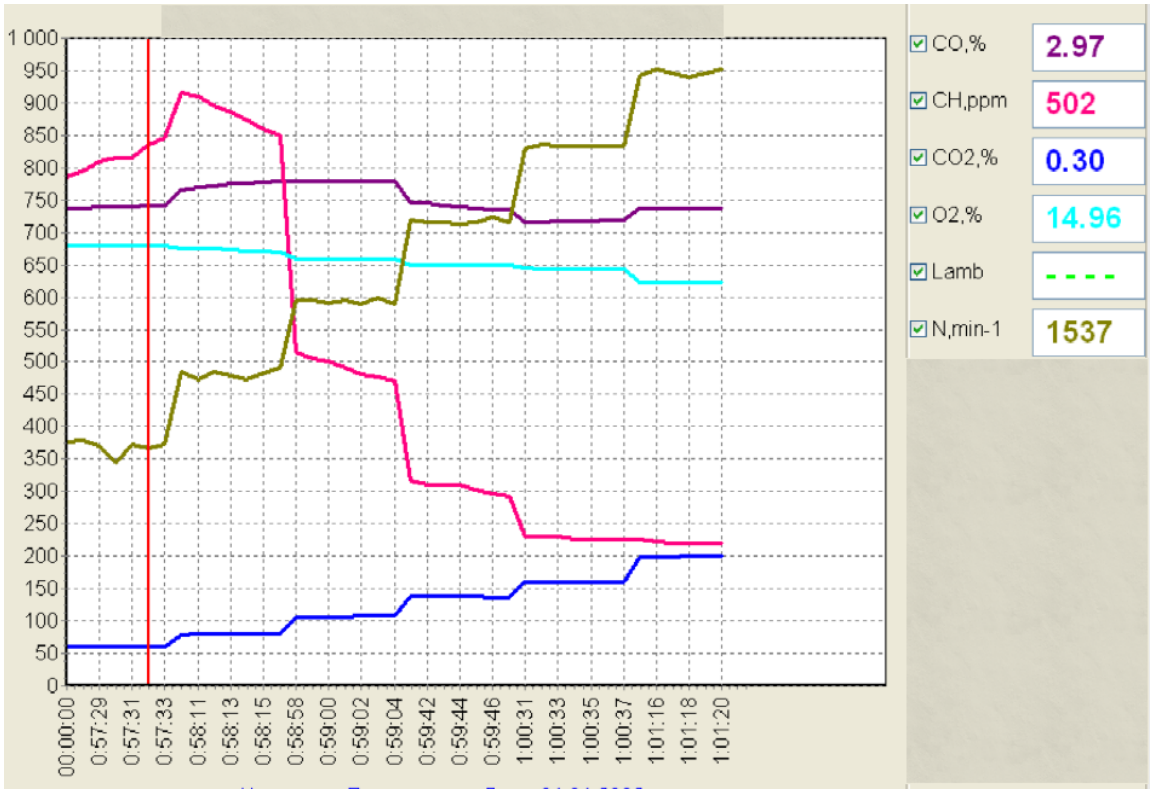


Fig. 6. *Carbon dioxide emissions after passing through the neutralization converter at different engine rotation numbers*

Table 1. Experimental study on carbon dioxide emissions

CO_2 emissions %	ICE rotation numbers, rpm						
	n	1596	2159	2587	3037	3498	3977
	CO_2	1.82	1.97	2.36	2.65	2.97	3.08
CO_2 emission % after neutralization	n	1537	1987	2499	3007	3499	3969
	CO_2	0.3	0.4	0.53	0.69	0.8	0.99
Difference (times)		6.01	4.9	4.45	3.84	3.71	3.11

The amount of CO_2 emitted from the ICE at the same engine rotation numbers was measured in the exhaust gases (Table 2). The exhaust gases were then directed and passed through a neutralizing converter. Based on the received digital data, diagrams were constructed, which are shown in Fig.7. The numerical data are given in Table 2.

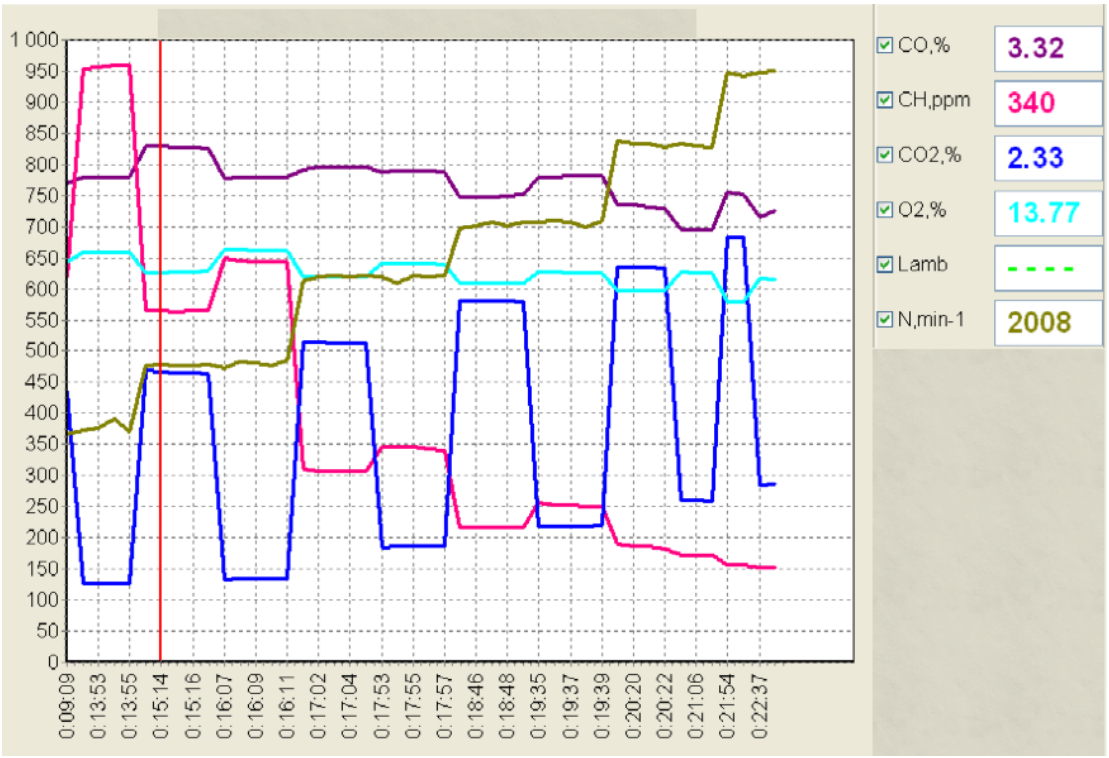


Fig. 7. *Carbon dioxide emissions at the same rotation numbers after passing through the neutralizing converter*

Table 2. Emissions of CO_2 and quantitative values of their neutralization during the same ICE rotation numbers

Measurement mode	ICE rotation numbers, rpm					
	1558	2087	2537	3028	3549	3956
CO_2 % without neutralization	2.01	2.14	2.45	2.69	2.87	3.12
CO_2 % through neutralization	0.96	1.12	1.37	1.56	1.78	1.86
Reduction (times)	2.09	1.91	1.79	1.72	1.161	1.67

The comparison of carbon dioxide numerical data shows that CO_2 neutralization is stable under increased engine rotary numbers, i.e., the process is technically proficient and effective, and has stable characteristics. It seems from the experimental data analysis, that the rate of CO_2 neutralization decreases with the increase in the ICE rotation numbers. The reason is the relatively small active surface of the neutralizing converter, i.e., the productivity of the neutralizer is insufficient for the gas volumes released from the ICE.

It means that, for the complete neutralization of the CO_2 emitted from the ICE, it is necessary to create an analytical relationship between the ICE working volume and the active surface of the converter.

Used materials

According to the findings, the main CO_2 absorption process is provided by the converter's first battery, which has a fractional composition of $Ca(OH)_2$ at 94.5% and NaOH at 6.5%. The second battery fractional composition is Na_2O (8%), KOH activators, and a filter in the form of natural clay powder. The third battery contains zeolite SiO_2 (24%) with Al_2O_3 (1%), Fe_2O_3 (4%), and CaO (30%) with a 40% mass of volcanic slag for absorbing dry materials from exhaust gases.

The absorption process mainly occurs in the first battery of the converter based on the molecular network effect, according to the following chemical reaction:

$$Ca(OH)_2 + CO_2 = CaCO_3\downarrow + H_2O.$$

The absorption process proceeds through the medium of activators in the converter's second and third batteries in accordance with the following chemical reactions:

$$CaO + CO_2 = CaCO_3\,,\ KOH + CO_2 = KHCO_3.$$

Zeolite, dry clay powder, and volcanic slag were used as absorbent mineral materials. The total cost of the used materials is 3-5$.

Discussion of CO_2 gas neutralization test results

Neutralization of CO_2 is because of the chemical reactions occurring in the converter, in which activators, volcanic slag and dry powdered clay are present.

The peculiarity of CO_2 neutralization among the existing methods is the absorption process, which occurs in the medium of mineral dry materials and is the only acceptable method for automobiles.

The study's limitation is the need to change periodically the converter’s absorbent batteries.

The disadvantage of the study is the need for three different batteries in the converter, which can be eliminated by combining them into one common mass.

The further development of the study is to develop high-efficiency and productivity absorbents, which requires long-term experimental studies.

Conclusion

1. With the proper structural modifications (adjustments), the developed technology and converter for the neutralization of greenhouse gases and CO2 emitted from the automobile exhaust system can be installed in the automobile pipeline for exhaust gas removal and provide CO2 reduction of up to 92%, according to the analysis of the conducted scientific results.
2. For calculating the CO2 neutralization converter capacity and productivity, it is necessary to solve a simple analytical problem regarding the dependence of the ratio of the engine's working volume and the active surface of the converter.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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