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# Establishment of Parameters of Electric Pulse Equipment Storage Device for Exhaust Gas Purification

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***Abstract.*** *The physics of the process of electric pulse purification of exhaust gas is outlined. The article analyzes the mode of operation of the electropulse equipment of the storage device, designed to clean the exhaust gases of the car. The scheme and a description of the laboratory bench operation are given. On the basis of the analysis of the experimental results the conditions of corona discharge occurrence at the experimental stand are established. The data confirming the best cleaning efficiency when corona discharge occurs in comparison with pulse and arc discharges are given. The dependences of the luminosity of the cleaned gas, on the pulse exposure time, pulse frequency and the distance between the electrodes are obtained. The results of calculating the cleaning efficiency for 1 minute of ionization exposure at different modes of operation of the equipment are given.*

***Keywords:*** *electric pulse, corona discharge, frequency, electrode, voltage, cleaning, exhaust gas.*

**Introduction**

Car engines significantly pollute the air, especially in cities. The reduction of this damage is carried out in the following directions: the operation of electric cars and cars with hybrid engines, as well as with the help of catalysts of various actions built into the car's muffler [1, 2, 3].

Despite the relevance of the above solutions, they have a number of drawbacks: in the coming decades, replacing all cars with electric cars is not possible; catalysts are very expensive and have a short (no more than 100 thousand/km) service life [4, 5, 6]. The following methods of cleaning exhaust gases are used: dry, wet, electric, catalytic and ultrasonic methods [7].

The authors developed and investigated silencers with ultrasonic cleaning method. Tests have shown that this method is effective, but the main disadvantage is the short life of the ultrasonic generator [8, 9]. We carried out preliminary tests of electric pulse system of car exhaust gases cleaning, mounted in the muffler [10].

There are corona, pulse and arc discharges. Spark and arc discharges occur in a homogeneous or inhomogeneous electric field. Corona discharges occur only in an inhomogeneous electric field, with the necessary shape of electrodes and the distance between them [11, 12].

The physics of the corona discharge process is well understood. Charge development begins with the application of a high voltage to the charge electrode and the formation of electrons by shock ionization. Subsequently, avalanche or chain ionization occurs. The essence of which is that a free electron, which has a higher binding energy, when it collides with an atom, knocks one electron out of it and a single-charged positive ion is formed. After the collisions, the electrons will gain energy, and the next collisions will produce four electrons. Then eight, then sixteen and so on. The electrons will move to the anode and the positive ions to the cathode [13].

Our experiments have shown that during spark discharge the cleaning efficiency is less than during corona discharge. In this regard, it is necessary to determine the parameters for the corona discharge occurrence: the distance between the electrodes; the frequency and the duty cycle of the charge.

The aim of the study was to establish relationships between the parameters of the electric pulse equipment, such as charge frequency and duty cycle, inter-electrode distance and gas purification efficiency.

The following tasks are solved:

- the stand was designed and made;

- the criterion of gas purification efficiency is substantiated;

- dependences and experimental data on the value of the distance between the electrodes at which the corona discharge occurs have been determined.

Research hypothesis: depending on the frequency, charge power and distance between the electrodes, there is an optimal mode of gas purification.

The scientific novelty of the study lies in the establishment of dependences between the degree of transparency of the purified gas, the pulse frequency and pulse well and the distance between the electrodes.

**Materials and methods**

An active force, determined by the electric field strength, and the frictional resistance force act on the particle between the electrodes. The value of the electromotive force F is determined by the expression:

$$F = Eq, \tag{1}$$

where $E$ – is the tension;

$q$ – the value of the charge.

When particles move, there is a force of frictional resistance (Stokes Force) equal to:

$$F_c = 6\pi\mu r\vartheta, \tag{2}$$

where $r$ – is the radius of the particle;

$\mu$ – dynamic viscosity;

$\vartheta$ – the velocity of the particle.

Assuming that the corona discharge process is similar to the discharge between the plates, accept the dependence of the voltage and the distance between the electrodes:

$$E = \frac{U}{l}, \tag{3}$$

where $U$ – is the applied voltage;

$l$ – electrode spacing

Equating (1) and (2) and considering (3) we obtain:

$$Eq = 6\pi\mu r\vartheta, \tag{4}$$

$$\frac{U}{\Delta}q = 6\pi\mu r\vartheta, \tag{5}$$

$$l = \frac{Uq}{6\pi\mu r\vartheta}. \tag{6}$$

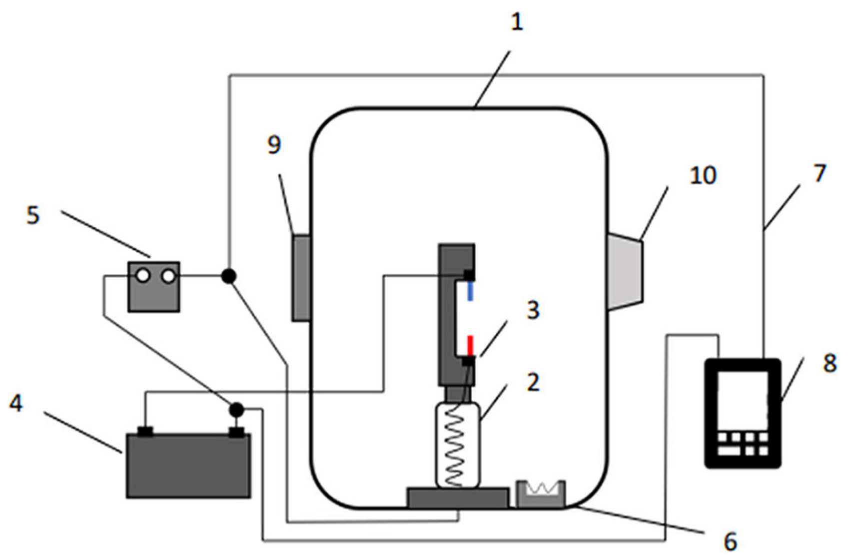
The physical meaning of the obtained dependence is that the distance between the electrodes Δ increases with increasing electromotive force and decreases with increasing Stokes friction force.

As the value $l$ corona discharge is replaced by spark discharge and cleaning efficiency decreases. In this connection it is necessary to have experimental values Δ for the existence of corona discharge. The greater the degree of purification of the gas, the greater its transparency. Experimentally the transparency is determined through its relationship with the illuminance. To carry out experiments on smoke purification by means of electric discharge, a stand was created, the scheme of which is shown in Figure 1.

The plan for the experiment is shown in Table 1.

**Results.** The results of the experiments are presented in Table 2.

**Discussion.** The light transmission capacity of a medium depends on the fine light-absorbing particles contained in it in suspension and is characterized by the transparency coefficient. Transparency coefficient of the medium inside the tank is determined by the formula:




1 – tank for smoke accumulation; 2 – high-voltage ignition coil; 3 – spark plug; 4 – battery; 5 – frequency and duty cycle controller; 6 – smoke source; 7 – connecting wires; 8 – oscilloscope; 9 – luxmeter; 10 – light source

Figure 1 – Schematic diagram of the storage device for electric pulse purification of exhaust gas

| Table 1 – Order of the experiment | |
|---|---|
| **Stage** | **Operations** |
| The first stage (determination of absolute illuminance) | 1. Add a drop of oil to the nichrome coil |
| | 2. Place the coil inside the container |
| | 3. Heat the coil for 15 seconds |
| | 4. Perform illuminance measurement without turning on the electric pulse |
| | 5. Release the smoke from the container |
| The second stage (at $l_1$ = 0,012 m) | 6.Set the distance between the electrodes $l_1$ = 0.012 м |
| | 7. Add a drop of oil to the nichrome coil |
| | 8. Place the coil inside the container |
| | 9. Heat the coil for 15 seconds |
| | 10. Apply voltage to the electrodes |
| | 11. Fix the change of illumination for 60 seconds |
| | 12. Release the smoke from the container |
| Stage Three (at $l_2$ = 0,015 m) | 13.Set the distance between the electrodes $l_2$ = 0.015 м |
| | 14. Add a drop of oil to the nichrome coil |
| | 15. Place the coil inside the container |
| | 16. Heating the coil for 15 seconds |
| | 17. Apply voltage to the electrodes |
| | 18. Fix the change of illumination for 60 seconds |
| | 19. Release the smoke from the container |
| Stage Four (at $l_3$ = 0,018 m) | 20.Set the distance between the electrodes $l_3$ = 0.018 м |
| | 21. Add a drop of oil to the nichrome coil |
| | 22. Place the coil inside the container |
| | 23. Heating the coil for 15 seconds |
| | 24. Apply voltage to the electrodes |
| | 25. Fix the change of illumination for 60 seconds |
| | 26. Release the smoke from the container |
| Stage Five (at $l_4$ = 0,021 m) | 27.Set the distance between the electrodes $\Delta l_4$ = 0.021 м |
| | 28. Add a drop of oil to the nichrome coil |
| | 29. Place the coil inside the container |
| | 30. Heat the coil for 15 seconds |
| | 31. Apply voltage to the electrodes |
| | 32. Fix the change of illumination for 60 seconds |
| | 33. Release the smoke from the container |
| Stage Six (at $l_5$ = 0,024 m) | 34.Set the distance between the electrodes $l_5$ = 0.024 м |
| | 35. Add a drop of oil to the nichrome coil |
| | 36. Place the coil inside the container |
| | 37. Heating the coil for 15 seconds |
| | 38. Apply voltage to the electrodes |
| | 39. Fix the change of illumination for 60 seconds |
| | 40. Release the smoke from the container |

$$\alpha = \frac{E_i}{E_B}, \quad (7)$$

where $E_i$ – illuminance at the $i$-th moment, lx;

$E_в$ – the luminosity of the empty tank, lx.

The results of calculation of the change in the transparency coefficient $\alpha$ as a function of time $t$ at different values of the interelectrode distance $l$ for the pulse frequencies 16, 21 and 22 Hz are presented in Table 3.

The intensity of the process of suspended particles deposition in the gas volume under the action of ionizing radiation characterizes the rate of change in the transparency coefficient, and is determined by the formula:

$$k_\alpha = \frac{a_i - a_i}{\Delta t}. \quad (8)$$

The results of calculating the rate of change in the transparency coefficient $k_\alpha$ are presented in Table 4.

Plots of the dependence of the rate of change of the transparency coefficient $k_\alpha$ with time are presented in Figure 2.

The cleaning efficiency, determined by the degree of purification from suspended particles by ionization action, we define by the following ratio:

$$Э = \frac{\beta_0 - \beta i}{\beta_0} \cdot 100\% = \left(1 - \frac{\beta_i}{\beta_0}\right) \cdot 100\%, \quad (9)$$

where $\beta$ is the light absorption coefficient, characterizing the concentration of suspended particles in the gas, determined by the formula:

$$\beta = 1 - a. \quad (10)$$

The results of calculating the efficiency of cleaning $E$ for 1 minute of ionizing action are shown in Table 5.

**Conclusion:** The results of calculation of the rate of change of transparency coefficient $k_\alpha$ from time for all experiments show an insignificant growth of the rate of change of the coefficient $k_\alpha$ at increasing the distance between the electrodes $l$ from 0.012 m to 0.021 m. At increase of $l$ up to 0.024 m sharp inten-

**Table 2 – Results of experimental studies**

| Distance between electrodes l, m | | 0.12 | | | 0.15 | | | 0.18 | | | 0.21 | | | 0.24 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frequency of the electrical pulse | | $v_1$=16 Hz | $v_2$=21 Hz | $v_3$=22 Hz | $v_1$=16 Hz | $v_2$=21 Hz | $v_3$=22 Hz | $v_1$=16 Hz | $v_2$=21 Hz | $v_3$=22 Hz | $v_1$=16 Hz | $v_2$=21 Hz | $v_3$=22 Hz | $v_1$=16 Hz | $v_2$=21 Hz | $v_3$=22 Hz |
| Illuminance of the empty vessel – Eв, lk | | 23600 | 23260 | 23730 | 23570 | 24160 | 23446 | 24510 | 23285 | 23670 | 23832 | 22370 | 22235 | 22730 | 20977 | 20840 |
| Capacity illuminance Ei, lx at time t | $t_0$=0 c | 482 | 557 | 626 | 626 | 535 | 443 | 862 | 493 | 432 | 475 | 407 | 424 | 506 | 449 | 624 |
| | $t_1$=15 c | 711 | 706 | 749 | 852 | 670 | 639 | 1269 | 694 | 618 | 736 | 681 | 636 | 954 | 923 | 1394 |
| | $t_2$=30 c | 797 | 785 | 841 | 988 | 755 | 732 | 1483 | 819 | 737 | 984 | 879 | 862 | 1986 | 2015 | 2669 |
| | $t_3$=45 c | 890 | 870 | 944 | 1150 | 870 | 824 | 1689 | 940 | 894 | 1387 | 1118 | 1202 | 4624 | 4098 | 5067 |
| | $t_4$=60 c | 976 | 983 | 1058 | 1410 | 985 | 931 | 1981 | 1114 | 1121 | 1831 | 1286 | 1630 | 7387 | 6705 | 8078 |

**Table 3 – Change of transparency coefficient over time**

| Distance between electrodes l, m | Frequency of the electrical pulse v, Hz | Transparency coefficient – $\alpha \cdot 10^{-2}$ | | | | |
|---|---|---|---|---|---|---|
| Time interval | | $t_0$ = 0 c | $t_1$ = 15 c | $t_2$ = 30 c | $t_3$ = 45 c | $t_4$ = 60 c |
| 0.012 | 16 | 2.042 | 3.013 | 3.377 | 3.771 | 4.136 |
| 0.012 | 21 | 2.395 | 3.035 | 3.375 | 3.74 | 4.226 |
| 0.012 | 22 | 2.638 | 3.156 | 3.544 | 3.978 | 4.458 |
| 0.015 | 16 | 2.656 | 3.615 | 4.192 | 4.879 | 5.982 |
| 0.015 | 21 | 2.214 | 2.773 | 3.125 | 3.601 | 4.077 |
| 0.015 | 22 | 1.889 | 2.725 | 3.122 | 3.514 | 3.971 |
| 0.018 | 16 | 3.517 | 5.177 | 6.051 | 6.891 | 8.082 |
| 0.018 | 21 | 2.117 | 2.98 | 3.517 | 4.037 | 4.784 |
| 0.018 | 22 | 1.825 | 2.611 | 3.114 | 3.777 | 4.736 |
| 0.021 | 16 | 1.993 | 3.088 | 4.129 | 5.82 | 7.683 |
| 0.021 | 21 | 1.819 | 3.044 | 3.929 | 4.998 | 5.749 |
| 0.021 | 22 | 1.907 | 2.86 | 3.877 | 5.406 | 7.331 |
| 0.024 | 16 | 2.226 | 4.197 | 8.737 | 20.343 | 32.499 |
| 0.024 | 21 | 2.14 | 4.4 | 9.606 | 19.536 | 31.964 |
| 0.024 | 22 | 2.994 | 6.689 | 12.807 | 24.314 | 38.762 |

**Table 4 – Results of calculating the rate of change of the transparency coefficient $k_\alpha$**

| Distance between electrodes l, m | Frequency of the electrical pulse ν, Hz | The rate of change of the transparency coefficient – $k_\alpha \cdot 10^{-3}$ | | | |
|---|---|---|---|---|---|
| Time interval | | $t_1 = 15$ c | $t_2 = 30$ c | $t_3 = 45$ c | $t_4 = 60$ c |
| 0.012 | 16 | 0.6468927 | 0.2429379 | 0.2627119 | 0.2429379 |
| 0.012 | 21 | 0.4270565 | 0.2264259 | 0.2436228 | 0.3238750 |
| 0.012 | 22 | 0.3455542 | 0.2584633 | 0.2893665 | 0.3202697 |
| 0.015 | 16 | 0.6392307 | 0.3846698 | 0.4582096 | 0.7353981 |
| 0.015 | 21 | 0.3725166 | 0.2345475 | 0.3173289 | 0.3173289 |
| 0.015 | 22 | 0.5573090 | 0.2644374 | 0.2615940 | 0.3042452 |
| 0.018 | 16 | 1.1070311 | 0.5820753 | 0.5603155 | 0.7942336 |
| 0.018 | 21 | 0.5754778 | 0.3578842 | 0.3464319 | 0.4981748 |
| 0.018 | 22 | 0.5238699 | 0.3351641 | 0.4421912 | 0.6393466 |
| 0.021 | 16 | 0.7301108 | 0.6937451 | 1.1273358 | 1.2420275 |
| 0.021 | 21 | 0.8165698 | 0.5900760 | 0.7122634 | 0.5006705 |
| 0.021 | 22 | 0.6356345 | 0.6776104 | 1.0194138 | 1.2832621 |
| 0.024 | 16 | 1.3139757 | 3.0268368 | 7.7372049 | 8.1038275 |
| 0.024 | 21 | 1.5064118 | 3.4704677 | 6.6199488 | 8.2852648 |
| 0.024 | 22 | 2.4632118 | 4.0786948 | 7.6711452 | 9.6321177 |

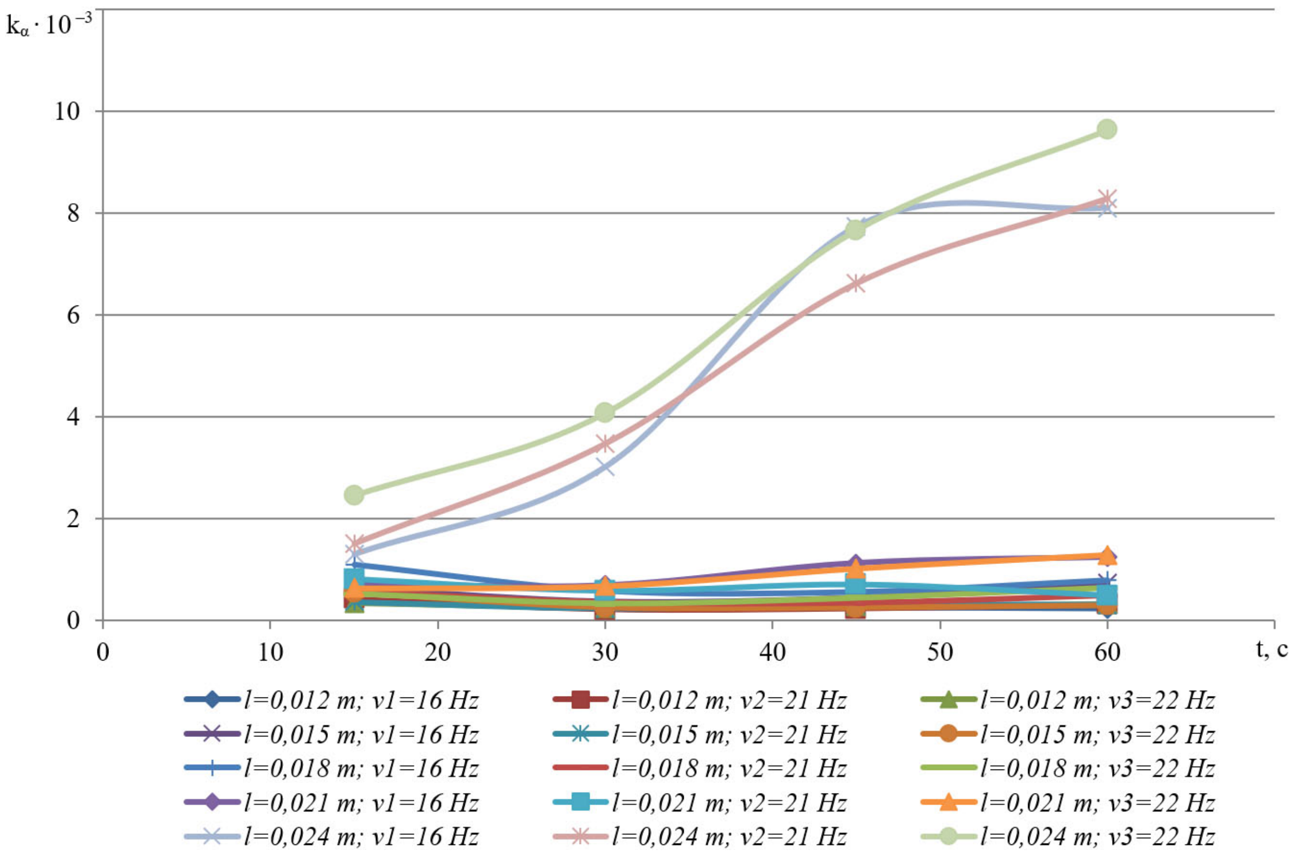



**Figure 2 – Plots of the rate of change in the transparency coefficient $k_\alpha$ with time**

sification of cleaning process is observed at all frequencies of electric impulse, characterized by speed of change of transparency $\alpha$, that is explained by occurrence of corona discharge at $l = 0.024$ m.

At the spark discharge the greatest degree of purification is observed at low experimental frequencies

| Table 5 – Efficiency of electric pulse gas purification E for 1 minute | | |
|---|---|---|
| **Distance between electrodes l, m** | **Frequency of the electrical pulse ν, Hz** | **Efficiency of gas purification, %** |
| 0.012 | 16 | 2.14 |
| 0.012 | 21 | 1.88 |
| 0.012 | 22 | 1.87 |
| 0.015 | 16 | 3.42 |
| 0.015 | 21 | 1.90 |
| 0.015 | 22 | 2.12 |
| 0.018 | 16 | 4.73 |
| 0.018 | 21 | 2.72 |
| 0.018 | 22 | 2.96 |
| 0.021 | 16 | 5.81 |
| 0.021 | 21 | 4.00 |
| 0.021 | 22 | 5.53 |
| 0.024 | 16 | 30.96 |
| 0.024 | 21 | 30.48 |
| 0.024 | 22 | 36.87 |

of the electric pulse, whereas at the corona discharge at $l = 0.024$ m the greatest degree of purification is achieved at the maximum experimental frequency of 22 Hz.

The obtained dependences are necessary to establish the optimal modes of operation of the electric pulse equipment of the designed exhaust gas purification systems.

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***Пайдаланылған газды тазартудың жинақтаушы құрылғысының электр импульсті жабдығының параметрлерін белгілеу***

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***Аңдатпа.*** *Пайдаланылған газды электрлік импульсті тазарту процесінің физикасы көрсетілген. Мақала автомобильдің пайдаланылған газдарын тазартуға арналған сақтау құрылғысының электр импульсті жабдықтарының жұмыс режимін талдауға арналған. Зертханалық стенд жұмысының сызбасы мен сипаттамасы берілген. Эксперименттердің нәтижелерін талдау негізінде эксперименттік стендте тәж разрядының пайда болу шарттары белгіленді. Импульстік және доғалық разрядпен салыстырғанда тәждік разряд пайда болған кезде тазалаудың ең жақсы тиімділігін растайтын деректер берілген. Тазартылған газдың жарыққа, импульстің әсер ету уақытына, импульстің жиілігіне және электродтар арасындағы қашықтыққа тәуелділігі алынды. Жабдықтың әр түрлі жұмыс режимдерінде иондану әсерінің 1 минутында тазарту тиімділігін есептеу нәтижелері келтірілген.*

***Кілт сөздер:*** *электрлік импульс, тәж разряды, жиілік, электрод, кернеу, тазарту, пайдаланылған газ.*

***Установление параметров электроимпульсного оборудования накопительного устройства очистки отработавшего газа***

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***Аннотация.*** *Изложена физика процесса электроимпульсной очистки отработавшего газа. Статья посвящена анализу режима работы электроимпульсного оборудования накопительного устройства, предназначенного для очистки выхлопных газов автомобиля. Даётся схема и описание работы лабораторного стенда. На основе анализа результатов экспериментов установлены условия возникновения коронного разряда на экспериментальном стенде. Приведены данные, подтверждающие наилучшую эффективность очистки при возникновении коронного разряда по сравнению с импульсным и дуговым. Получены зависимости освещенности очищаемого газа, от времени воздействия импульса, частоты импульса и расстояния между электродами. Приведены результаты расчета эффективности очистки за 1 минуту ионизационного воздействия при различных режимах работы оборудования.*

***Ключевые слова:*** *электроимпульс, коронный разряд, частота, электрод, напряжение, очистка, отработавший газ.*

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