Development of installation for study of electrostatic fields

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Abstract. The safe installation for studying the model electrostatic fields in the model areas of the cyclone is developed. It is found that the induction neutralizer reduces the concentration of ethyl alcohol (ethanol) in the examined object. The distance between the charged region in the cyclone and the neutralizer is the correction value of the height of the corona needles that is characterized by the magnitude of the ignition energy of the medium in the cyclone. The research results can be used in the development of cyclone apparatus for explosive industries, as well as measures to reduce technological emissions into the environment.

1. Introduction

Generation of electrostatic potential at the physical interaction in a heterogeneous system consisting of substances with a high specific volumetric electric resistance (ρ) is not only a technological problem, but also a safety issue for these processes. The interaction effect depends on the following factors: friction, pressure, temperature, humidity of the medium, the type of interacting objects and the more noticeable the larger the contact surface of the phases. The authors [1, 2] have found that the electrization intensity increases if $\rho \geq 10^6$ ohm·m. These statements also can be applied to fine-dispersed air-dust flows, often containing a vapor phase of organic substances. In these cases, the manifestations of static electrization create a danger of ignition of the environment, because the magnitude of the static electricity discharge energy exceeds its minimum ignition energy [3, 4].

The methods of protection against dangerous manifestations of static electricity are described in the Russian standard GOST 12.4.124-83 “Occupational safety standards system. Means of the protection against static electricity . General technical requirements”. The implementation of these methods is based on two basic principles: preventing the accumulation of electrostatic charges and preventing its dangerous manifestations.

The known and the most used methods of controlling static electricity manifestations are the grounding of technological equipment and the use of electrostatic neutralizers [5], installed both inside and outside the technological equipment.

The aim of this work was the development of an installation for modeling and studying spark manifestations of electrostatic fields in model areas of the cyclone.

2. Experimental

Assuming that the material flow, moving through the cyclone, will undergo the impulse action of the electrostatic field, which appears in the form of a corona discharge on the needles located inside the apparatus, we proposed to model the electrostatic field in the form of electric pulses. On this basis, an installation was developed to study the technological parameters of the electrostatic neutralizer. The structural scheme of the installation is shown in figure 1.

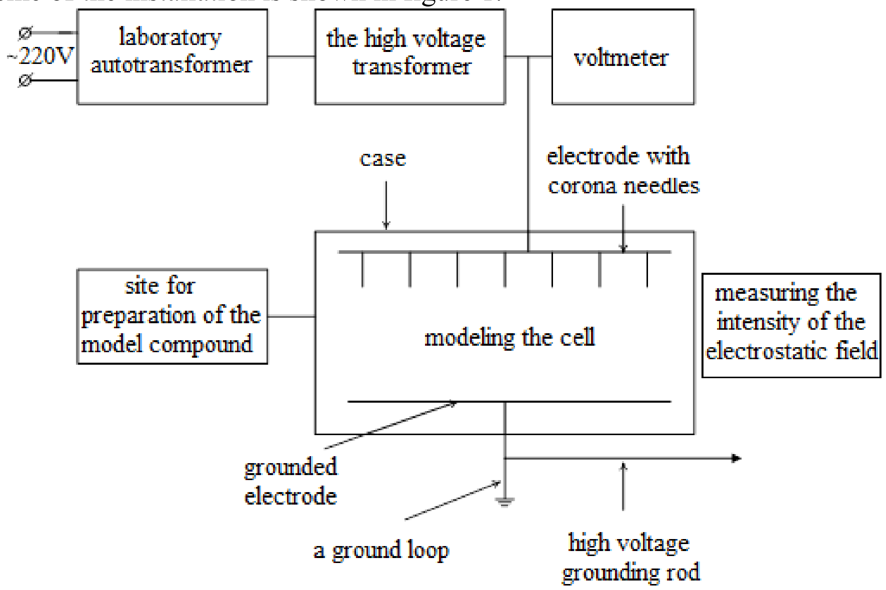

Figure 1. The scheme of installation on research of technological parameters of electrostatic neutralizer.

The installation works as follows. The voltage 220 V is supplied to the laboratory autotransformer of E-378. On the secondary winding, the voltage is regulated in the range from 0 to 250 V, which is then fed to the switching block that generates the required pulse frequency. The generated pulses are fed to the high-voltage transformer FA 4720000. The output voltage on the secondary winding of the step-up transformer is measured with a voltmeter of the type C-96 (0-20 kV). The measured voltage corresponds to the potential on the electrode. The location of the neutralizer needles in the simulating cell is performed according to the calculation procedure for the neutralizer of static electricity for cyclone devices [5]. Due to the difference in potential between the electrodes with the corona needles and the grounded electrode, a pulsating electric field appears. The measurer of the electrostatic field intensity of IESP-7 measures its value. The unit of preparation of the model mixture consists of a ventilator, heater and dispenser of the test substance.

According to the methodology of the research, a pulsed electric field was created with a frequency from 1 to 90 pulses per second and the voltage up to 20 kV. The processing time of the sample in the field lasted up to 30 seconds, and then the voltage was removed. After checking for voltage absence, a gas-vapor sample was taken for analysis. After this, a pulsed electric field was applied to the cell, the gas-vapor volume was processed, and then the sample was taken for analysis again. During the period of the experiment there was never a spark discharge. The obtained samples were analyzed on the gas chromatograph Hewlett-Packard 5898 in the laboratory "Sib test".

3. Results and discussion

The results of the analysis of gas-vapor samples for the content of ethanol vapor, carried out with the help of the chromatograph, are shown in figure 2.

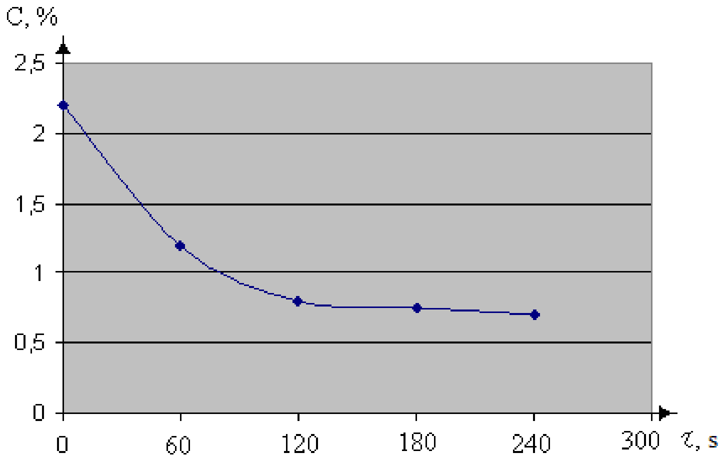

Figure 2. The dependence of the content of ethanol vapor in the system on the sample processing time.

The analysis of the experimental results showed that the electric field generated by the neutralizer reduces the concentration of pollutant vapors in the model mixture to 30%. This leads to a reduction in environmental pollution and fire hazards of the cyclone.

As a result of the study, the effect of a double electric layer was observed at the interface between two media: a heterogeneous flow and a grounded side, which is close to the flow of the needle component. This effect is equivalent to a plane capacitor, the total charge Q of which (in Кл) was determined from the expression:

$$Q = ee_0SU/l \tag{1}$$

where S is the area of phases contact, m^2; e is the dielectric constant of the medium enclosed between the phase interfaces (for air e = 1); e_0 – the dielectric constant equal to of $8.85{\cdot}10^{-12}$, F/m [6]; U – voltage at the electrode, V; l – the distance between the needles and the grounded electrode, m.

This expression adequately describes the essence of the process in the cyclone.

Based on the experimental and calculated data, the distance between the charged region in the cyclone and the neutralizer was plotted as a function of the electrostatic charge, which is shown in figure 3.

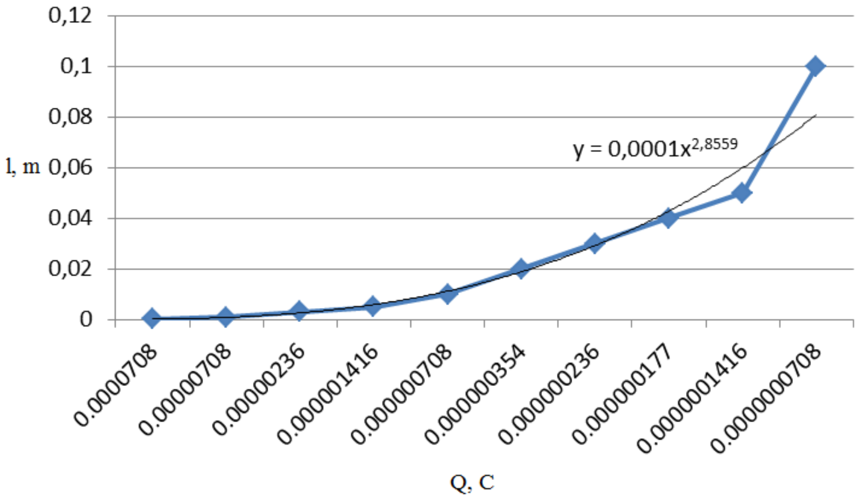

Figure 3. The dependence of the distance between a charged region in the cyclone and the neutralizer on the electrostatic charge.

According to the graph in figure 3, it is possible to determine the distance between the charged region in the cyclone and the neutralizer, based on the value of ignition energy of the medium being circulated in the cyclone. This value is the correcting value of the height of the neutralizer needles.

The analysis of the results obtained and monitoring of the production process showed that the presented installation does not allow modeling the changes in the parameters of the electric discharge, which was observed in the existing technological processes. At the working installation, electric discharges were spark-shaped at voltages of 15-25 kV and were observed in the first half a turn at the entrance to the cyclone as it is shown in figure 4.

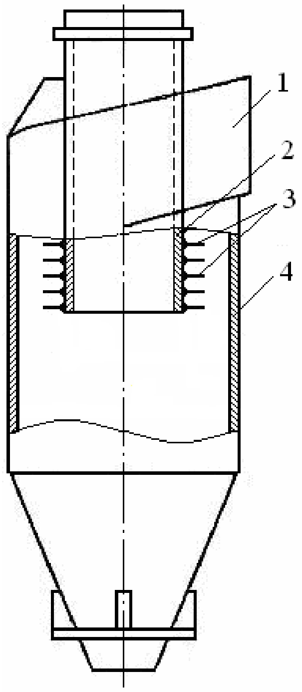

Figure 4. The scheme of the neutralizer of static electricity installed in the cyclone: 1 – inlet pipe; 2 – outlet pipe; 3 – corona needles; 4 – body of the cyclone.

It is found that the electric discharge should act in times up to 300 μs because the initial state of plasma formation in air corresponds to $\tau = 0.26$ s. It can occur through several channels, be invisible to optical detectors, but it is effective for activating chemical processes. The need to regulate and control the frequency of the pulsed electric field was also shown.

4. Conclusions

In this study the installation for modeling and studying electrostatic fields in model areas of the cyclone was developed. It is proposed to determine the distance between the charged region in the cyclone and the neutralizer, based on the amount of ignition energy of the medium circulated in the cyclone, which is the correcting value of the height of the neutralizer needles.

The results of the research can be used in the development of cyclone devices for explosive industries, as well as measures to reduce technological emissions into the environment.

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