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OZONE GENERATOR BASED ON SURFACE DIELECTRIC BARRIER DISCHARGE WITH PULSE POWER SUPPLY

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A pilot model of an ozone generator with a pulsed power supply has been developed. The ozone generator can be used for disinfection of domestic and industrial premises, in medicine and the chemical industry. Ozone is generated by a surface dielectric barrier discharge reactor (SDBD), consisting of 18 parallel-connected quartz tubes, inside and outside of which spiral the stainless steel high-voltage electrodes are wound. The measurements of the main parameters of the ozone generator showed that the ozone concentration reached 57 mg/l, and the output ozone concentration is 9.4 g/h. The developed design takes into account the technical features of the implementation of a particular type of discharge used, allows reducing energy consumption for ozone generation, having improved output parameters.

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INTRODUCTION

Ozone is a powerful oxidizing and disinfecting agent, naturally destroying harmful microorganisms and compounds by oxidizing them. Oxidation occurs when ozone molecules come into contact with oxidizing substances, including microorganisms (viruses, molds and bacteria), organic and inorganic materials (iron and manganese). Ozone suppresses viruses, partially destroying their shell. The process of reproduction stops and the ability of viruses to connect with the cells of the body is disrupted. Under the influence of ozone on microorganisms, including yeast, their cell membrane is locally damaged, which leads to death or the inability to reproduce. It has been established that gaseous ozone kills almost all types of bacteria, viruses, molds and yeast-like fungi and protozoa. At concentrations of 1 to 5 mg/l for 4...20 min, it leads to the death of 99.9 % of staphylococci, streptococci, mucobacteria, Escherichia and Pseudomonas aeruginosa, Proteus, Klebsiella, Salmonella, dysentery pathogens and others [1].

Ozone is environmentally friendly and eliminates the risk of chemical residues. Ozone can replace chlorine, hot water and steam. In turn, this reduces the consumption of chemicals, saves water and energy for its heating. The versatility of ozone makes it a great alternative to traditional disinfection methods, saving you money while still delivering guaranteed results. The effectiveness of the use of ozone for the destruction of the virus on surfaces and air was confirmed by the international organization International Scientific Committee of Ozone Therapy (ISCO3) [2].

Ozone technologies and solutions are used in various areas of everyday life, the agricultural sector, trade, logistics and industry [3–8].

An ozonator is a device that generates ozone from the air. The ozonator generates ozone from ordinary air. The remaining ozone is again converted into oxygen after the process of ozonization. This is another benefit of ozonation. In the modern world, the environmental factor is becoming more and more decisive when choosing disinfectants, therefore, the absence of harm to the environment makes ozonators the most preferable for air and water disinfection. Today, ozonators are becoming more in demand due to COVID-19 pandemic.

In the Institute of Plasma Physics of the NSC KIPT, a series of ozonators have been developed that generates a surface dielectric barrier discharge to form ozone from passing air. They have a flexible system of settings and are autonomous and mobile sanitary devices for disinfection of enclosed spaces up to 500 m^3 [9]. In the present research, a pilot model of an ozone generator with pulse power supply has been developed.

1. EXPERIMENTAL SETUP

General view of the ozone generator is shown in Fig. 1. On the front panel of the device there is a network toggle switch, a timer that allows you to set the required operating time of the ozone generator, a grid for air inlet with its subsequent conversion into ozone.

Fig. 1. General view of the ozone generator

The block diagram of the ozone generator is shown in Fig. 2. The scheme consists of:

1. "Network" toggle switch, which turns on the ozone reactor purge fan and brings all the elements of the device into working condition.
2. Fuse.
3. A filter that filters out the high frequencies generated by the ozone reactor and prevents them from passing into the network.
4. A fan designed to cool all elements of the ozonator circuit.
5. AC-DC modular power supply with an output voltage of 12 V. The module is designed to power the cooling fan and the switching power supply circuit of the ozone reactor.
6. Pulsed ozone reactor source.
7. A timer that allows applying mains voltage to the reactor's switching power supply board. The timer has two modes of operation: constant switching on and switching on of the ozone reactor up to 30 min with a step of 2 min.
8. High-voltage transformer, which increases the pulse voltage coming from the PWM controller up to 6.5...7 kV.
9. A fan creating an air flow of 165 m^3/h. The fan is designed to purge the ozone reactor.
10. Ozone reactor. The ozone reactor is a module assembled from 18 quartz tubes, 15 cm long, with an outer diameter of 6 mm. Spiral-shaped windings are wound inside and outside the tubes with stainless steel wire, which are high-voltage electrodes. All electrodes of the 18 tubes are connected in parallel.
11. Plastic housing for ozone reactor.

The ozone reactor is housed in a plastic housing through which the purge passes. The switching power supply creates a surface dielectric barrier discharge (SDBD) on the surface and inside the tubes. SDBD is one of the most effective methods for obtaining near-surface plasma in various plasma technologies [10–15].

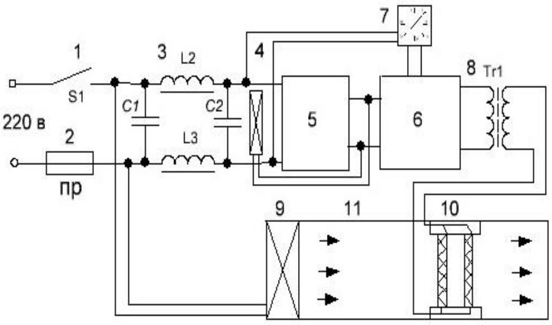

Fig. 2. Block diagram of the ozone generator

Air ignition of the reactor is structurally carried out both from the outside of the tubes and from the inside. Visual observation of the ozone reactor showed that the discharge plasma not only covers the spiral electrodes, but also fills the volume between the turns of the windings. With an increase in the voltage on the electrodes of the reactors, the number of micro-discharges increases and the color of the discharge glow changes, which causes an increase in the active power of the reactor, this characterizes the discharge in the reactor.

2. RESULTS AND DISCUSSION

A circuit of a switching power supply has been developed for a power the spiral windings of the reactor. The circuit was developed on the basis of the PWM controller TL494 (pulse-width modulation). For optimal operation of the ozone reactor, the PWM controller generates voltage pulses of a certain frequency and duration. Supplied to the input MOSFETs, the load of which is a high-voltage transformer that steps up the voltage to 6.5...7.0 kV, from the output of the transformer, the high-voltage voltage is supplied to the ozone reactor module.

The power consumption of the ozonator, ozone concentration, and air flow rate were measured. The ozone concentration was measured on an automated stand using an MDR-2 monochromator (LOMO) and PMT.

The ozone yield rate could also be calculated theoretically from equation (1)

$$y/A = V^2 f\varepsilon/d, \quad (1)$$

A – is ozone yield per unit area of electrode surface; V – voltage across the discharge gap; f – frequency of applied voltage; ε – dielectric constant; d – thickness of dielectric and air gas. The power dissipated during the ozone generation is calculated by Manley equation (2).

$$P = 4fC_d \times \frac{C_d}{C_g} + C_g \times V_{min}(\hat{V} - V_{min}), \quad (2)$$

where f is the applied frequency (Hz); C_d is the capacitance of dielectric (F); C_g is the capacitance of gas gap (F); $\hat{V}$ is the peak value of applied voltage (V), and V_{min} is the minimum external voltage to initialize discharge (V). Equations (3) and (4) show how the capacitances of gas gap (C_g) and dielectric layer (C_d) can be expressed for a cylindrical DBD

$$C_d = 2\pi S_d l/\ln(b/r_i), \quad (3)$$

$$C_g = 2\pi S_g l/\ln(r_0/b), \quad (4)$$

where *l* is the discharge length (cm) and ε_g and ε_d are the relative permittivity of background gas and dielectric, respectively. In DBD cylindrical tube r_i – inner radius, *b* air volume and r_0 – outer radius [14].

The parameters of the ozonator are given in Table.

Parameters of an ozone generator with pulse power

Consumed power, W	230
Ozone concentration, mg/l	57
Air flow rate, m^3/h	165
Ozone yield rate, g/h	9.4

CONCLUSIONS

An ozone generator with a pulse power supply has been developed. The ozone generator can be used for disinfection of domestic and industrial premises, in medicine and the chemical industry. The main element of the ozonator is a plasma reactor based on a surface dielectric barrier discharge. The measurements of the main parameters of the ozone generator showed that the ozone concentration comprises 57 mg/l, the generator ozone productivity is 9.4 g/h.

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ГЕНЕРАТОР ОЗОНУ НА ОСНОВІ ПОВЕРХНЕВОГО БАР’ЄРНОГО ДІЕЛЕКТРИЧНОГО РОЗРЯДУ З ІМПУЛЬСНИМ ДЖЕРЕЛОМ ЖИВЛЕННЯ

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Розроблено пілотну модель генератора озону з імпульсним живленням. Генератор озону можна використовувати для дезінфекції побутових і промислових приміщень, у медицині та хімічній промисловості. Озон генерується реактором поверхневого діелектричного бар'єрного розряду, що складається з 18 паралельно з'єднаних кварцових трубок, всередині і зовні яких розташовані спіральні обмотки з нержавіючої сталі, що служать високовольтними електродами. Вимірювання основних параметрів генератора озону показало, що концентрація озону досягла 57 мг/л, а вихідна концентрація озону становить 9,4 г/год. Розроблена конструкція враховує технічні особливості реалізації конкретного виду розряду, що використовується, дозволяє знизити енерговитрати на генерацію озону і покращити вихідні параметри.