SECTION 4 IRRADIATION INSTALLATIONS, DIAGNOSTIC AND RESEARCH METHODS

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DEVELOPMENT AND OPTIMIZATION OF OZONE DESTRUCTOR FOR LOW-TEMPERATURE PLASMA STERILIZER

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An ozone destructor for a plasma ozone sterilizer has been developed. This is an improved model of an ozone destructor, consisting of two parts, which significantly increases the contact area of activated carbon with ozone. This destructor design is suitable for ozone concentrations of 100…120 mg/l at an oxygen flow rate of 1 l/min. A study was conducted to determine the dependence of the temperature of carbon at the contact point with ozone depending on the amount of decomposed ozone at various oxygen flow rate. It was monitored that output ozone did not exceed the maximum permissible concentration in the working area proving the effectiveness of the developed ozone destructor.

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INTRODUCTION

Low-temperature plasma sterilization is a very promising technology for sterilization of medical instruments which couldn't withstand high-temperatures during processing [1–8]. The use of plasma sterilizers significantly reduces the time (up to 20…30 min) for sterilization of medical instruments. It is also important to avoid using high temperatures. Cold sterilization using the novel plasma technologies is promised to be a very safe and efficient method of sterilization and disinfection.

At present, there are few works describing the development and research of ozone destructors. It is known that the ozone destructor is designed to decompose ozone contained in the spent ozone-oxygen mixture to a level not exceeding the maximum permissible ozone concentration in the air of the working area. These devices are easy to assemble and do not consume electricity. The design features of the device and the substance used as a catalyst are selected depending on the type of ozone generating unit and its operating modes. At know, without ozone destructors, it is almost impossible to achieve reliability and safety in working zone where ozone is used. The main purpose of destructors is to destroy unreacted ozone before it enters the working area. The presence of ozone in the working area is monitored using ozone analyzers. Ozone, as a highly toxic agent, primarily affects the respiratory tract. Symptoms of ozone poisoning include headache, dizziness, burning eyes and throat, strong taste and smell, and cough. Symptoms of chronic intoxication can cause headache, weakness, and memory loss, etc. Even a small concentration of it can have a negative impact on human health. This determines the need to effectively neutralize residual ozone and to develop a new type of destructors.

Modern destructors operate according to the catalytic (for atmospheric ozonators) or thermocatalytic (for oxygen-powered ozonators) decomposition principle [9, 10]. Catalytic modifications of the ozone destructor are installed in conjunction with oxygen and atmospheric ozone generators. The catalyst function is performed by activated carbon, used in the pharmaceutical and food industries, specially processed using patented technologies developed for this purpose, pressed tablets or molded extrudates of GTP grade carbon [11]. The catalyst intensifies the process of converting ozone into oxygen. Catalytic destructors do not use additional energy sources, since the process of ozone, decomposition is accompanied by the release of heat, and the catalyst heats up on its own. Thermal ozone destructor is the optimal solution for installations with medium and high productivity. With its help, you can easily neutralize large volumes of residual ozone and release harmless oxygen into the atmosphere. In installations of this type, gas is heated to a temperature of 340…350 °C within a few seconds. Thermal catalytic ozone destructor involves the use of catalysts, the presence of which makes it possible to reduce the treatment temperature to 80…100 °C.

1. EXPERIMENTAL SETUP

The ozone destructor consists of two parts: a destructor with an increased area and a destructor with three sections (Fig. 1). This is due to the need to increase the contact time of ozonized air with activated carbon.

In previous destructor models with a small contact area between ozone and activated carbon, a large amount of heat was released and the coal ignited. Therefore, in this model of the destructor its area was increased. This destructor design is suitable for ozone concentrations of 100…120 mg/l at an oxygen flow rate of 1 l/min. Fig. 2 shows a schematic representation of an ozone destructor with an increased area.

Fig. 1. Ozone destructor inside the sterilizer

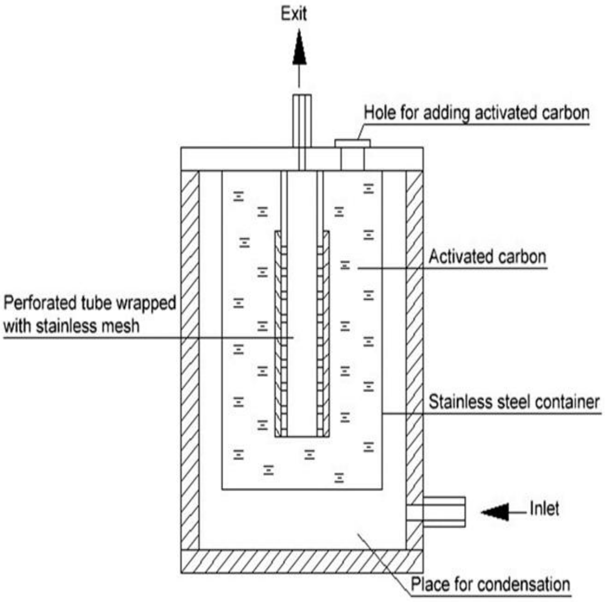

Fig. 2. Schematic representation of an ozone destructor with an increased area (first part)

The size of the first part of the ozone destructor is 100x150x250 mm. The grade of carbon used in the destructor is AGN-1 (3.35…1.7 mm). The ozone destructor is made of plexiglass (stainless steel can be used). In the lower part of the destructor there is room for condensate, since the water-air mixture is a humid environment, leading to an increase in the moisture content of the coal and, as a consequence, a decrease in its adsorption properties.

The second part of the ozone destructor, as well as the tubes, are made of plexiglass (Fig. 3). Tube length – 80 mm, diameter – 10 mm. The tubes are necessary to prevent the passage of ozonized air in the plane of the destructor design. In past models of ozone destructor, channels with spent carbon were formed and traces of ozone exceeding the maximum permissible concentration were observed at the destructor output. Therefore, this destructor model has three sections (to increase the contact time of ozonized air with carbon). The first section contains a mesh d ~ 70 mm, made of stainless steel with a cell size of 0.5×0.5 mm.

Such a mesh can be made of any non-flammable material, since when coal interacts with ozone, a large amount of heat is released, the coal becomes heated and subsequently this can lead to the melting of the material. In Fig. 4 shows a schematic representation of the destructor.

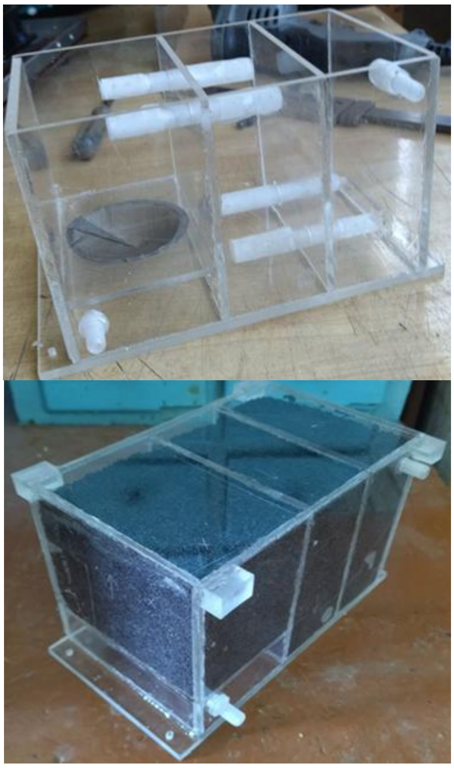

Fig. 3. Ozone destructor with and without activated carbon (second part)

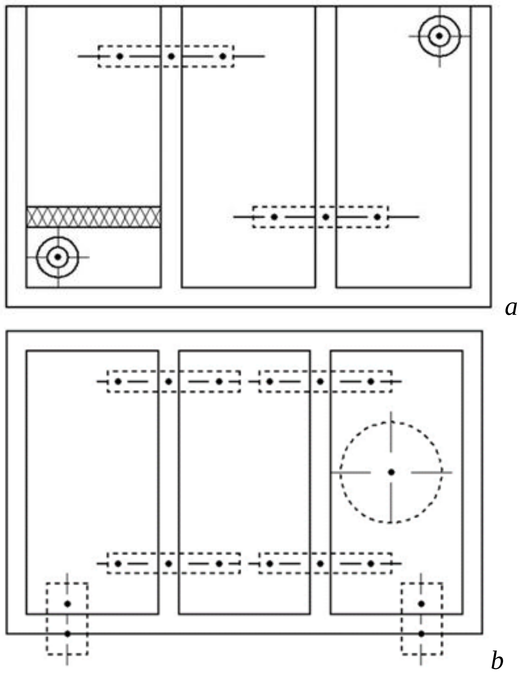

Fig. 4. Schematic representation of an ozone destructor (second part): a – side view; b – top view

2. RESULTS AND DISCUSSION

A number of experiments were conducted to study the effectiveness of the ozone destructor. Oxygen from the oxygen concentrator through the air flow meter was supplied to the ozone generator. The ozone generator operates on the principle of a dielectric barrier discharge at atmospheric pressure with high-frequency power. A dielectric barrier discharge was generated between two flat metal electrodes (180x100 mm) coated with glass enamel (0.2 mm thick). The ozone generator voltage is up to 12 kV, frequency is 16 kHz. The oxygen flow varied from 0 to 5 l/min, while the ozone concentration at the reactor outlet ranged from 30 to 120 mg/l. The output ozone concentration was measured with an M454 DIN (USA) ozone meter. The temperature of the stainless mesh in the destructor was recorded using a pyrometer. The grid area was calculated in such a way that its temperature did not exceed 80 °C. The experiments were carried out for 100 h. At the same time, the ozone analyzer located at the outlet of the destructor did not record an ozone concentration exceeding the maximum permissible concentration in the working space in any of the experiments performed. Fig. 5 shows a diagram of experiments on the effectiveness of an ozone destructor.

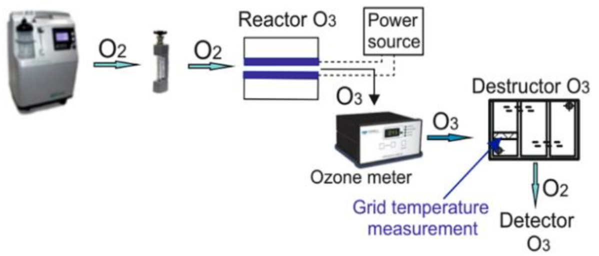

Fig. 5. Scheme of experiments

An experimental destructor was also used to measure the optimal parameters (Fig. 6).

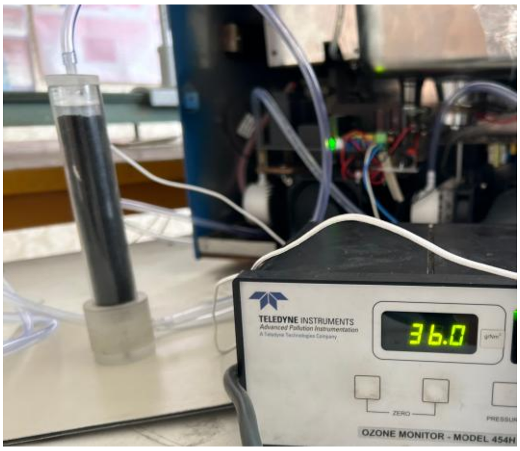

Fig. 6. Experimental destructor used for calculations

It should be noted that when ozone decomposes into oxygen, activated carbon heats up, especially at the point of direct contact of carbon with ozone. With a small contact area and a large amount of decomposed ozone, ignition of carbon or deformation of the destructor material is possible.

A study was conducted of the dependence of the temperature of carbon at the point of contact with ozone depending on the amount of decomposed ozone at various oxygen flow rate.

According to the graph in Fig. 7 and Table, one can select the optimal contact area between carbon and ozone, depending on the specific reactor. The graph shows that the higher the oxygen flow rate, the more ozone can be decomposed at the same temperature.

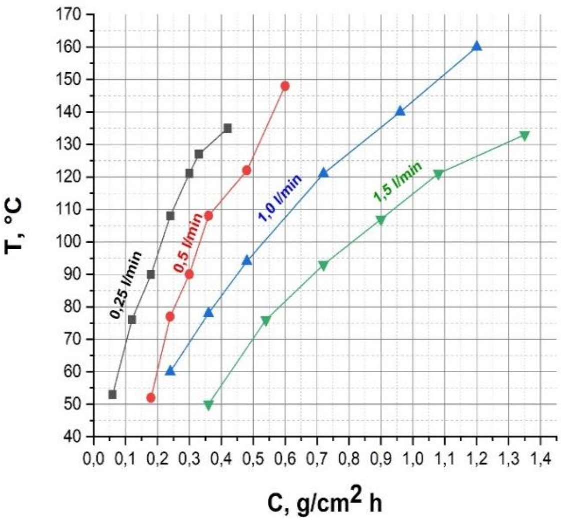

Fig. 7. Dependence of the temperature and oxygen flow rate, carbon mesh area on ozone decomposition

Dependence of temperature (T) in the contact zone of activated carbon with ozone depending on ozone concentration (C) and oxygen flow rate (Q)

Q=0.25 l/min		Q=0.5 l/min	
C, g/(cm^2·h)	T, °C	C, g/(cm^2·h)	T, °C
0.42	135	0.6	148
0.33	127	0.48	122
0.3	121	0.36	108
0.24	108	0.3	90
0.18	90	0.24	77
0.12	76	0.18	52
0.06	53		
Q=1.0 l/min		**Q=1.5 l/min**	
C, g/(cm^2·h)	**T, °C**	C, g/(cm^2·h)	T, °C
1.2	160	1.35	133
0.96	140	1.08	121
0.72	121	0.9	107
0.48	94	0.72	93
0.36	78	0.54	76
0.24	60	0.36	50

CONCLUSIONS

The research describes the development of an ozone destructor for its further use in a plasma ozone sterilizer. This is an improved model of an ozone destructor, consisting of two parts, which significantly increases the contact area of activated carbon with ozone. This destructor design is suitable for ozone concentrations of 100…120 mg/l at an oxygen flow rate of 1 l/min. Studies of the effectiveness of the ozone destructor have shown that during experiments an ozone concentration did not exceed the maximum permissible concentration in the working space.

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РОЗРОБКА І ОПТИМІЗАЦІЯ ДЕСТРУКТОРА ОЗОНУ ДЛЯ НИЗЬКОТЕМПЕРАТУРНОГО ПЛАЗМОВОГО СТЕРИЛІЗАТОРА

А.С. Лозіна, І.Є. Гаркуша, А.В. Таран, В.О. Махлай, Р.О. Павліченко, О.Г. Чечельницький, Ю.П. Гніденко, П.М. Воронцов

Розроблен деструктор озону для плазмового озонового стерилізатора. Ця вдосконалена модель деструктора озону складається із двох частин, що значно збільшує площу контакту активованого вугілля з озоном. Така конструкція деструктора підходить для концентрації озону 100…120 мг/л за швидкості протоку кисню від 1 л/хв. Було встановлено, що вихідний озон не перевищував гранично допустиму концентрацію у робочій зоні, це свідчить про ефективність розробленого деструктора озону.