https://doi.org/10.46813/2024-154-096

PORTABLE OZONE GENERATING DEVICE FOR TREATMENT OF INFECTED WOUNDS

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Ozone therapy for treating wounds is not commonly used in many regards and such a technology is still being developed even with extremely promising results. The most important key of wound treatment with ozone is its ability to eliminate bacterial growth and population. In this regard there is an urgent need for alternative options for antiseptic treatment of wounds at the stage of evacuation and pre-medical care for their further effective treatment. In this research, a portable ozone generating device for wound treatment has been developed and the main technical characteristics have been discussed.

PACS: 85.50.-n, 81.20.-n, 52.75.-d

INTRODUCTION

In the conditions of russian aggression, injuries among our defenders and, as a result, wound infections of the skin cause complications that worsen and reduce the effectiveness of traditional methods of treatment. Problems in wound care are increasingly caused by co-morbidities, as well as by the sharp increase in further resistance to antibiotics.

Currently, there is a limited choice of methods of treatment of infected skin wounds [1]. As a result, in the conditions of war, there is an urgent need for alternative options for antiseptic treatment of wounds at the stage of evacuation and pre-medical care for their further effective treatment, as well as for the development of modern, portable plasma devices based on dielectric barrier discharges.

Cold atmospheric plasma (CAP) wound treatment is an alternative treatment method for surface wounds that utilizes charged and reactive species produced by a high energy source, such as dielectric barrier discharge (DBD), to eradicate bacteria in the wound [1-4]. Due to technological innovations that enable more efficient production of CAP and its numerous beneficial properties, there has been great interest in developing portable plasma systems for wound care applications. Although several studies have shown the efficacy of many such systems in treating chronic and infected wounds, they often require complex and costly systems, which limits their accessibility to many patients and health care providers [1]. Additionally, the high energy of the plasma and the UV radiation produced in many such systems can cause degenerative changes in the cells and fibrous tissues around the site of treatment [5, 6]

Gaseous ozone-based treatment is the process of administering highly unstable gaseous ozone molecules to treat a wound or a disease. The fundamental process involves the generation and application of gaseous directly to the skin surface to promote wound healing, antibacterial effect, and immunoregulation [7, 8].

Additionally, because ozone has a long lifetime outside of the plasma region and can be delivered as a gas flow, it can increase the accessibility and application time significantly through simplified systems without the direct application of high-energy CAP plasma that can lead to toxic and harmful effects to the skin tissue.

In this research directly applying gaseous ozone to the wound surface using a portable system can provide a means to administer the promising ozone therapy while eliminating the complex storage requirements and higher efficacy. It is crucial to develop a simple and swift reliable technique for controlled and localized delivery of ozone gases into the healing region.

The key functionality of DBD-based ozone generation systems is their ability to be powered through simple and low-power electronics, which can aid their portability. Furthermore, many of such ozone-generating setups are highly effective in generating ozone at room temperature with ambient air, which is necessary to develop a portable device. The developed device is easy to use and can be powered either from 12 V, in the field, or from the mains in a hospital.

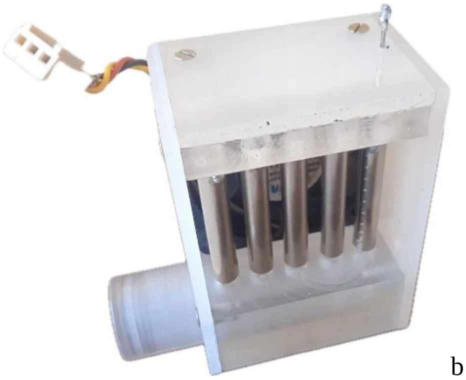
1. DESIGN OF THE OZONE REACTOR BLOCK

There are two main methods of ozone generation commonly used for constructing of ozone reactors. Reactor can be based on a barrier volume discharge or on a barrier surface discharge. Volume discharge requires a higher breakdown voltage, forced cooling and a pump to purge the reactor but it provides higher ozone concentrations. Barrier surface discharge is generated at lower potentials since there is no air gap and only a solid dielectric is necessary. There are many options to construct various reactors. The cooling flow simultaneously creates ozone output and air supply into the reactor zone. Thus, it dilutes the ozone concentration at the outlet and allows one to obtain high ozone productivity, but at a low concentration. All "barrier based" reactors can only operate on alternating current and pulsed current.

There is a method for producing ozone using high voltage direct current with a high-voltage glow discharge. It has its own characteristics and is less commonly used.

A surface discharge with a specific type of a reactor has been applied in the device. To ensure optimal discharge, forced cooling of the reactor is required. The reactor is made of 6 mm quartz tubes. On the outside there is a grounding electrode made of thin stainless-steel foil, and on the inside, there is a thin twisted stainless-steel spiral (Fig. 1).

a



b

Fig. 1. The reactor block of the portable ozonator with a cooler front view (a); back view (b)

The occurrence of a barrier streamer discharge is possible only when the critical breakdown field strength is reached, and the number of streamers is proportional to the derivative of the supply voltage (Fig. 2). This means that the higher the supply voltage and frequency, the higher the ozone productivity. The most advantageous mode is provided with pulsed power supply and high duty cycle. And the shorter the pulse, the higher the steepness of the voltage rise. This mode is also called the shock excitation mode, since the inductance of the transformer winding and the reactor capacitance constitute an oscillating circuit with a high-quality factor. And, at the same time, the capacitance is nonlinear.

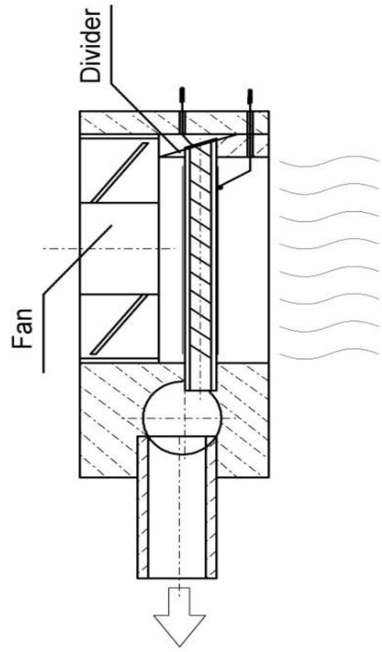


Fig. 2. The principal scheme of portable plasma generator

At the beginning of the discharge, the capacitance is small, but as the voltage increases, the surface area of the discharge increases, and the capacitance increases accordingly. In our version, we choose a duty cycle ranging from 100 to 50.

2. TRANSFORMER SYSTEM

To obtain the maximum natural resonant frequency of the reactor-transformer system, it is desirable to obtain the minimum inductance of the transformer. Since the transformer is high-voltage, and therefore multi-turn, this is the main compromise in its design. Traditional construction methods involve layer-by-layer winding with a closed magnetic wire. In our case a linear transformer design with a linear open core has been realized.

Fig. 3. The main view of the transformer

The winding construction is not layer-by-layer, but linear with return turns, which ensures both the minimum winding capacitance and a smooth increase in the potential gradient from the beginning and end of the winding. Such a design is the most reliable and protected from breakdowns (Fig. 3). It was tested for a critical mode up to 10 kV, which has a large margin of reliability. The actual operating voltage comprises 3.5 kV. The resonant frequency was obtained to be about 180 kHz.

3. MICROPROCESSOR CONTROLLING AND DEVICE OPERATION

To ensure reliable and stable operation of the device, a microprocessor was used to incorporate all the functions of controlling and stabilizing the ozone generator modes. The block diagram of the device is shown in Fig. 4.

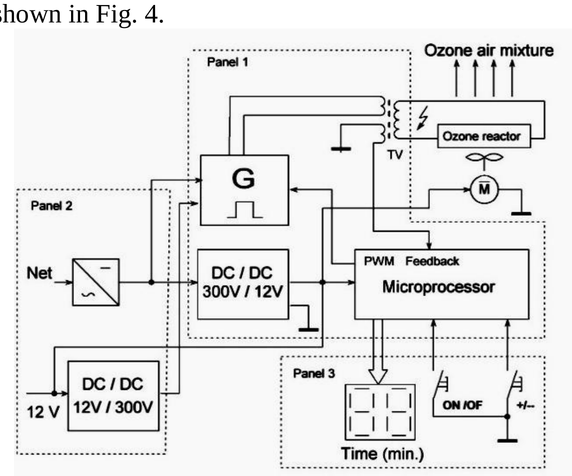


Fig.4. Block diagram of the device

Fig. 5. depicts the control signals used for programmatic microprocessor.

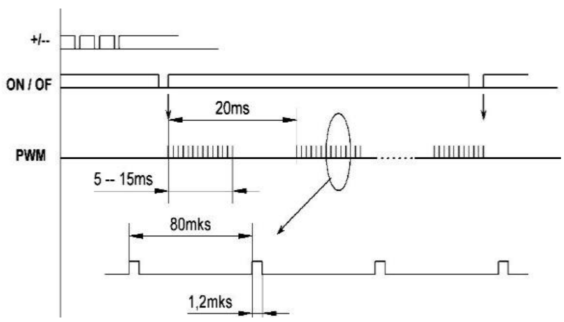


Fig. 5. The control signals of the microprocessor

In field conditions, the device is powered by a 12V battery. At the end of the tube there is a timer indicator and two control buttons. (+/-), this is a button for setting the work timer regime and (ON/OF) this is a start and force stop button. Then, by pressing the button (ON/OF), the process of generating ozone by the reactor immediately starts. Generation occurs according to a complex algorithm.

At the end of the handle there are two sockets for power cords, 12 V from the battery and 220 V from the network. A two-digit indicator displays the timer running time.

After starting, the countdown starts and the ozone-air mixture exits at the outlet of the bell-nozzle. Afterwards, you need to lean the bell against the wound to provide treatment. The volume of the socket is filled with ozone and the disinfection process occurs. At the end of the time, the timer will automatically stop ozone production.

The layout of printed circuit boards for the microprocessor module, for the DC-DC converter 12…300 V and the indication and control board has been carried out is shown in Fig. 6.

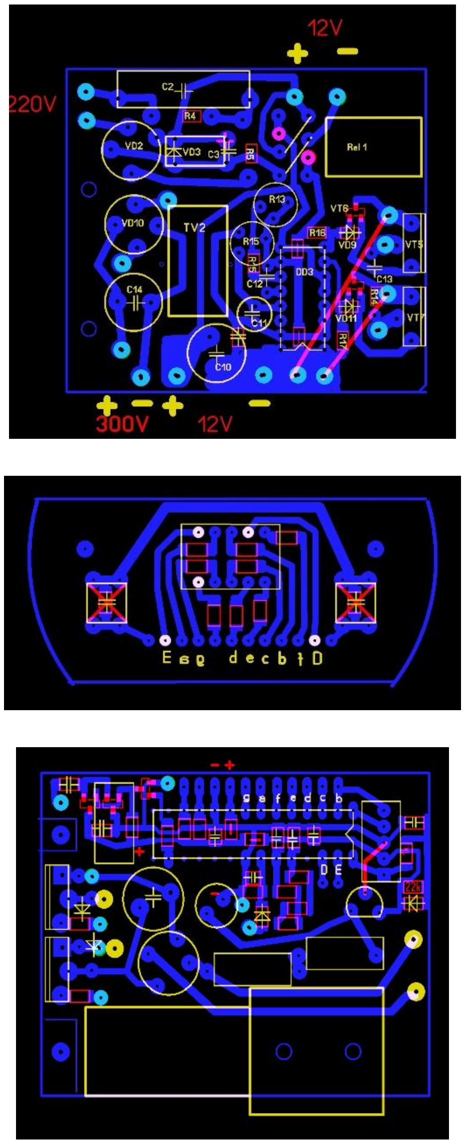


Fig. 6. The main printed circuits

In Fig. 7,a the key control signal is depicted on the top beam, short 2 µs, opens the current key transistors, which excites an impact oscillatory process in the transformer winding with a frequency of about 180 kHz. Fig. 7,b shows the image of low-frequency modulation for controlling the performance of the ozonator.

A pulse-width modulated signal with a duty cycle of about 60 and pulses of 1.2 µs is generated, also modulated with a frequency of 50 Hz, but also with pulse-width modulation. This makes it possible to regulate the output voltage amplitude from the high-voltage transformer. The adjustment is carried out according to a signal from the output winding of the signal feedback (Feedback).

By changing the duration of short pulse packets from 5 to 15 ms, it is possible to change the average generation energy in a wide range and thereby automatically maintain its value in a given mode.

a
b

Fig. 7. The control signals of the microprocessor

CONCLUSIONS

Portable ozone generating device based on a surface dielectric discharge with a specially constructed reactor has been developed for wound healing. The developed device is easy to use and can be powered either from 12V, in the field, or from the mains in a hospital. The manipulation of the device itself is simple in principle and does not require special skills from user personnel. The entire operating algorithm is embedded in the microprocessor. It generates all signal sequences for the ozone generator and maintains a constant amplitude of the output voltage on the transformer for the ozone reactor.

ACKNOWLEDGEMENTS

The research was supported by the National Research Foundation of Ukraine "Science to Strengthen Defense Capabilities of Ukraine", Grant № 2023.04/0016.

Two members of the team of authors are grateful to the Simons Foundation Program: Presidential Discretionary-Ukraine Support Grants, Award № 1290591.

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Article received 30.09.2024

ПОРТАТИВНИЙ ОЗОНОГЕНЕРУЮЧИЙ ПРИСТРІЙ ДЛЯ ОБРОБКИ ІНФІКОВАННИХ РАН

Р.О. Павліченко, А.В. Клосовський, Ю.С. Кулик, І.О. Місірук, А.В. Таран, П.М. Воронцов, Ю.П. Гніденко, Є.О. Нестеренко

Озонотерапія для лікування ран зазвичай не використовується в багатьох відношеннях, і така технологія все ще розробляється, навіть з надзвичайно багатообіцяючими результатами. Найважливішим ключем лікування ран озоном є його здатність усувати ріст бактерій і їх популяцію. У зв'язку з цим виникає нагальна потреба в альтернативних варіантах антисептичної обробки ран на етапі евакуаційної та долікарської допомоги для їх подальшого ефективного лікування. У цьому дослідженні розроблено портативний пристрій генерації озону для лікування ран та обговорено основні технічні характеристики такого пристрою.