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Identification of the electromagnetic field of a laboratory bench with a low-temperature plasma generator

***Abstract**: The aim of the study was to identify the electromagnetic field generated by a cold plasma generator in the working space of the personnel operating this apparatus. The cold plasma generator is constructed with two half-bridges in an H configuration on MOSFET transistors feeding a resonant circuit with a high-voltage transformer. The secondary winding supplies the ionising electrode with 7.5 kV. The sinusoidal waveform of the generator is modulated with an adjustable frequency in the range 0 - 350 Hz and an adjustable pulse filling in the range 0-100%. Tests were carried out with a frequency of 50Hz and a pulse fill factor of 10%. It was noted that EMF levels do not pose a risk to personnel operating the cold plasma generator. However, it should be noted that the device's parameter settings were set to the minimum, which translated into the propagation of the electromagnetic field, both the electric component, the magnetic component and the power density. It was found that the highest variation was characteristic of the magnetic component of the analysed electromagnetic field propagation. In the case of the electric component, the variation of values was much smaller.*

***Streszczenie:** Celem badań była identyfikacja pola elektromagnetycznego generowanego przez generatora zimnej plazmy w przestrzeni pracy personelu obsługującego tą aparaturę. Generator zimnej plazmy jest zbudowany z dwóch półmostków w konfiguracji H na tranzystorach MOSFET zasilających obwód rezonansowy z transformatorem wysokiego napięcia. Uzwojenie wtórne zasila elektrodę jonizującą napięciem 7,5 kV. Przebieg sinusoidalny generatora jest modulowany z regulowaną częstotliwością w zakresie 0 - 350 Hz i regulowanym wypełnieniem impulsu w zakresie 0-100%. Testy zostały przeprowadzone z częstotliwością 50Hz i współczynniku wypełnienia impulsu wynoszącym 10%. Odnotowano, że poziomy pól elektromagnetycznych nie stanowią zagrożenia dla personelu obsługującego generator zimnej plazmy. Należy jednak pamiętać, że ustawienia parametrów pracy urządzenia były ustawione na minimum, co przekładało się na propagację pola elektromagnetycznego, zarówno składowej elektrycznej, składowej magnetycznej oraz gęstości mocy. Stwierdzono, że najwyższe zróżnicowanie było charakterystyczne dla składowej magnetycznej analizowanej propagacji pola elektromagnetycznego. W przypadku składowej elektrycznej zróżnicowanie wartości było znacznie mniejsze. (**Identyfikacja pola elektromagnetycznego stanowiska laboratoryjnego z generatorem plazmy niskotemperaturowej**).*

Keywords: electromagnetic field, cold plasma, occupational safety.
Słowa kluczowe: pole elektromagnetyczne, zimna plazma, bezpieczeństwo pracy.

Introduction

Identification of the risks arising from the effects of electromagnetic fields on humans is a basic and indispensable part of the study of any device that potentially generates such a field. The impact of electromagnetic fields, both directly on the human body and on the material working environment, can cause numerous risks to the safety or health of workers, which can lead to both impaired work performance or deterioration of health, and even fatal accidents. Induced currents can interfere with the body due to disruption of natural electrophysiological processes in nerve or muscle cells, and the increase in tissue temperature can cause thermal damage of varying degrees and extensiveness, which can occur both on the surface of the body and internally - depending on the frequency of radiation [1]. While a person is in an electromagnetic field, the following biophysical effects may occur in his body as a result: stimulation of nerve or muscle tissue (when fields with frequencies not exceeding a few megahertz are affected); increase in tissue temperature (when fields with mega- or gigahertz frequencies are affected); nuclear magnetic resonance; magnetohydrodynamic phenomenon; effect on the processes of free radical metabolism. Direct impact of magnetic fields on a person can result in stimulation of the central or peripheral nervous system due to induction of electric currents in the body, manifested, for example, by disturbances of balance or eye-hand coordination [2]. The analysis of the results of RF PEM tests and measurements for more than 450 selected devices representative of the economic departments in which they are most often used made it possible to assess the current state of workers' exposure to these fields and showed their high intensities occurring at the workstations of such occupational groups as physiotherapists, dielectric welding machine operators, wearable radio operators and technical mast group workers in broadcasting and radio communication facilities [3]. After analyzing the obtained data, it was found that the occurring levels of radiated emissions during plasma torch cutting are in the frequency range below 30 MHz. The maximum measured levels are 80 dB-μV/m (10 mV/m) for the electrical component and 55 dB-μA/m (570 μA/m) for the magnetic component, respectively. [4]. The operation of military technology equipment involves, to a significant extent, the need to be in electromagnetic fields with the values of the occupational safety and health protection zones established by national regulations. The values of electromagnetic field intensities at the positions of employees, operating these devices, often exceed the values found at equipment used in other sectors of the economy [5-8]. Extensive research on the level of electromagnetic radiation in the environment was conducted by Bienkowski [9,10], generating maps of the spatial variation of the field in question, taking into account the location and type of GSM stations. The properties of the field-EM are most often presented with respect to its two components: the electric field (in volts per meter, V/m) and the magnetic field (in amperes per meter, A/m), which are not correlated in the field-EM of the near zone, while when considering the radiation-EM of the far zone, in which the field-E and field-M intensities are correlated, a frequently used parameter is the power density of this radiation (in watts per square meter, W/m^2) [11]. Karpowicz [12], after analyzing the legal requirements (ICNIRP, IEEE, INIRC, ICNIRP), noted that despite the development of many documents by experts systematizing the knowledge of the mechanisms of formation of individual hazards-EM, the circumstances requiring the introduction of protective measures, and the measures and methods of assessing hazards-EM, so far there is no international consensus in the requirements of labor law in this area.

The use of cold plasma in life sciences and medicine focuses on its antimicrobial properties. Cold plasma is assumed to exist in the energy range of 0.2 eV to 3 eV, which roughly corresponds to the temperature range of 2,000 K to 30,000 K (l eV = 11600 K). Low-temperature plasma is usually a low-ionized gas with a high or very high content of neutral particles. The impact of cold plasma causes modification of the physical-chemical-mechanical plasma environment, which is especially true for liquids. The use of cold plasma in the microbiological decontamination of food products allows at the same time to preserve the basic attributes of the product. The properties of plasma are determined by four basic parameters: temperature, pressure, thermodynamic equilibrium and degree of ionization. For technological purposes, plasma is produced by means of electrical discharge. There are three basic electrode configurations in barrier discharges, which lead to: 1) volume discharges (volume discharges, VD), 2) surface discharges (SD), and 3) capillary discharges (coplanar discharges). There are also reactors being built in which all of the above-mentioned discharges occur.

Material and methods

Electromagnetic field measurements were performed in accordance with the following standard: PN-EN 62233:2008 Methods for measuring electromagnetic fields of electrical household and similar equipment with regard to human exposure. Permissible values were determined based on the Decree of the Minister of Health of December 17, 2019 on permissible levels of electromagnetic fields in the environment (Journal of Laws, December 19, 2019, item 2448). The research was carried out using a 3-axis field strength meterTM196. The subject of the study was a laboratory device equipped with a cold plasma generator [13], which is built with two half bridges in an H configuration on MOSFET transistors feeds a resonant circuit with a high-voltage transformer. The secondary winding supplies the ionizing electrode with a voltage of 7.5kV. The sinusoidal waveform of the generator is modulated with an adjustable frequency of 0 - 350Hz and an adjustable pulse filling of 0-100%. (Fig.1).

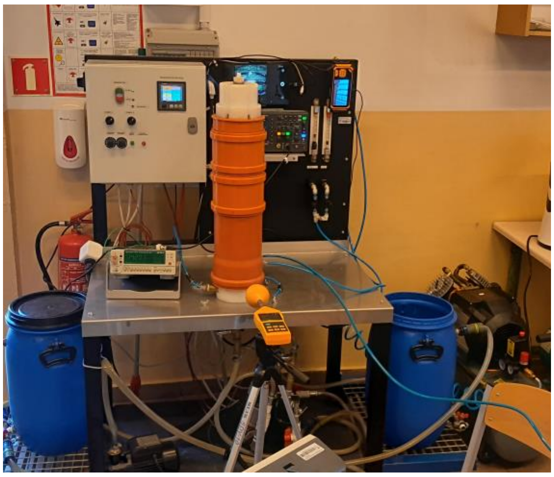

Figure 1. View of the laboratory bench equipped with a cold plasma generator with the location of the meter at a height of 10 cm in relation to the structural frame

The tests were carried out at a frequency of 50Hz and a pulse fill factor of 10%. The fluid flow rate through the generator was 0.9 l/min. The fluid used for testing was spring water whose turbidity was 0.13 NTU, hydrogen ion concentration (pH) 8.0, electrical conductivity 603 μS/cm, total hardness 282 mg/l CaCO3, nitrates 33.6 mg/l, chlorides 69 mg/l, coliform bacteria 0, these values were determined by a PCA-accredited laboratory with accreditation number AB521. Measurements were taken around the inductor horizontally in three directions and one direction for the vertical axis (Fig.2).

Fig 2. Location of the TM 196 meter in relation to the cold plasma generator.

There were 6 variants of the distance of the meter's location in the horizontal plane, i.e. 5 cm,10 cm, 15 cm, 20 cm, 25 cm, 30 cm, and 6 variants of its location in the case of the vertical plane, where measurements were made at heights of 10 cm, 20 cm, 30 cm, 40 cm, 50 cm and 60 cm from the base of the structural frame on which the generator was placed (Fig.3).

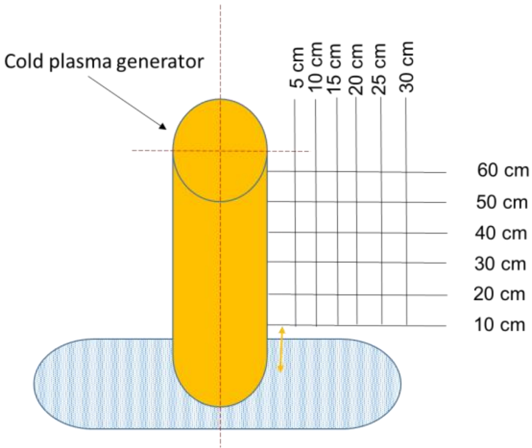

Figure 3. Diagram of the location of measurement points around the cold plasma generator

The distribution of measurement points within the generator space allowed to determine the characteristics of spatial variation of the electromagnetic field with sufficient accuracy, necessary to identify potential risks for personnel operating the cold plasma generator.

Results

It was observed that at a distance of up to 5 cm from the generator, regardless of the height of the placement of the sensor in relation to the support frame of the device, the value of the eclectic field strength exceeded 12 V/m. It should be noted that the variation in electric field strength resulting from the height of the measurement carried out from the generator support frame did not exceed 2 V/m (Figure 4). The greatest variation between the measured values of electric field strength was recorded at a distance of 10 cm from the cold plasma generator because at a height of 60 cm the electric field strength was 3 V/m and at a height of 20 cm it was 11 V/m. Also at a height of 50 cm, a relatively high electric field strength was recorded, as it was about 7 V/m.

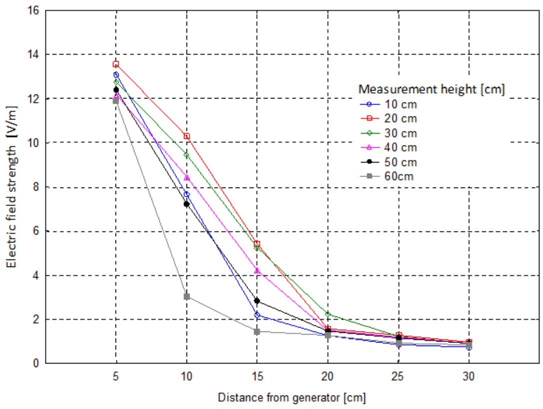

Figure 4. eclectic field intensity within the cold plasma generator

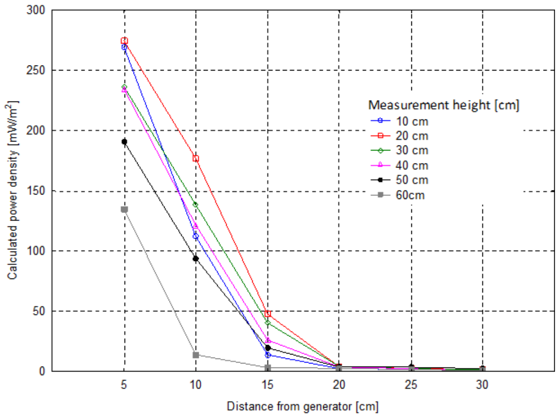

Figure 6. Power densities within the cold plasma generator

Figure 5 shows the spatial distribution of electric field strength in the vicinity of the cold plasma generator. The highest values of electric field strength were recorded at a height of 20 cm from the frame of the device, which exceeded 10 V/cm at a distance of 11 cm from the cold plasma generator. In contrast, at a distance of more than 21 cm from the generator, the electric field strength did not exceed 1 V/cm.

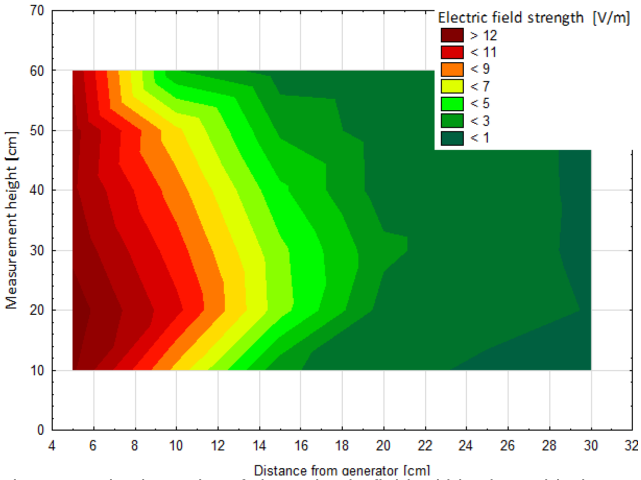

Figure 5. The intensity of the eclectic field within the cold plasma generator

Analyzing the electric field strength at a height of 50 cm from the device's support frame, values exceeding 11 V/cm were observed at a distance of no more than 10 cm from the cold plasma generator. A similar observation applies to measurements at the level of the device frame, where an eclectic field strength of 11 kV/cm was recorded at a distance of 12 cm from the cold plasma generator. The absolute difference in distance from the cold plasma generator where the value of the electric field strength exceeded 11 V/cm within the analyzed range of generator height was 5 cm. Taking into account the current applicable standards, the recorded electric field strength at the tested settings of the cold plasma generator does not pose a threat to personnel operating the apparatus.

Analyzing the distribution of the power density generated by the cold plasma generator in the potential handling space, it was noted that at a horizontal distance of up to 5 cm from the generator, regardless of the height of the placement of the sensor, the power density exceeded 130 mW/m^2 (Fig.6) It should be noted that the variation of the value in question resulting from the geometric height of the measurement carried out, defined as the difference between the highest and the lowest value, was 160 mW/m^2.

The greatest variation between the measured values of electrical power density was observed at a distance of 10 cm from the cold plasma generator because at a height of 60 cm the power density was 17 mW/m^2 and at a height of 20 cm it was 170 mW/m^2. A rapid decrease in power density was also observed to be less than 50 mW/m^2 at a distance of 15 cm from the source.

Figure 7 shows the spatial distribution of power density around the cold plasma generator that is part of the test apparatus. The highest values of power density were recorded, as were the electric field strengths at a height of 20 cm measured from the support frame of the apparatus regardless of the horizontal distance from the cold plasma generator. It should be noted that the highest power density propagation was also recorded at this height, with values of 210 mW/m^2 found at a distance of 12 cm from the cold plasma generator.

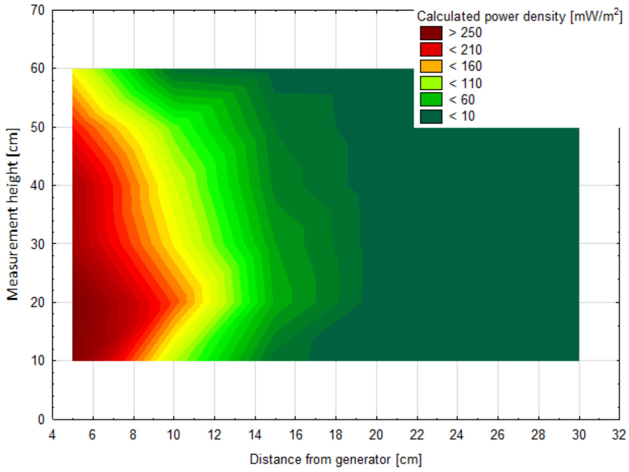

Figure 7 Spatial distribution of power density in the vicinity of the cold plasma generator

It was found that a power density value not exceeding 10 mW/m2 within the entire workspace was recorded at a distance of more than 19 cm from the cold plasma generator. The shape of the propagation itself was oval in nature with aligned and smooth edges.

Figure 8 shows the magnetic field strength values for which there was a clear variation in the magnetic field strength values measured at different heights of the cold plasma generator. The highest difference in magnetic field values was recorded at a distance of 20 cm from the cold plasma generator, which was about 20 mA/m between the magnitude in question recorded at a height of 60 cm and a height of 20 cm.

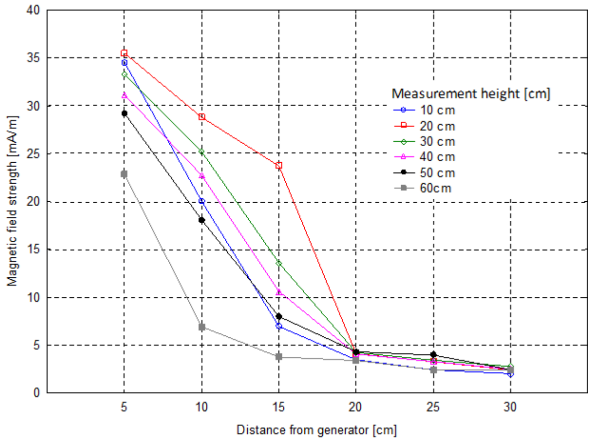

Figure 8: Magnetic field intensity around the cold plasma generator

Figure 9 shows the distribution of magnetic field intensity propagation within the cold plasma generator. Analyzing the propagation of magnetic field strength, it was found that the highest values were recorded at the height of 20 cm of the cold plasma generator measured from the support frame of the device. At the aforementioned height, a magnetic field strength value exceeding 23 mA/m was recorded at a distance of about 17 cm from the cold plasma generator, while already at a height of 25 cm from the cold plasma generator support frame, a magnetic field strength value of 23 mA/m propagated to a distance of 13 cm from the generator in question..

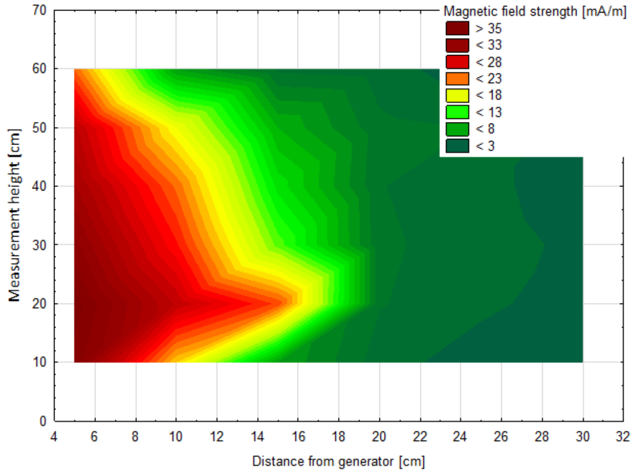

Figure. 9. Spatial distribution of magnetic field strength in the vicinity of the cold plasma generator

The smallest magnetic field propagation was recorded for a measurement height of 60 cm, where the magnetic field value of 23 mA/m reached a space at a distance of 7 cm from the cold plasma generator.

Conclusions

It was noted that electromagnetic field levels did not pose a threat to personnel operating the cold plasma generator. However, it should be noted that the device's operating parameter settings were set to the minimum, which translated into the propagation of the electromagnetic field, both the electric component, the magnetic component and the power density. It was found that the highest variation was characteristic of the magnetic component of the analyzed electromagnetic field propagation. In the case of the electrical component, the variation of values was much smaller and recorded at a distance of 10 cm or more from the cold plasma generator. At distances exceeding 20 cm, the variation of the magnetic field for each analyzed component is marginal.

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