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CHARACTERISTICS OF OZONIZERS WITH TWO BARRIER DISCHARGE

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Abstract- The presented work is devoted to investigation of the physical proceeding in ozonators with the two-barrier discharge. The obtained results and their analysis show that it is necessary to choose frequency of the applied voltage, for effective work of the ozone plant in each concrete case, at which the maximal efficiency is provided.

Keywords: Ozonator, Discharge, Barrier, Efficiency.

I. INTRODUCTION

As is well known at the heart of work of the most industrial ozonators laid or two-barrier discharges. The physicochemical processes proceeding in such discharges are sufficiently complex and completely are not investigated [1-3].

The present work is investigating of two-barrier discharge in the coaxial placed cylindrical gaps. The section and equivalent schemes of one of active elements of such type are shown on Figure 1. Air or oxygen are banished through an gap between two electrodes limited with dielectric barriers from a glass. The typical volt-ampere characteristic of such discharge is resulted on Figure 2. Apparently from the characteristic, in two-barrier discharges at voltage up to 10 кV and low frequencies in consecutive half-cycles, because of change of polarity of electrodes, superficial charges will neutralize the charges going from volume, as is well known, at the appendix to a discharge gap of a voltage, there is its redistribution.

II. DISCUSSIONS

If the voltage coming directly on gas interval U_g, does not exceed size of a discharge voltage of the given gas, at the given thickness of a gas gap it remains constant up to size $U_g = U_{ds(g)}$.Other voltage appears putted on to dielectric barrier U_d i.e. $U = U_g + U_d$. It allows supporting at rather low values of putted on voltage U the barrier discharge with the maximal intensity of a field in gas interval $U_g = U_{ds(g)}$ and high density of a current (up to 100 mA/cm^2).

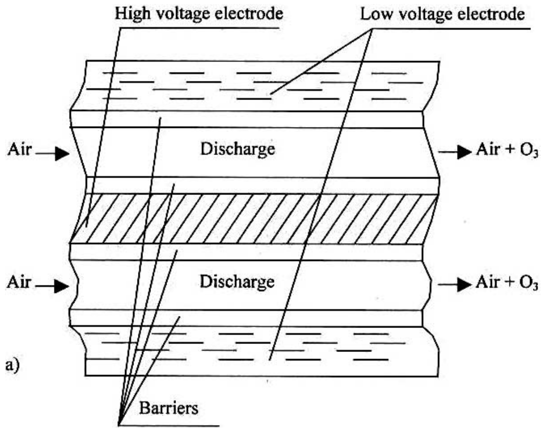
At the big voltage intensity of a field grows, the quantity of carriers of a charge grows, the current of the discharge accordingly grows. It depends on size of frequency of the putted on voltage. The top limit of the putted on voltage should not exceed a discharge voltage of a material of a barrier. At $U_d \geq U_{ds(d)}$ there is a discharge of a material of a barrier, there is a localization of the discharge and its transition in the spark or arc form. But are practically important processes till discharge, which use during synthesis of ozone.

The analysis of experimental data on dependences of mobility of molecular ions in own gases from the resulted intensity of field shows, that this dependence - very weak, anyway in a range of $\frac{E}{P}$ of our experiments and consequently, mobility of ions from intensity of a field practically does not depend. So, in oxygen at various $\frac{E}{P}$ in a range 10÷50 $\frac{V}{\text{cm}\times\text{tor}}$ was observed the spectrum of negative ions which are identified as ions O- with mobility $K_i = 3.2$ [cm^2/(V×s)], and O_2- $K_i = 2.25$ [cm^2/(V×s)] and O_3- $K_i = 32.5$ [cm^2/(V×s)] [8], i.e. mobility of atomic and molecular ions differ a little, and their values are insignificant.

Really, by our calculations, time of a relaxation of charges on the surfaces of a dielectric barrier because of their small mobility about 4 ms, and extent of a half-cycle of the putted on voltage for frequencies in limits 250÷1000 Hz makes accordingly 0.5 ms up to 0.02 ms, i.e. going away of ions from a discharge gap is insignificant, that promotes increase in concentration of ions in volume.

Besides with increase of intensity of a field from several up to 10 kV energy of electrons grows and volumetric processes amplify. Here concern recombination, photo ionization, sticking of electrons to molecules of gas with formation of negative ions, etc. In result concentration of ozone and consequently productivity of ozonizers grows.

Starting from above stated, in the present work dependences of concentration of ozone both from frequencies (Figure 4), and from size of the putted on voltage are investigated. These dependences were taken at continuous measurement of concentration of ozone with application [7] optical methods offered by us.



Equivalent scheme of two barrier discharge

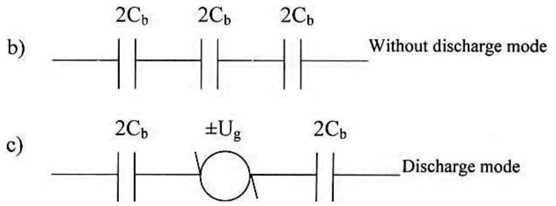


Figure 1. Section of an active element of ozonizers with two barrier discharge

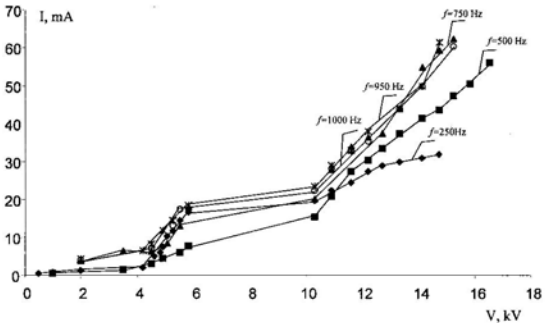


Figure 2. Volt-ampere characteristic of an active element of ozonizer

Results show, which on the first site VAC there are only small traces O3, in the second - micro discharge - dependence of concentration of ozone on frequency of the putted on voltage is appreciable. To explain this dependence, on seen, it is possible starting from equivalent circuits (b, c on Figure 1), consisting of series connected capacities. Since the capacitance falls with growth of frequency, the current accordingly grows. The similar branching volt - ampere characteristic takes place for some devices of corona discharge with cylindrical geometry of electrodes depending on size of a ratio $\frac{r_e}{r_i}$ (Figure 3).

For 1 and 2 $r_H / r_{ex} = 1 \div 10$; for 3 and 4 $r_H / r_{ex} = 10 \div 100$ makes tens units, a corner of an inclination of straight line $J = f(U)$ is insignificant, and at r_H / r_i =1÷10 a corner of an inclination grows.

This area is used in stabilizers based on corona discharge. In case of 1, 2 radiuses of electrodes are close, at coronize an internal electrode is formed uniformly luminous shell which covers all interval is formed.

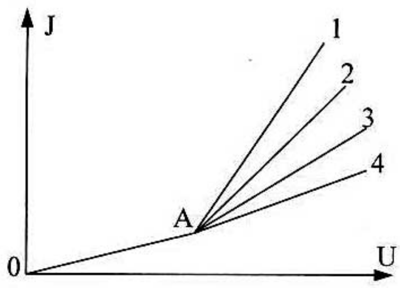


Figure 3. Volt-ainpere characteristic of a coronad discharge.at different $\frac{r_H}{r_{ex}}$

The size of a current linearly grows with increase in a voltage. And in case of 3, 4 ratio of radiuses strongly differ, thickness of a luminous layer are small, the dark space limits size of a current. Part OA according to discharge of Kruks or the dark dependent discharge. Due to available in volume a discharge gap of charges insignificant currents proceed. At atmospheric corona discharge it is necessary to take into account as convection, and induced currents. All this concerns to corona discharge without barrier.

In barrier discharges because of a voltage drop across a dielectric barriers strongly decreases intensity of a field, energy of electrons, volumetric processes considerably weaken. Processes in one-barrier discharges are close to discharges without barrier because of neutralization of charges in a conducting electrode in opposite half-cycles of the putted on sinusoidal voltage. Here the branching of lines is connected with geometry of electrodes, in our case, for the fixed construction, this branching is connected to frequency of the putted on voltage, namely on a measure increase in frequency, the corner of an inclination of lines of a branching grows.

The third site - transitive where the discharge is unstable, changes its structure, transition to the fourth site occurs jump (Figure 2). On the fourth site occurs pumping the volumetric processes, promoting formation of ozone, and is observing strong dependence of concentration of ozone on frequency.

Increasing of concentration even more amplifies at some resonant value of frequency, when own frequency of the connected contours coincides with frequency of the putted on voltage. At excess of resonant frequency, concentration of ozone essentially decreases, and further the discharge stops, apparently, including, because of the processes proceeding in connected oscillatory contours due to occurrence in an entrance contour of resulted resistance [5].

The presented work is continuation of investigation of the physical processes proceeding in ozonators with the two-barrier discharge, stated in [4] where it has been shown? That the active power put in discharge interval, ceases to depend on the frequency if the applied voltage in the certain interval (500-900 Hz), and then decreases with frequency increasing (Figure 4).

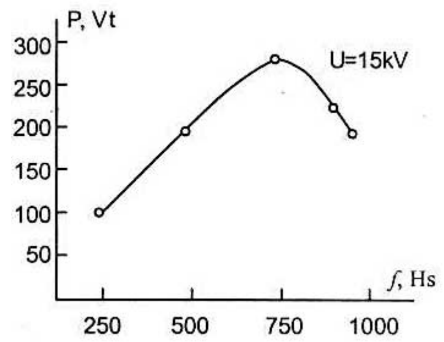


Figure 4. Dependence of capacity including to discharge interval of ozonator on the frequency of the applied voltage

The power was determined from volt-ampere characteristics of the discharge by the formula of

$$P = [I_{ac} - I_{ic}] \cdot U_d \tag{1}$$

where I_{ac} is the average current, I_{ic} is the current at ignition potential and U_d is voltage of discharge burning. The discharge stops with increasing of frequency up to values exceeding 1000 Hz. This conclusion actually contradicts the design formula established ozonators theory to where, power increases when frequency increases.

$$P = \frac{2}{\pi}\omega U_d [C_b (U - U_d) - U_d C_d] \tag{2}$$

where $\omega = 2\pi f$ is the circular frequency, U_d is voltage of discharge burning, U is the voltage ozonators, C_b is the capacity of barrier and C_d is the capacity of discharge interval.

We shall make the full equivalents circuit ozone plant working on the basis of the two-barrier discharge in pulse regime for elucidation of the above-stated rejection of experimental results from theoretical expression (2) (Figure 5).

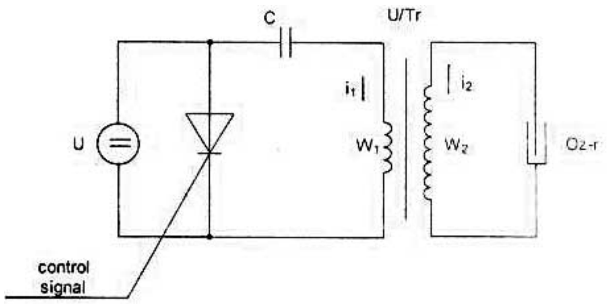


Figure 5. The simplified basic circuit of ozone plant

In this circuit ozone plant, it presented as system of two-coupled circuit. The supply voltage is transferred from primary circuit to secondary by means of the pulse transformer. The big role at transfer of voltage pulses from the primary circuit to secondary play leakage inductance (L_s) and magnetization (L_m). The first of this influences on the form of pulses at transfer of fast processes and formation of their forward fronts, and the second-influences at transfer of slow-reformative parts of pulses and forms their tops.

The discharge current had two half-cycles and had strongly decaying character. It can be presented in complex kind as $\dot{I}_1 = \dot{I}_{m1} e^{j\omega t}$ for the primary and $\dot{I}_2 = \dot{I}_{m2} e^{j\omega t}$ for the secondary circuit. I_1 is created by influence of e.m.f of the primary circuit $e_1(t)$. The electromotive force created in secondary circuit by this current equal to:

$$\dot{E}_{m12} = -\frac{M d\dot{I}_1}{dt} = -j\omega M \dot{I}_{m1} \tag{3}$$

$\dot{I}_2$ is the current of secondary circuit, and creates the e.m.f in the primary circuit:

$$\dot{E}_{m21} = -j\omega M \dot{I}_{m2} \tag{4}$$

where M is the factor of reciprocal induction: $M = F\sqrt{L_1 L_2}$ (F is the connection factor L_1 and L_2 are the inductance of primary and secondary circuit accordingly). $\dot{I}_{m1}$ and $\dot{I}_{m2}$ are the complex amplitudes of currents.

Let us write down Kirkhofs equations for the given system of the coupled circuit:

$$\begin{cases} \dot{I}_{m1} * \dot{Z}_1 = \dot{E}_m + \dot{E}_{m21} \\ \dot{I}_{m2} * \dot{Z}_2 = \dot{E}_{m12} \end{cases} \tag{5}$$

For the electromotive force $\dot{E}_{m12}$ and $\dot{E}_{m21}$ we shall obtain the formula taking into account here expressions (3) and (4):

$$\dot{I}_{m1}\left(\dot{Z}_1 + \frac{\omega^2 M^2}{\dot{Z}_2}\right) = \dot{E}_m \tag{6}$$

Where $\dot{Z}_1$ and $\dot{Z}_2$ are the complex resistance of circuits. The equation (6) expresses the Ohm law for considered system. As seen from formula, the primary circuit includes as though the certain complex resistance:

$$\dot{Z}_{вн} = \frac{\omega^2 M^2}{\dot{Z}_2} \tag{7}$$

The reactive part of this formula, so-called brought resistance, compensates reactive resistance of the primary circuit as a result of resistance of system becomes active and, naturally, independent on the frequency. This assumption explains the independence of capacity including to the discharge on the frequency nearby resonant frequency ($\omega_0 = 750 Hs$), observable in our experiments [4]. Obviously, thus other characteristics, in particular factor of transfer of considered system of the coupled circuits change also.

III. RESULTS

It is necessary to note, that brought resistance is the conditional concept. It allows determining the degrease of primary circuit current, as result of increase of the primary circuit resistance on magnitude of $\dot{Z}_{bn}$. Actually, not for anything resistance is not brought from one circuit to another.

The capacity absorbed on active resistance of the secondary circuit of R_2, which is composed from resistance of secondary winding of the pulse transformer, $R_{2w.t.}$, moreover resistance of discharge interval of active element of the ozonator changing on time, equals:

$$P_2 = I_2^2 R_2 \tag{8}$$

where $R^2 = R_{2w.t.} + R_2(t)_{oe}$.

The equivalent circuit (Figure 3.b) at resonance when reactive resistances vanish processes the active resistance:

$$R_e = R_1 + Z_X = R_1 + \frac{\omega^2 M^2}{R_2} \tag{9}$$

And capacity

$$P_e = I_1^2 \left(R_1 + \frac{\omega^2 M^2}{R_2} \right) \tag{10}$$

The available active capacity including to discharge interval of the ozonator is a part of this equivalent capacity allocated on equivalent resistance of R_e:

$$P_a = aP_2 = a(P_e - P_1) = aI_1^2 R_{or} \tag{11}$$

where $P_1 = I_1^2 R_1$ is the capacity spent in active resistance of primary circuit, a is the constant. From here it is possible to estimate the efficiency (η) of ozone plant at resonance:

$$\eta = \frac{P_a}{P_e} = \frac{aI_1^2 R_e}{I_1^2 R_{\text{Э}}} = \frac{aR_{or}}{R_{\text{Э}}} = a\frac{1}{1 + R_1 / R_{or}} \tag{12}$$

As seen from the equation, the efficiency of ozone plant increases with the brought resistance value. It is necessary to increase reciprocal induction factor of M and accordingly collection factor as it is directly connected to reciprocal induction factor for increase of brought resistance value. All these reasoning show necessity of creation the critical connection between the ozone plant circuits: FQ=1, where Q is the good quality of system.

IV. CONCLUSIONS

Thus, the results obtained in this paper and their analysis show that it is necessary to choose frequency of the applied voltage at which the maximal efficiency is provided for the effective work of ozone plants in each concrete case.

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BIOGRAPHIES

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