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Improvement of Efficiency of a UV Lamp Type Ozonizer.

Md. Fayzur Rahman, Dong-In Lee, Kwang-Sik Lee
Hyun-Jig Song, Byung-Joon Chun, Sang-Keun Lee

School of Electrical Eng, College of Eng, Yeungnam university

1. Introduction

In an industrial society, environmental problems like air and water pollution have been the vital point of concern to health. O_3 is widely used for the purpose of environmental improvement.[1][2][3][4] In general O_3 is a powerful oxidizing agent and it decays without residues, which can be harmful to the environment. Werner Von Siemens developed primarily a silent discharge type ozonizer for the first time in 1857[5] using the principle of using dielectric between dischargers, so as to obtain brush discharge. Scheneller produced the same in 1894 but without dielectric. Since then the problem of low efficiency has become the burden of all researchers. Dr. Hyun-Jik Song and Cheon-Su Kang developed lamp type ozonizer and produced a maximum of 4000 mg/kWh.[6][7] The lamp type ozonizers having low efficiency are very important in O_3 area as they perform a role of lighting source as well as ozonizer that is used in sterilizing E. coli(Escherichia coli) bacteria. So it has become very important to increase the efficiency of the UV ozonizer. Sufficient improvements on efficiency were confirmed by using improved operation. By using the lamp under consideration we found that the yield rate in the improved ozonizer were 7369.33 mg/kWh at the flow rate of Q = 8 l/min and 6881.48 mg/kWh at Q = 2 l/min while the corresponding values in normal UV ozonizer were 671.43 mg/kWh and 2217.14 mg/kWh respectively.

2. O_3 generation mechanism by photo and chemical reaction methods

The important reaction of ozone generation and decomposition by photo-chemical reaction methods are as per given in equation (1) through (6).[8] Fig. 1 shows the schematic diagram for the basic principle of ozonizer in photo and chemical reaction method.

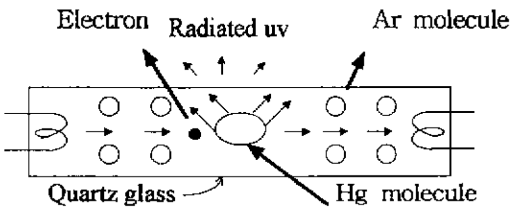
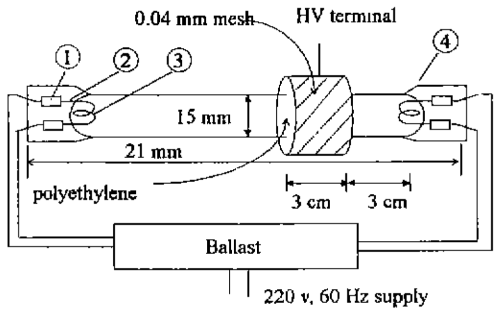


Fig.1 The basic principle of ozonizer in photo and chemical reaction methods.



(1) Dummet wire, (2) Leading wire, (3) Filament, (4) Pinching

Fig. 2 Schematic diagram of the UV ozonizer with mesh used for improved ozonizer.

$$O_2 + h\nu \rightarrow O^* + O \quad \text{.................(1)}$$
$$(\lambda = 130 - 175 \ [nm])$$
$$O_2 + h\nu \rightarrow O + O \quad \text{.....................(2)}$$
$$(\lambda = 175 - 242 \ [nm])$$
$$O + O_2 + M \rightarrow O_3 + M \quad \text{.............(3)}$$
$$O_3 + h\nu \rightarrow O_2^* + O \quad \text{..........................(4)}$$
$$(\lambda = 310 \sim 374 \ [nm])$$

$$O_3 + h\nu \rightarrow O^* + O_2 \quad (5)$$
$$(\lambda = 210 \sim 300 \text{ [nm] })$$
$$O_3 + h\nu \rightarrow O_2 + O \quad (6)$$
$$(\lambda = 550 \sim 610 \text{ [nm] })$$

3. Experimental Apparatus and Methods

Fig. 2 shows the schematic diagram of the improved UV ozonizer. As shown in the figure the tube of the lamp is made by a clear quartz glass of thickness 1 mm which is melted in SiO_2(99.1 %) and B_2O_2(0.1 %). The dumet wire is made of an alloy of Ni(41 %), Mn(0.75 - 1.25 %) and Si. The leading wire is made of Ni(99.9 % purity).

After washing and drying the lamp it is evacuated by vacuum pump unto 10^{-3} torr through a whole made at the mid point of the tube. As shown in the figure there is a mesh of 0.04 mm wound upon polyethylene.

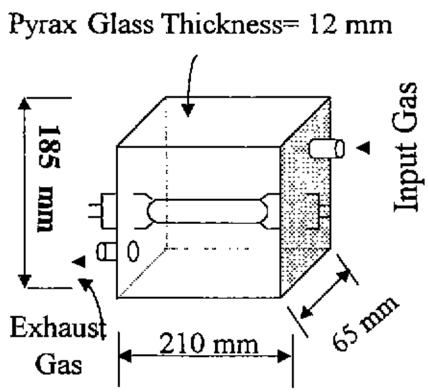
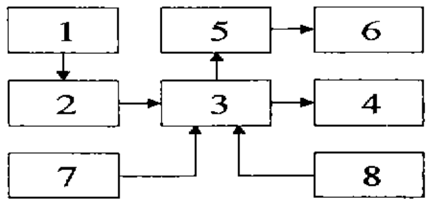


Fig. 3 Schematic diagram of the UV lamp chamber (ozonizer gas chamber).

High voltage is applied between the mesh and one of the filament terminals. The lengths of the mesh and the discharge path are both 3 cm. Fig. 3 shows the schematic diagram of the UV lamp chamber which is made by pyrex glass in the form of the inner compartment of a rectangle for the sake of research purpose.

Thickness is 12 mm and the size is Length×Width×Height = 210×65×185 mm In the experiment only one tube was used.

Commercial oxygen gas [99.99 % purity] was used as supplied gas. The discharge voltage (V_d), discharge current (I_d) were recorded by means of a digital storage oscilloscope (500 MHz, 1 Gs/s). The quantity of supplied gas is controlled by the flow meter [0 - 25 l/min].



1. Chamber of supplied Gas
2. Flow meter
3. Discharge chamber
4. Ozone monitor
5. Oscilloscope
6. Pc
7. HV source for silent discharge operation
8. 220v, 60 Hz, supply for uv ozonizer

Fig. 4 Block diagram of the UV ozonizer system.

The Ozone concentration of ozonized gas for gaseous phase was measured by using ozone monitor [0 - 110,000 ppm]. O_{3g} is calculated by using $O_{3,con}$ and O_{3Y} is calculated by O_{3g} and power W. Fig. 4 shows the block diagram of the UV lamp ozonizer system.

4. Experimental Results and Discussion

Fig. 5, 6 and 7 show the waveforms of discharge voltage and current in the both low voltage and high voltage circuit while Fig. 8 shows the Ozone concentration, O_{3con} against time in the normal UV ozonizer. Fig. 9 and 10 show the same in the silent discharge and improved operations respectively. Fig. 11 shows the O_{3con} characteristics against flow rate Q for three cases. Fig. 12 shows the yield rate curve.

Fig. 13 shows the increasing factor for the yield rate. The following points are observed:

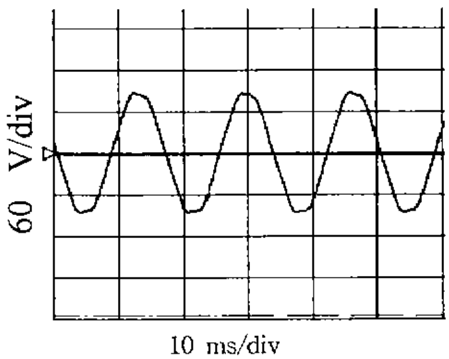


Fig. 5 Waveform of discharge voltage.

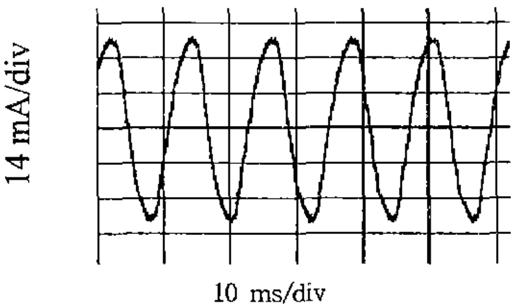


Fig. 6 Waveform of discharge current in UV lamp.

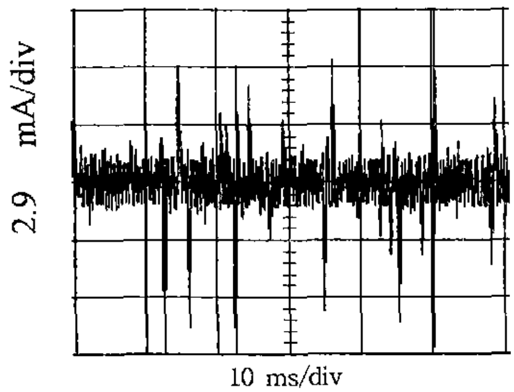


Fig. 7 Waveform of silent discharge current in high voltage circuit.

(1) The illumination characteristics of the UV ozonizer is found to be useful for color distinctive and intermittent works in the dark spaces.

(2) At lower gas flow rate in the UV ozonizer the ozone concentrations O_{3con} in the gaseous phase is high. But for the same input energy the amount of O_3 is fixed. The settling time for reaching the steady state value depends on the volume of the ozonized gas chamber. For the size under consideration the rise time at Q = 2 l/min is 110 sec. as shown in fig. 8.

(3) The upward trend of the curve in fig. 9 shows that O_{3con} tends to increase as the applied voltage goes on increasing. Due to the structure and insulation constraint we applied only 12.42 kV. With the modification of the tube structure the result can be upgraded.

(4) At higher flow rate the O_{3con} in the normal UV ozonizer becomes less and less and hence it's effect on the overall performance becomes negligible. So at higher flow rate, O_{3con} curve for the improved ozonizer, as shown in fig. 11 has a tendency to align with that in the silent discharge method.

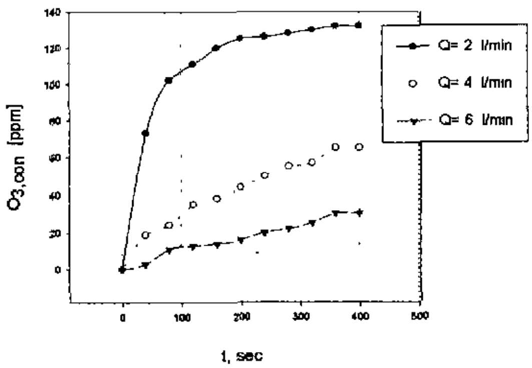


Fig. 8 O_{3con} in the normal UV ozonizer .

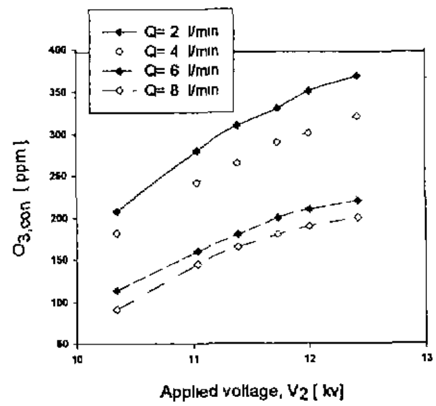


Fig. 9 O_{3con} in silent discharge operation.

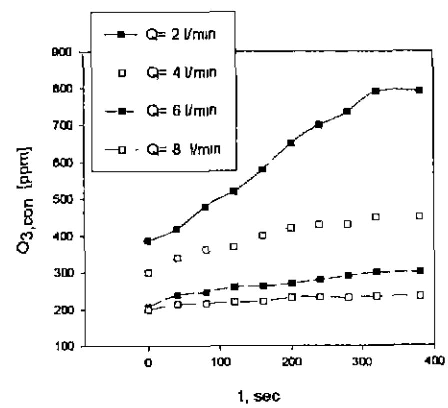


Fig. 10 O_{3con} in the improved ozonizer .

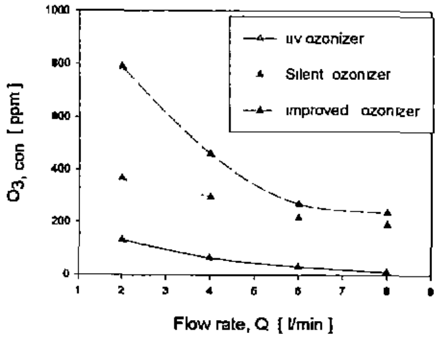


Fig.11 O_{3con} in all three operation against the variation of flow rate, Q

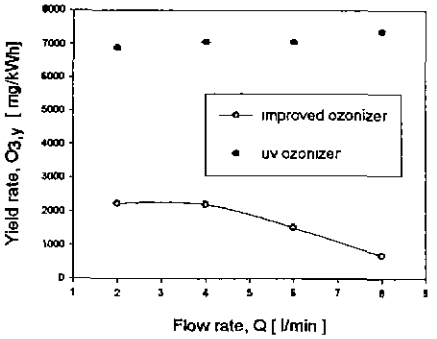


Fig. 12 Yield rate of O_3 in two methods.

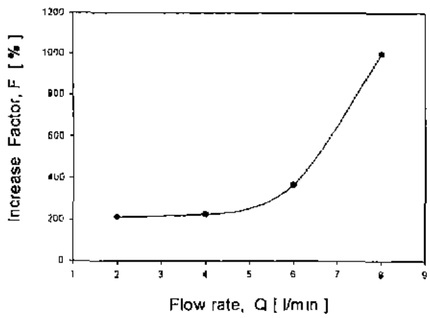


Fig. 13 Increase factor in percentage against flow rate, Q.

(5) The increase factor F is defined in percentage as

$$F = \frac{(O_{3con} \text{ in the improved ozonizer } - O_{3con} \text{ in the UV ozonizer }) \times 100}{O_{3con} \text{ in the UV ozonizer}}$$

At a higher gas flow rate, the yield rate in the silent discharge method, as shown in fig. 12 is high while that in the UV ozonizer it is very low. So the increase factor, F, as shown in fig. 13 is very high at higher flow rate while low at lower rate.

(6) Polyethylene was used to make more air space in the discharge area. If we don't use it, the discharge space will reduce and hence the result will degrade. lower gas flow rate Q.

5. Conclusion

(1) The yield rate in the normal UV ozonizer is 2217.15 mg/kWh at Q= 2 l/min and 2184 mg/kWh at Q= 4 l/min. In the improved ozonizer the corresponding values are 6881.48 mg/kWh and 7056 mg/kWh respectively. Hence depending on the gas flow rate, from 210% to 997.55% increase in the efficiency is possible.

(2) By modifying the structure of the UV ozonizer to make it fit for withstanding high voltage the result can be improved.

6. References

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