

## OZONE GENERATOR AND OZONE GENERATION

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### Abstract

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Because ozone is a very active oxidizing agent and powerful antimicrobial property, it has found use in many areas. It has long been used in dentistry, in medical laboratories, in cleaning up chemical waste mixed with hospital sewage, in extending the shelf life of food through ozonation, in cleaning urban drinking water, in raising pools and fish aquariums. So that ozone can be used in different amounts depending on the area of application and industry, it must be produced in the laboratory using artificial methods. The aim of this study was to impart knowledge and technical skills to the students at the Vocational School of Technical Sciences, Amasya University. As part of this goal, we presented a model of an ozone generator that works on the corona discharge principle to generate significant amounts of ozone. The aim of the study is to present the advantages of the ozone generator and to raise awareness for the areas of application.

**Key Words:** Corona Discharge, Ozone, Ozone Generator,

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## **Özet**

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Ozonun çok aktif bir oksidan ve kuvvetli bir antimikrobiyal özelliği olması bakımından birçok sektörde kendine uygulama alanı bulmuştur. Uzun bir süredir diş hekimliğinde, tıbbi laboratuvarlarda, hastanelerin atık sulara karışan kimyasal atıklarının yok edilmesinde, gıda ürünlerinin ozonlanarak raf ömrünün uzatılmasında, şehir içme sularının arıtılmasında, havuzların ve balık akvaryumlarının artırılmasında kullanılmaktadır. Ozonun uygulandığı alan ve sektöre göre değişik miktarlarda kullanılabilmesi için laboratuvarlarda yapay yöntemlerle üretilmesine ihtiyaç vardır. Bu çalışmada Amasya Üniversitesi Teknik Bilimler Meslek Yüksekokulu'nda öğrencilere bilgi ve teknik beceri kazandırmayı hedefledik. Bu hedef çerçevesinde önemli miktarlarda ozon elde edebilmek için korona deşarj prensibi ile çalışan bir ozon jeneratörünün modelini kullanıma sunduk. Ortaya konan çalışmanın hedefi ozon jeneratörünün faydalarını tanıtmak ve uygulama alanları hakkında insanları bilinçlendirmek amaçlanmıştır.

**Anahtar Kelimeler:** Korona-Boşalması, Ozon, Ozon Jeneratörü,

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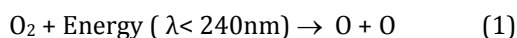
## **1. Introduction**

### **The story of the discovery of ozone**

The German chemist Christian Friedrich Schönbein (1799-1868) is considered to be the inventor of this new molecule, although he does not yet know for sure that the O<sub>3</sub> (ozone) molecule is created by combining three oxygen atoms. The chemist Schönbein noticed that a pungent smelling gas was released after a lightning strike in the sky. He noticed a similar smell in the 1840s during the electrolysis of dilute acid, during which oxygen was converted into ozone as a by-product at the positive pole in the laboratory. Schönbein could not determine the structure of ozone with three oxygen atoms, which was later determined by other researchers.

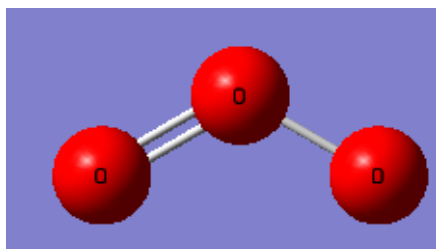
The 7th edition of the Pierer Konversations-Lexikons from 1892 contains the following information on the subject of ozone: "Ozone (active, polarized oxygen), O<sub>3</sub> ... When inhaled, it damages the respiratory tract severely, it can kill very small living beings very quickly for a short time. It is a powerful energetic oxidizer. The air mixture in the atmosphere usually continuously contains ozone, very little of it, especially after severe thunderstorms there is a significant increase in the amount of ozone [1].

As can be seen in reaction (1) and (2), ozone ( $O_3$ ) is created in the stratosphere by the addition of an oxygen atom (O) to an oxygen molecule ( $O_2$ ). The formation of this added O atom is achieved through the breakdown of an oxygen molecule by high-energy and short-wave sunlight (less than 240 nm). In the 1940s, the Dutch chemist Arie Jan Haagen-Smit discovered while working in the “summer fog” in California that the oxygen atom in ozone formation is caused by nitrogen dioxide ( $NO_2$ ).



## 2. Material and Methods

Ozone, or tri, is an inorganic molecule and its well-known formula is  $O_3$ . It is a pale blue gas with a distinctive pungent odor. Ozone, which is much less stable than the diatomic allotrope  $O_2$ , is an oxygen allotrope.



**Fig.1.** The ozone molecule

The data obtained from the calculations made with the Gaussian 09W program and the GaussView Interface program are shown in Fig.1 and Table 1.

**Table1.** Calculation of some parameters of  $O_3$  molecule with Gaussian 09W program

Properties of ozone molecule	
Method of Calculation	Hartree-Fock
Basis Set	6-311G
Charge	0
Spin	Singlet
Dipol Moment	0.55 Debye
Total Energy	-224.2 a.u.

The calculation of the ozone molecule by the Gaussian 09W program and the Hartree-Fock method and some parameters of the molecule are shown in Table 1.

In this study, a high voltage, high frequency power supply is used to generate ozone. It is designed for use in ozone generation, air and water disinfection. To regulate the output power, a power stage consisting of a single-phase full-bridge inverter, a current push-pull inverter (driver) and a control circuit is explained and analyzed. This laboratory is used as a power source with a high voltage ferrite transformer and a PIC microcontroller system is built into it to power a dielectric barrier discharge (DBD) ozone generator.

It has a simple structure in the control part and has a fixed operating frequency of 8 kV and 50 Hz. Using a cylindrical DBD ozone generator (Dielectric Barrier Discharge) of this power source, an experiment was carried out to ozonate virgin olive oil, to break down odor molecules in the ambient air and for cleaning the blue ink-water mixture (see Fig.2 and Fig.3).



**Fig.2. a-**Before ozonating olive oil



**b-**After ozonating olive oil



**Fig.3. a-** Before ozonating Blue ink-water

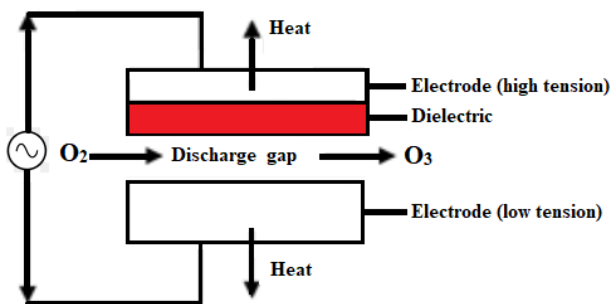


**b-** After ozonating Blue ink-water

### 3. Results and/or Discussion

#### 3.1. Ozonproduktion

For ozone production, both for its spontaneous formation in nature and for its artificial production, a diatomic oxygen molecule must first be broken down. This free radical oxygen atom must therefore react with another diatomic oxygen molecule to form the triatomic  $O_3$  molecule. But it takes a lot of energy to break the O-O bond. With the help of UV light (ultraviolet radiation) and corona discharge processes, ozone can be generated after the formation of oxygen radicals. In the commercial sector, the corona discharge process is mostly used to generate ozone (Fig. 4).



**Fig. 4.** Schematic representation of ozone production using the corona discharge method [5].



The ozone generator seen in Fig.5, which was produced within the scope of the applied applications of the "System Analysis and Design" course at the Vocational School of Technical Sciences of Amasya University, was designed together with the students.

**Fig.5.** Outside view of ozone generator

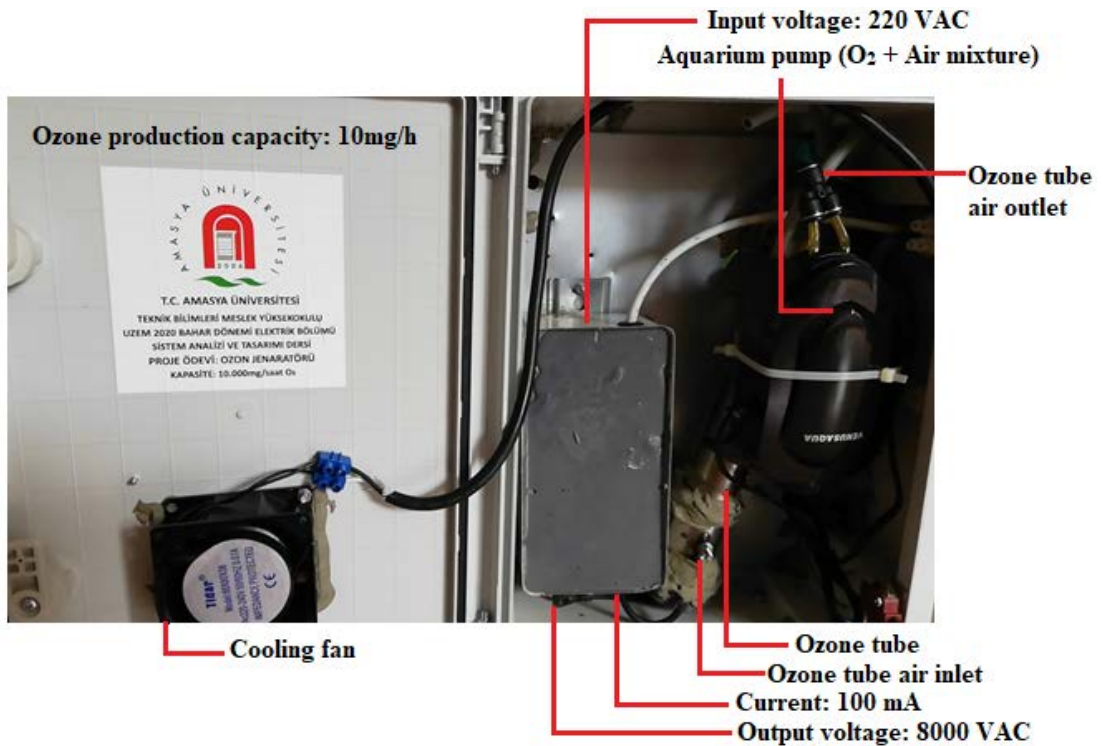


Fig.6. View of the internal equipment of the ozone generator

The ozone generator used in this study (see Fig.6) was designed and built in the Technical Sciences Vocational School, Amasya University. The input voltage of the device is 220 volts, the frequency value is 50-60 Hz and it is selected for operation with 100 mA input currents. The supply voltage of the corona discharge tube, boosted by the transformer, was increased to 8000 volts. It is based on the basic principle of applying high voltage so that the corona discharge can generate ozone gas.

### 3.2.Properties of Ozone Gas

When molecular oxygen (O<sub>2</sub>) and free oxygen radicals react, an ozone molecule (triatomic) is formed. The ozone molecule has a characteristic pungent odor [2] and is a blue colored gas when it is produced from dry air at normal temperature. But when O<sub>3</sub> gas is made from oxygen

with high purity, it has no color. Regardless of the source of production, many industries that use ozone do not recognize color for gas concentrations. It has a higher redox potential (ORP = 2.07 mV) compared to chlorine (1.36 mV) and hypochlorous acid (1.49 mV), but lower than fluorine (3.06 mV) [3, 4].

**Table 2.** Ozone Properties.

<b>Property</b>	<b>Ozone</b>
Molecular Formula	O <sub>3</sub>
Systematic IUPAC name	Trixygen
Molecular Weight	48 g.mol <sup>-1</sup>
Color	light blue
Smell	clothes after being outside on clothesline; photocopy machines; smell after lightning storms.
Boilint Point	-111.3 °C
Density	2.141 kg.m <sup>-3</sup>
Solubility in water (LO <sub>3</sub> / LH <sub>2</sub> O)	0.64 (190 mg.L <sup>-1</sup> )
Dipol Moment	0.53D

Guzel-Seydim et al. (2004) and Ozone Solutions (2007).

**Table 3.** Oxidation power of some oxidizing-disinfectants of drinking water <sup>3</sup>

<b>Oxidant agent</b>	<b>Oxidation Potential, V</b>	<b>Reactive power of oxidation<sup>4</sup></b>
Fluorine	3.06	2.25
Ozone	2.07	1.00
Hydrogen Peroxide	1.77	0.86
Potassium Permanganate	1.49	0.72
Hypochlorous acid	1.49	0.72
Chlorine gas	1.36	0.66
Hypobromous acid	1.33	0.64
Chlorine dioxide	1.28	0.62
Monochloramine	1.16	0.56

<sup>3</sup>At 25 °C, relative to hydrogen electrode. <sup>4</sup>Based on ozone.

### 3.3. Advantages and Disadvantage

The advantages and disadvantages of the ozone disinfection methods recommended for various ozone applications (treatment of wastewater and city water, disinfection of fish ponds, packaging of organic vegetables, fruit and meat products, etc.) are as follows [6,7].



### **Advantages**

- When used against viruses and bacteria, ozone is stronger than chlorine.
- The ozonation process of wastewater and indoor spaces should be short (approx. 10 to 30 minutes).
- Since  $O_3$  is broken down quickly, no harmful waste is generated after ozonation.
- Microorganisms do not multiply after ozonation.
- Since ozone is generated during use, safety problems during transport and handling are minimal.
- The ozonation process increases the concentration of dissolved oxygen in the wastewater.
- Low running costs, only power supply related to the cost.
- It is an environmentally protective and low-cost technology.

### **Disadvantages**

- Long-term inhalation of ozone can lead to throat and respiratory problems.
- Ozone is an unstable gas, so it should be generated in a controlled manner.
- Since it is corrosive in high concentrations (greater than 4 ppm),  $O_3$  should be directed into the destruction chamber after application.
- In the event of a leak, continuous warning in indoor applications requires monitoring with the aid of a sensor.
- Because it is not a stable structure, on-site manufacturing is required.

## **4. Conclusion**

Transformers that are operated with 50 or 60 Hz mains frequency and 230 volts are relatively bulky and heavy. Since the rate of change of the magnetic field strength determines the voltage induced in the windings, a transformer operated at a higher frequency can also transmit more power. With increasing frequency, the speed or the core cross-section (core volume) can decrease without the voltage changing. In switched-mode power supplies, semiconductor switches can be used to generate input voltages for the transformer with frequencies of up to 20 kHz. As a result, the manufacture of light ozone generators using the advantage of power sources with small dimensions makes it possible to use portable ozonation

devices in different areas. Our goal is to further develop this ozone generating device to make it easier to transport and more effective in use.

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