

# Insulator testing set for finding the efficiency in Ozone generator design

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**Abstract:** This paper presents a testing of three insulators namely solid, fluid and gas for choosing the best electric insulators. In order to generate the ozone gas, the insulator must be selected in electrode set. Nowadays, the insulators do not have the optimal test procedure for getting total efficiency. Therefore, in this paper, a design of ozone generator is proposed by using the fundamental of electric field stress. The ozone generator is a coaxial cylindrical electric type that has solid insulator in center of glass tube. This solid insulator will be dielectric among the high voltage electrodes. Ozone gas will generate in this air gap. This paper also focuses on the insulator testing of three insulators. It will find the efficiency of 3 insulators and compares them with the density and stress of ozone gas. The experimental results show the performance and ensure the optimal ozone generator design.

**Keyword:** electrode, electric field , dielectric , ozone

## 1 INTRODUCTION

The ozone is an active modification of the oxygen. It has clear blue color and spicy odor, it is more soluble in water and much more active than the oxygen, it is considered the more powerful oxidant over the earth and it has a lot of applications mainly in sanitation, salubrity and contamination. Due to its chemical properties, it is used as a disinfectant and germicidal. It is employed in air and residual water treatment, deodorization, oxidation process, dental medicine, etc. An important property of the ozone is the absence of toxic substances as a result of its application to disinfect water or other substances, by this reason is commonly used by purification and deodorization industry. The principle of operation of ozone generator consists to apply a high voltage between two parallel plaques with air inside, the high voltage produces the phenomenon know as silent discharge or corona effect. The silent discharge produces ultraviolet radiations that break the oxygen molecule producing ozone. It is important to avoid the arc discharge to maintain the silent discharge, which is obtained adding a dielectric between the air gap and one of the electrodes.

The ozone generator uses the high voltage for generating the ozone gas. So this paper proposed the testing of dielectric insulator to protect the high voltage phenomena and fine the efficient of each insulator. The

insulator that is selected is the best insulator for designing the ozone generator. There are two procedures that is given for generating ozone gas in this paper. First the aim of high voltage generation and second is the insulator testing. The three types of insulator named solid, liquid and gas are selected to be the dielectric. The shape of ozone tube is also designed in the world wide standard.

The rest of this paper is organized as follows: Section 2 presents the design process of insulator testing set. The dielectric losses are measured by using C-tan $\delta$  meter Tettex AG 2805 by Haefely Trench Laboratory. The basic equations are also given in this section. Section 3 presents the simulation results by using FEMLAB program. The experiment results are shown in Section 4. Finally Section 5 is given the discussion and conclusion.

## 2 DESIGN PROCEDURE

Design of the insulator testing in order to generate the electric field and calculate the model of electrode is proposed. It is necessary to calculate the electric filed in testing set for comparing the ozone gas volume. First it needs to find out the capacitance and measures by using the C-tan $\delta$  meter Tettex AG 2805.

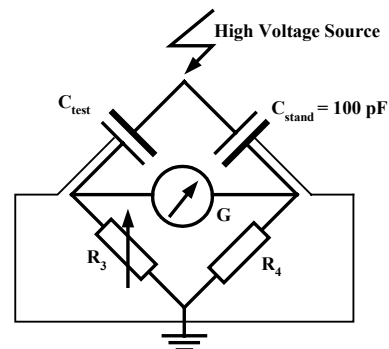


Fig. 1: Circuit test of C-tan  $\delta$

Fig. 1 shows a circuit test of C-tan $\delta$  to find the capacitance and dielectric loss where  $C_{test}$  is the capacitance of tested insulator,  $R_{test}$  is the equivalent resistance in tested insulator,  $C_{stand}$  is the standard capacitance,  $R_3$  and  $R_4$  are variable resistor that has no inductance characteristic and  $G$  is sensitive meter for balancing the circuit.

Electric field is in the three-layer of insulator calculated by using basic electric field of  $E = U/d$  because the electric field uses the relation of  $D = \epsilon E$  and the alternative current electric field, therefore, the capacitance in D will be constant and insulator placement is like the capacitor in series connection. The capacitance can be calculated as follows:

$$Q = CU \quad (1)$$

$$Q = C_1U_1 = C_2U_2 = C_3U_3 \quad (2)$$

Where  $C_1$ ,  $C_2$  and  $C_3$  are the capacitance of insulation layer that have  $\epsilon_1$ ,  $\epsilon_2$  and  $\epsilon_3$ , respectively. The capacitances depend on as follows:

$$C_1 \approx \frac{\epsilon_1}{d_1}, C_2 \approx \frac{\epsilon_2}{d_2}, C_3 \approx \frac{\epsilon_3}{d_3} \quad (3)$$

$$\frac{U_2}{U_3} = \frac{C_3}{C_2} \quad (4)$$

$$Q = C_1U_1 = C_2U_2 = C \quad (5)$$

Where  $C = \epsilon A/d$ , the capacitance  $C_1$  is the oil at 1 cm,  $C_2$  is the plastic at 1 cm and  $C_3$  is air at 2 m.

When the copper is used to be the electrode that has diameter at 128 mm. therefore, we can find the capacitance from the equation above as follows:

$$\begin{aligned} \phi &= 12.8 \text{ mm} \\ A &= \pi r^2 = 0.05147 \text{ m}^2 \\ \epsilon &= \epsilon_0 \epsilon_r \end{aligned} \quad (6)$$

According to  $\epsilon_r = 1.0$  [2]

$$\epsilon = 8.854 \times 10^{-12} \text{ F/m} \times 1.0 = 8.854 \times 10^{-12} \text{ F/m}$$

From equation (2),

$$\begin{aligned} C &= \frac{8.854 \times 10^{-12} \text{ F/m} \times 0.05145 \text{ m}^2}{0.04 \text{ m}} \\ &= 11.39 \text{ pF} \end{aligned} \quad (7)$$

Where  $\epsilon$  is material permittivity,  $\epsilon_0$  is air permittivity of  $8.854 \times 10^{-12} \text{ F/m}$  and  $\epsilon_r$  is relative permittivity



Fig. 2: dielectric capacitance meter

Table 1 shows the value of capacitance of the electrode that have relative humidity of 38 g/m<sup>3</sup>, temperature 33 °C, air pressure 760 mm.Hg at gap distance 2 cm, acyclic insulator 1 cm and oil 1 cm.

Table 1: Measured capacitance for three insulators.

order	U <sub>t</sub>	d	f (Hz)	C <sub>test</sub>	Tan δ	Loss (mW)
1	40	4.0	49.9	32.3635	8.845*10 <sup>-4</sup>	62.12
2	40	4.0	49.9	33.4152	9.112*10 <sup>-4</sup>	61.23
3	40	4.0	49.9	31.8523	9.248*10 <sup>-4</sup>	63.82
1	50	4.0	49.9	31.2365	9.418*10 <sup>-4</sup>	71.85
2	50	4.0	49.8	33.4123	9.261*10 <sup>-4</sup>	70.74
3	50	4.0	49.8	32.5237	9.362*10 <sup>-4</sup>	72.64
1	60	4.0	49.8	31.8956	8.952*10 <sup>-4</sup>	83.18
2	60	4.0	49.8	32.4512	9.142*10 <sup>-4</sup>	84.54
3	60	4.0	49.8	32.6523	9.437*10 <sup>-4</sup>	84.52

### 3 ELECTRIC FIELD SIMULATION

From the design procedure, it can illustrate the electric field by using commercial program named FEMLAB version 3.1 that calculated with the finite element method. Fig. 3 and Fig. 4 show the voltage and electric field that occurred at the electrode. It can be noticed that the high voltage occurred around the electrode and the electric field is also high density at the electrode.

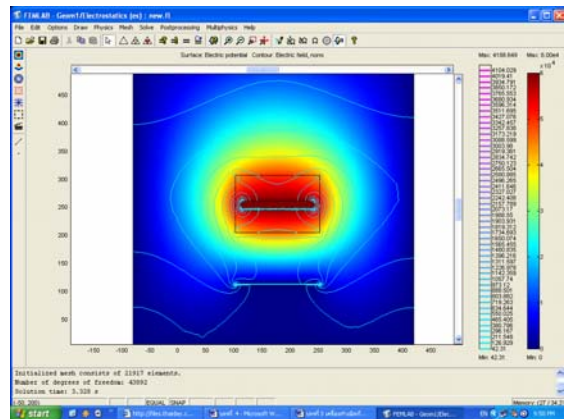


Fig. 3: Voltage level at electrode

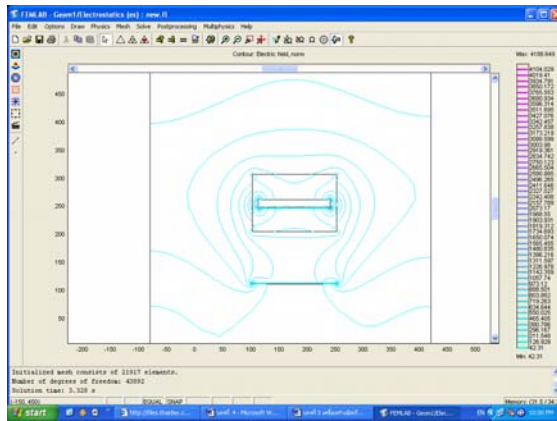


Fig. 4: Electric field at electrode

Table 2 shows the electric field that calculated by FEMLAB. The electric field at air insulator is highest when compared to each others. The three layer of insulator can get the lowest electric field.

Table 2: Electric field that calculated by FEMLAB 3.1

V Level (kV)	Electric field (kV/cm)			
	air 2 cm	Oil 1 cm + air 2 cm	Acyclic 1 cm + air 2 cm	Three layers insulator
10	6.061	2.341	1.960	1.532
20	8.935	3.076	2.309	1.954
30	10.143	3.627	2.744	2.527
40	12.561	3.810	3.441	2.919
50	14.239	4.086	3.877	3.680
60	15.923	4.453	4.226	4.100

#### 4 EXPERIMENT RESULTS

An analysis of ozone generation by measuring the gas volume with the ozone meter named Teledyne API Model 450H O<sub>3</sub> Monitor from United State. Table 3 shows the ozone gas values of three insulators.

Table 3: Ozone gas values for three type insulators

	Ozone gas (ppm)			
10	19	14	11	8
20	30	19	18	12
30	35	29	22	19
40	40	35	23	21
50	BD.	41	28	22
60	-	BD	34	24

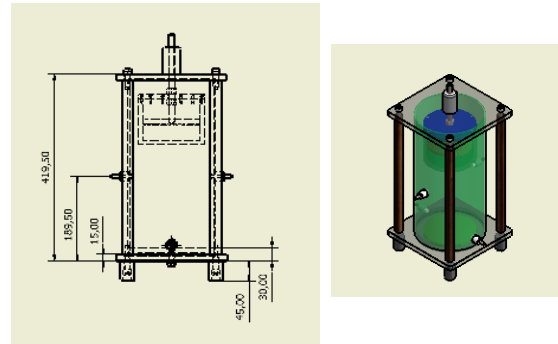


Fig. 5: Insulation testing



Fig. 6: Set-up of insulation testing with ozone meter

The most experiments were done with a 50-Hz power supply. The prototype was set at RMUTT high voltage laboratory. In table 3 when we increased the voltage level the amount of ozone gas will be increased in PPM. The gas (air) and oil is the good insulation.

#### 5 CONCLUSION

Testing of electrical insulation for find the efficiency of the ozone generator is proposed in this work. The three types of insulator are selected named solid, oil and air. In order to use the insulator as dielectric among electrode for generating the high voltage level, the air is the best insulation for ozone generator applications. However, for this research, the oil insulation can produce the ozone gas highest when compared to each other.

## 6 ACKNOWLEDGEMENT

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## 7 REFERENCES

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