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Experimental Studies on Corona Discharge Ionization

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Abstract: *This study investigates the possibility of corona discharge ionization technique for reduction of fog. For corona discharge ionization a high voltage power supply is designed and developed indigenously. The high output voltage is developed by using isolation transformer, autotransformer, and high voltage neon transformer and it is converted into DC voltage by using Wheatstone bridge circuit and high voltage capacitor. Formation of negative corona, positive corona and voltage-current characteristics of corona ionization was studied. By selecting -9 kV voltages to discharge electrode, the performance of this circuit was tested for removal of fog, Fog was generated by using ultrasonic water fogger collected in closed glass container. Various runs were carried out. The light intensity was measured for each run as a function of time, in presence and absence of the discharge. After continuous operation of device for 6 minutes, 90% to 95% of the aerosols were removed from container in addition to the natural decay effect.*
Keywords: *Corona discharge, High voltage, Ionization of Air, Positive Corona, Negative Corona*

I. INTRODUCTION

Fog is a weather phenomenon where in tiny water droplets suspended in the vicinity of the earth's surface cause a reduction in visibility. The poor visibility leads to severe disruption and delay in rail, road and air traffic, causing great economic loss [1]. Fog along with other pollutants is responsible for reduction in agricultural yield considerably. It is essential to search for solution for fog dispersal. Hence it is needed to have detailed information about the optical nature of fog particulate system (water droplet + fog condensation nuclei), leading to poor visibility. Atmospheric fog is composed of sub-micron size range up to tens of micron [2]-[5].
Daniels (2002) reported that negative air ions (NAIs) reduce aerosol particles, airborne microbes, odors and volatile organic compounds (VOCs) in indoor air [6]. The particle removing mechanisms by NAI is due to particle charging by emitted ions and electromigration which increases migration velocity of particles [7]-[9]. Several studies have been conducted for particle removing efficiency using ionic cleaners to remove particles from the air [10]-[12]. Ozone in troposphere levels is highly poisonous for plants and animals and the high voltage used for corona discharge, produces Ozone above threshold voltage of 16000 volts [13]. Hence precaution is to be taken to avoid Ozone production which is an air pollutant at ground level that can be harmful to breathe and damages crops, trees and vegetation [http://www.epa.gov/oar/particlepollution]. Several studies have been conducted for particle removing efficiency using ionic cleaners to remove particles from the air. Removal of the atmospheric pollutants such as suspended particle, pollutant gases CO, NO_x and Volatile organic compounds is urgent need of the future to control air pollution[14]-[18]. The Oxygen ion production using corona discharge is powerful tool for removing effect of above pollutants along with removing suspended biological species.

In this paper we present construction of corona discharge instrument with experiment on fog and its removal by using corona discharge ionization.

II. METHODOLOGY

2.1 Design & Testing

High voltage power supply layout used in corona discharge ionization instrument is shown in "Fig.1". The ac mains supply is connected to an isolation transformer which isolates the high voltage side from the line. The output is connected to a autotransformer that supplies the input to neon transformer. The neon transformer output (variable output of 0-15 kV) is connected to a bridge rectifier configuration. Total 52 diodes are used and each arm consists of 13 high voltage diodes. High voltage epoxy/resin combination is used surrounding to the diode chain and resisters to avoid shorting of the components in any weather condition. The rectified output is filtered and stored in a large 1 μF capacitor. The diode terminals and connections have covered with a thick layer of silicon sealant to prevent arcing or corona discharge. The capacitor used for the power supply circuit has a rating of 1 μF ±10 % at 50 kV dc. The voltage across the capacitor is measured with a high resistance voltage divider with 100:1 input to output ratio by a high input impedance digital voltmeter. All high voltage components, switches, plugs, meters are mounted on non-conducting polycarbonate sheet.

Neon transformer of 15 kV, 450VA rating will deliver a maximum dc voltage of about 21 kV and a maximum possible current flow of 30 mA. High voltage power supply is designed to achieve any polarity at the output.

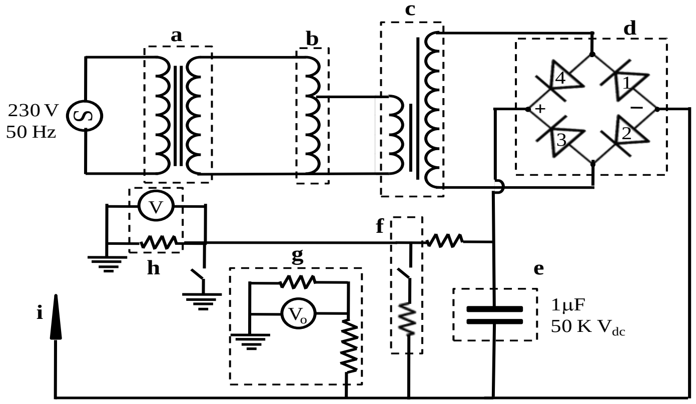

Fig.1. Schematic layout of the power supply a) isolation transformer b) autotransformer c) neon transformer d) bridge rectifier e) high voltage capacitor f) capacitor discharge system g) high voltage measurement system h) current measurement system i) discharge electrode

Qualitative record of corona formation result was tested shown in “Table 1” and voltage-current characteristics of positive and negative corona shown in “fig. 2”. For the electrode made negative, there was no corona visible up to 9.5 kV. At 9.5 kV one glowing spot of corona was visible on the sharp edge of the discharge electrode. As the voltage was increased, two corona spots became visible on the sharp edge at 10 kV. At 11 kV, there were four corona spots visible. At a little over 11.5 kV, a loud arc shot across the electrode to the ground. The corona is seen as bluish-white spots on the tip of the sharp edge of the electrode.

TABLE 1 CORONA TEST RESULTS

Negative Corona		**Positive Corona**	
Voltage	Effects	Voltage	Effects
9000V	Nil	4500V	Spots of corona
9550V	One corona spot	6000V	Spots of corona
10000V	Two corona spots, hissing sound.	7000V	Spots of corona
10570V	Two corona spots, hissing sound.	8000V	Spots of corona
11040V	Four corona spots, Strong hissing.	9000V	Spots of corona
11555V	Loud Arc shot once, Power supply cut off	10035V	Loud Arc, power supply cut off.

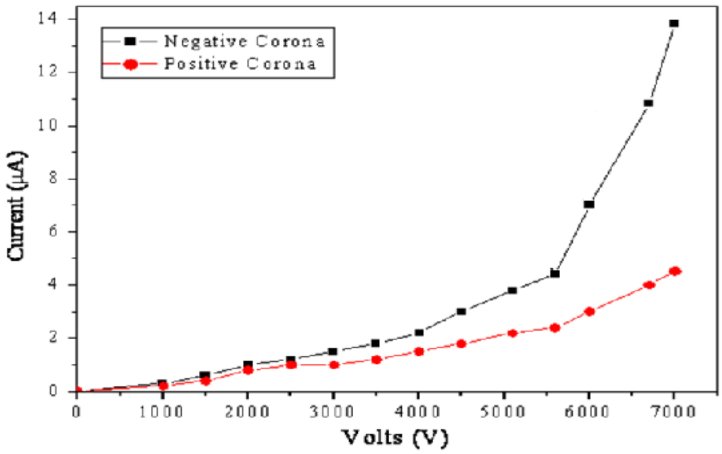

Fig. 2 V-I Characteristic of corona ionization

For the positive corona tests, the electrode was made positive with respect to the ground, there was strong hissing sound and smell of ozone in the air; however, there were no visible corona up till the arcing at about 10 kV. It was observed that arcing occurred at a lower voltage for positive corona. It is important to keep the HV level high enough to generate sufficient ion current but low enough to prevent the production of ozone (which can be dangerous for people who suffer respiratory difficulties). From these results, it is desired to select -9 kV voltages to discharge electrode to test the performance of this circuit for removal of fog collected in closed glass container.

2.2 Experimental procedure

Photograph of experimental set up is as shown in "Fig.3". For this an unventilated glass container of size 72 cm^3 is used. A Helium-Neon Laser of 2mW, 633 nm wavelength light source was used. Visibility was measured in terms of light intensity using light meter (lux) model LX – 101A of Lutron. The detector and other electronic equipments were placed at the other end of chamber. Fog was generated by using Ultasonic water fogger with 230 V adaptor, Teflon coated disc of MainLand Mart Corp. EL mount. CA 91732, U. S. A. The discharge electrode placed inside the container. The light emitted by the source enters the experimental container filled with fog. Before and after concentration of fog light intensity was recorded for every 15 second time interval. Number of runs were carried out as a function of time in presence and absence of corona discharge.

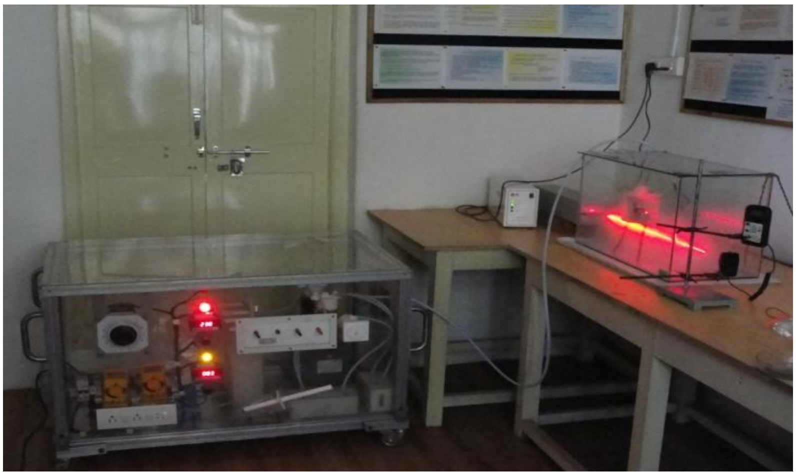

Fig. 3 Experimental setup

2.3 Data Analysis

By using Beer – Lambert's Law data was analyzed

$$I = I_0 \exp\left(-\alpha\, m\right) \tag{1}$$

Where, $\mathbf{I_0}$ - incident light intensity, **I** - observed light intensity, **m** - number of particles and **α** - absorbance or scattering cross section of fog / smoke.

The natural decay of particle concentration was determined as a base line to test for each particulate matter. Prior to the test, particles of different substrates were generated in the chamber. Then the particle concentration decay with negative discharge(NAI) was determined. For each particulate matter (Pm), two concentration decay curves were obtained: the natural decay i.e. when the negative discharge was 'off' [$C_{Natural}$ (Pm, t)], and the one with the negative discharge 'on' [C_{NAI} (Pm, t)]. [12]

The particle removal efficiency was determined as follows:

$$\text{Particle removal efficiency} = \frac{C_{\text{Natural}}(\text{Pm, } t=0) - C_{\text{NAI}}(\text{Pm, } t)}{C_{\text{Natural}}(\text{Pm, } t=0)} \times 100\% \tag{2}$$

III. RESULTS

Particle concentration & particle removal efficiency verses time with natural decay and with negative discharge (NAI) application for fog is shown in "Fig. 3". The particle concentration decay was of the order, natural decay of fog < fog decay with negative discharge application. Particle concentration shows negligible decrease in natural decay process while in presence of negative discharge the particle concentration shows a sudden decrease in the initial 30 to 120 seconds. The curve shows that the decay is highest in case of fog with negative discharge.

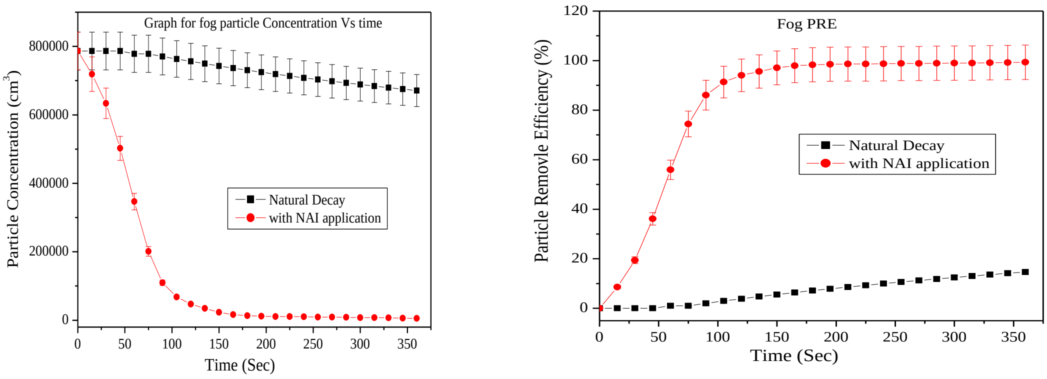

Fig. 3 Particle concentration & PRE verses time with natural decay and negative discharge (NAI) application for fog.

The particle removing efficiency is obtained by subtracting the natural decay from the observed value. After continuous operation of device for 6 minutes, 90% to 95% of the aerosols were removed from container in addition to the natural decay effect.

IV. CONCLUSION

A corona discharge unit was designed and developed indigenously. For negative corona tests, corona was visible at a higher voltage as compared to positive corona. In this study, we concluded that the negative electric discharge can remove the aerosol pollutants such as fog in closed chamber. The particle removal depends on the ion emission rate and the time of emission. The rate of change of particle removal efficiency is highest for fog as compared to smoke.

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