# Application Study of Electrostatic Precipitation with Earthed Atomizing Discharges

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**Abstract:** The comparative researches on both positive- and negative-direct current earthed atomizing corona discharges were carried out, and the influence of water flux on corona discharges was also studied. The experimental results showed that the capture efficiency of negative electrostatic precipitation with earthed atomizing discharges is higher than that of the positive one with earthed atomizing discharges. The reason is probably that the ionization region of positive-earthed atomizing discharges was expanded and more aerosol particles passed through the ionization region, which tended to neutralize the charges on the aerosol particles. In contrast, the expanding ionization region was not existent in the negative-earthed atomizing discharges. In addition, under the condition that the wire discharge electrode is 70 mm in length and 1 mm in diameter, the mean diameter of spraying droplets was larger than 80μm when the water flux was more than 3320 μL/min, while it was smaller than 80μm when the water flux was less than 2280 μL/min.

**Keywords:** Negative-earthed atomizing corona discharge, Positive-earthed atomizing corona discharge, Ionization region

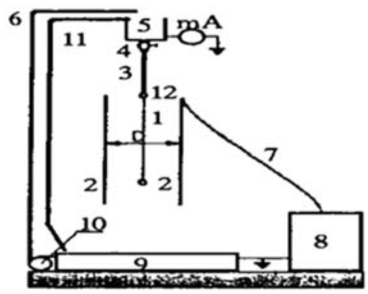
## 1 INTRODUCTION

The technology of electrostatic precipitator was improved by many researchers to satisfy some special requirements. For example, the distribution of the electric field was influenced by changing the electrode configuration to capture dust of wide range [1]. Besides, direct current earthed atomizing corona discharge was an efficacious method to remove viscous dust in diet industry or other industry production. Based on conventional corona discharges, this technology is a combination of electrostatic method and waterish technology, and the collecting electrode in which could be automatically and effectively cleaned [2]. The characteristics of discharge and charging aerosol particles have been primary researched [3, 4]. And in this paper, the research on earthed atomizing corona discharge was further carried out in order to make better usage of this technique.

## 2 EXPERIMENTAL APPARATUS

The experimental apparatus for the electrostatic precipitation of direct current earthed atomizing corona discharges is shown in Fig. 1. The discharge electrode 1 was made from stainless steel wire with diameter 1 mm and the length of the electrode was 700 mm. The discharge electrode 1 was grounded through the tube dividing water 12, soft tube 3, valve 4 and water container 5. The ammeter was connected between the stainless steel water container 5 and the earth, and the water on the discharge electrode flowed down from a hole of the tube dividing water.

The positive- and negative-direct current high voltage discharges were respectively applied for comparing their characteristics in this experiment. The HV plate electrode 2 was connected to HV power supply 8 via the HV cable 7. The HV value was measured by the HV probe from the HV plate electrode 2. The HV plate electrodes of stainless steel were 500 mm in width and 900 mm in height. The HV electrodes were suspended and fixed on the insulating frame. The spacing between the two plate electrodes was adjustable as 60 mm.




1—discharge electrode; 2—HV plate electrode; 3—soft tube; 4—valve; 5—water container; 6—water tube; 7—HV cable; 8—HV power supply; 9—water basin; 10—pump; l1—overflow tube; 12—tube dividing water

**Fig. 1** Experimental apparatus

The water in water basin 9 was pumped to water container 5 via water tube 6 by water pump 10 in the supplying water system, after that the water flowed onto discharge electrode, and then flowed into water basin 9 from both discharge and collecting electrodes. The water flux was controlled by the valve 4 in this process, and the HV insulation was not needed because both discharge electrode and the supplying water system were low Potential.

Though the discharge electrode with a small curvature radius was earthed, the non-uniform electric field could be formed as a result of the induction of HV plate electrode. Therefore, Steady atomizing corona discharges could be produced.

## 3 COMPARATIVE INVESTIGATION ON POSITIVE AND NEGATIVE ATOMIZING

According to the previous studies [2-4], the strong electric field occurs near the surface of the water-wire electrode. And both charge density on water surface and polarization of water molecules are enhanced at the same time, the Surface Stress of water is thus weakened. The electric field produces an electrostatic force, which is outward and perpendicular to the water surface. The electrostatic force is proportional to the electric field strength, therefore, the instability of water surface increases and the Taylor Cone is formed. When electric field is strong enough, the number of filament flows increases and at their ends electrohydrodynamics (EHD) spray phenomenon occurs [5]. And the spraying droplets with diameter 0.02 mm-2 mm are observed in the same condition [6]. When voltage is higher than the onset voltage of corona discharges, besides the mechanism of EHD spray, the water sputtering is also induced [7]. Consequently, atomizing corona discharges are formed on the surface of water-wire electrode.

### 3.1 Influence of Earthed Atomizing Corona Discharges on Ionization Region

When the positive and negative high voltages were respectively applied to plate electrode, the earthed atomizing positive and negative corona discharges were formed. In the atomizing positive corona discharge, when the voltage was unceasingly enhanced from 12 kV, purple weak bright region occurs near the wire electrode. As shown in Fig. 2, both brightness and volume of bright region increased with the voltage. When the voltage reached spark discharge, the edge of bright region expanded to the middle of wire-plate spacing with 30 mm. But this similar phenomenon was not existent in the atomizing negative corona discharge. In the conventional positive corona discharge, the thickness of ionization region is only 1 mm-2 mm near the discharge electrode. However, the thickness of purple bright region could reach 1 cm-2 cm in the atomizing positive corona discharge, and its intensity gradually reduced from discharge electrode to plate electrode. The experimental results and theory analysis showed that this bright region consisted of a lot of droplets under corona discharges. Compared with conventional corona discharges, the plasma region was expanded approximately 100 times in the atomizing positive corona discharge.

In the earthed atomizing negative corona discharge, the voltage at first increased suddenly, and then reduced quickly because steady Trichel pulses was formed in negative corona discharge. As a result, both the energy input and expanding of ionization region were restrained in this discharge mode. On the contrary, steady glow discharges could be formed in conventional needle-plate corona discharges [8]. According to fig.2, the discharge configuration was formed between many cone-jet mode and plate electrode, which was similar with needle-plate configuration. So the condition of glow discharge was formed. In conclusion, there are two probable reasons why the plasma region expanding in the atomizing positive corona discharge. Firstly, the volume of discharge electrode was increased by atomizing. Secondly, the condition of glow discharge was formed.

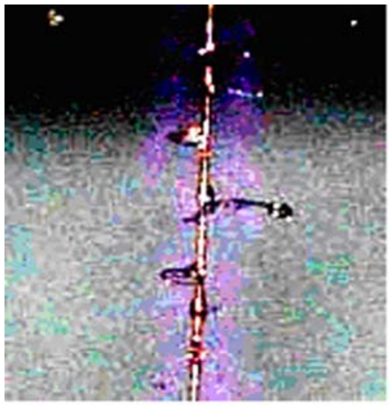


**Fig. 2** Phenomena plasma region expanding in atomizing positive corona discharge

### 3.2 Influence of Atomizing Droplets on Electric Field Distribution

The inception voltages were lower in the atomizing corona discharges than that in conventional corona discharges, and the inception voltage was almost not influenced by inter-electrode distance. So it was supposed that curvature radius of the Taylor Cone tip was smaller than that of wire discharge electrode Therefore, a stronger electric filed could be formed near the Taylor Cone tip. In addition, there are two possible reasons why more space charges accumulated in the inter-electrode region of the atomizing corona discharges. 1) The discharge currents enhanced, and the ionization increased, which thus more space charges in the inter-electrode region; 2) The atomizing droplets moved more slowly, and the individual droplet mass was heavier than that of air molecule, so the charges on the droplets accumulated more easily in the inter-electrode region. Therefore, the enhancement of ionization was restrained by these space charges.

According to the above analysis, the influence of the small curvature radius of the Taylor Cone tip on electric field distribution is in the opposite direction of that of space charges accumulating on the electric field distribution.

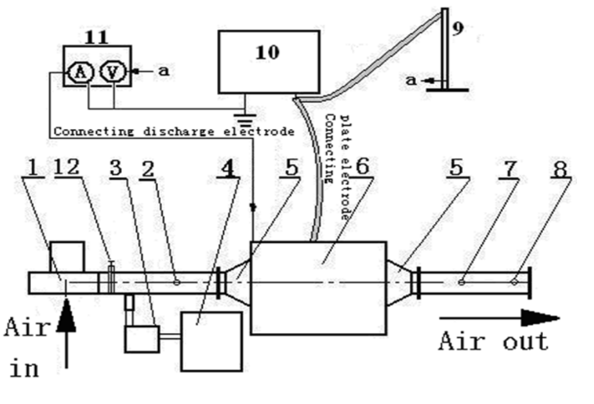
The experimental results showed that the ionization was enhanced in the atomizing corona discharges, which indicated that the electric field was enhanced near the Taylor Cone tip. However, the electric field was weakened far from the ionization region because the voltage was constant between the two electrodes. According to diffusion charging mechanism, it is beneficial to charging fine dust to form a weaker electric field in the charging region. As shown in Fig. 2, the inter-electrode distance was reduced because many cone-jets occurred, which was just another reason why the ionization was enhanced.

### 3.3 Influence of Water Supplying on Atomizing Droplets

In the above experiment, the slide was smeared by the silicon oil, and then it was used to sample atomizing droplets. The diameters of droplets were measured by using microscope. The results showed that the mean diameter of spraying droplets was larger than 80μm when the water flux was more than 3320 μL/min, while it was smaller than 80 μm when the water flux was less than 2280 μL/min. The charge number the unit volume water holding reduced with the increasing of water supply. And the curvature of the water-wire electrode increased with the increasing of water supply, which further reduced the electric field intensity near the water-wire electrode. Therefore, the Coulomb force acting on electriferous water reduced, which directly influenced the volumes of droplets. So the atomizing action was weakened with the increasing of water supply.

## 4 COMPARATIVE INVESTIGATION ON EARTHED ATOMIZING POSITIVE AND NEGATIVE CORONA DISCHARGES AND THEIR REMOVING DUST EFFICIENCIES

The experimental apparatus was shown in Fig. 2. The electrostatic precipitator (EPS) 6 was the wire-plate configuration. The discharge electrode was earthed to form atomizing corona discharge EPS, in which the spacing between the two plate electrodes was keeping at 60 mm, and the curvature of wire electrode was 0.2 mm. The high voltage of plate electrode was supplied by HV power supply 10 via HV cable, and was measured by high voltage divider 9. Controller 11 was used to adjust the high voltage value of EPS. And the currents and high voltages were measured by ammeters in atomizing corona discharges.




1—air compressor; 2—front measure hole; 3—dust container; 4—dust generator; 5—gradual expanding pipe□6—EPS; 7—rear measure hole 7; 8—air velocity measure hole; 9—high voltage divider; 10—HV power supply; 11—controller; 12—valve

**Fig. 3** Schematic of experimental apparatus of capturing aerosol particles with spraying corona discharge electrostatic precipitator

The current experiment was carried out at the room temperature, and the air in the room was absorbed by Air Compressor. The aerosol particles consisted of fly ash, was collected from the rear stage of an EPS in a coal-fired power station. The dust was sprinkled into absorbed air by dust generator 4 and dust container 3 to form stimulant soot. The air velocity could be measured at the air velocity measure hole 8, and the air flow could be controlled by the valve 12. The constant speed sampling technique and weighting method were used in present experiment. At first, the dust concentration was measured before they entered the EPS at the front measure hole 2, and then the dust concentration was measured after they removed from the EPS at the rear measure hole 7. Based on this method, the efficiencies of EPS could be calculated.

When the high voltage of plate electrode was 12 kV, the positive and negative high voltages were respectively applied, and the capturing efficiencies were compared at different air velocities. According to Fig. 4, when the air velocity was close to actual velocity (the air velocity in the electric field of EPS is 0.448 m/s ), the capturing dust efficiency of atomizing negative corona discharge, enhanced from 82.3% to 84.2%, was 11% higher than the atomizing positive one.

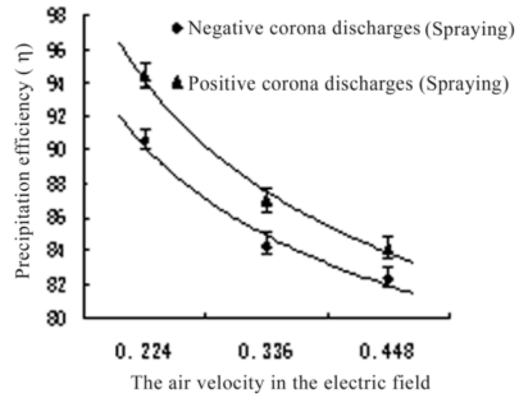



**Fig. 4** Precipitation Efficiency of Spraying Negative and Positive Corona Discharges

The efficiency of atomizing positive EPS was relatively lower. The main reason was that the plasma region expanded in the atomizing positive corona discharges, which will reduce the efficiency of the dust charging [9]. Thus, its capturing efficiency was reduced. The ionization region expanding phenomenon, however, was not observed in the atomizing negative corona discharge with the applied voltage enhanced.

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