

# Study on Charging Particles of Magnet Enhancement Corona Discharges<sup>1</sup>

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**Abstract:** In this paper, the characteristics of the magnet enhancement corona discharges and their function for charging particles are introduced. The experimental results demonstrated that the magnet field could obviously increase the discharge current and enhance the particle agglomeration in corona discharges. The deflection of free electrons between the discharge and collection electrodes was measured. Therefore we can deduce that both the energy of free electrons and the concentration of free electrons and ions are increased in the magnet enhancement corona discharges. Comparing with the uniform magnet field, the uneven magnet field formed by the permanent magnet nearby the discharge electrodes can more effectively intensify corona discharges. We developed an aerosol charger of the magnet enhancement corona discharges with permanent magnet. The charging current was increased by 25% in a magnet field of 0.02T.

**Keywords:** Corona discharges, Magnet enhancement, Charging particles

## 1. Introduction

In recent years, more and more countries begin limit the emissions of micrometer and sub-micrometer particles. The process of electrostatic precipitation depends on the force acting on charged particles in an electric field. The more the charges on a particle are, the greater the force is. It is important to increase the charges on the fine particles, in order to improve the capture of the particles.

The most effective approach for increasing charges on fine particles in corona discharges is to enhance the ion diffusion charging mechanism and the electron charging mechanism. When the energy and the density of free electrons increased, not only the charging mechanism of free electrons is enhanced, but also the density of ions is raised. About 15 years ago, researches on the charging particles of free electrons under short (sub-microsecond) pulse high voltage started in the world<sup>[1]</sup>. According to the researches of author in recent yeas, increasing fine particle charges under short pulse high voltage is limited<sup>[2]</sup>. The short pulse power supply of high power is difficult to make and the charging time is too short. In addition, the short pulse discharges are different from the traditional pulse corona discharges with the pulse width longer than 10  $\mu$ s. During short pulse discharges, non-thermal plasma leads of streamer discharges almost fill in the whole interelectrode space, which would neutralize charged particles and decrease the charges on the particles. Even if in negative short pulse discharges, a great deal of energy consumption only can increase a few charges on the particles.

In recent years, we did some researchers on the magnet enhancement corona discharges and the function for changing particles<sup>[3]</sup>. In our researches, free electrons were deflected in a magnetic field and traveling lengths of the free electrons was greatly increased. The electron energy was enhanced and the densities of both the electrons and negative ions were increased. Moreover, a power supply was employed for ordinary direct current high voltages and the discharging time was continued. Therefore, the magnet enhancement corona discharges can serve as an advantage charging technique and will be promising in the applications. The experiments on removal of harmful gases in the corona discharges with a crossed magnetic field were also reported<sup>[4]</sup>.

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## 2. Discharge characteristics of magnetic enhancement corona discharges

### 2.1 Experimental apparatus

The electrodes configuration of the experimental apparatus for the magnet enhancement corona discharges is shown in Fig. 1.

The effective discharging length of a stainless steel wire electrode 4 was 45 mm and the diameter of the wire was 0.5 mm. Two strings of the permanent magnets 5 had a cylinder shape and 10 mm diameter. The strings of magnets were respectively assembled at each end of the wire electrode. The magnetic flux density near the wire electrode could be changed by increasing or decreasing the length of the magnet strings. The spacing between two magnet strings was 50 mm. The joint of the magnet strings and the wire electrode was formed with an arc shape, in order to prevent the discharges of the magnet string edge. The wire electrode was settled in the symmetric center of the two stainless plate electrodes 3, which were 200 mm in both width and height. The spacing between the plate electrodes could be adjusted from 30 to 100 mm. The directions of the magnetic force lines were approximately perpendicular to the directions of the electric force lines. The wire electrode situated the upper part of the plate electrodes, in order to insure all the spraying droplets running to the plate electrodes. In the upper end of the wire electrode connected with a syringe. The water was supplied by a water bottle 2 to wire electrode through the syringe. The water flow rate could be controlled by a valve 6. High-voltage power supply 1 could provide 0-50 kV positive or negative DC high voltages. The wire electrode, magnets, water tube and the water bottle composed an electric potential system, while the two plate electrodes composed another electric potential system with opposite electric polarity. When two plate electrodes were grounded, the apparatus produced traditional corona discharges. When two plate electrodes connected with high voltage power supply, the corona discharges with grading discharge electrodes were produced.

Figure 1 also shows the circuit diagram of the experiment for the corona discharges with a grounded negative discharge electrode. Between the negative discharge electrode and grounding wire there were two ampere-meters, which had different measurement ranges. One ampere-meter was to measure the corona onset voltage and another was to measure the discharge currents. We could read the HV value of the power supply using a HV divider. Between the ampere-meters and the grounding wire there was a shielding line, which could avoid the interference of the high-voltage electromagnetic noise to the corona currents.

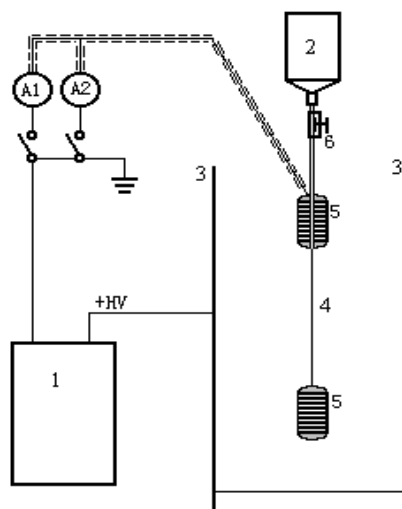


Fig.1 Schematic of experimental apparatus for the magnet enhancement corona discharges

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|----------------------|------------------|--------------------|
| 1. H.V. power supply | 2. Water bottle  | 3. Plate electrode |
| 4. Wire electrode    | 5. Magnet string | 6. Valve           |

Figure 2 shows the magnetic field distribution between discharge and collecting electrodes, when the mean magnetic flux density is 730 Gauss. In the line connecting the centers on the circle surfaces of two magnet strings, we take six points and respectively measure their magnetic flux densities. The average value of the six values is defined as the mean magnetic flux density of the whole magnet field.

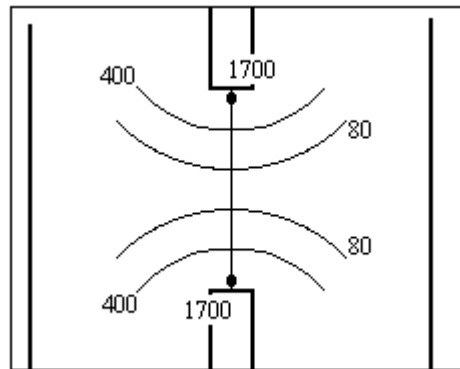


Fig. 2 The interelectrode distribution of magnetic flux density (Gauss)

## 2.2. Magnet enhancement to negative corona discharges

The circuit diagram is shown in Fig. 1. The wire electrode was grounded through ampere-meters and the water bottle did not supply water. When the power supply applied positive high-voltage to the plate electrodes, dry negative corona discharges with grounding discharge electrode occurred along the wire electrode. The I-V characteristics curves of the corona discharges in different magnetic fields are shown in Fig. 3. The star signs indicated the HV values of the spark-over discharges.

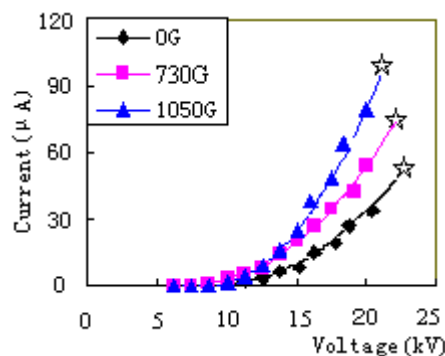


Fig.3 The I-V characteristics curves of positive HV and negative corona discharges in different magnetic fields

It can be seen from Fig. 3 that the discharge current was greatly increased, when the magnetic field was increasing. When the average magnetic flux density increased from 0 to 1050 Gauss, the increment of the current reached 120% or so. In an experiment, a cylindrical electromagnet with 900 Gauss inner magnetic flux density was adopted and the discharge current increased only 10-20%. It can be demonstrated that the enhancement of the magnetic field near the wire discharge electrode has a significant influence on the increment of the discharge current.

The charged particles are obliged to move along the electric lines of force because of the Coulomb force in the electric field. If the magnetic force lines were crossed with the electric force lines, the charged particles would receive a Lorentz force. The component motions of the particles along the electric force lines did not change and another component motions surrounding the wire electrode occurred. As a result, the velocities of charged particles were increased. The deflection motions of the charged particles made the traveling lengths between electrodes prolonged, which are beneficial for charging particles. The traveling length increment of the particles in the region beyond ionization zone did not obviously change the current, because the component motions of charged particles along the electric force lines did not change in the region. However, in the ionization zone near the wire electrode

the increment of the magnetic field could significantly increase the energy and the traveling length of the electrons. The electron avalanche process was greatly enhanced as well more free electrons and ions were produced. Therefore the discharge current increased greatly.

In figure 1, the high-voltage power supply was switched for supplying negative high-voltage and wire electrode was connected to the negative HV. The traditional negative corona discharges occurred. Figure 4 shows the I-V characteristics curves of the corona discharges in different magnetic fields.

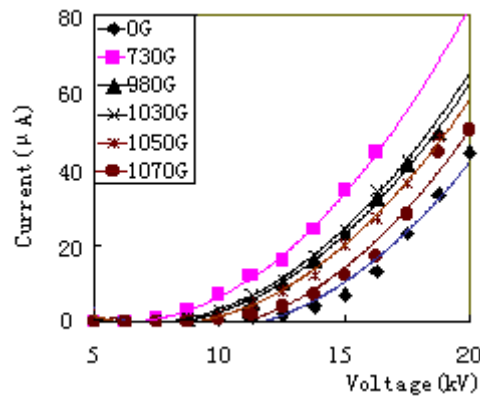


Fig.4 I-V characteristics curves of the negative corona discharges in different magnetic fields

Fig. 4 indicates that with the increment of the magnetic field, the discharge current increases rapidly at first but then gradually reduces. In the experimental apparatus of traditional negative corona discharges, the potential of place between two plate electrode edges was similar to that of plate electrodes, which was almost earth potential. When magnetic field was increasing, not only the discharge current enhanced but also the more ions and electrons were deflected out the plate electrodes. The ions and the electrons could not be detected by the ampere-meters and entered into earth directly. Therefore the discharge current appeared to increase at first and then reduce. As to the experimental apparatus adopted by Fig. 3, the potential of positive high-voltage collecting electrode was much higher than the surrounding ground potential. Therefore all the ions and the electrons fled into plate electrodes at last and were measured by the ampere-meters, although they had been deflected near the discharge electrode. From Fig. 4 we can find that about 2/3 to 4/5 of ions and electrons were deflected out the plate electrodes, when the magnet fields were 730 Gauss to 1070 Gauss. The mass of an electron is much smaller than that of a negative ion and their charges are the same. The electron velocity is about 3 orders of magnitude higher than ion in the same electric field. As a result the electrons can receive much larger Lorentz force than the ions and the electron deflection from the electric force lines are much greater than that of the ions.

### 2.3. Influence of magnetic field on spraying corona discharges

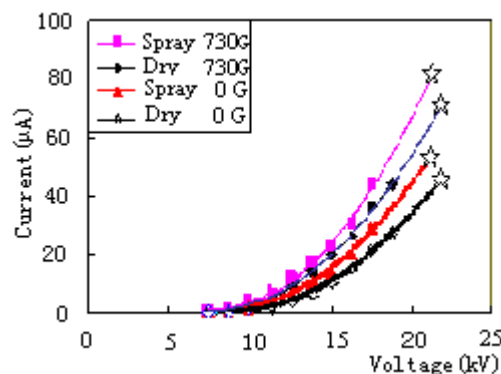


Fig.5 The influence of magnetic fields on spraying corona discharges

The precipitation techniques of spraying corona discharges with the discharge electrodes of ejecting saturated water steam or grounding were developed by author in recent years <sup>[5][6]</sup>. As a result,

not only the efficiency of gas purification can be improved, but also the difficulties of traditional precipitation can be solved. The influence of magnetic fields on spraying corona discharges was researched in this paper.

In the apparatus indicated by Fig. 1, water was supplied to wire electrodes by a bottle with a 40 ml/min flow rate and spraying discharges were formed. The apparatus was used for spraying negative corona discharges with grounded electrode. When the spacing between two plate electrodes was 70 mm and magnetic flux density was 730 gauss or without magnetic field, we respectively measured the characteristics curves when the corona discharges were dry or spraying. The measured results were shown in Fig. 5.

It can be seen that the magnetic fields had the same enhancement function in both the dry and the spraying corona discharges. This shown that the energy of free electrons as well the concentration of free electrons and ions were increased too by magnetic field in spraying discharges, although water molecules has higher attachment coefficient of free electrons.

Fig. 6 illustrated the changes of the spraying droplet size distribution, when magnetic flux density was 730 gauss or without magnetic field in spraying negative corona discharges with grounding electrodes. In this experiment, we employed tap water for spraying. The droplet samples were taken by the sheet glass covered with silicone oil. The sizes of the droplets were measured by a microscope and the size distribution was computed by a statistics method. The influence of the magnetic field was obvious. The numbers of bigger droplets increased, while the numbers of smaller ones decreased. The results demonstrated that, the agglomeration of fine sprays was greatly enhanced by magnetic field in corona discharges.

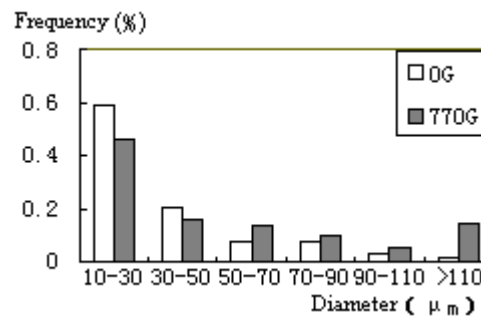


Fig.6 Comparing of size distribution in different magnetic fields

### 3. Charger of magnet enhancement corona discharges

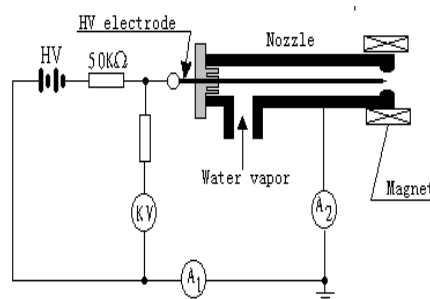


Fig.7 Schematic of experimental system of the charger

Adopted magnet enhancement corona discharges, a new kind of aerosol particle charger with low-pressure saturation steam was developed by us. The schematic of the charger is shown in Fig. 7. In this charger, the H.V. insulation employed both the distilled water and saturation steam, which is usually available from coal-fired boilers. The saturation steam with low pressure (0.2-0.3Mpa) was ejected from a hole of nozzle with the diameter of 6-10 mm. A needle electrode was supplied by 10kV negative HV and the corona discharges formed near the tip of needle electrode. The magnetic field

confined the energetic electrons and the corona region along with the axis of the hole. Electrons moved spirally, taking the magnetic force lines as the axes of the spires. Therefore, the near corona region was enlarged and prolonged out from the hole. The charges on the ejected droplets were increased in the magnetic field. The ejecting electric current with a magnetic field of 0.02T increased 25% than that without any magnetic field.

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