New Corona Charging System For Low Cost Printers

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Abstract

Upon accepting an invitation from Aetas Technology Incorporated to help develop a small, low cost charging system to charge a photoreceptor in a xerographic full color printer, we designed a charger by connecting an AC corona voltage to the coronode through a high voltage capacitor. In this manner, the capacitor will automatically bias itself to whatever voltage is needed to ensure equal positive and negative corona currents from the wire. The corona wire was partially surrounded by a conducting channel shield biased to the desired asymptote DC potential. The connection through the self-biasing high voltage capacitor produced I-V curves that were concaved downward. This proved to give profound advantages of a more definitive asymptote, and hence better charging uniformity, as well as higher efficiency, permitting higher process speeds.

Introduction

Aetas Technology Inc. requested our help to develop a small, low cost, reliable, low maintenance system for charging a photoreceptor in a xerographic full color printer. It was also a goal that ozone generation should be low compared to existing corona charging means for xerographic printers. In addition, the system must charge a photoreceptor uniformly to its optimum potential at a rate of 10 cm/second through at least 100,000 prints without maintenance.

Concept I - DC Biased AC Corona Unit:

Initially we conceived of a system based on a DC biased AC corona wire. We hoped we could use insulating supports of the coronode, and might use insulating shields, too. Support means could actually contact the corona wire, preventing singing and sagging of the corona wire. We felt the insulating support surfaces would charge to or near the DC voltage that we applied to the AC coronode, and serve as a reference potential to drive ions to the photoreceptor, charging it to that same reference potential.

Various Geometries of Insulating Support Means:

A 50 μm corona wire was attached to various insulating supports, such as 1) an insulating commercial printing screen, 2) an insulating threaded rod, and 3) an insulating block of ridges and grooves, hoping to force a regular periodic pattern to the "hot spots" of negative corona, reducing overall non-uniformity of its output.

Procedures:

DC voltages were applied to the AC coronode, and currents, (I_p) to a grounded bareplate were measured over a range of DC biases, (V_c), on the AC coronode voltage. Data were plotted I_p, vs. V_c for AC coronode voltages of 7kV to 9.5 kV $_{(p\text{-}p)}$ at a frequency of 2 kHz, and spacings (coronode-to-plate gaps) of 3.0 and 4.5 mm were explored. The DC bias was applied to the AC corona wire over a range from +600 to -600 volts. Wire diameters of 25 to 89 μn were tested.

Results:

Coronode wires less than 50 μm diameter were too fragile, whereas wires greater than 75 μm diameter required higher AC voltages and closer spacings in order to deliver the necessary charging current, which too frequently caused arcing to the bareplate, burning out the corona wire and / or damaging the support structure. Further testing was confined to 50 μm diameter corona wire. All of the I-V data from these configurations produced curves that were concave upward, as typified by Figure 1.

Conclusions:

Such curves are undesirable, producing prolonged charging times and erratic asymptote voltages. Therefore, we limited further studies to freely suspended coronodes, exploring other factors that might contribute to more rapid charging to dependable and uniform asymptote.

Concept II - Capacitively Connected AC Coronode with DC Biased Reference Electrode:

It became clear that the concave upward I-V curves result because as negative potential on the bareplate grows, negative corona ionization is suppressed. That led to the decision to supply the AC corona voltage through a high voltage capacitor in order to ensure that equal amounts of positive and negative ionization would be generated. The connecting capacitor from the AC power supply would bias itself to whatever potential was needed to equalize negative and positive corona output. The capacitor need not withstand the peak voltages reached by the applied AC potentials; only the peak voltage minus the ionization threshold would be impressed across the capacitor. To be safe, we used pairs of low cost capacitors rated at 3kV, connected in series, to reduce the voltage across each by one half. A 50 µm diameter blue-black oxidized tungsten wire proved most uniform in corona output over long periods of time, and was also easier to handle without kinking, so this was used in all of the following tests.

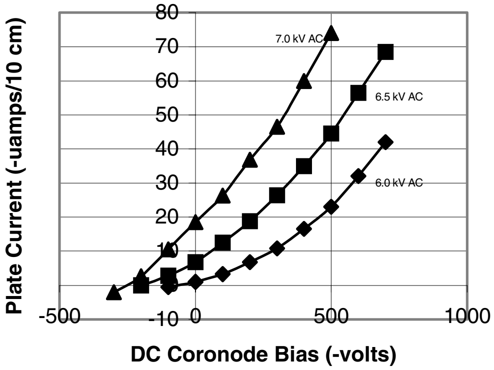

Figure 1. Plate current for DC biased, AC corona configuration

Parametric Studies:

Corona Wire Supported Midway Between A Reference Electrode and the Bareplate:

Procedure

Using a coronode connected through a capacitor as shown in Figure 2, data were taken of bareplate current vs. shield voltage for various AC voltages on the wire coronode. The resulting I_p vs. V_{sh} curves are plotted in Figure 3.

Results

The I-V curves were not concave upward as with the previous experiments; they were now concave downward. This not only ensures that the point of zero current is better defined, but for a given starting current, it will take less time for the photoreceptor voltage to reach its asymptote surface potential.

Discussion

The discovery that a capacitive connection of the AC voltage to the wire coronode produces a *concave downward I-V curve has profound significance for charging uniformity, greater efficiency, and therefore less ozone generation*. Even though points of higher ionization ("hot spots") are still evident, they will charge the plate faster, but will equilibrate at the same asymptote of surface potential. This capacitively connected charging unit was named the "*Capatron*".

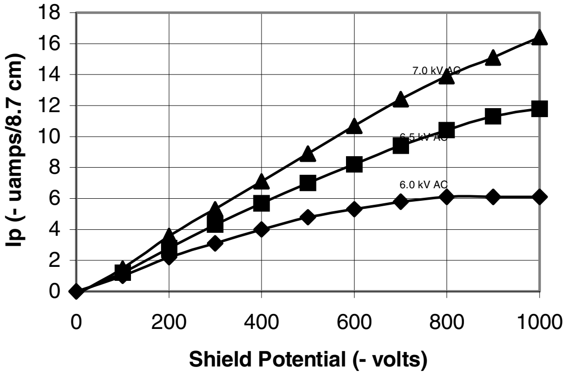

Figure 2. I-V curve for Capatron

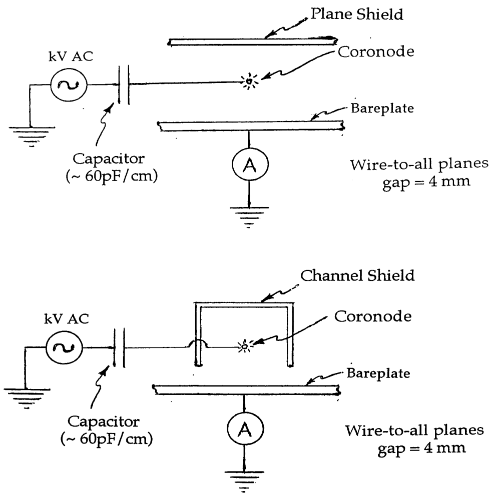

Figure 3. Schematic for Capatron set-up

Coronode Spacings:

Procedure

The above experiment was repeated, except the planar shield and bareplate were mounted 8 mm apart, with the coronode 4 mm from each. I_p vs. V_{sh} data were measured for capacitively connected AC voltages of 6 kV, 6.5 kV, and 7.0 kV, with a DC shield voltage ranging from zero to -1000 volts *for Capatron*.

Results

Bareplate currents were about 50% higher for 3 mm gaps from the coronode to the conducting planes than for the 4 mm gaps. This is seen by comparing Figures 3 and 4.

Discussion of Results

While the corona currents were considerably higher for the 3 mm spacings, the danger of arcing was much greater at 3 mm than at 4 mm.

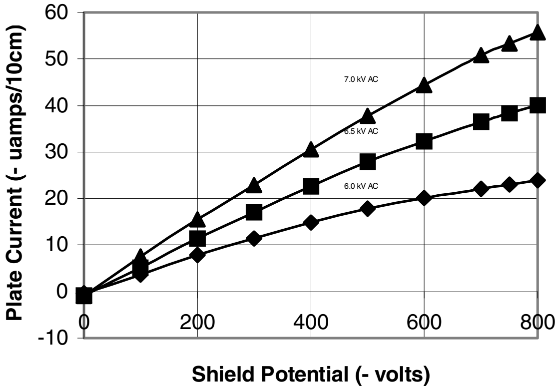

Figure 4. I-V curve for Capatron with 4 mm side shields

Shield Sideplates:

It was theorized that shield sideplates would increase the AC fields from the coronode, and therefore the rate of ionization, and sideplates would also increase DC fields to the bareplate, so sideplates of various widths were explored.

Procedure:

Using 4 mm spacings from the coronode, sideplates of 3,4,5,6, and even 7 mm in width were built, and I-V data were taken for each width of sideplates.

Results:

Compared with the plane shield with no sideplates, plate current increased by nearly a factor of two, reaching its maximum when the sideplates were 5 mm wide. This is shown in Fig. 5.

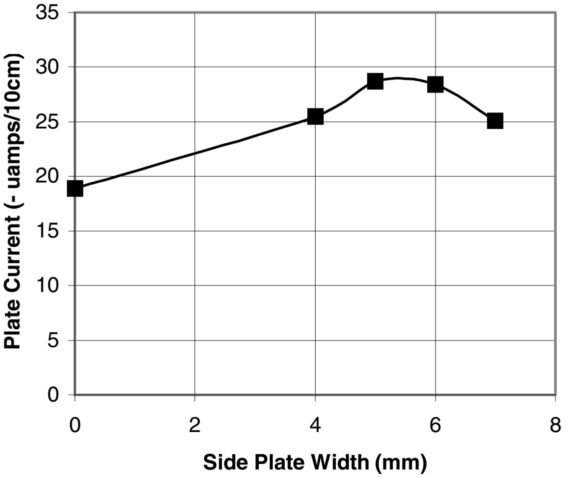

Figure 5. Plate current versus side plate width

Discussion of Results:

The substantial increase resulting from the use of sideplates encourage us to recommend 3.5 to 4 mm spacings from the coronode, rather than 3 mm spacings, reducing the likelihood of arcing without sacrificing the required corona currents to the bareplate (or photoreceptor).

Explore Range of Capacitance:

Procedure:

The capacitance needed to deliver the required current of 2.8 μA/cm to the photoreceptor for single pass charging at 10 cm/sec was calculated. Assuming we must deliver a C x ∇V of charge each cycle, where C is the capacitance, *and ∇V is the peak voltage above corona threshold* for 6.5 kV AC (3.25 kV peak, or 550 volts above threshold), and *assuming it drops the full 550 volts to threshold,* we need a capacitance, C, c~1.4 x 10^{-9}/550 = 2.5 x 10^{-12} Farads, or 2.5pF per cm of the corona wire.

Data were taken for I-V plots using a range of capacitors from 0.15 to 9.4 nF/10 cm of wire.

Results:

As shown by Fig 6, plate current increased with increasing capacitance up to about 0.6 nF/10 cm, or 60 pF/cm of coronode. That's 1.3 nF for a coronode 22 cm long.

Discussion of Results:

Clearly, and not surprisingly, the empirically determined required capacitance exceeds our calculation based on the assumption that the corona *voltage on the wire might drop all the way to the corona threshold voltage in about 1/8000 second that the power supply exceeds the corona threshold.*

We have no difficulty believing that the difference in the theoretical requirement of 2.5 pF/cm, and the empirically determined value of 60 pF/cm indicates the capacitor charges only 4.2% of its maximum possible C x ∇V product of charge each cycle, or about *23 volts* in the 125 microseconds or so that the applied AC voltage exceeds the corona threshold of the coronode by up to 550 volts.

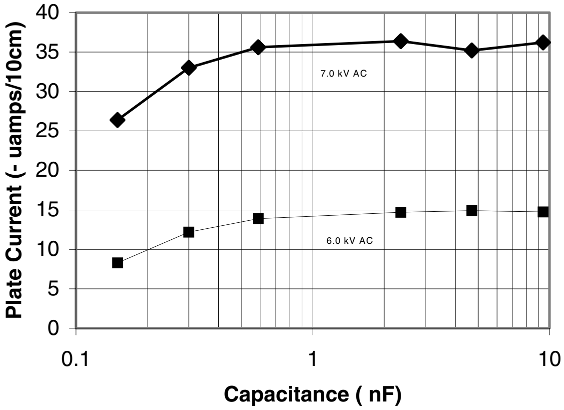

Figure 6. Plate current versus capacitance for Capatron

Characterization:

Uniformity and Lifetime tests:

Electrometer data were measured with the electrometer head at frequent intervals across the Mylar drum, after each time period of operation as follows: Results showed deviations from the mean surface potential of +/- 1.2% up to l8 hours, 1.8 % after 42 hours, remaining no more than +/- 2.2 % through 90 hours of operation.

The deviations fall within the specified limits of +/- 3 %, making the Capatron a very acceptable charging unit for the Aetas color printer.

Sensitivity to Toner Contamination

Procedure:

A test was designed to test the "worst case" scenario, in which toner was thrown and rubbed onto the coronode and the inside surface of the shield of the 8 x 6 mm Capatron on one end only. This unit was incorporated in the Xerox 214 Digital Printer. AC coronode voltages and DC shield potentials were varied to find values giving the optimal prints, and the range of potentials that produced acceptable background and print densities.

Results:

Prints were best at about 6.75 kV AC coronode potential and -600V shield potential. Good print densities and low background resulted over a range of AC voltages of 6.0 to 7.0 kV AC, and DC shield biases of -600 to -800 volts.

Electrometer scans from the toner dusted Capatron charging unit with the coronode set at 6.0 to 7.0 kV AC and -800 volts DC on the shield gave a range of surface potentials of +/- only 0.5%.

Discussion of Results:

We believe we have discovered yet another unique advantage of AC corona over DC corona charging. The effects of ion deposits on insulating layers of airborne deposits of powder on metal from AC and DC corona are very different, in favor of AC corona charging, for understandable reasons. High frequency AC ion currents have a negligible influence on the effective shield potential, compared to DC ion currents on a dust-coated shield.

Conclusion

The performance of this charging system proved to be superior, even to scorotrons in uniformity and efficiency, resulting in less ozone, and more rapid charging to the asymptote for a given initial plate current. Further, this charging device can be made smaller without arcing, than any other corona charging unit we know of.

The Capatron is recommended for any low cost xerographic copier or printer, especially for single pass full color imaging, where space and maintenance-free long term stability are important.

Acknowledgement

The authors wish to thank Aetas Technology Inc. for sponsoring this project, showing unwavering faith through many seemingly nonproductive research efforts.

Biography

Robert Gundlach received his B.S. degree in Physics from the University of Buffalo in 1949 and continued graduate studies there until 1951. He joined the Xerox Corporation (then know as the Haloid Corp) in 1952 and retired from Xerox in 1995. Since 1995 he is a consultant in electrostatics and xerography. He has numerous publications and has been granted more than 160 US patents. He is a life-time member of IS&T, Electrostatics Society of America and National Academy of Engineering.