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# Influences of the pulsed power supply on corona streamer appearance

ABSTRACT
Pulsed positive corona streamers in air are studied by images obtained with an intensified CCD camera. Using a switched capacitor power supply, thin streamers are observed that branch. A power supply consisting of a 4-stage transmission line transformer gives pulses of much higher current to the same gap. In this case, the number of streamers is less, they are wider and they hardly branch. The current density is roughly 1 A/mm$^2$ in both type of streamers.

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*Keywords and Phrases:* discharges, streamers, experiments
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# INFLUENCES OF THE PULSED POWER SUPPLY ON CORONA STREAMER APPEARANCE

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**Summary**

Pulsed positive corona streamers in air are studied by images obtained with an intensified CCD camera. Using a switched capacitor power supply thin streamers are observed that show branching. A power supply which comprises a 4-stage transmission line transformer gives pulses of much higher current to the same gap. The amount of streamers becomes much less in this case and they do not show branching, their diameter, however, is much larger. The current density is roughly 1 A/mm2 in both types of streamers.

Keywords: *pulsed corona discharge, streamer propagation, pulsed power supplies*

## Introduction

Corona discharges are in use for more than a century for purposes such as ozone generation and dust precipitation. Gas and water cleaning by corona discharges has been under investigation since the 1980s and it was soon discovered that in this area of chemical applications that corona discharges created with nanosecond pulses had much higher efficiencies than DC coronas [1].

The introduction of pulsed corona cleaning technologies in to the market is limited up to now. One of the main reasons for this is that up to now there are no pulsed power supplies with sufficient capacity combined with a long life time and an acceptable price [2]. Another remarkable fact related to the pulsed power supplies is that there is almost no knowledge of how the supply influences the properties of the discharge and consequently the chemical reactions that follow.

It is generally accepted that the propagating streamer head with its high electric field is the most effective creator of ions and radicals. Therefore the rise time of the voltage pulse should be considerably shorter than the time required by the streamers to cross the gap. The duration should be of the order of this crossing time. This does not say anything on power input, optimum amplitude or repetion rate etc.

In order to couple the power supply parameters to the chemical efficiency in an application much more knowledge is required. For this purpose in recent years fundamental studies on corona discharges have been carried out e.g. [3, 4]. Streamer propagation and branching is studied experimentally in these papers and in [3] it is observed that small changes in the pulsed power supply leads to changes in the branching pattern in a small point-plane gap.

Streamers are also studied theoretically, mostly by numerical simulations of 2-D models [4-6]. These models give predictions of streamer diameter and propagation velocity and also electron densities and energies. Although 2-D models cannot yield branching patterns as observed in experiments they do show instabilities that appear to be the onset of streamers [5, 6].

In this paper first results are shown of branching patterns of streamers where with the same discharge gap two power supplies are used of very different design. The first is a spark gap switched capacitor, which acts as a voltage supply, it will be called *C-supply*. The second one combines a switched capacitor with a transmission line transformer (*TLT-supply*). This one has much more the characteristics of a current source. It will be shown that the streamer discharge patterns are quite different.

**Experimental set-ups**

The C-supply is often used in laboratories its diagram is shown in fig. 1. This circuit is easy to build and by changing the values of the components its parameters can be adapted. The high voltage switch for the measurements presented here is a spark gap. Resistor R4 is a current measuring shunt of a rather low value, 2.75 Ohm (for details see [7]). This method to determine the current is much more sensitive than the use of a Rogowski coil at the anaode as used in [3].

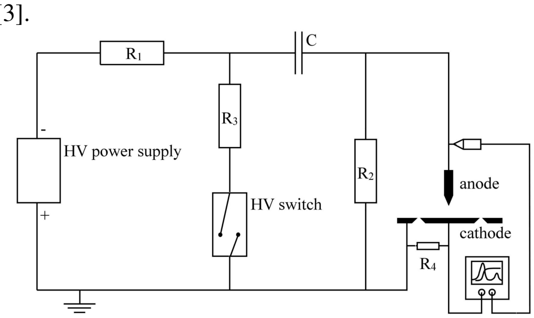


*Fig. 1: Conventional pulsed power supply using a switched capacitor*

This supply basically puts the high voltage across the gap with a rise time determined by the switching time of the spark gap, the inductance of the current loop and the optional resistor R3. The resistor R2 determines the decay time of the voltage pulse. This time must be much longer than the rise time in order to get the pulse amplitude as high as the voltage from the DC supply. The measured peak current is up to ~1A and the pulse energies are in the range of ~1 to 4 mJ [8].

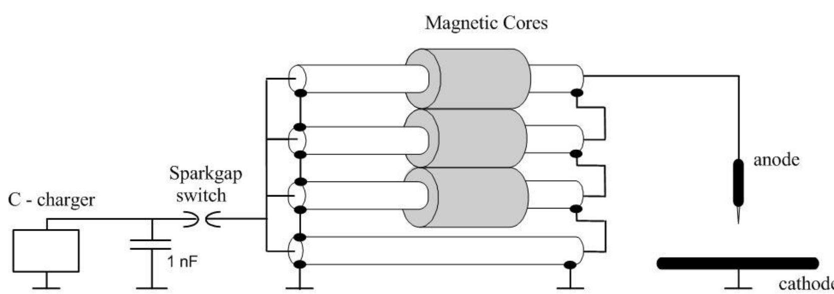


*Fig. 2: Pulsed power supply with spark gap switch and transmission line transformer.*

In the second supply, as shown in fig. 2, again a spark gap switches a capacitor but the current flows into four parallel coax lines of 50 Ohm, i.e. an effective impedance of 12.5 Ohm. This current pulse travels through the coax lines and at the end these are put in series so their voltages add up and the output imedance becomes 200 Ohm. This power supply is able to give current pulses of ~50 A with a duration of ~40 ns and ~50 mJ energy [9].

**Results**

Photographs of the streamers are made with an intensified CCD camera (Andor ICCD-452). All pictures are time integrated over several microseconds to ensure that all corona events are captured. Two types of gap are used a point-plane of 40 mm gap and a wire-plane gap with the same gap spacing and a wire length of 50 mm. Fig. 3 shows photographs of the point-plane gap using the C-supply with a pulse of 40 kV peak and rise time ~40 ns.

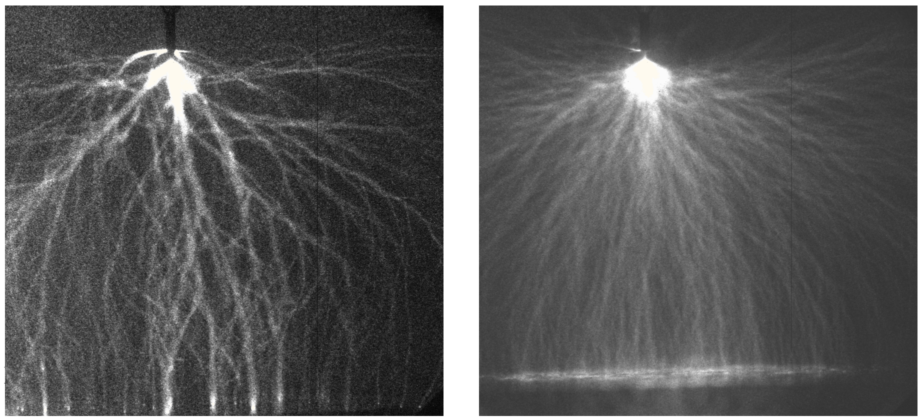

*Fig. 3: CCD images of corona streamers in a point-plane gap using the C-supply. On the left a metal cathode is used and on the right a cathode with a dielectric layer.*

The left photo is taken using a metal cathode; it shows a streamer pattern quite similar to previous results [3]. On the right photo a dielectric is covering the cathode. The discharges now spread over the cathode instead of forming a small intense spot. On this photo it also looks as if there are more and finer streamers, this effect is however not always reproduced.

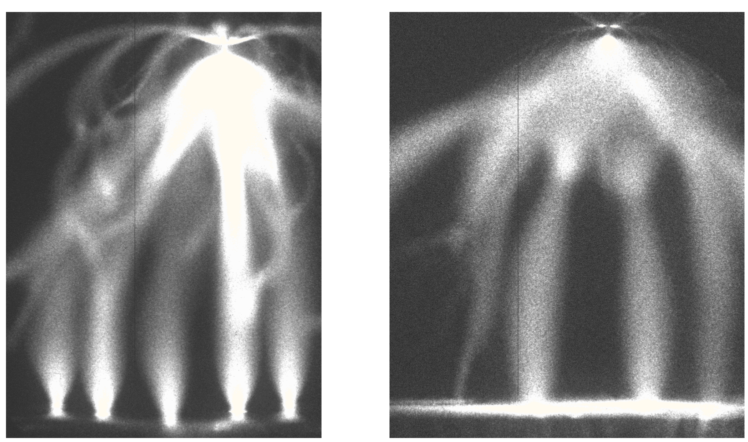

*Fig. 4: CCD images of the point plane gap using the TLT-supply*

The photos taken with the TLT supply show a much lower number of streamers with a larger diameter. A rough estimate shows that the current density is both types of streamers is similar, ~1 A/mm$^2$ [9]. On the left photo some thin streamers are seen near the point. This effect is seen before [10], these streamers start later i.e. when the current is lower.

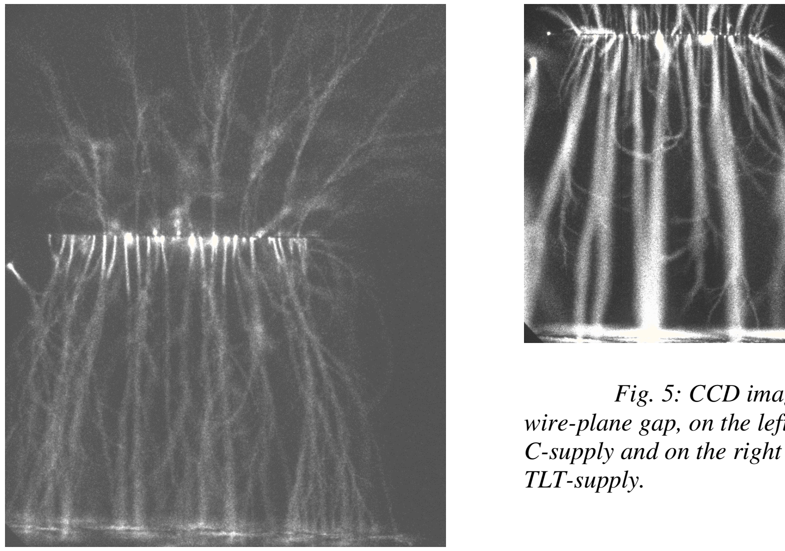

*Fig. 5: CCD images of the wire-plane gap, on the left with the C-supply and on the right with the TLT-supply.*

The photos of the wire-plane discharge show also thicker streamers with the TLT-supply, although less pronounced. Here it is interesting to see that a few of the thick streamers do not reach the cathode but change into thin streamers with branching. Probably at the instant of this transition the current drops, the current duration is approximately the same as the time required for the streamers to cross the gap.

**Conclusions**

The patterns of streamers created by positive high voltage pulses in air have been recorded using an intensified CCD camera. These patterns not only depend on the configuration of the gap, but also on the type of power supply used. A comparison is made between a switched capacitor supply and a supply that uses a transmission line transformer. With the C-supply thin streamers are observed which show branching. Using the TLT-supply the total number of streamers decreases but their diameter becomes much larger. These phenomena appear to be related to the fact that the C-supply is a voltage source and the TLT-supply is a current source giving much highe currents at the same applied voltage. The temporal evolution of the streamers and the role of the peak voltage are currently under investigation.

**References**

[1] E.M. van Veldhuizen (ed), *Electrical Discharges for Environmental Purposes: Fundamentals and Applications*, (New York: Nova Science) ISBN 1-56072-743-8 (1999).
[2]K. Yan, G. J. J. Winands, S. A. Nair, E. J. M. van Heesch, A. J. M. Pemen, I de Jong, J. Adv. Oxid. Technol. **7**(2004)116.
[3] E.M. van Veldhuizen, W.R. Rutgers, J. Phys. D: Appl. Phys., **35** (2002) 2169-2179.
[4] S. Pancheshnyi, M. Nudnova, A. Starikovskii, Phys. Rev. E, **71** (2005) 016407.
[5] A. Rocco, U. Ebert, W. Hundsdorfer, Phys. Rev. E **66** (2002) 035102(R).
[6] N. Liu, V.P. Pasko, J. Geopyhys. Res. **109**(2004)A04301.
[7] B. Gavendeel, *Negative Corona Discharges: A Fundamental Study*, PhD Thesis Eindhoven University of Technology (1987).
[8] T.M.P. Briels, E.M. van Veldhuizen, U. Ebert, XXVII ICPIG, Eindhoven, The Netherlands, July 2005 (see www.icpig2005.nl).
[9] L.R. Grabowski, T.M.P. Briels, E.M. van Veldhuizen, A.J.M. Pemen, XXVII ICPIG, Eindhoven, The Netherlands, July 2005.
[10] E.M. van Veldhuizen, W.R. Rutgers, U. Ebert, Proc. XIV Int. Conf. on Gas Dicsh. and Appl., Liverpool, 2002, p. 228-231.