



# 1 kW PULSE CORONA REACTOR FOR VOC DESTRUCTION

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## Abstract

A 1 kW pulse corona reactor has been developed capable of treating gas flows up to 100 m<sup>3</sup>/h. The discharge efficiency reaches 80 % in air and nearly 100 % in nitrogen flows. The efficiency of radical production has been proved by ozone synthesis as well as by NO to N<sub>2</sub> conversion.

## 1 Introduction

Nonthermal atmospheric-pressure discharges are a promising technique for pollutants removal from off-gas flows. In recent investigations the potential of streamer-like discharges has been demonstrated for the removal of NO<sub>x</sub>, SO<sub>2</sub> and volatile organic compounds (VOC's) from combustion flue gases, vehicle off-gases and contaminated air flows [1-4].

Corona reactors are well suited for large flow rates because of its design simplicity and low pressure drop. However for reliable kW-excitation schemes a compromise between fast rise time, high peak voltage and good load matching is necessary.

In this paper we report the electrical parameters obtained in a kW pulse corona system. The efficiency of N radical and O<sub>3</sub> production was measured and compared with published data.

## 2 Technical Details

### 2.1 Plasma reactor

The cylindrical discharge chamber consists of four parallel stainless steel tubes with 150 mm diameter. The corona electrodes are M3-thread rods with 5 m active length and two more 10 mm rods of about 2 m length. The system is equipped with an axial fan for flow rates up to 100 m<sup>3</sup>/h.

The discharge circuit is capable of delivering repetitive pulses of both polarities (positive or negative pulse corona) with up to 9 J of pulse energy. A fast switch (thyatron, EG&G LS-3229) is used together with a high voltage pulse transformer. The voltage pulse can be superimposed on a dc bias voltage of ±0...30 kV.

Corona pulse voltage and total current are measured on line by means of a capacitive voltage divider, a high voltage (Tektronix, P6015A) and a fast current probe (Pearson, PEA 1010). The maximum (open circuit) peak voltage is 145 kV with a rise time (from 10 to 90 %) of 200 ns.

The current and voltage oscilloscope traces (Tektronix, TDS 540) were properly synchronized, multiplied and

integrated over the pulse duration to yield the energy deposited into the discharge.

### 2.2 Chemical diagnostic

Room temperature ozone synthesis and NO reduction experiments (in N<sub>2</sub> [5]) were performed in 20 slm flows of synthetic air and nitrogen 5.0 (containing 100 ppm NO) respectively. The gases were metered through mass flow controllers. The gas composition was monitored with a Fourier transform IR spectrometer (Perkin Elmer, Paragon 1000) equipped with a 20 m absorption cell. The spectrometer was connected with the reactor via PTFE hose pipes. The ozone concentration was calibrated by iodometric titration, the NO content by means of a lecture bottle.

## 3 Results

Comparing the discharge stability for positive and negative high voltage pulses (first half cycle) the plasma is in general more stable for positive corona. All the following results belong to this case.

In fig. 1 the temporal development of corona voltage and total current in nitrogen is shown. Instantaneous power is large during the first two half cycles. Fig. 2 confirms that most of the energy is deposited into the discharge in roughly 800 ns.

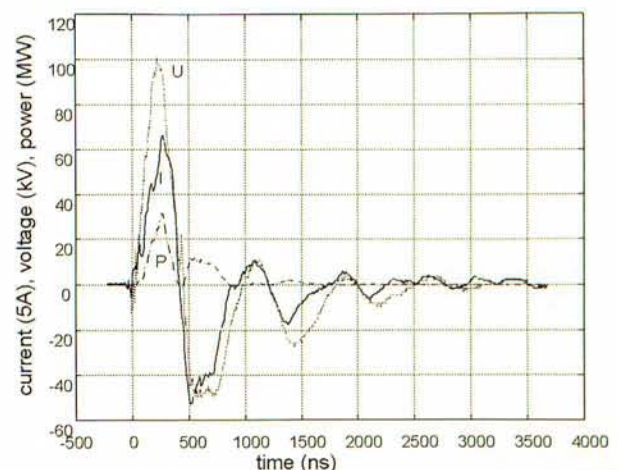


Fig. 1: Pulse corona in nitrogen: charging voltage 40 kV

The situation is somewhat different for pulse corona in air (fig. 3). Here energy deposition is large for the positive voltage half cycle (0...400 ns) and much lower during the following negative half wave (400...1000 ns).

The overall discharge efficiency is compared in fig. 4. At a charging level of 40 kV it reaches nearly 100 % in nitrogen and is somewhat lower in normal air (80 %). At

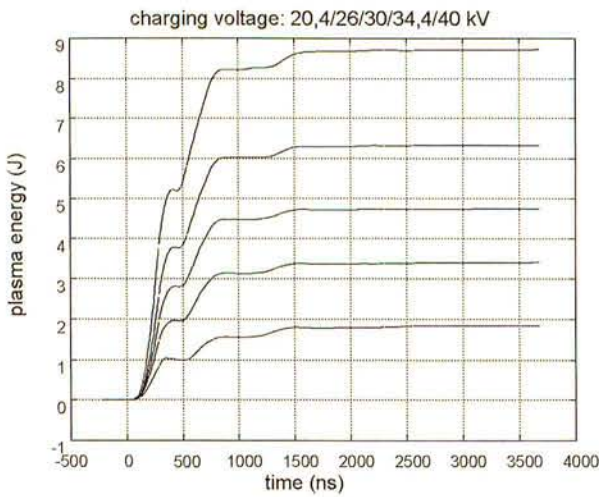


Fig. 2: Pulse corona in nitrogen: energy deposition

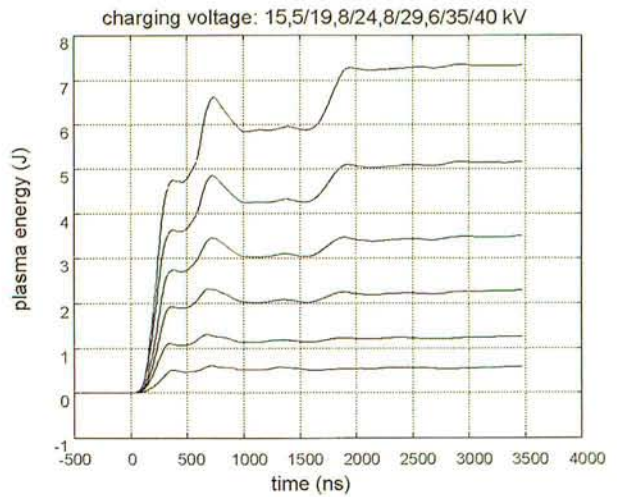


Fig. 3: Pulse corona in air: energy deposition

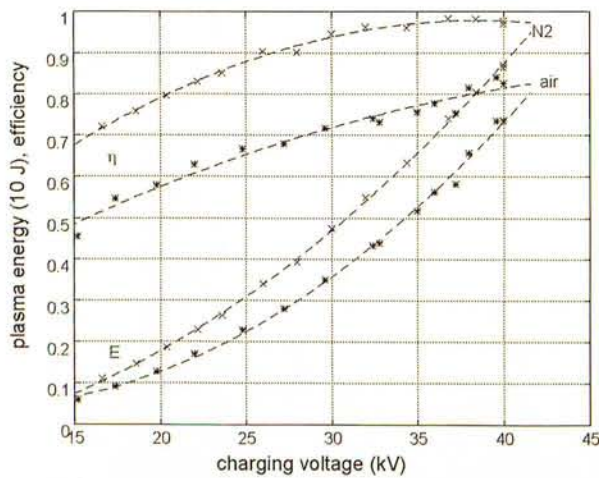


Fig. 4: Pulse corona in nitrogen and air: plasma energy and discharge efficiency

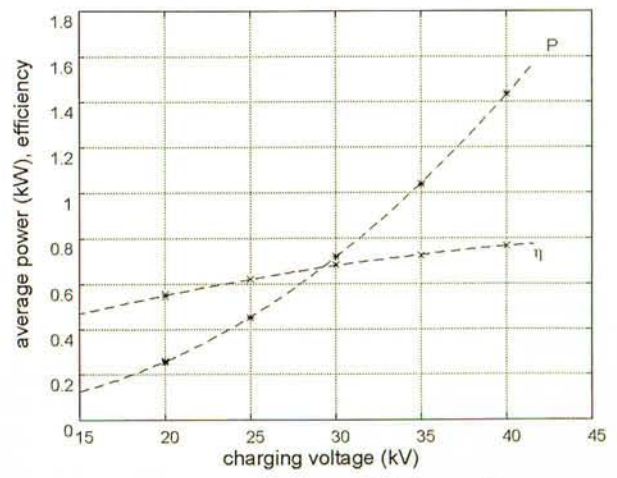


Fig. 5: Pulse corona in air: average power and discharge efficiency (100 m<sup>3</sup>/h, 210 pps)

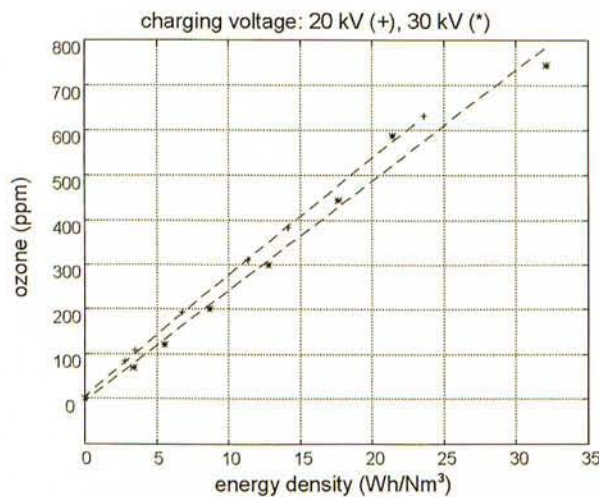


Fig. 6: Ozone synthesis in synthetic air (20 slm)

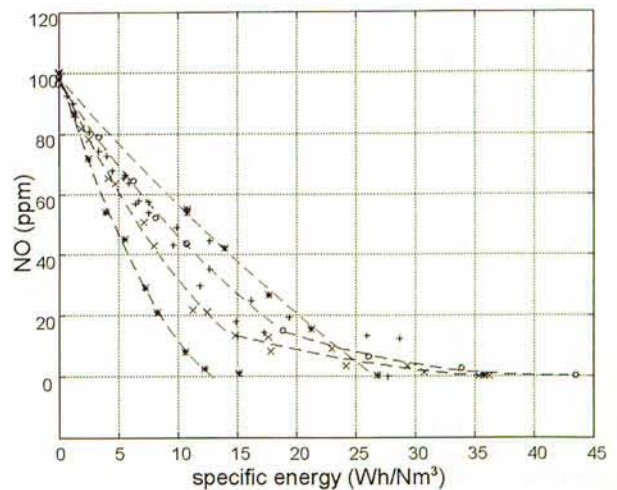


Fig. 7: NO removal in N<sub>2</sub>: (\*) – low power corona reactors Ø 100 mm/900 mm (upper trace), Ø 150 mm/735 mm (lower trace), (x,o) – 1 kW reactor 30 kV and 40 kV, (+) – [6]

high repetition rates and a gas flow of 100 m<sup>3</sup>/h the efficiency at 40 kV charging voltage decreases to 75 % (see fig. 5) because of changes of the gas composition. The average power reaches 1 kW and 1.4 kW at 35 kV and 40 kV charging voltage levels respectively. In fig. 6 and 7 the energetic efficiencies for ozone synthesis and NO removal in N<sub>2</sub> are shown. Ozone production depends only slightly on the charging voltage level. The specific power consumption is

22.9 kWh/kg and 20.9 kWh/kg at 20 and 30 kV respectively (see [6]). Efficiency of NO removal also depends on charging voltage level (see fig. 7, marks „o“ for 40 kV and „x“ for 30 kV). The traces with „\*“ marks were obtained in laboratory scale reactors of different geometry and similar excitation schemes (2 slm). The „+“ marks represent



results from a recent international comparison [5] (Siemens, Livermore 1, Karlsruhe 1).

#### 4 Discussion and Conclusions

We believe that in the case of nitrogen discharges the streamers close the discharge gap during the first half voltage cycle. The plasma does not terminate within this time so that further energy deposition is possible during the next half waves at perhaps lower E/N values. So this part of the plasma energy is less efficient with respect to N radical production and hence to NO to N<sub>2</sub> conversion [5]. The highest reported efficiency (lower trace marked with „“ in fig. 7) we obtained by using very short voltage pulses of low amplitude (no streamer crossing of the gap).

In normal laboratory air however the plasma has the tendency to die out because of fast electron attachment processes at low E/N values. We assume that during the second (negative) half cycle (fig. 3, 400...1000 ns) the plasma filling of the discharge tube is incomplete. Furthermore the higher plasma impedance in air seems to be the reason for larger load mismatch compared with the nitrogen discharge at all charging voltage levels.

In summary results on a kW pulse corona reactor have been presented. The energetic efficiencies of ozone synthesis and NO to N<sub>2</sub> conversion are comparable to those of other laboratories. For long term operation in air the discharge circuit impedance needs further optimization. The average power will be tried to increase by higher repetition rates as well as by applying a dc bias voltage. The reactor is intended to be used in a VOC removal system.

#### 5 Acknowledgments

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#### 6 References

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