Optimal Design Considerations On A High Oxidation Pulsed-Corona Reactor For NOx Mitigation

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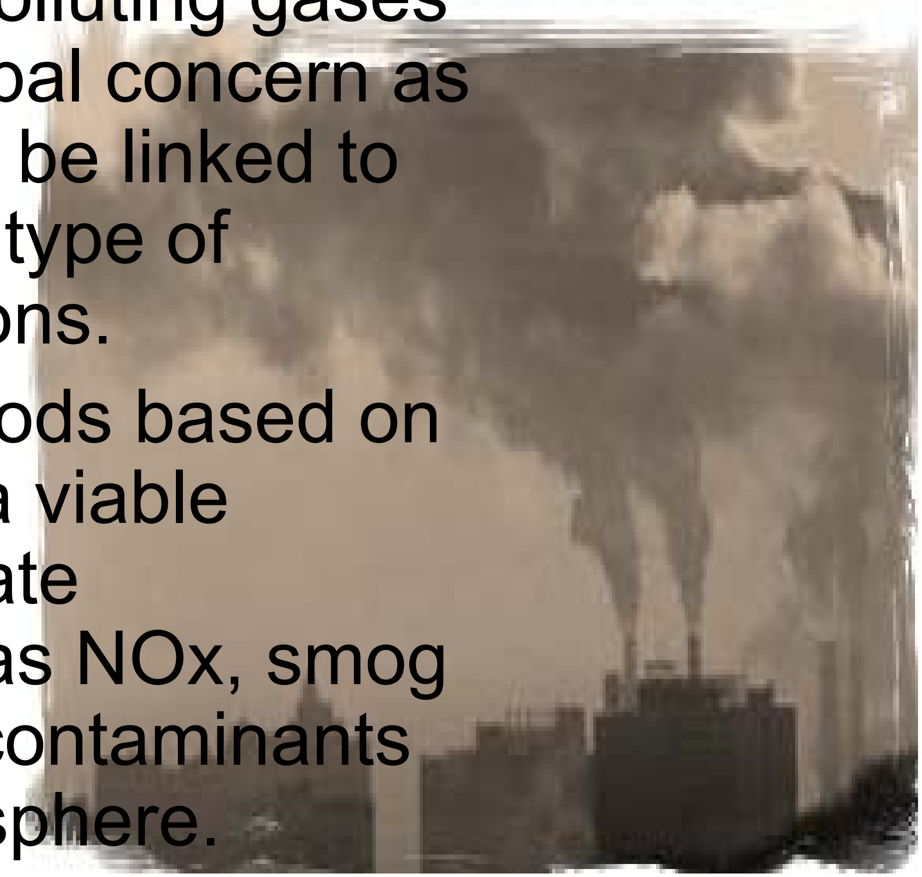
INTRODUCTION



- The NOx family of polluting gases remains being a global concern as climate change may be linked to the presence of this type of atmospheric emissions.
- High oxidation methods based on electrical fields are a viable alternative to eliminate contaminants such as NOx, smog particles and other contaminants present in the atmosphere.

Tranformation and destruction of nitrogen oxides-NO,NO_2-in a pulsed corona corona discharge reactor

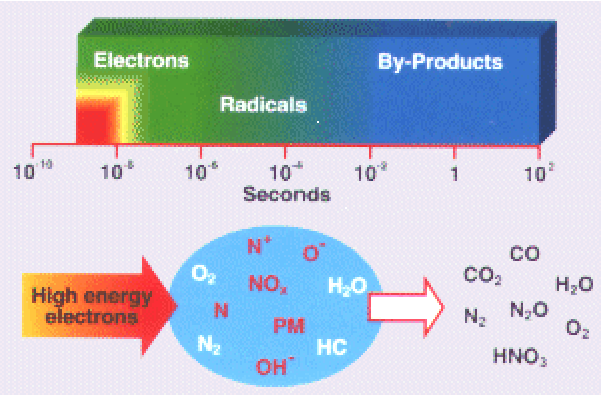
- The pivotal role of corona discharge in the removal of NO is through the oxidation of NO to NO_2, a part on the NO_2 can, of course, be further oxidized to nitric acid, which can be neutralized by a basic compound.
- The removal of NO results from the reactions with the reactive components such as O, OH, HO_2, O_3, N, etc. These components originate from water vapor, oxygen, and nitrogen, and thus the composition of feed gas stream is very important factor affecting the removal.
- As well, the dominant reactions for the removal may depend on the gas composition because it affects the concentration of each radical produced.

Pulsed streamer corona technique

- A corona discharge is an ionic and electronic emisions from a high voltage corono, charactized by the formation and flow of positive ions, negative ions, and electrons in an electric field between two or more elctrodes.
- A difference marked from normal continuous discharge (dc corona), ac discharge, and long pulse corona discharge it uses a high voltage electric discharge (25 – 40 KV) and a very short pulse width (aprox. 500 – 1000 ns).

Pulsed streamer corona technique

- One very important consequence of the brief duration of the pulse is that it minimizes the power normally wasted on ionic migration because the mobility of ions is much less than that of electrons.

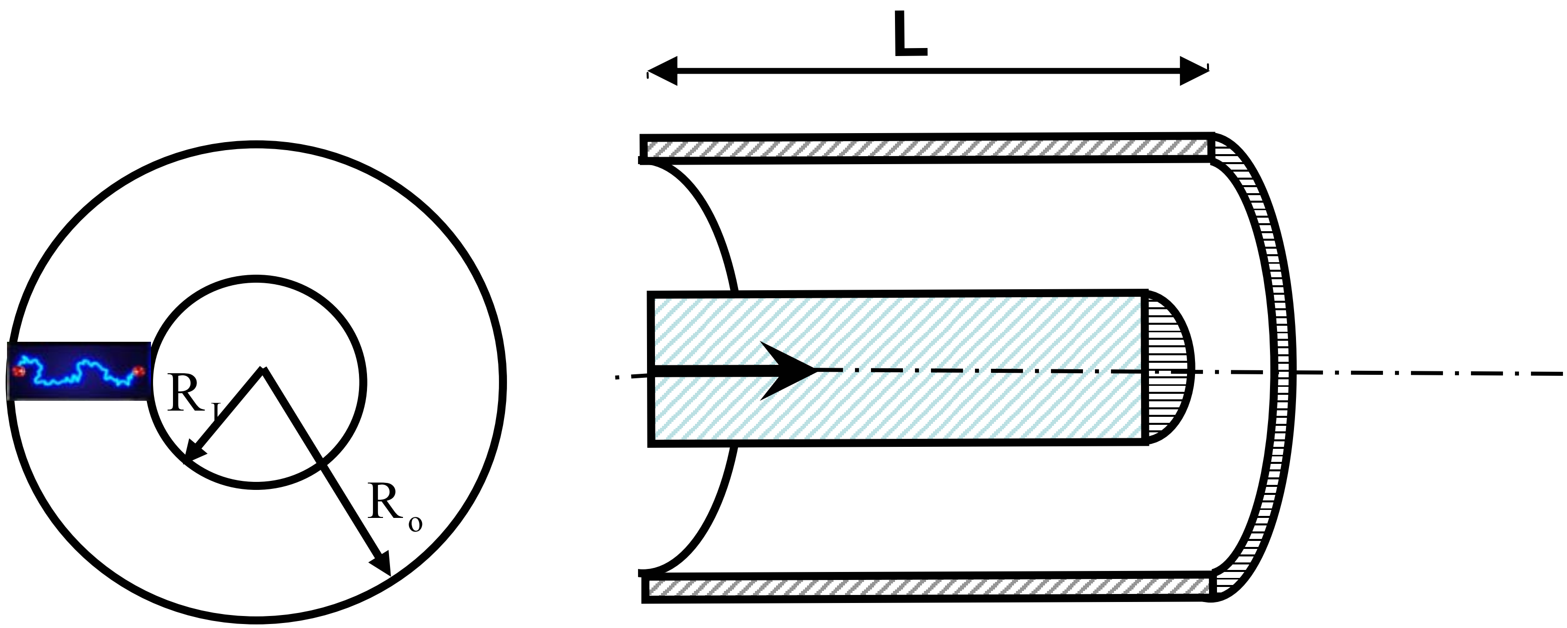


- Ions do not contribute to free radical formation, however energetic electrons do actively promote these reactions.

Pulsed streamer corona technique

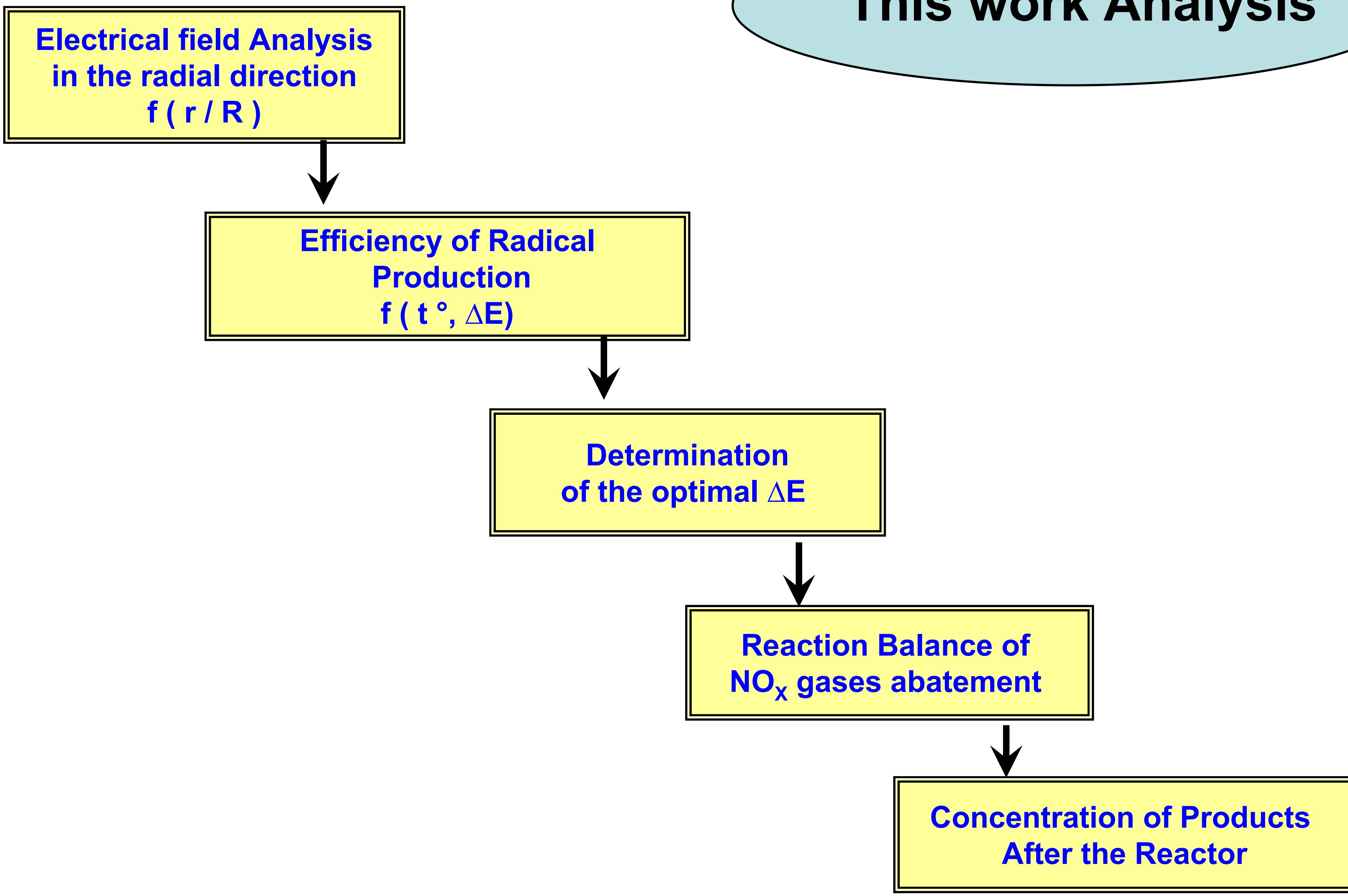
- Free electrons produced by pulsed corona discharge can be **accelerated** by an **imposed electric field** to gain energy.
- The collisions of energetic electrons with oxygen, water vapor and nitrogen result in the formation of actives species.
- These species with strong reactivity can react with a variety of gaseous pollutants such as SO_2 y NO, leading to the removal of them.

Cylindrical Reactor Corona Sketch



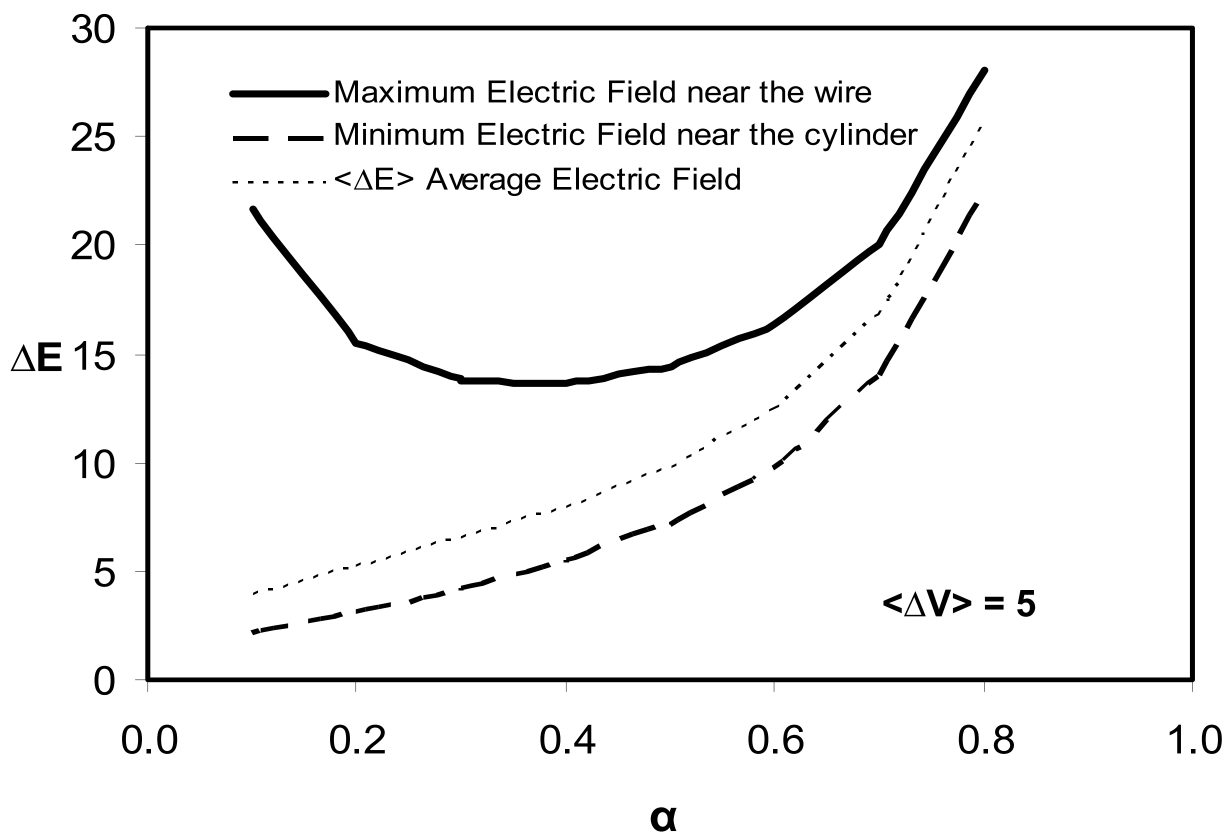
$$\alpha = \frac{R_I}{R_o}$$

This work Analysis



Analysis of the Electrical Field vs. Electrode ratio in a Cylindrical Corona Reactor

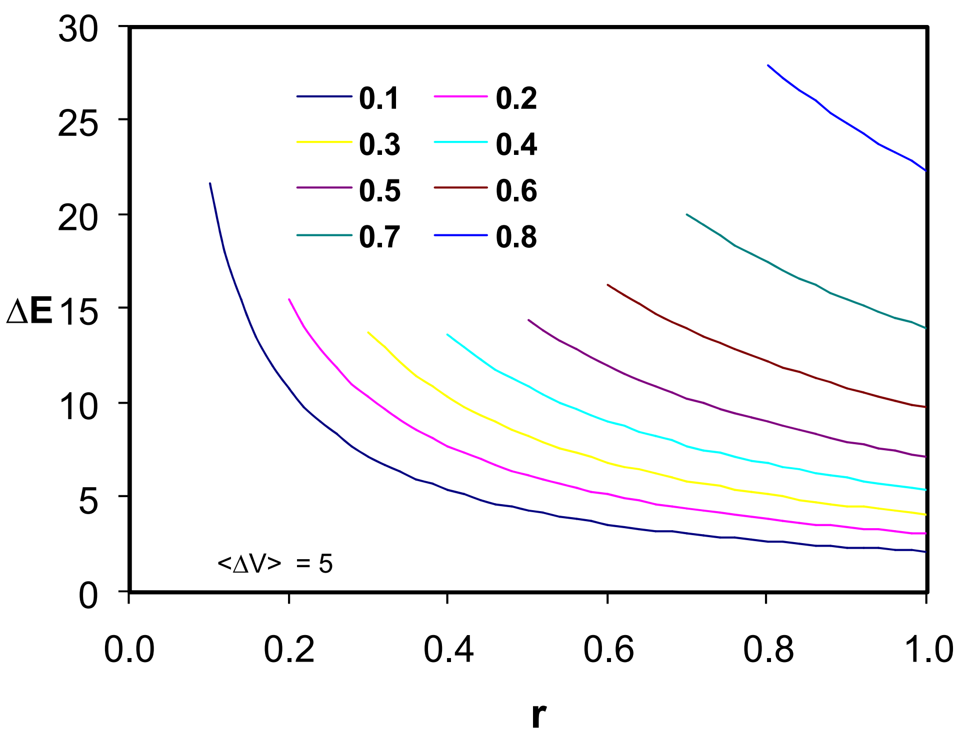
$$\Delta E = \Delta V / r \times \ln(1/\alpha)$$



The electrical field presents maximum and minimum values for every α and fixed ΔV values.

The average Electric Field follows a trend closer to the minimum electric field values.

Analysis of the Electrical Field vs. Electrode ratio in a Cylindrical Corona Reactor



The average Electric field is maximum near the surface of the electrode.

Efficiency of Radical Production
f (t °, ΔE)

- Radical production inside the reactor depends on the application of an optimal electric field value.

- Average Concentrations of radicals produced per single pulse :

$$[OH]\,c = \eta\, c, OH \times Ep / V_R$$

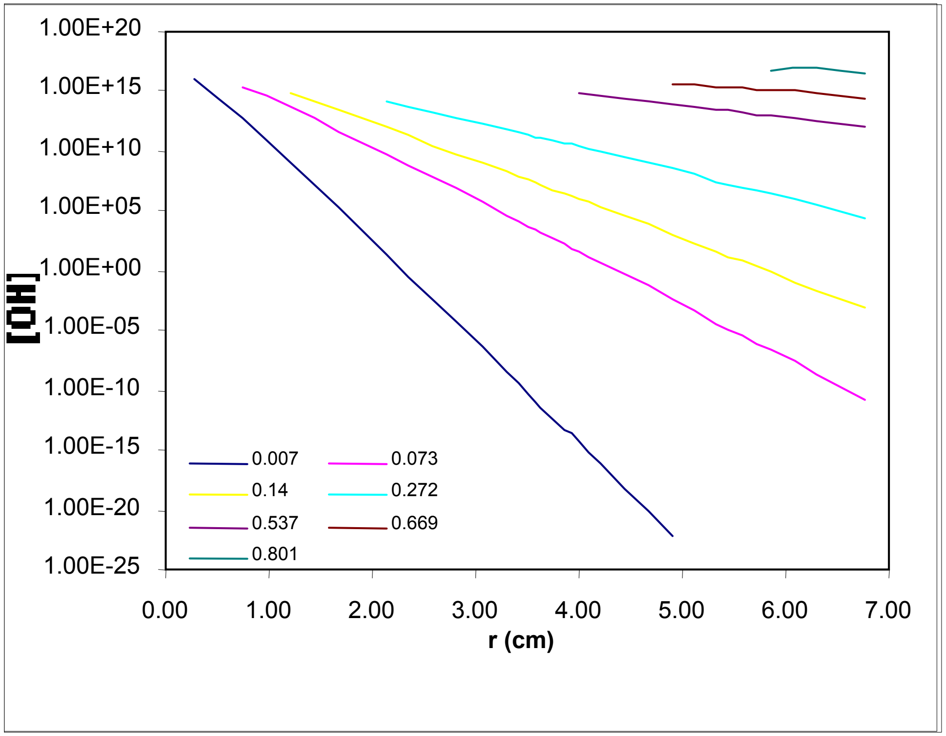
$$[O]\,c = \eta\, c, O \times Ep / V_R$$

$$[H]\,c = \eta\, d, H \times Ep / V_R$$

$$[N]\,c = \eta\, d, N \times Ep / V_R$$

Efficiency of Radical Production
f (t °, ΔE)

T° = 298 °K



For every α value the concentration of radicals is maximum near the surface of the electrode

Efficiency of Radical Production
f (t °, ΔE)

Radical Production Efficiency

$$\eta c,OH = \frac{2 \times k\,e1 \times [H2O] \times \eta d,O(\text{'}D)}{A} + \eta d,OH \qquad \eta c,O = \frac{B}{A} \times \eta d,O(\text{'}D) + \eta d,O$$

$$A = \{ (k\,e1 + k\,e4) \times [H2O] + k\,e2 \times [O_2] \} \times [O(\text{'}D)]$$

$$B = \{ ke2 \times [N_2] + ke3 \times [O_2] + ke4 \times [H_2O] \} \times [O(\text{'}D)]$$

ke = Depletion Rate Constant

ηc = Overall Radical Production Efficiency
ηd = Radical Production Efficiency by dissociation Impact

$$\eta d, OH = kd1 \times [H_2O] / qe \times vd \times N_T \times (E / N_T) = \eta d, H$$

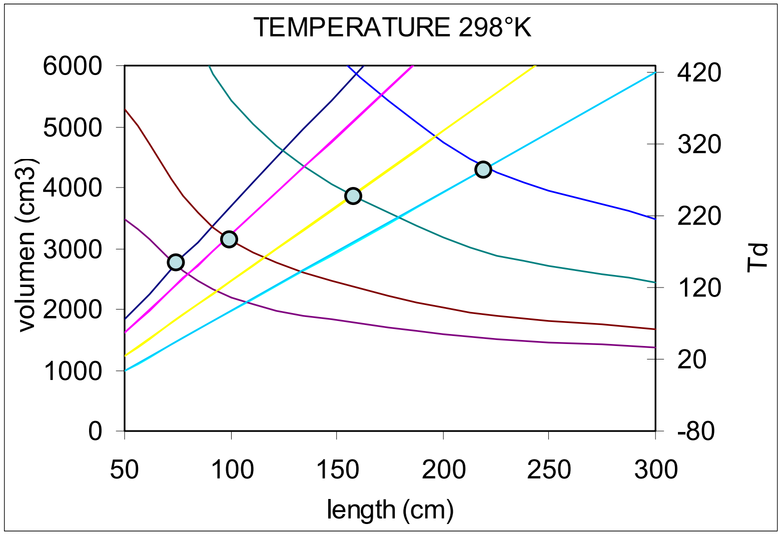
$$\eta d, O = 2 \times kd2 \times [O_2] + kd3 \times [O_2] / qe \times vd \times N_T \times (E / N_T)$$

$$\eta d, O(\text{'}D) = kd3 \times [O_2] / qe \times vd \times N_T \times (E / N_T)$$

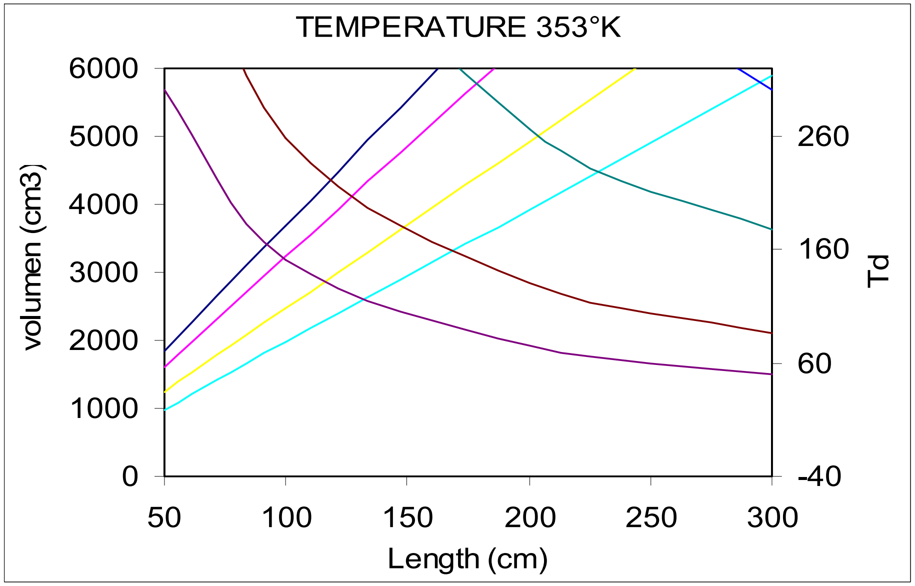
$$\eta d, N = 2 \times kd4 \times [N_2] / qe \times vd \times N_T \times (E / N_T)$$

$$vd = 3.2 \times 10^{5} \times (E / N_T)^{0.8} \quad ; \quad qe = 1.602 \times 10^{-19} \text{ coulomb}$$

Optimal Reactor Dimension Procedure



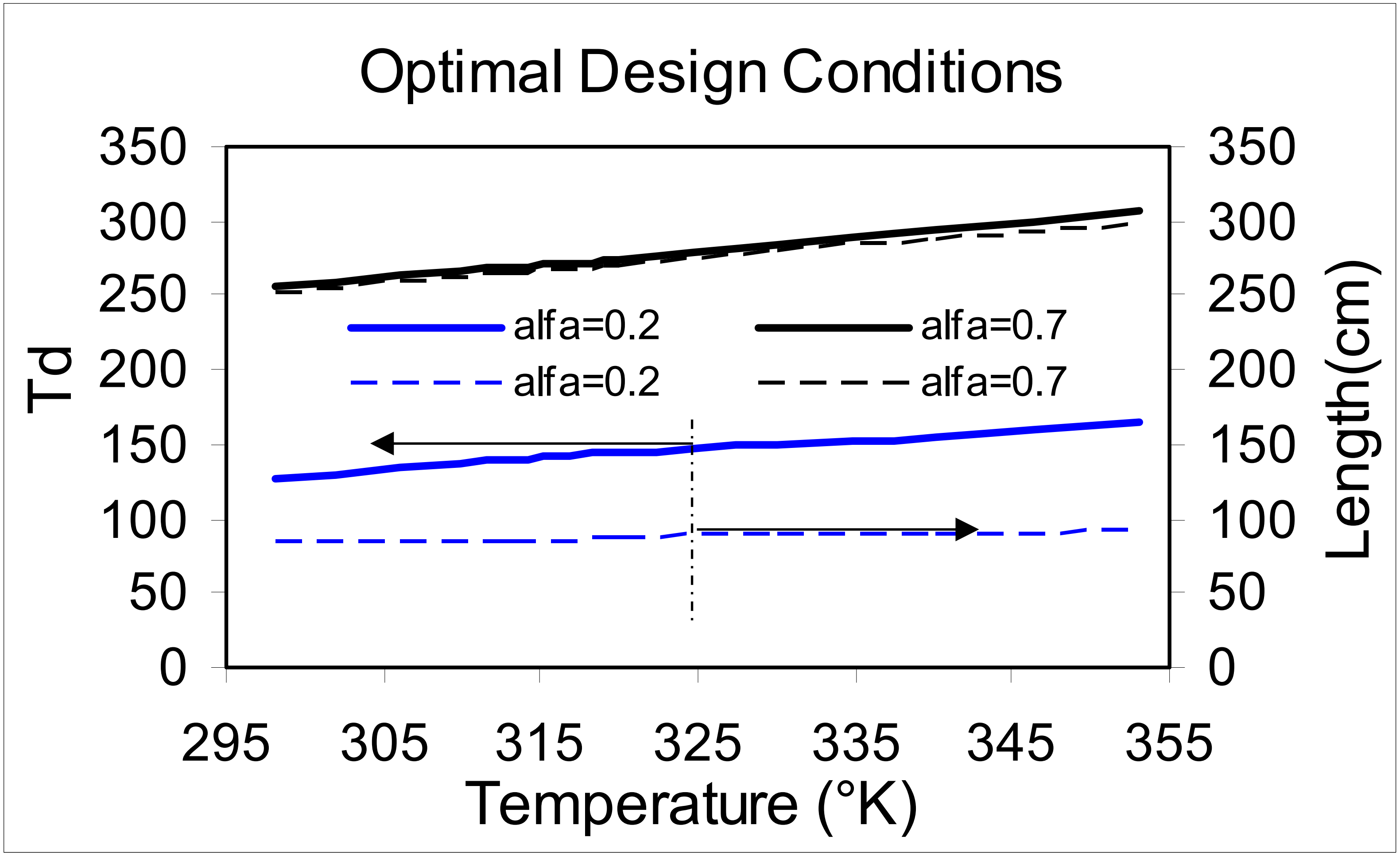
$$Td = \frac{PxV_{molar}}{N_T\ f\ R_o\ I\ V_R\ \ln(1/\alpha)\ (1+\alpha)}$$



$$V_R = \pi L_R\ R_o^2\ (1-\alpha^2)$$

Optimal Reactor Dimension Procedure

• The minimum electric field value [Td] is obtained with minimum radius ratio, α, value.



CONCLUSIONS

- Optimal parameters of operation have been determinated for ea pulse corona reactor of cylindrical geometry.
- These optimal parameters will allow to obtain higher efficiency in NOx mitigation.
- Future work will involve the study of other reactor geometries and gases
- And the application of the methodologgy to continues systems.