

REINHOLD ENVIRONMENTAL Ltd.



2011 APC Round Table & Expo Presentation

July 11-12, 2011, in Cleveland, OH / Hosted by FirstEnergy

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Aspects on Low Resistivity Dust Operation of ESPs

PCUG/Round Table
Reinhold Environmental

Per Ranstad

Cleveland, July 12th, 2011

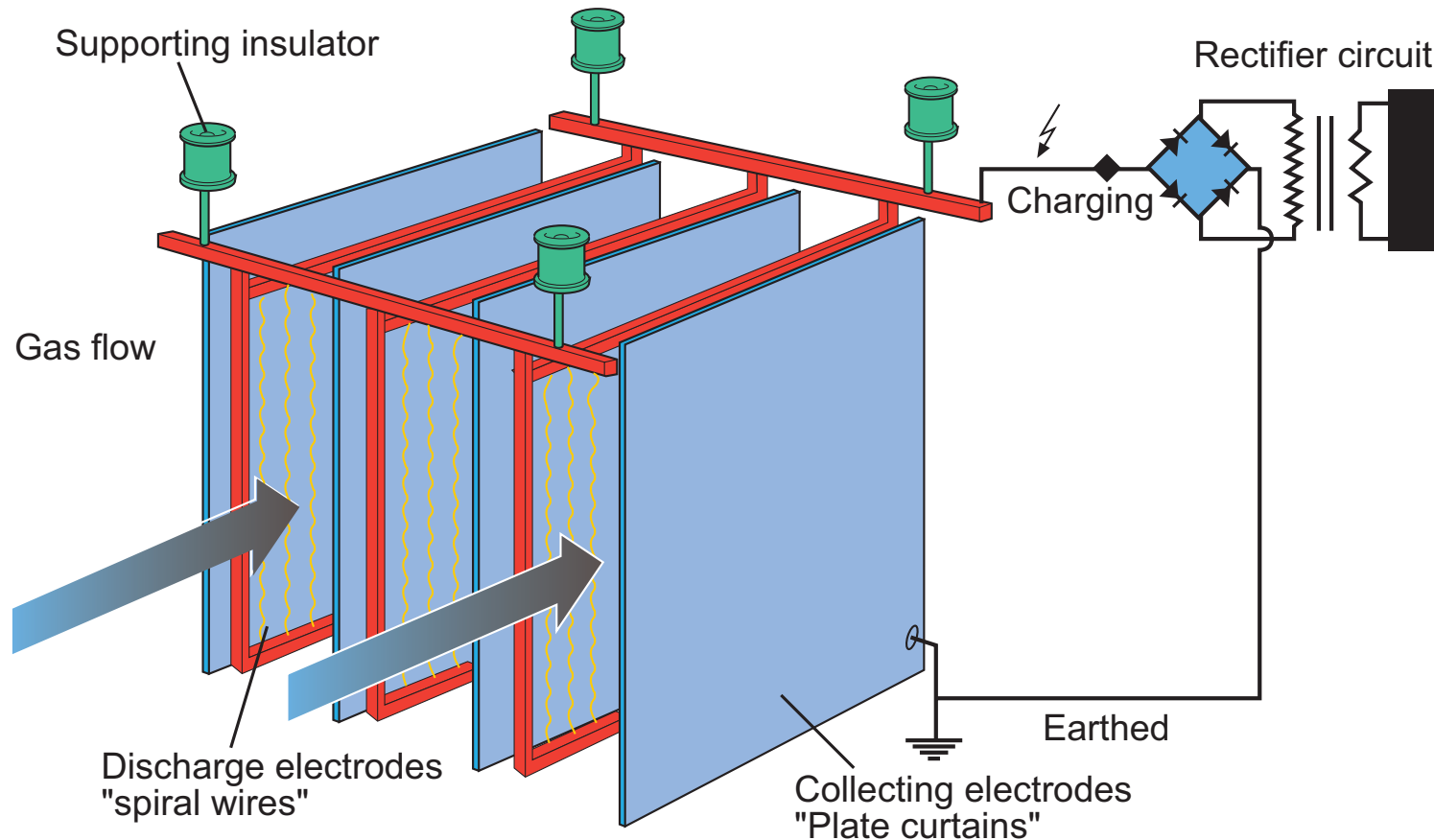
POWER

ALSTOM

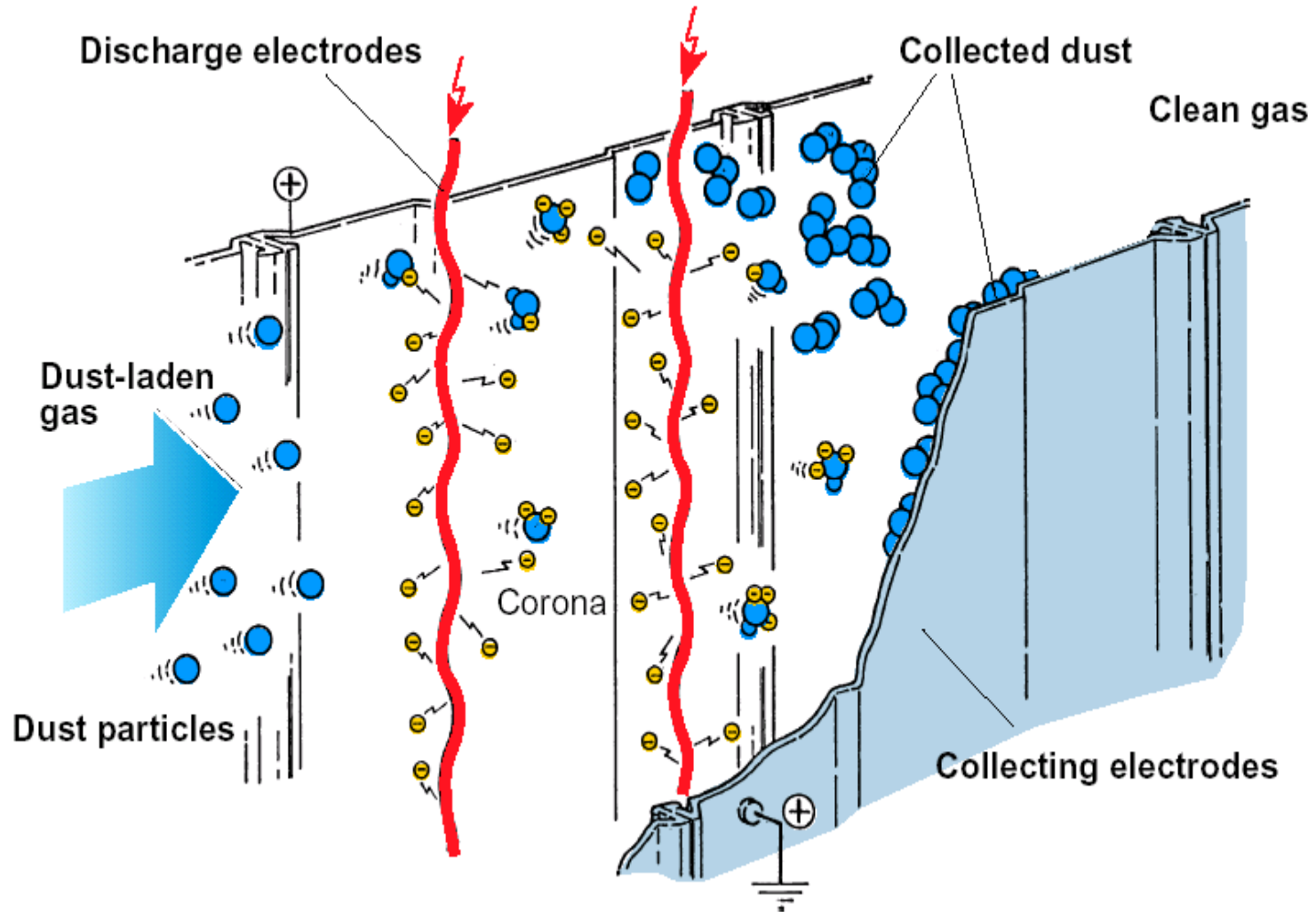
- *Introduction*
- *Gas flow*
- *Current distribution*
- *Current, variations in time*
- *Rapping losses*
- *Summary*

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Principal design of Electrostatic Precipitator



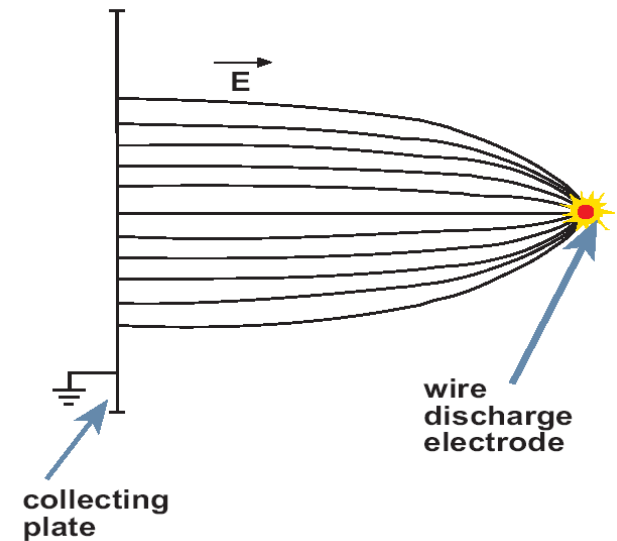
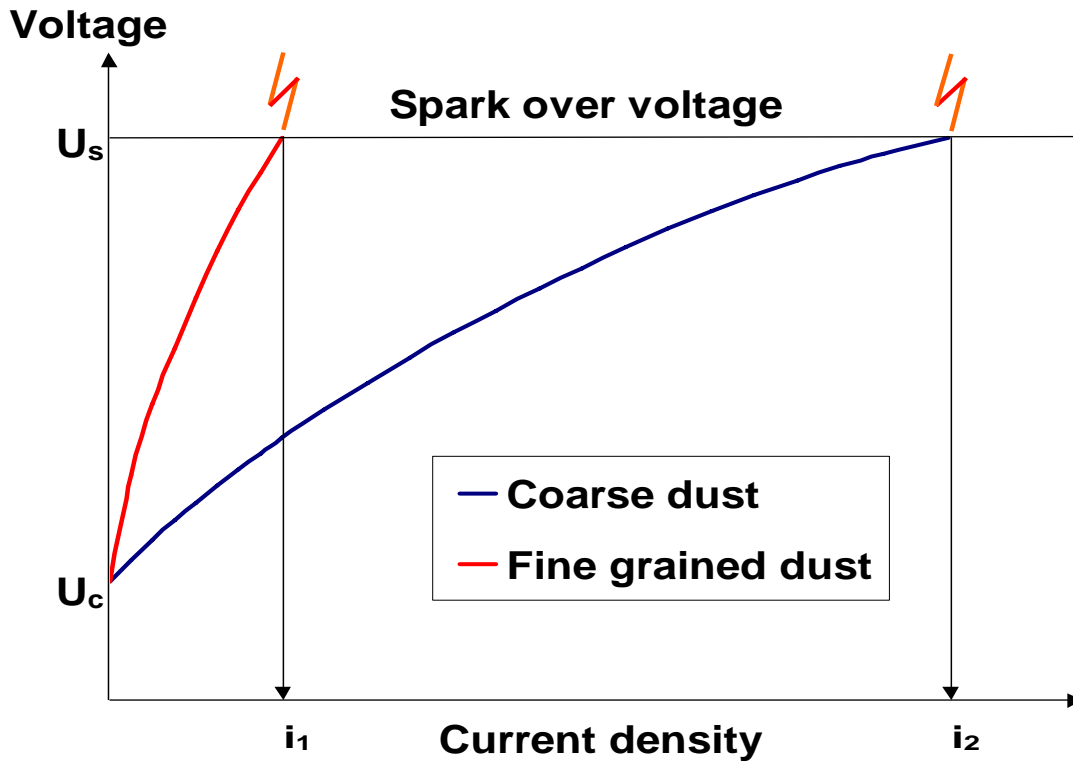
ESP dust collection



2.2

- Corona quenching
 - *Particle size distribution, 'Fine dust'*
 - *Reduce E-field at the emitting electrode*
 - *Less Corona current*
- Back Corona
 - High resistivity dust
 - High E-field in the dust layer
 - Injects positive charges into the gas
- Reentrainment
 - Low resistivity dust
 - Low E-field in the dust layer
 - Reduced holding forces in the dust layer

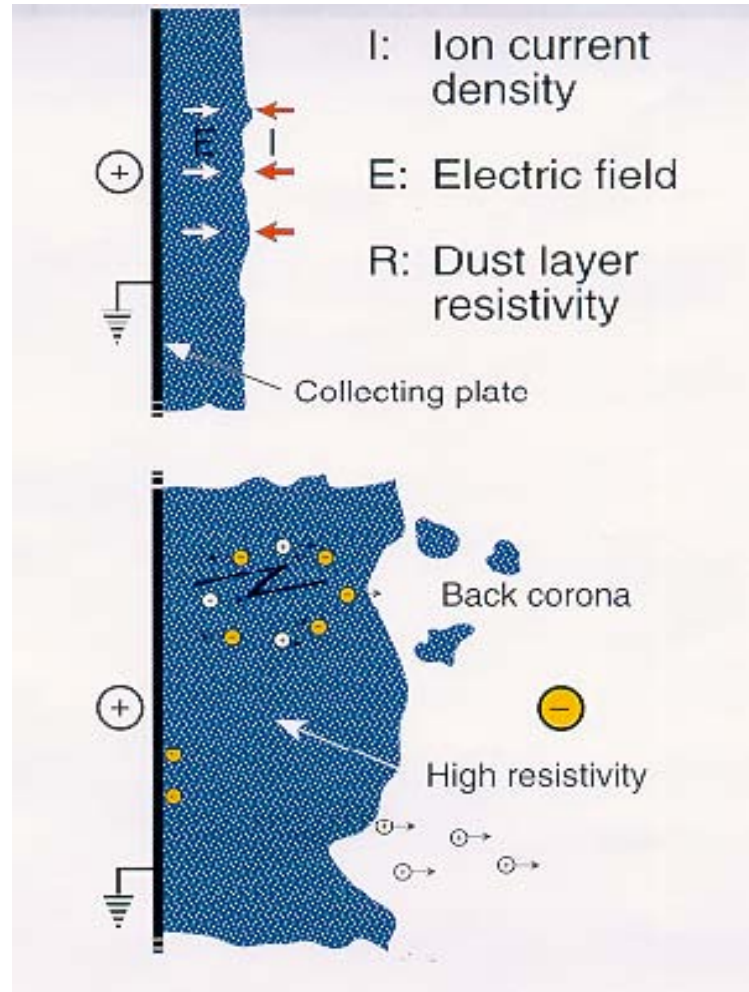
Poor Power Input



Fine grained dust increases the Space Charge Effect

The resistivity challenge

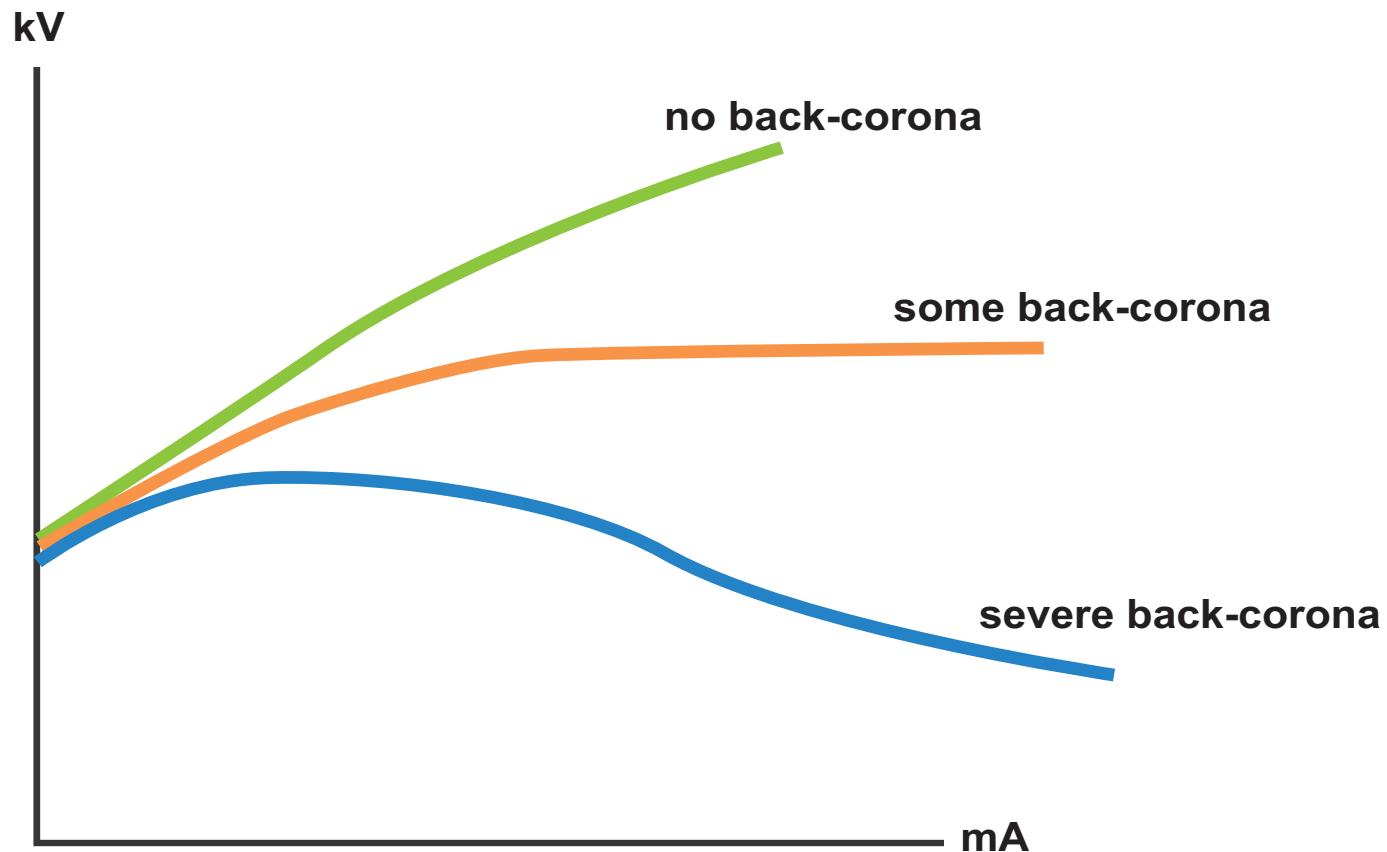
$$\underline{E = R \times I}$$



Dust cake formation inside ESP

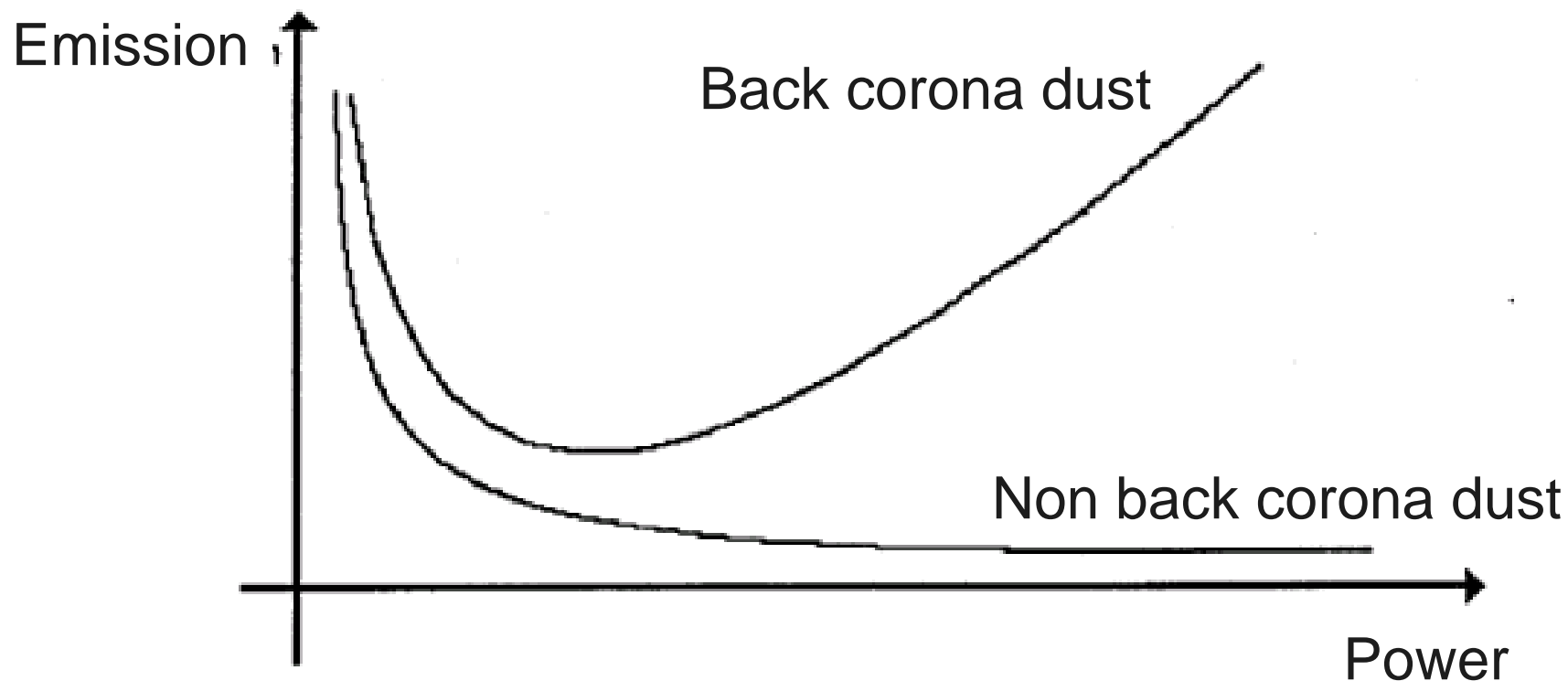


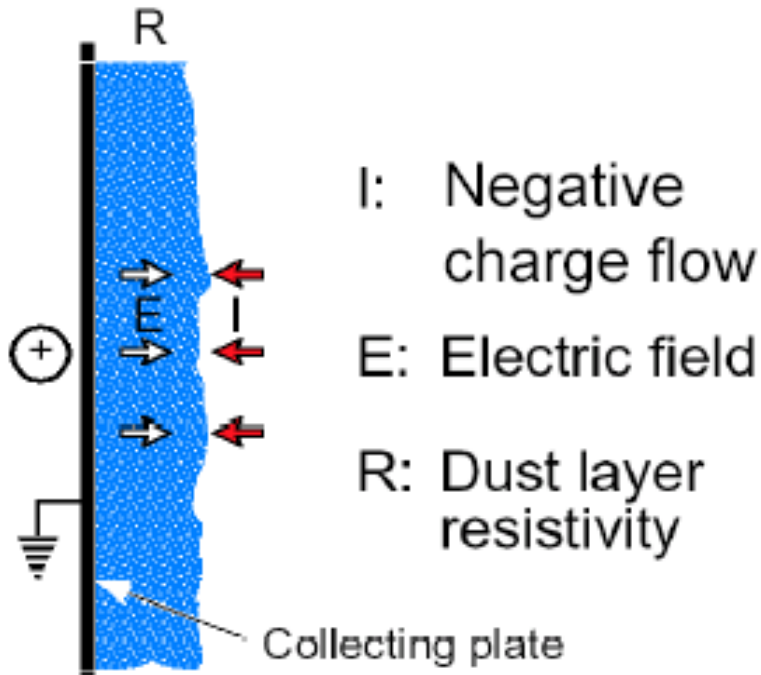
Curve forms for different operating conditions



Best efficiency with reduced power when back-corona

Dust emission vs. power consumption





Tear off

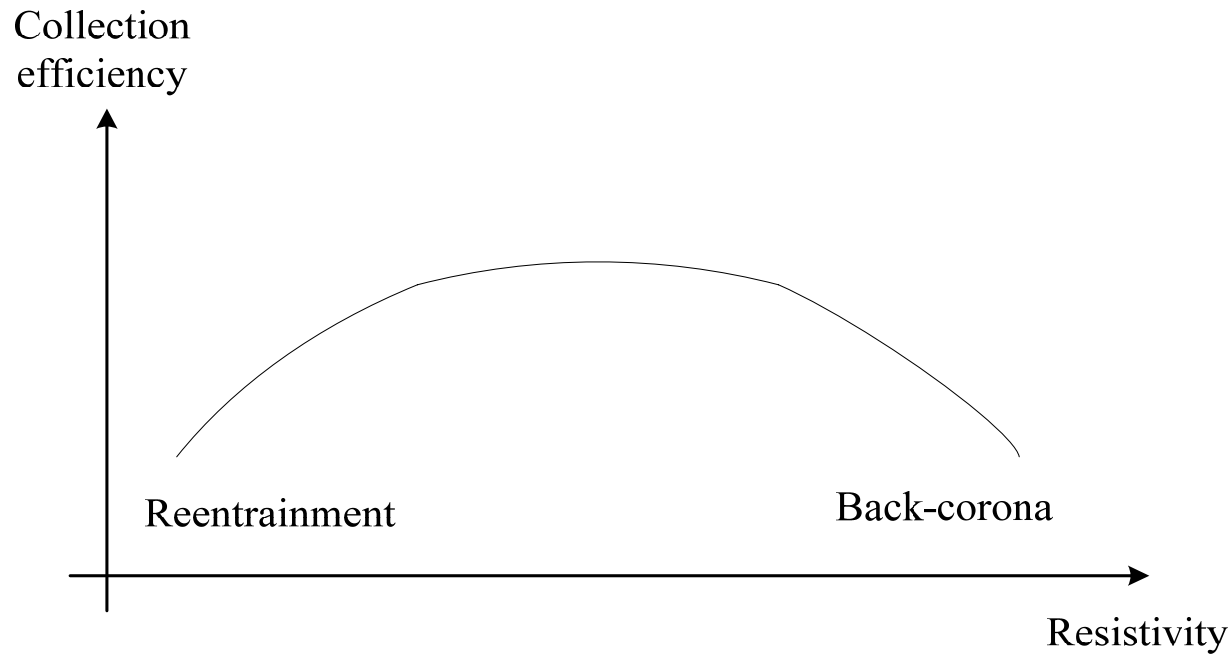
Gas flow (drag)
Gravity

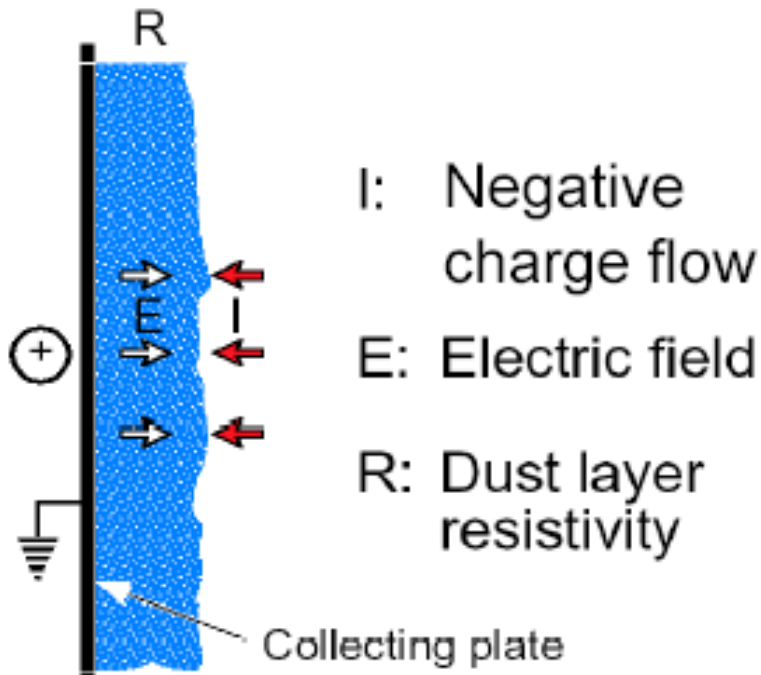
Holding

Electrostatic forces
Chemical (cohesion)

Reentrainment related to low resistivity depends on the relation between dust layer electrostatics and gas flow close to the collecting electrode.

Dust emission vs. resistivity





Classification 1

<i>Conductive</i>	$10^4 - 10^8 \Omega\text{cm}$
<i>Normal</i>	$10^8 - 10^{10} \Omega\text{cm}$
<i>Moderate</i>	$10^{10} - 10^{11} \Omega\text{cm}$
<i>High</i>	$10^{11} - 10^{13} \Omega\text{cm}$

[Parker et.al, Applied Electrostatic precipitation, 1997]

Classification 2

<i>Low</i>	$10^7 - 10^9 \Omega\text{cm}$
<i>Best perf.</i>	$10^9 - 10^{11} \Omega\text{cm}$
<i>High</i>	$10^{11} - 10^{13} \Omega\text{cm}$

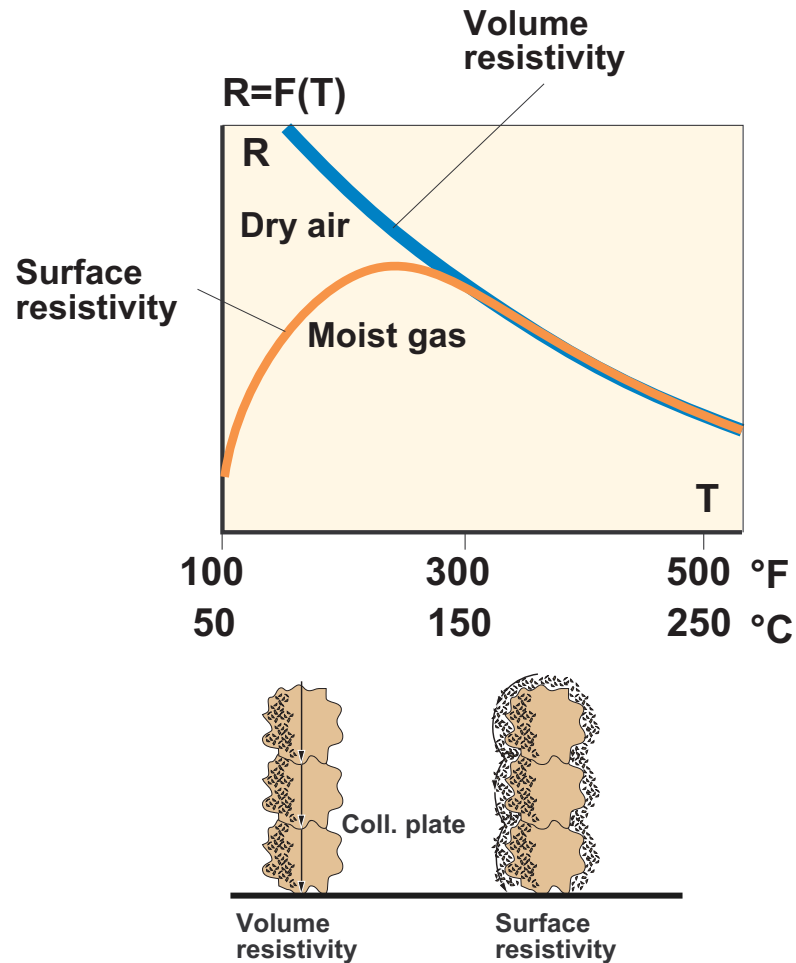
[Porle, Francis, Bradburn, ESPs for ind. Applications, 2005]

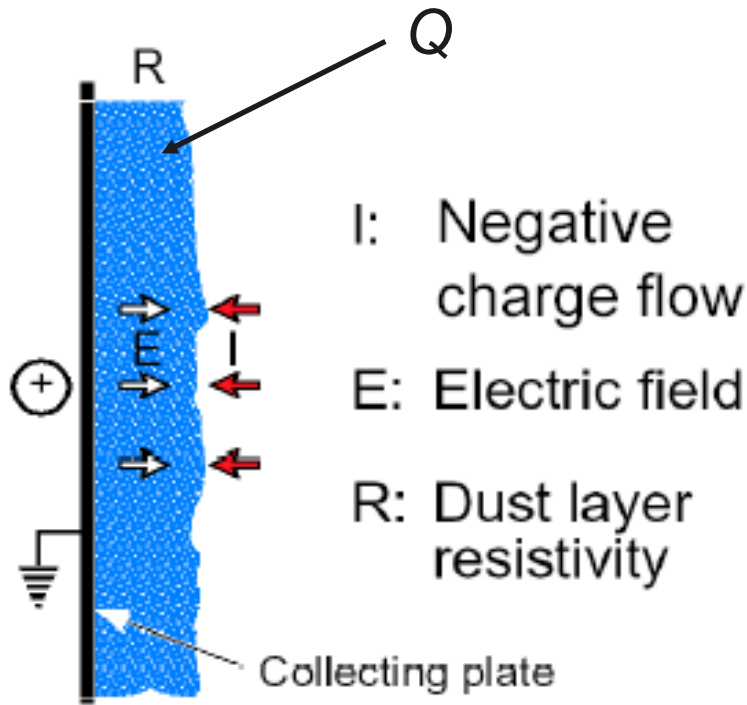
Classification 3

<i>High</i>	$> 10^{10} \Omega\text{cm}$
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[White, Industrial Electrostatic Precipitation, 1963]

Dust resistivity versus moisture and temp.





I: Negative charge flow

E: Electric field

R: Dust layer resistivity

Collecting plate

$$F = Q E$$

$$E = j \rho$$

$$\Rightarrow F = Q j \rho$$

F Force, [N]

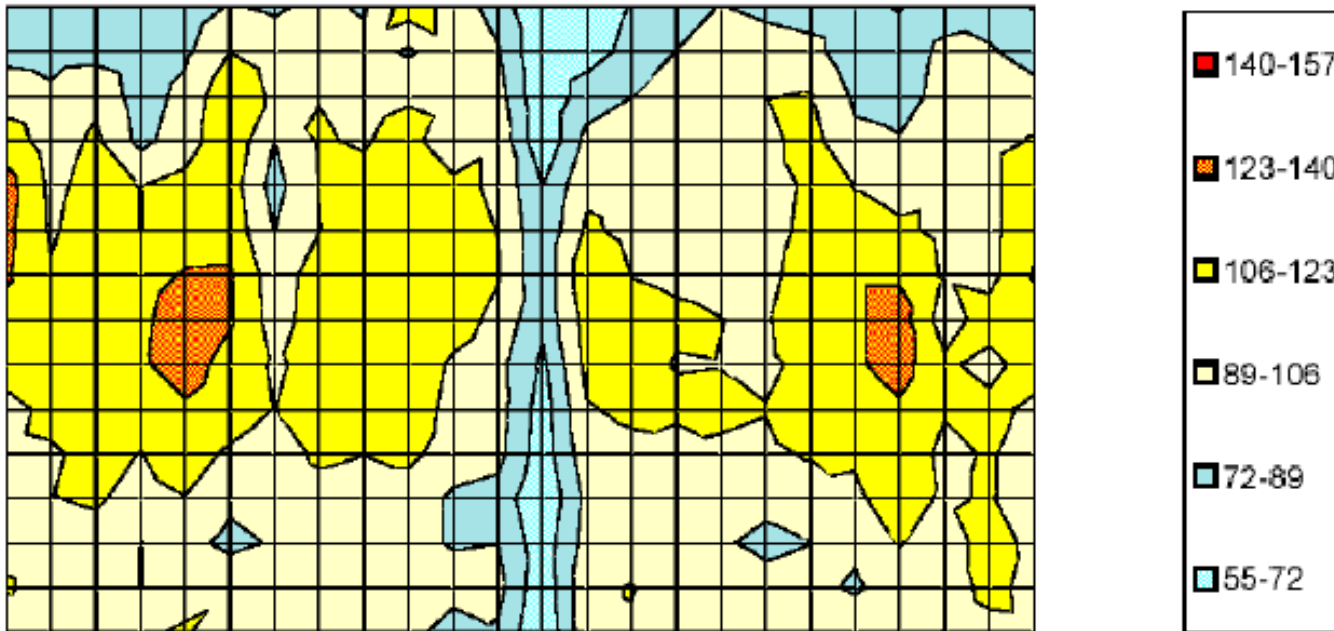
Q Charge, [C, (As)]

E Field strength, [V/m]

j Current density, [A/m²]

ρ Dust layer resistivity, [Ω m]

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Velocities in percentage of average

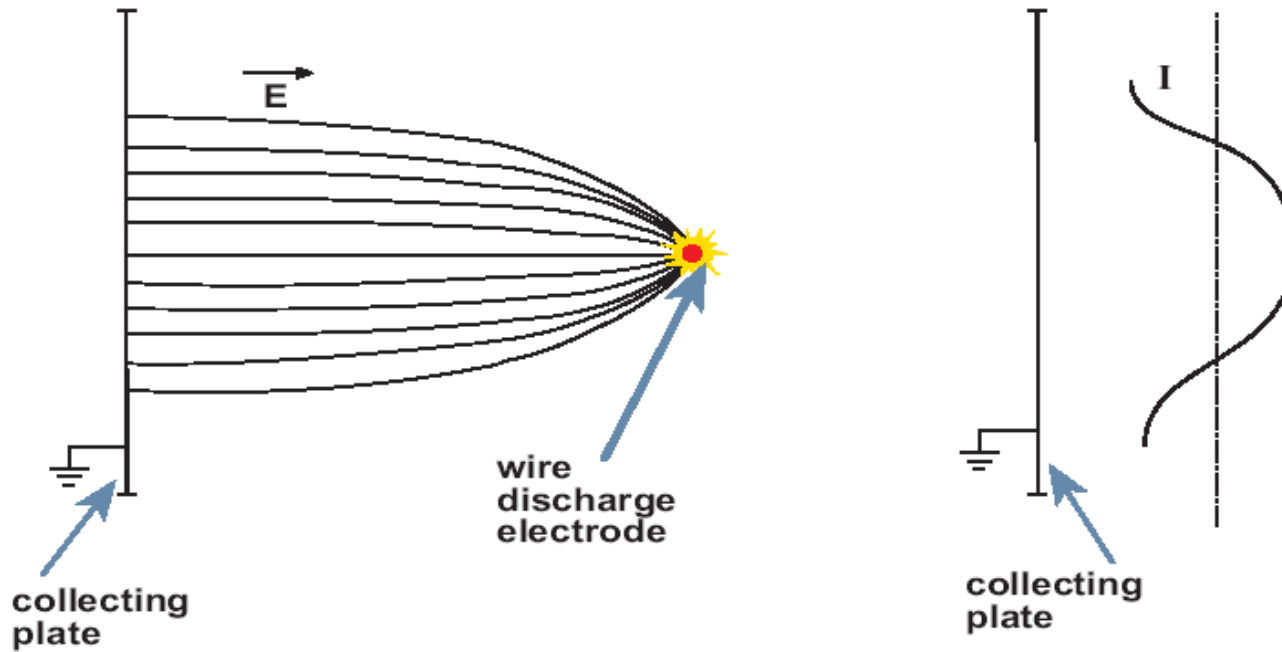
Measured after the first field

Gas flow distribution, means to minimize reentrainment

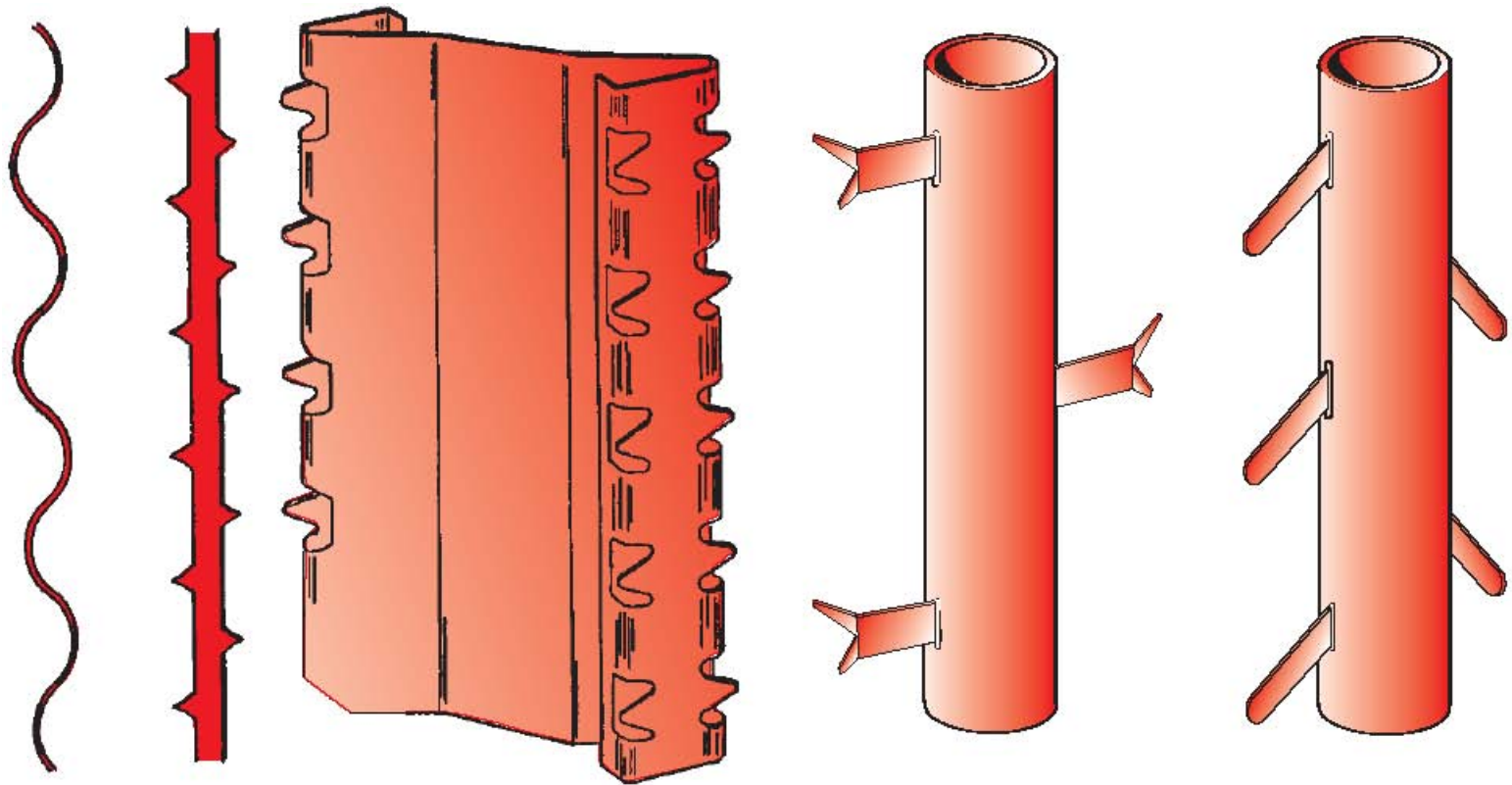
- Minimize high gas velocities
- Uniform flow distribution
- Avoid in-leakage

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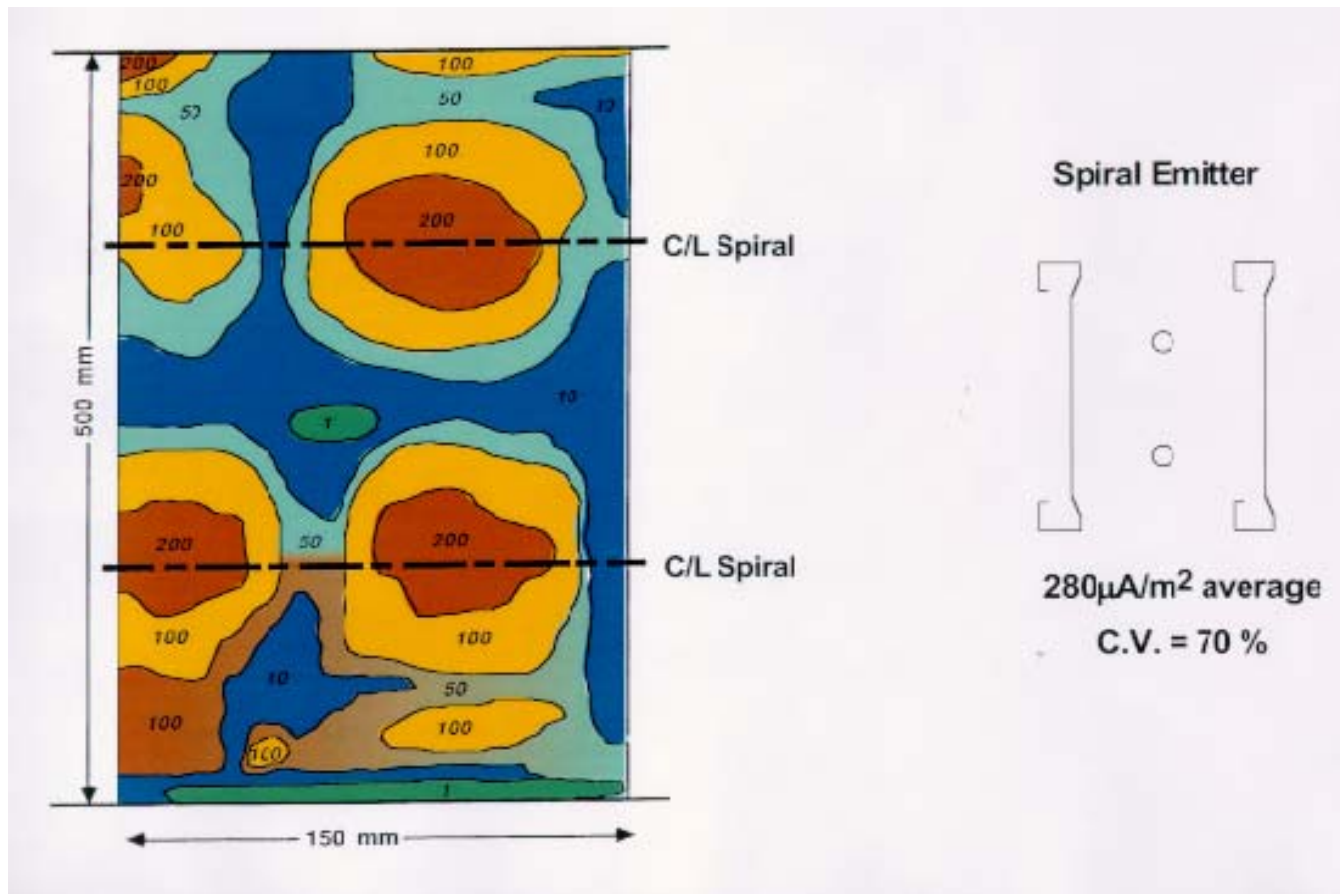
Current distribution, general



ESPs - discharge electrode

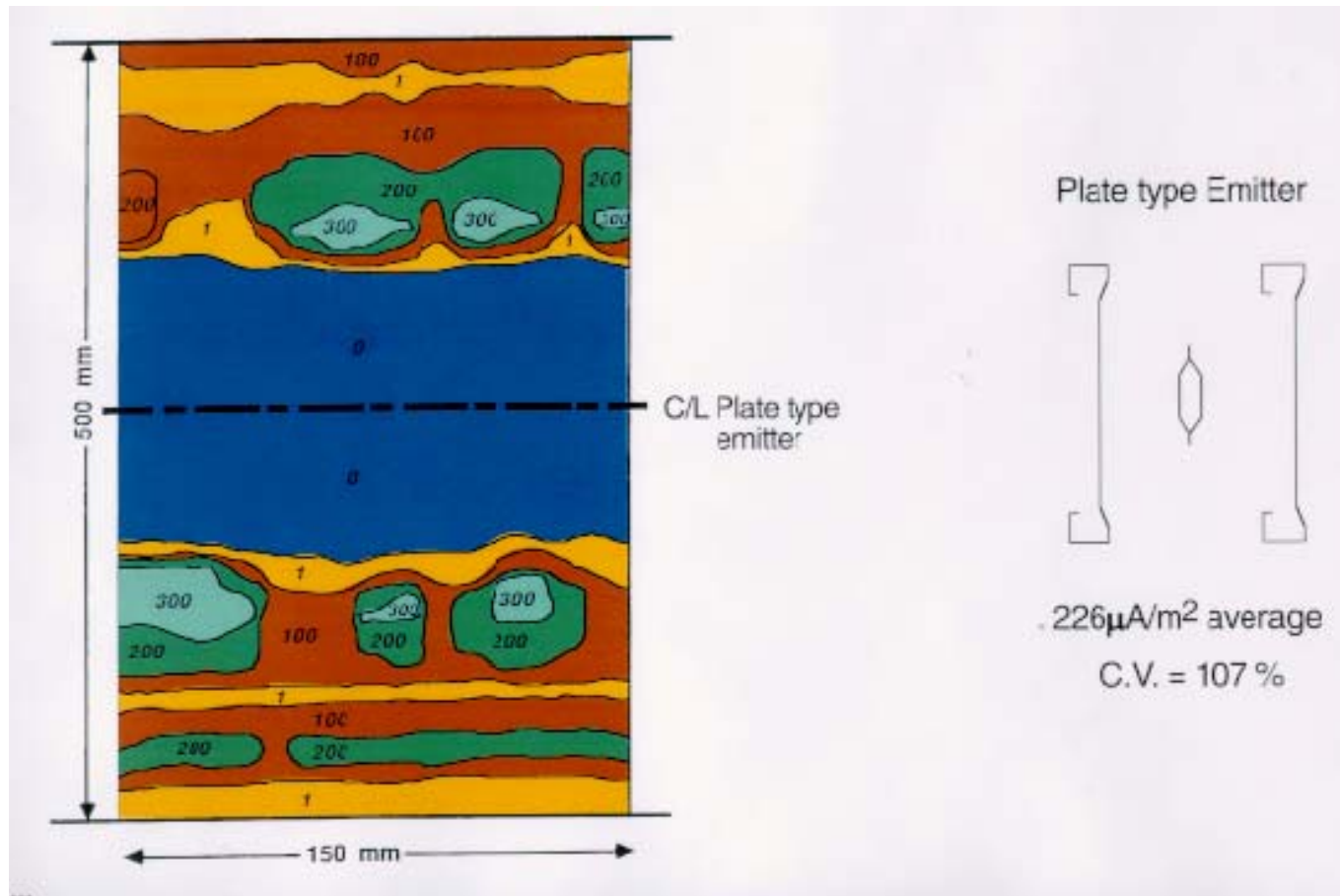


Current distribution on collecting plates



- Best available and proven discharge electrode -

Current distribution on the collecting plate

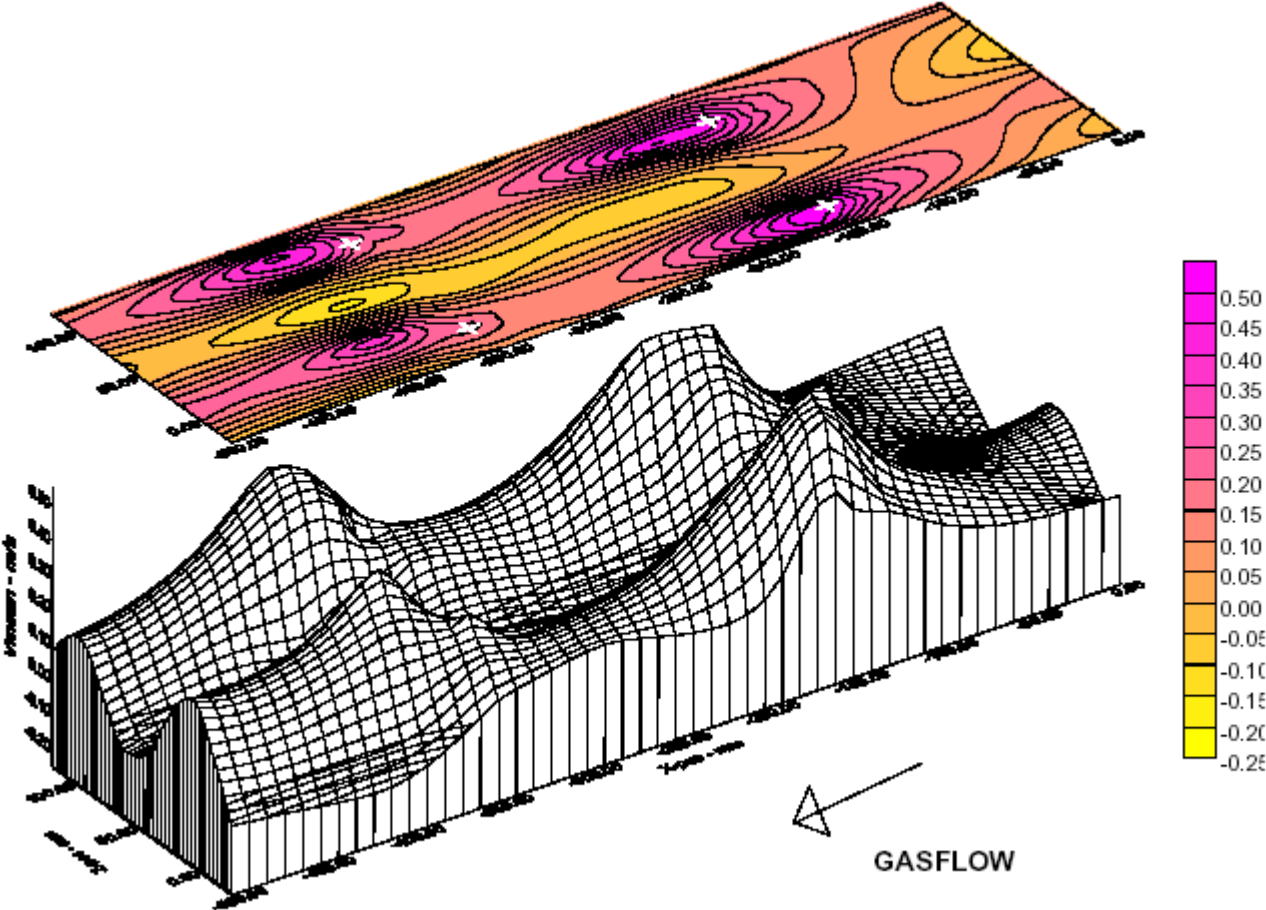


- Large areas with either high or zero current -

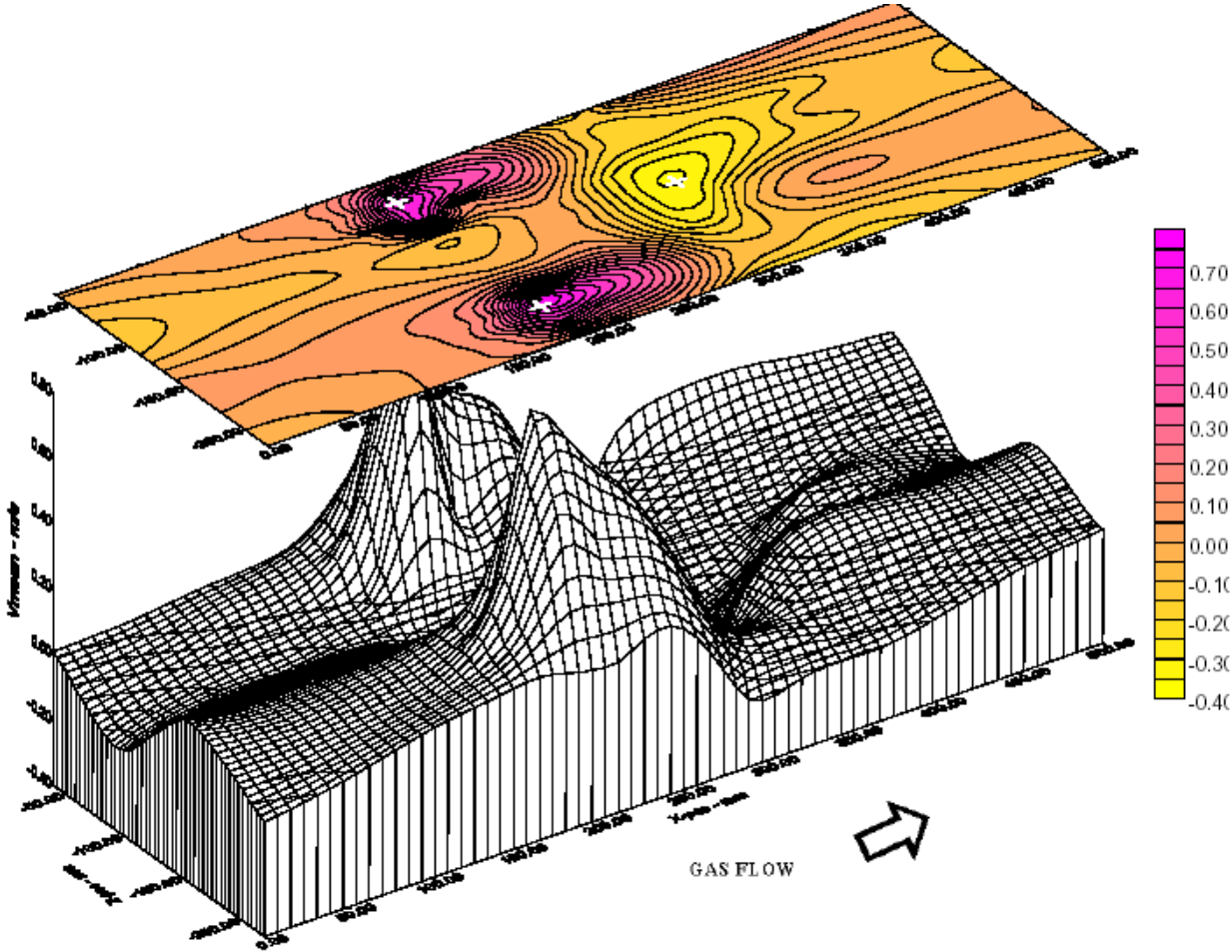
- Dust pattern similar to current distribution
- High CV-value in current distribution
- Poor utilisation of collecting plate
- Reentrainment



Ionic wind, spiral

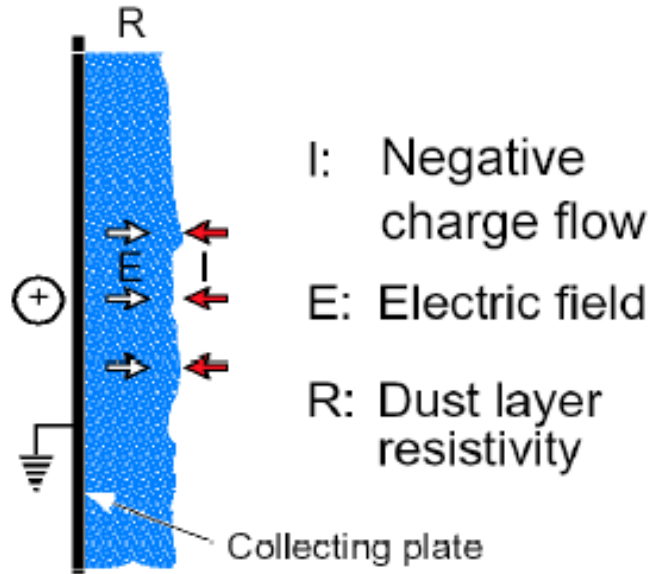


Ionic wind, RDE

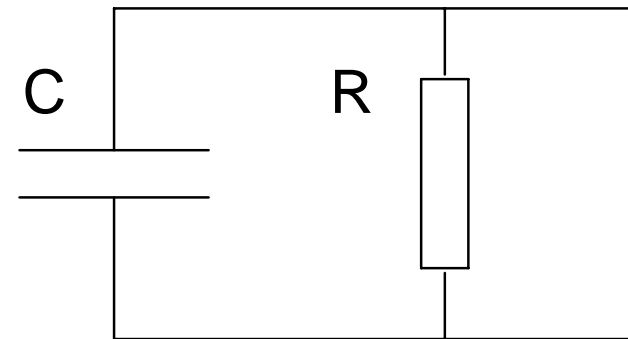


- Influenced by emitting electrode design
- Non uniform current distribution gives:
 - Substantial areas of low current densities
 - Negative effect from the ionic wind, high current areas

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$$\tau = R \cdot C$$



τ Time constant, [s]

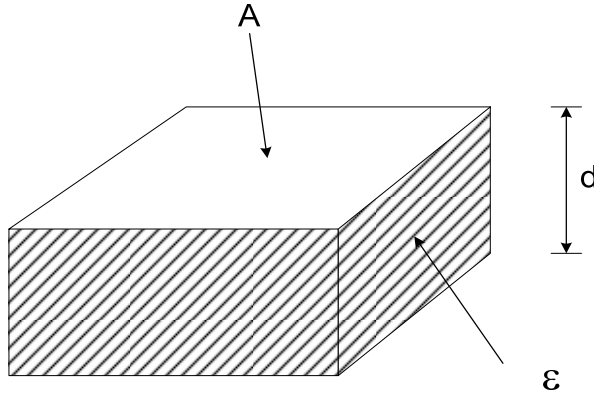
A Area, [m²]

d Distance, [m]

ϵ Dielectric constant, [As/Vm]

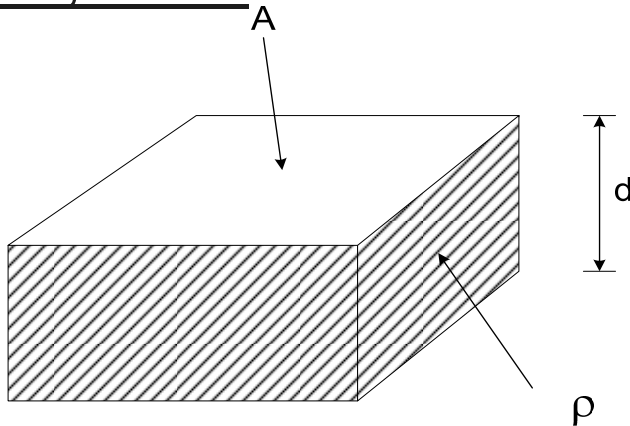
ρ Resistivity, [Ω m]

Capacitor, plate



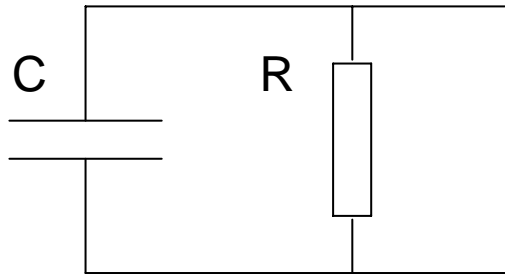
$$C = \epsilon \frac{A}{d}$$

Resistor, block



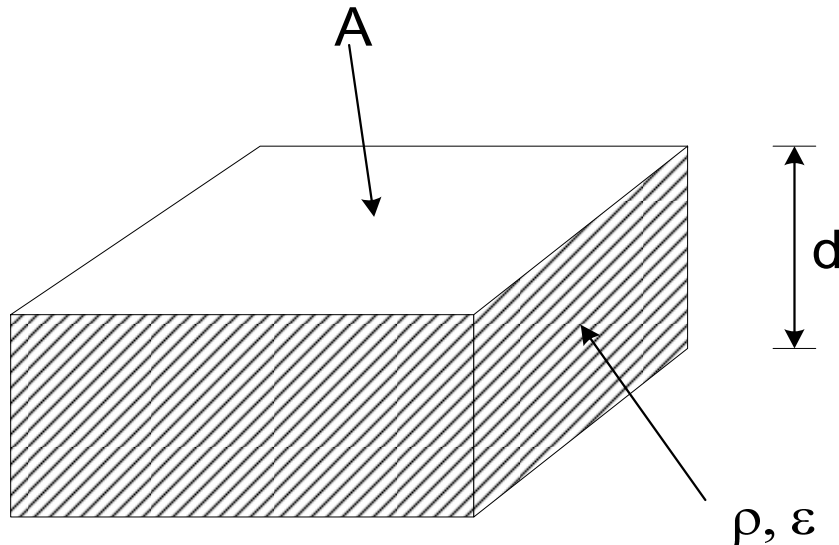
$$R = \rho \frac{d}{A}$$

Estimation of dust layer time constant



$$C = \epsilon \frac{A}{d}$$

$$R = \rho \frac{d}{A}$$



$$\tau = R \cdot C = \rho \cdot \epsilon$$

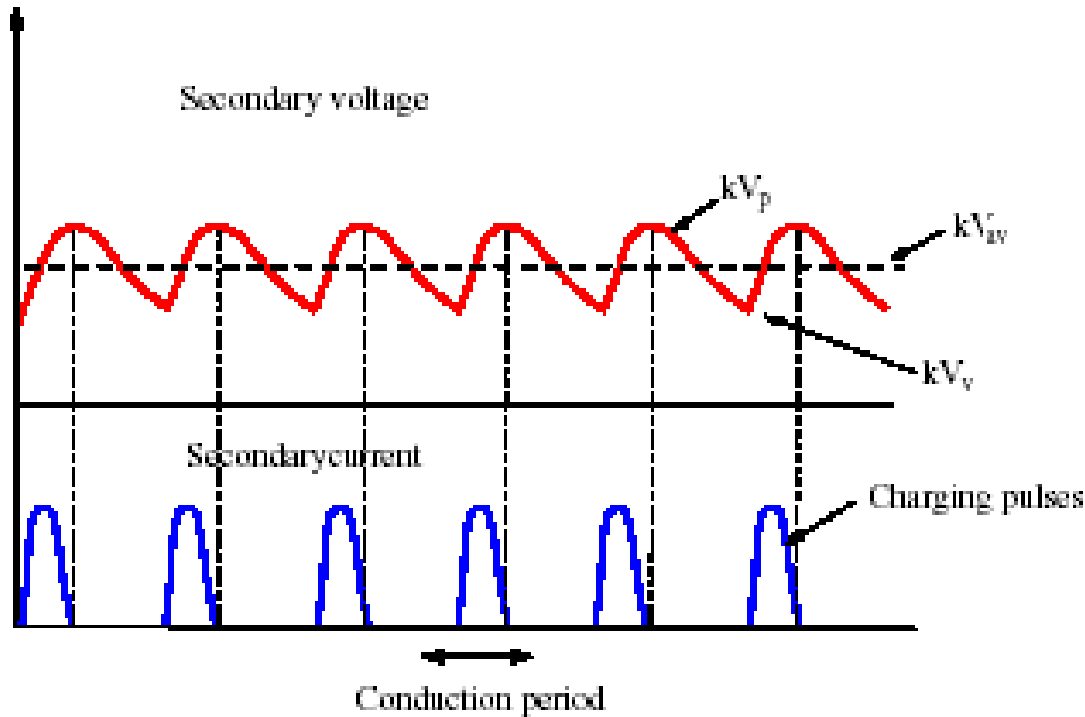
$$T=RC=\rho\varepsilon$$

$$\varepsilon=1 \cdot 8,85 \cdot 10^{-12} \text{ As/Vm} \approx 1 \cdot 10^{-11} \text{ As/Vm}$$

$$\rho=1 \cdot 10^{10} \text{ } \Omega\text{cm} = 1 \cdot 10^8 \text{ } \Omega\text{m} \Rightarrow \underline{T=1 \cdot 10^{-3} \text{ s}}$$

<u>ρ [Ωcm]</u>	<u>T [ms]</u>
$1 \cdot 10^8$	0,01
$1 \cdot 10^{10}$	1
$1 \cdot 10^{12}$	100
$1 \cdot 10^{14}$	$10^4 (=10 \text{ s})$

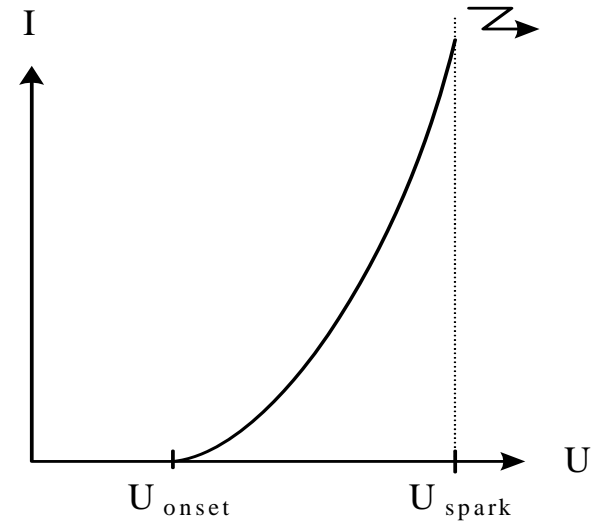
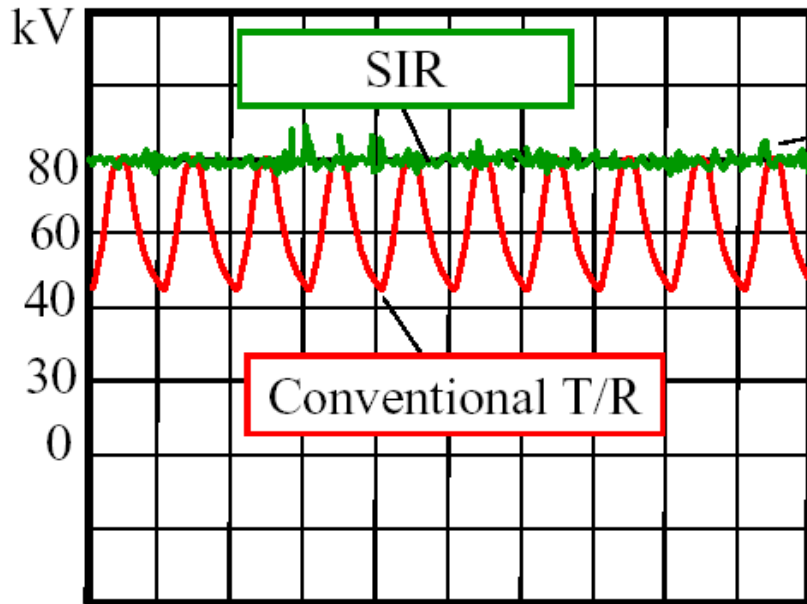
Voltage ripple



If the time constant of the dust layer is short compared to the variations of the ESP voltage then the current in the dust layer follows the corona current.

=>Keep corona current constant

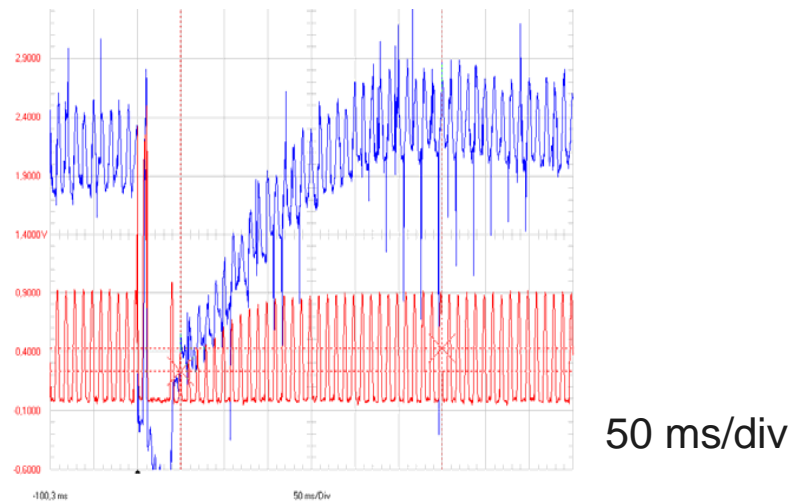
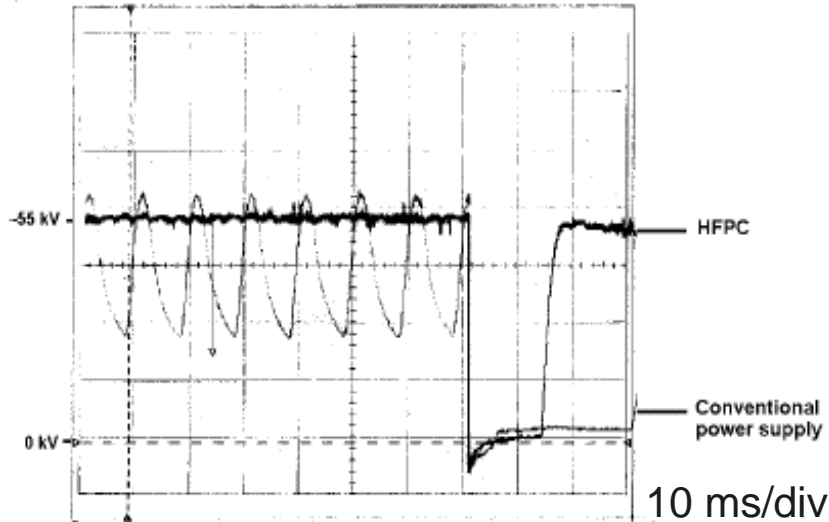
Voltage ripple vs reentrainment



$$i_{Corona} = k \cdot (u - U_{Onset})^2$$

$$F = Q j \rho$$

$\Rightarrow F$ is very low at U_V



- HFPS may have a shorter blocking time, no 50/60 Hz dependency
- Superior bandwidth of the control loop (faster) enables improved spark recovery.

Time variations of current, means to minimize reentrainment

- Reduce voltage ripple
- Spark over control
 - Minimize blocking time
 - Optimize voltage recover

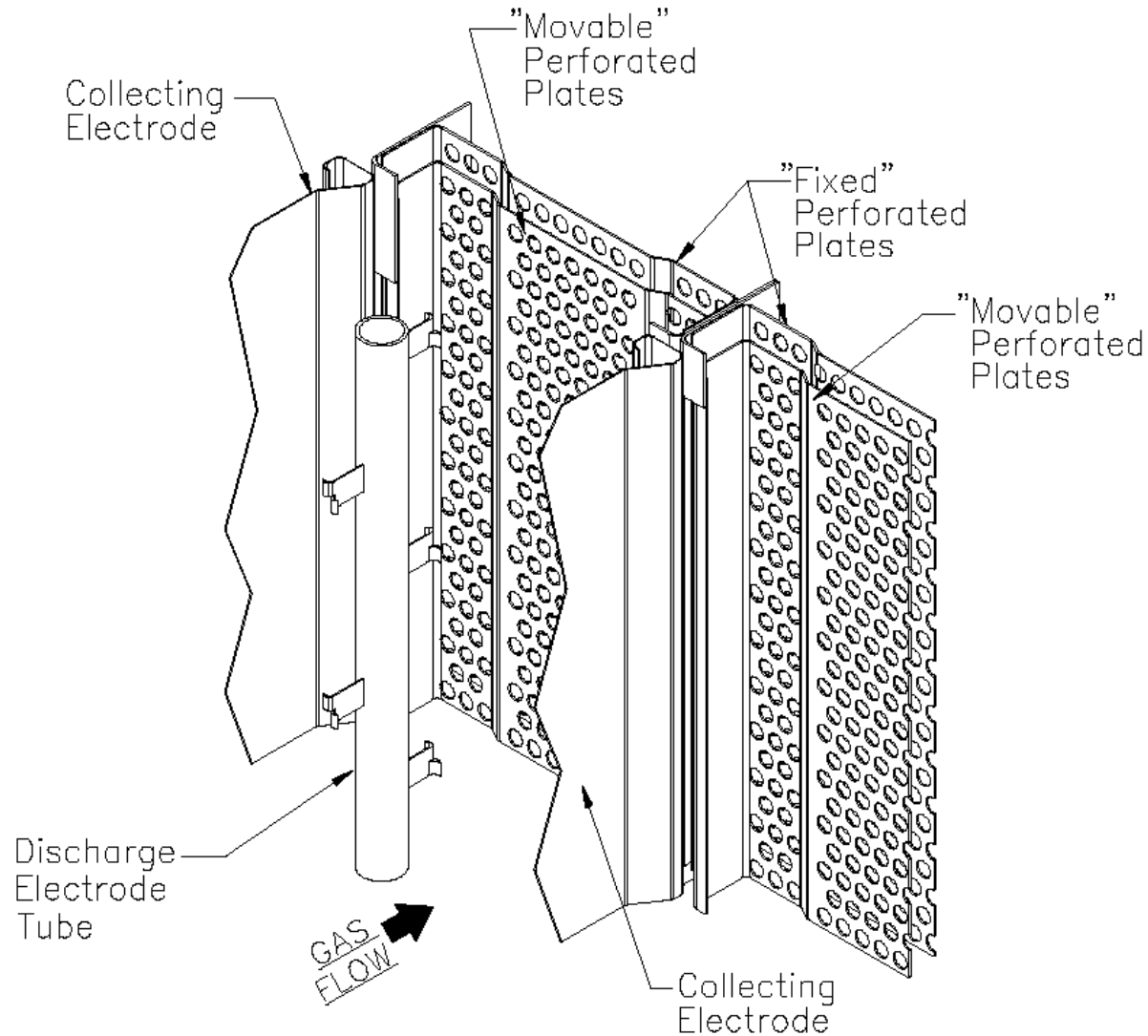
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Rapping acceleration



An uniform distribution of acceleration forces is preferred.

Off-Flow Rapping Design



Rapping losses, means to minimize reentrainment

- High rapping losses are expected due to low holding forces
- Tuning of rapping sequence
- Uniform acceleration
- Off flow rapping

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- Low resistivity calls for higher current, $F=Q \cdot j \cdot \rho$
- Gas flow distribution
 - Reduce high velocities
- Current distribution
 - Minimize low current zones
 - Ionic wind
- Time variation of Corona current
 - Minimize voltage ripple
 - Spark over control
- Rapping losses
 - Optimize rapping sequence

Thanks for your attention !

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