REINHOLD ENVIRONMENTAL Ltd.

2013 APC Round Table & Expo Presentation

July 8-9, 2013, in St. Louis, MO / Hosted by Ameren

Corona Gone Bad

2013 APC Conference

St. Louis, Missouri – July 8-9, 2013

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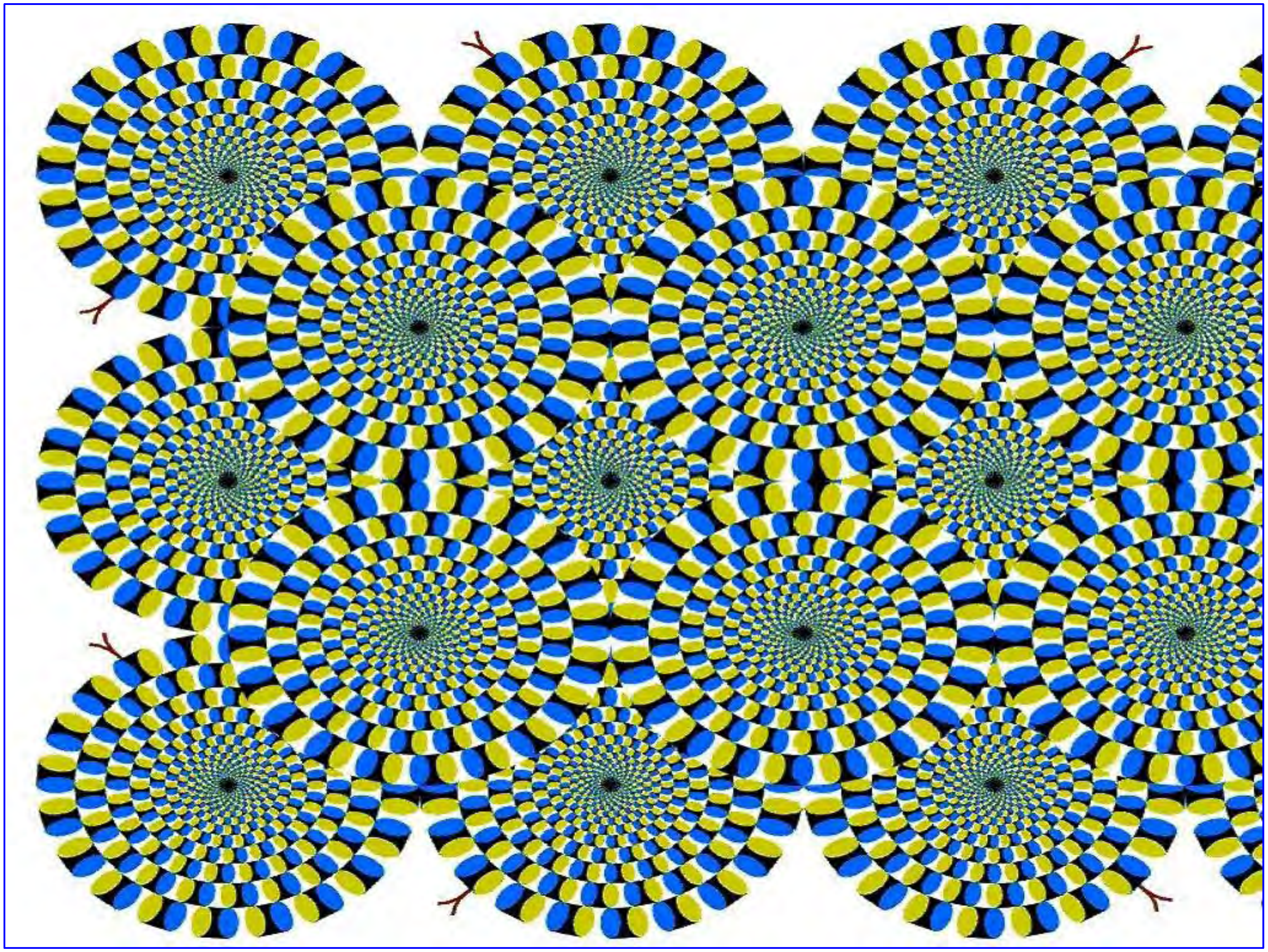
Corona Gone Bad



Sometimes your eyes can play tricks on you!

Is this slide animated for motion?

Corona Gone Bad

This photo of a Discharge Electrode and Collecting Plate can also be tricky, at first.

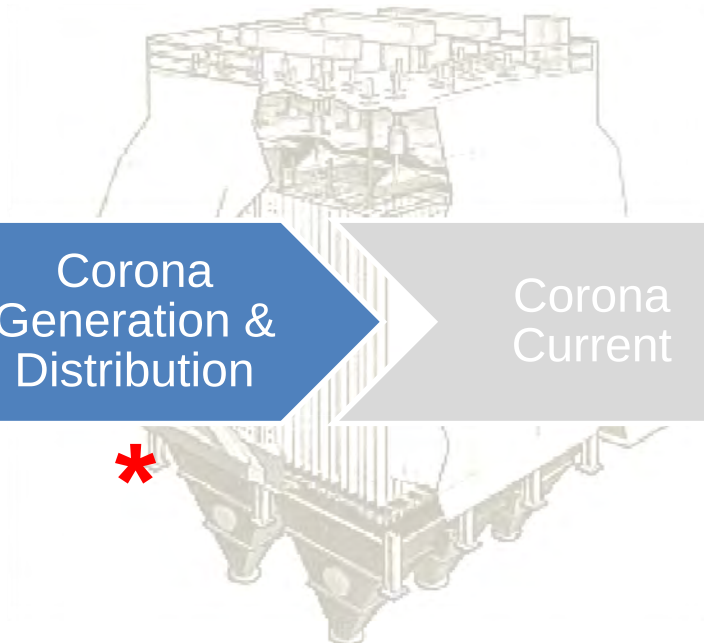
The image is not from the camera's flash but from the relative deposition of dust on the collecting plate.

Corona Gone Bad

1. The light areas represent areas of greater dust collection.
2. The dark areas represent little or no dust collection.
3. A somewhat similar pattern would appear for all types of rigid electrodes, not just this one.
4. The question is: "Why and how are these dust patterns created?"

Taking the Mystery Out of Corona Generation and Distribution

An Ongoing Process of Research and Development



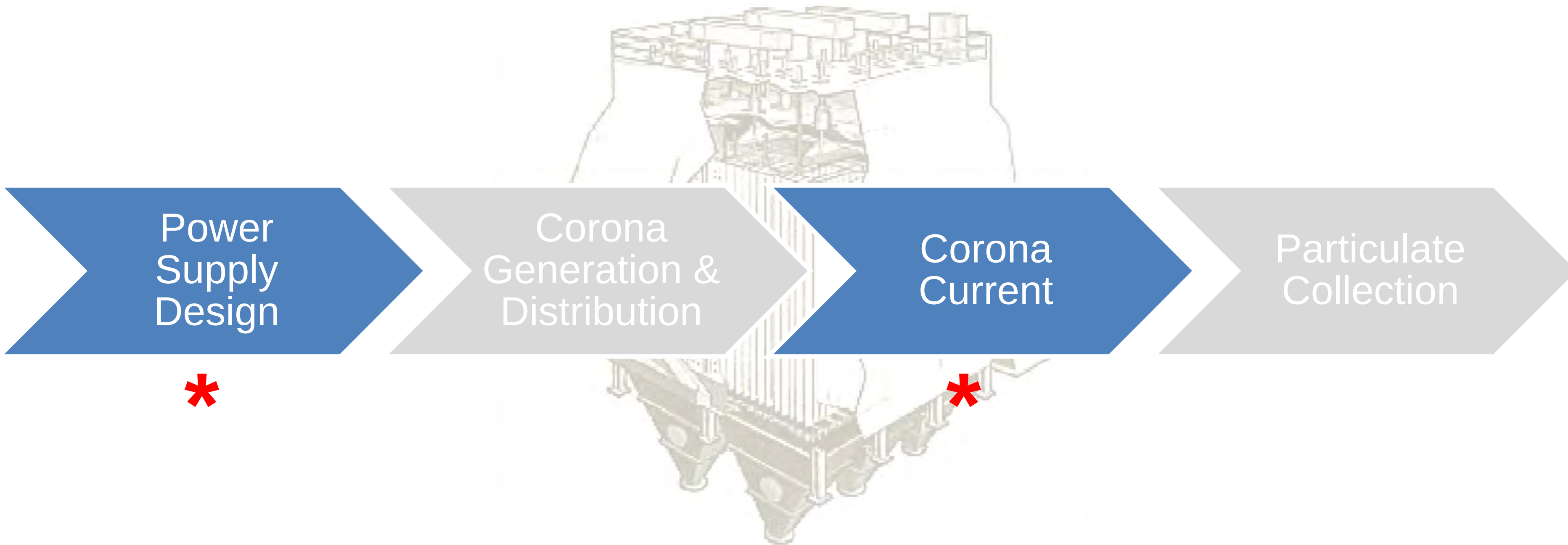
Steps to Understanding

Power Supply Design → Corona Generation & Distribution * → Corona Current → Particulate Collection *

**** Discussed in this Workshop: "Corona Gone Bad"***

Taking the Mystery Out of Precipitator Power Supplies

An Ongoing Process of Research and Development



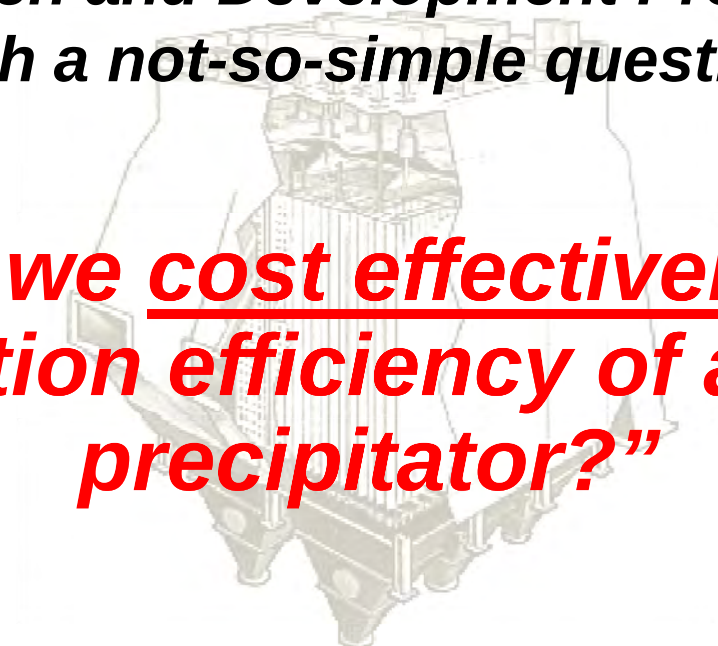
** Discussed in Workshop 20: "Taking the Mystery out of Precipitator Power Supplies" (Presented by David Johnston)*

B&W R&D Facility – Newport News, VA

- ***To unravel the corona generation and distribution mystery, funding was obtained and a testing facility was set up.***
- ***That testing will now be described by Rob Hummell; then John Knapik will discuss its impact on ESP collection efficiency.***

Unraveling the Mystery

The Research and Development Process began with a not-so-simple question:



"How can we <u>cost effectively</u> increase the collection efficiency of an existing precipitator?"

Unraveling the Mystery

To increase collection efficiency we can:

1. **Increase collection area (rebuild)**
2. **Decrease flow rate (reduce production, decrease air inleakage)**
3. **Increase migration velocity (optimize the electric field)**

Unraveling the Mystery

The Deutsch-Anderson Equation

$$\text{Efficiency} = 1 - e^{\frac{-A}{V}\omega}$$

Where:

- **A = Collection Area**
- **V = Flow rate**
- **ω = Migration Velocity**

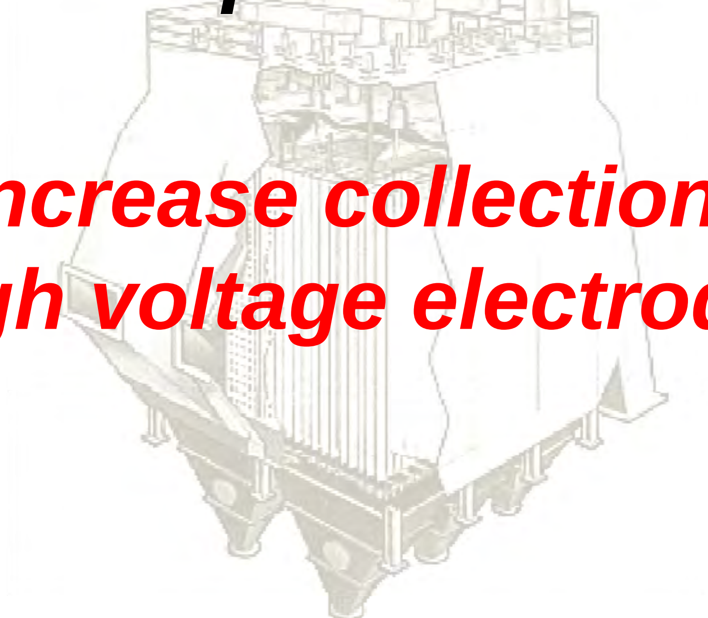
$$^{*}\omega \approx \beta \, Kv_{average} \, KV_{peak}$$

β = Constant for a given Precipitator

**Reference: Industrial Electrostatic Precipitation by Harry White, equation 7.6*

Corona Generation

We questioned:

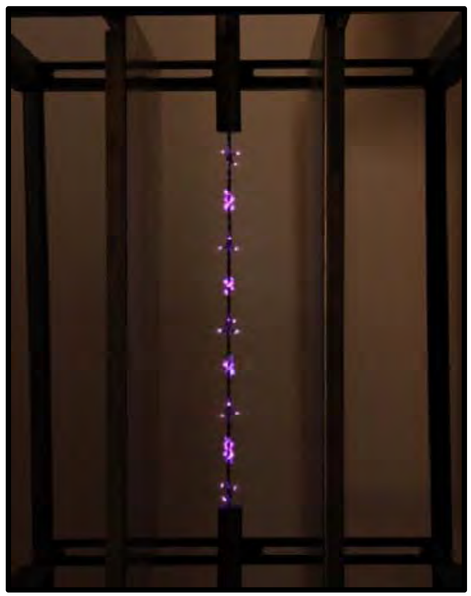


"Can we increase collection efficiency through high voltage electrode design?"

Corona Generation

We first tried to determine what the corona looked like using photography:

Round Electrode



Barbed Wire Electrode

V Pin Electrode

Electrode1

Corona Generation

Although the pictures were interesting, they did not tell us the current density profile on the collecting surface.

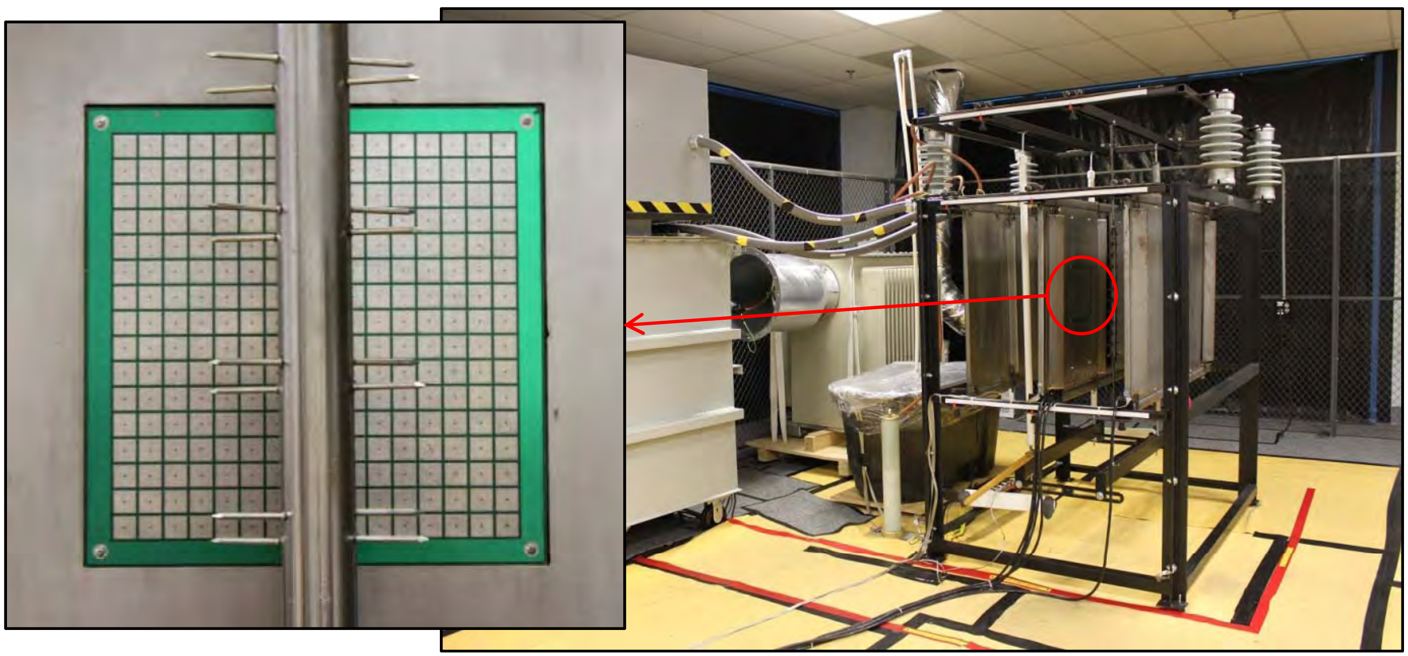
We made an initial assumption:

"Some electrodes create 'hot spots' of current on the collecting plate surface."

However, we had no means to measure this.

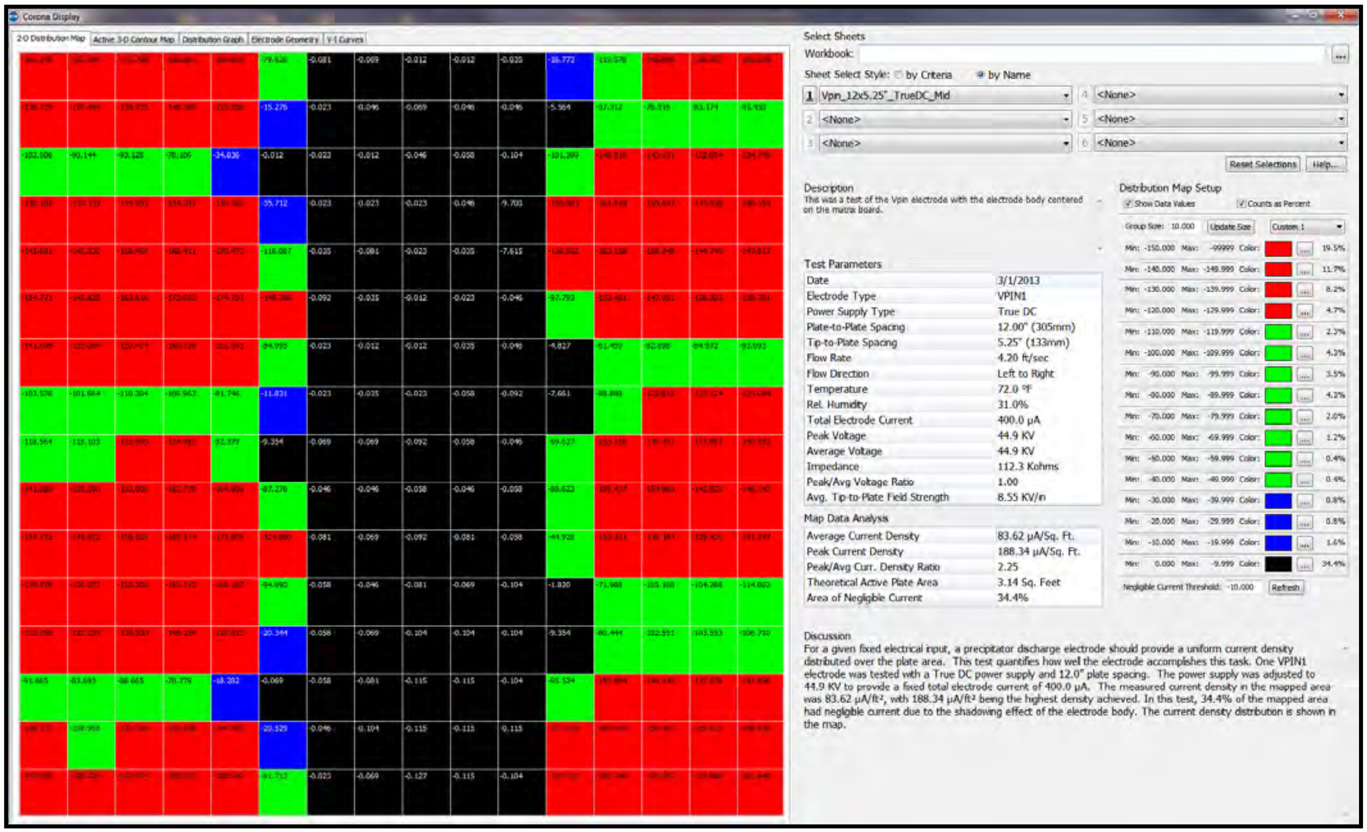
Corona Distribution

- ***We continued the research and development process by building a scale ESP test stand and a measurement board. The board allowed us to measure the current from each square, equating it to current density.***



Corona Distribution

- ***Now we had a means to gather the current density at the collecting surface. However, we had no method to objectively show and compare data sets…until we created it.***



Corona Display

Corona Distribution

ESP Performance is Determined Primarily by Electrical Conditions

An ESP should be operated at the highest kilovolts and current density in order to achieve maximum collection efficiency.

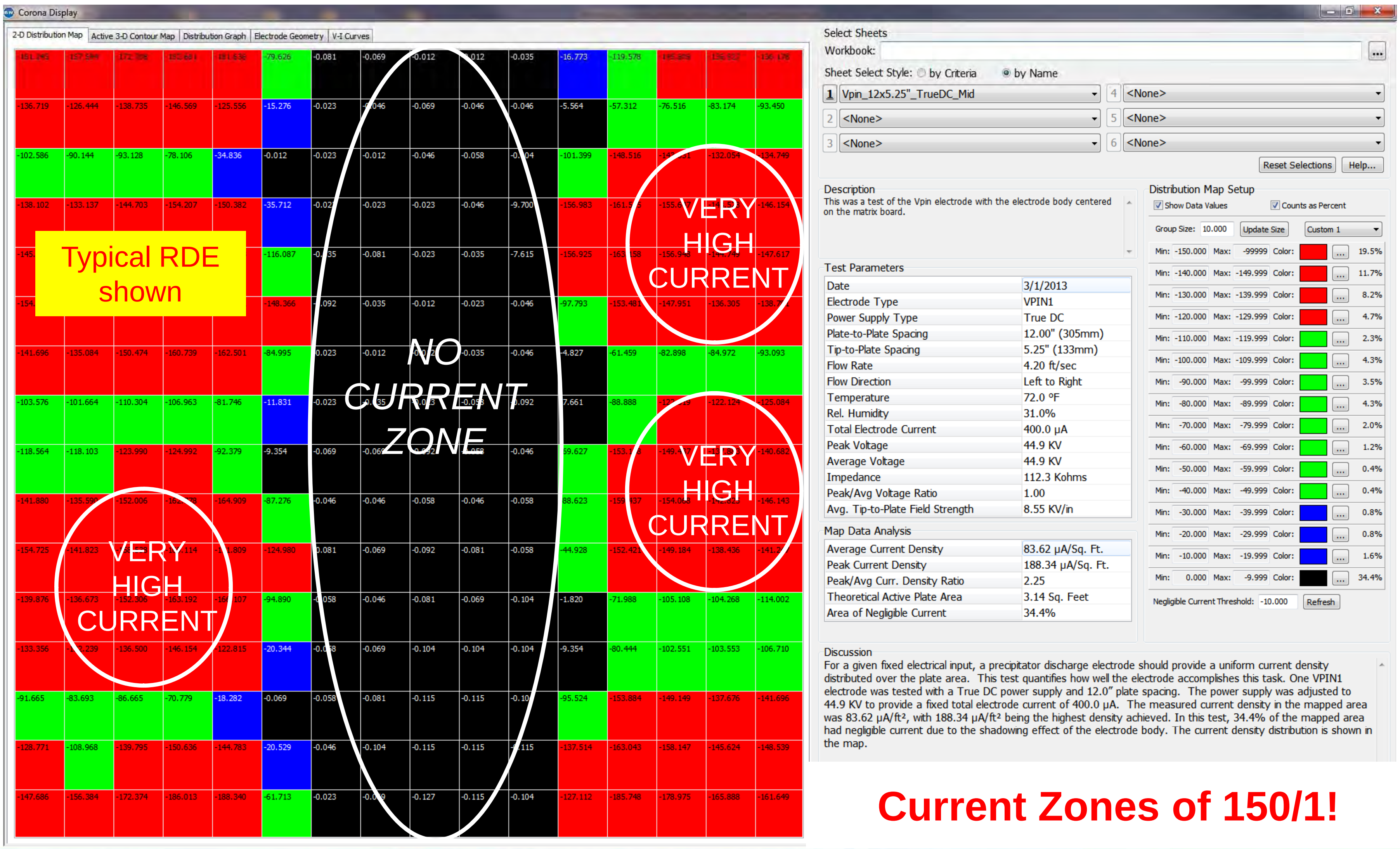
1. **High current densities produce high rates of particle charging**

2. **High current densities produce an increased electric field near the collecting plate due to ionic space charge contribution to the field**

3. **High KV produces high electric fields**

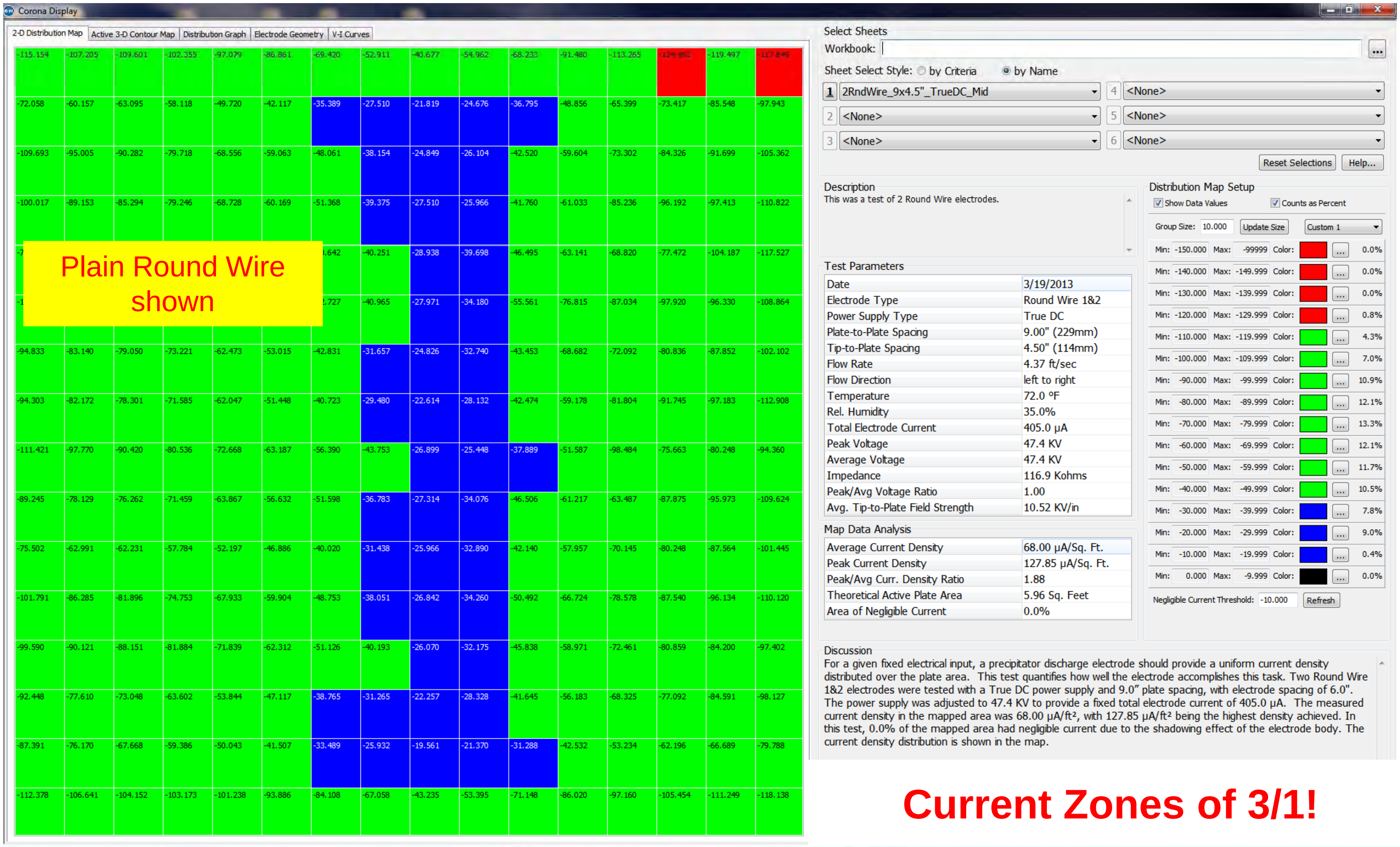
4. **High electric fields produce high values of particle charging**

But Too Much Current Density Can Be a Bad Thing!



Current Zones of 150/1!

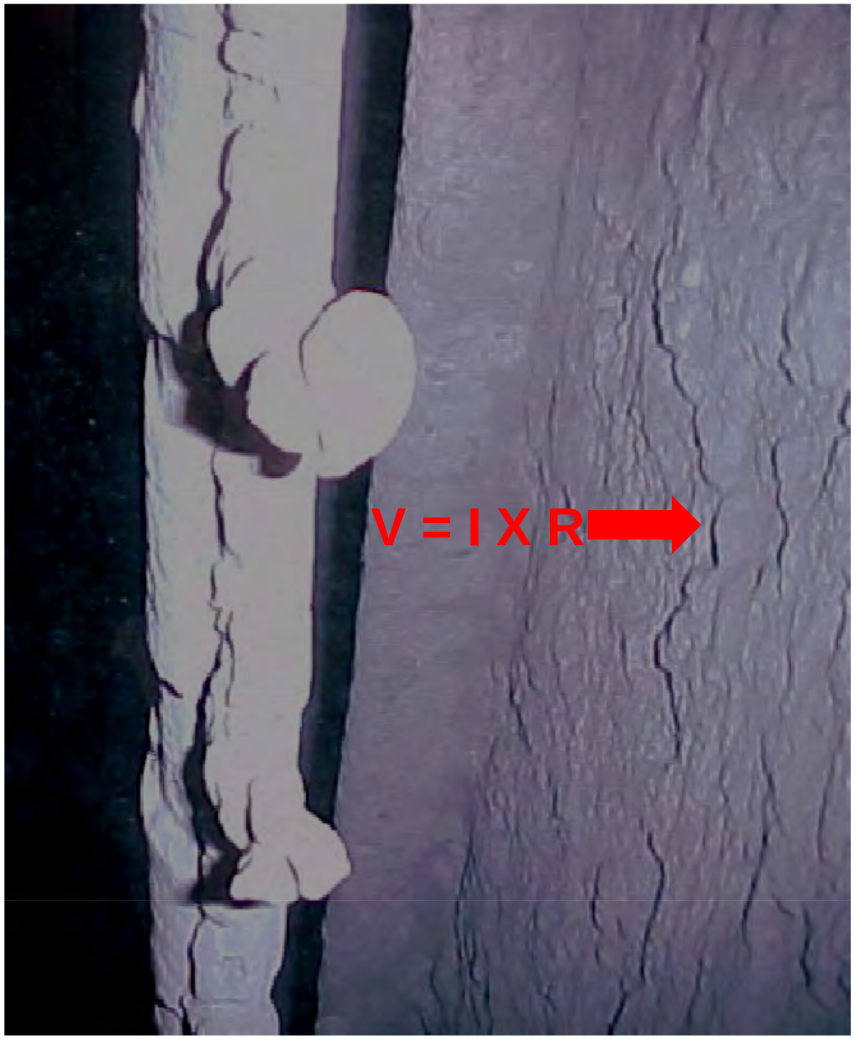
Round Wires Have Better Corona Current Distribution and Lack the Presence of a "Dead Zone"



Current Zones of 3/1!

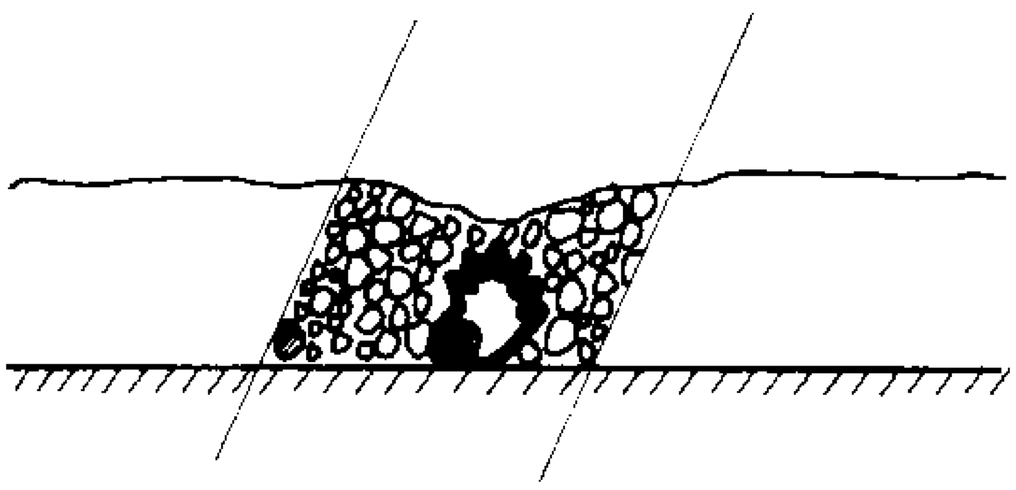
Current Density and Dust Deposition on the Collecting Plate

1. Corona current must pass over or through the dust layer on the plates.
2. The voltage drop across that layer is a product of the current density, the resistivity of the ash, and the thickness of the ash layer.
3. The electric field in the dust layer (current x resistance) can get so high that it breaks down the gas in the interstitial space between dust particles.
4. If the resistivity of the dust is moderate (10^{11} ohm-cm), then a spark will propagate across the interelectrode space.
5. If resistivity is high ($>10^{12}$ ohm-cm), then the applied voltage may not be high enough to spark, interelectrode, but rather will breakdown the dust layer (the feared and revered back corona).



Back Corona

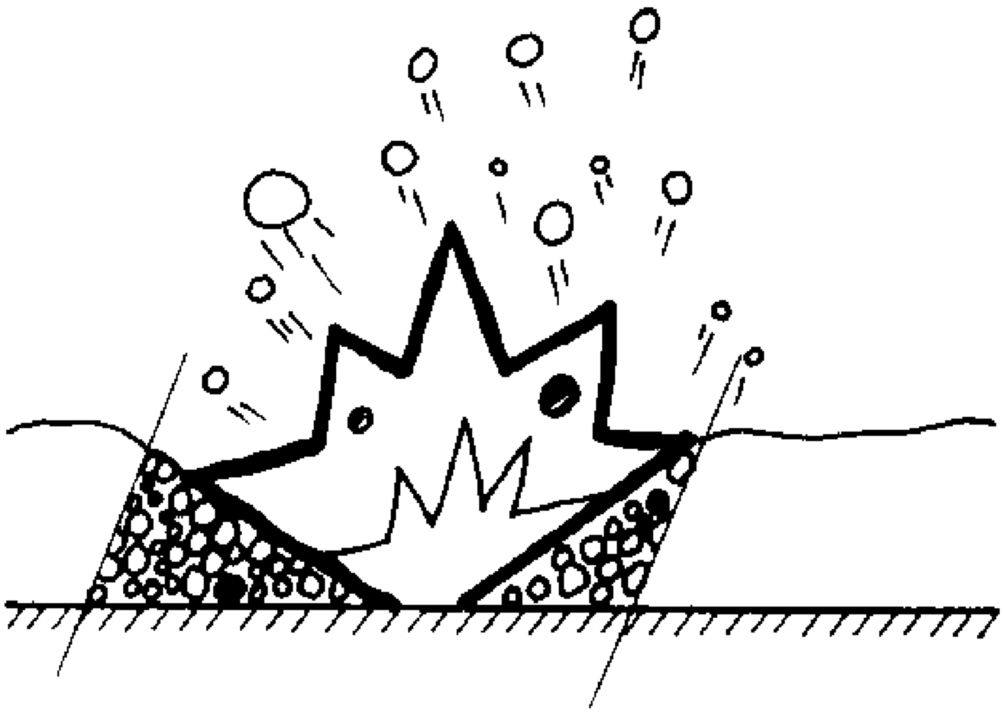
1. ***Dust layer breaks down***
2. ***Heat from discharge causes gas to expand***
3. ***Expansion blows dust outward***



Reference: Electrostatic Precipitator Handbook by D. A. Lloyd

Back Corona

1. ***Crater forms***
2. ***Positive corona flows from bottom of crater***



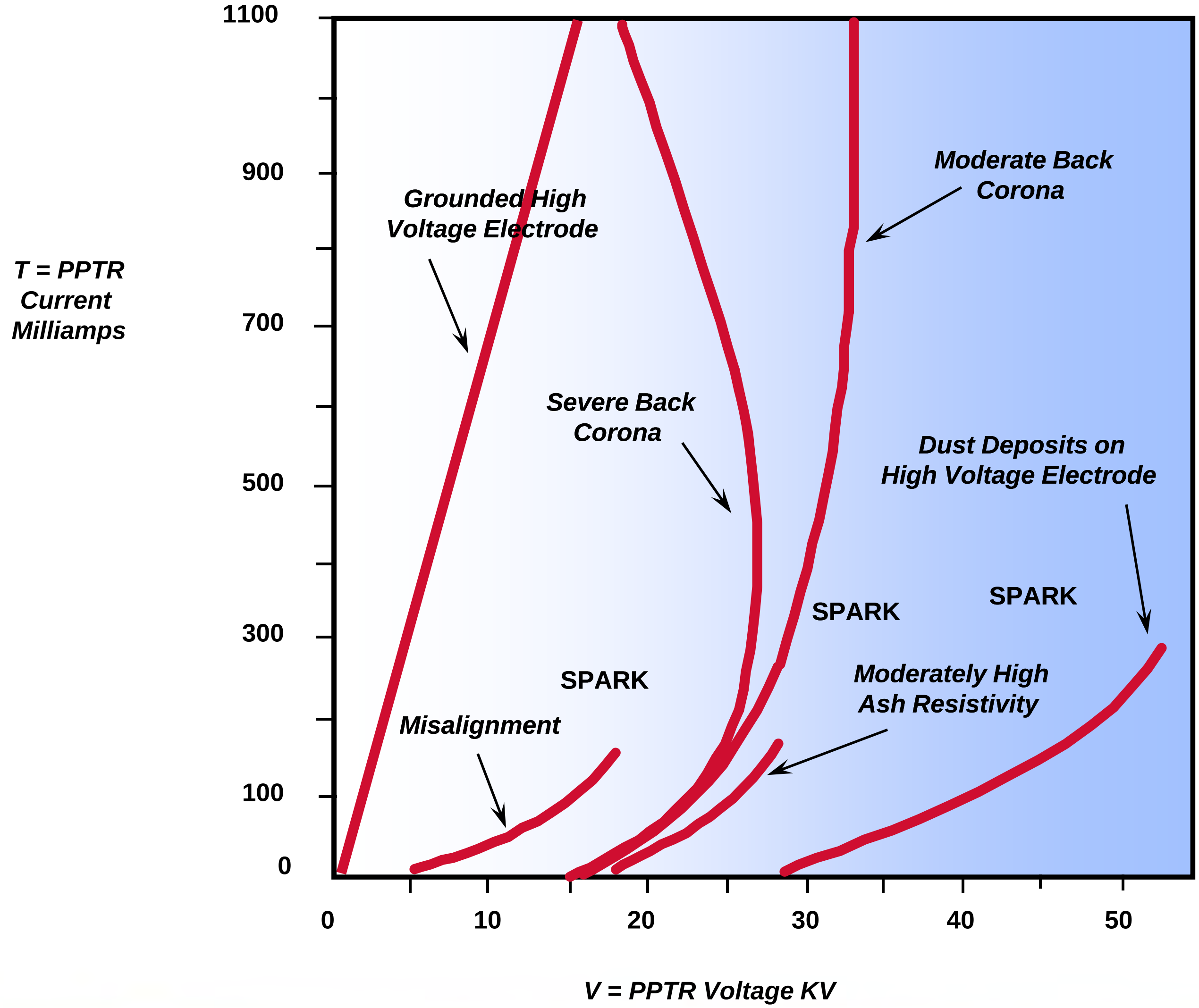
Reference: Electrostatic Precipitator Handbook by D. A. Lloyd

Corona Gone Bad

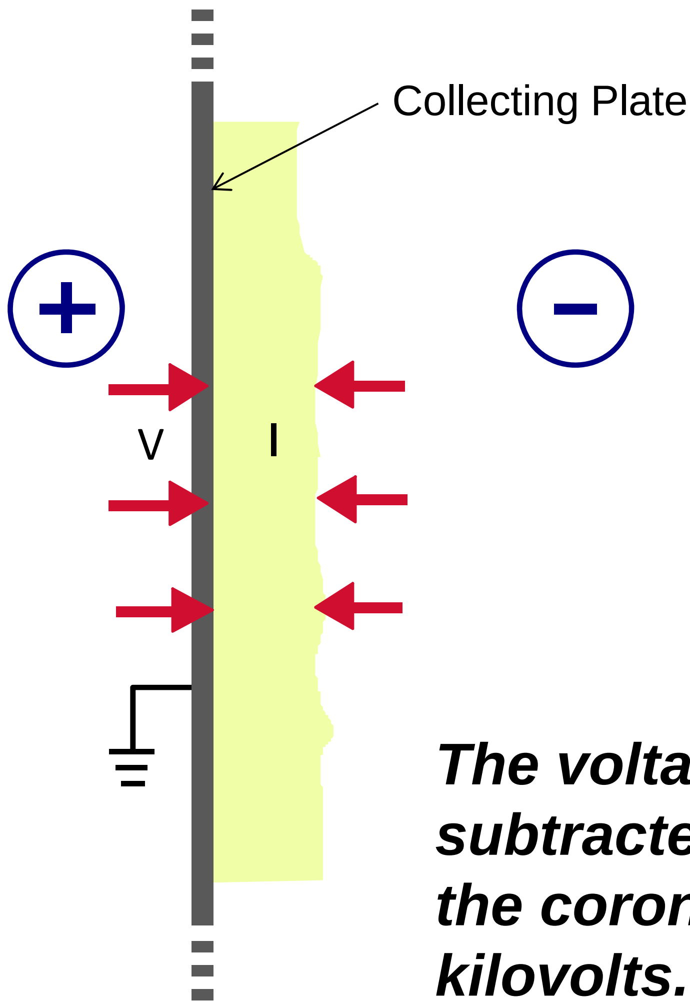
V-I Curves & Their Interpretation

(The ESP Stethoscope)

Abnormal Precipitator Current Voltage Curves



Ohm's Law and Too Much Current



$$V = R \times I$$

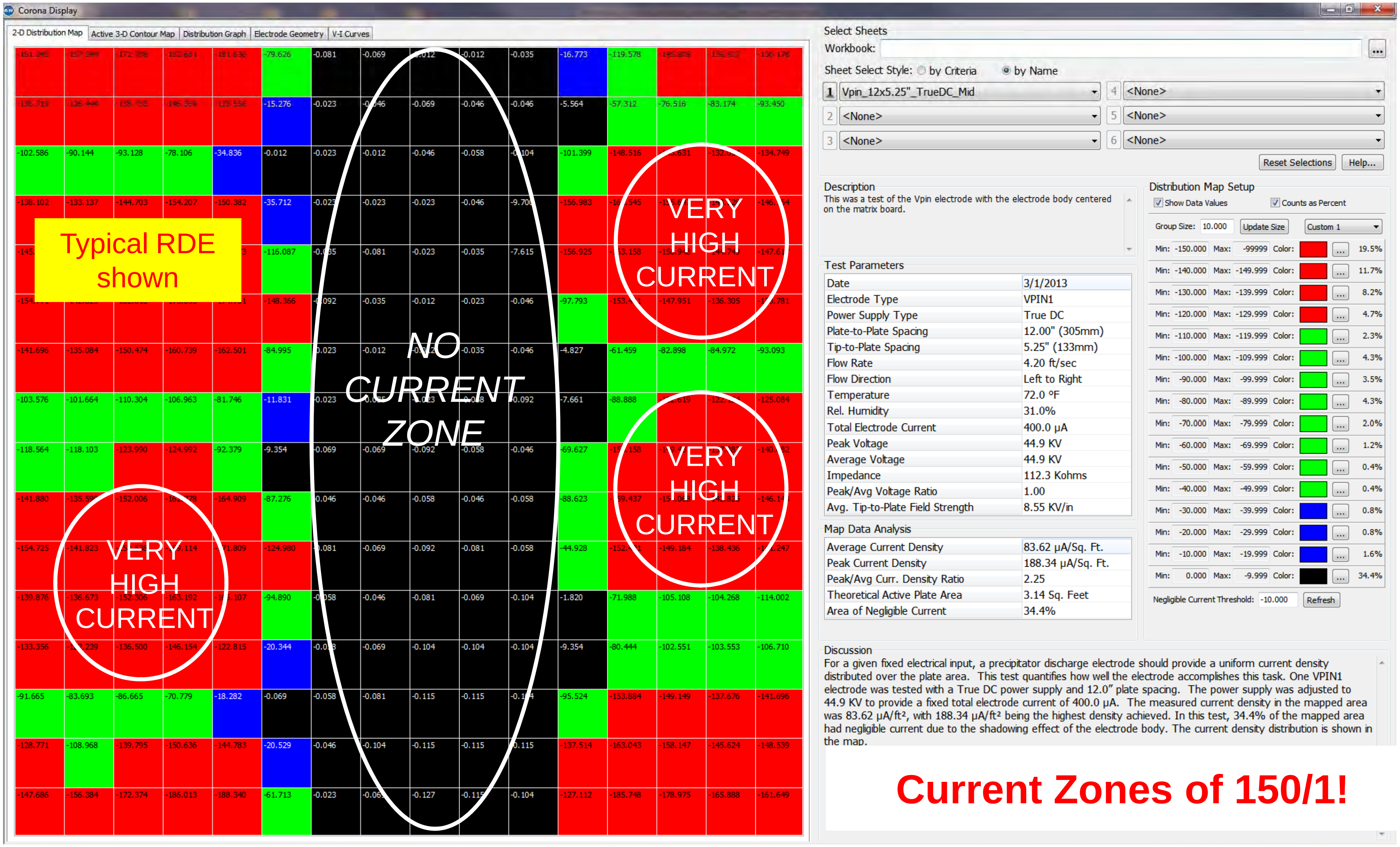
V: Voltage Drop

R: Dust Layer Resistivity

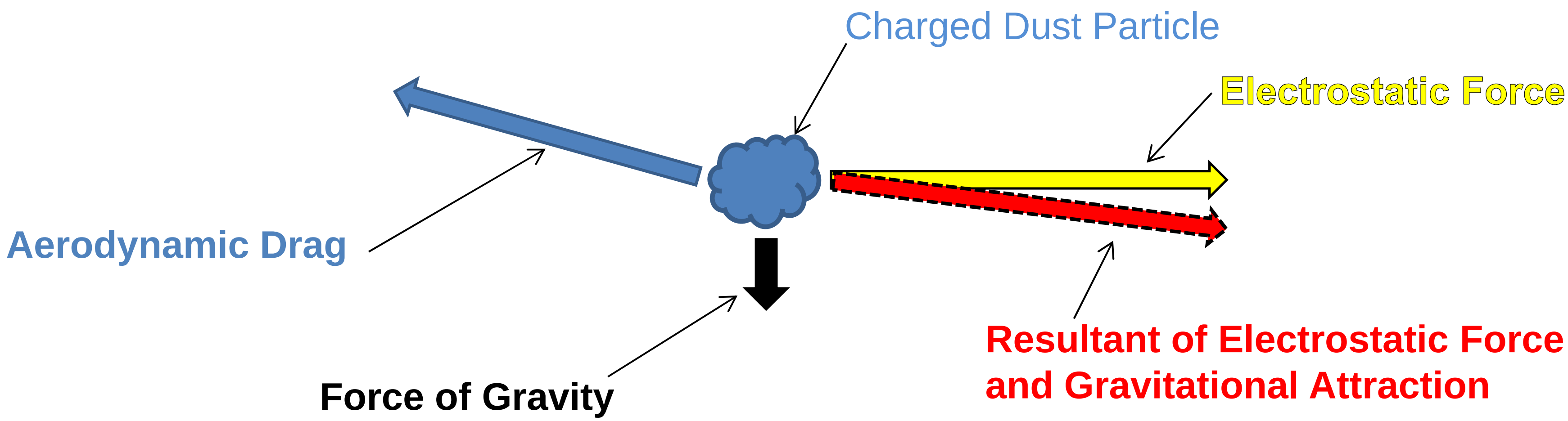
I: Ion Current Density

The voltage drop across the layer is subtracted from the voltage applied to the corona, reducing it by several kilovolts. A several kilovolt drop can drop ESP current significantly.

And Too Little Current Density Can Be Worse!

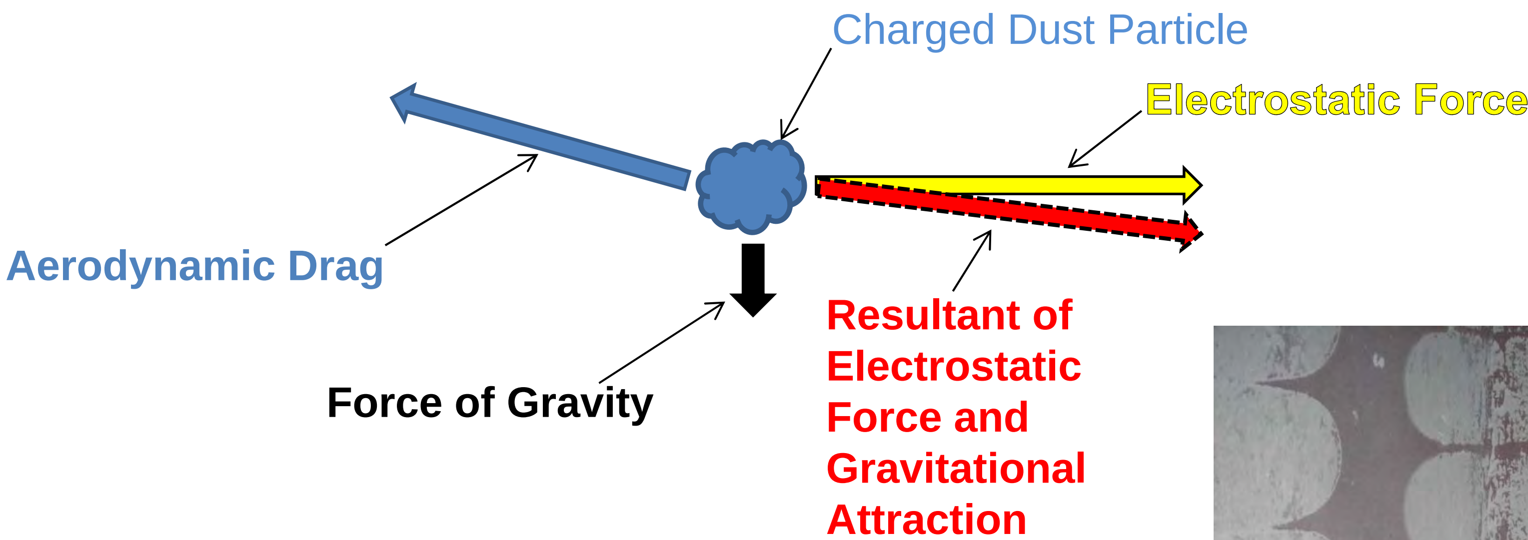


Forces Acting on a Dust Particle at First Touching the Grounded Collecting Plate



1. ***The cohesive forces within the dust layer have not yet taken affect***
2. ***At this moment Current Density and Resistivity are critical to hold it against the pull of gravity and the drag of the gas flow***

The "Dead Zone"



The lack of current density in the "dead zone" opposite the body of any RDE leads to minimal dust collection in those areas in lower resistivity applications

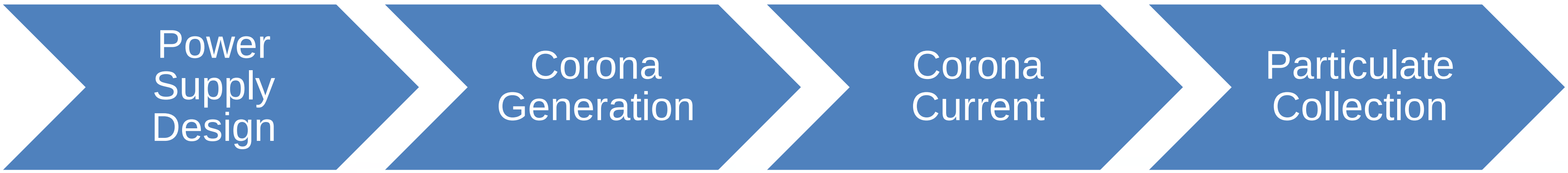
Corona Gone Bad

An Ongoing Process of Research and Development

The Learning to Date:

- **A significant area -- 34% -- of negligible current occurs due to electrode body mass.**
- **High current densities are indicated opposite electrode points.**
- **Maximum ESP collection efficiency can be obtained if the "dead zone area" can be reduced and the current distribution made more even.**
- **Initial testing has produced an electrode design that can reduce the negligible current areas to 15%.**
- **Testing is ongoing, and when the optimum electrode design is achieved, a dust load will be introduced to the test set up.**

The Path Forward:



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THANK YOU. QUESTIONS?

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