

REINHOLD ENVIRONMENTAL Ltd.



**2014 APC Round Table  
& Expo Presentation**

July 14-15, 2014, in Louisville, KY / Hosted by LG&E/KU

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# *Precipitator Research and Development an Unfinished Work in Progress*

*2014 APC Round Table*

*Louisville, Kentucky – July 14-15, 2014*

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**David Johnston**  
*Operations Manager, PrecipTech Products*

# ***Business Environment***

- ▶ **Electrostatic precipitators and precipitator technology remain a viable alternative for air pollution control**
  - ✓ **The market will be here for some time to come**
- ▶ **There is a significant installed base worldwide, many of which can benefit from a performance upgrade**
  - ✓ **There is a large international market**
- ▶ **The technology, business, market, and key suppliers have all noticeably changed**
  - ✓ **Both the business organization and the technology must change to be successful**
- ▶ **There have been key changes in electrical controls, the mechanical configuration, and data acquisition**
  - ✓ **This is a technology driven business**
- ▶ **Failure in the field is expensive and difficult to correct**
  - ✓ **There is business risk**



# Key Takeaways

- ▶ **Our organization must be prepared to change and adapt quickly**
  - ✓ **Organizational change is expected**
- ▶ **We need a greater understanding of the technology than we ever had before**
  - ✓ **R&D will be the foundation of the business and will be an ongoing process, not an event**
- ▶ **We need state-of-the-art tools to improve the business**
  - ✓ **Software modeling and laboratory testing will be used to evaluate approaches, predict performance, improve reliability, and direct development**

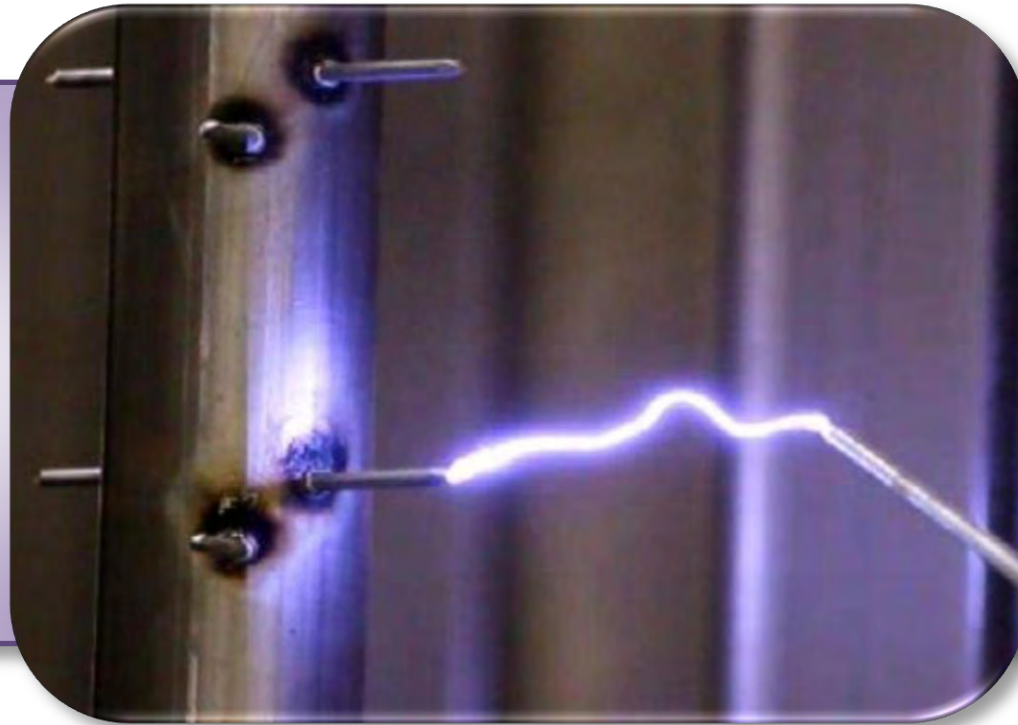


# *Introduction*

- ▶ **Today we are going to discuss some of the ongoing research and development that is being performed by B&W PrecipTech**
- ▶ **The goal is to pose some, but not all of the questions we are asking**
- ▶ **The emphasis today will be on the questions, not necessarily the answers**
- ▶ **The tools that are being used include:**
  - **electrical circuit models, where the many real-world field variables can be controlled and valid comparisons made**
  - **an in-house Test Precipitator where power supplies, components, and spacings can all be changed**



# ***Power Supply Research***



# Power Supply Characteristics - Modeling

Precipitator Power Supply Characteristics<sup>1</sup>

Power Supply	Low Ripple Output	Frequency	AC Line Input		DC Voltage and Current Output					Sparking	
			Power Factor	Total Harmonic Distortion (Input)	Ripple in Output Voltage <sup>2</sup>	Peak to Average Voltage Ratio	Ripple in Output Current <sup>2</sup>	Peak to Average Current Ratio	Total Harmonic Distortion (Output) <sup>3</sup>	Maximum Time to Spark Quench	Energy Delivered to Spark by Power Supply <sup>4</sup>
Single-Phase	No	Low	0.566	21.40%	11.80%	1.235	72.59%	2.132	0.97%	8.33 x 10 <sup>-3</sup> seconds	7.8 x 10 <sup>-3</sup> Joules < .1% of Total Spark Energy
Single Phase with External Filter <sup>5</sup>	Yes	Low	0.580	18.15%	2.39%	1.036	68.19%	1.883	0.75%	8.33 x 10 <sup>-3</sup> seconds	22.05 x 10 <sup>-3</sup> Joules < .1% of Total Spark Energy
Switch Mode - Phase Controlled	Yes	Medium	0.917	29.61%	1.68%	1.033	71.64%	2.281	40.21%	1.25 x 10 <sup>-3</sup> seconds	≈ 8.53 x 10 <sup>-3</sup> Joules < .1% of Total Spark Energy
Switch Mode - Amplitude Controlled	Yes	Medium	0.917	29.43%	1.35%	1.032	58.69%	2.050	44.25%	1.25 x 10 <sup>-3</sup> seconds	≈ 4.17 x 10 <sup>-3</sup> Joules < .1% of Total Spark Energy
Switch Mode - Frequency Controlled	Yes	High	0.926	35.17%	0.11%	1.002	122.55%	3.324	132.34%	30 x 10 <sup>-6</sup> seconds	55.7 x 10 <sup>-6</sup> Joules < .1% of Total Spark Energy
Switch Mode - Phase Controlled	Yes	High	0.914	36.25%	0.02%	1.000	48.57%	1.589	69.07%	60 x 10 <sup>-6</sup> seconds	70.9 x 10 <sup>-6</sup> Joules < .1% of Total Spark Energy
3-Phase	Yes	Low	0.826	13.01%	0.57%	1.009	10.45%	1.126	1.78%	5.55 x 10 <sup>-3</sup> seconds	5.7 x 10 <sup>-3</sup> Joules < .1% of Total Spark Energy
Perfect Power Supply <sup>6</sup>	Yes		1.000	0.00%	0.00%	1.000	0.00%	1.000	0.00%	0.00 seconds	0.00 Joules

<sup>1</sup> Modeled for power supply rated at 80 KV, 1000 mA, field capacitor 0.1 μF, field resistor 80KΩ.

<sup>2</sup> Percent Ripple (RMS of Ripple/Average Output)

<sup>3</sup> Harmonic frequency content above 1000 Hz

<sup>4</sup> Total spark energy = 320 Joules

<sup>5</sup> External filter .37 μf capacitor, 335Ω resistor

<sup>6</sup> Theoretical ideal data

# Existing Power Supply Comparison Results

## Precipitator Power Supply Cost, Size, and Weight Comparison<sup>1</sup>

Power Supply	Cost Comparison <sup>2</sup>	Volume (Cu Ft)	Volume Comparison <sup>3</sup>	Weight (Lbs)	Weight Comparison <sup>3</sup>
SMPS(1) 21 KW	1.49	77	1.04	1,050	0.56
SMPS(2) 20 KW	1.78	25	0.34	528	0.28
3 Phase 24 KW	1.16	128	1.73	3,527	1.88
Single Phase 24 KW	1.00	74	1.00	1,874	1.00
SMPS(1) 35 KW	1.89	81	1.09	1,200	0.64
SMPS(2) 28 KW	1.76	25	0.34	528	0.28
3 Phase 32 KW	1.16	128	1.73	3,638	1.94
Single Phase 32 KW	1.00	74	1.00	1,874	1.00
SMPS(1) 70 KW	2.31	101	0.95	1,300	0.46
SMPS(2) 60 KW	1.70	25	0.24	528	0.19
3 Phase 72 KW	1.17	139	1.31	3,968	1.41
Single Phase 72 KW	1.00	106	1.00	2,822	1.00
SMPS(1) 120 KW	2.31	152	1.23	2,300	0.65
SMPS(2) 120 KW	2.22	47	0.38	1,100	0.31
3 Phase 120 KW	1.12	193	1.56	5,071	1.44
Single Phase 120 KW	1.00	124	1.00	3,527	1.00

<sup>1</sup> Four power supply ratings are compared. Within each rating, the cost, size, and weight are compared to single phase.

<sup>2</sup> For Single Phase and 3-Phase: external control cabinet cost is included.

<sup>3</sup> For Single Phase and 3-Phase: CLR(s) are included in the T/R set, volume and weight specified are for T/R Set only, external control cabinet not included.



# ***Power Supply Harmonics***

## ▶ **The input harmonic distortion is too high**

- Precipitator power supplies connect to the power line and draw power not only at the fundamental frequency but at harmonic frequencies which are whole number multiples of the fundamental frequency. This non-linear load causes distortion of the input waveform

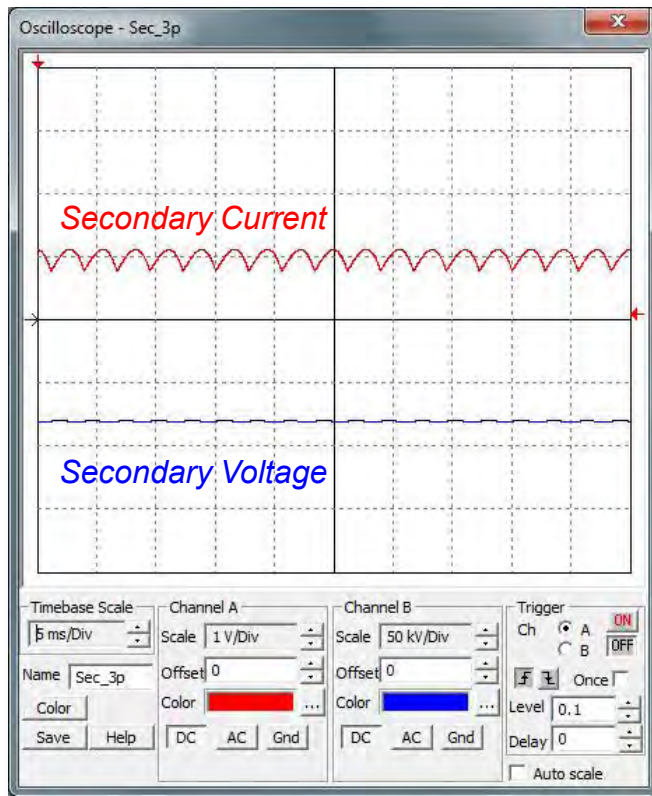
## ▶ **The output harmonic distortion is too high**

- Precipitator power supplies also produce harmonics at the output. This is sometimes hard to understand since one would expect the output to be true DC with no frequency components. However, the DC waveform is made up of many frequencies including a fundamental frequency and its harmonics

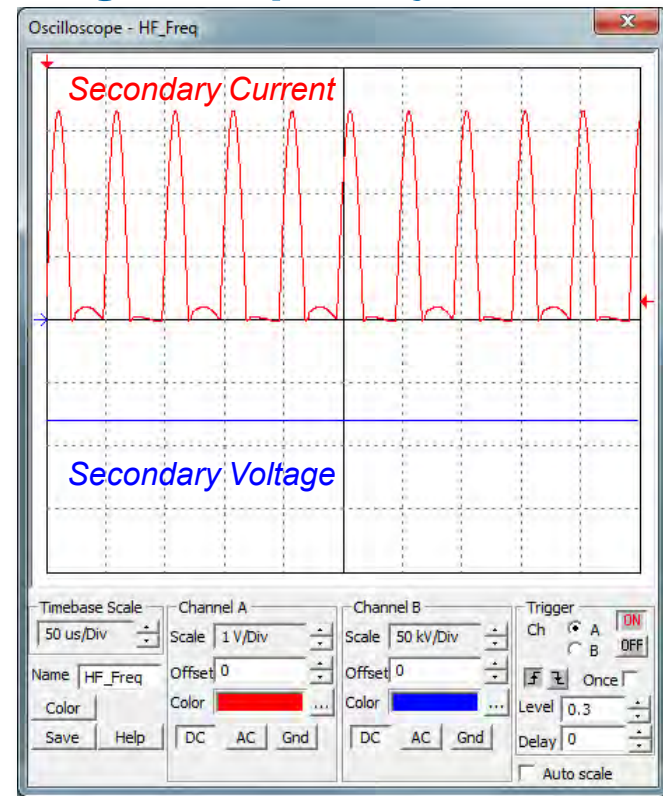


# What is the Effect of a High Peak to Average Current Ratio?

## 3-Phase



## High Frequency



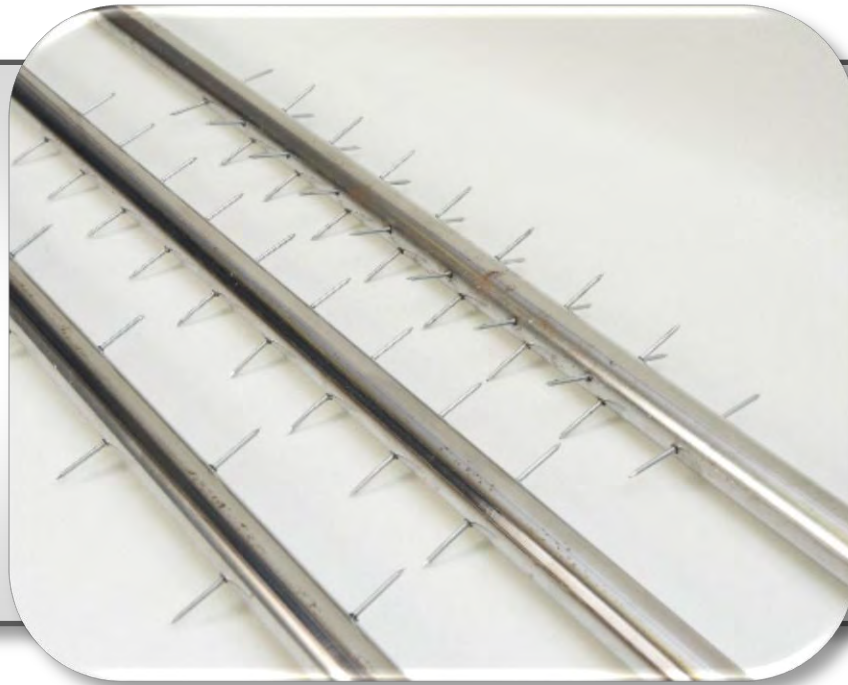
- ▶ The effect of the peak to average current ratio on collection efficiency needs to be quantified

# ***Electronics Fabrication***



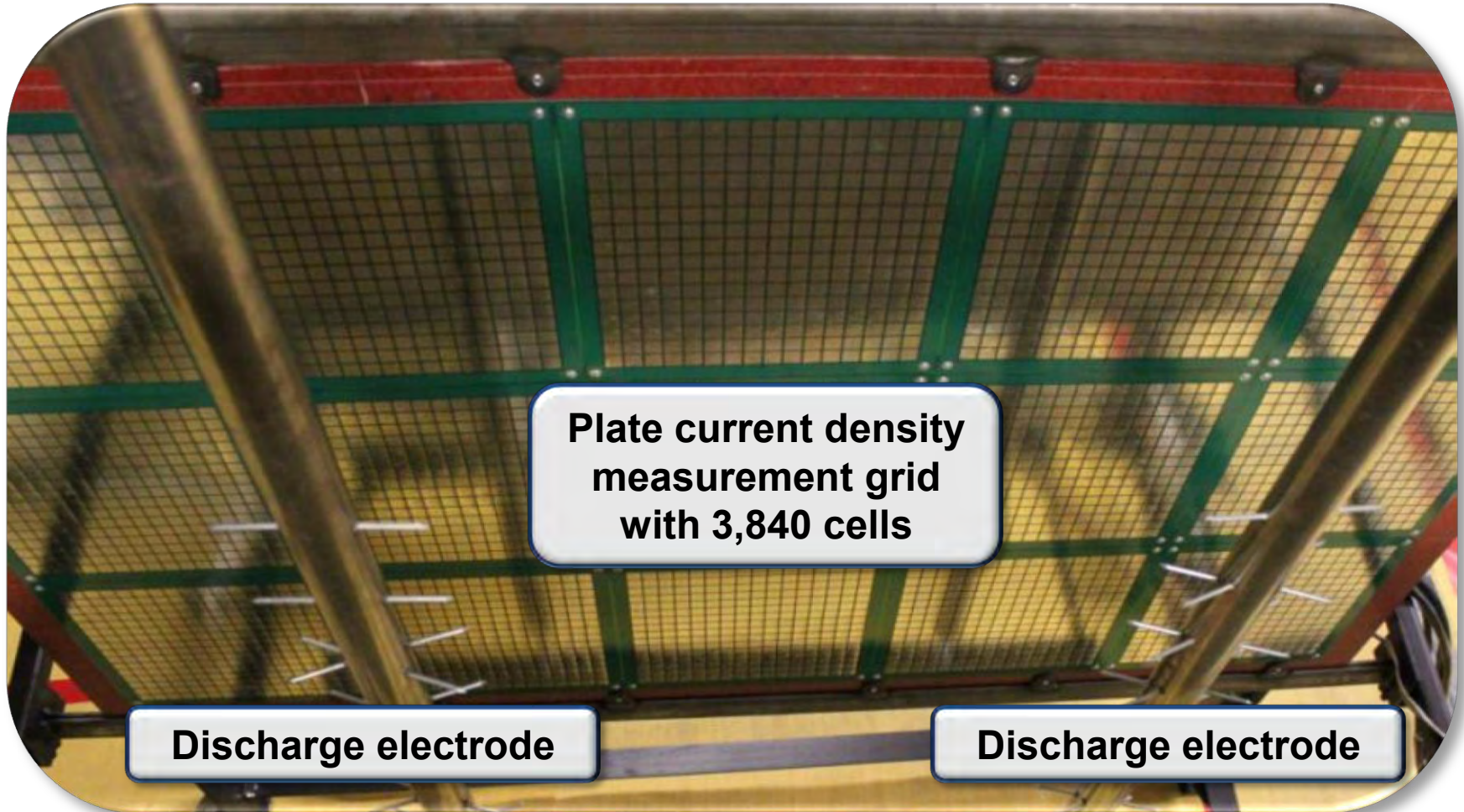
- ▶ **Control size and complexity are significantly reduced through the use of modern, large-scale integration components and assemblies**
- ▶ **New materials and techniques enhance reliability**

# ***Discharge Electrode Research***



# ***We Map the Current Density For Each Power Supply***

## ***Test ESP with 2 Popular Discharge Electrodes***

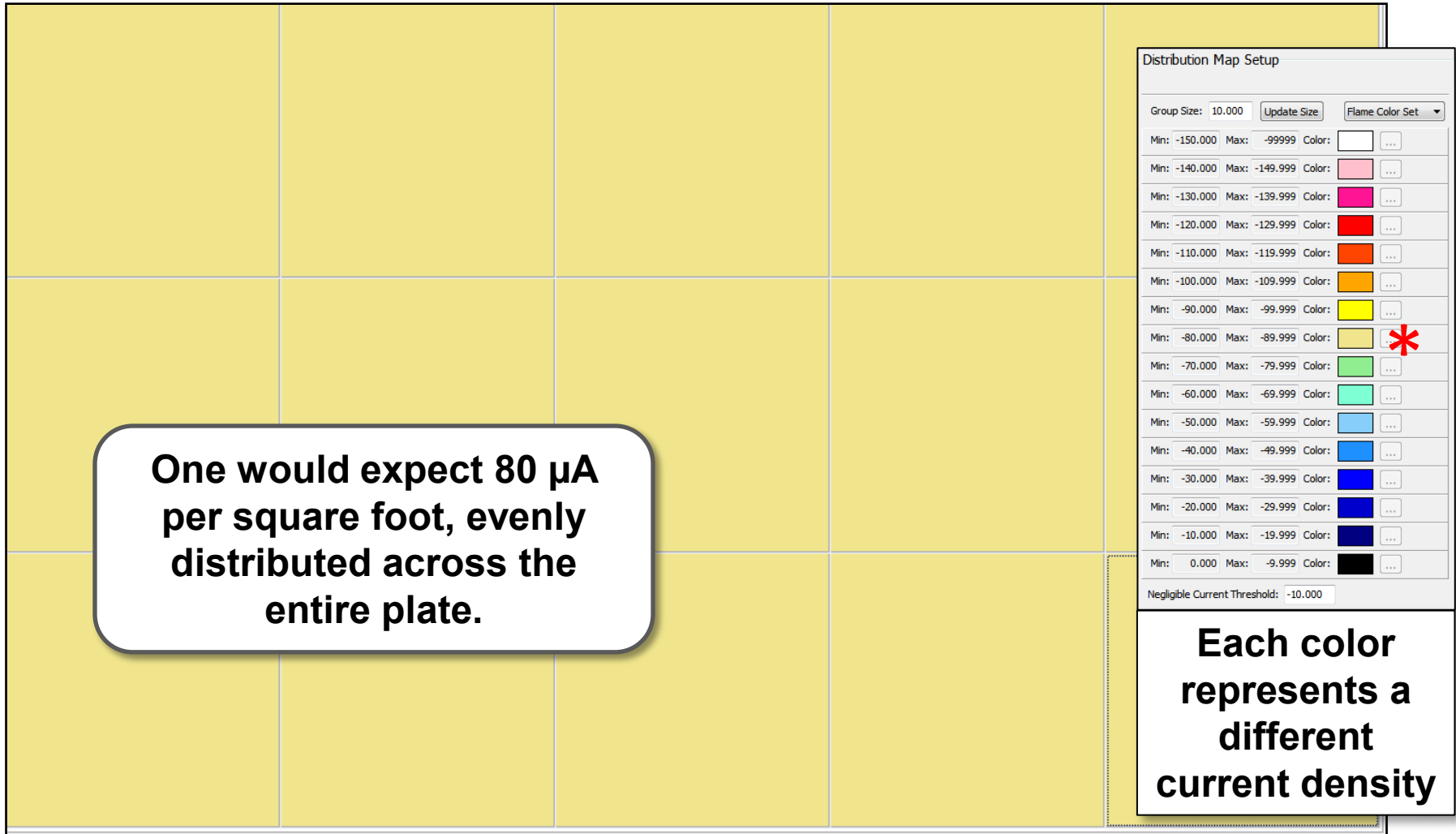


**Plate current density  
measurement grid  
with 3,840 cells**

**Discharge electrode**

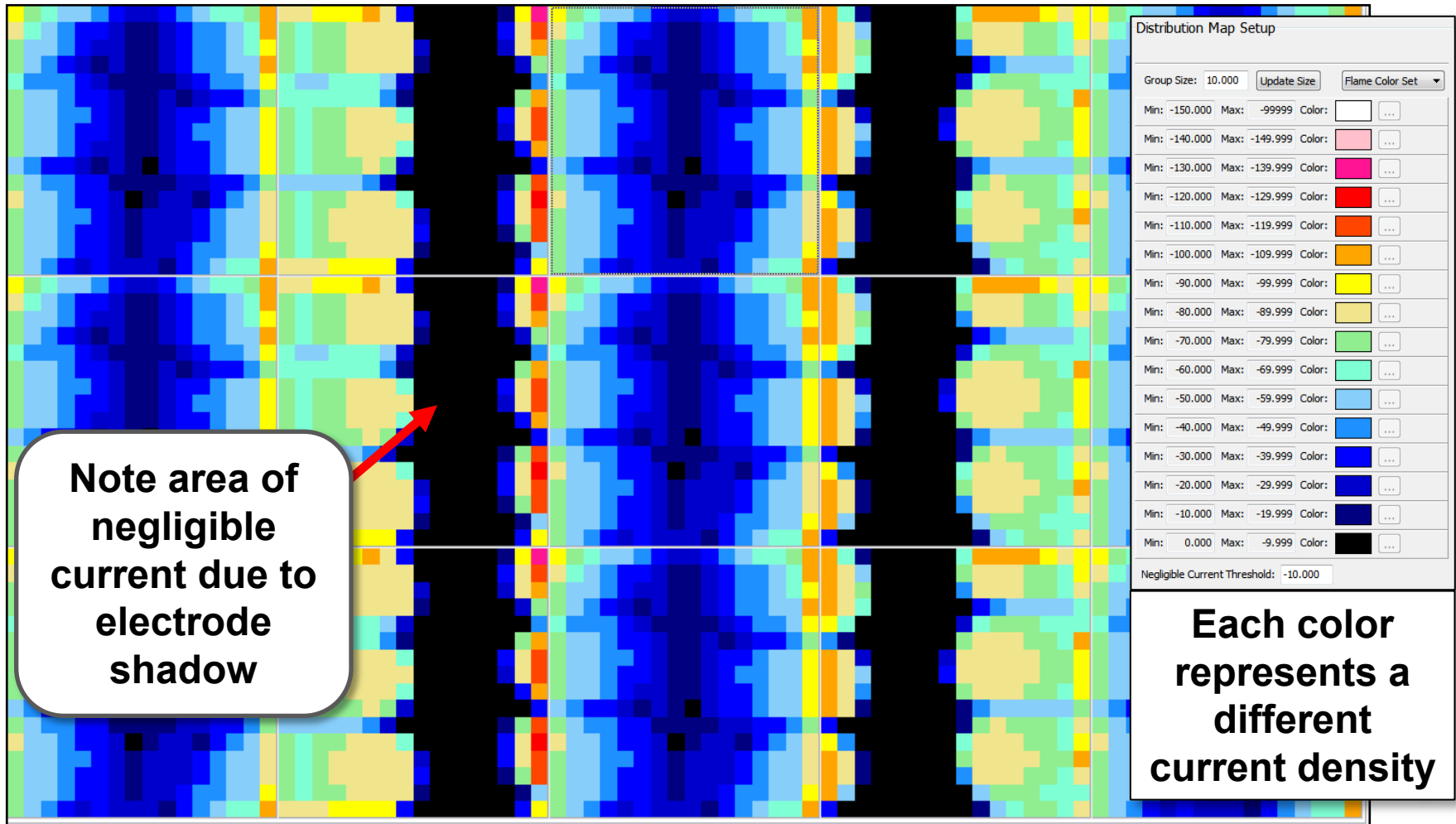
**Discharge electrode**

# The Ideal Current Density Map One Would Expect

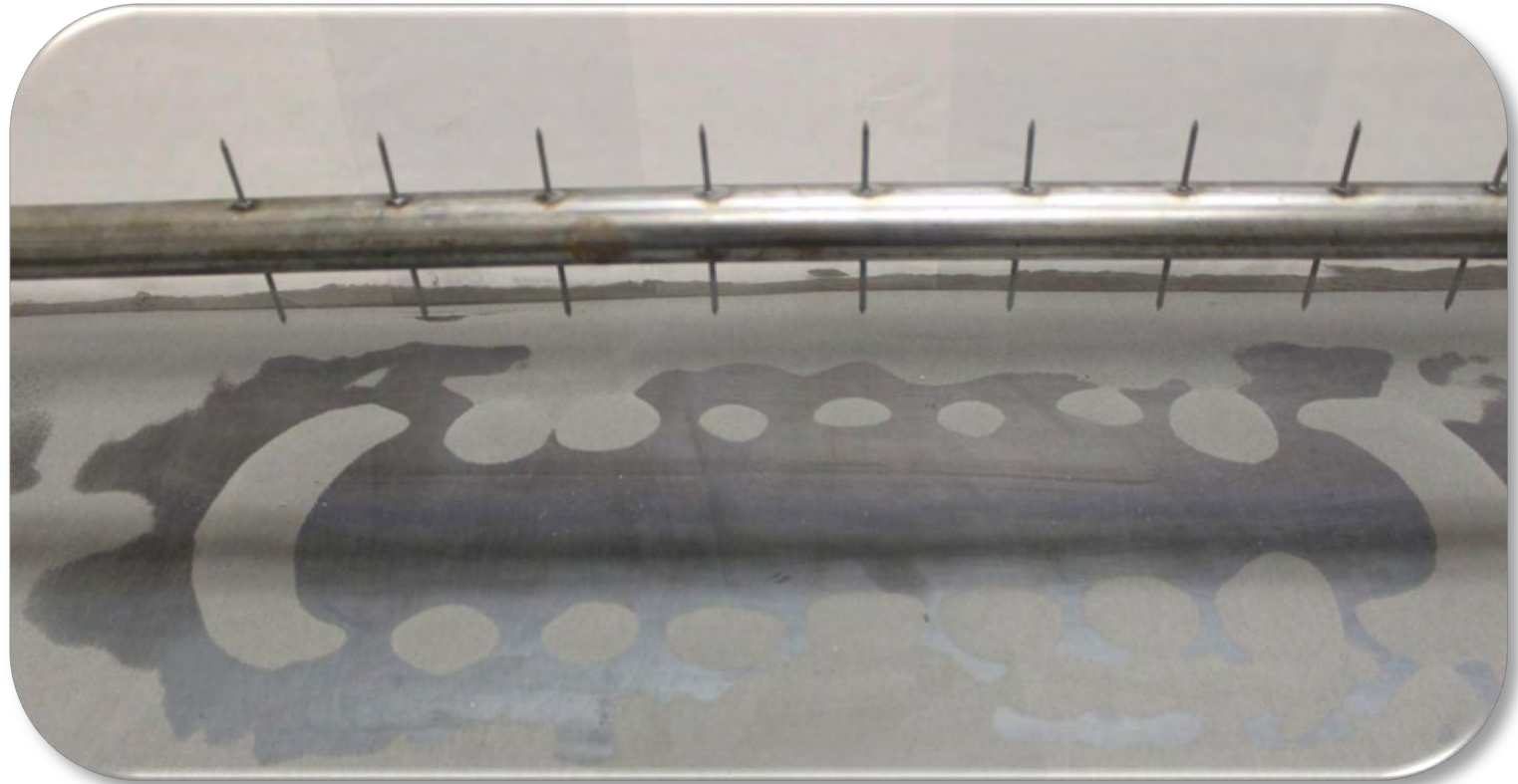


# Actual Current Density Map Measured

## Test ESP with 2 Popular Discharge Electrodes



# *Physical Model Testing*



- ▶ **Determining the corona pattern using a physical model and iron filings**

# *Areas of Research*

- ▶ **The rigid discharge electrode has a “shadow” on the plate of negligible current density. How can we reduce this?**
- ▶ **Which discharge electrode geometry and spacing provides the most uniform current density?**
- ▶ **Using a discharge electrode, how do we impedance-match the precipitator field to the power supply? Do we use different discharge electrodes in different fields?**
- ▶ **Can the geometry of the discharge electrode cause hot spots of corona density and produce localized glow discharge back corona?**
- ▶ **Can coatings or different materials reduce the wear on discharge electrodes and make them last longer?**
- ▶ **Can a grading system be developed to give the end user a method of selecting discharge electrodes?**



# ***Wet ESP Research***

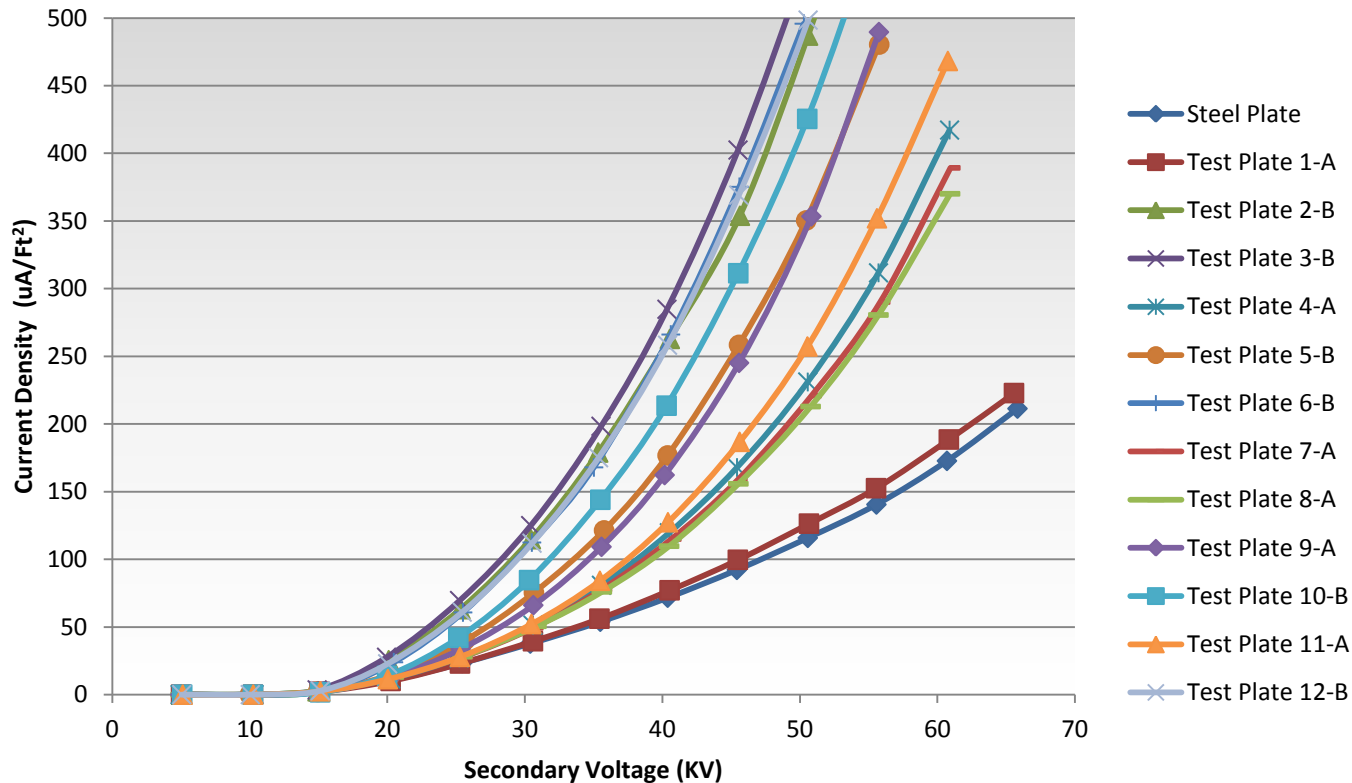


# ***Designing the Next Generation of Wet ESP***



- ▶ **Laboratory testing using the Test ESP with spray bars, nozzles, and liquid reservoir**

# Exotic Plate Materials



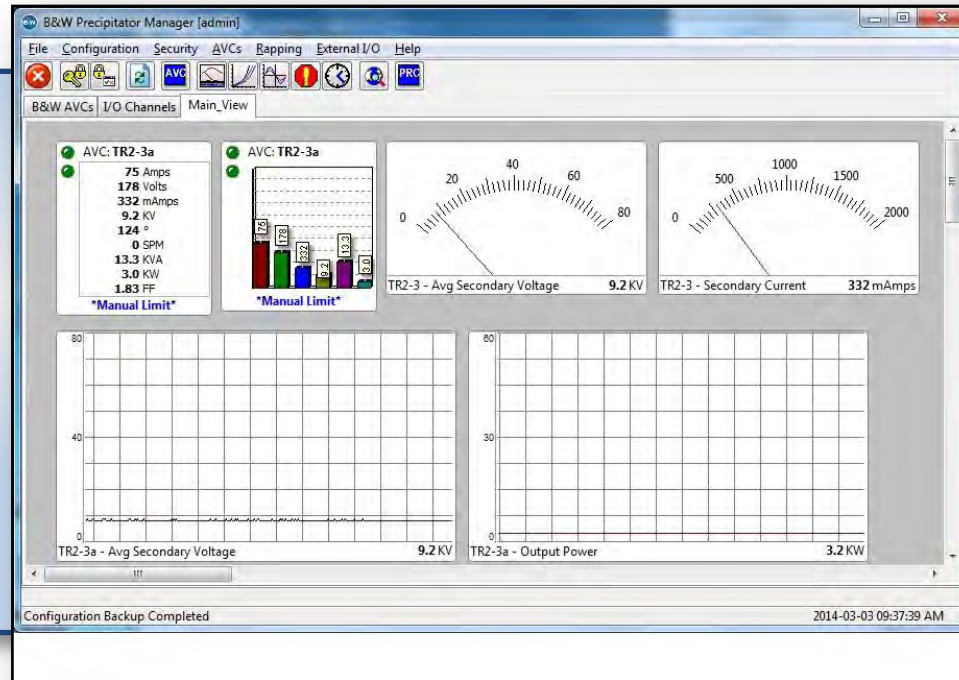
- ▶ **Changing the plate material from steel to other materials made the VI curve more aggressive! Where else does this have application?**

# Areas of Research

- ▶ **The Wet ESP generally has fewer power supplies and therefore the reliability of the power supply is even more critical**
- ▶ **The environment is often corrosive, so the location and protection of equipment becomes more important**
- ▶ **The materials used in the Wet ESP must survive the corrosive environment. What materials and coatings can help here?**
- ▶ **What are the electrical effects of making the ESP wet?**



# Software Development

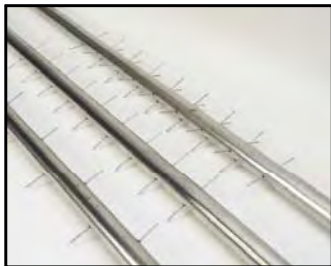
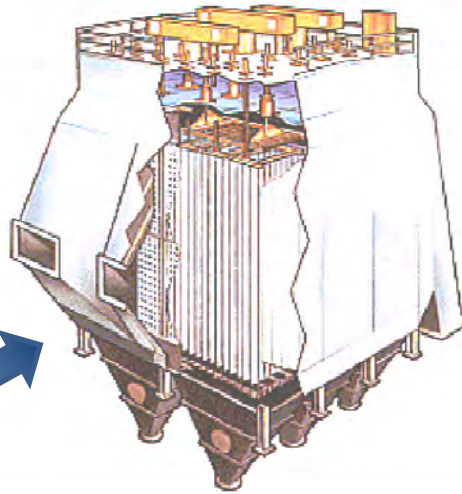


# Areas of Research

- ▶ The software is the greatest R&D tool we have!
- ▶ Remote Diagnostics can be used to collect and compare field data worldwide
- ▶ Maintaining compatibility with the evolving security standards (NERC) to maintain absolute security of the precipitator data and operation
- ▶ The man-machine interface. What evolving displays, graphics, and interface are the best choice for the user demographic of this equipment?
- ▶ Maintaining compatibility with the evolving interface standards so that data can be easily transported and shared
- ▶ What does the precipitator operation tell us about the remainder of the plant and what is the effect of the precipitator on other plant systems?



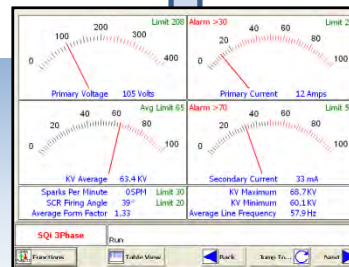
# Next Generation Precipitator



**Optimum Discharge Electrode**



**Optimum Plate Spacing/Material**



**Optimum Power Supply**

# Summary

- ▶ **Although precipitators are a mature technology, there is much to learn and many things we do not know**
- ▶ **There is a business case to continue this research and development and will be for some time to come**
- ▶ **Remote Diagnostics and data collection allow us to fine-tune modeling and test processes based on real-world precipitator operation**
- ▶ **This presentation offers a sampling of the areas that need more research and development**
- ▶ **New materials and coatings may play key roles in future enhancements**
- ▶ **There is room for improvement in precipitator power supplies, discharge electrodes, and optimizing plate and discharge electrode spacing**





# ***Precipitator Research and Development an Unfinished Work in Progress***

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## ***Thank You. Questions?***

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