REINHOLD ENVIRONMENTAL Ltd.

2015 APC Round Table & Expo Presentation

July 13 & 14, 2015, in Atlanta, GA / Hosted by Southern Company

Challenges to the ESP from MATS Compliance

2015 APC Round Table
Atlanta, Georgia
July 14, 2015

John A. Knapik
ESP Applications Engineer

MATS

1. Filterable Particulate Matter (PM) emissions limit of < 0.03 #/MMBtu
    1. Or Total non-mercury HAP Metals < 0.000040#/MMBtu
    2. Or Individual HAP Metals
2. Acid gas, HCl limit of < 0.002#/MMBtu
    1. Or SO_2 < 0.2#/MMBtu
3. Mercury emissions limit < 1.2#/TBtu

Achieving the PM limit of 0.03, will depend on:

- ***The amount of dust coming into the ESP***
- ***The resistivity of that dust***
- ***The gas volume to the ESP***
- ***The gas flow quality in terms of uniformity, sneakage, and re-entrainment***
- ***The quality of the electrical energization***

Meeting the Acid gas and Mercury requirements of MATS may affect one or all of the above. This presentation discusses each aspect

Example of a 600+MW Unit's Avenues to Comply with MATS

- ***Supercritical opposed wall boiler with 48 burners***
- ***Presently burning an eastern bituminous, high sulfur, Bailey coal***
- ***Low NOx burners and overfired air***
- ***No SCR and no Scrubber***
- ***European Designed ESP with 2 boxes, 5 fields/box, 16 x 48ft collecting plates, conventional single phase power supplies, original design gas volume of 2,600,000 ACFM and SCA of 645_{12} or 860_{9}***

	Fuel Data	Bailey	Black Thunder	West Elk Low Ash	Colombian	Benedict
1.	Higher Heating Value, (HHV) Btu/lbm	12,947	8,882	11,400	12,510	13,430
	Hardgrove Grindability, HGI	54	49	56	48	
	Proximate Analysis (Wet Basis, % by weight)					
	Total Moisture	6.1	26.6	11.5	7.24	5.19
	Volatile Matter	34.41	31.23	34.7	37.3	35.96
	Fixed Carbon	51.78	36.82	46.68	48.6	51.99
2.	Ash	7.71	5.35	7.12	6.68	6.86
	Ultimate Analysis (Wet Basis, % by weight)					
	Carbon	70.83	50.94	65.45	69.5	74.54
	Hydrogen	4.77	3.77	4.65	4.2	4.93
	Oxygen	6.78	12.36	9.37	9.91	6.29
	Nitrogen	1.38	0.67	1.46	1.61	1.52
3.	Chlorine	0.1	0.0007	0.0006	0.027	0.02
4.	Mercury (Lbs/TBtu)	7.24	7.37	1.46	4.24	4.22
5.	Sulfur	2.33	0.32	0.45	0.67	0.75
	Ash Analysis (% by weight), Dry					
	Silica, SiO2	46	37.21	49.45	60.42	51.08
	Alumina, Al2O3	21.79	19.15	27	20.98	28.91
	Titania, TiO2	0.97	1.33	1.01	0.97	1.54
	Iron Oxide, Fe2O3	22.8	6	8.49	8.03	7.8
	Lime, CaO	2.44	19.4	4.89	1.74	2.87
	Magnesia, MgO	0.77	3.91	1.42	1.44	1.2
6.	Sodium, Na2O	0.58	1.25	1.68	0.6	0.97
	Potassium, K2O	1.7	0.61	1	2.41	2.53
	Phosphorous, P2O5	0.41	0.83	0.69	0.44	0.34
	Sulfur Trioxide, SO3	2.17	8.61	2.8	0.63	2.15
	Undetermined	0.37	1.7	1.57	2.34	0.61

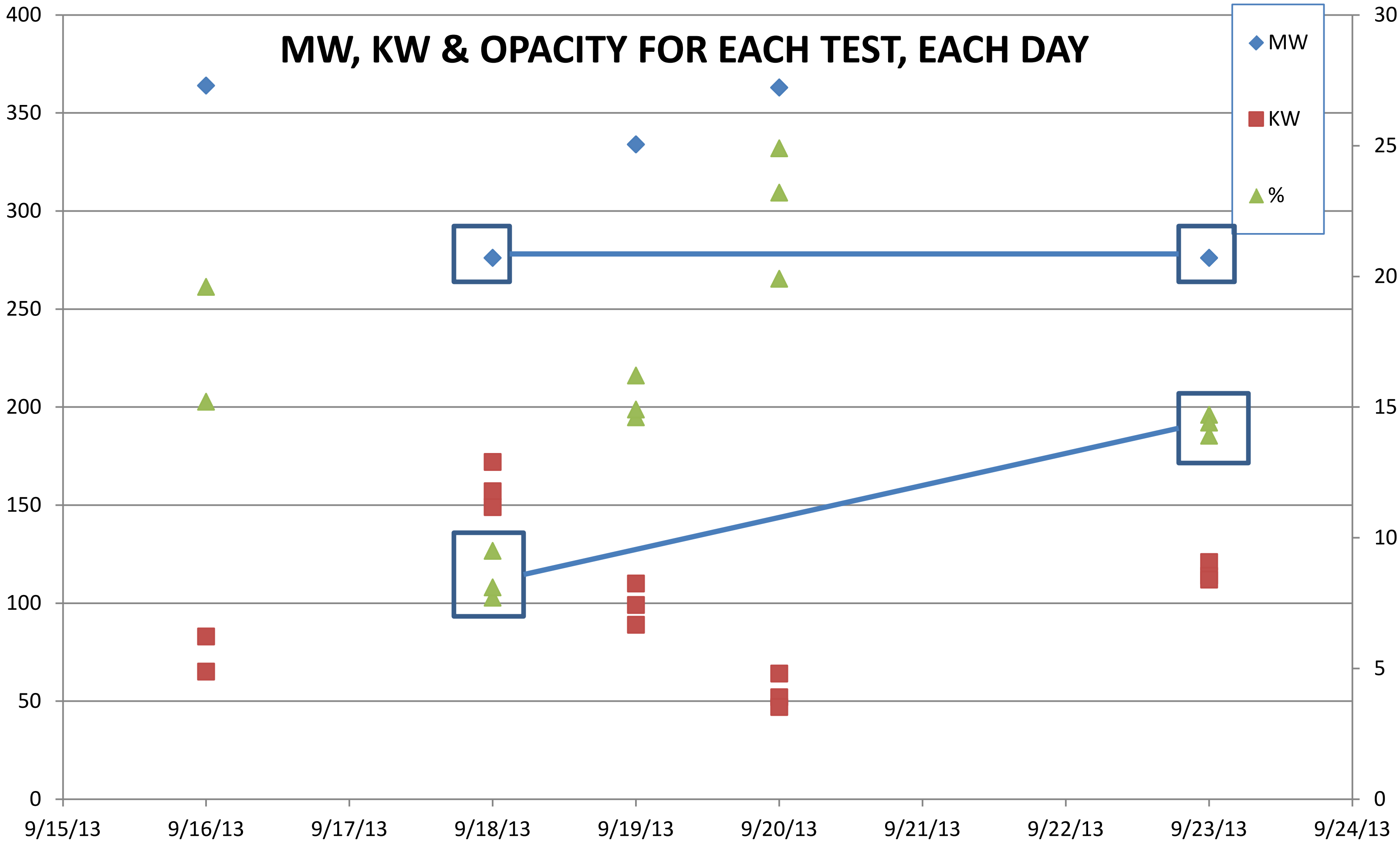
Impact of changing coals to meet the Acid Gas and Mercury requirements of MATS. Six (6) criteria to look at.

Acid gas compliance without a scrubber

Ways to comply would be:

- ***fuel switching to a low Chlorine coal***
- ***Or dry sorbent injection of a calcium based or sodium based compound***
- ***Both sorbents will add to the amount of dust going to the ESP (inlet loading)***
- ***Sorbents may affect the dust resistivity.***
- ***Sodium based sorbents tend to decrease resistivity***
- ***Calcium based sorbents tend to increase resistivity***

Same Load, Same Coal, but DSI (Lime) Causes Opacity Increase



Acid gas compliance (< 0.002#/MMBtu HCl) with DSI

	CASE	Bailey	Colombian	Black Thunder	Antelope	West Elk Low Ash	Benedict
1.	Cl in coal in, ppm	1000	278	7.2	9	6	190
2.	HCl emission, lb/mmbtu	0.08	0.026	0.0009	0.001	0.005	0.015
	HCl Removal, %	97.5	92.3	N/A	N/A	N/A	86.8
	Gas Flow, acfm	2,946,767	3,284,223	3,090,965	3,140,903	3,029,365	2,693,515
	Gas Temperature@ AHO, F	297	302	315	315	302	302
3.	SO3, concentration, ppmwv	8.4	2.8	0.5	0.5	1.7	1.65
	SO2, concentration, ppmwv	1560	560	364	276		576
4.	Ash loading to ESP, TPH	13.9	12.8	15.4	15.4	15.1	12
	DSI product	Hydrated Lime and Trona					
5.	Estimated DSI injection rate, TPH (Hydrated Lime)	85	25	0	0	0	13.5
6.	Estimated DSI injection rate, TPH (Trona)	32	4.1	0	0	0	2.7

Particulate Loading Changes with the Coal's Ash Content & Heating Value

1. Ash Loading to the ESP is related to:
   - A. T/Hr coal burned (Heating value of coal (BTU/lb) & boiler heat rate)
   - B. Coal Ash Content
   - C. Type of Boiler (PC Fired vs. Cyclone)

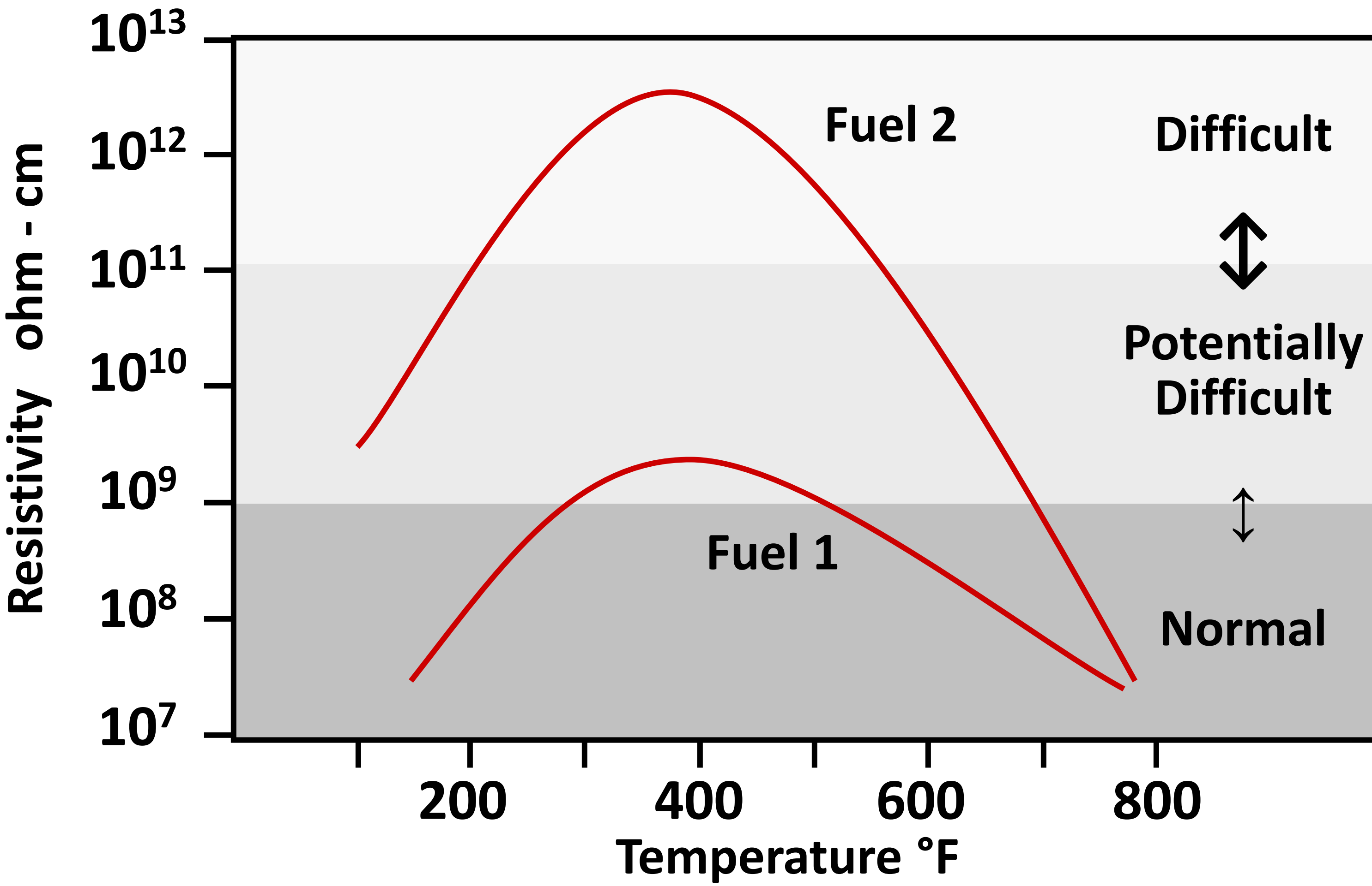
Example:

- 240 MW Unit, Coal HHV 12,000BTU/lb, PC Boiler 80/20 split
- Heat rate 10,000 BTU/ KwHr, Coal Ash Content 10%
- Fuel Use – (240,000*10,000)/(12,000*2000lb/ton)=100 TPH
- Total Ash (Bottom + Fly) – 100T/Hr *10% = 10 TPH
- Fly Ash – 10TPH * 80% = 8 TPH

Particulate Loading and the ESP

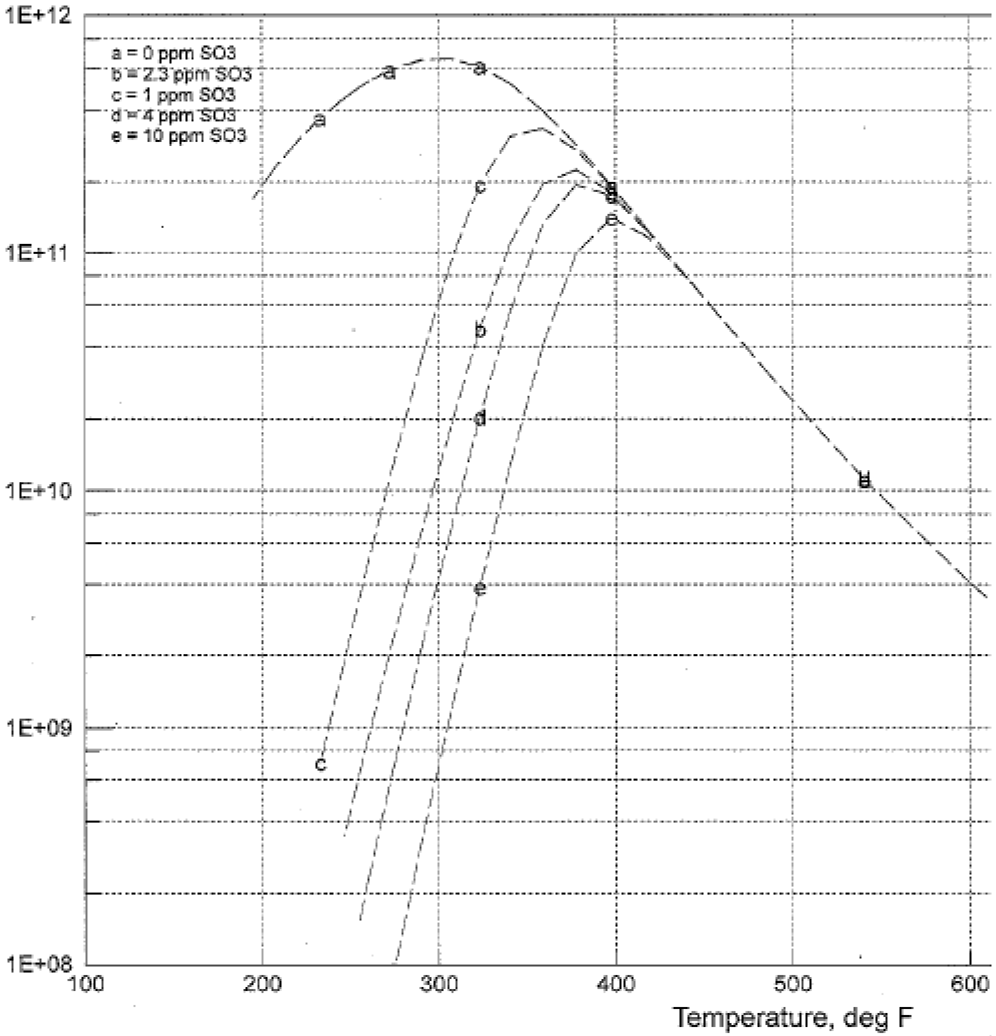
1. More PM in, always means more PM out, if everything else stays constant.
    1. Surprisingly, the collection efficiency of an ESP will increase with inlet dust concentration if the resistivity stays the same or goes lower.
    2. Effect is usually greatest at low dust burdens
    3. May be due to an increase in mean particle size
    4. Also due to the greater space charge (greater electric field)
    5. If the resistivity of the ash changes (sorbent loading), then the ESP efficiency can go down or up . (Hydrated lime vs. trona)

Particulate Resistivity – Good Dust vs. Bad Dust

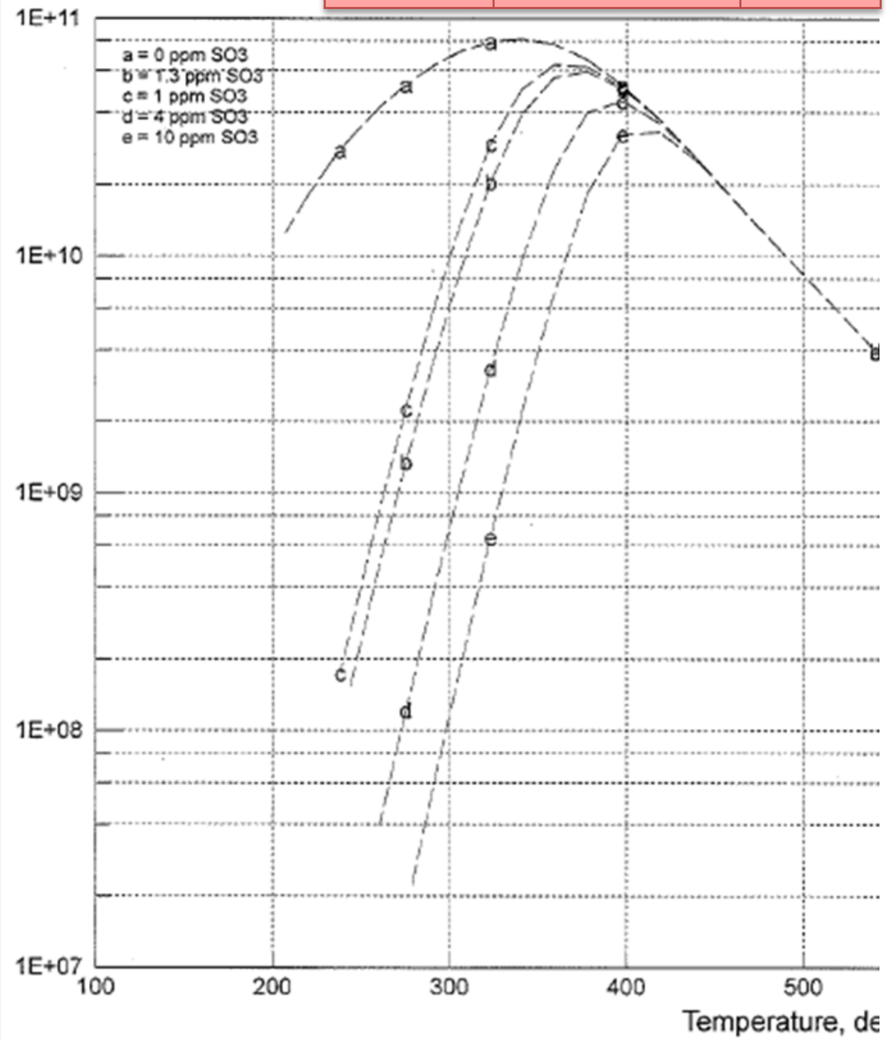


Dust Resistivity

COAL	LONE MOUNTAIN	WEST ELK
SULFUR %	0.77	0.45
SODIUM %	0.66	1.68
RESISTIVITY	3.5EE11	6EE10



Resistivity versus Temperature
Lone Mountain Mine Coal



Resistivity versus Tem
West Elk - Low Ash

Particulate Resistivity

How poorly/how well the particle conducts:

10^4 – 10^7 ohm-cm	**Low**
10^9 – 10^{10} ohm-cm	**Optimum**
10^{11} – 10^{13} ohm-cm	**High**

Major factors:

- ash chemistry
- SO_3
- temperature
- moisture

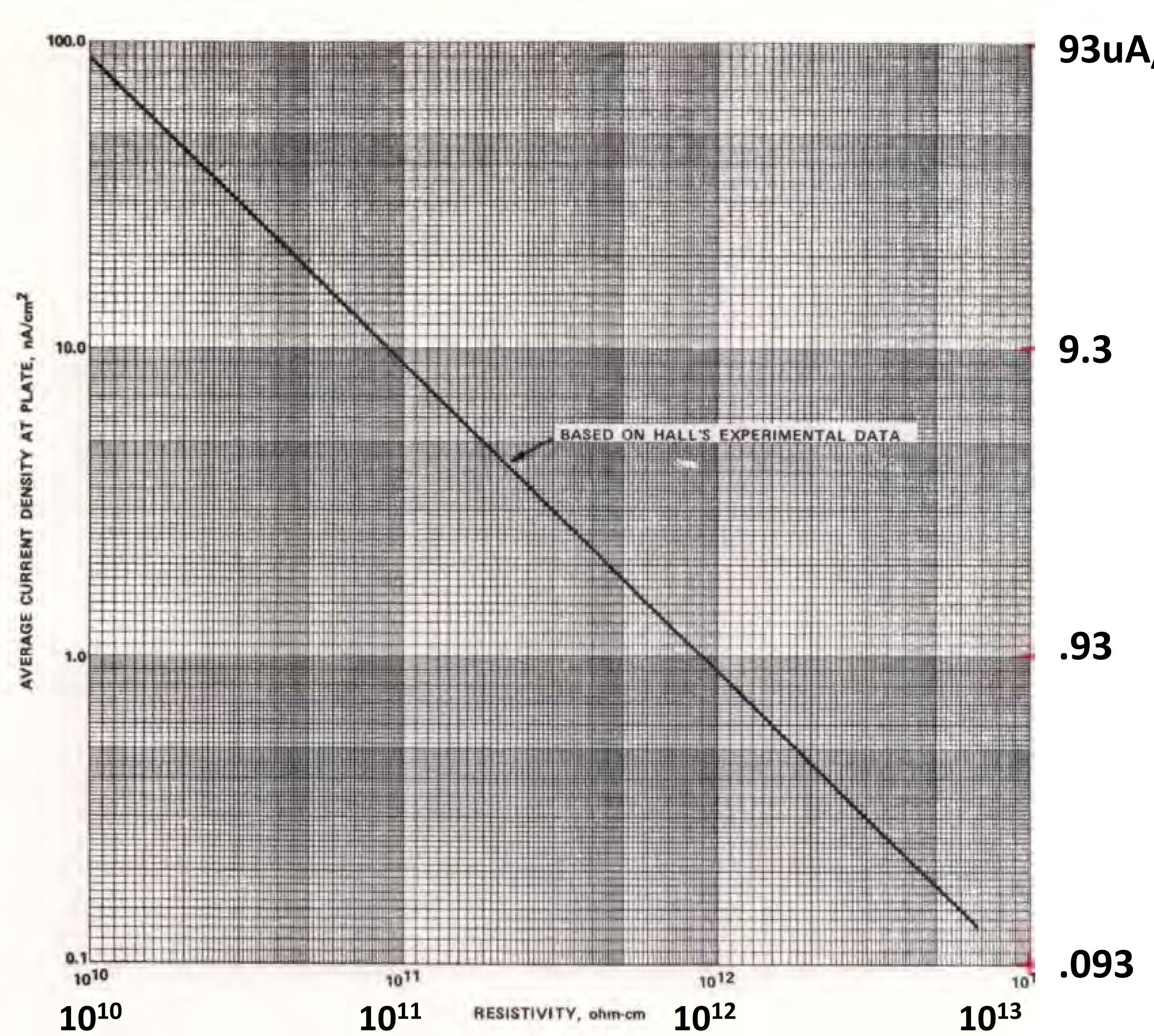


Figure 16. Experimentally Determined Effect of Resistivity on Allowable Current Density in a Precipitator

High ash resistivity (no SO_3) will severely limit operating corona current, that's an ESP Killer.

Deutsch-Anderson Equation

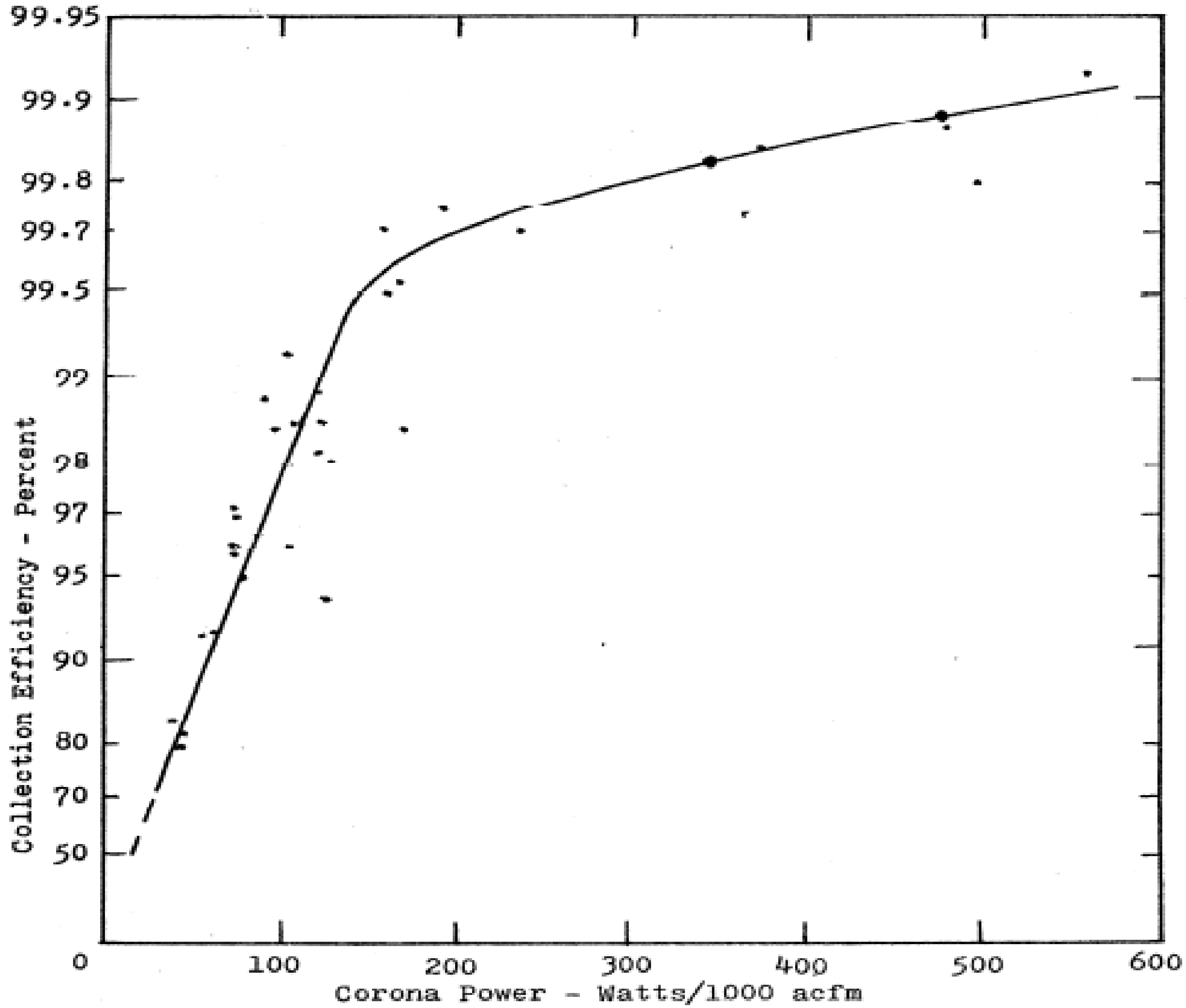
$$\text{Efficiency} = 1 - e^{\frac{-A}{V}\omega}$$

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

$$\omega \approx \beta * KV_{average} * KV_{peak}$$

β = Constant for a given Precipitator

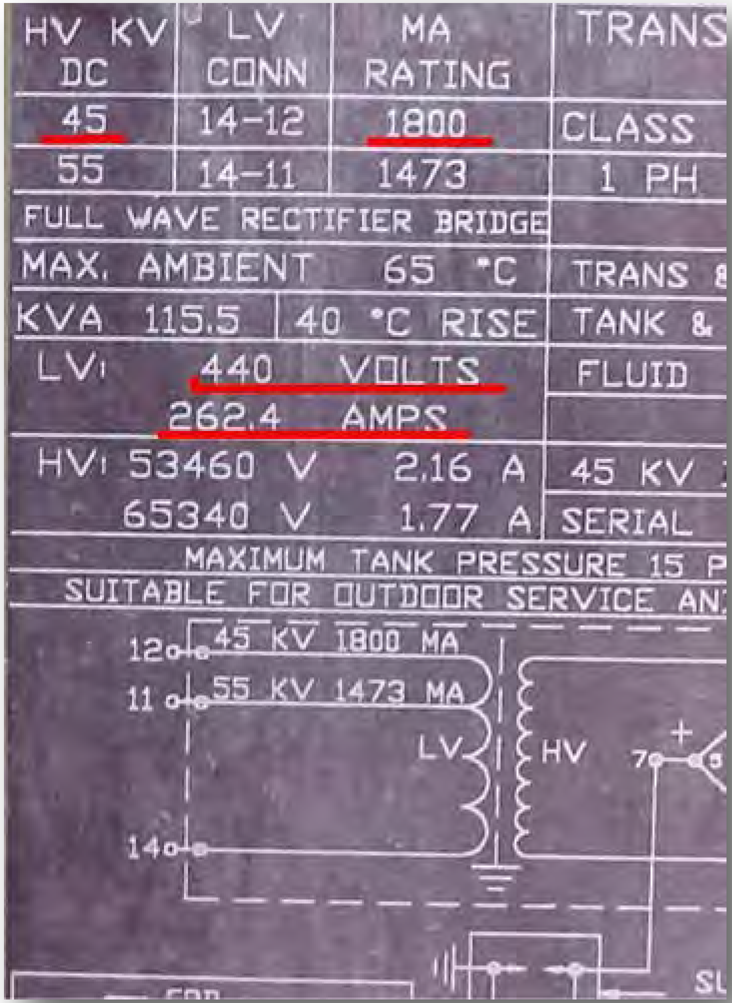
ESP Efficiency vs. Specific Corona Power



Limits to Corona Power

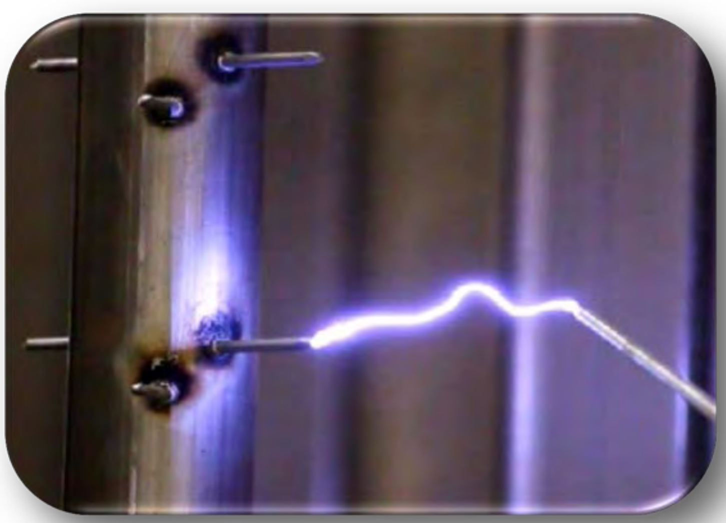
Nameplate Ratings

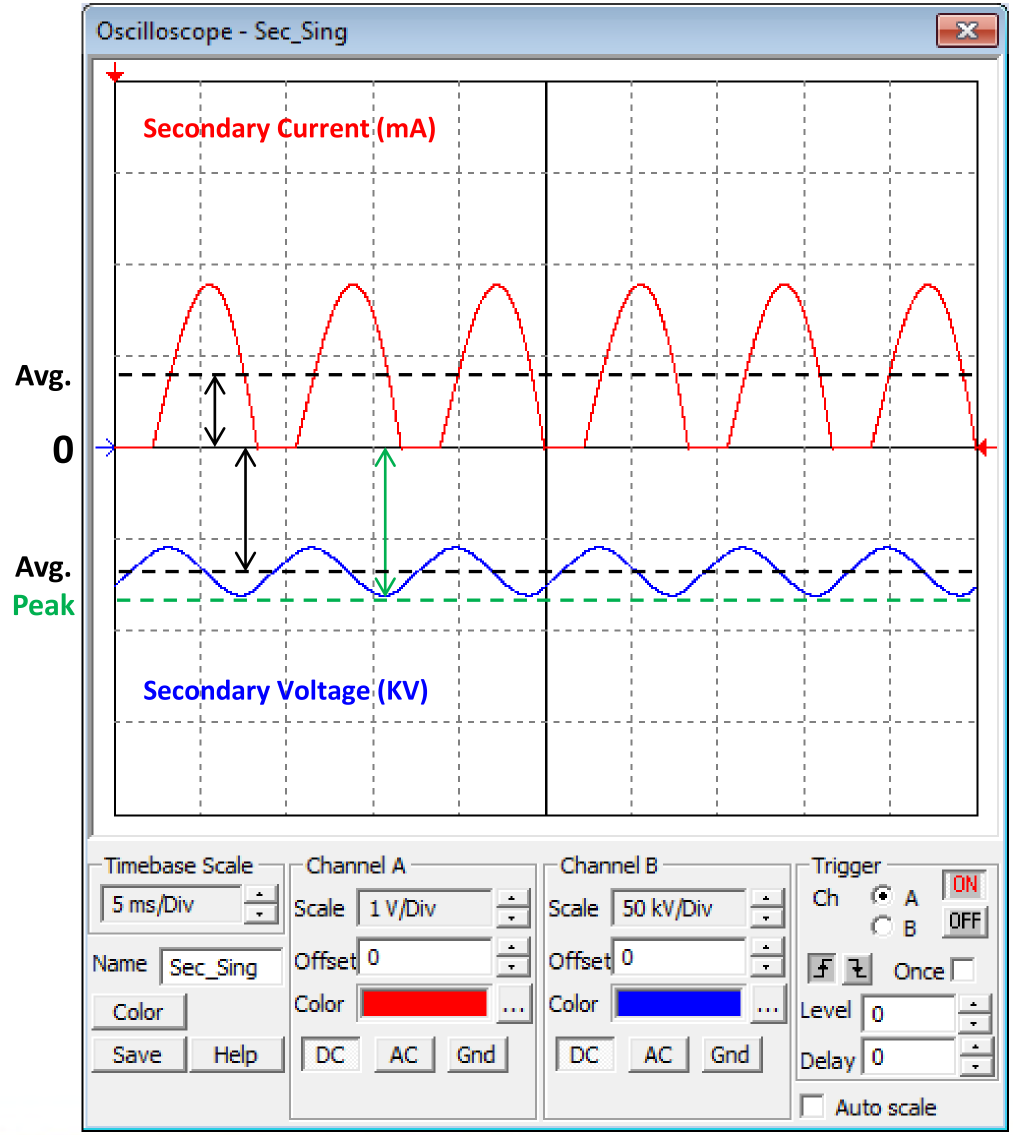
Of course the nameplate ratings of the power supply and its corresponding voltage and current limits, control how much corona power can be applied to the precipitator. These limits normally apply on precipitator fields that are not sparking.



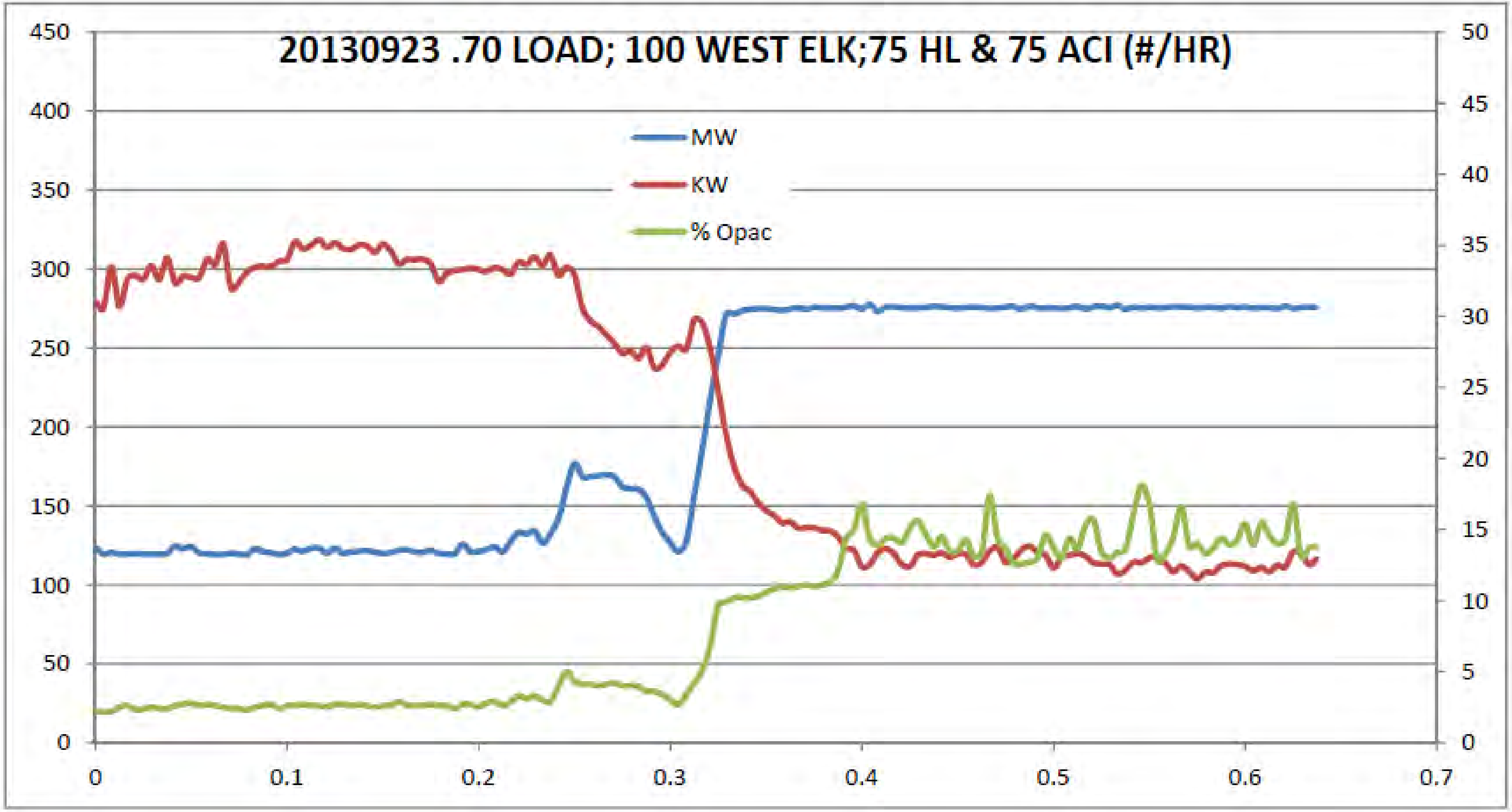
Sparking

Sparking in the precipitator field limits the amount of corona power which can be applied. We normally expect that a spark will occur at the peak of the secondary voltage. Therefore, peak voltage becomes a limiting factor in the precipitator.





ESP Opacity vs. ESP Corona Power



MATS also Requires Mercury Reduction

1. Filterable Particulate Matter (PM) emissions limit of < 0.03 #/MMBtu
   1. Or Total non-mercury HAP Metals < 0.000040#/MMBtu
   2. Or Individual HAP Metals
2. Acid gas, HCl limit of < 0.002#/MMBtu
   1. Or SO_2 < 0.2#/MMBtu
3. Mercury emissions limit < 1.2#/Tbtu

Activated carbon injection (ACI) is the most widely used technology for the control of mercury

Expected ACI (Brominated PAC)

CASE	Bailey	Colombian	Black Thunder	Antelope	West Elk Low Ash	Benedict
Estimated PAC rate, lb/hr	425	200	280	190	72	160

- ACI tends to lower resistivity
- ACI adds an insignificant increase to the dust loading
- Reentrainment may be a problem if the ESP has a high velocity (>5.5 ft/sec)

Coal choice also affects the SCA

Coal	Volume	SCA12	SCA9
	acfm	ft2/1000 cfm	ft2/1000 cfm
100% Bailey	2,093,249	802	1069
100% West Elk Low	2,275,773	738	984
100% Black Thunder	2,467,689	680	907
100% Colombian	1,747,262	961	1281
100% Benedict	1,795,417	935	1247

What if we have a scrubber?

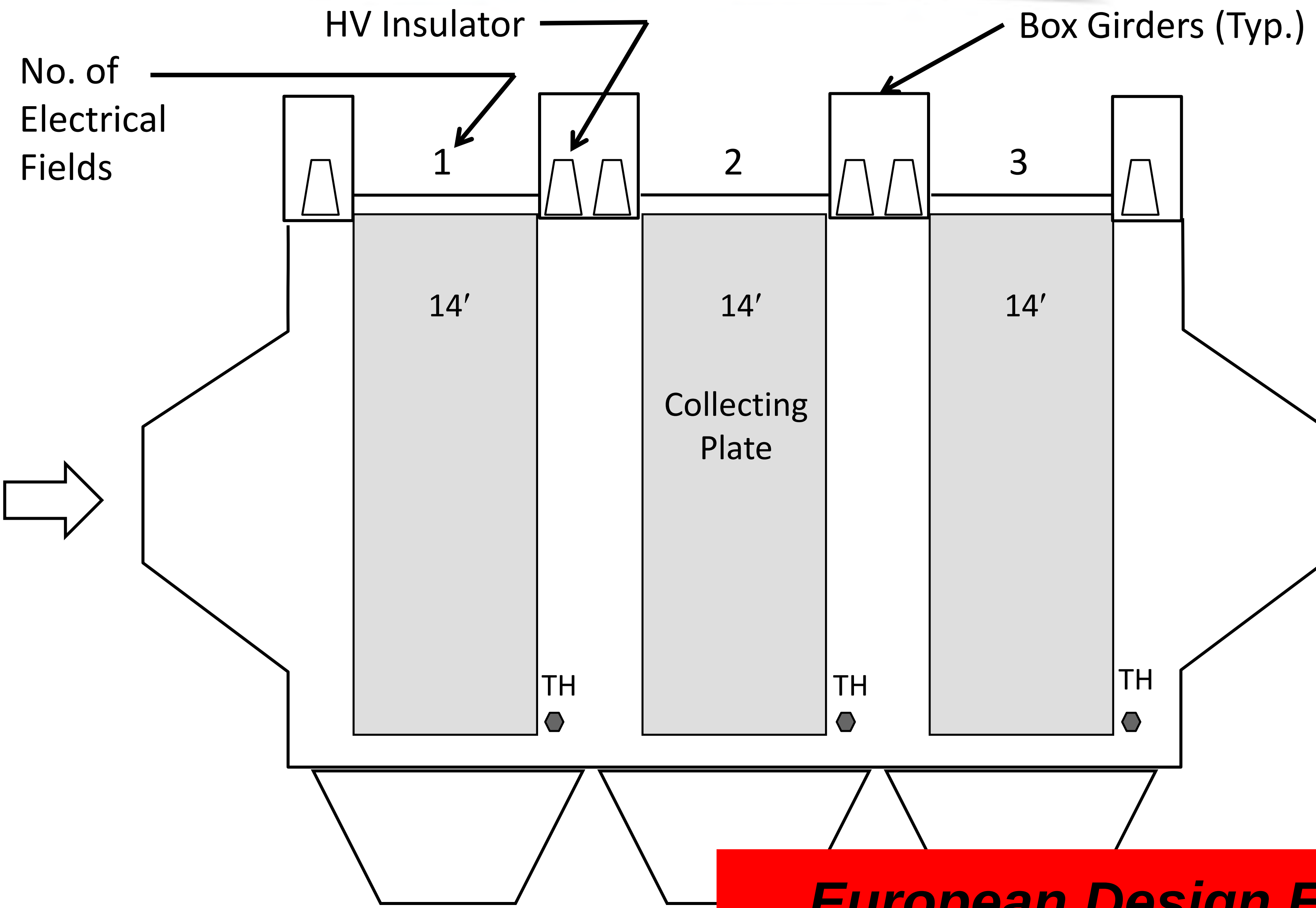
- *In cases where a scrubber follows the ESP, generally they will elect the SO_2 < 0.2#/MMBtu limit and therefore not require a sorbent*
- *However, if the unit has an SCR and is burning high sulfur coal, they then may have a problem with a visible sulfuric acid "blue plume." Thus requiring a sorbent to reduce the SO_3*
- *Or, because of the high concentration of SO3 in the gas stream, a sorbent is needed to increase the effectiveness of ACI*

How to deal with MATS induced problems

- ***In cases where there is no scrubber:***
  - Increase the size (SCA) of the ESP if possible
  - Increase the electrical sectionalization
  - Change out conventional, high ripple power supplies, to low ripple devices
  - Perform a model study to check for non-uniform gas flow and/or gas sneakage
  - Perform field studies to check for rapping reentrainment

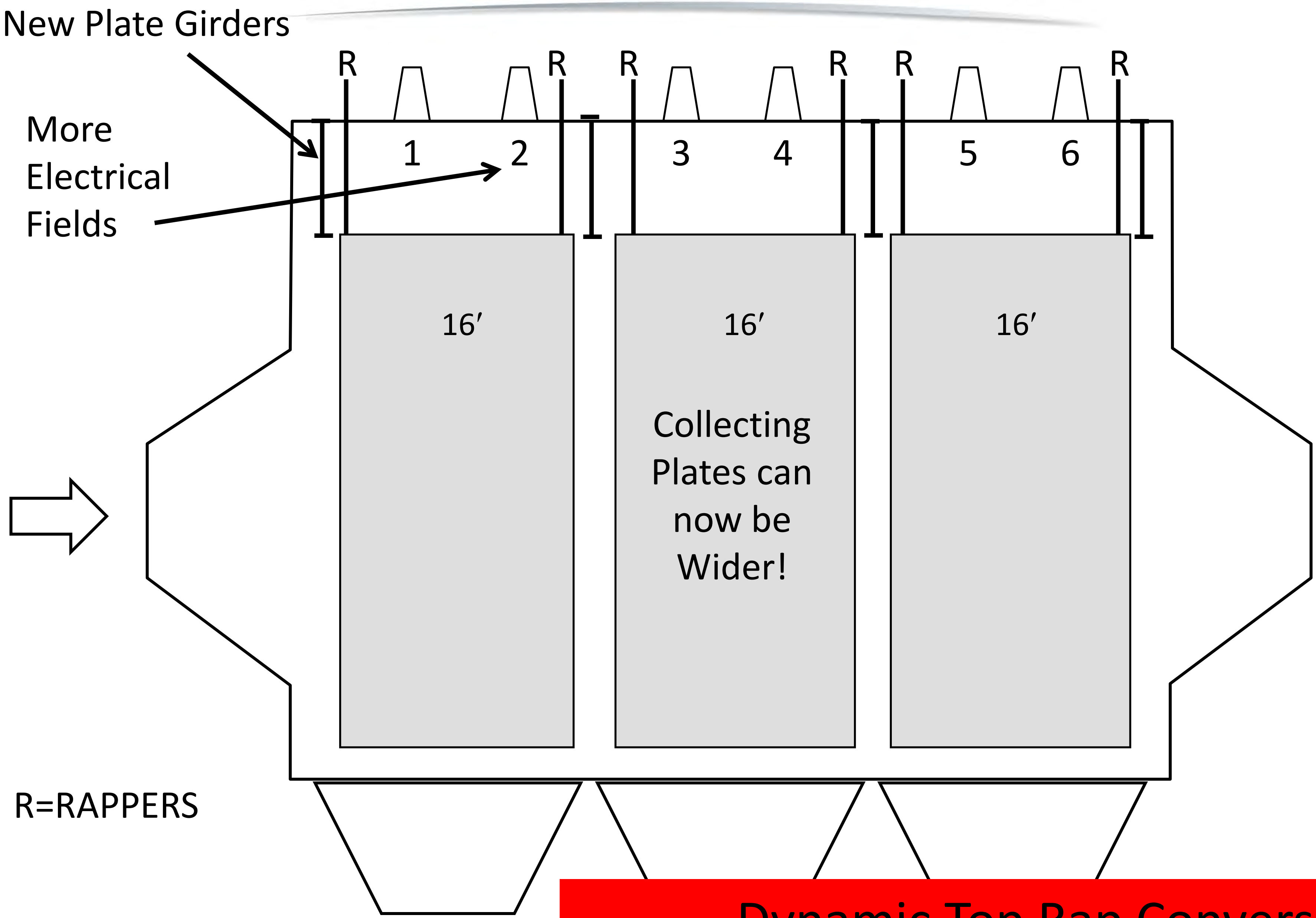
How to deal with MATS induced problems

- ***In cases where there is no scrubber:***
  - <u>Increase the size (SCA) of the ESP if possible</u>



TH=TUMBLING HAMMERS

European Design ESP



Dynamic Top Rap Conversion

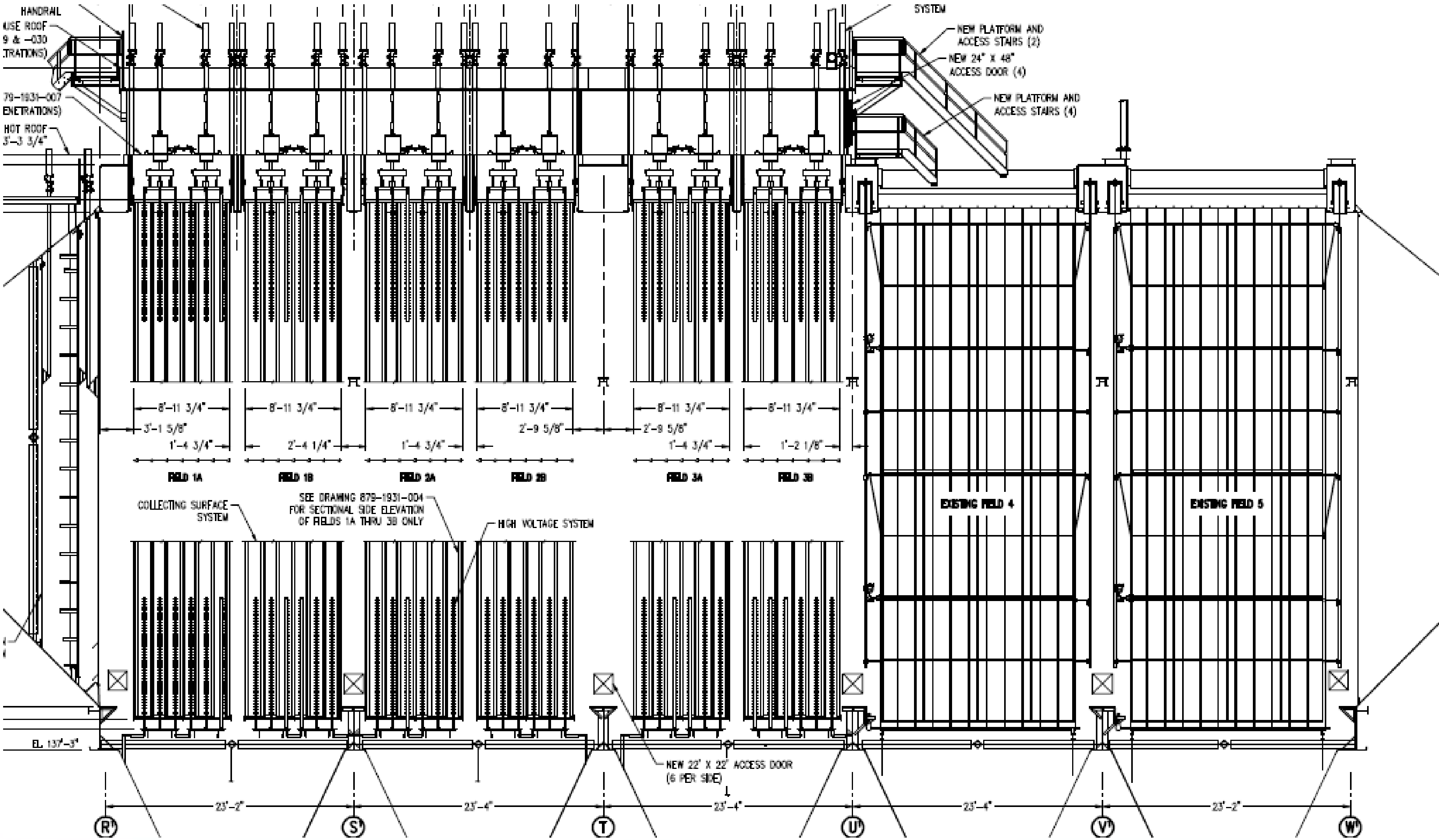
How to deal with MATS induced problems

- ***In cases where there is no scrubber:***
  - **Increase the electrical sectionalization**

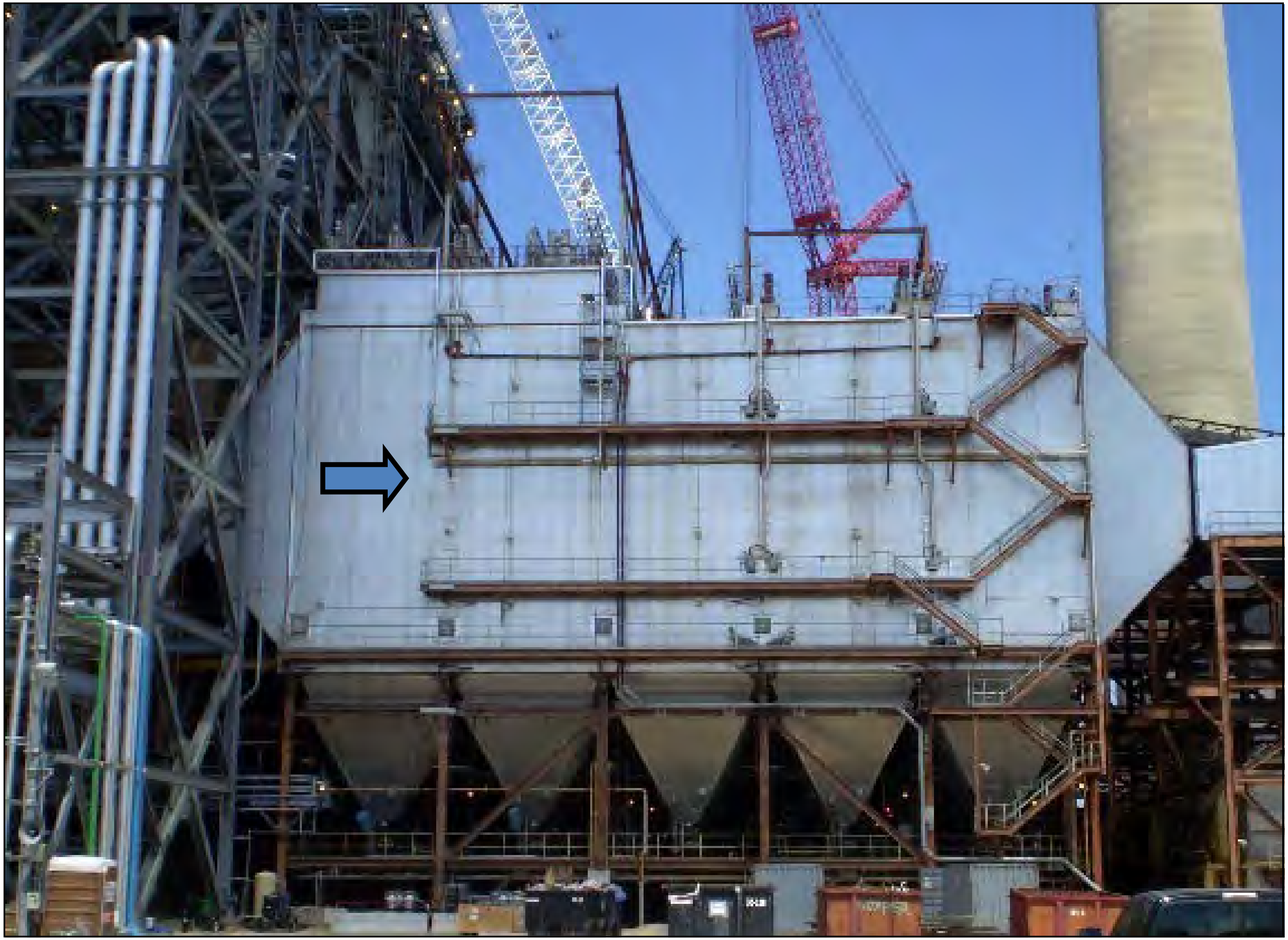
Sectionalization =
4, then 8, then 10, then 14 TR sets!!

Converting one electrical field to two. Rule of thumb 15000 sq. ft/tr set or less.

A European ESP converted to Top Rapped



Top Rapped Fields next to Original Fields



Closer View of New Fields and Existing

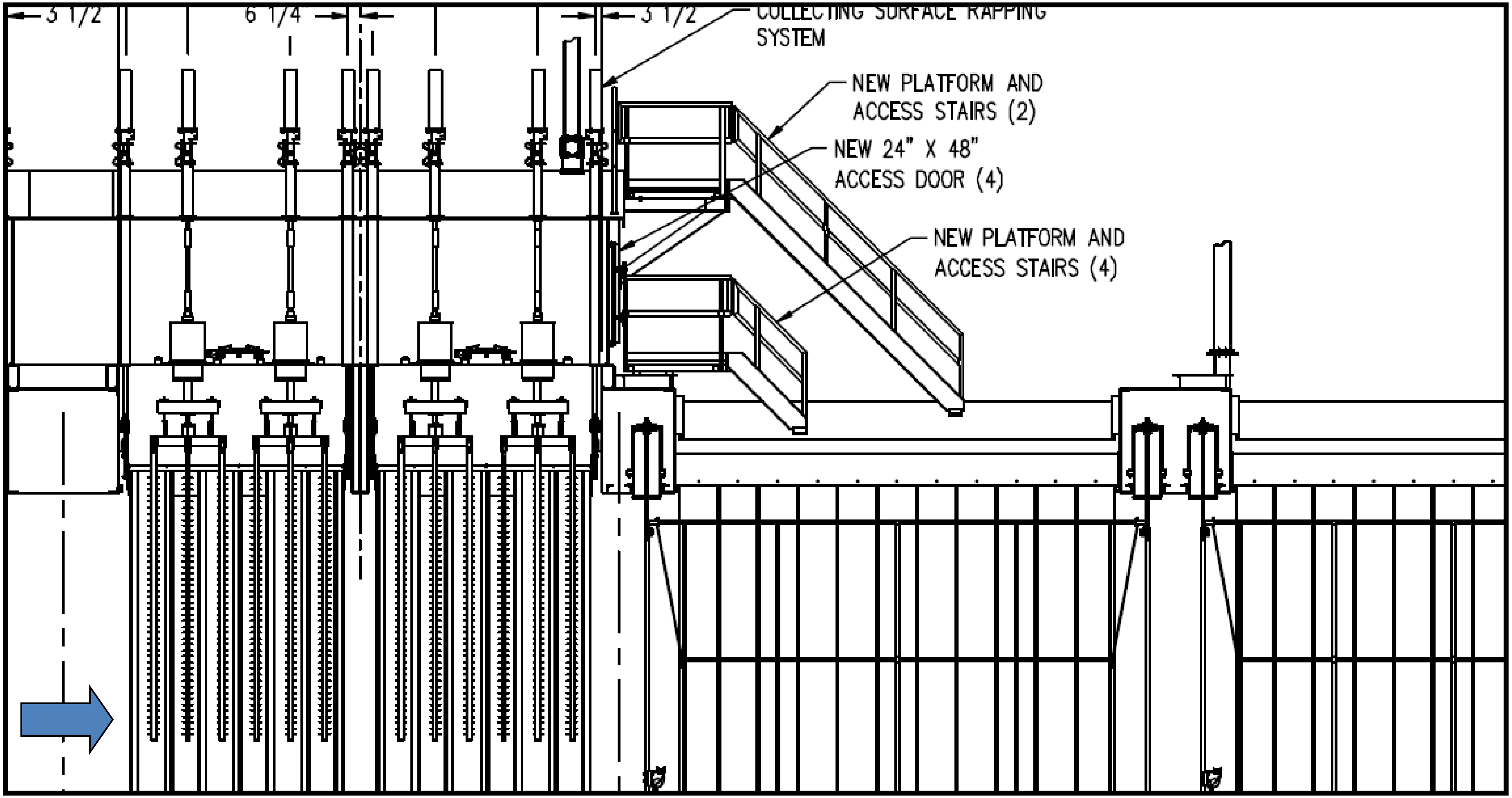


Photo of Previous View from Job

One, 9 Ft. Top Rapped Field Shown

How to deal with MATS induced problems

- ***In cases where there is no scrubber:***
  - Change out conventional, high ripple power supplies, to low ripple devices
  - Note, the emphasis is on the amount of ripple in the DC KV waveform and not the frequency
  - The following slides emphasize why

Power Supply Options to Control Corona Power

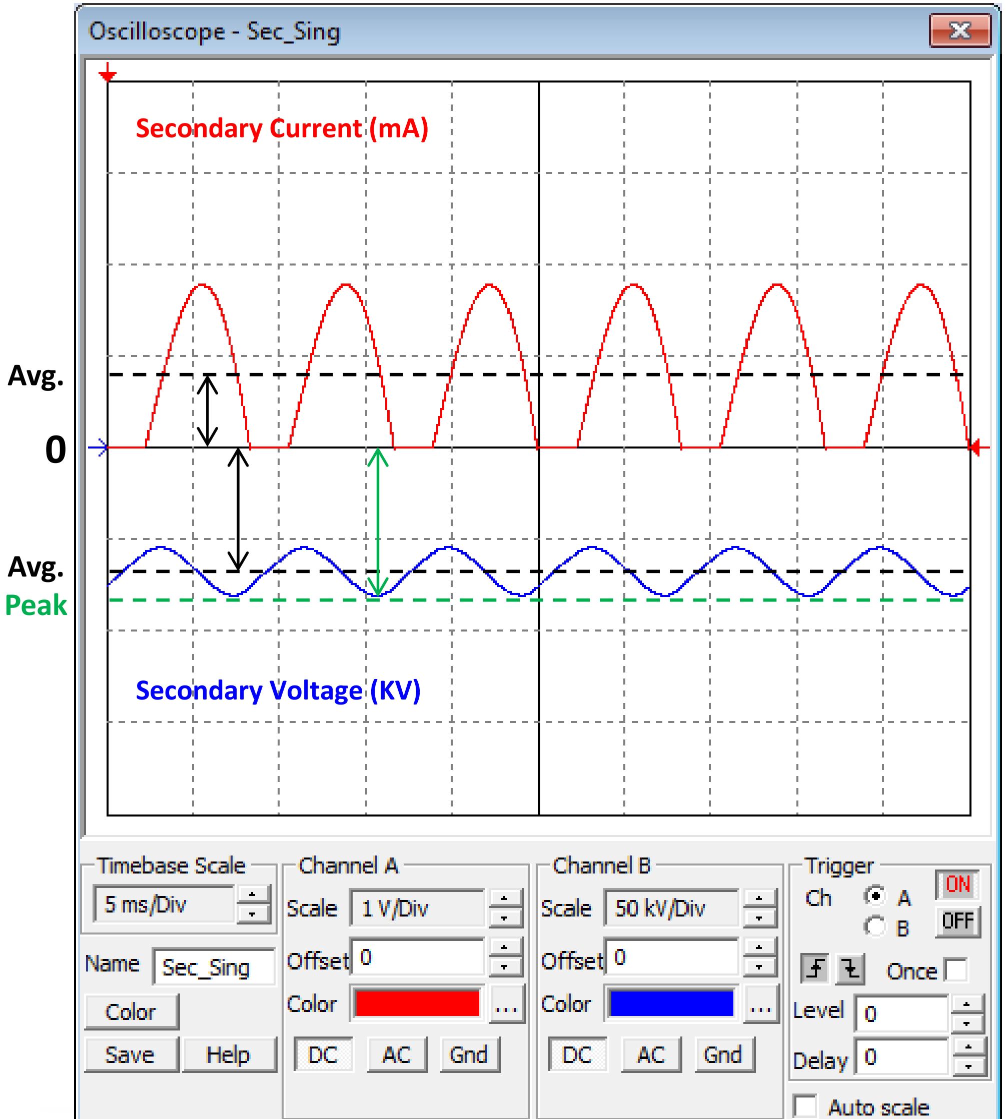
Three Choices

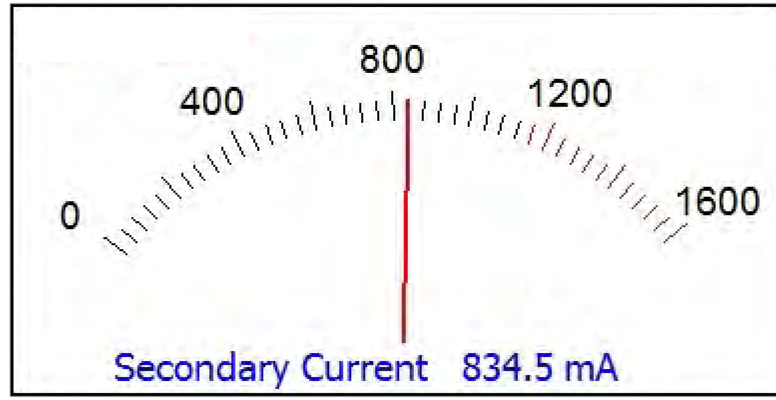
Single-Phase Power Supply

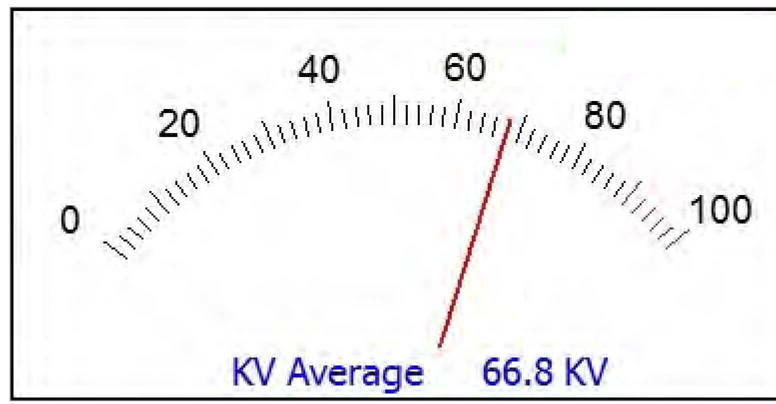
High Frequency Power Supply

3-Phase Power Supply

Single-Phase Power Supply



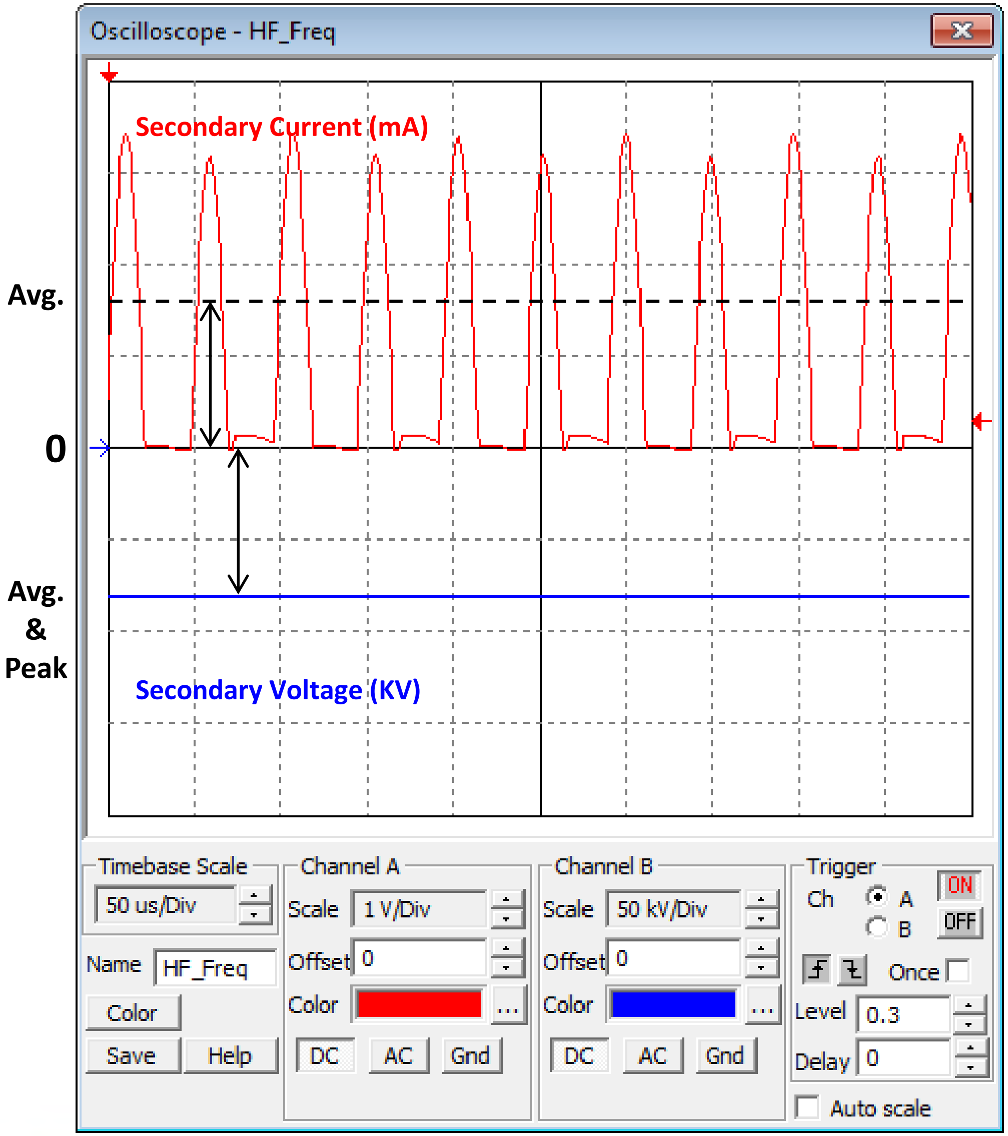


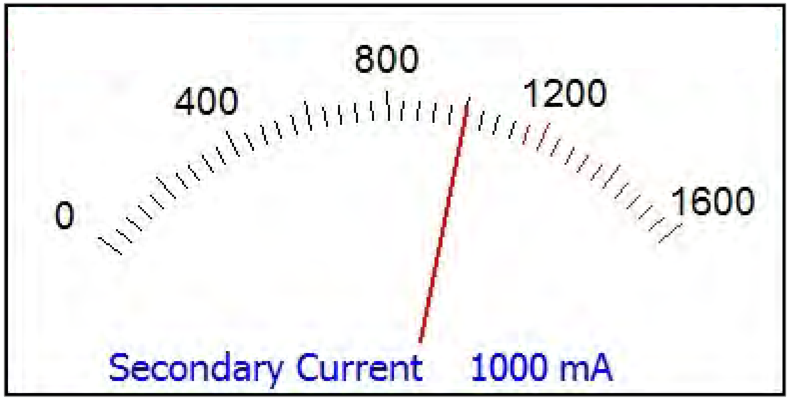


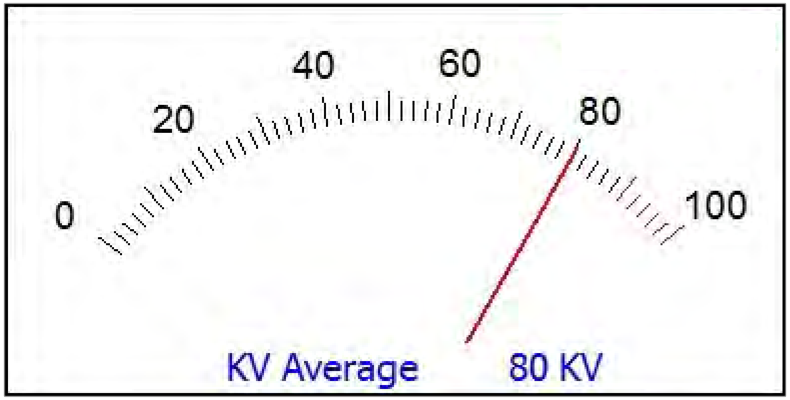
Peak to Avg. Voltage Ratio = 1.2

ω ≈ β * 67 KV Avg. * 80 KV Peak

High Frequency Power Supply



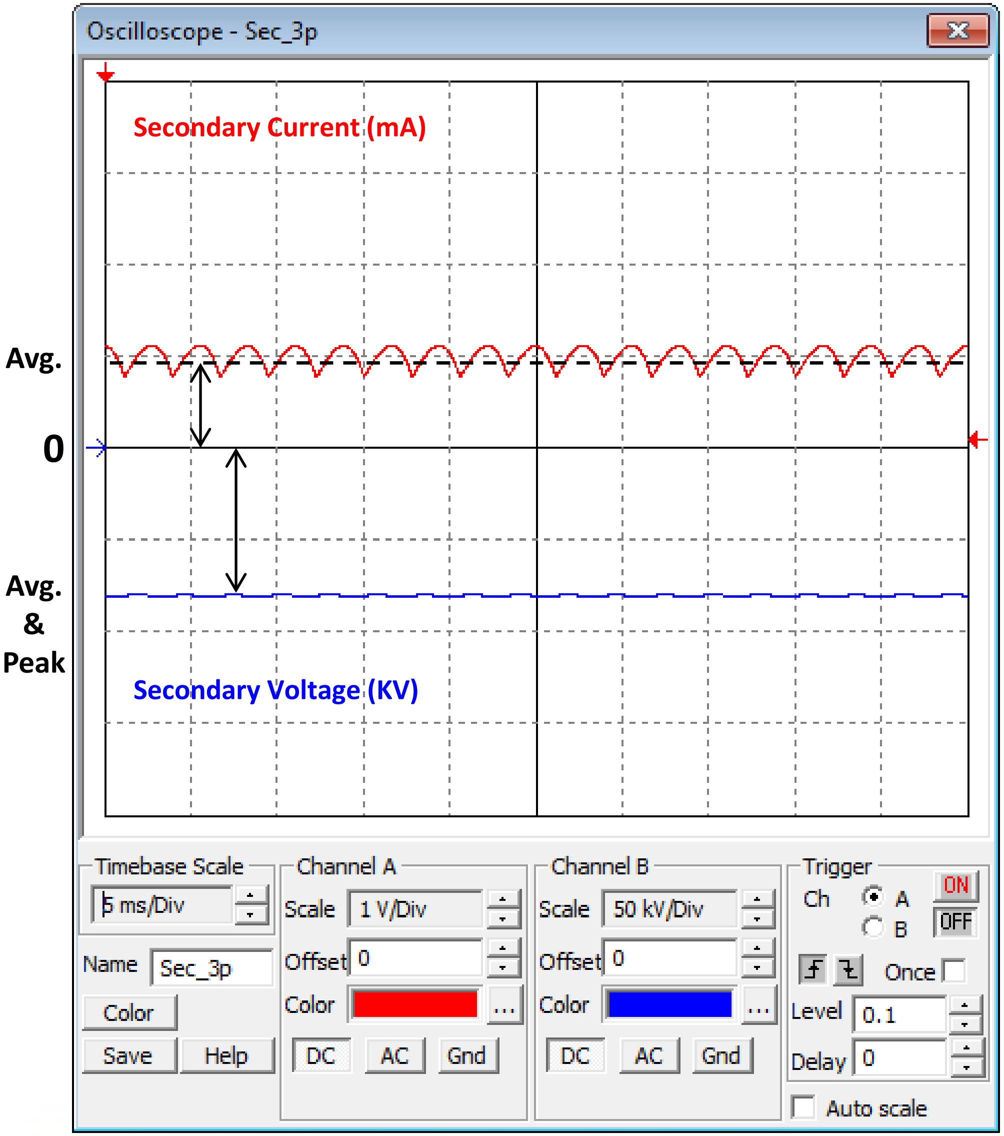


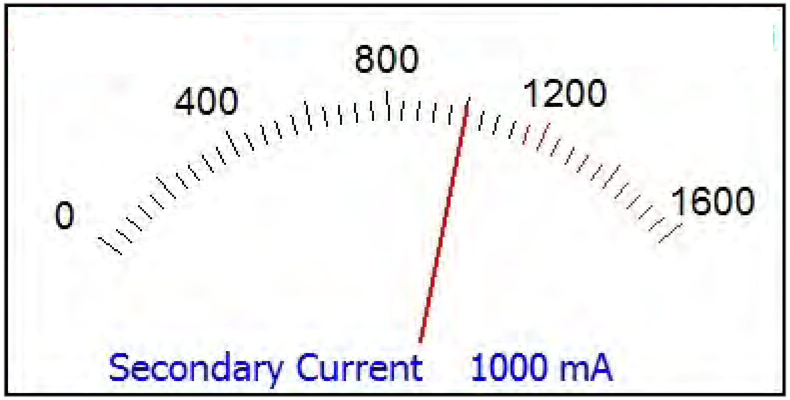


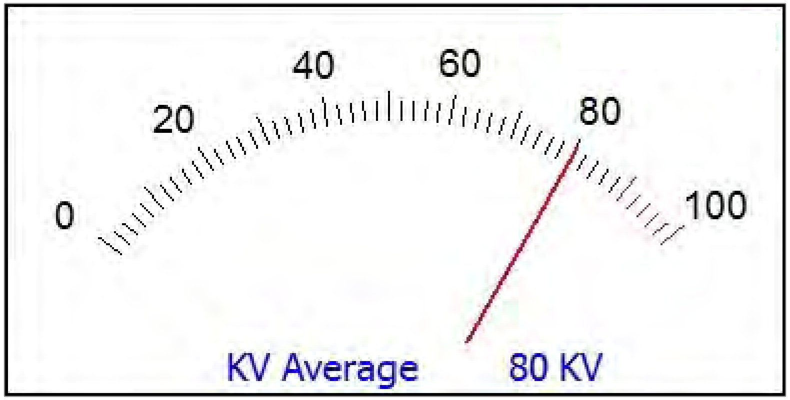
Peak to Avg. Voltage Ratio = 1.2

$\omega \approx \beta$ * 80 KV Avg. * 80 KV Peak

3-Phase Power Supply





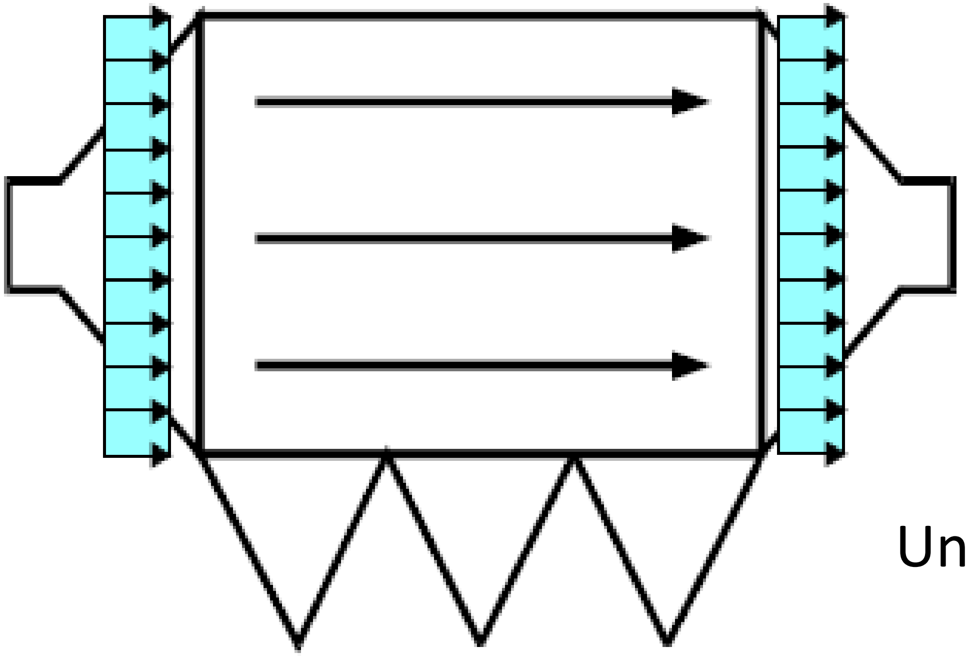


Peak to Avg. Voltage Ratio = 1.0

ω ≈ β * 80 KV Avg. * 80 KV Peak

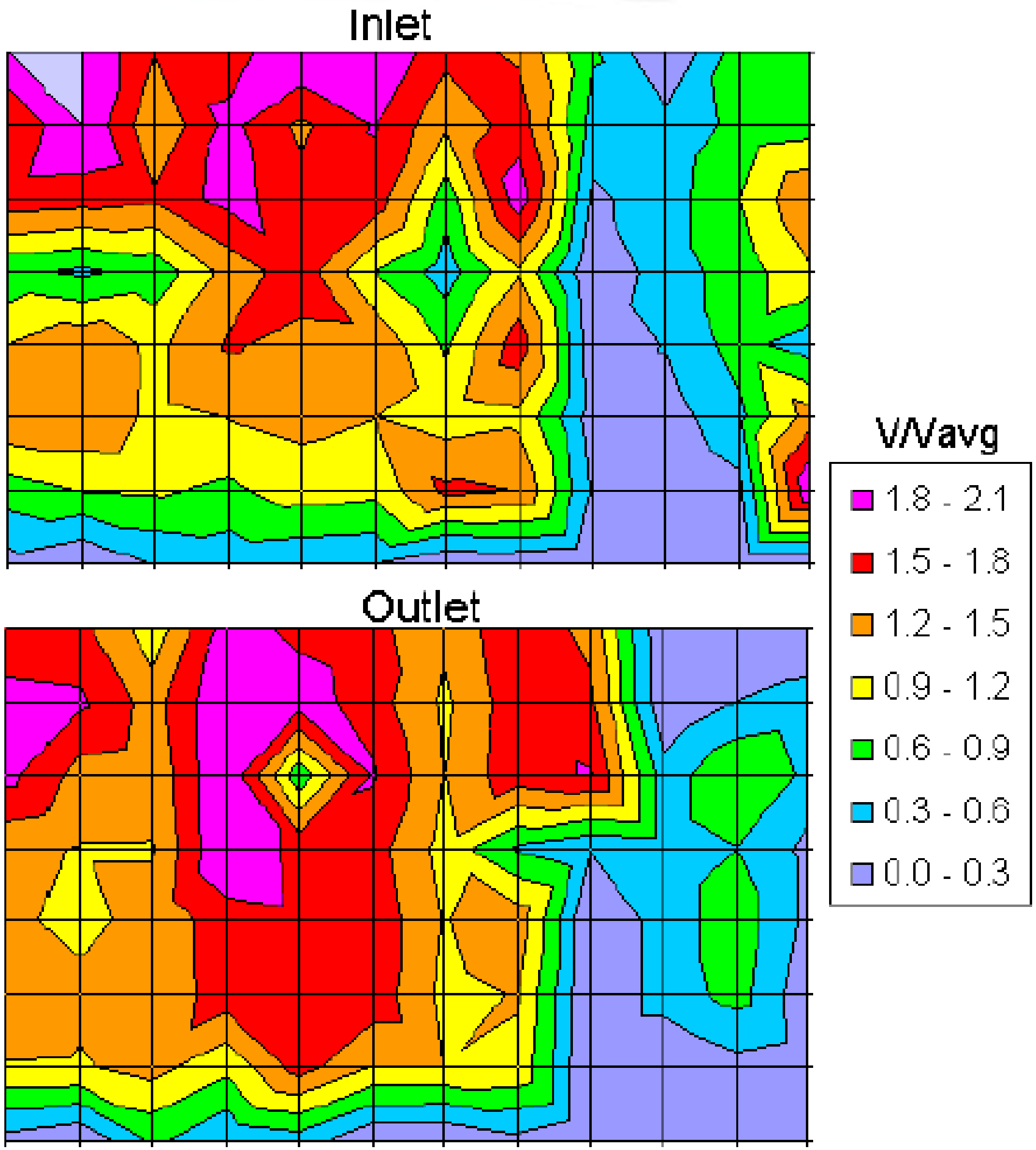
How to deal with MATS induced problems

- ***In cases where there is no scrubber:***
  - Perform a model study to check for non-uniform gas flow and/or gas sneakage

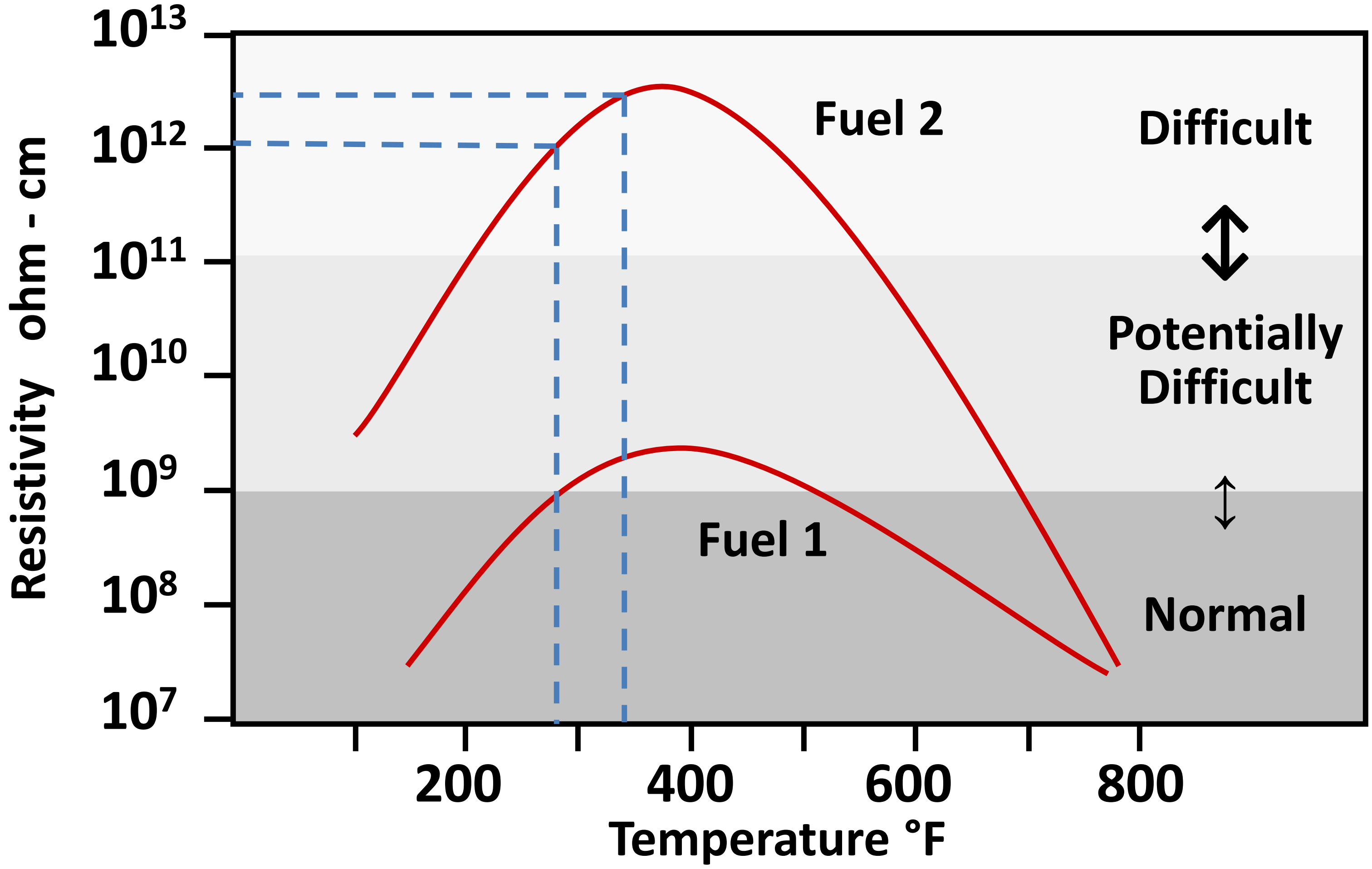


Uniform Gas Flow

Perform a model study to check for non-uniform gas flow and/or gas sneakage



Resistivity – Lowering the flue gas temperature, while treating for acid gas, will decrease particle resistivity and aid in mercury capture



How to deal with MATS induced problems

- ***In cases where there is no scrubber:***
  - **<u>Power-off rapping is often your friend when dust resistivity goes high. It can become critical to achieving PM emissions limits</u>**

thebabcock&wilcoxcompany

The End

Thank you.