REINHOLD ENVIRONMENTAL Ltd.

2013 APC Round Table & Expo Presentation

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

REDKOH INDUSTRIES

Stein Industries Inc.

Engineered Electrical Apparatus & Systems

ESP 101: Fundamentals

Paul Ford	Dan Steinhaur
Redkoh Industries	Stein Industries

With support from Peter Aa

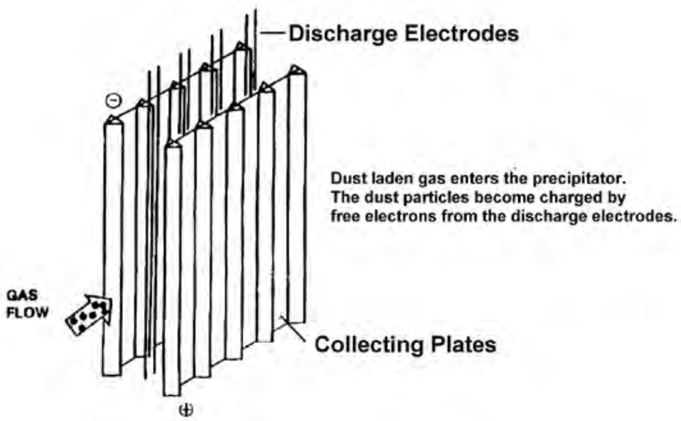
What is an Electrostatic Precipitator

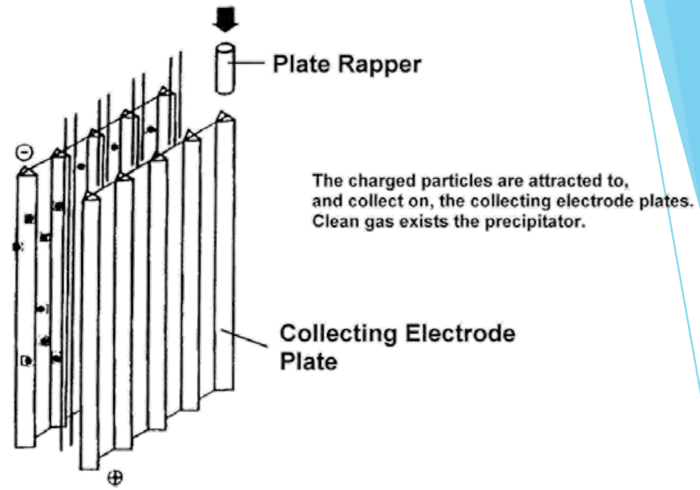
An **electrostatic precipitator** (**ESP**), or **electrostatic air cleaner** is a particulate collection device that removes particles from a flowing gas (such as air) using the force of an induced electrostatic charge.

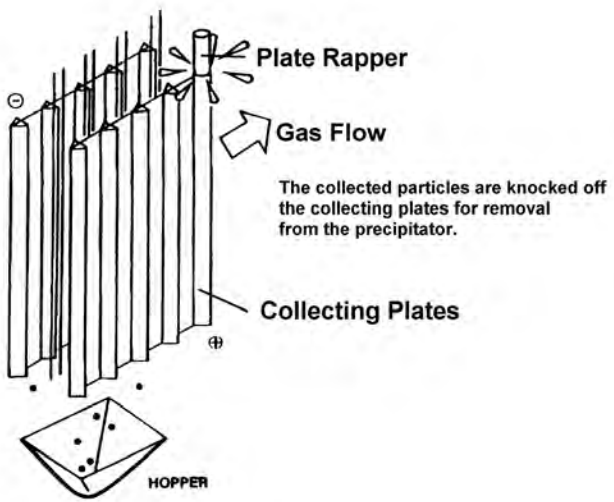
Electrostatic precipitators are highly efficient filtration devices that minimally impede the flow of gases through the device, and can easily remove fine particulate matter such as dust and smoke from the air stream:

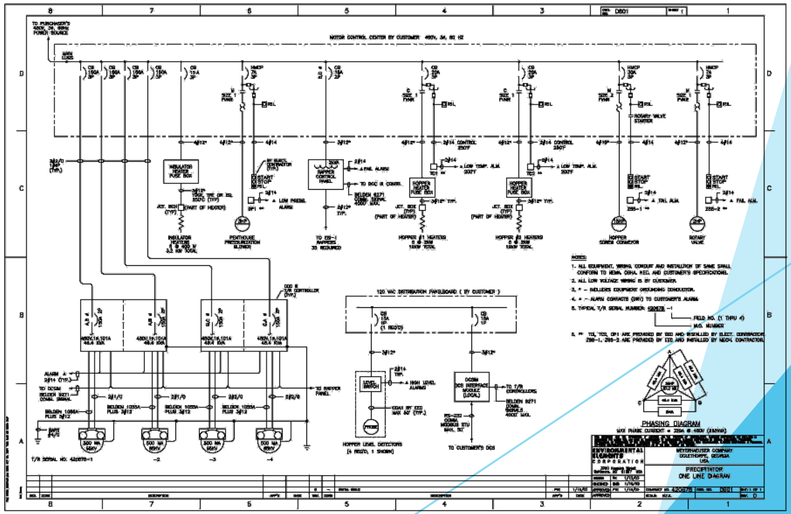
Thanks Wikipedia

How does it work





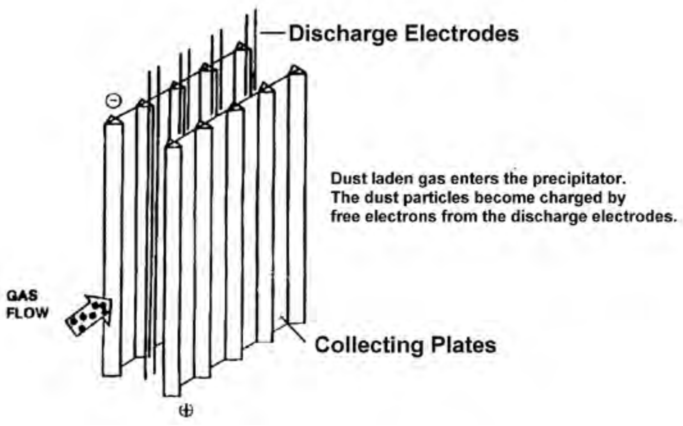


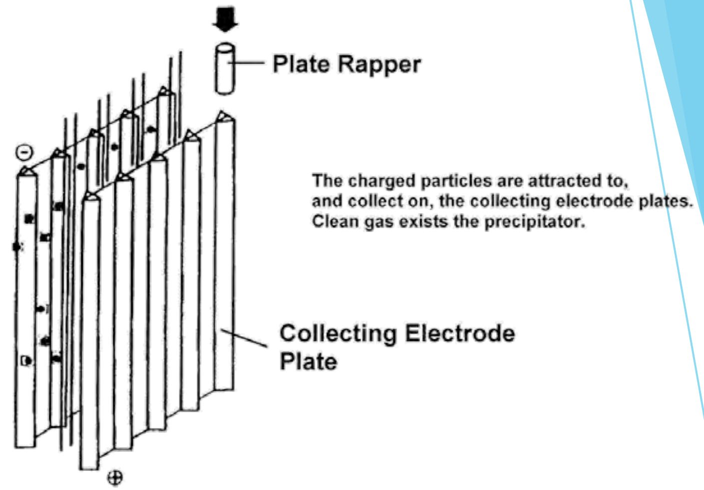


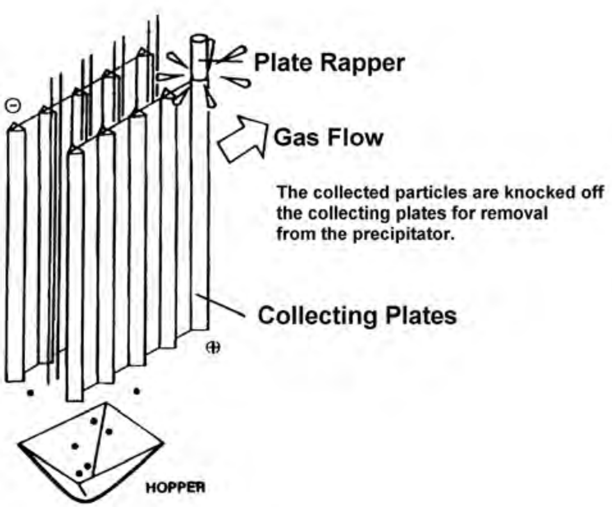
Collector Plates and Discharge Electrodes

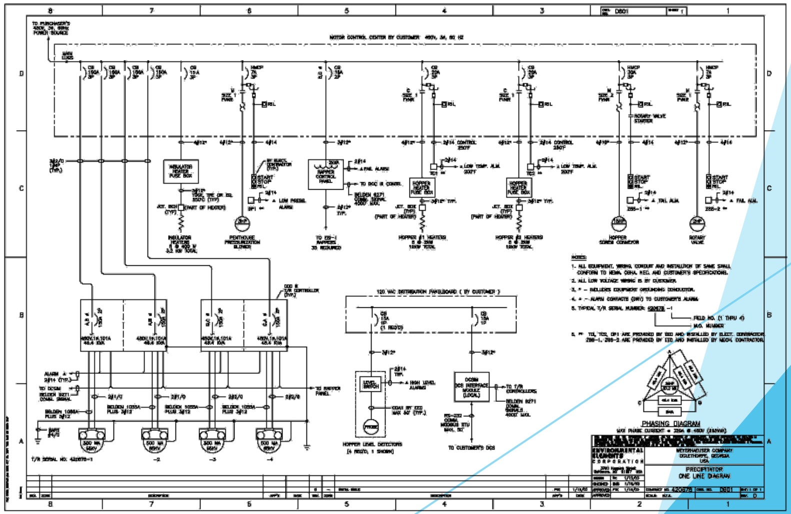
Courtesy of GEECOM

How does it work

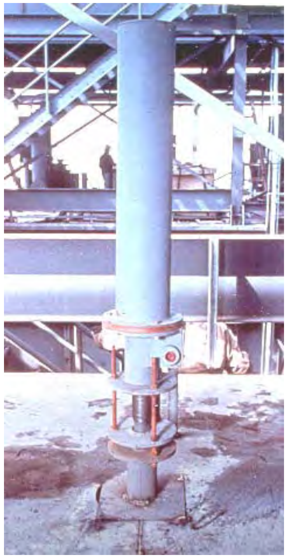


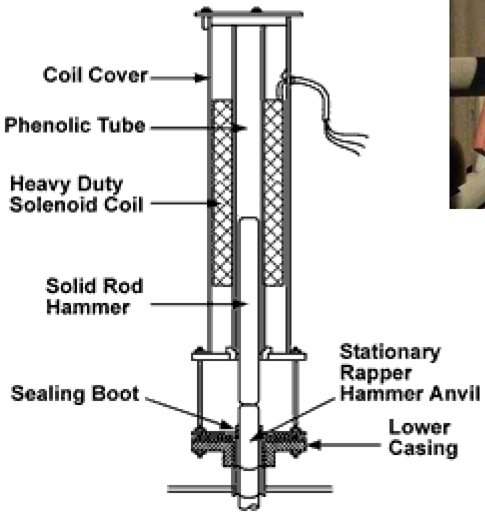




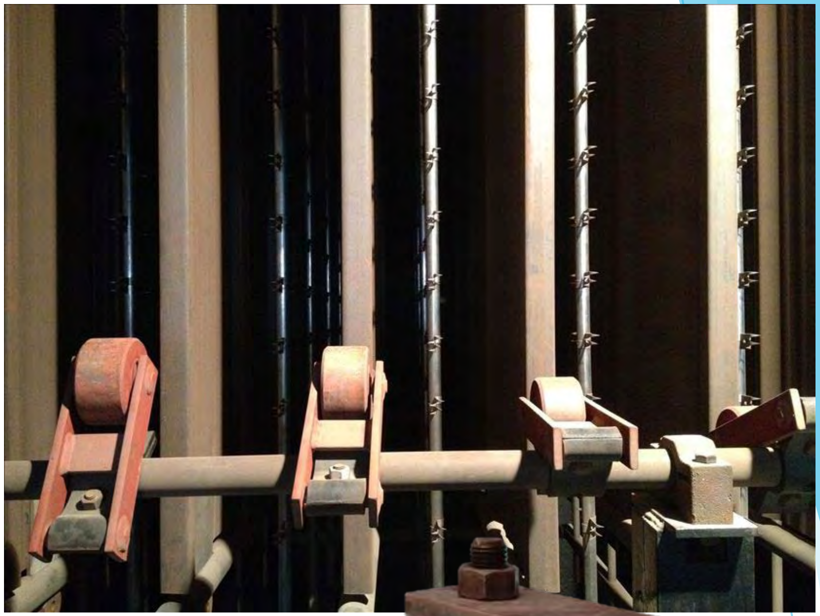


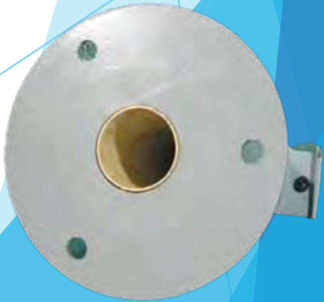
Rapping



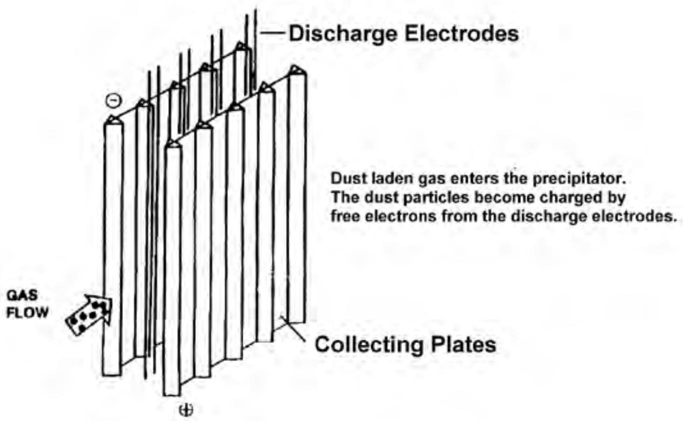


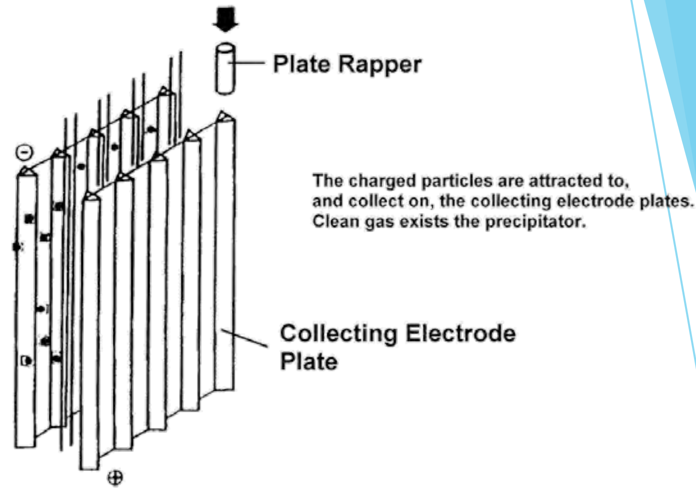
Coil Cover
Phenolic Tube
Heavy Duty
Solenoid Coil
Solid Rod
Hammer
Stationary
Rapper
Hammer Anvil
Sealing Boot
Lower
Casing

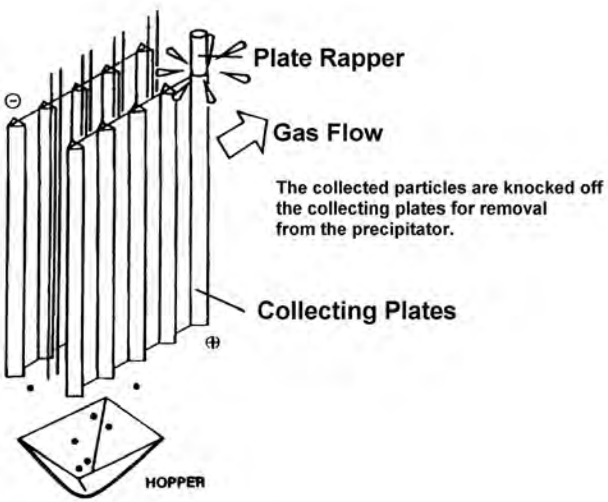


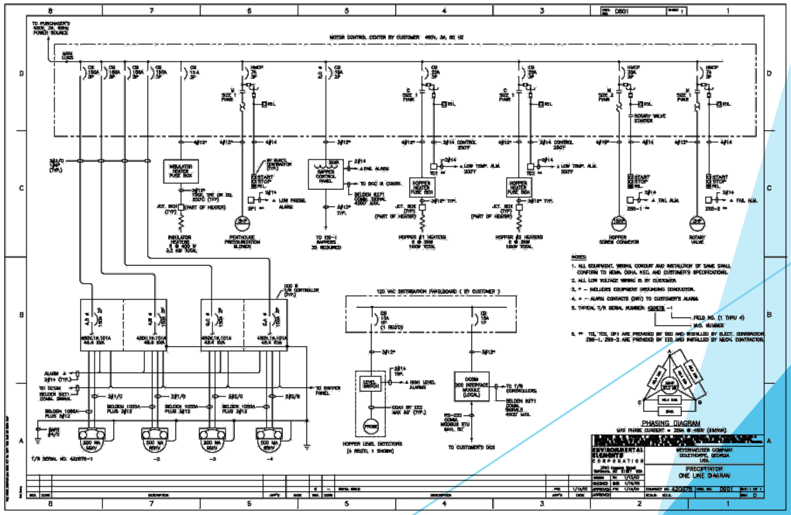


How does it work

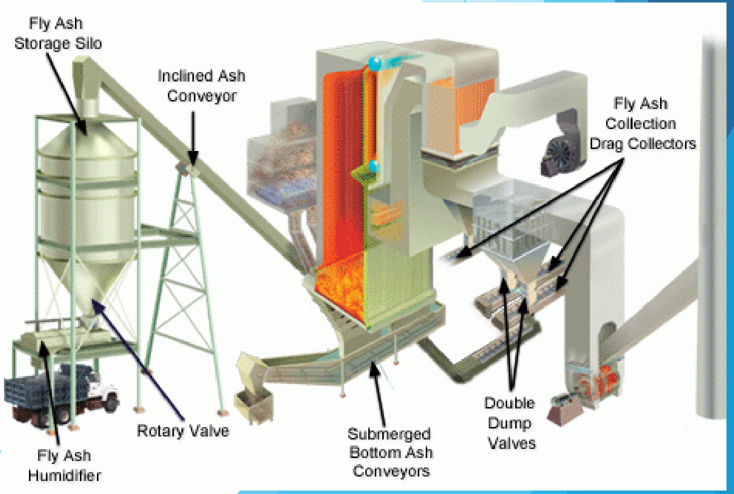








Ash Collection and Removal



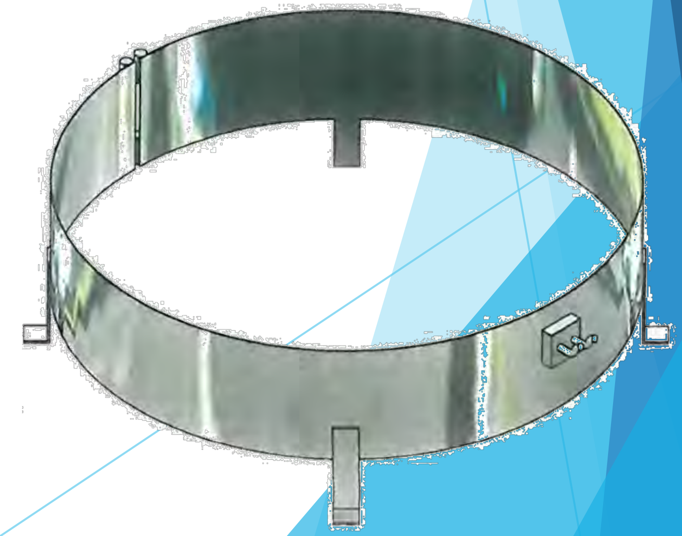
What does it need to make it work

Lots of Money

Lets talk a little about that

- What needs power and what does it do
  - Purge Air Heating / Insulator Heating
  - Hopper Heating
  - Transformer Rectifiers
  - Transformer Rectifier Controls
  - Rapping Systems
  - Ash Handling Systems
  - Instrumentation

Purge Air Heating / Insulator Heating



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Hopper Heating

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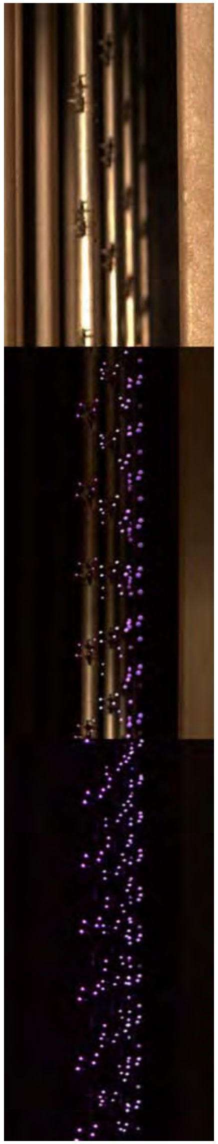
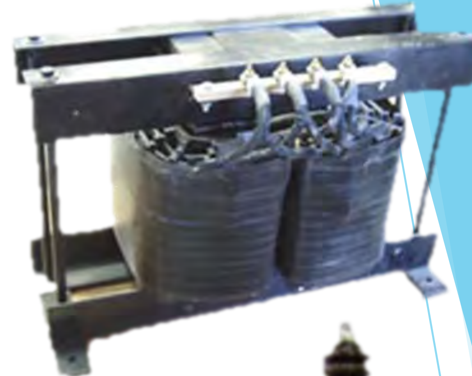
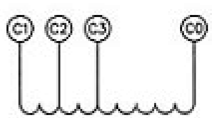
Transformer Rectifiers







Tap	Hy	%IMP
C0 - C3	0.00637	30
C0 - C2	0.00424	40
C0 - C1	0.00531	50

Transformer Rectifier Controls

Lets talk a little about that

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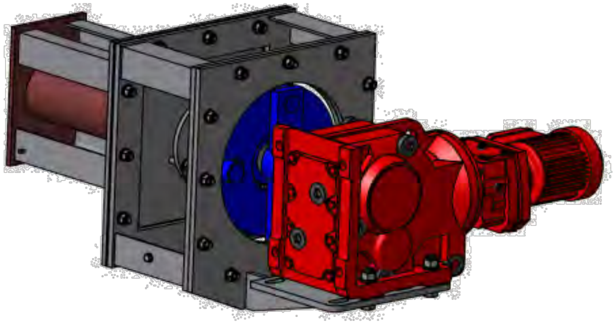
Rapping Systems



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Ash Handling Systems

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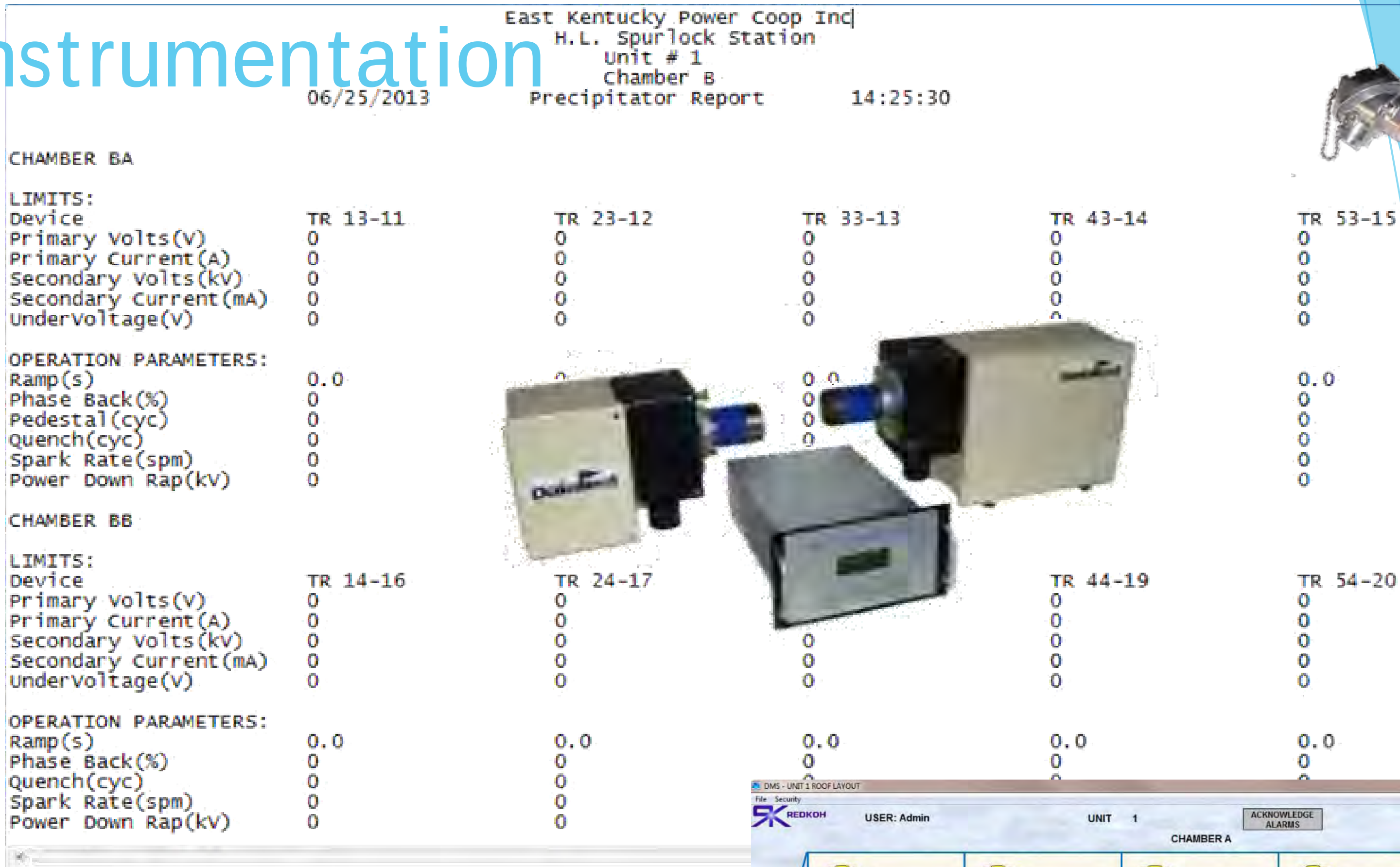
Instrumentation



East Kentucky Power Coop Inc
H.L. Spurlock Station
Unit # 1
Chamber B
06/25/2013 Precipitator Report 14:25:30

CHAMBER BA

LIMITS:

Device	TR 13-11	TR 23-12	TR 33-13	TR 43-14	TR 53-15
Primary Volts(V)	0	0	0	0	0
Primary Current(A)	0	0	0	0	0
Secondary Volts(kV)	0	0	0	0	0
Secondary Current(mA)	0	0	0	0	0
UnderVoltage(V)	0	0	0		0

OPERATION PARAMETERS:

Ramp(s)	0.0		0.0		0.0
Phase Back(%)	0		0		0
Pedestal(cyc)	0		0		0
Quench(cyc)	0		0		0
Spark Rate(spm)	0				0
Power Down Rap(kV)	0				0

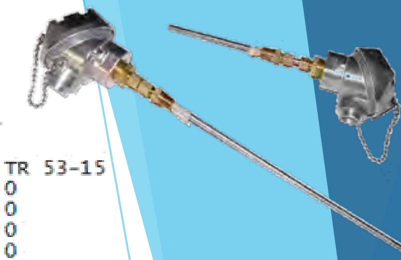
CHAMBER BB

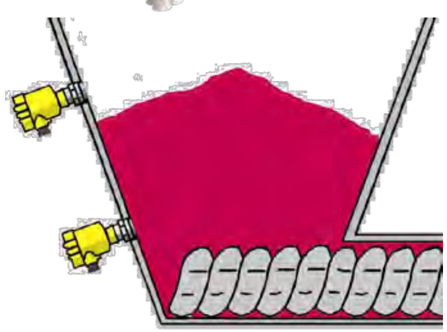
LIMITS:

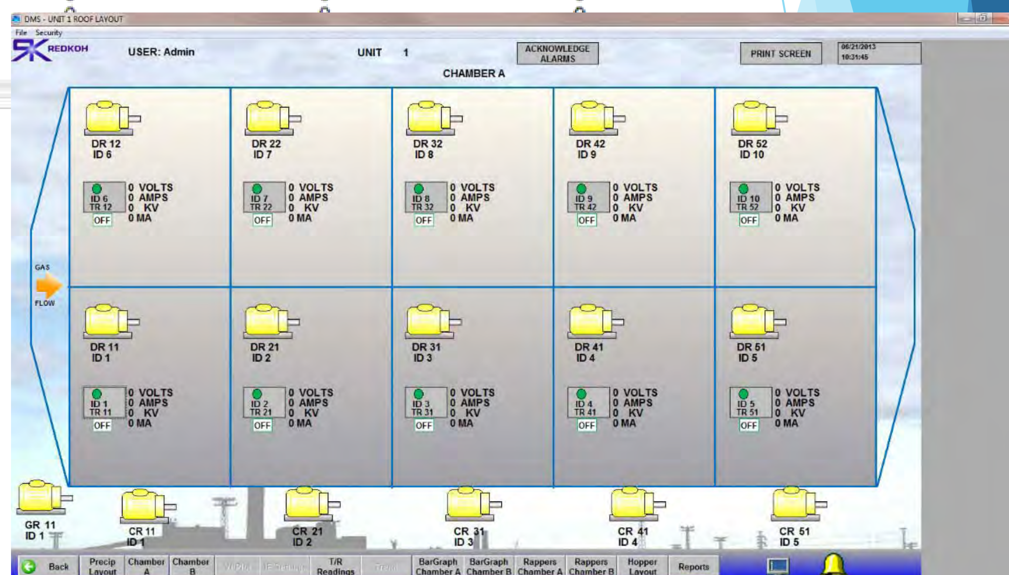
Device	TR 14-16	TR 24-17		TR 44-19	TR 54-20
Primary Volts(V)	0	0		0	0
Primary Current(A)	0	0		0	0
Secondary Volts(kV)	0	0	0	0	0
Secondary Current(mA)	0	0	0	0	0
UnderVoltage(V)	0	0	0	0	0

OPERATION PARAMETERS:

Ramp(s)	0.0	0.0	0.0	0.0	0.0
Phase Back(%)	0	0	0	0	0
Quench(cyc)	0	0			
Spark Rate(spm)	0	0			
Power Down Rap(kV)	0	0			







Precipitator Buzz.

- High Frequency TR Sets
- Gas Flow Sneakage
- Particulate Distribution
- Particle Size
- Electrical Sectionalization
- Rapping Density
- Rapping Re-entrainment
- Particulate Resistivity
- Voltage vs. Current Curves
- Electrode Management
- Wire Breakage
- Hopper Problems
- Record Keeping

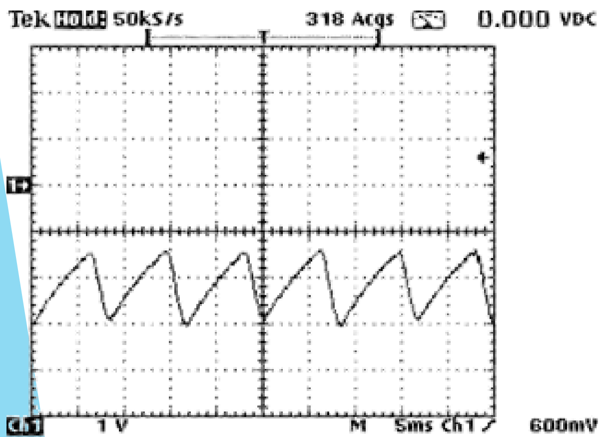
High Frequency TR sets

Maximize the average voltage to the ESP, while minimizing the peak voltage.

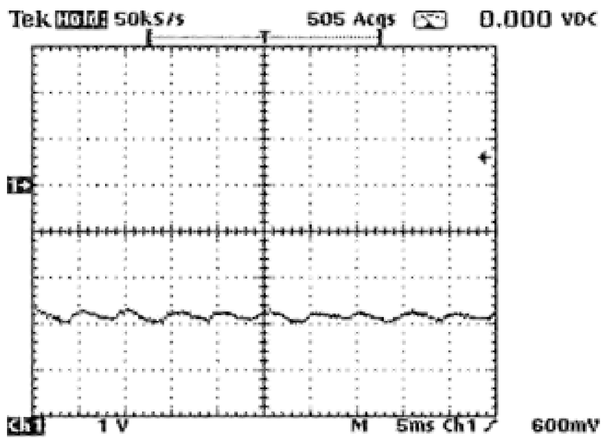
Reduce the peak to peak ripple of the secondary voltage supplied by the TR set to the ESP

Precipitators spark most frequently at the peak of the applied KV.

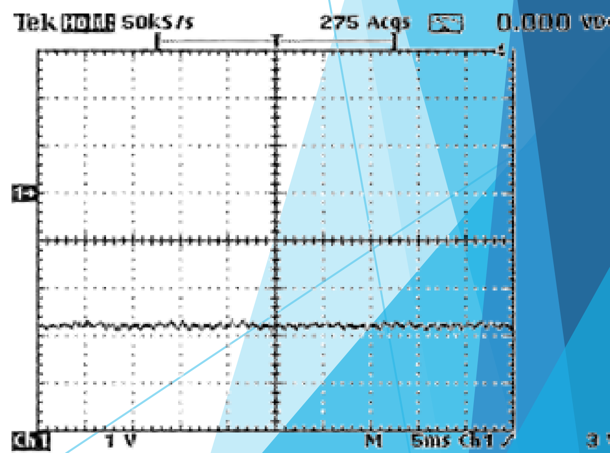
Reducing the peak voltage while maintaining a high average voltage reduces the sparking within the ESP.



60 Hertz – SCR Energized



100 Hertz – IGBT Energized



400 Hertz – IGBT Energized

High Frequency TR sets

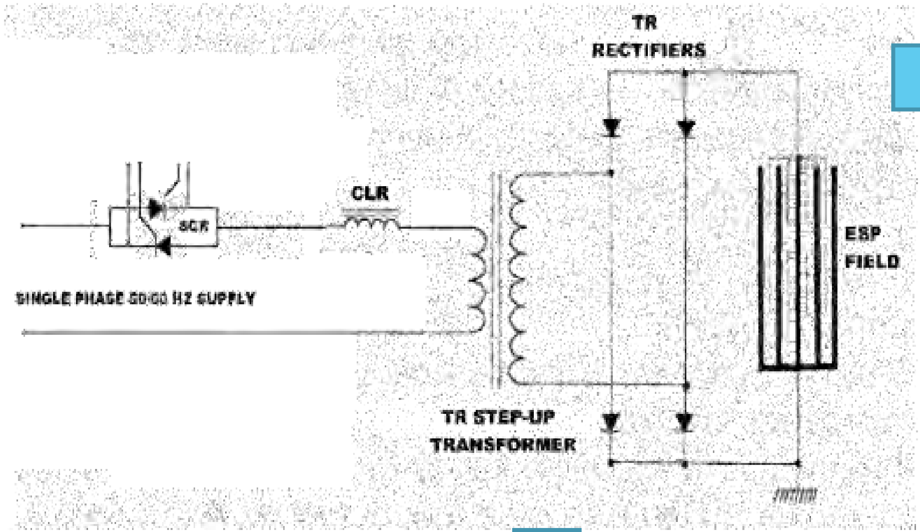
Reducing the frequency of sparking reduces the voltage “downtime” on the ESP

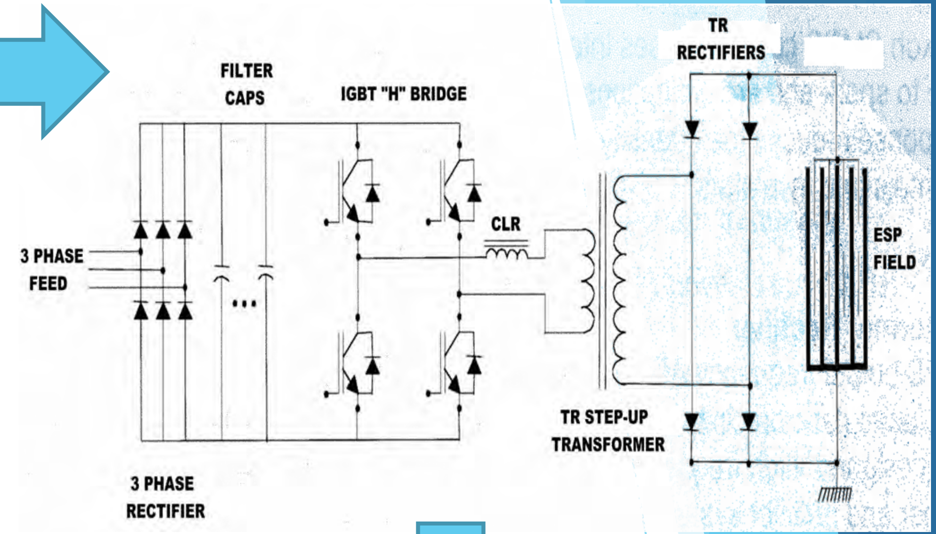
Minimizing the downtime allows longer durations for the current in the ESP to build up.

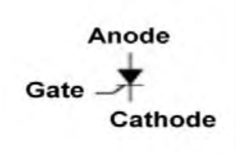
Higher average precipitator voltage allows more time for current to flow keeping the power levels to the maximum.

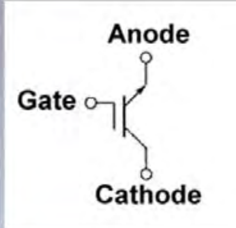
Higher power in the ESP promotes improved ESP collection efficiency.

Power Supply Side





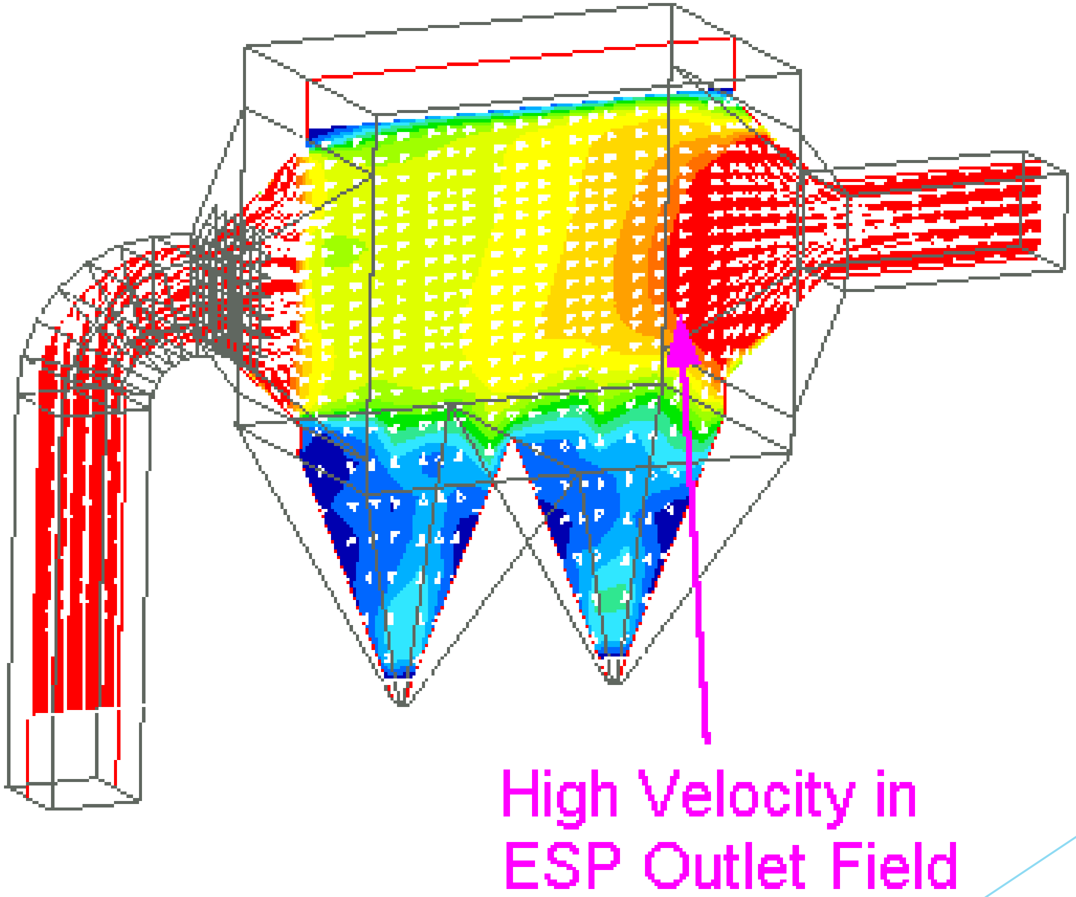




TR Side

- **The Conventional (60Hz) TR set operating at 400Hz**
  - **Separate TR and Controls**
- **The Conventional TR Set at 100 Hz modulated with 1.6 kHz**
  - **Separate TR and Controls**
- **The 400Hz TR Set**
  - **Either separate TR and controls or Integrated unit for Roof Mount**
- **The kHz Switch mode power Supply**
  - **Roof mount at point of HV entry to ESP**

Gas Flow Distribution

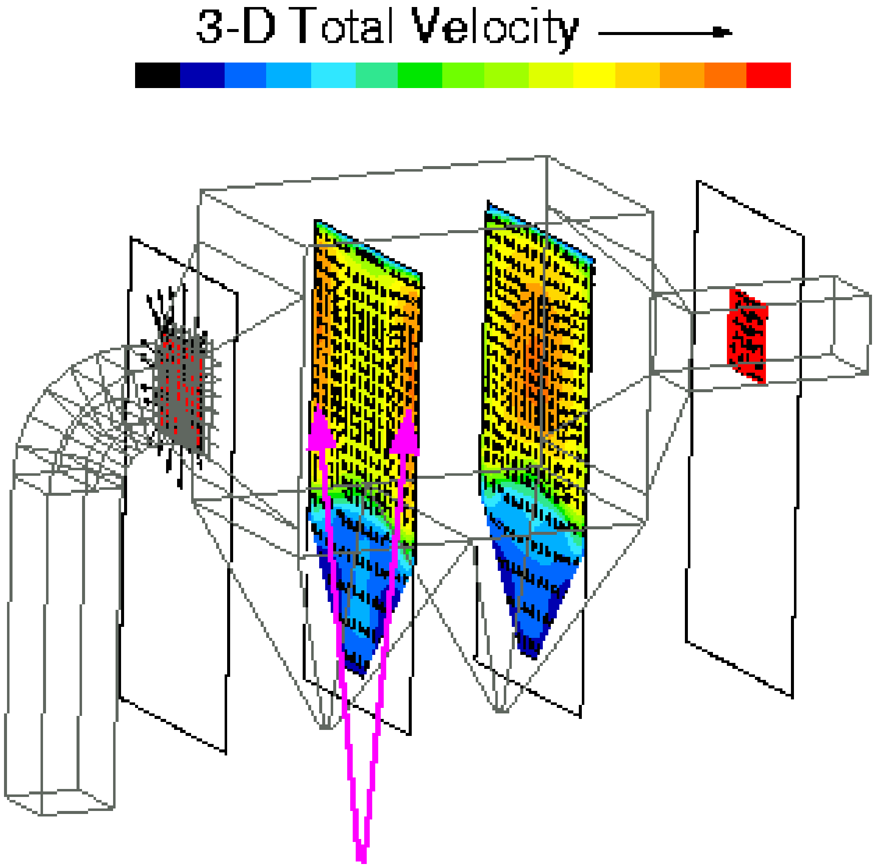


Thanks Air Flow Sciences

Gas Flow Distribution

- Sizing and power requirements are based on each square foot of collecting area performing efficiently.
- Higher flows can results in reduced migration velocity, re-entrainment/ scouring.
- Lower flows can result in wasted power.

Poor Gas Flow Distribution

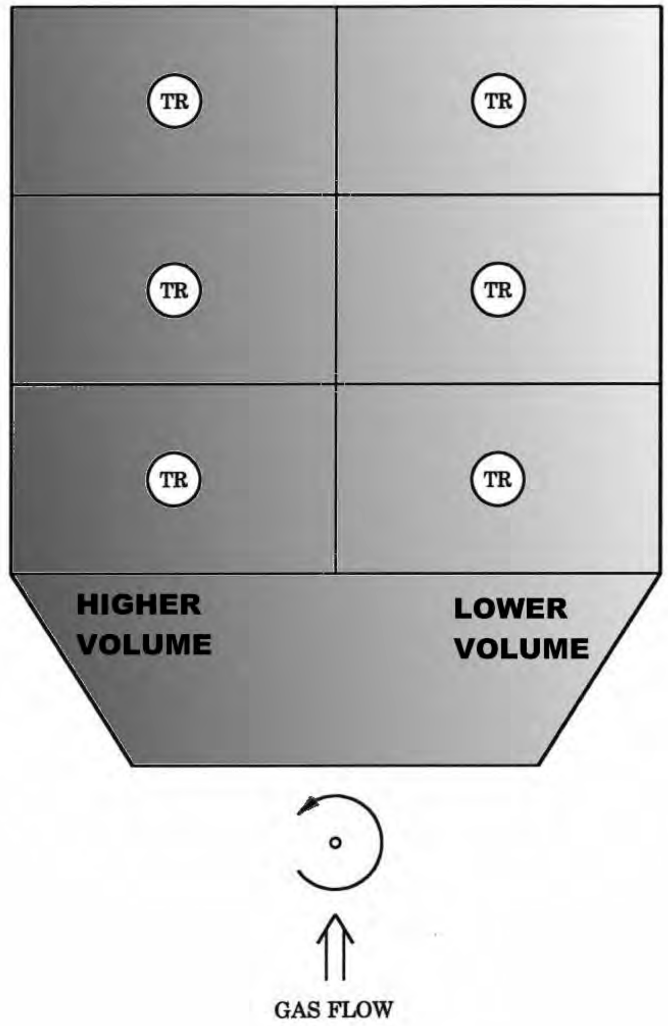


Thanks Air Flow Sciences

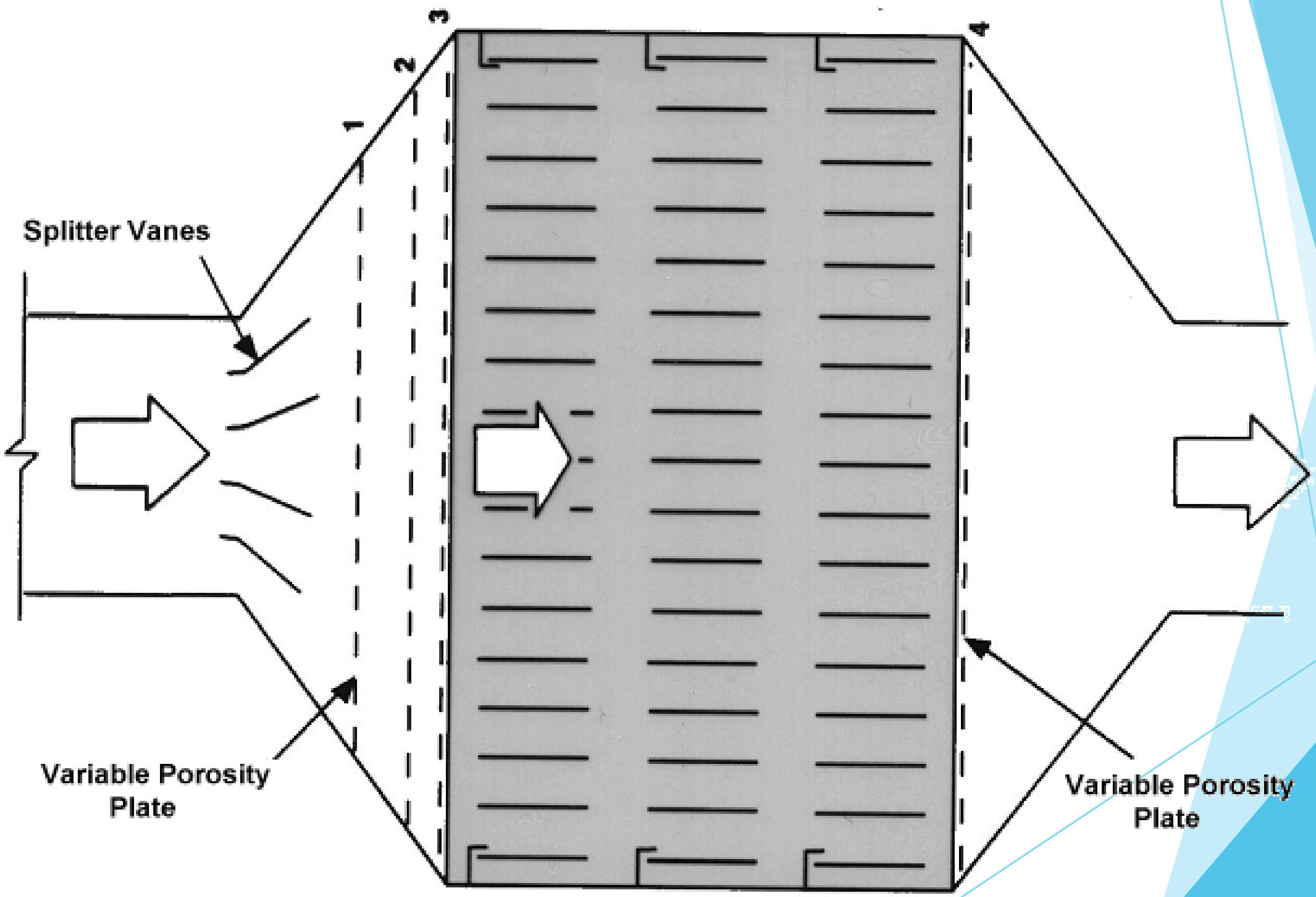
Poor Gas Flow Distribution

- Side to Side
  - Tends to follow rotation of the air heater
- Top to Bottom
  - Poor distribution plate/turning vane location/construction
- Outside In
  - General poor duct design or vane type or location
- Inside Out
  - General poor duct design or vane type or location

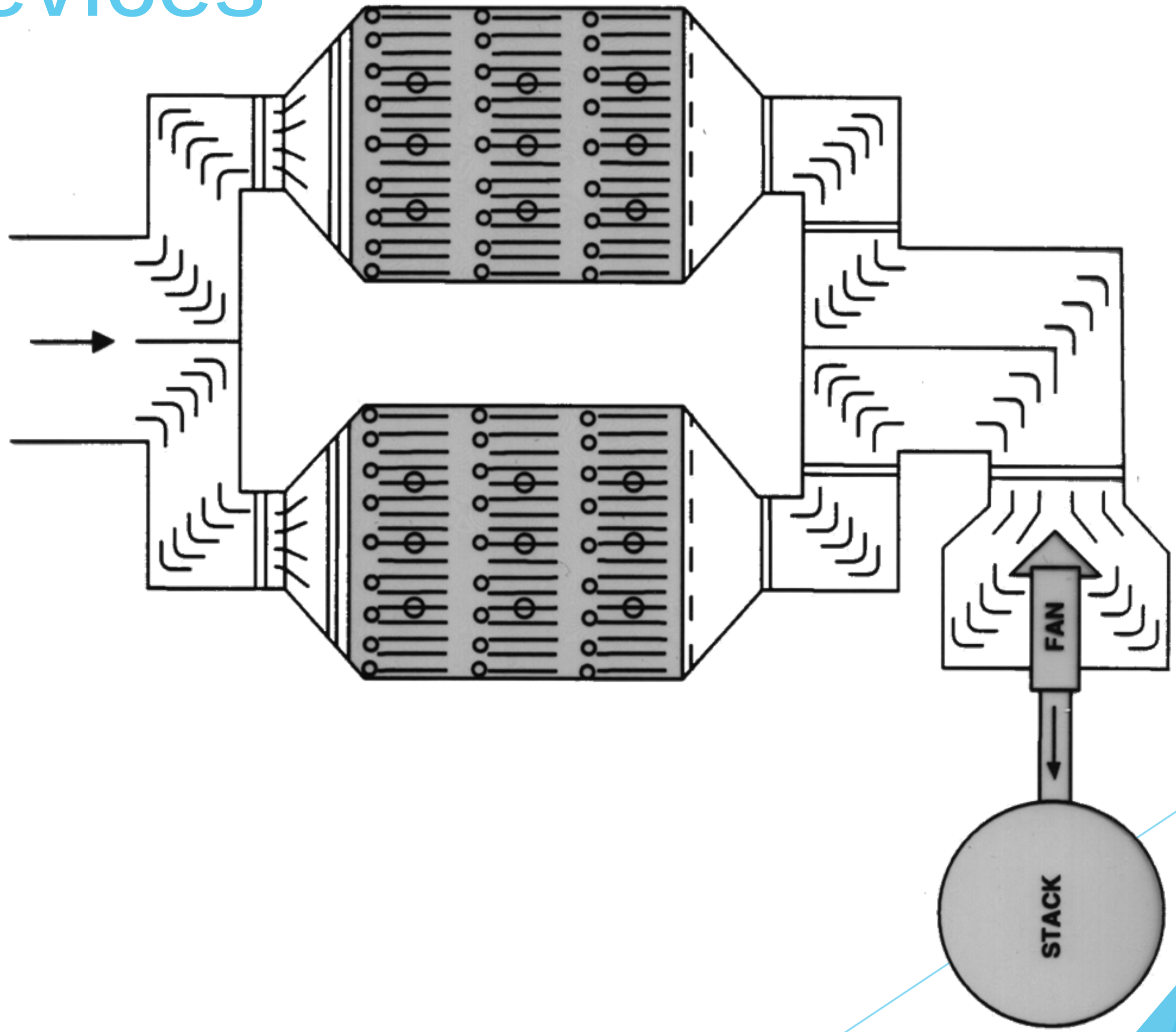
Poor Gas Flow Distribution



Gas Flow Distribution Devices



Gas Flow Distribution Devices

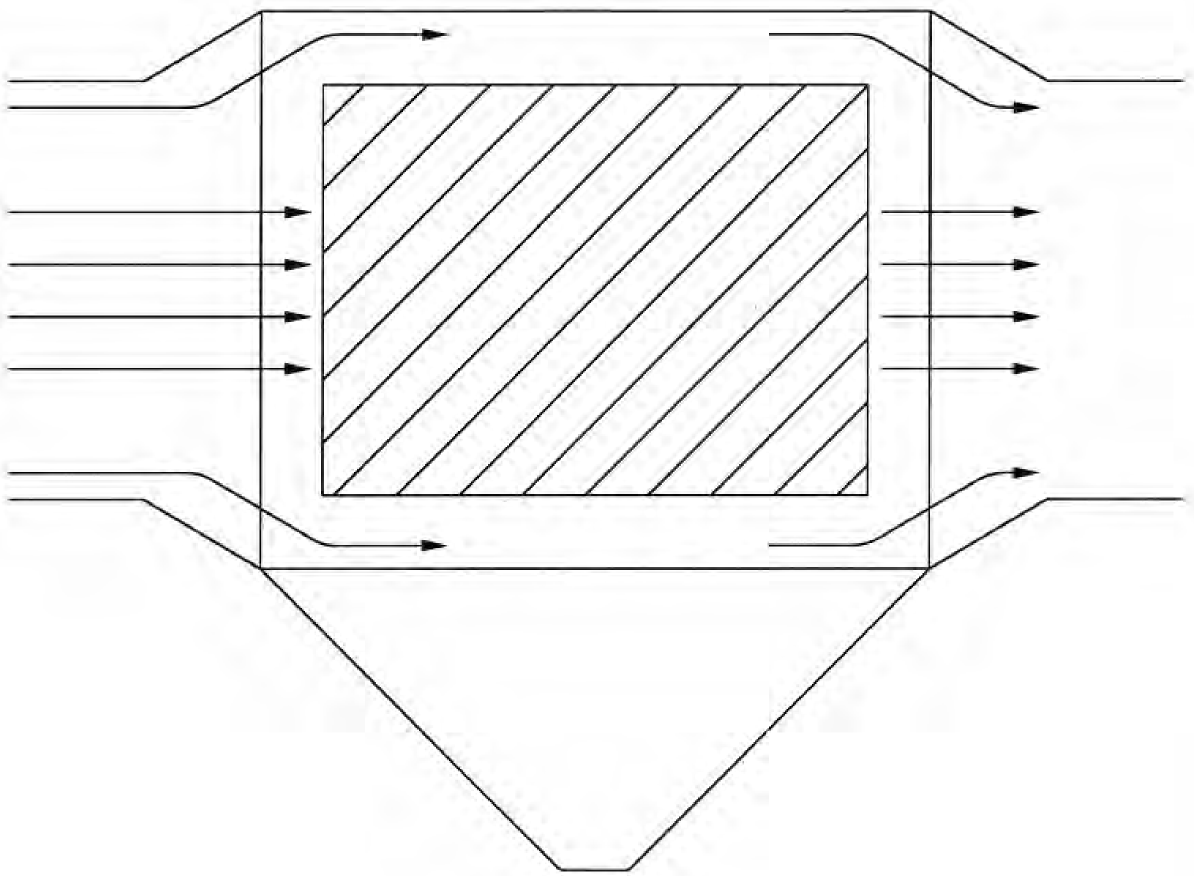


Gas Flow Sneakage

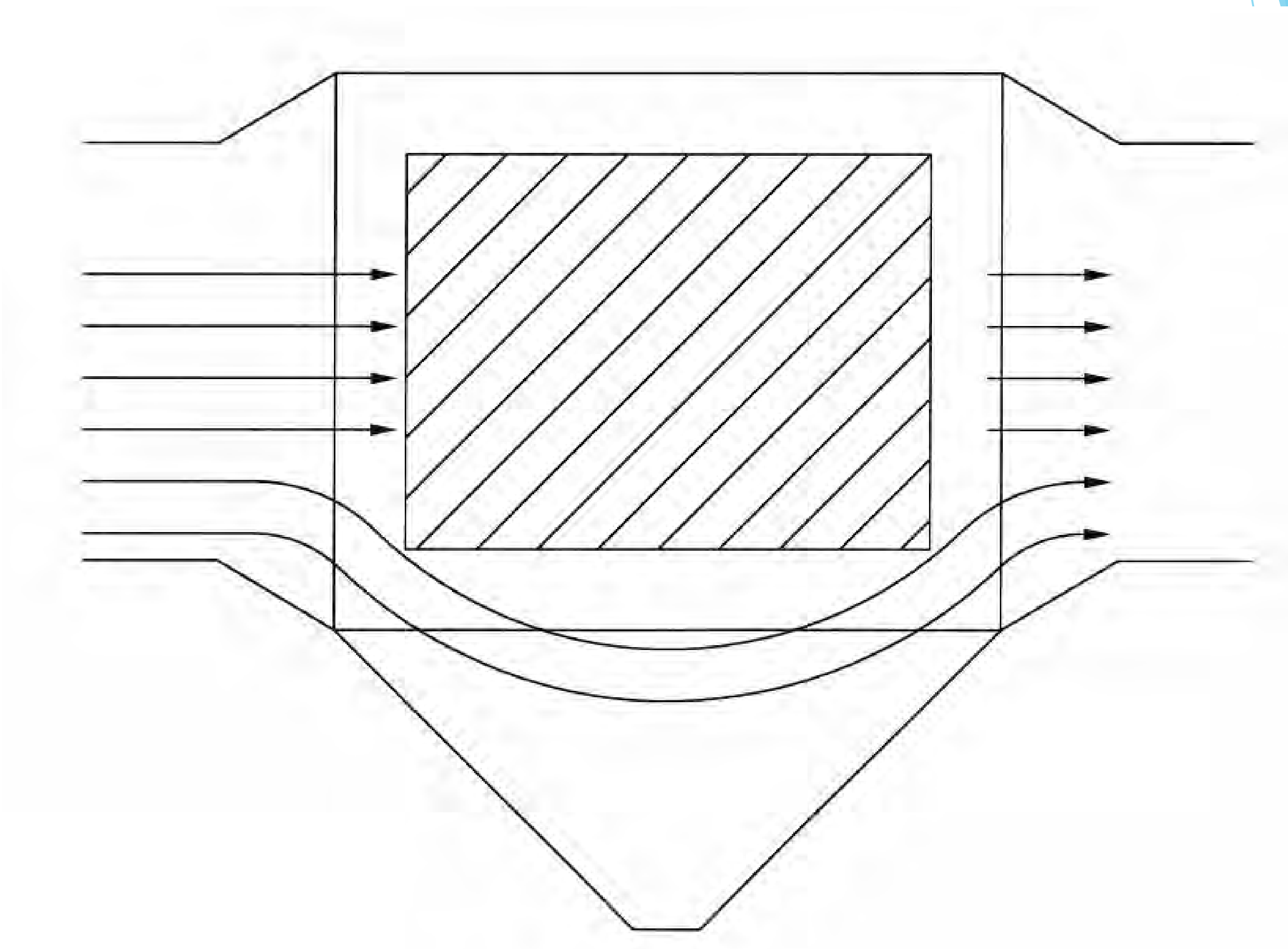
Gas Flow Sneakage

- Gas Flow Outside the Treatment Zone Reduces Precipitator Efficiency
- Types of Sneakage
  - Over the top
  - Under the bottom
  - Around the sides
  - Up the sides
  - Through the hoppers

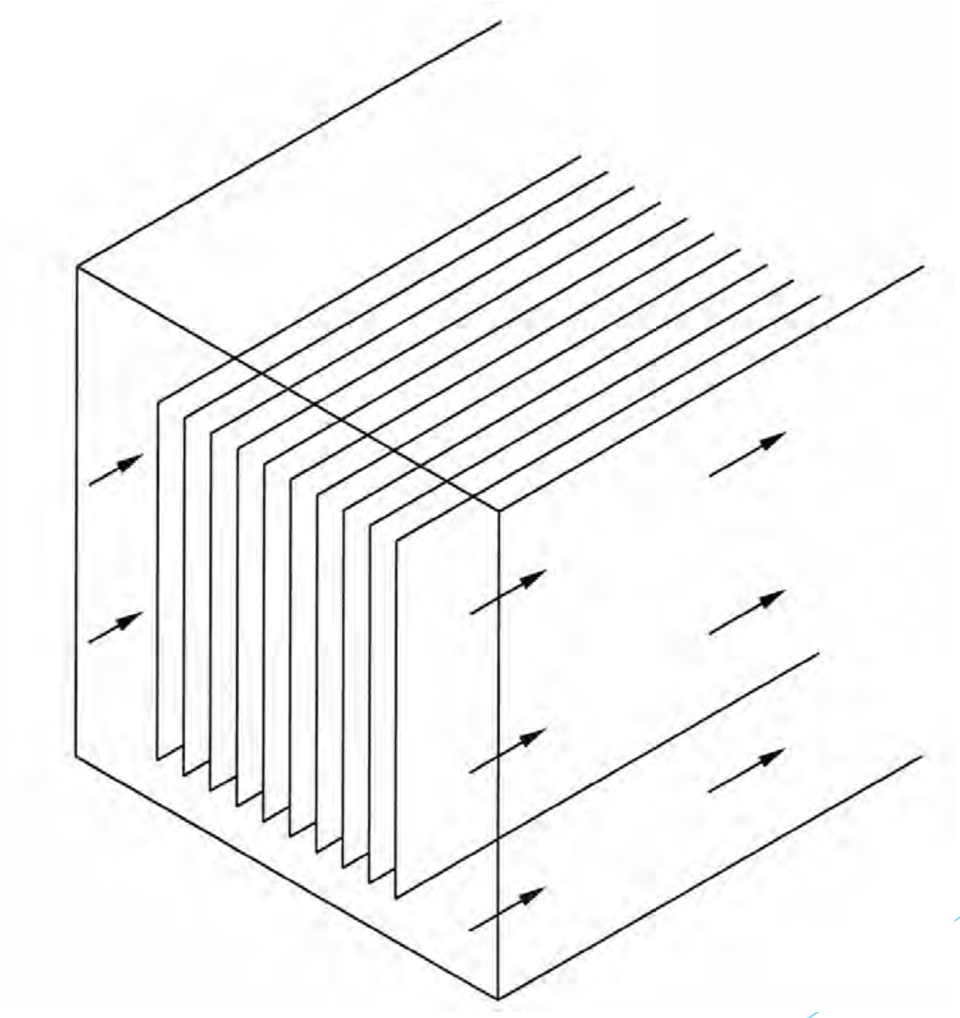
Over and Under Sneakage



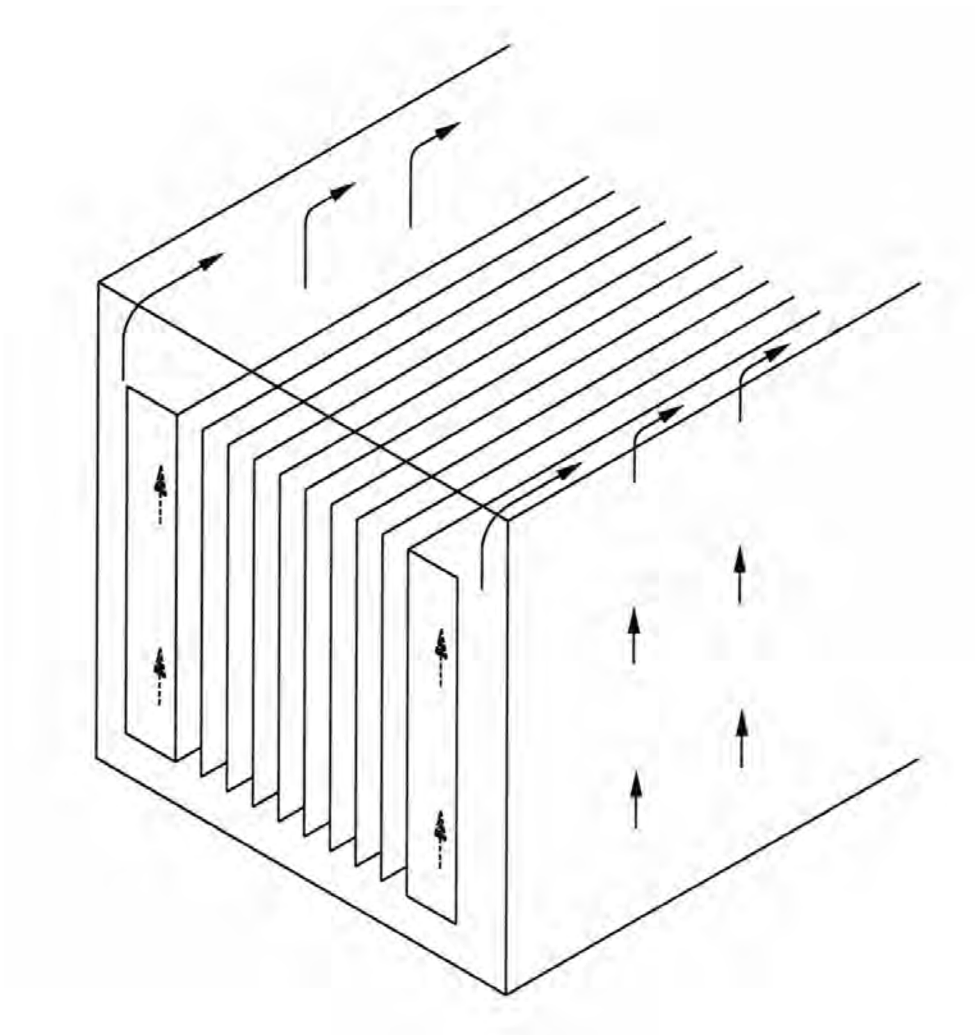
Severe Under Sneakage



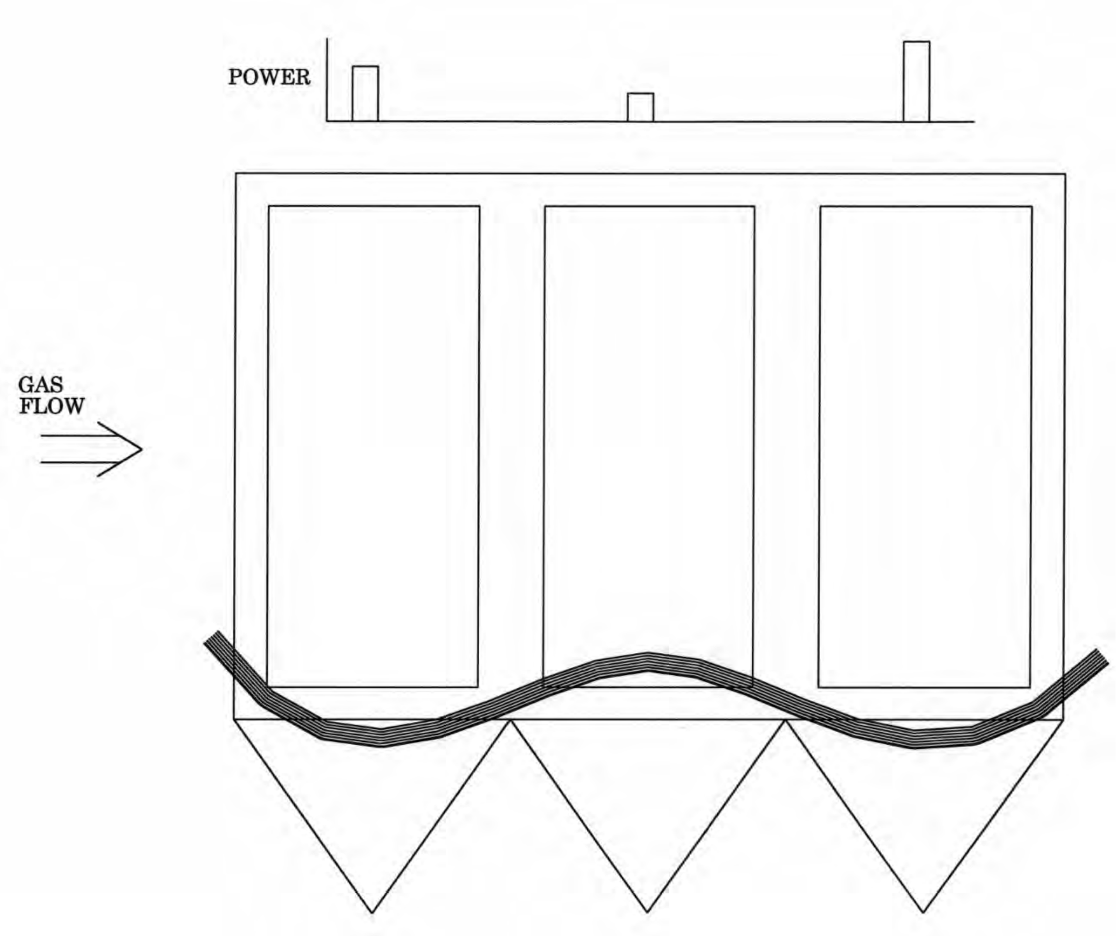
Side Sneakage



Vertical Sneakage



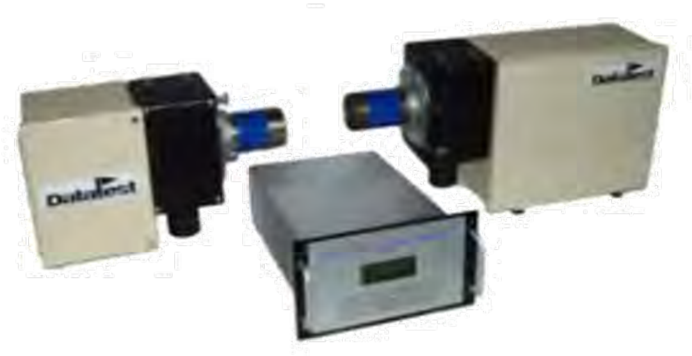
Snaking Hopper Flow



Particulate Distribution Uniformity

Particulate Distribution Uniformity

- Particulate Distribution Does Not Necessarily Follow Gas Distribution
- Heavier Particles Tend not to Follow Turns in the Gas Stream
- Small Particles are Carried by the Gas Stream

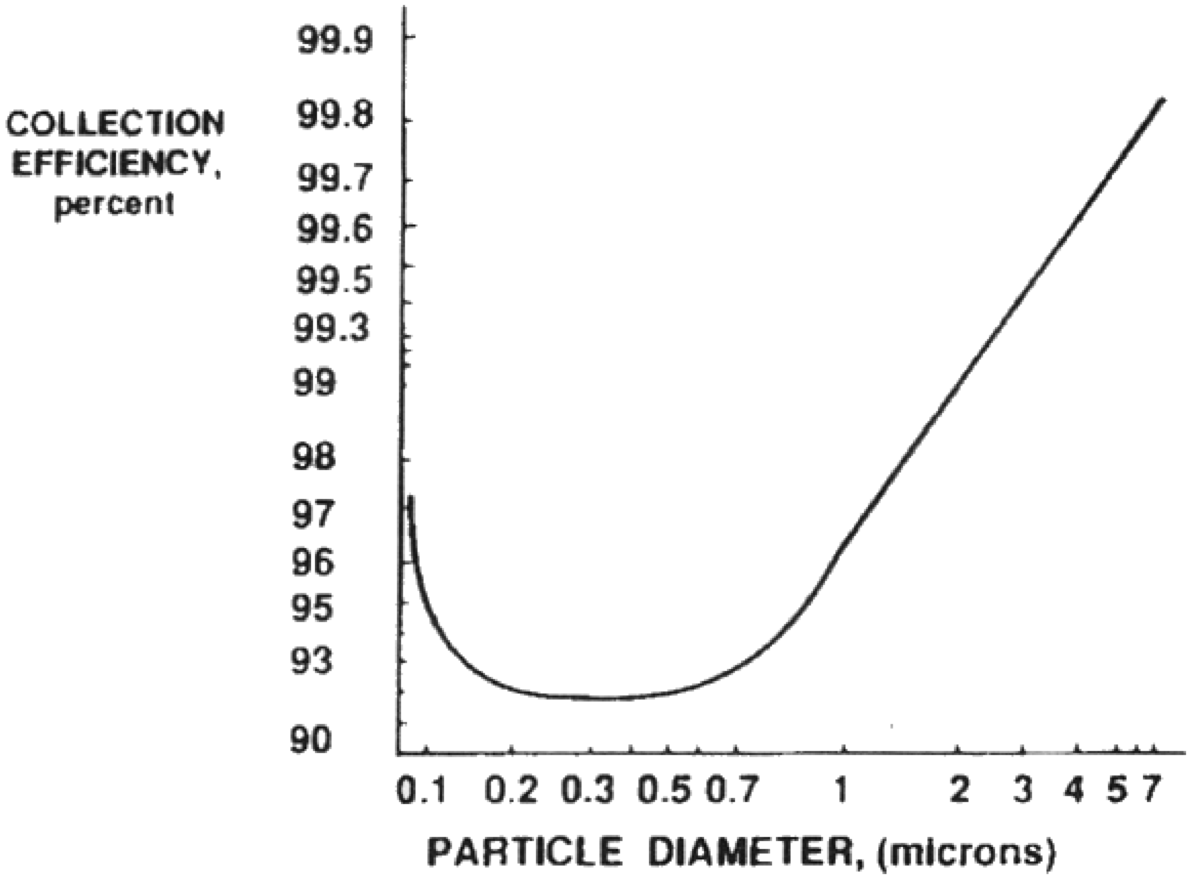


Particle Size Effect on Opacity

Particle Size Effect on Opacity

- For the Same Emissions by Weight
  - large size particles will show a lower opacity because they attenuate less light.
  - small size particles will show a higher because they attenuate more light.
- What Changes Particle Size?
  - Coal characteristic
  - Grinding of the coal
  - Firing of the coal

Particle Size Effect on Collection



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Correction Methods

- **Field Test**
- **Computer Model Study**
- **Physical Model study**

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Electrical Sectionalization

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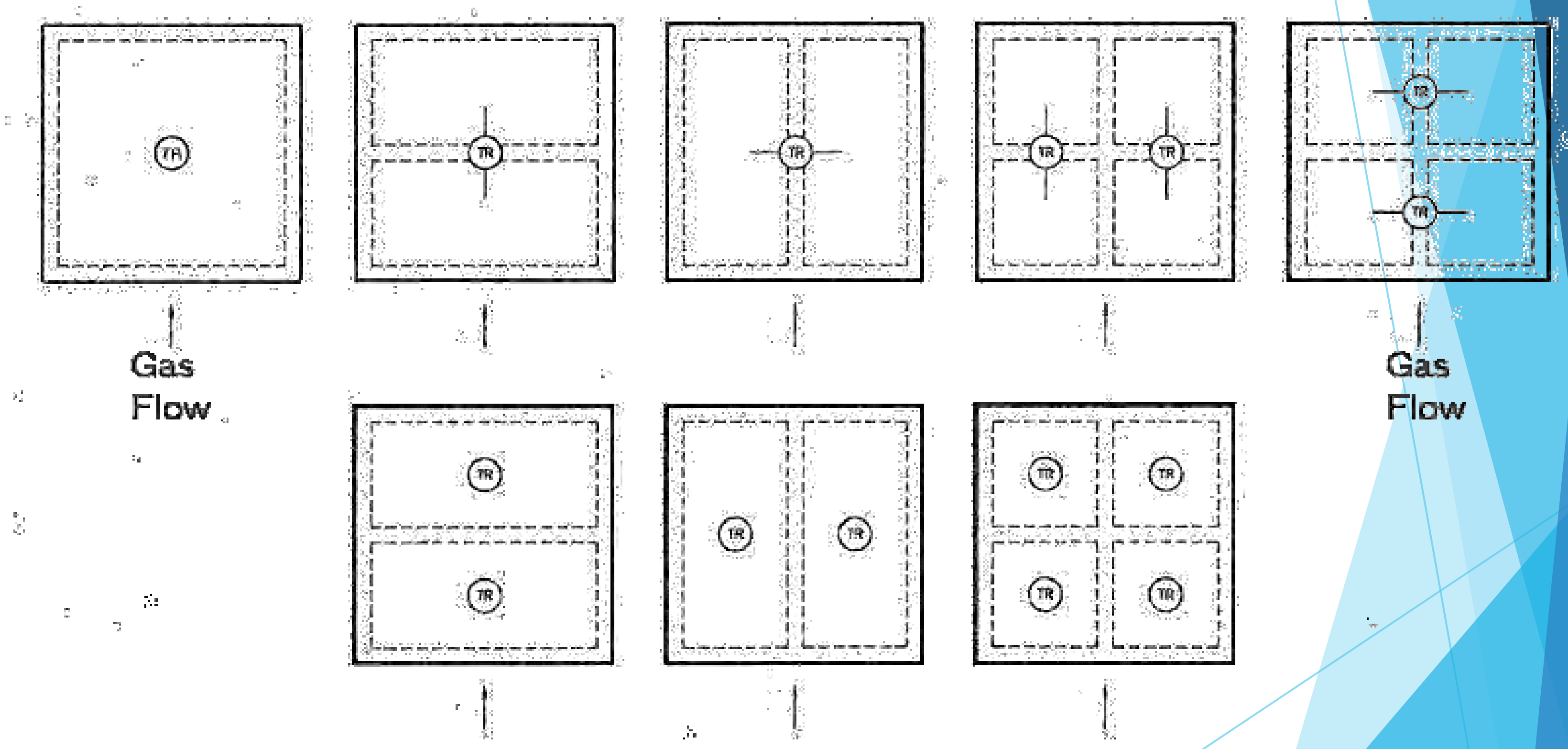
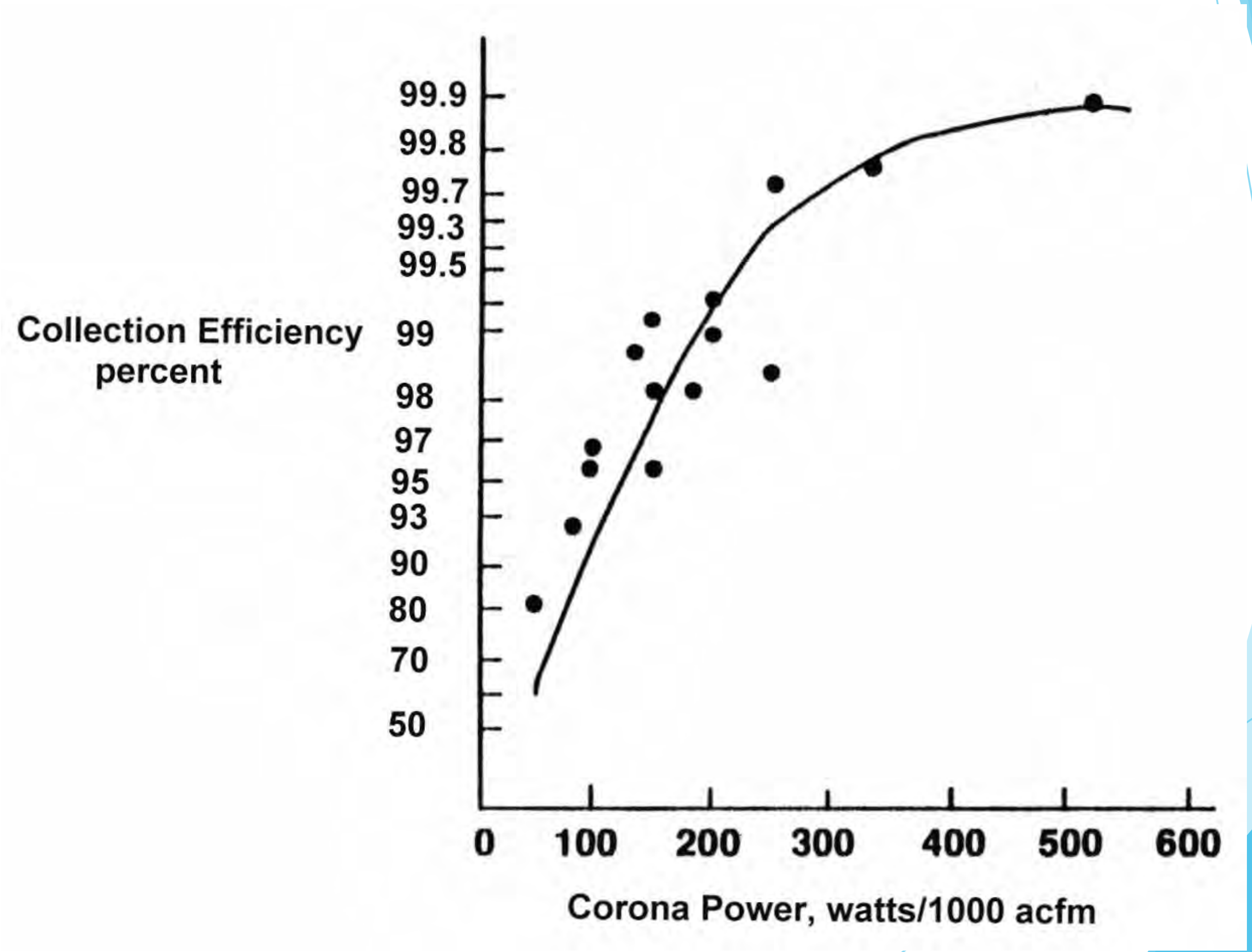
Electrical Sectionalization

- A High degree of Electrical Sectionalization Reduces the Effect of:
  - Broken Electrodes
  - Close Clearances
  - Full Hoppers
  - Tracked Insulators
  - Poor Particulate Distribution

Electrical Sectionalization



Electrical Sectionalization



Rapping Density

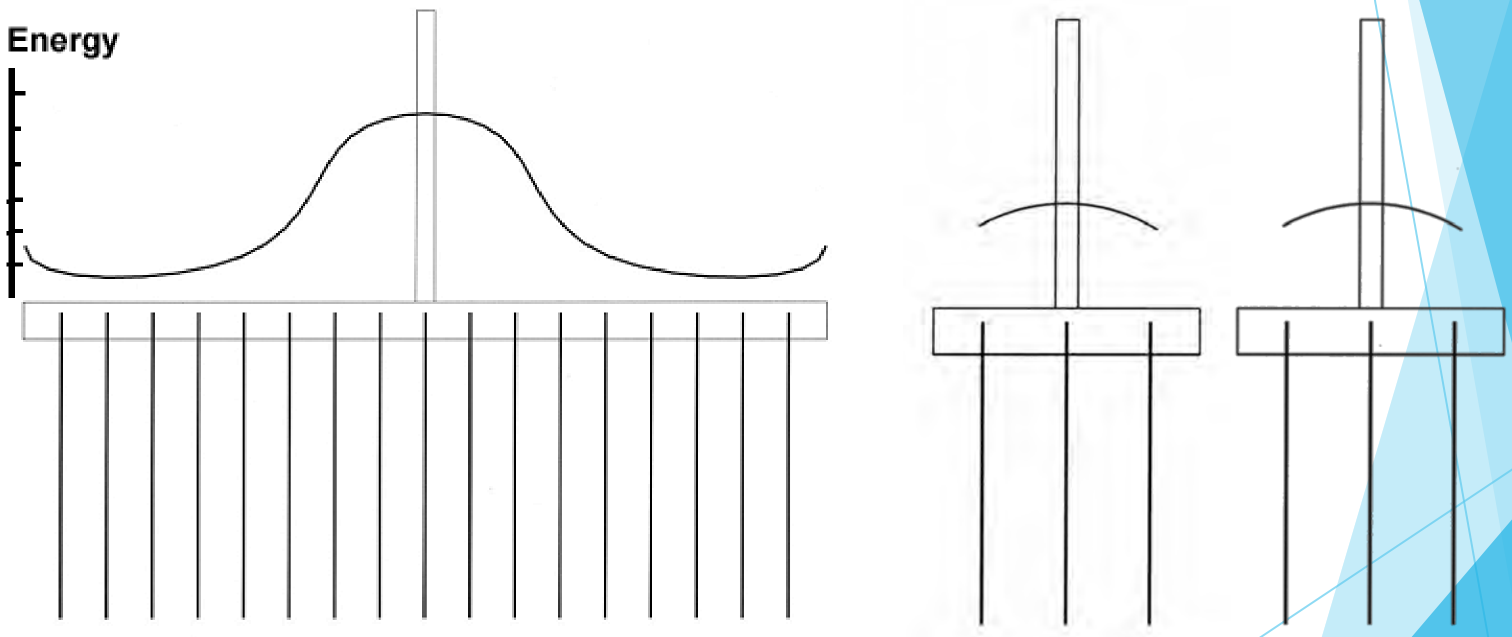
Rapping Density

- Rapping density is the square feet of collecting electrode or linear feet of discharge electrode cleaned by one “rapper”.

- Too High a CE Rapping Density Results in:
  - Clean plates below the point of impact
  - Dirtier plates at the outboard areas
  - Re-entrainment of particulate when rapping energy is increased to keep outboard plates clean

- Too High a DE Rapping Density Results in:
  - Corona suppression

Rapping Density



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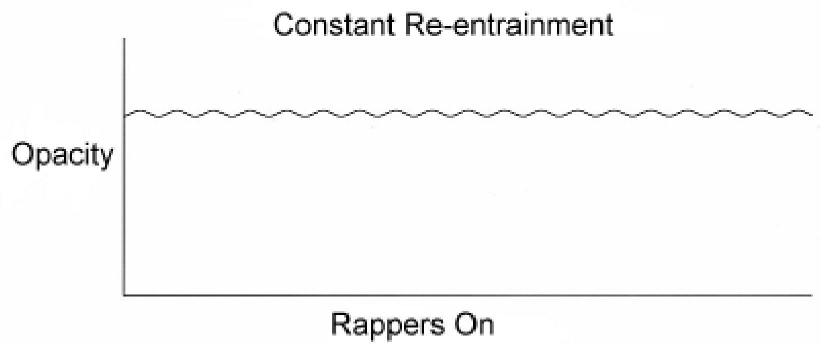
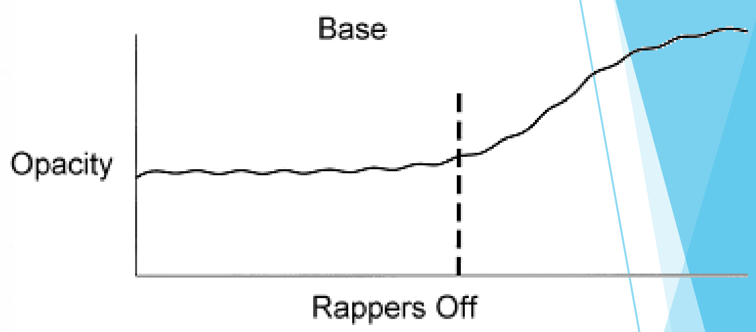
Rapping Re-entrainment

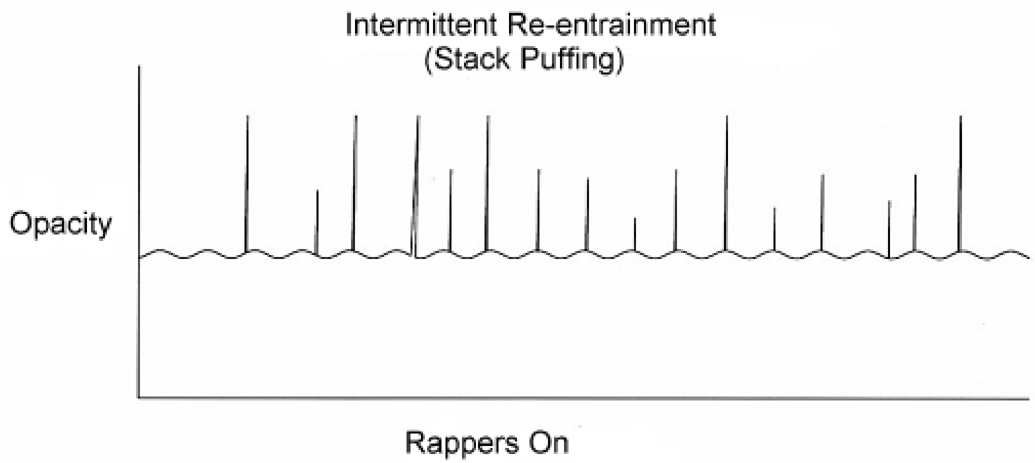
Rapping Re-entrainment

- Rapping Too Often Prevents Agglomeration
  - Results in continuous re-entrainment and elevated opacity/emissions
- Rapping Too Hard Causes Lateral Release
  - Results in spiking/puffing, especially towards the outlet where there is no backup field
- Optimization - Trial and Error - Experience

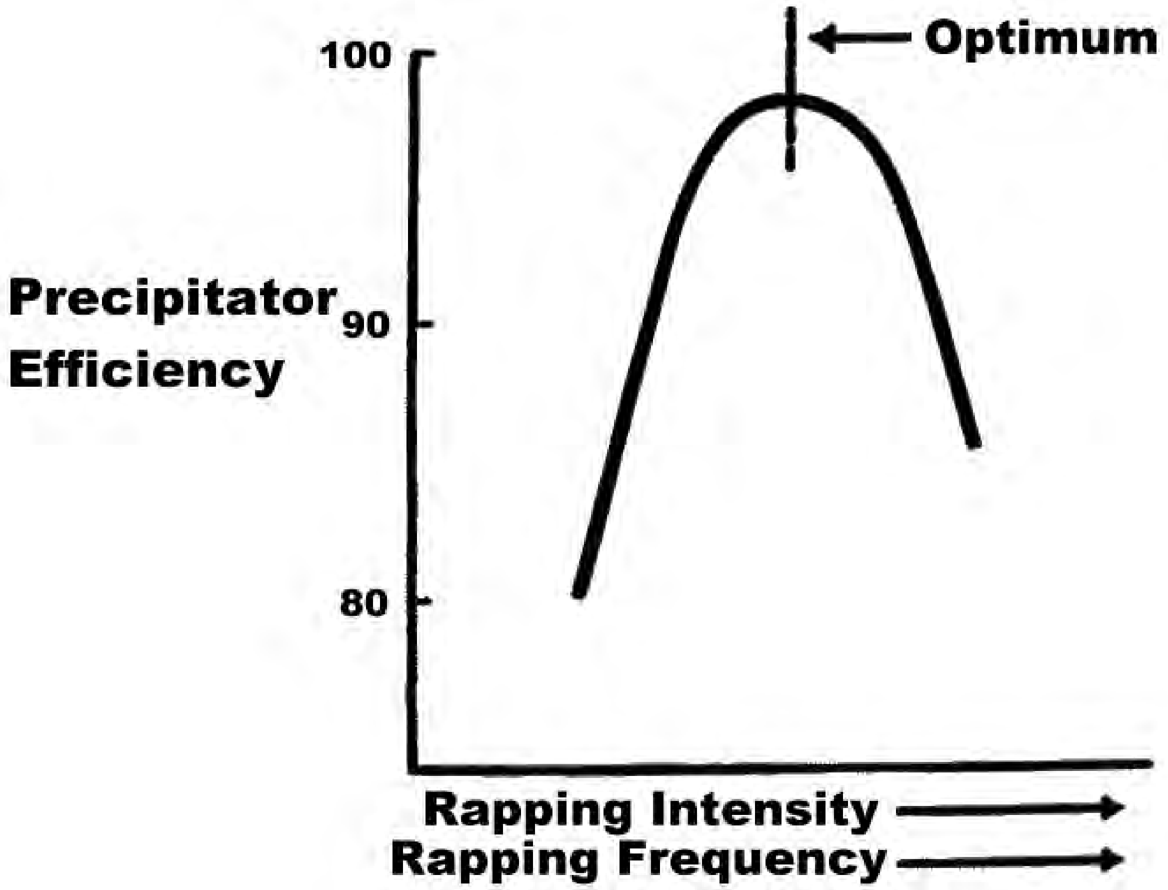
Rapping Re-entrainment







Rapping Re-entrainment



Particulate Resistivity

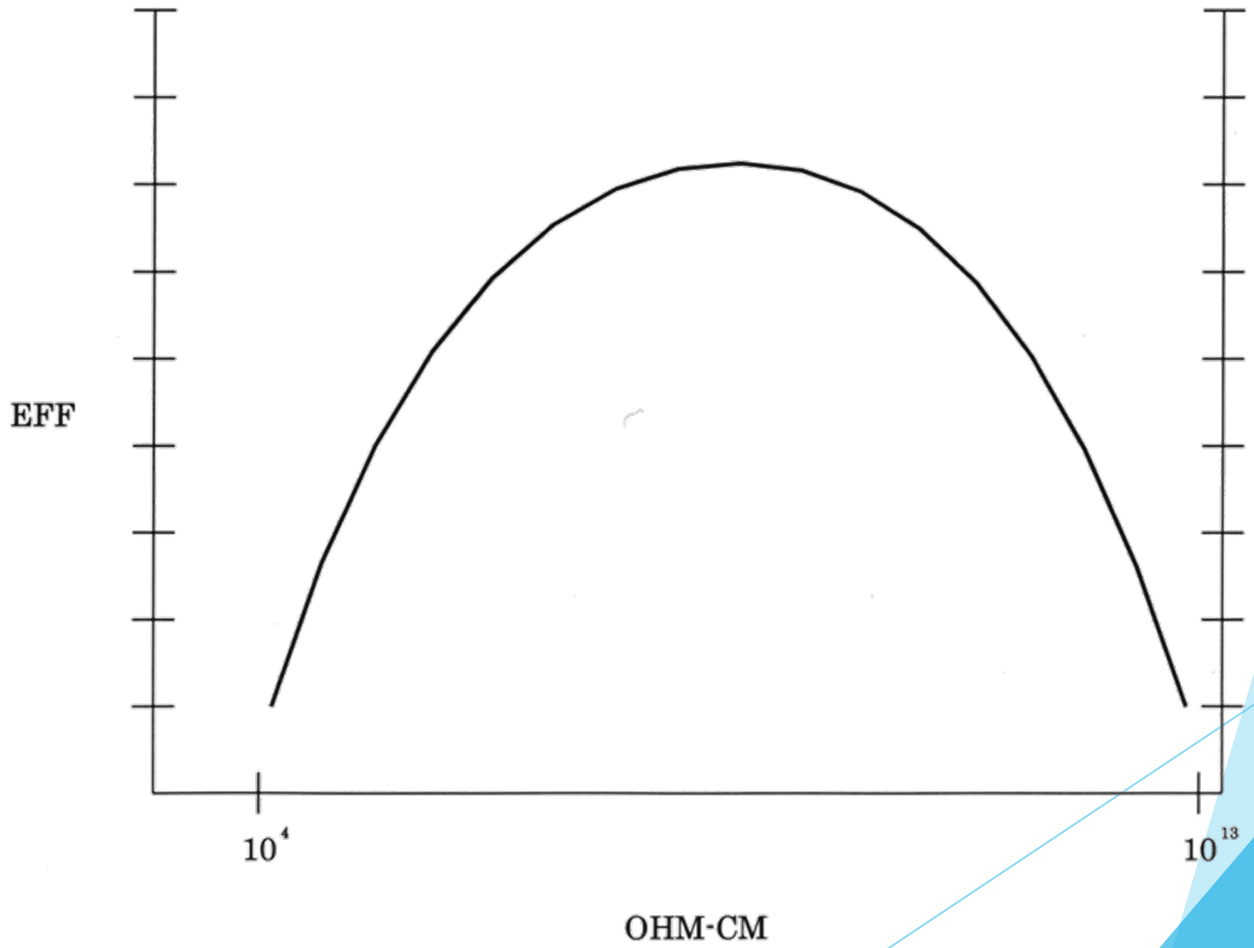
Particulate Resistivity (High)

- For a Given Precipitator Size (SCA)
  - The higher the particulate resistivity the harder it is to charge an ash particle
  - The higher the particle resistivity the more energy required to clean the collecting plates and the more frequent the cleaning is required
  - The higher the particle resistivity the lower the precipitator efficiency (and the higher the outlet emissions)

Particulate Resistivity (Low)

- For a Given Precipitator Size (SCA)
  - The lower the particulate resistivity the higher the the spark over voltage
  - The lower the particle resistivity the less energy required to clean the collecting plates and the less frequent the cleaning is required
  - For very low particle resistivity the lower the efficiency (and the lower the outlet emissions)

Particulate Resistivity

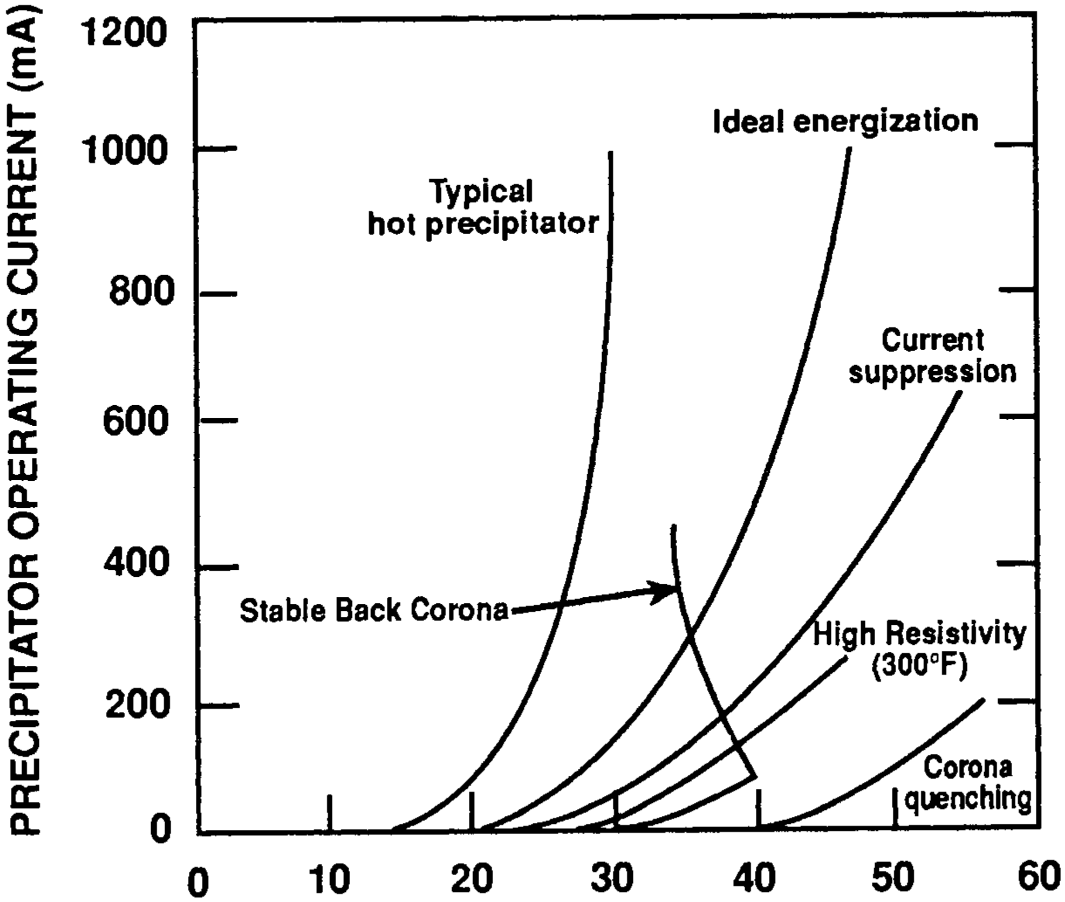


Voltage vs. Current (VI) Curves

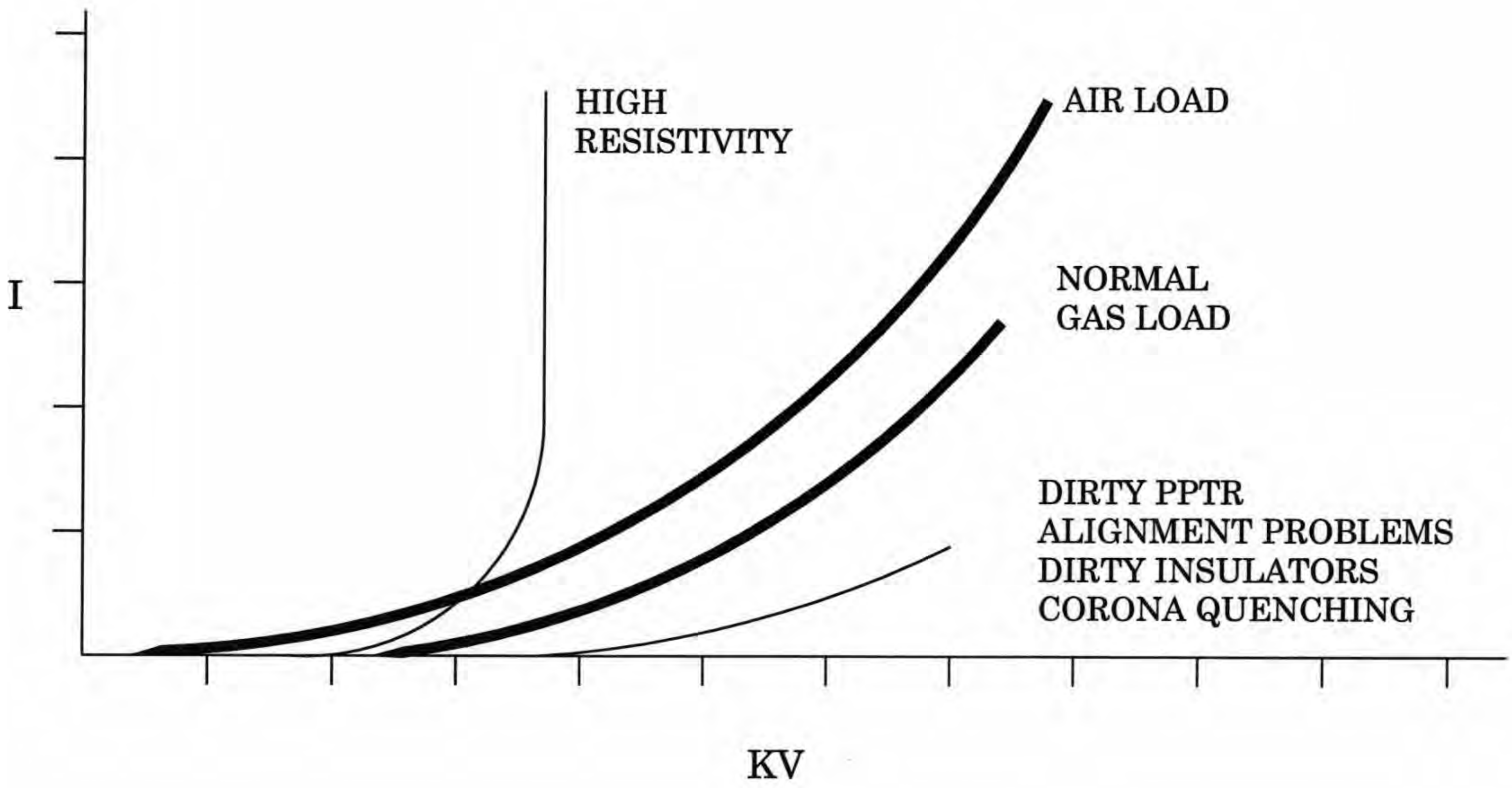
Voltage vs. Current (VI) Curves

- Show relationship between the secondary voltage and the secondary current for an electrical section
- Should be taken when a precipitator is new and clean
- Should be taken during normal gas load operation
- Should be compared before and after outages to determine if shifts have occurred
- Verifies the presence of back corona

Voltage vs. Current (VI) Curves



Voltage vs. Current (VI) Curves

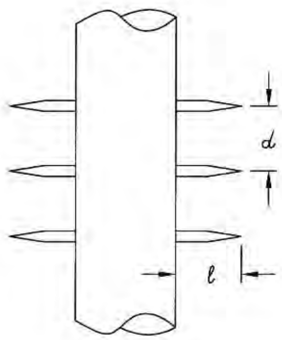


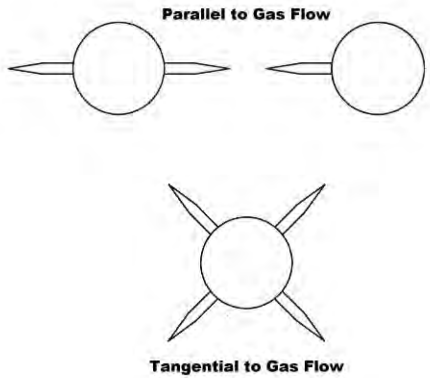
Electrode Management

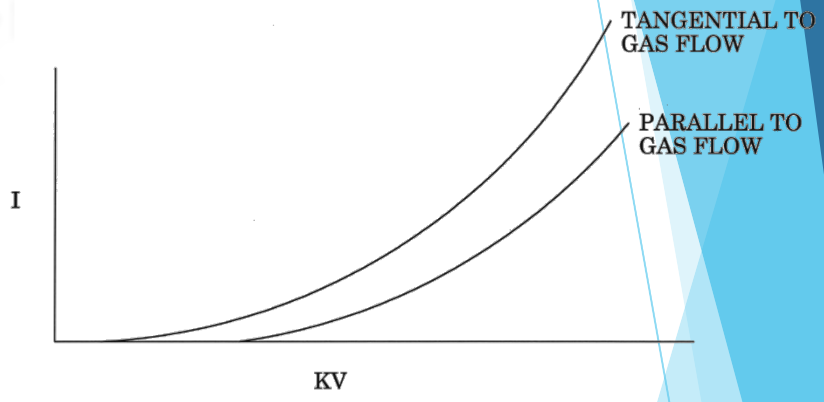
Electrode Management

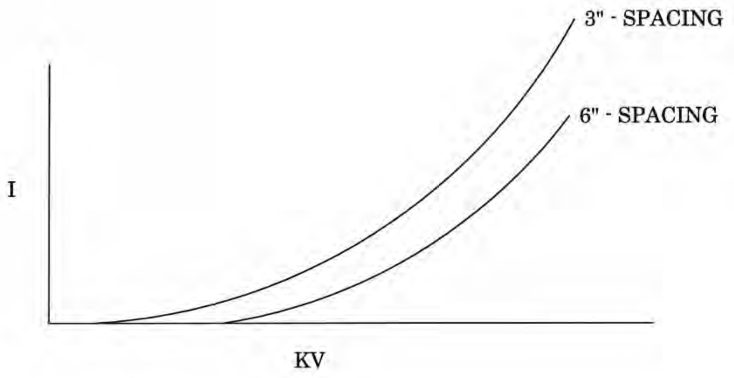
- The Voltage vs. Current (VI) Relationship Can be Adjusted by Changing:
  - DE Corona Generator Spacing
  - Length of DE Corona Generators
  - Corona Generator Alignment
  - Number of Discharge Electrodes

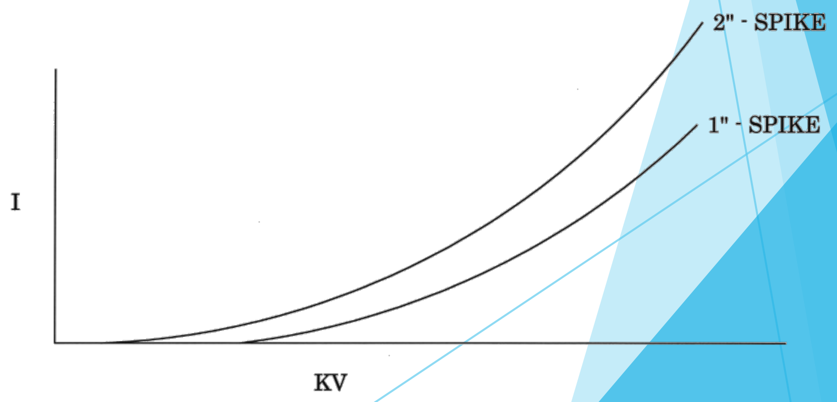
Electrode Management











Electrode Management

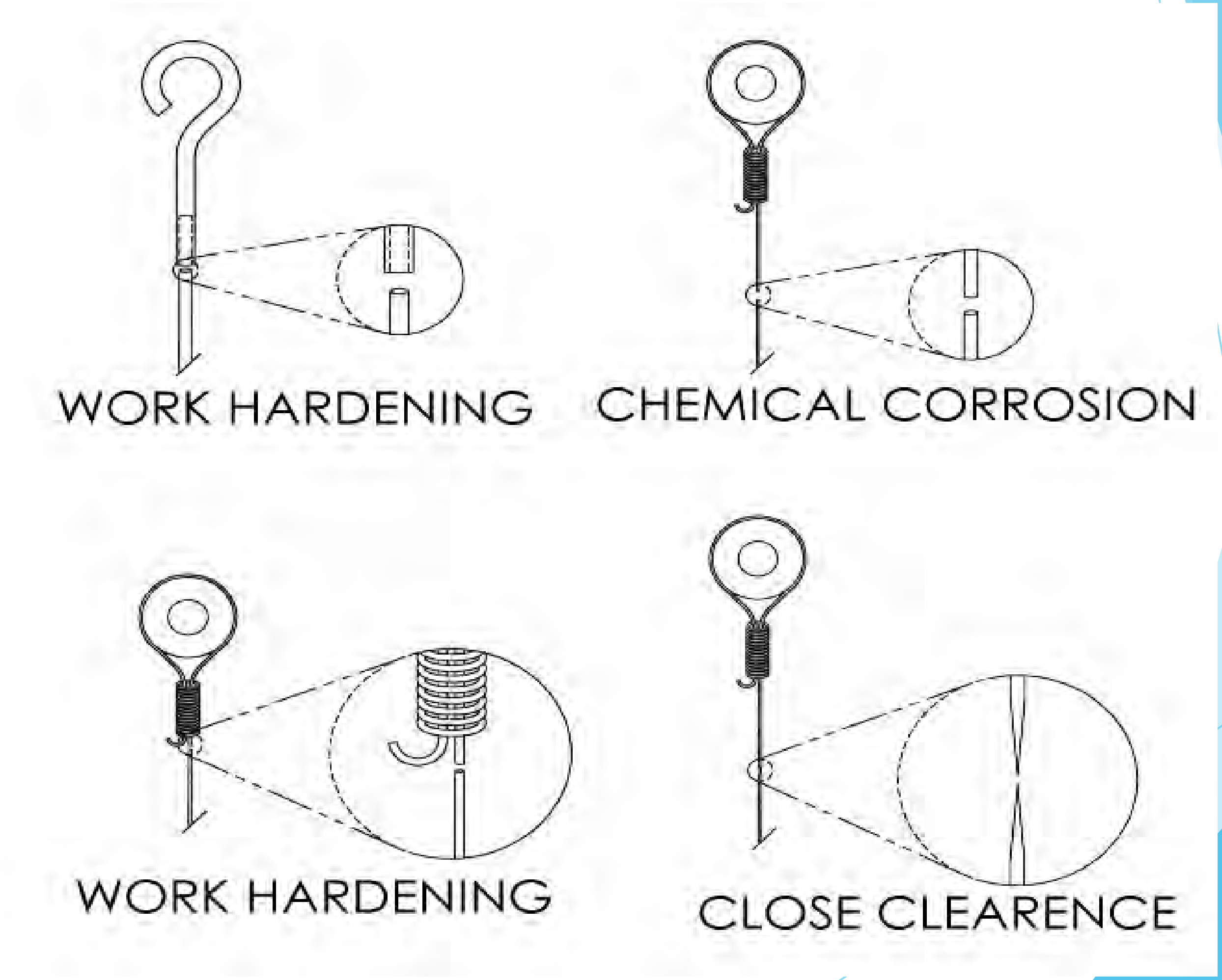
- Why Change the VI Relationship
  - High inlet particulate loading
    - Overcome corona suppression
    - Reduce low level sparking
  - High Resistivity
    - Overcome the resistance to accept charge
    - Manage back corona (back ionization)
  - Low Resistivity
    - Minimize power requirements

Wire Breakage

Wire Breakage

- Sharp needle point types of wire breakage are indicative of close clearance or buildup
- Blunt breaks at other than the ends of the wires indicate chemical corrosion or a brittleness in the wire
- Blunt breaks at the ends of the wires indicate work hardening of the wire

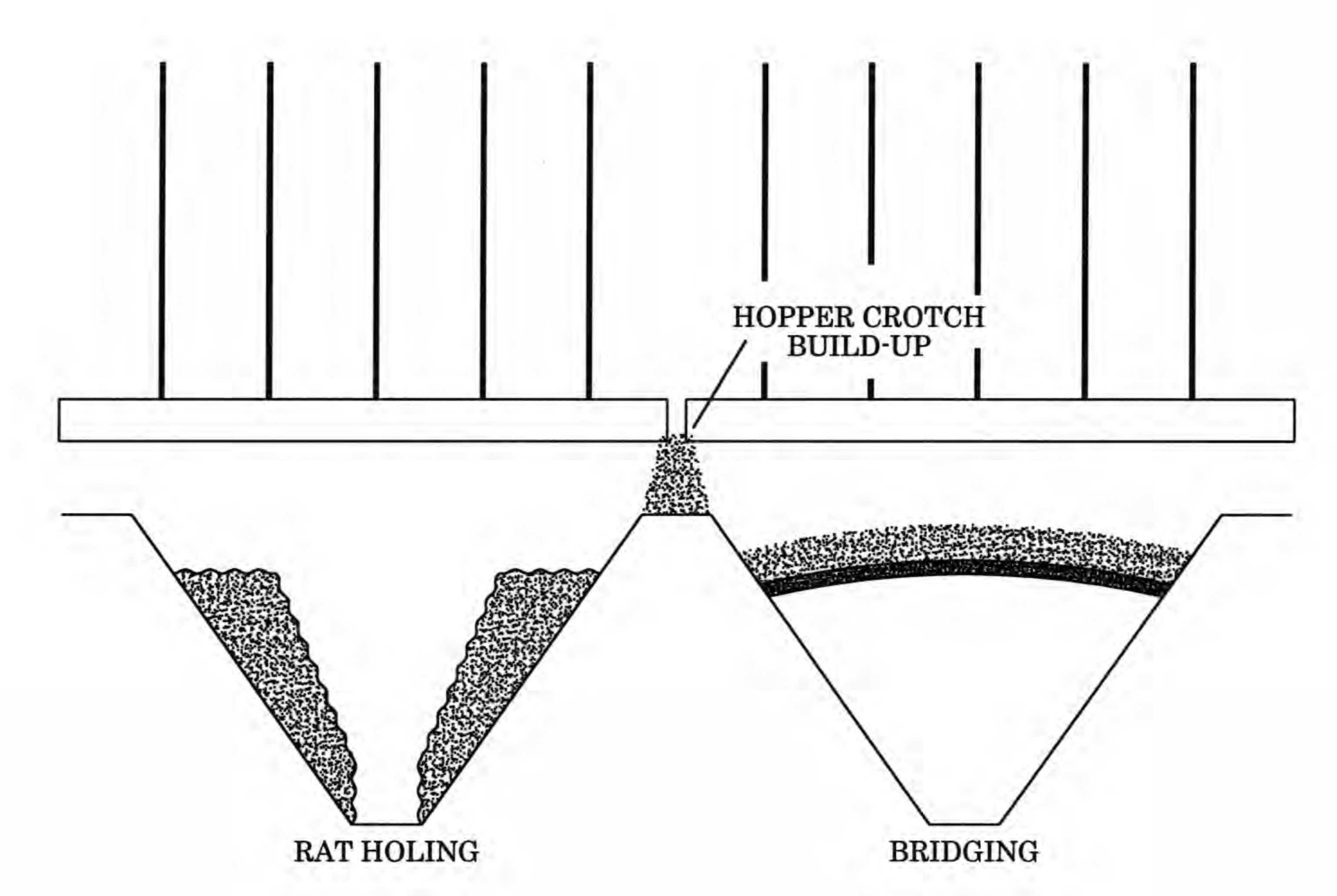
Wire Breakage



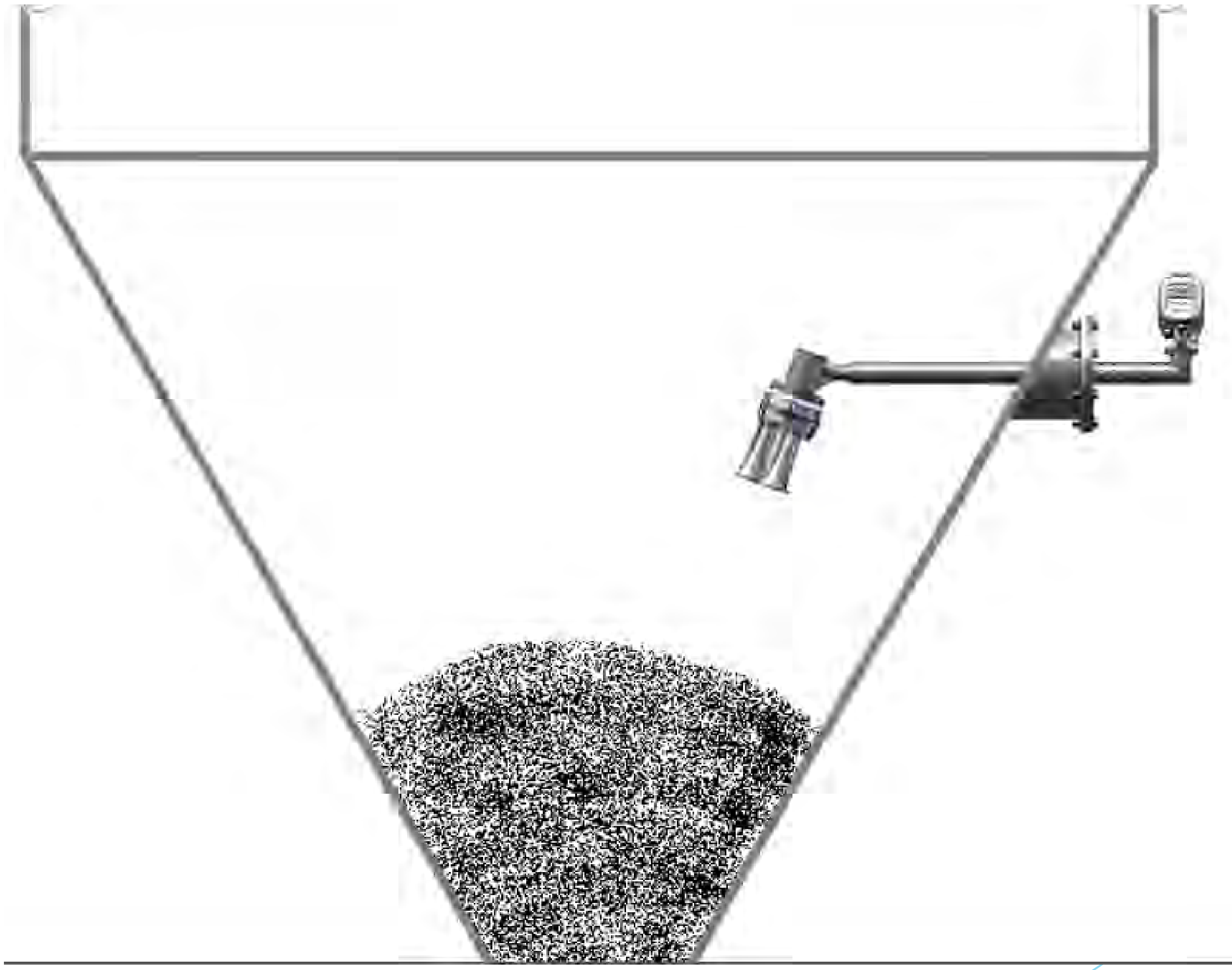
Hopper Problems

- Rat Holing
  - Particulate sticks to hopper skin usually due to cold temperature or ambient in-leakage – empties center only
- Bridging
  - Particulate collects moisture as it cools and tends to become cemented together – empties only below bridge
- Clinker Clog
  - Arcing/sparking through the particulate to ground and fusing the ash into large solid shapes that get stuck in the hopper outlet
- Plugged
  - Particulate has cooled, picked up moisture, and become sticky and refuses to flow

Hopper Problems



Decent Level Measurement

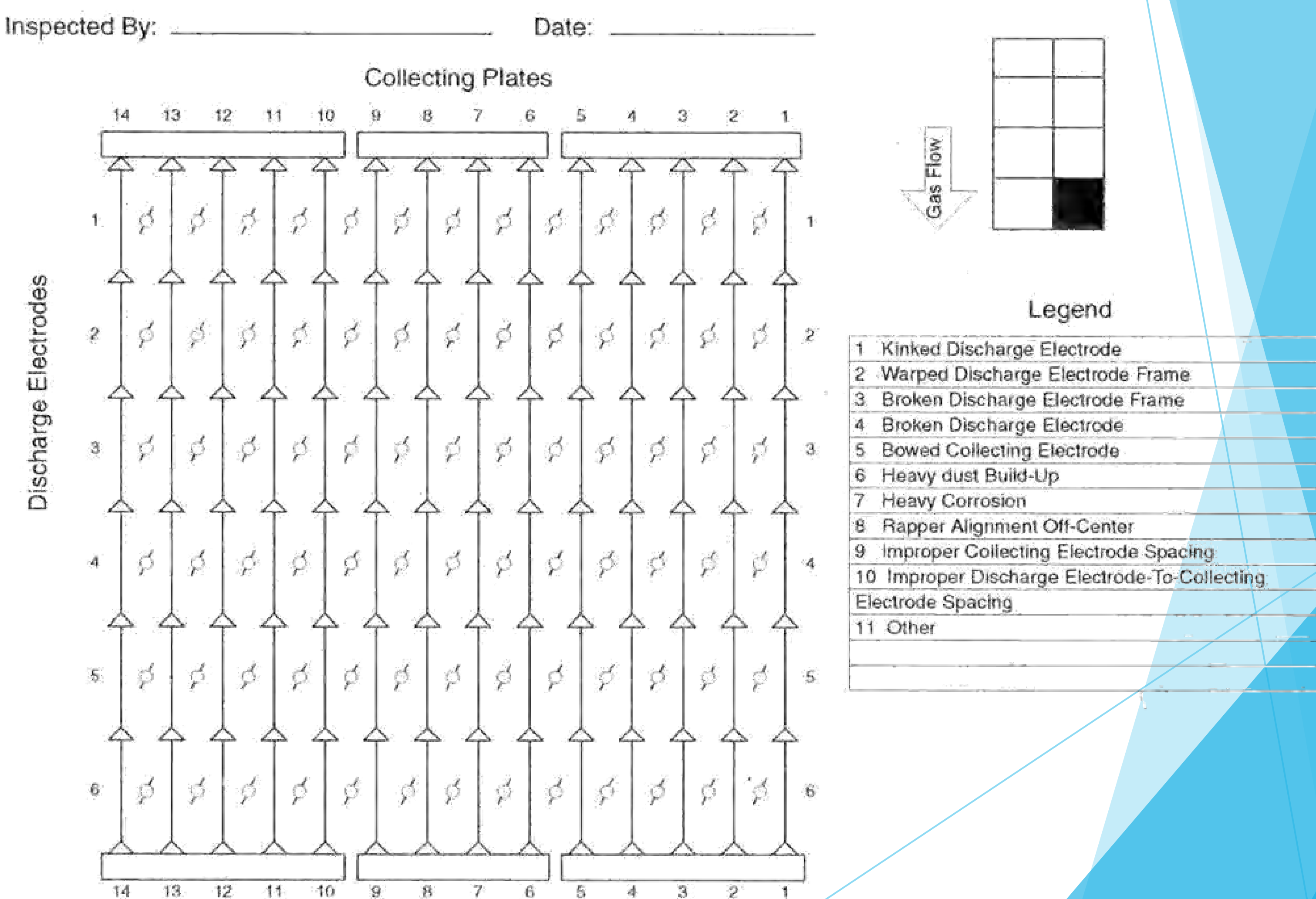


Record Keeping

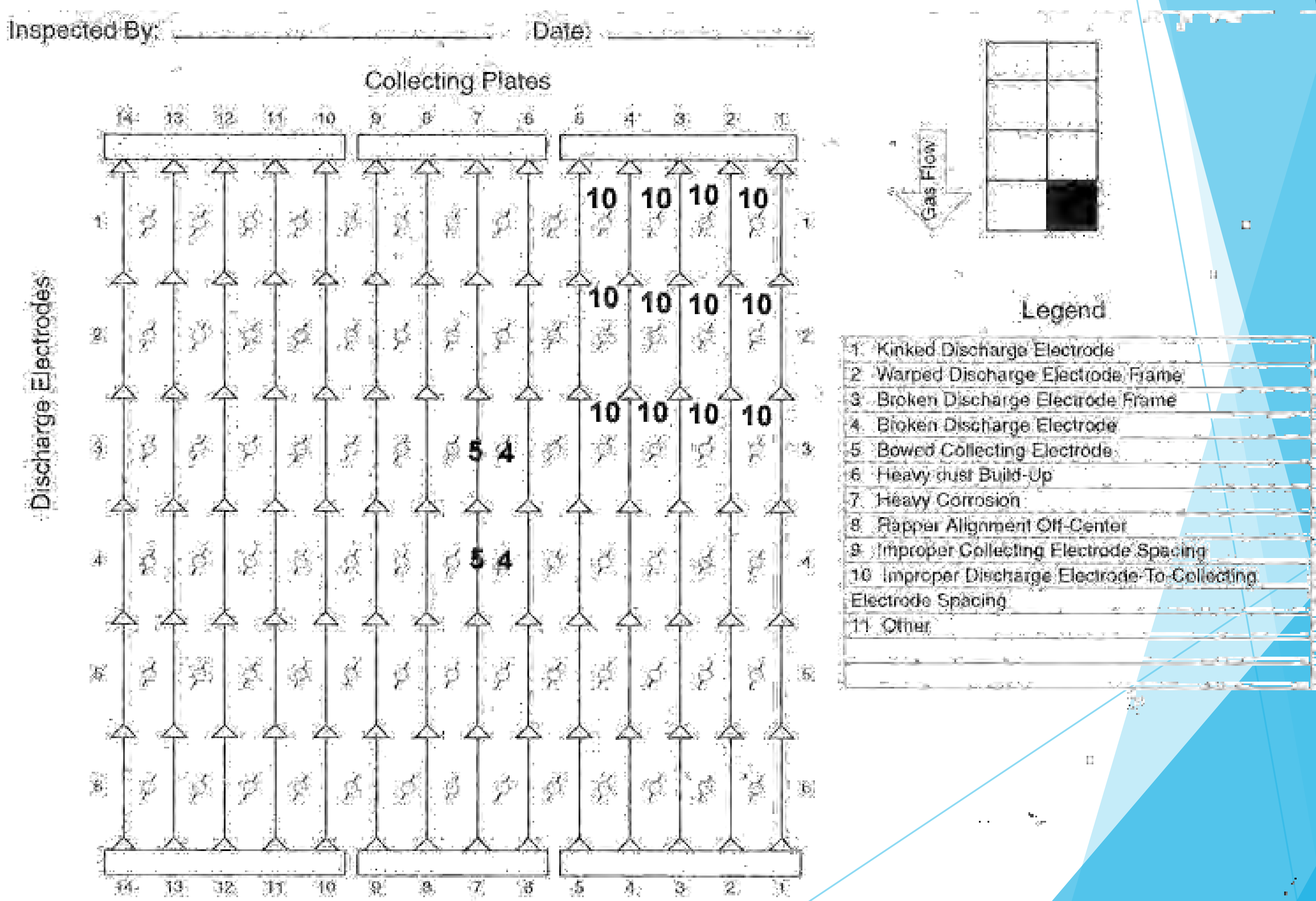
Record Keeping

- For Internal Inspections Draw a Road Map
  - Show and number ducts
  - Show and number collecting plates
  - Show and number discharge electrodes
  - Show legend of problems and section location

Record Keeping



Record Keeping



Let’s Sum it Up

- Although the precipitator is a rather simple device in terms of the basis of operation, there are numerous factors that can both positively and negatively effect the day to day efficiency.
- Stay aware of what these factors are, understand their effect, and optimize them for best performance.
- There are consultants who have spent their lifetime solving precipitator problems on a daily basis. Don't be shy about asking for help. In the long run it will save you time and money.