REINHOLD ENVIRONMENTAL Ltd.

2011 APC Round Table
& Expo Presentation

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Electrostatic Precipitator Operations I
July 11, 2011

John A. Knapik

4 Ways to Remove Particulate

1. **Electrostatic Precipitation**
2. **Inertial Separation (Multiclone)**
3. **Filtration (Baghouse)**
4. **Scrubbing**

History of Precipitators in USA

- ESP may be wet or dry, collecting fumes or dust
- First wet ESP was installed in 1907 to collect sulfuric acid mist (California)
- First dry ESP was installed in 1912 to collect cement kiln dust (California)
- First dry ESP to collect ash from a pulverized coal fired boiler was installed in 1923 (Detroit, Michigan)

Advantage of Precipitators

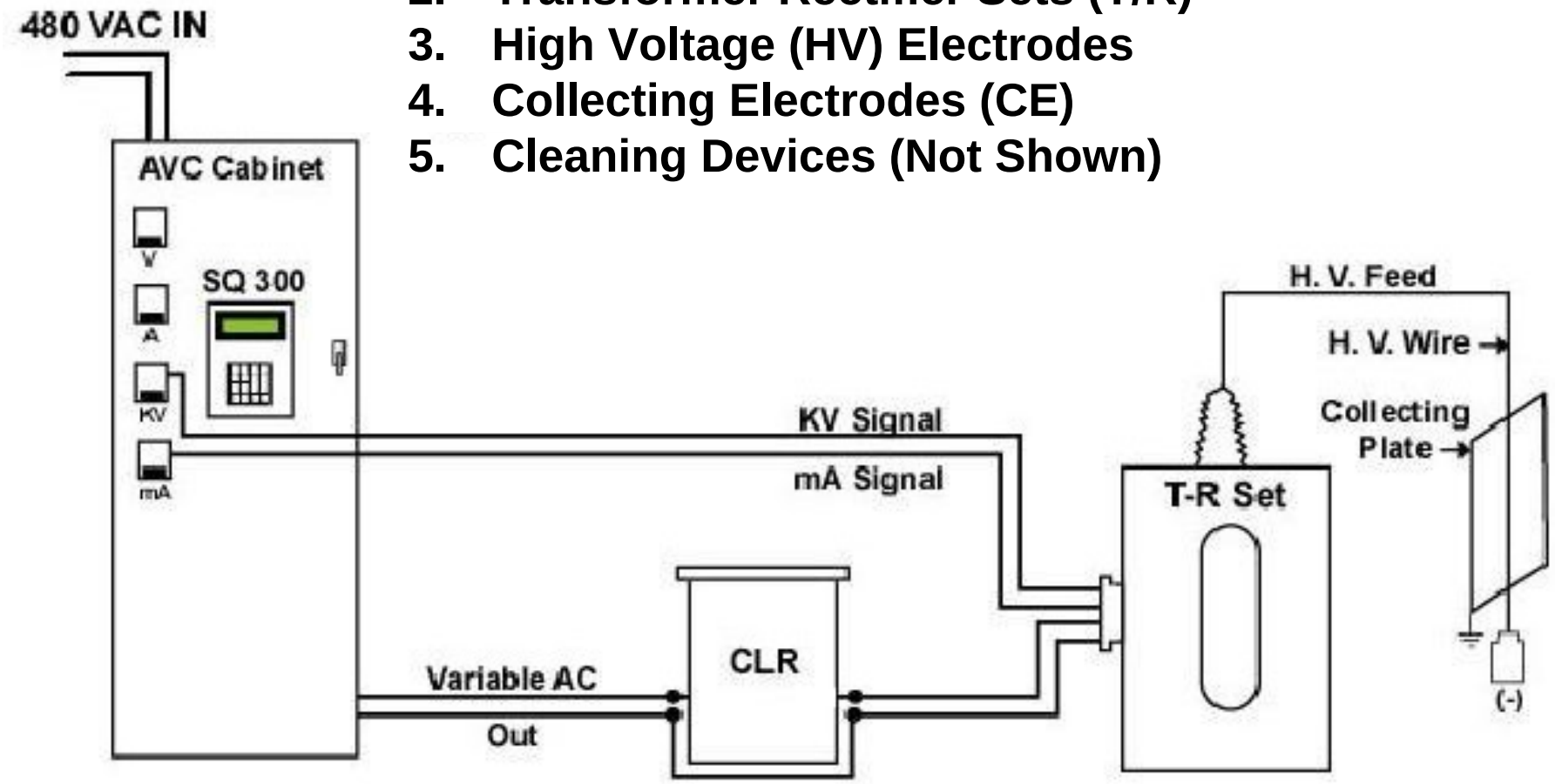
- Internals parts can sometimes last up to 50 years
- Can handle the greatest range of gas temperatures from 70 to 900^{0}F
- Can collect submicron particulate
- Operates at very low pressure drops

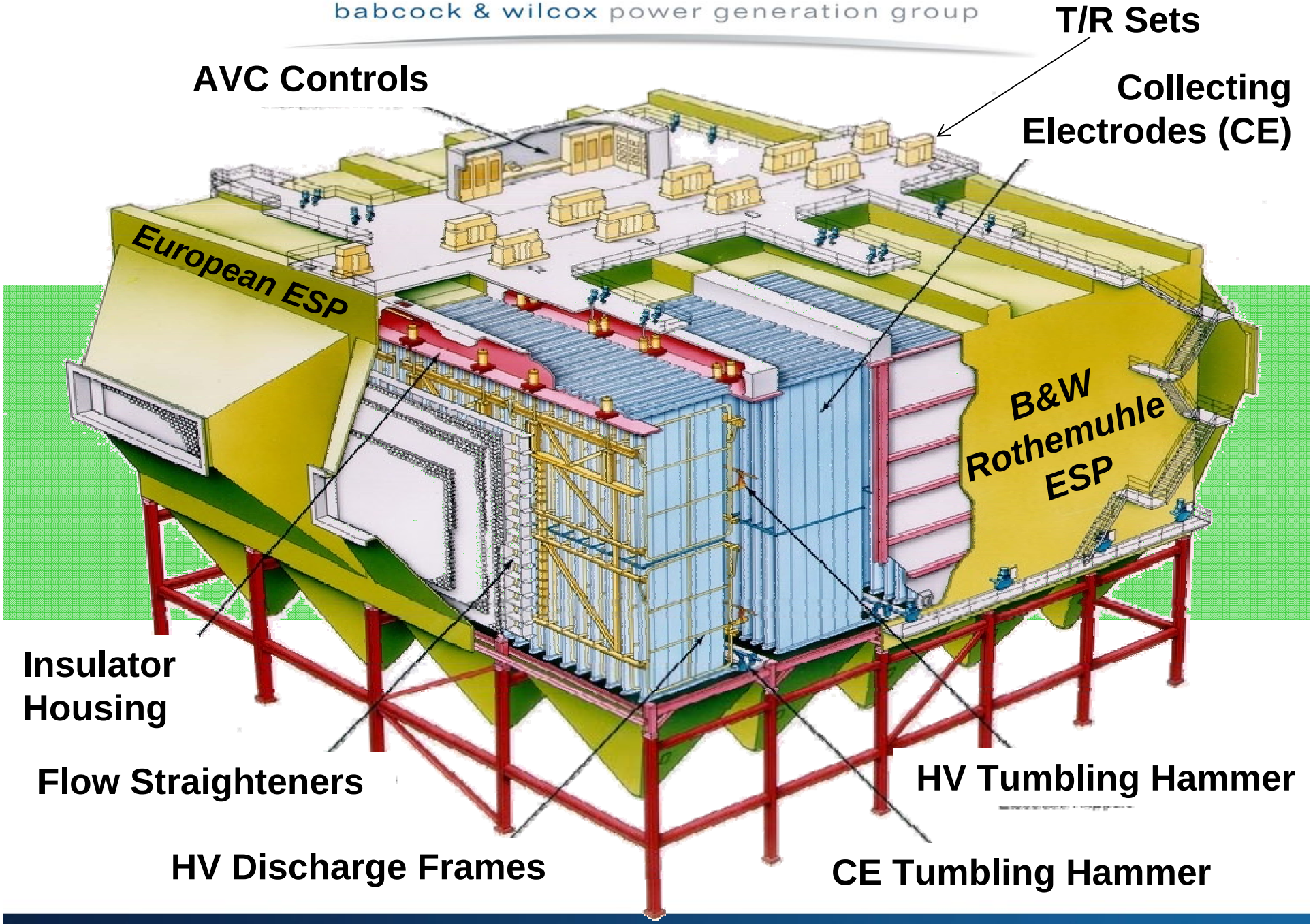
ESP Applications

APPLICATION	PARTICULATE COLLECTED
ELECTRIC POWER IND.	FLYASH OR OIL ASH
ROCK PRODUCTS	
1. CEMENT	CEMENT DUST & ALKALIES
2. LIME	LIME
3. GYPSUM	GYPSUM
PAPER MILLS	SALT CAKE; WOOD ASH; LIME DUST
STEEL	
1. BASIC OXYGEN FURNACE	FINE FUMES & DUST
2. SCARFING MACHINES	FINE FUMES & DUST
3. COKE OVEN GAS	TAR
4. SINTERING STRAND	IRON OXIDE & FLUXING MATERIALS
5. IRON ORE PELLETIZING	FINE FUMES & DUST
METALS: COPPER,LEAD, & ZINC	OXIDE FUMES,DUSTS, & SULFURIC ACID
ALUMINUM	POT LINE FUMES OR ALUMINA DUST
PETROLEUM - CAT CRACKERS	CATALYST FINES
WASTE INCINERATORS	FLYASH

The Major Parts of an ESP

1. Automatic Voltage Controls (AVC)
2. Transformer Rectifier Sets (T/R)
3. High Voltage (HV) Electrodes
4. Collecting Electrodes (CE)
5. Cleaning Devices (Not Shown)

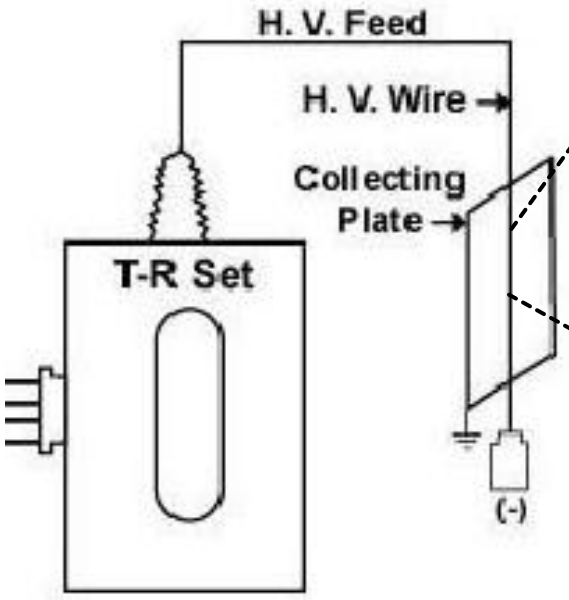


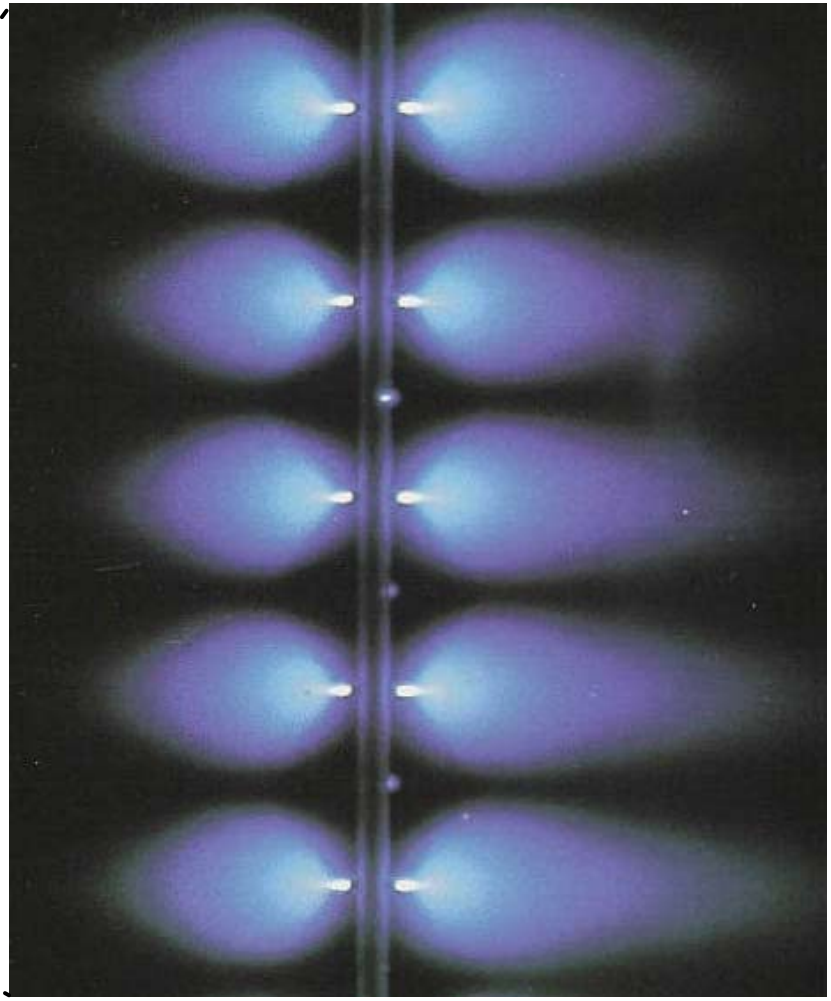


How an ESP Works

(Simplified Version)

- The T/R set energizes the HV electrodes with 15 – 70KVDC, negative polarity
- The HV creates a corona glow which ionizes the surrounding gas molecules
- The negative gas ions migrate towards the collecting plates

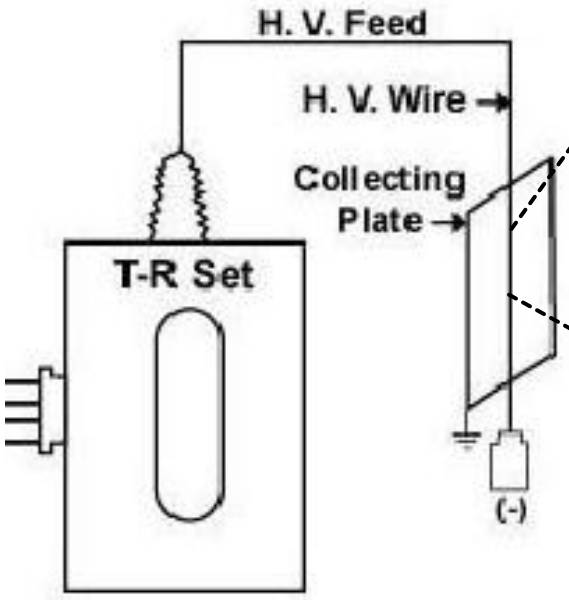


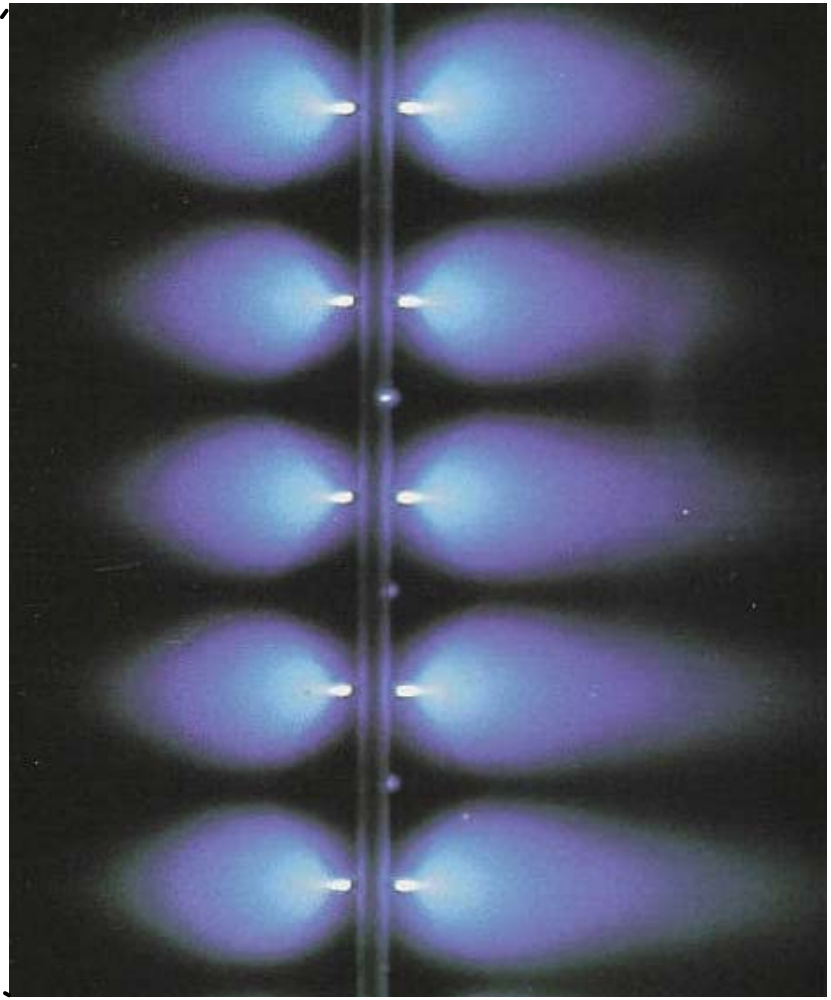


How an ESP Works

(Simplified Version)

- **The negative ions, in turn, charge the dust negatively**
- **The HV also creates an electric field which drives the dust toward the grounded plates**
- **The charging process occurs within a fraction of a second**

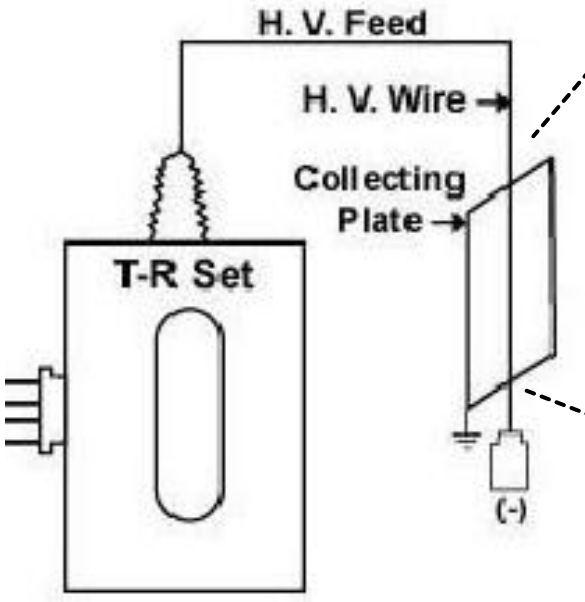




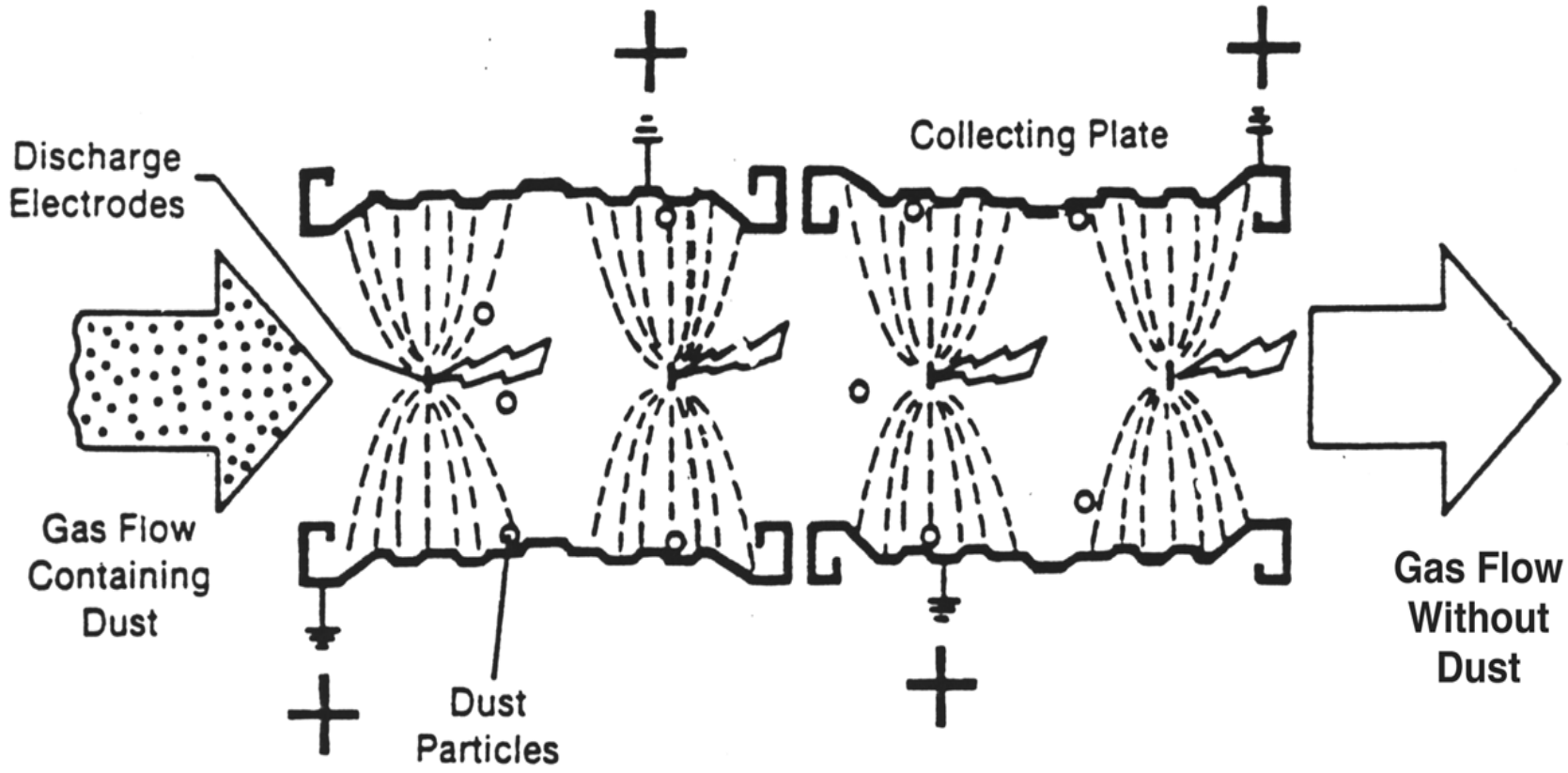
How an ESP Works

(Simplified Version)

- **At the positive collecting plate the particle is partially discharged**
- **The charge is slowly leaked to the grounded plate**
- **The partial charge left on the particles contributes to the cohesive and adhesive properties of the dust layer**



Dust is electrically charged and the electrical field propels the dust to the grounded electrode



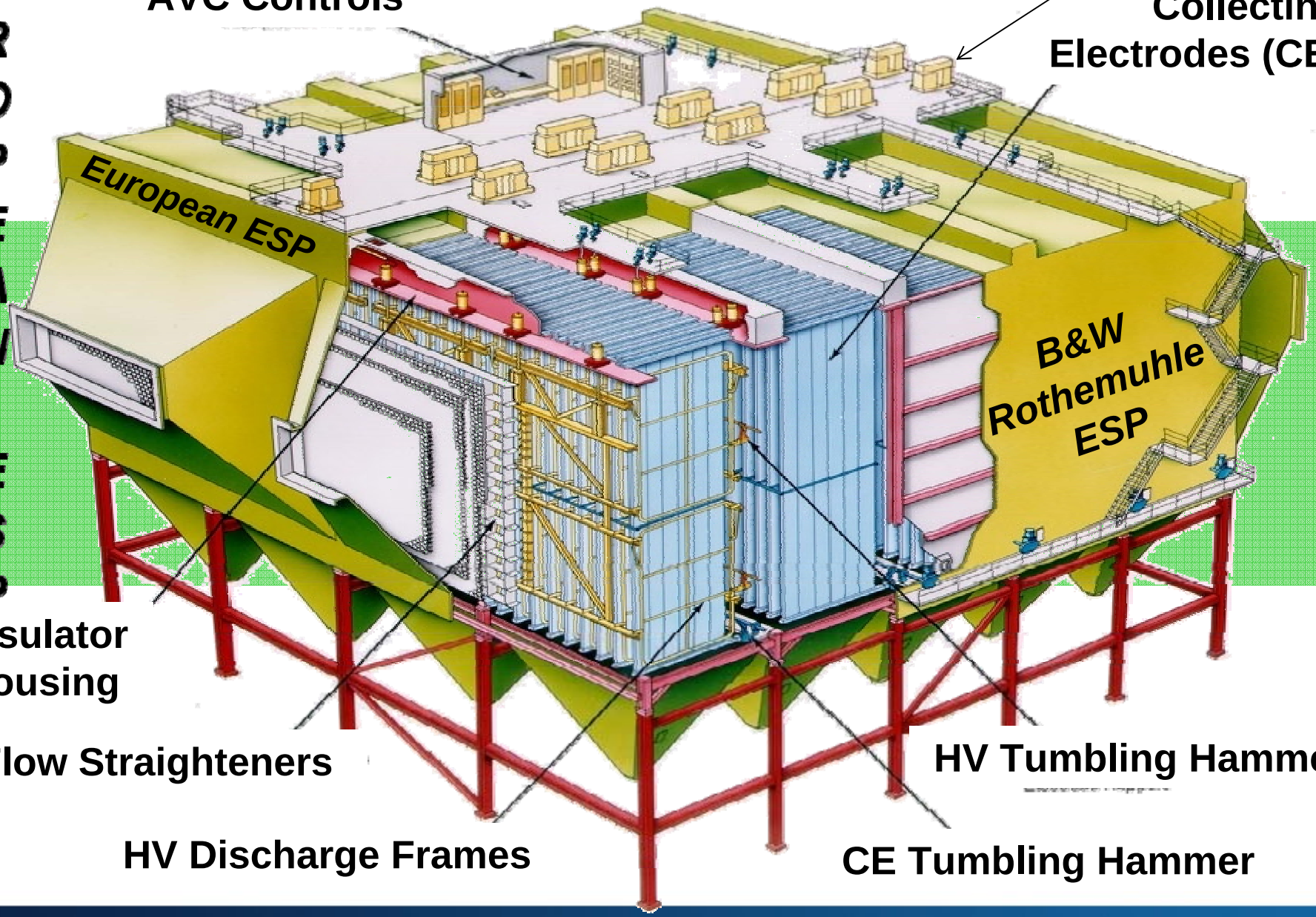
Particle Charging

- **Finer particles are harder to charge and harder to collect**
- **Therefore, an electrostatic precipitator (ESP) is less efficient when the dust is finer**
- **The opposite is true for larger particles**
- **Don't get misled. Given enough treatment time, an ESP can collect particles so fine you would need an electron microscope to see them**

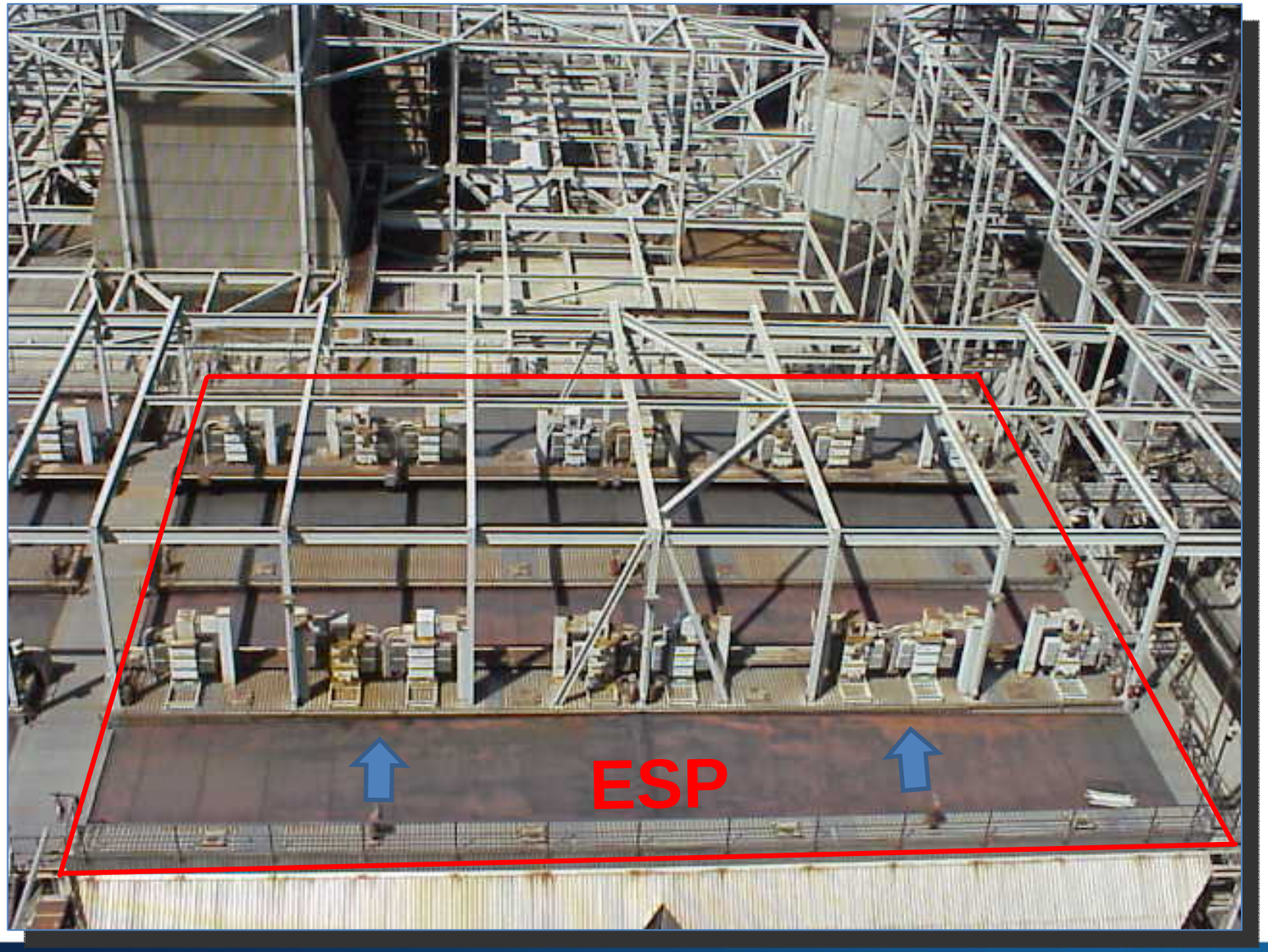
There are Basically Two Types of Precipitators

1. **The European Design, sometimes called a "Rigid Frame ESP"**
2. **The American Design of which there are two types:**
   a) **Weighted Wire ESP**
   b) **Rigid Electrode (RDE) ESP**

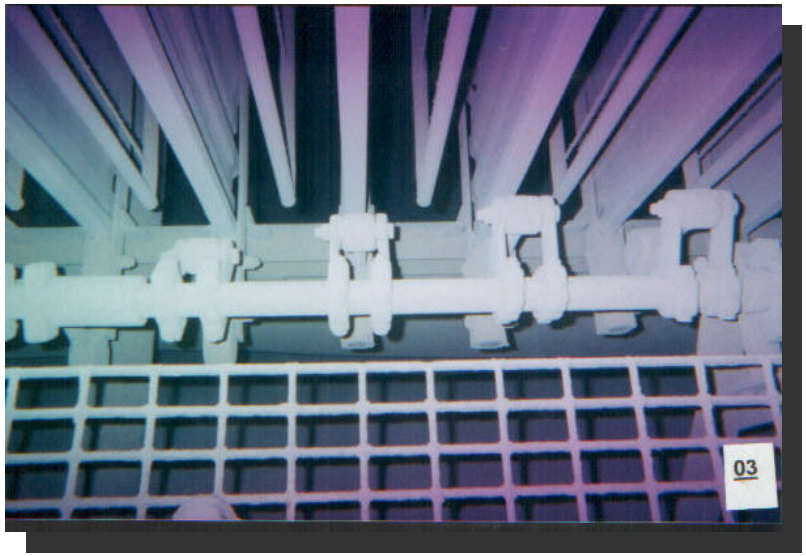
EUROPEAN ESP

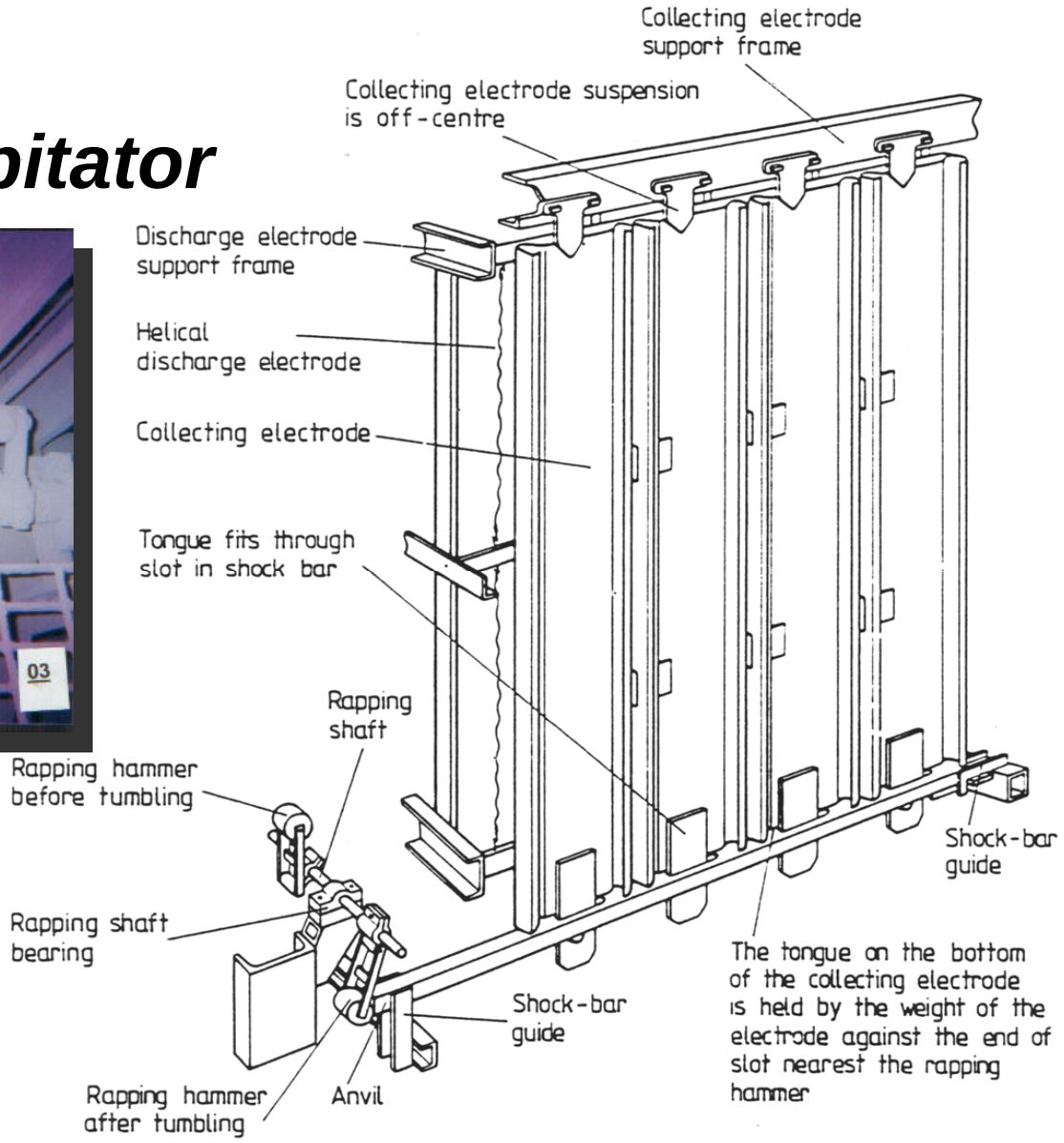


European ESP Leading to a Wet Scrubber

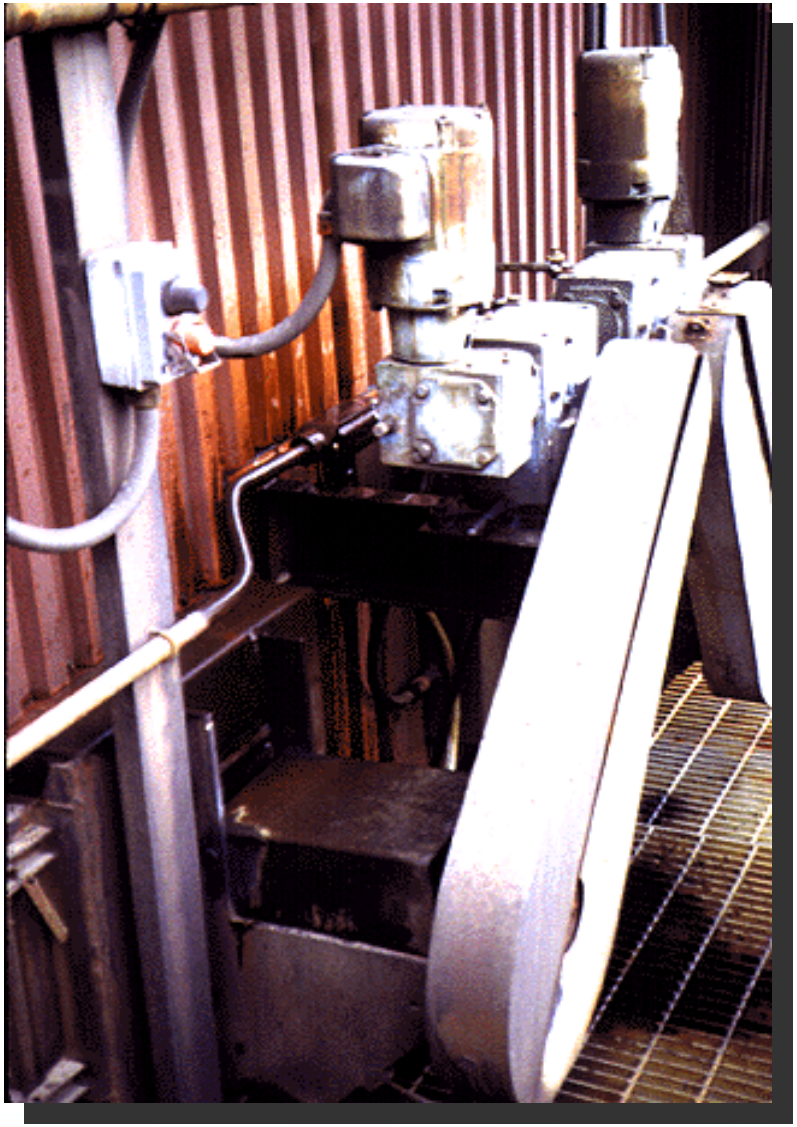


European Style - Rigid Frame Precipitator

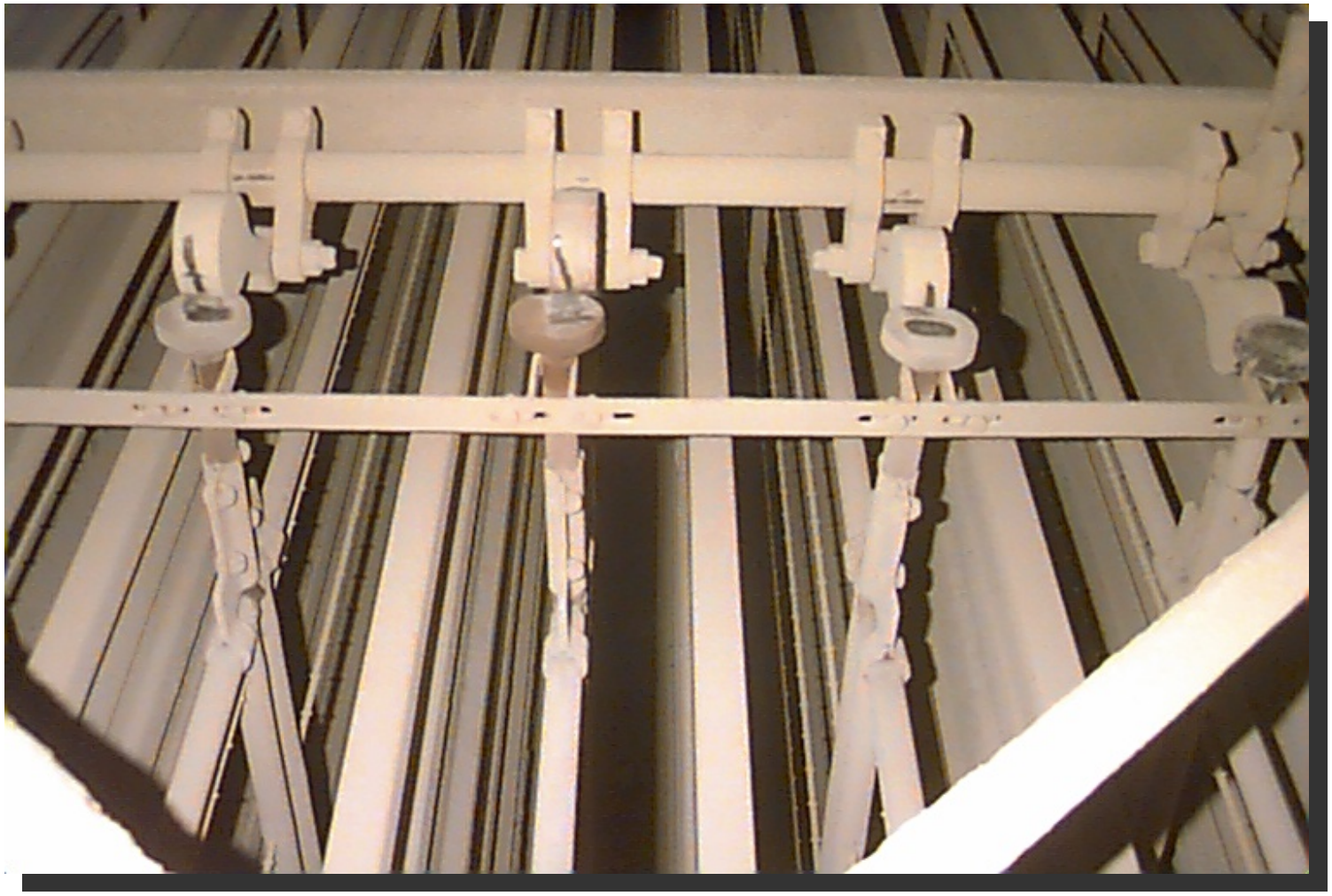




Tumbling Hammers: Motor and Drive

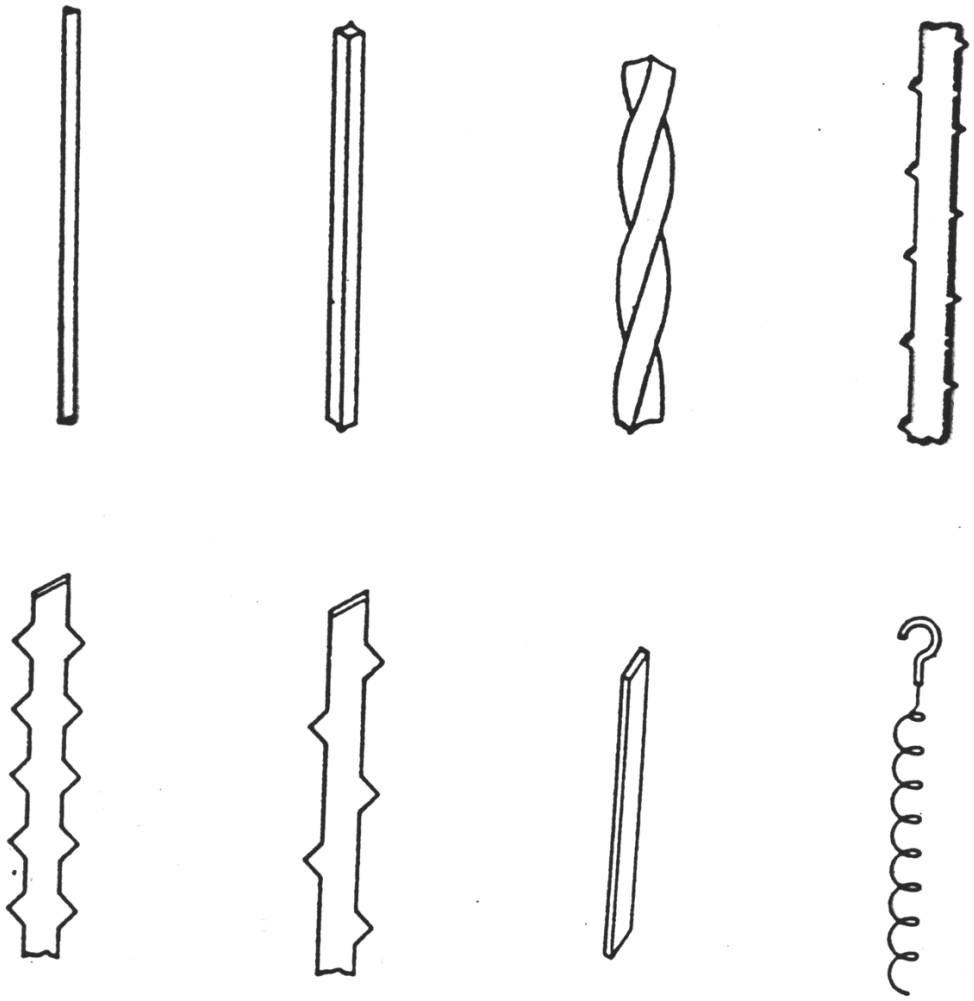


HV Tumbling Hammer System

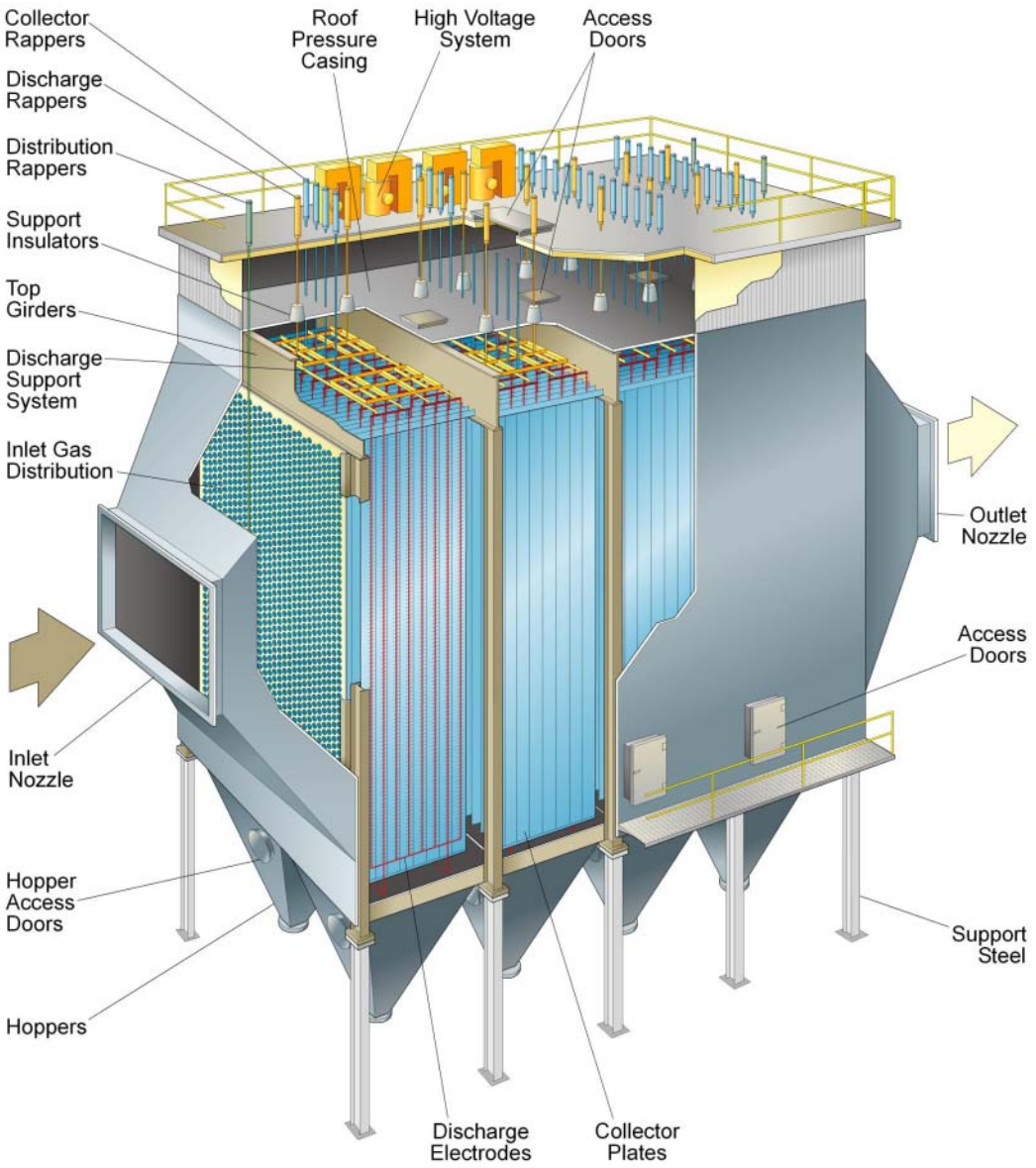


Rigid Frame, 300mm Gas Passages

Common Discharge Electrode Shapes

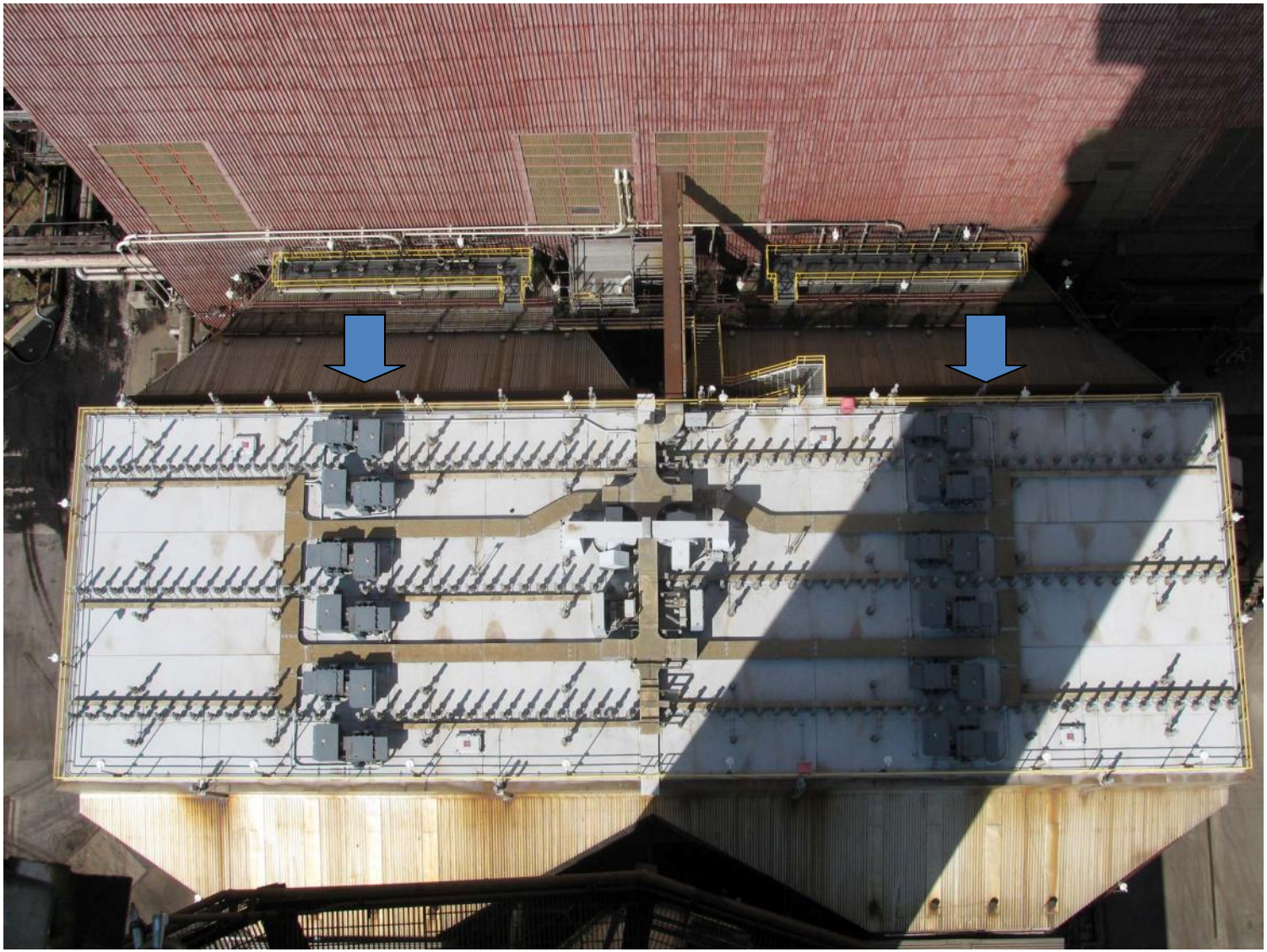


American Rigid Discharge Electrode (RDE) ESP

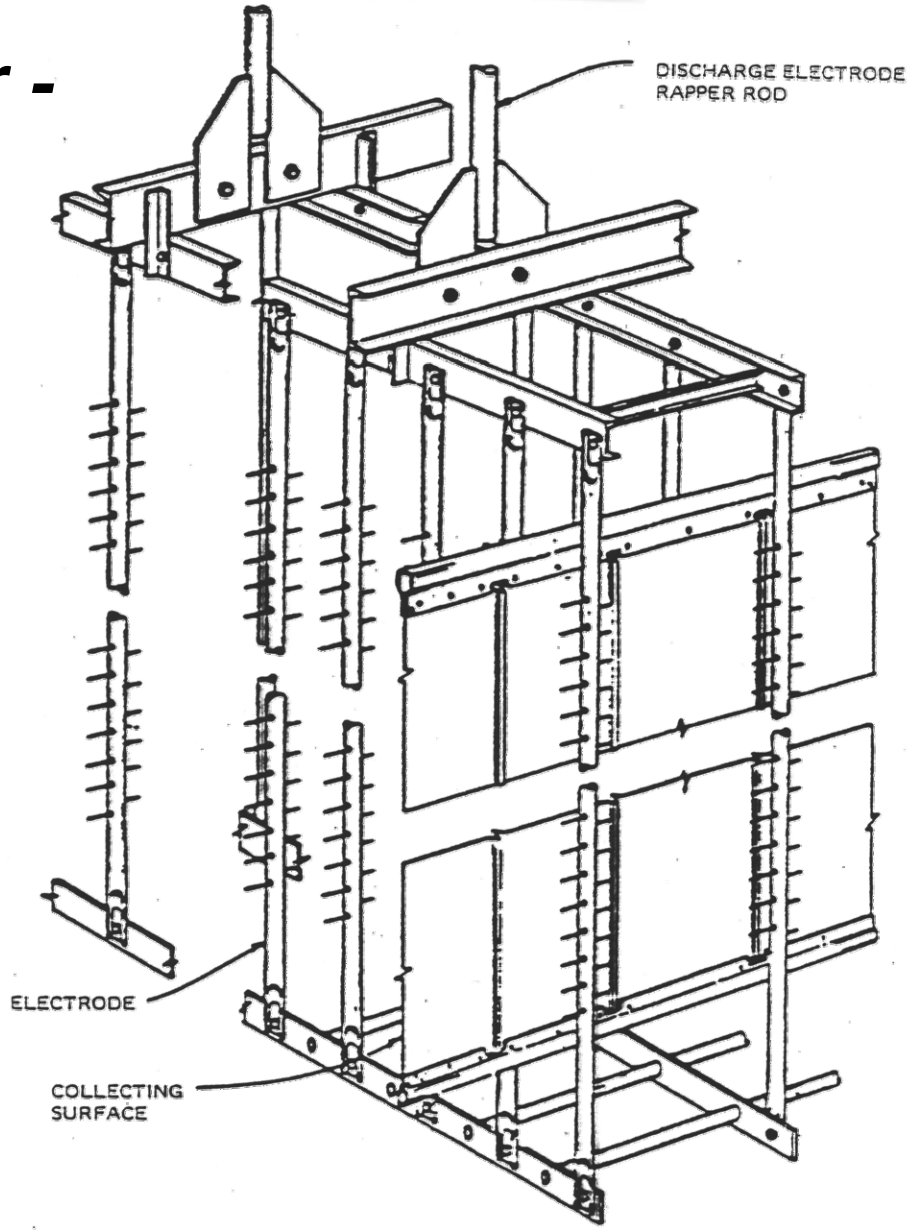


American ESP

American ESP

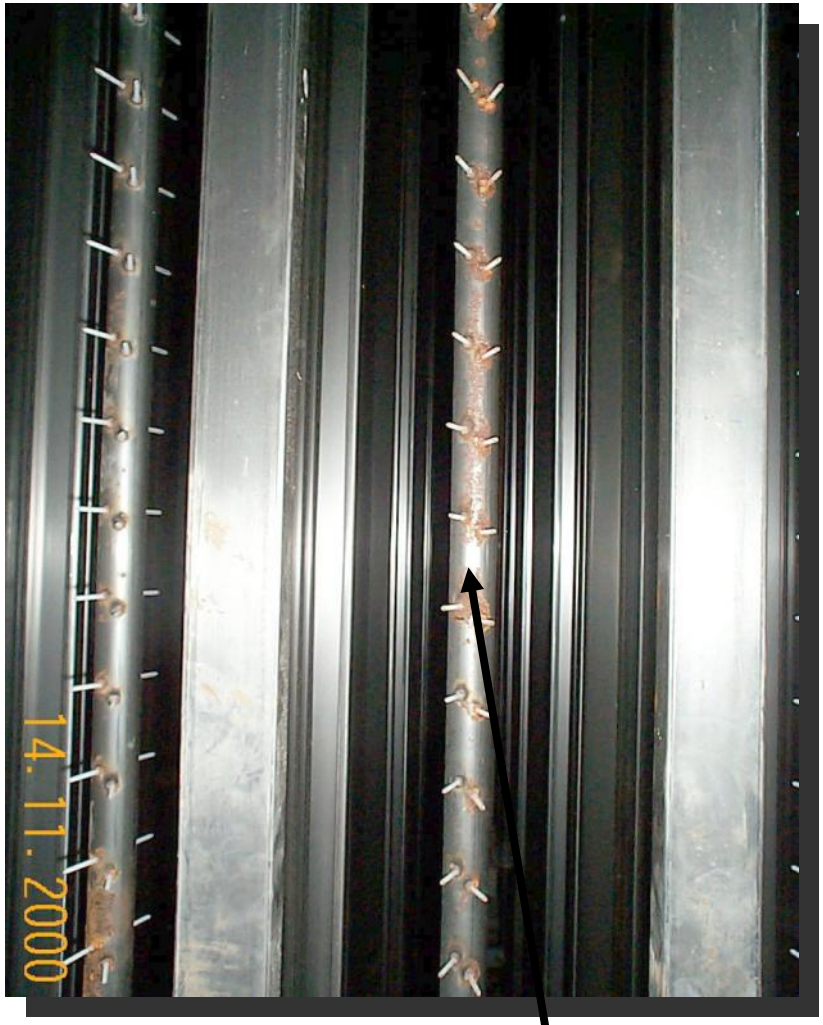


American Precipitator - Rigid Discharge Electrode



Top of RDEs Loaded In Gas Passage

Rigid Discharge Electrode: RDE 1



Gas duct of first field, RDEs with V-pins

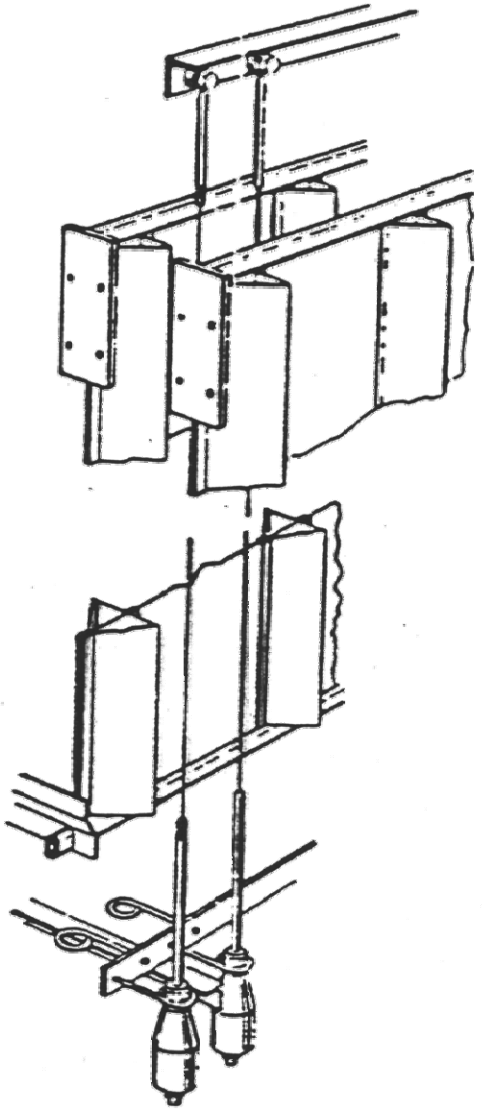
Rigid Discharge Electrode: RDE 1

Collecting Plates

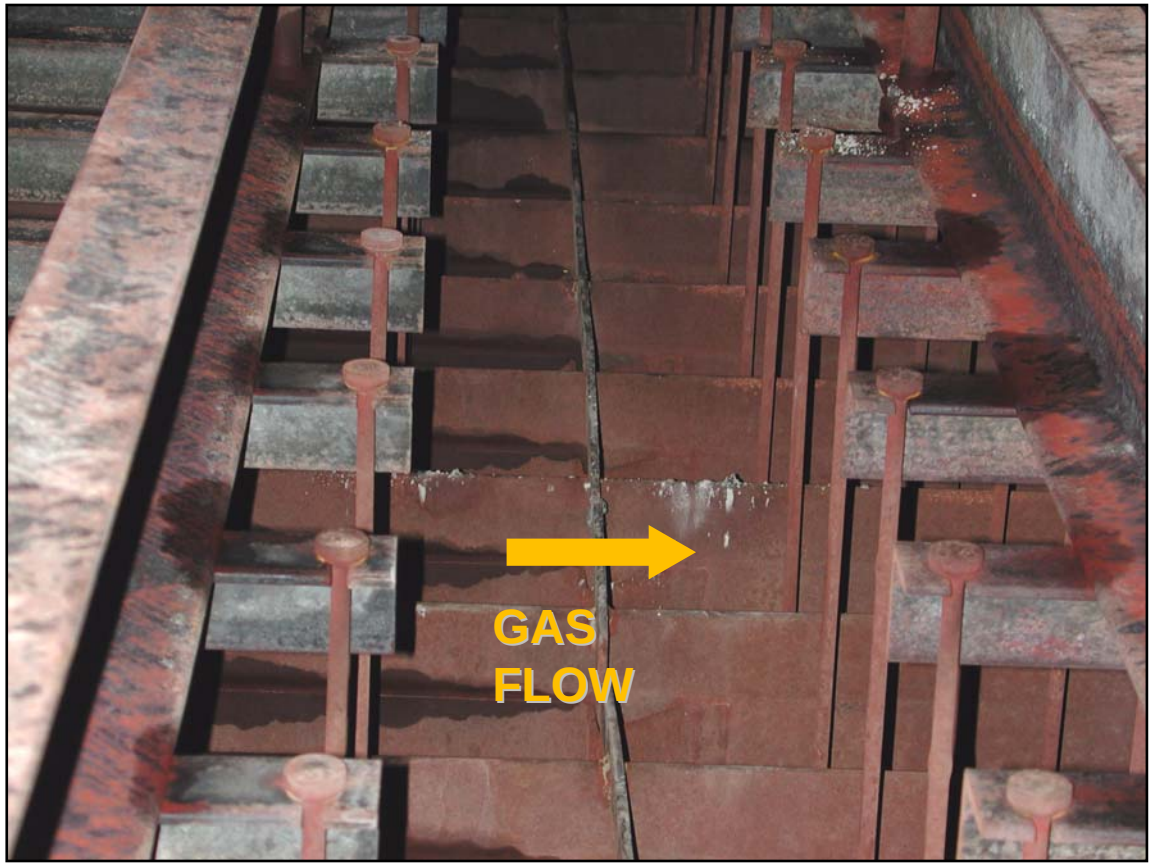
RDEs V-Pin

Anti-sneak baffles

American Style – Weighted Wire ESP



Gas Passages

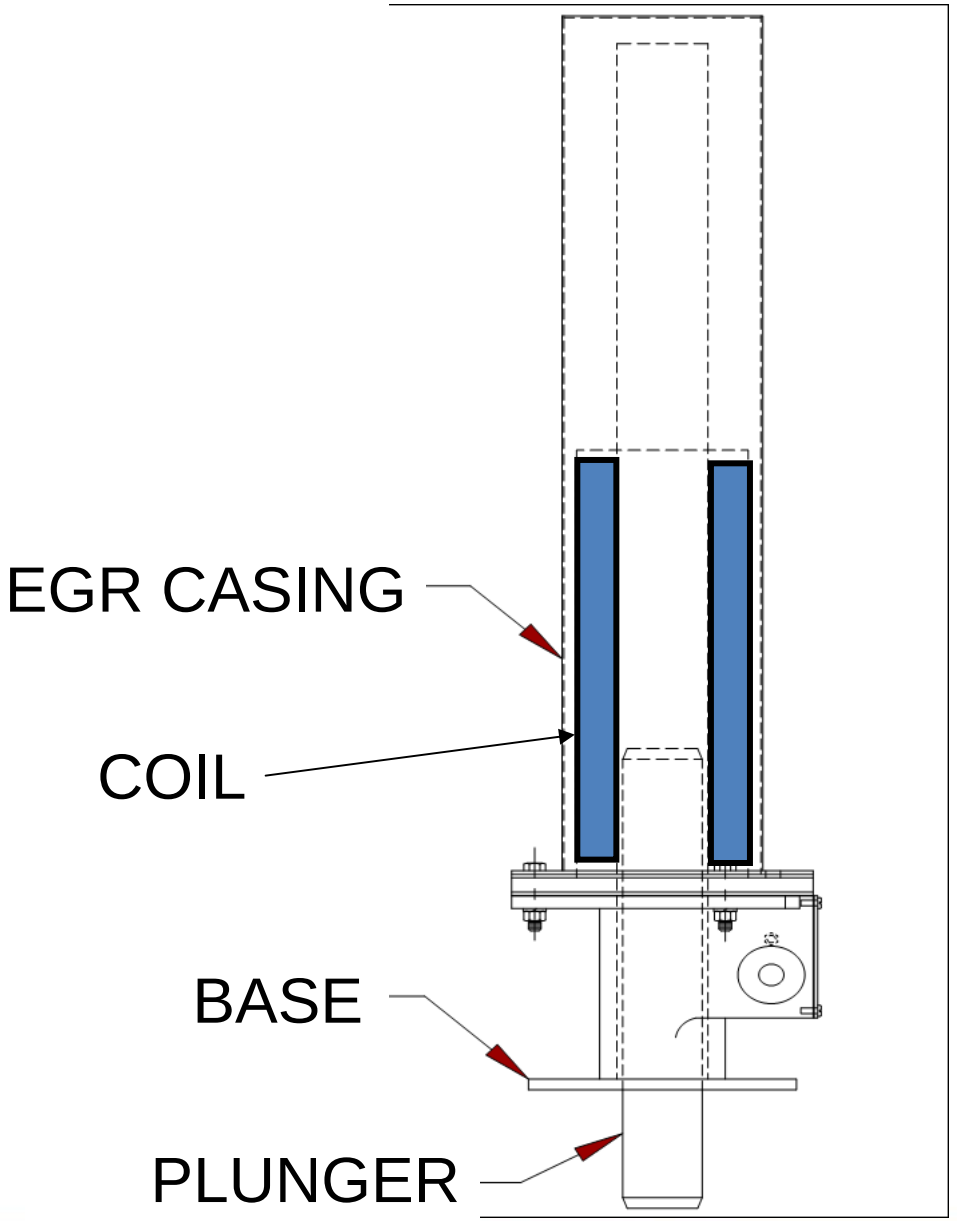


with wire electrodes

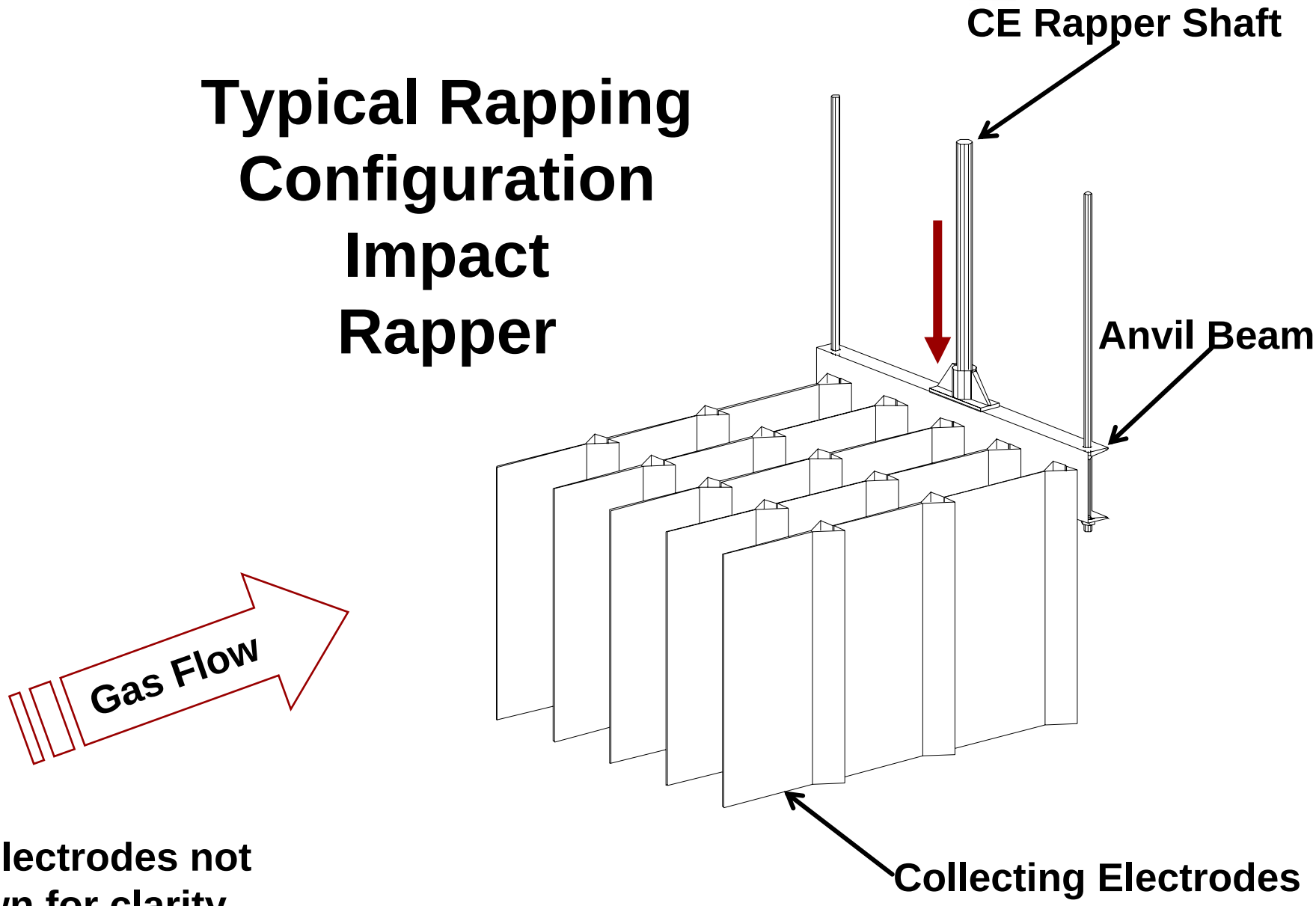
Bottom of Weights

Impact Type Rapper on Collecting Plates

Electromagnetic Gravity Rapper



Typical Rapping Configuration Impact Rapper



HV Electrodes not shown for clarity

Precipitators and Collection Efficiency

Precipitator Efficiency is directly proportional to:

- **How quickly the dust in the ESP migrates toward the plates (Electrical Conditions)**
- **The relative size of the ESP (SCA)**

Step 1 in becoming an ESP Expert !

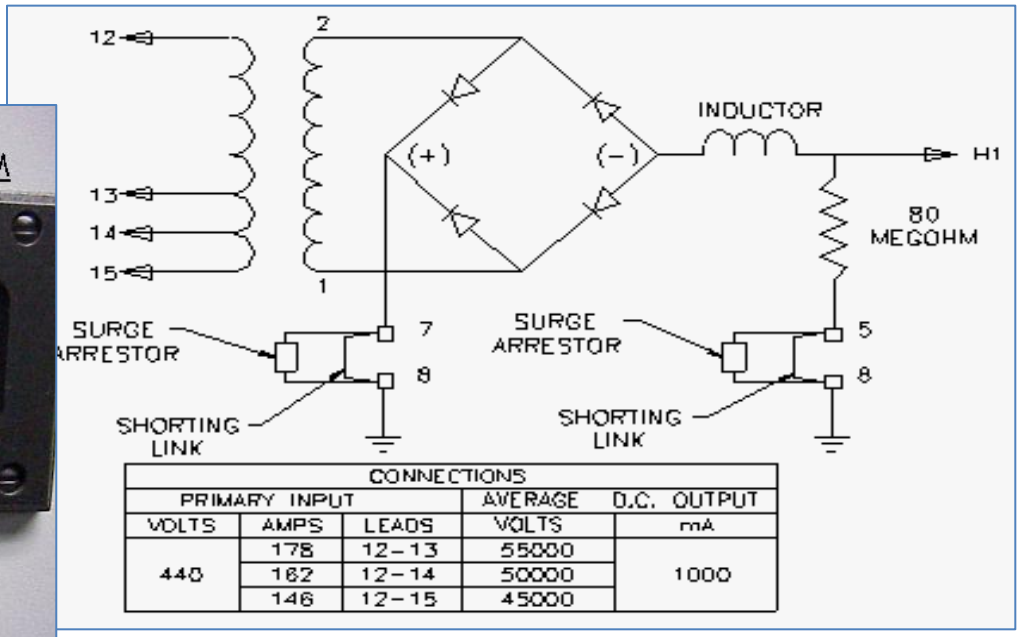
Automatic Voltage Control

1. The brains of the system. It controls what is happening in its section of the ESP
2. Sets the voltage and current at which the T/R set runs
3. Constantly watches for sparking in the ESP and controls the rate of sparking

Step 1 Expert: The AVC Has Two Jobs to Execute

- Control the amount of sparking in the ESP
- In the absence of sparking, push the T/R set to it's limit(s)

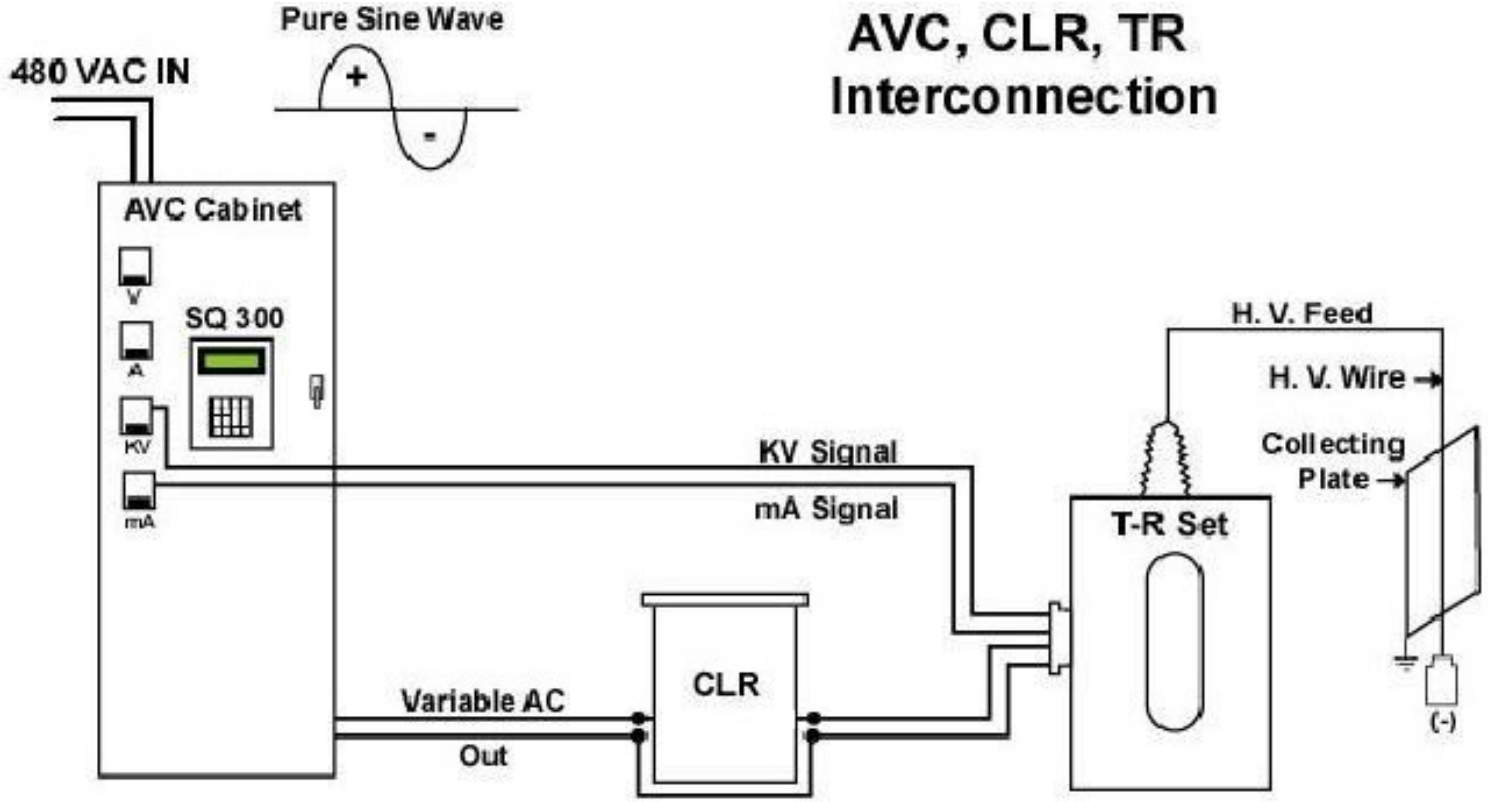
AVC at Spark Limit

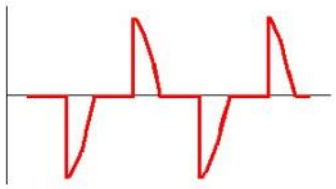


CONNECTIONS				
PRIMARY INPUT			AVERAGE D.C. OUTPUT	
VOLTS	AMPS	LEADS	VOLTS	mA
440	178	12-13	55000	1000
	162	12-14	50000	
	146	12-15	45000	

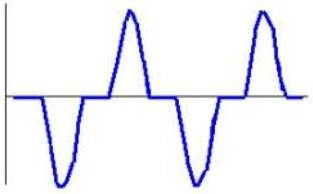
T/R Set Nameplate
(different than AVC at left)

AVC Cabinet, CLR & T/R Set

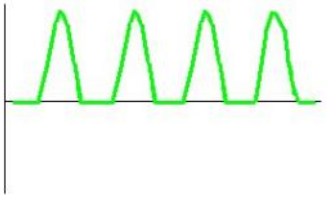




Switching Power Supply
SCR's



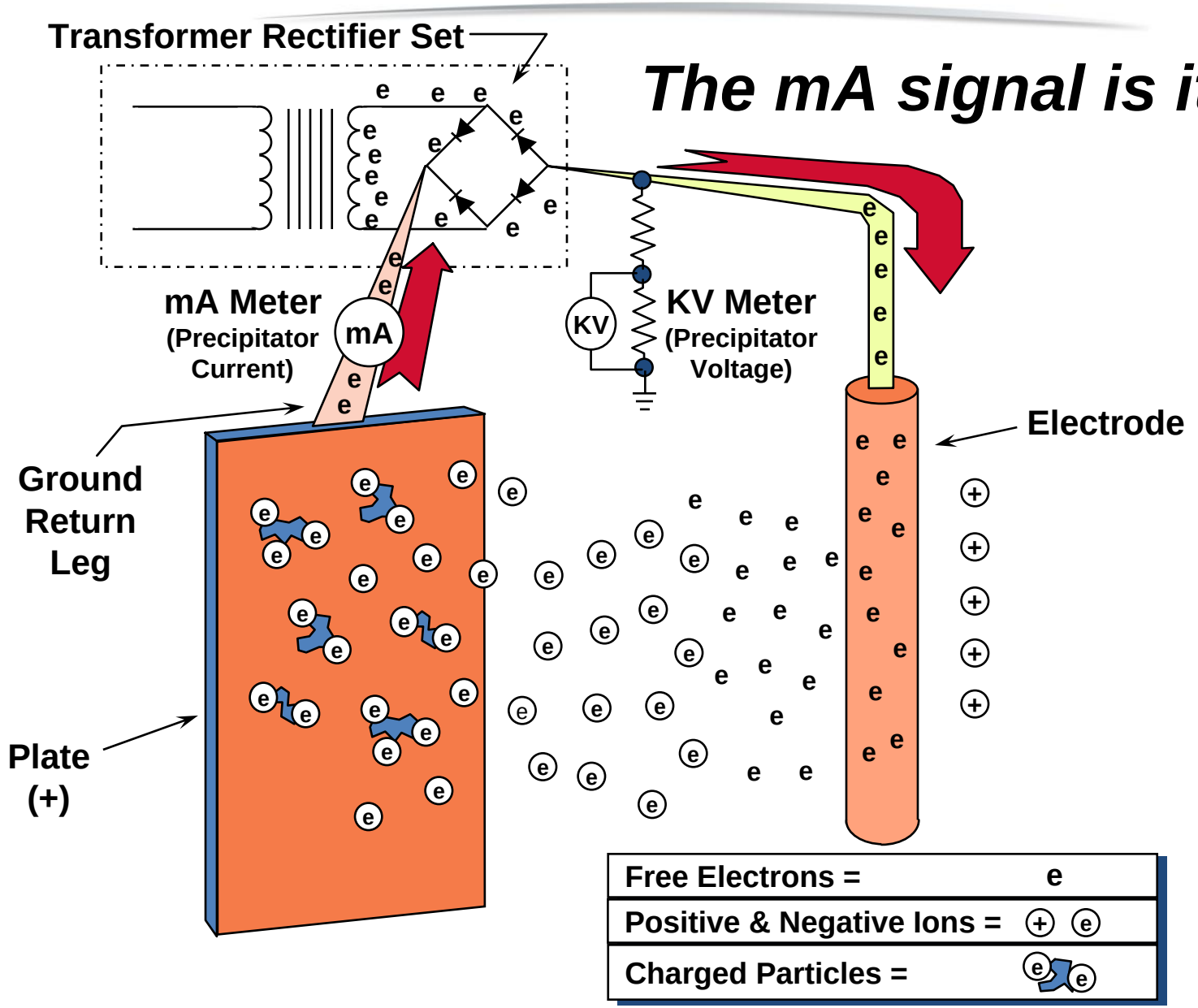
Waveshaping
CLR



Full Wave Rectification
TR Set

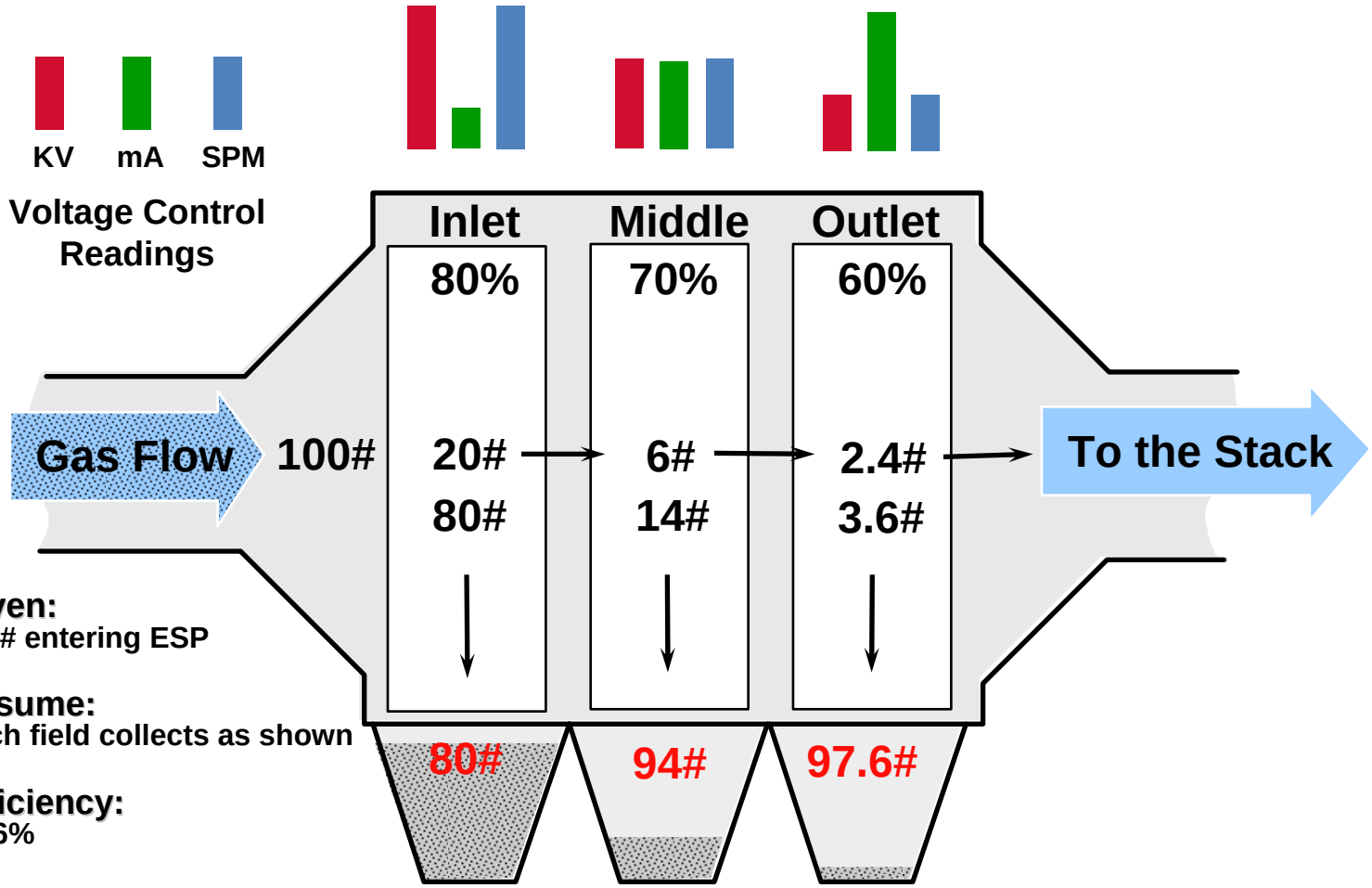
Transformer Rectifier (T/R) Set

The mA signal is its eyes!



INCREMENTAL COLLECTION

Step 2 in becoming an ESP Expert !



Given:
100# entering ESP

Assume:
Each field collects as shown

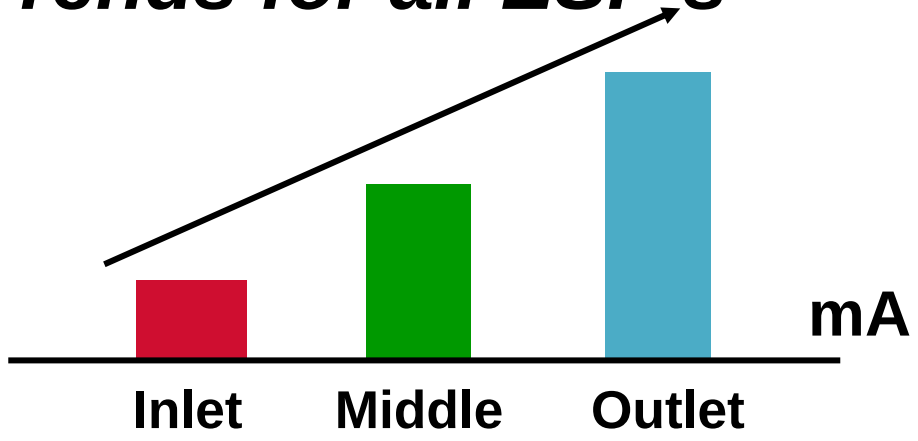
Efficiency:
97.6%

Values shown are to represent relationship only...not necessarily actual conditions

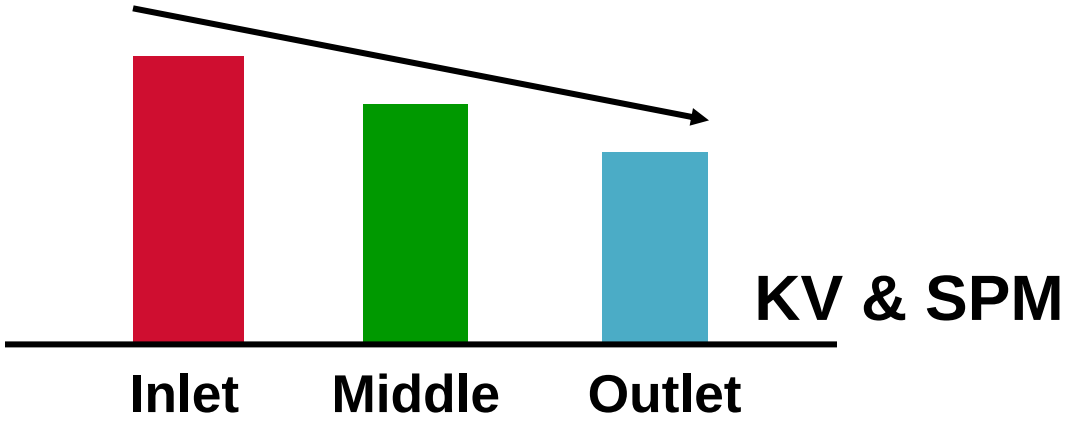
Step 2 for ESP Expert

Typical Trends for all ESP's

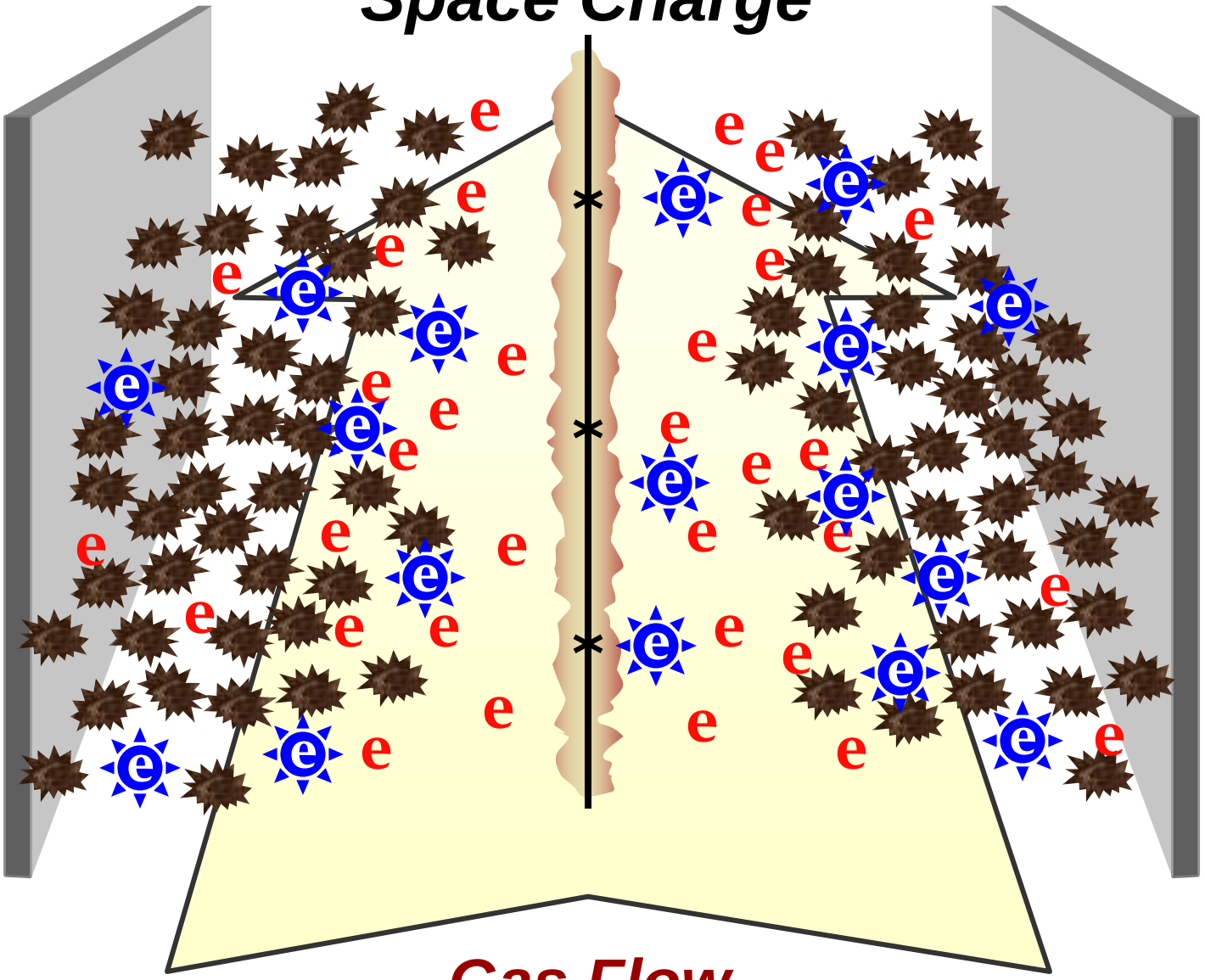
Always look for this trend...



Decreasing <u>KV per Unit Current</u> and SPM, from inlet to outlet, also should show



Space Charge



Gas Flow

Is This ESP Behaving Properly?

Good Dust — ***AVC Readings***

AVC	AMPS	VOLTS	mAMPS	KV	SPM
1	60	365	300	43	30
2	90	350	500	38	30
3	240	345	1390	40	10
4	240	310	1450	39	0

First, Check Each AVC

Good Dust — ***AVC Readings***

AVC	AMPS	VOLTS	mAMPS	KV	SPM
1	60	365	300	43	30
2	90	350	500	38	30
3	240	345	1390	40	10
4	240	310	1450	39	0

You Must Know Each T-R Set Rating

Good Dust — ***AVC Readings***

AVC	AMPS	VOLTS	mAMPS	KV	SPM
1	60	365	300	43	30
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You Must Know Each T-r Set Rating

Good Dust	AVC Readings				
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1&2 T-R	120	400	750	45	30
1	60	365	300	43	30
2	90	350	500	38	30
3&4 T-R	240	400	1500	45	30
3	240	345	1390	40	10
4	240	310	1450	39	0

You Must Know Each T-R Set Rating

Good Dust					AVC Readings
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1&2 T-R	120	400	750	45	30
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2	90	350	500	38	30
3&4 T-R	240	400	1500	45	30
3	240	345	1390	40	10
4	240	310	1450	39	0

Second, Check ESP Current From Inlet To Outlet

Good Dust			AVC Readings		
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1	60	365	300	43	30
2	90	350	500	38	30
3	240	345	1390	40	10
4	240	310	1450	39	0

Third, Sparking Usually Decreases From Inlet To Outlet

Good Dust			AVC Readings		
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1	60	365	300	43	30
2	90	350	500	38	30
3	240	345	1390	40	10
4	240	310	1450	39	0

Fourth, KV Per Unit Current Will Decrease But It Is Not Easy To Check

Good Dust — ***AVC Readings***

AVC	AMPS	VOLTS	mAMPS	KV	SPM
1	60	365	300	43	30
2	90	350	500	38	30
3	240	345	1390	40	10
4	240	310	1450	39	0

Step 3 in becoming an ESP Expert !

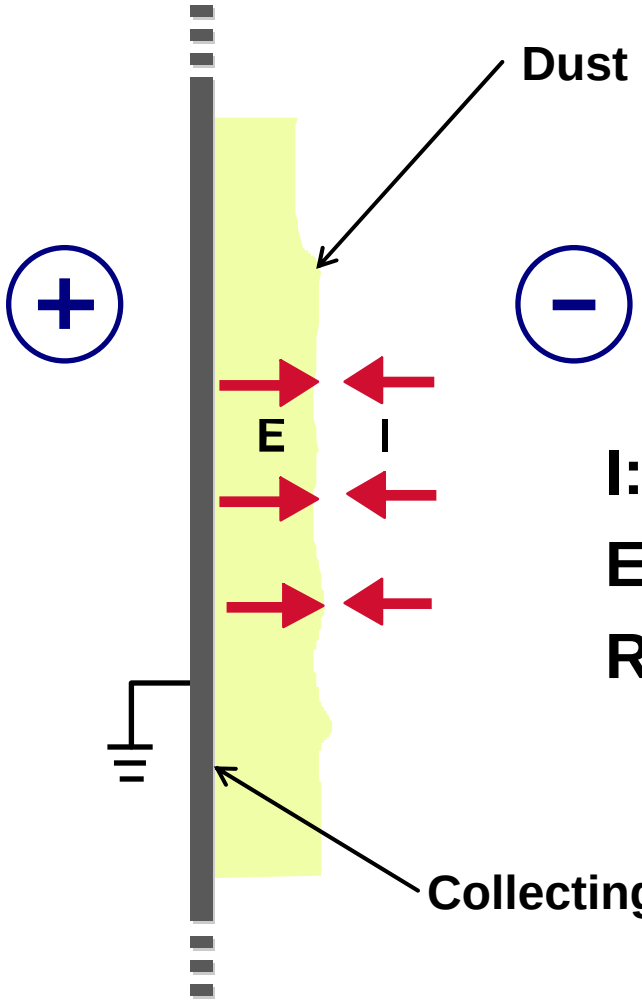
Resistivity

- **The resistance of the collected dust can make or break the ESP collection efficiency**
- **The resistance of the dust basically controls the allowable ESP operating current densities (current).**
- **High Resistivity will usually increase the sparking on all fields of the ESP.**
- **If current is affected, then ESP voltage will also be pulled down.**
- **If the total operating power in the ESP is dragged down, the outlet dust emissions will increase**

Resistivity is Affected by these Things

- **Flue gas temperature**
  - **Cold side ESP**
  - **Hot side ESP**
- **Flue gas composition**
  - **Moisture content**
  - **SO_3 content**
- **Fly ash mineral composition**
  - **Sulfur at cold side**
  - **Sodium oxide at cold side**
  - **Sodium oxide at hot side**

Ohm's Law and the Resistance of Dust



$$E = R \times I$$

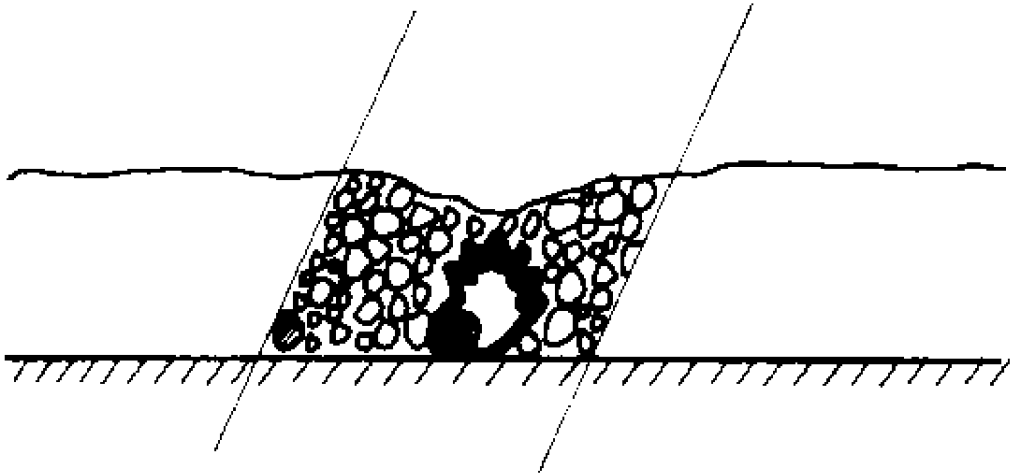
I: Ion Current Density

E: Electric Field

R: Dust Layer Resistivity

One Symptom of High Resistivity: Back Corona

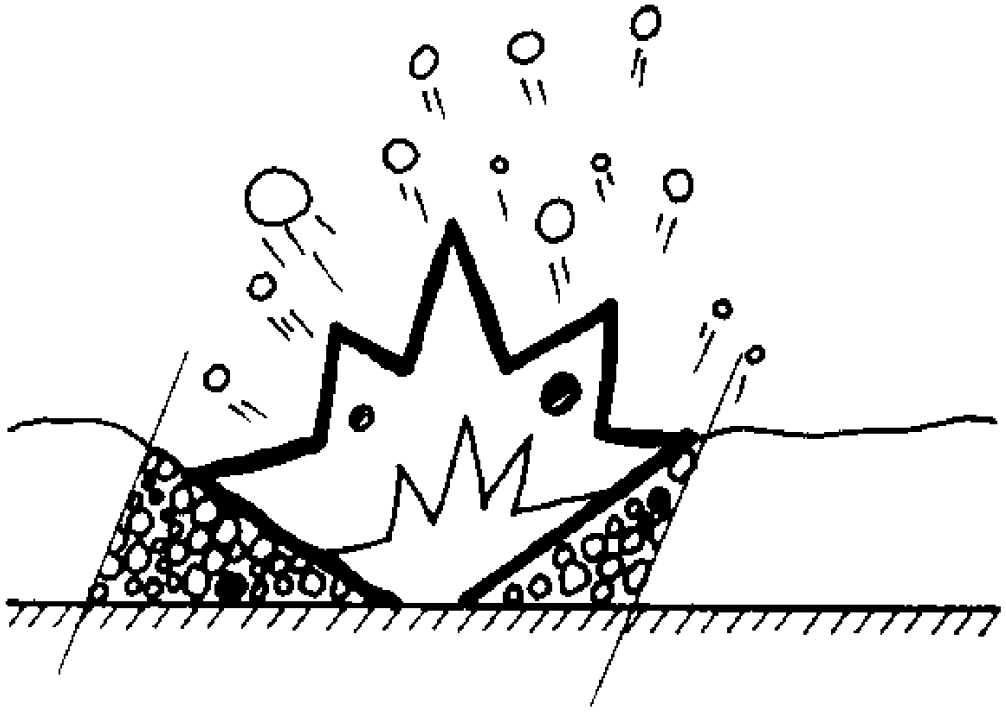
1. **Dust doesn't give up its charge. Layer breaks down because of the high electrical field**
2. **Heat from discharge causes gas to expand**
3. **Expansion blows dust outward**



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

If the Resistance is High, You Better have a Big ESP

Questions?

Thank you.