

REINHOLD ENVIRONMENTAL Ltd.



**2015 APC Round Table  
& Expo Presentation**

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

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## ENGINEERING AN OPTIMUM PRECIPITATOR UPGRADE



2015 APC ROUNDTABLE  
JULY 14, 2015  
ATLANTA, GA

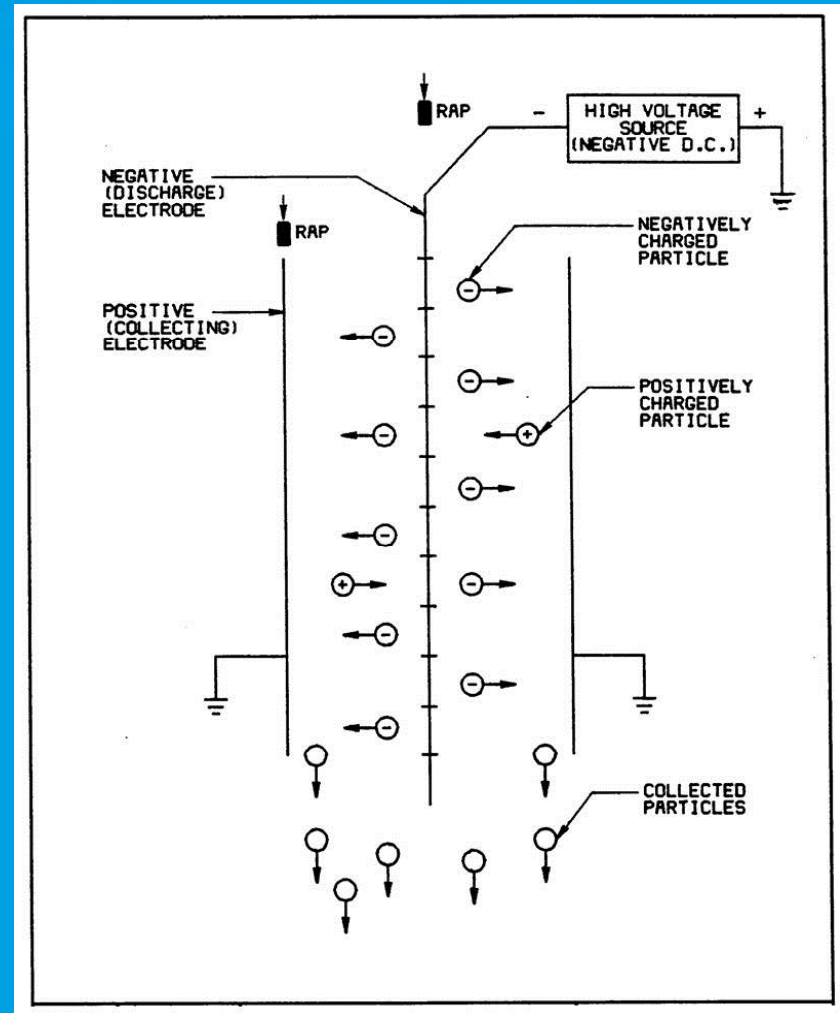
CHRIS ROGLIERI  
KC COTTRELL INC.

# Workshop Description

- **STANDARDS, METHODS, AND LIMITATIONS FOR REBUILDING PRECIPITATORS USING UPDATED TECHNOLOGY AND ENGINEERED DESIGNS**
- **UTILIZING THE SPACE AVAILABLE TO INCREASE TREATMENT TIME**
- **CONVERSIONS AND UPGRADES OF EUROPEAN-TYPE PRECIPITATORS TO AMERICAN-TYPE DESIGNS**

# Table of Contents

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- Precipitator Rebuilds Today
  - American Design
  - European Design
- Common Upgrade Methods
  - Minor Improvements
  - Moderate Rebuilds
  - Major Upgrades & Expansions
- Rebuilding European type precipits to increase treatment time



# Precipitator Rebuilds Today

- SCOTUS strikes down EPA MATS rule on June 29
  - Over 60 GW of coal units retired or converted to gas in an effort to comply with MATS regulation. Some retired due to age.
  - Most precipitators installed following 70's clean air acts already capable of outlet PM 0.03 lb/MMBtu
  - Older units were typ. designed for 0.1 lb/MMBtu.
- Units with back end FGD get additional PM reduction
- DSI and ACI systems can have significant effects on Resistivity and Inlet Loading to precipitators.
- Precipitators still need maintenance and upgrades for reliability.

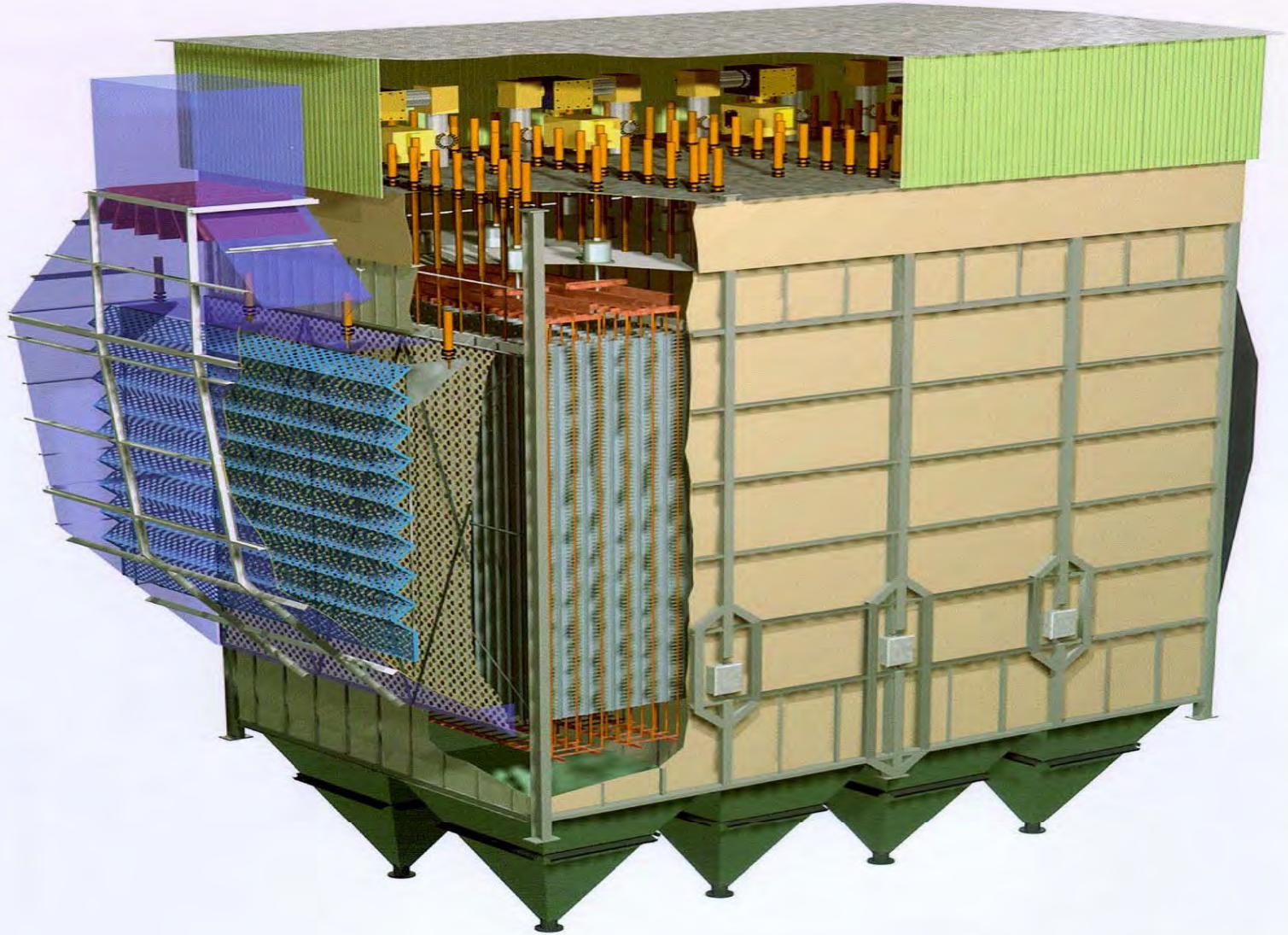
# American Design

- Standard weighted wire electrodes typ. 0.109” dia. with bottle weights up till late 1970s.
- Top Rapped Magnetic Impulse Rappers or Vibrators for Electrode Cleaning
- Electrode design migrated to rigid mast design for increased reliability
- Few changes in collecting plate design other than dimensions



# American Design

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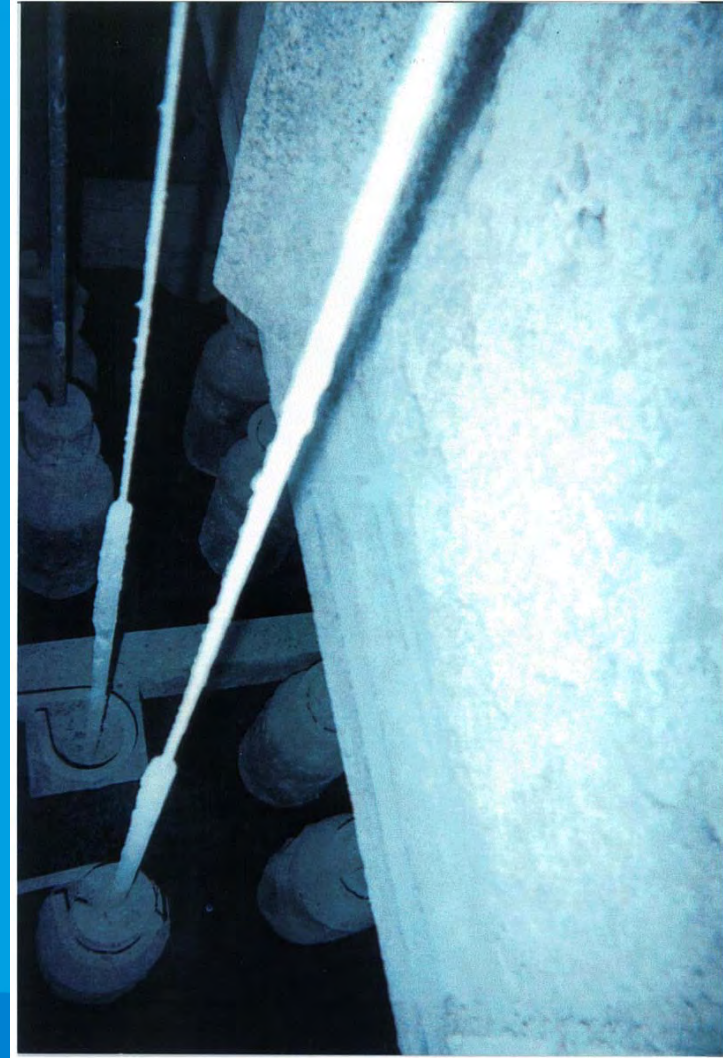
# American Design

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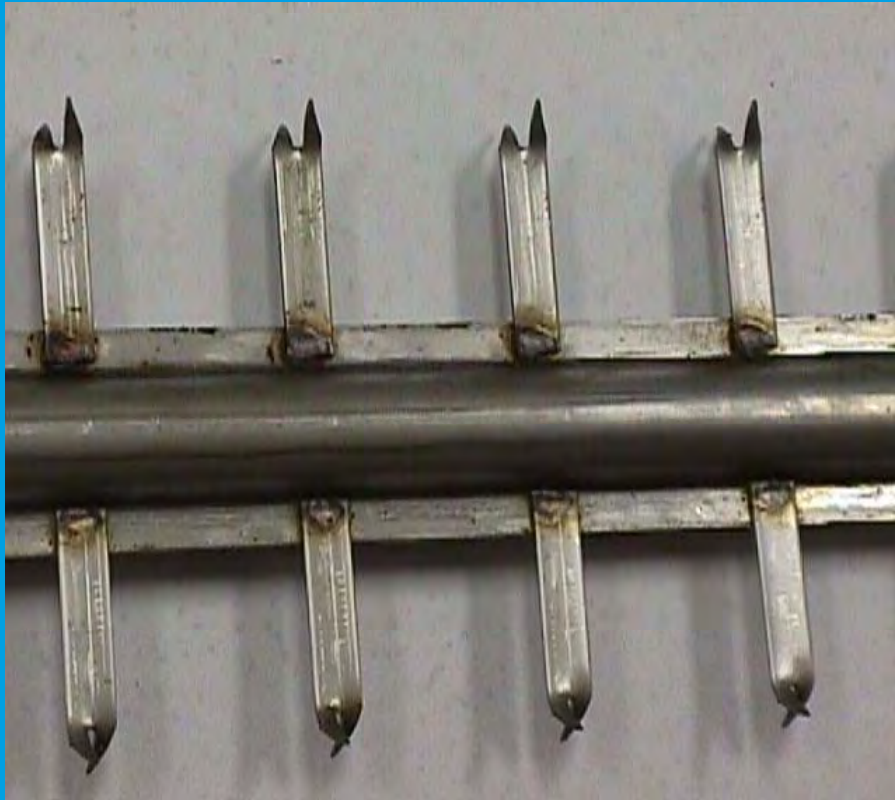


# Weighted Wire DEs

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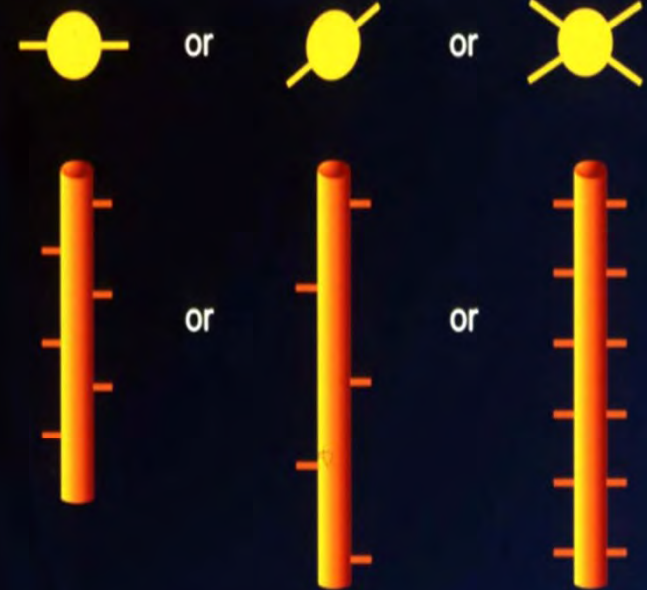


# Electrode Designs



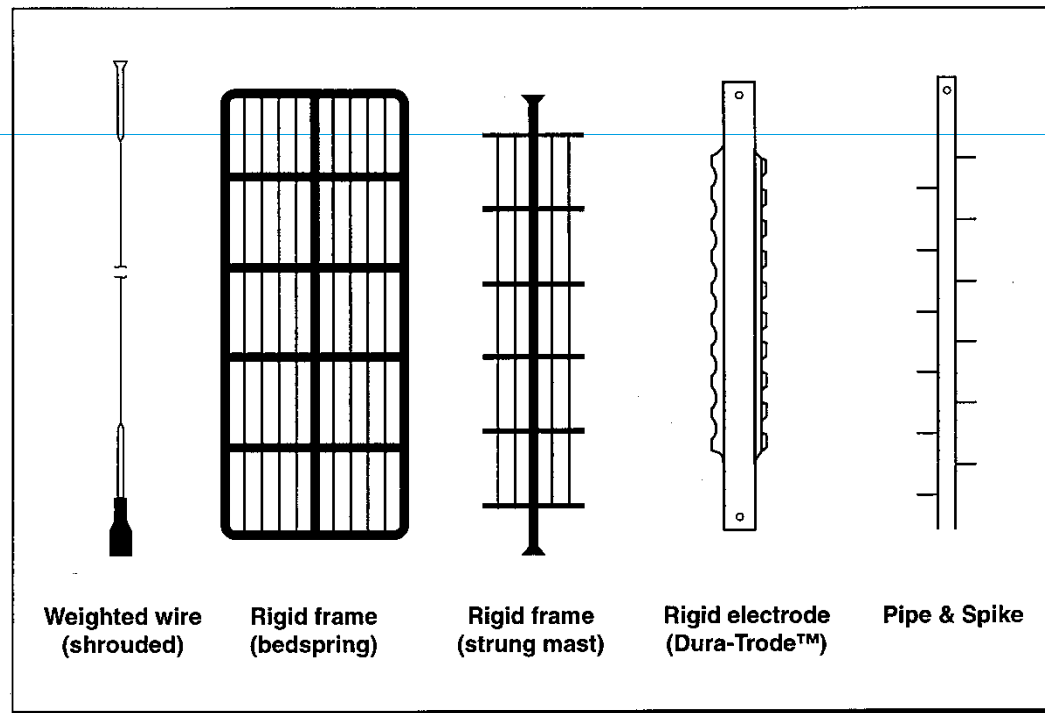
## Discharge Electrode Geometry

### 3) Orientation of Corona Generating Points



# Electrode Designs

## Discharge Electrode Types

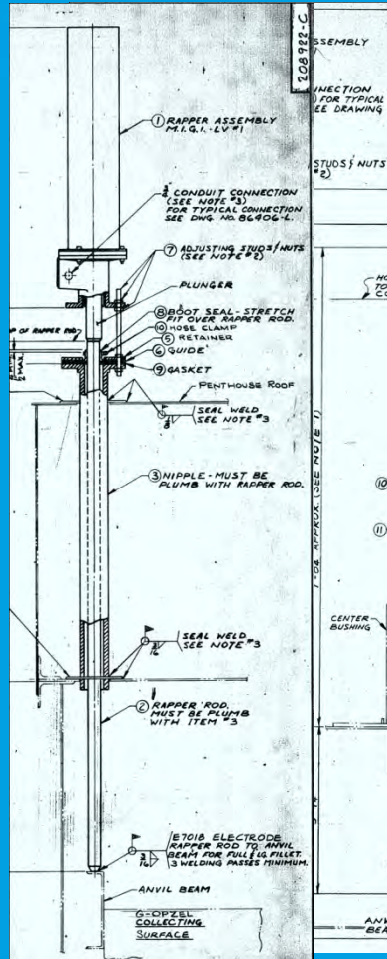
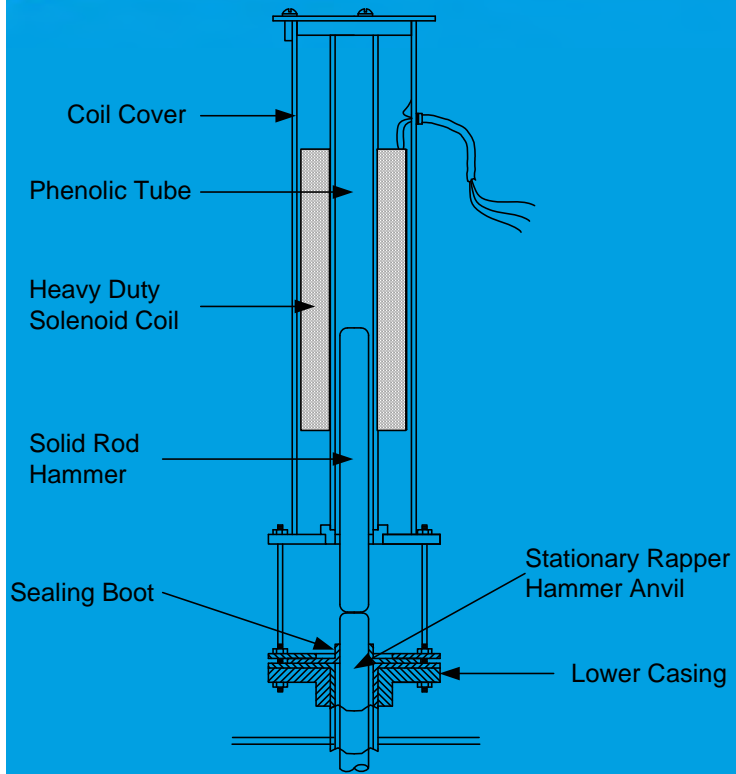


# CEs & DEs

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# Top Rapping Systems



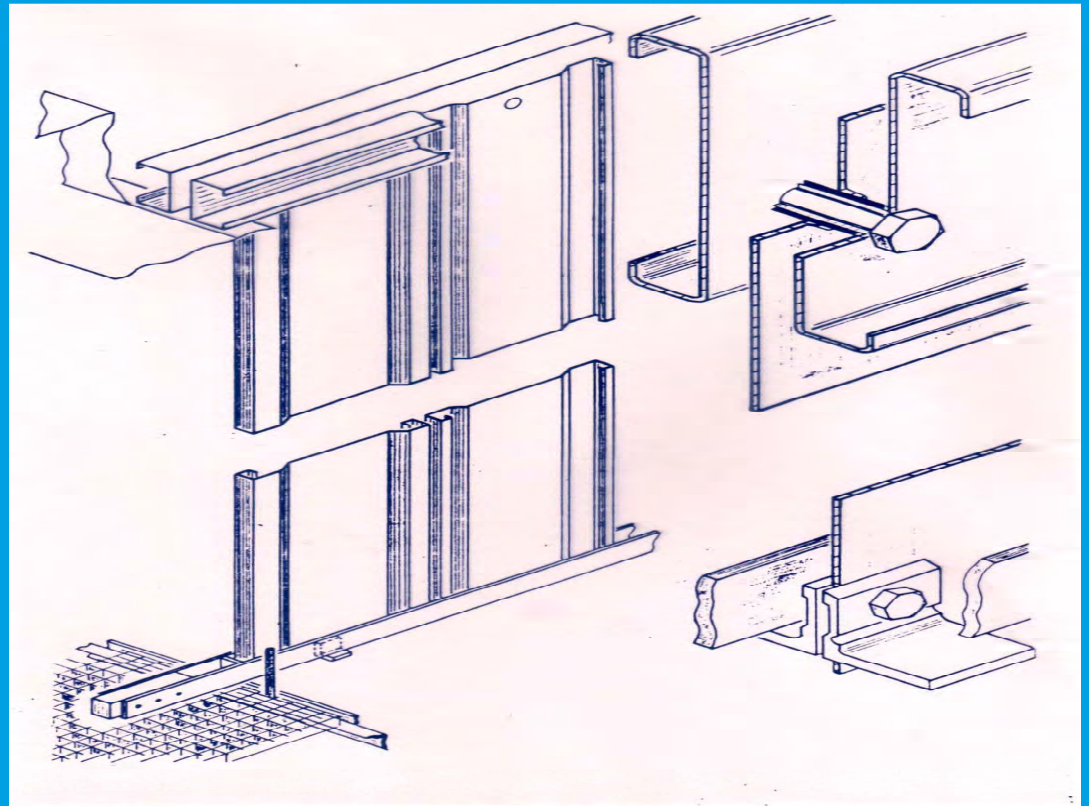
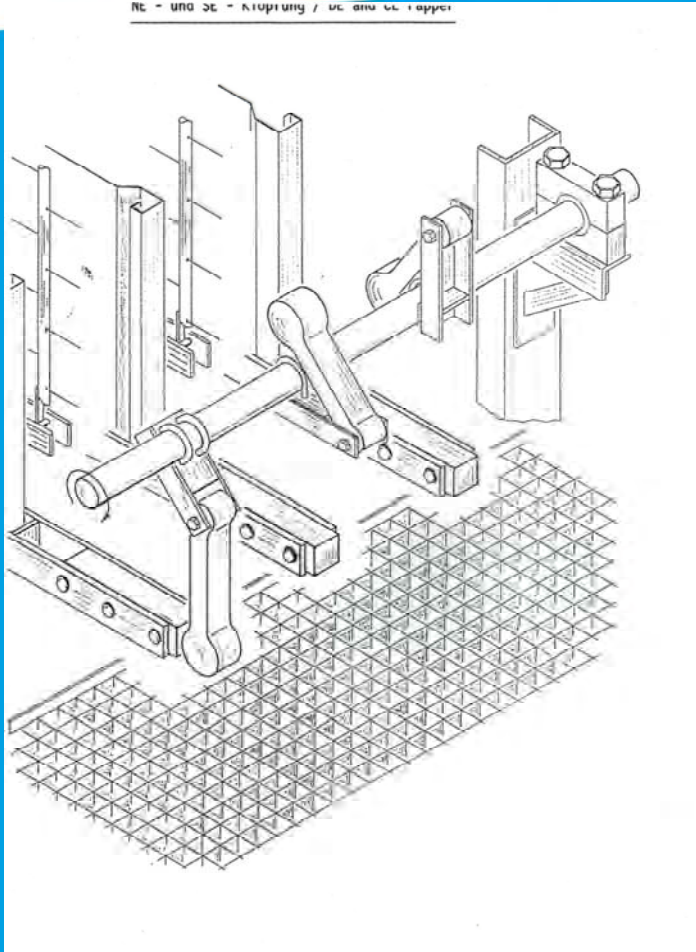
# European Design

- Electrode Cleaning by means of Tumbling hammer
  - Rotating Shafts & Hammers typ. located inside precipitator
  - Tumbling hammer systems installed between fields



# European Design

RE - und SE - Klappung / SE and SE - Klappe

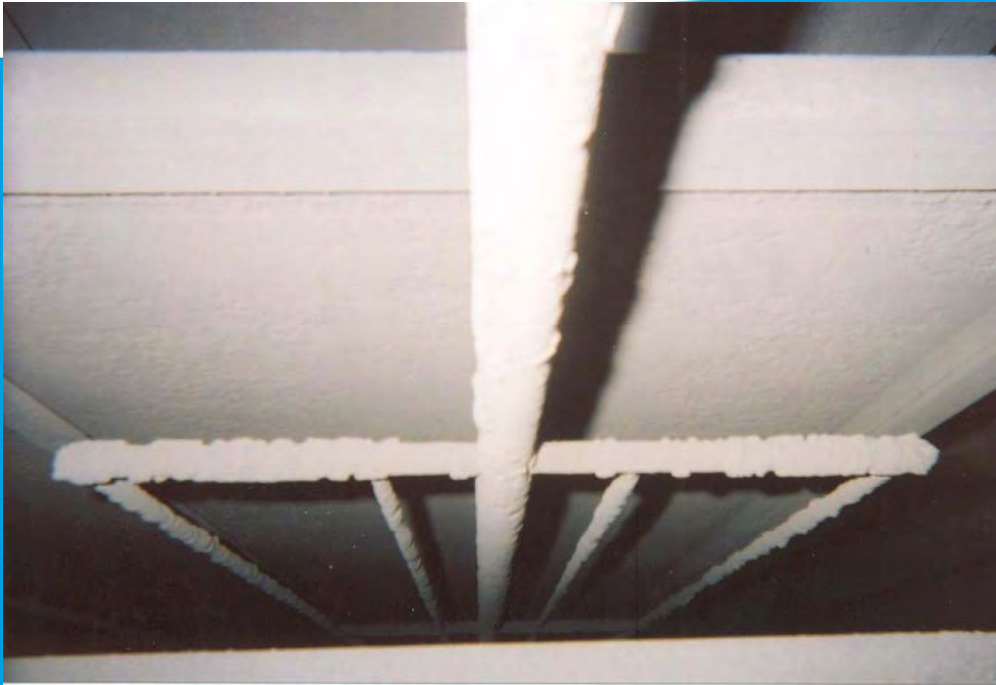


# Drop Hammers

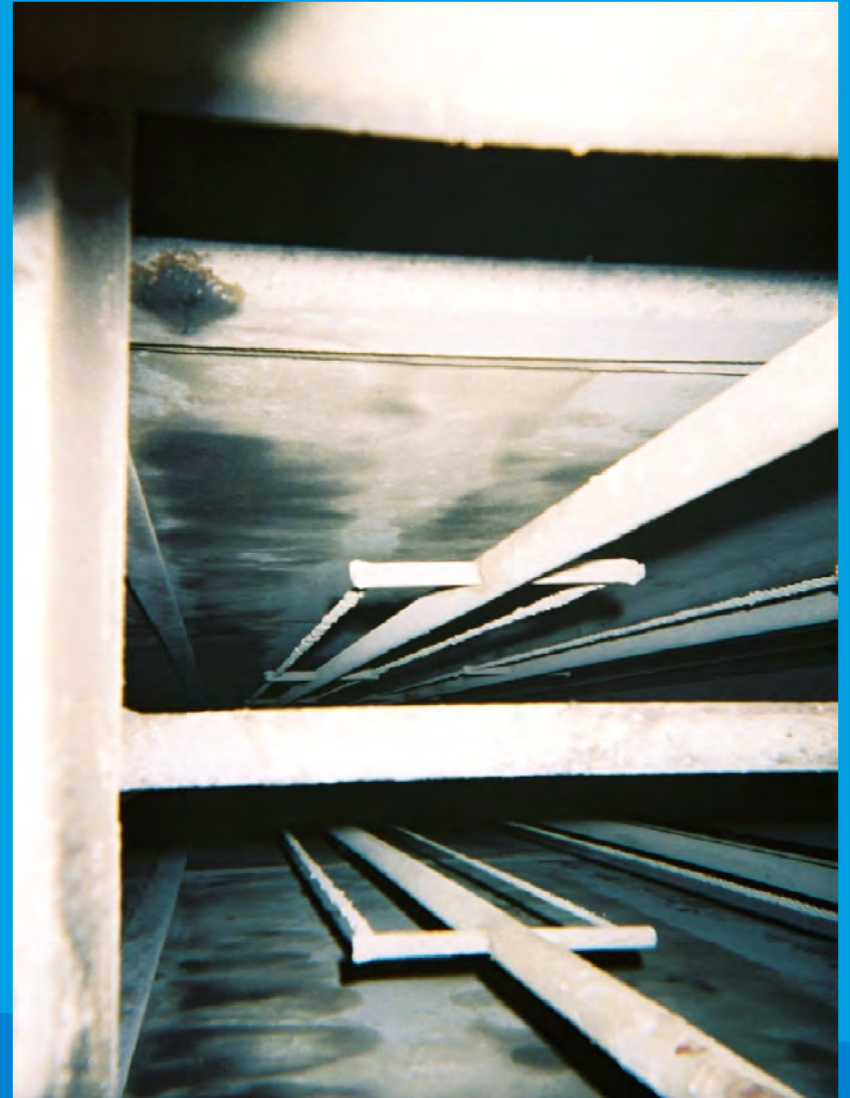
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# Strung Mast Design



Strung Mast Electrode



# Bedframe Design

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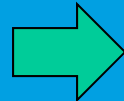
# Bedframe Design

KC Cottrell Inc. 



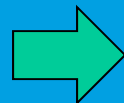
# Common Precipitator Upgrade Methods

Minor Improvements



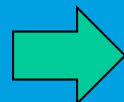
Controls, SMPS, Gas flow studies

Moderate Rebuilds



Gut & Stuff, Sectionalize Fields

Major Upgrades

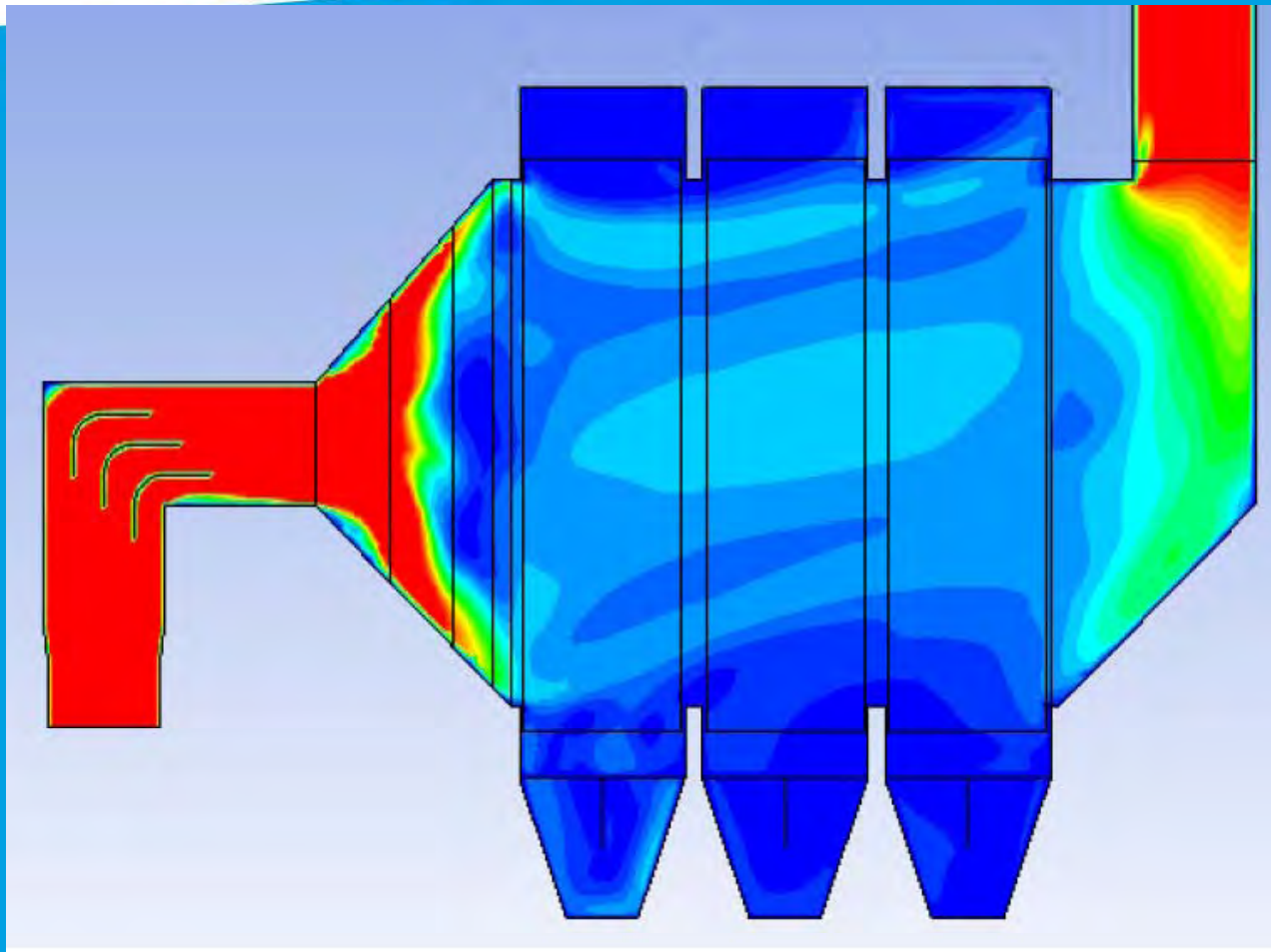


Increase Treatment Time

# Minor Improvements

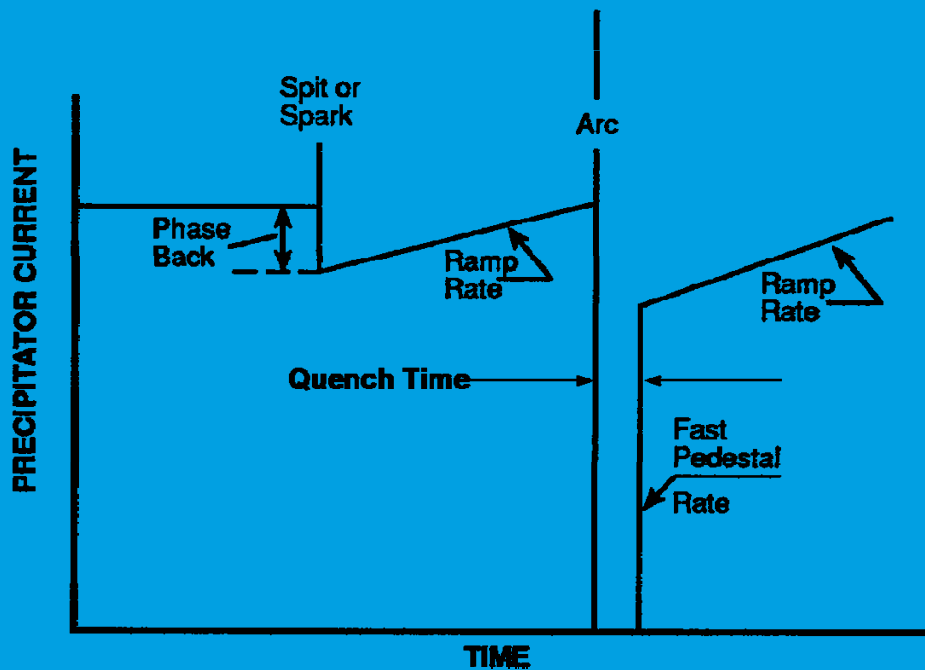
- Gas Flow Modeling and/or CFD Models to add or modify existing flow distribution devices
  - Objective to meet ICAC criteria
  - Reduce pressure loss
- SO<sub>3</sub> conditioning used to improve electrical characteristics of fly ash (improve resistivity)
- NH<sub>3</sub> conditioning used to agglomerate fly ash particles
- Flue gas conditioning used in an effort to offset the adverse affect of low sulfur coal, particulate fines, and high resistivity.

# Minor Improvements - Gas Flow Modeling

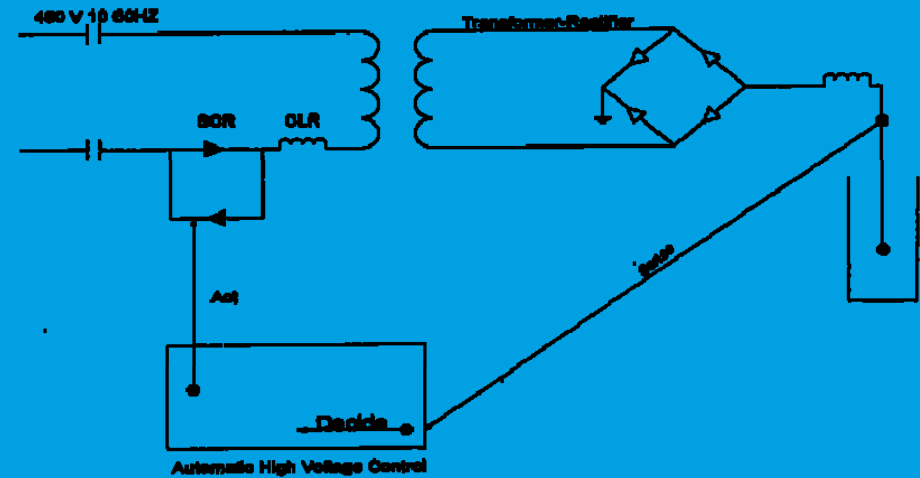


# Electrical Upgrades

- Nearly all ESPs have been updated with microprocessor based automatic high voltage controls (starting in the early 1980s)



## Precipitator Automatic Voltage Control



- 1.) Sense: Reads ESP Operating Conditions
- 2.) Decide: Control Makes Intelligent Decision
- 3.) Act: Control Modifies Operating Level Of TR

# Electrical Upgrades

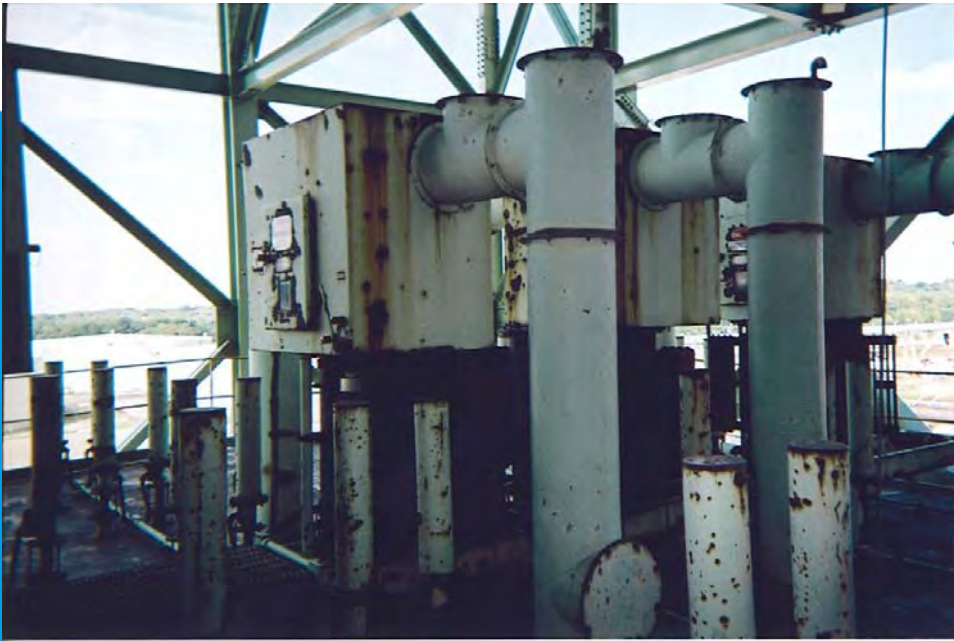


Mechanical Rectifier



External Solid State Rectifiers  
Replaced Vacuum Tube diodes

# Electrical Upgrades



The conventional Transformer Rectifier



# Electrical Upgrades

Switchmode Power Supplies have been the trend for the last 10 years



# SMPS

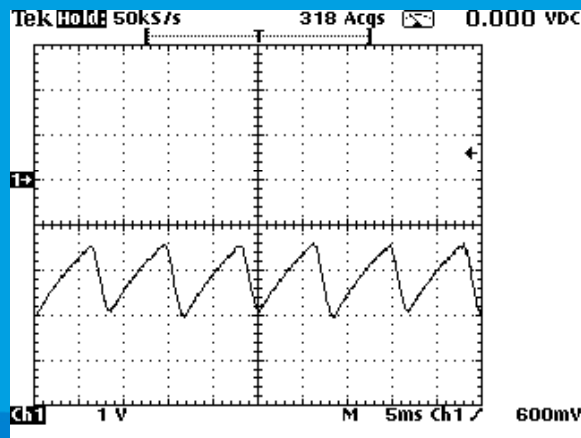


< Before & After >

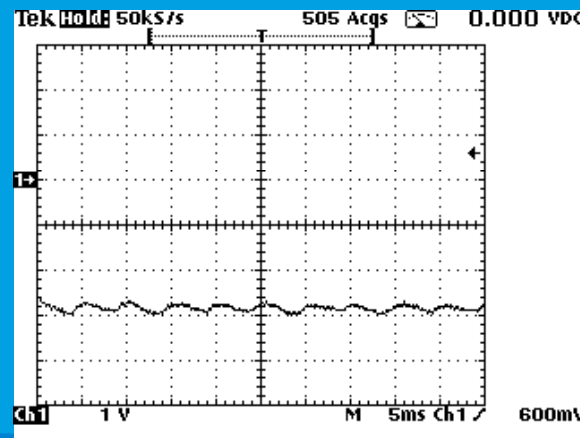
1. High Frequency T-R (Khz) enables smaller and lighter equipment
2. Power Factor - Input kVA is less than existing (with 3 Phase)
3. Average Output is higher than existing (Elevated Average Voltage)
4. Fine Tune for On/Off time during intermittent operation
5. Short Arc Shutdown time enables higher power with faster voltage recovery

# SMPS (cont'd)

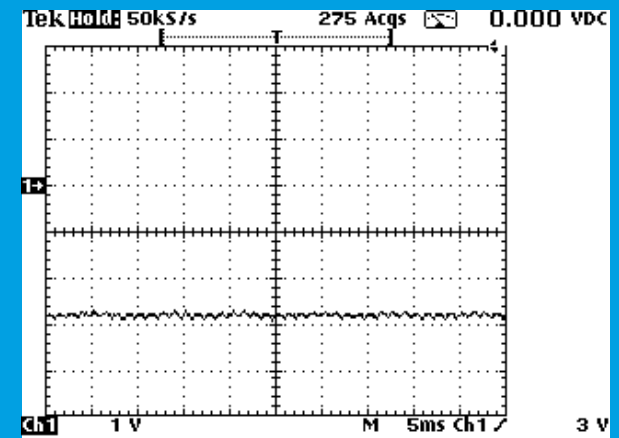
- Reduces ripple, average kV approaches peak kV
- Increases kV can be attained on inlet and middle fields that are often spark constrained.
- Small kV increase often results in significant increase in current
- 5-10% kV increase can result in total power level increase >20%
- Fast recovery following spark/arc condition



60 HZ WAVEFORM



100 HZ WAVEFORM



400 HZ WAVEFORM

Courtesy of Redkoh

# Impact on Performance

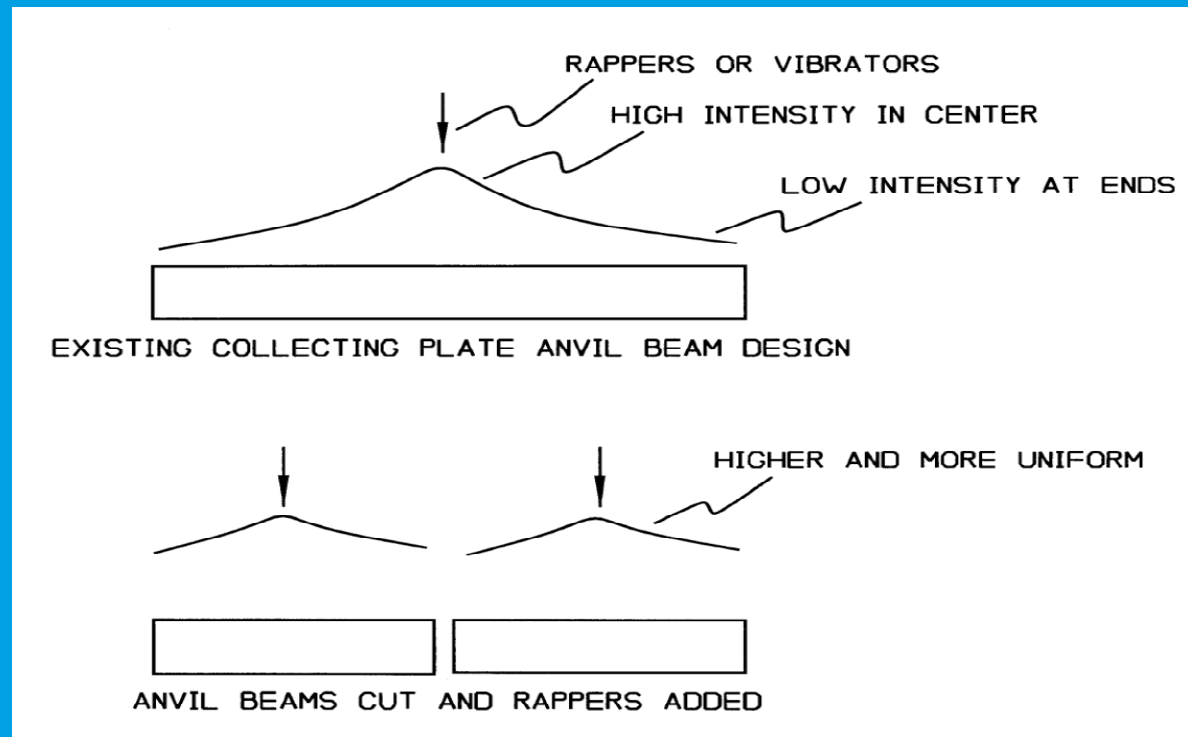
- Increase electrical sectionalization by adding TRs or Switch Mode Power Supplies
  - Reduces amount of collecting area affected by spark or upset condition.
- OEM's are claiming sizing credits between 10-20% with SMPS
  - Most effective on inlet fields with high loading (high spark rates)
  - Benefits low sulfur applications
- Recent interest in precipitator studies and upgrades due to MATS limits and ACI / DSI opportunities.
  - Ca based sorbents have adverse effect on resistivity
  - Na based sorbents improve resistivity
  - Inlet loading increase with both types of sorbents

# Common Upgrades

- Tumbling Hammer to Top Rapping Conversion.
  - Top rapping systems using magnetic impulse type rappers offer more flexibility for changing intensity and rapping frequencies
- Splitting anvil beams
  - Older P-C ESPs had as many as 9 or 10 CE's per anvil beam
  - Splitting anvil beams increases rapping density and sectionalization, reduces fly ash re-entrainment

# Common Upgrades

- Splitting anvil beams



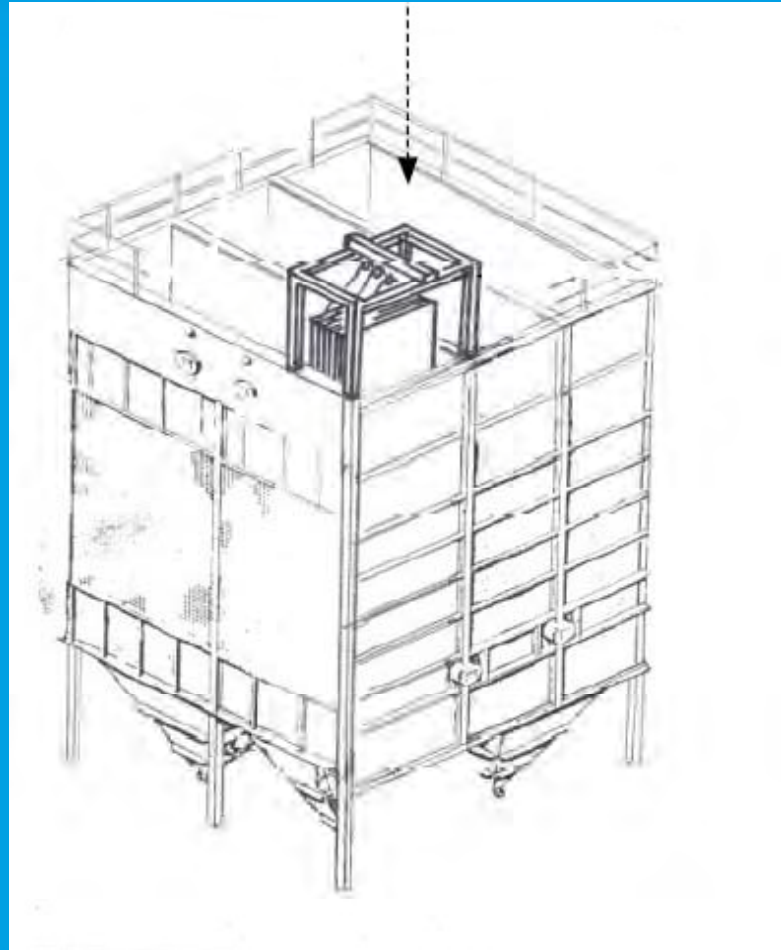
# Moderate Rebuilds

- Most common approach is “Gut and Stuff”
  - New internals for increased reliability
  - Gas passage spacing can be modified to reduce weight and costs
  - Auxiliary equipment can typically be reused
    - Transformer Rectifiers
    - Rappers
    - Seal air system
    - HV support system
  - No increase in treatment time

# Precipitator Casing

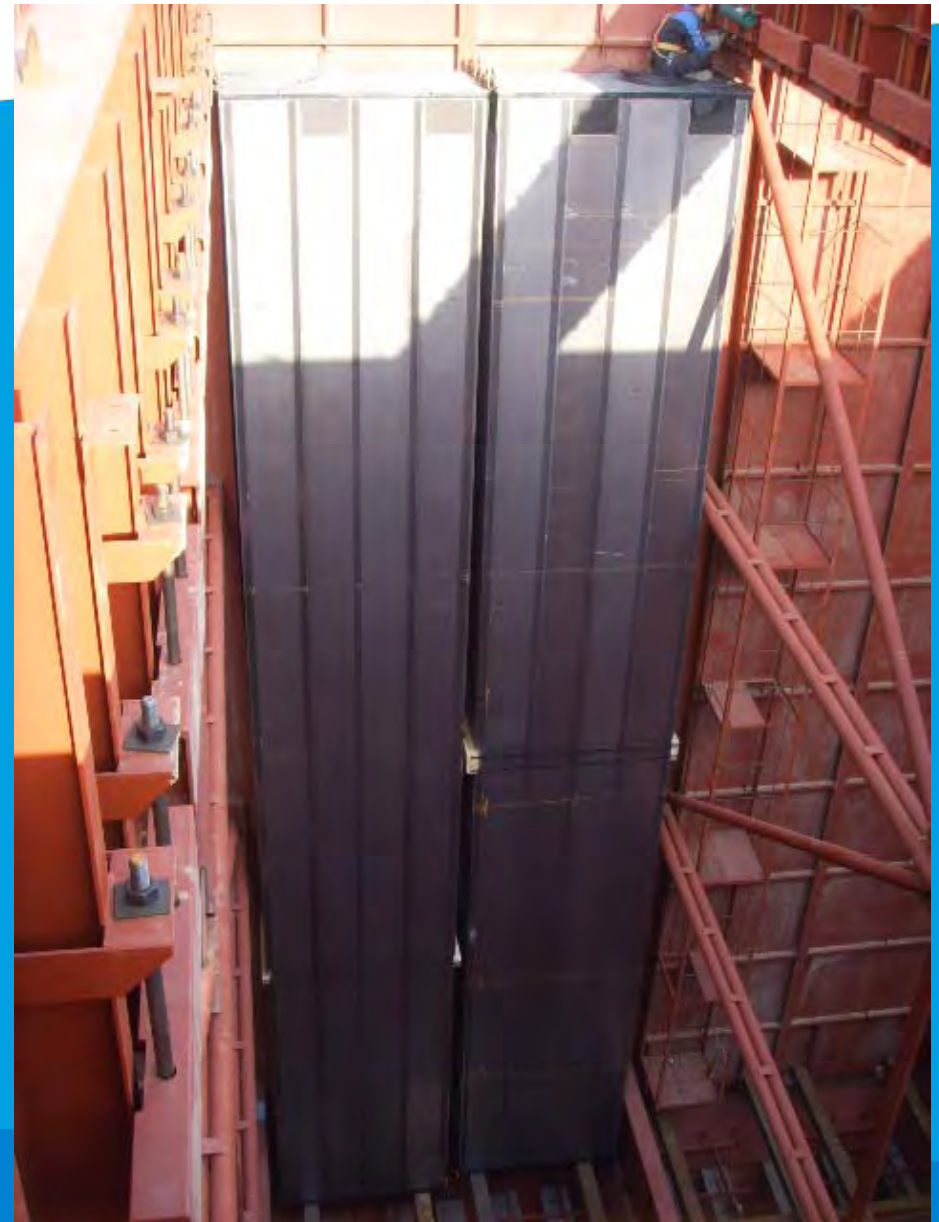
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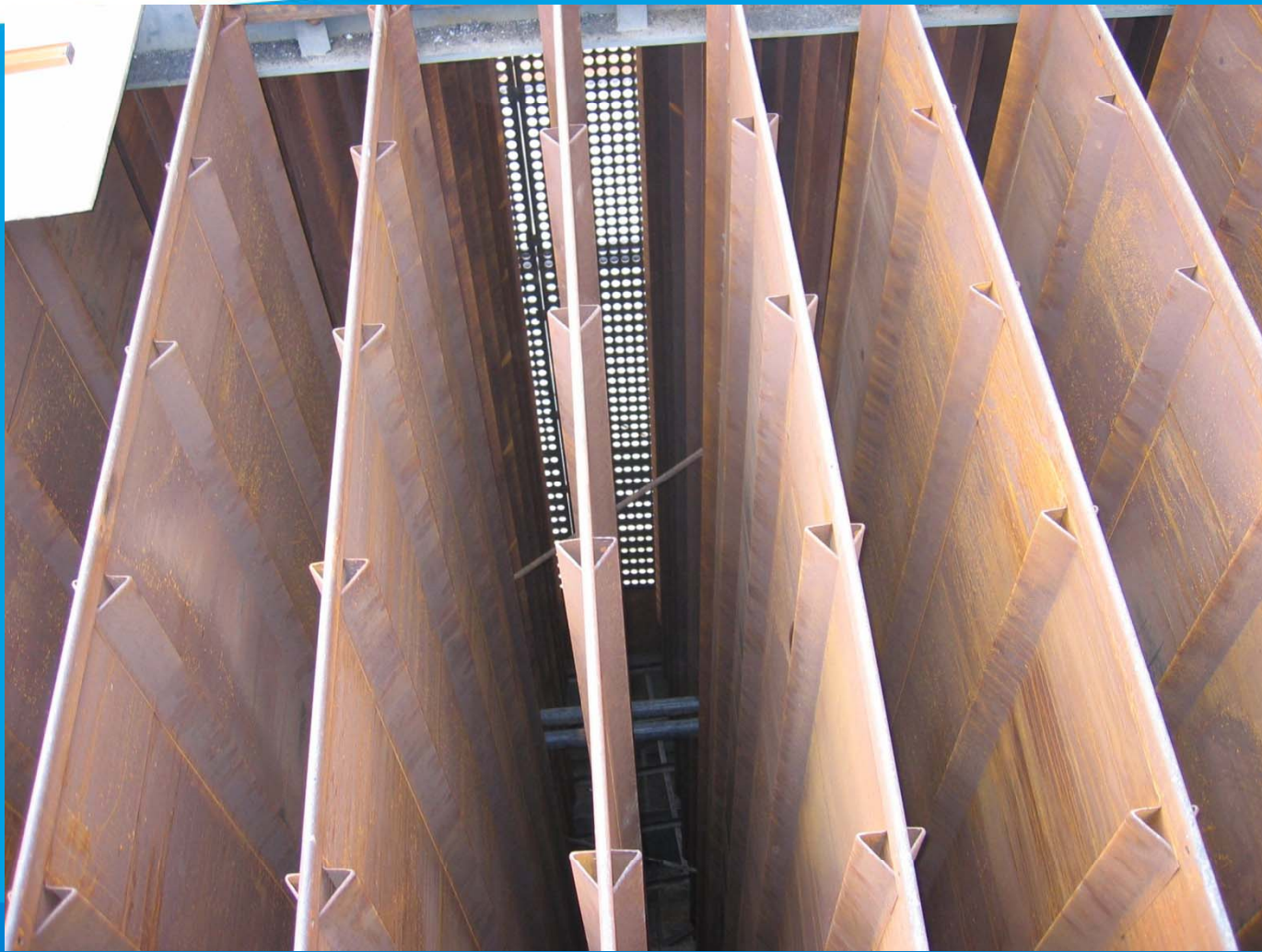
# Installing CEs

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# Installed Collecting Plates

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# Installed Collecting Plates

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# HV Framework

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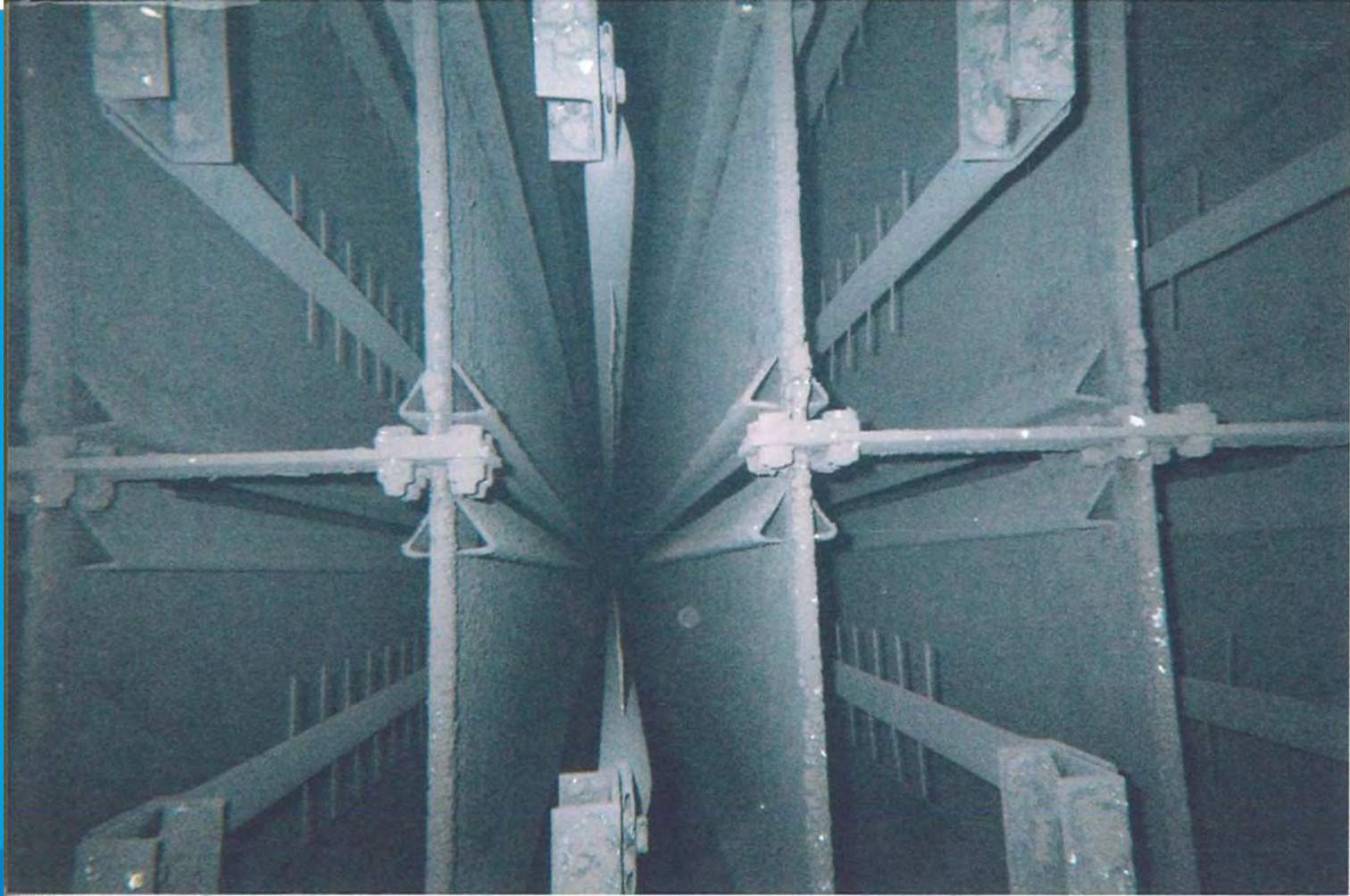
# Discharge Electrode Install

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# Pipe & Spike Electrodes

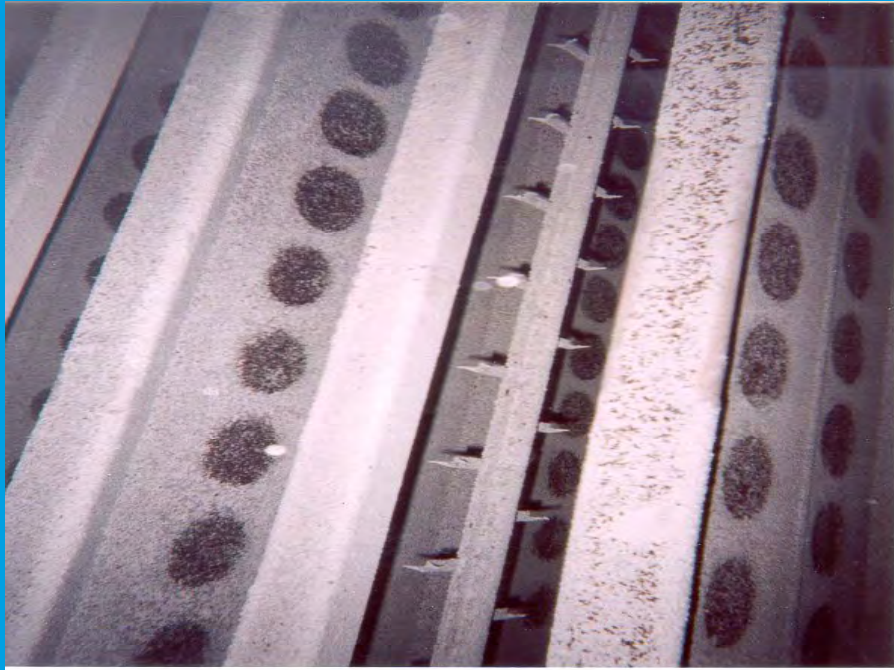
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# Common Upgrades

- Rebuild Options
  - Upgrade to more aggressive electrodes on inlet field
  - Common upgrade for high inlet dust loading or non-ideal electrode geometry (corona generator design and spacing)

# Electrode Geometry

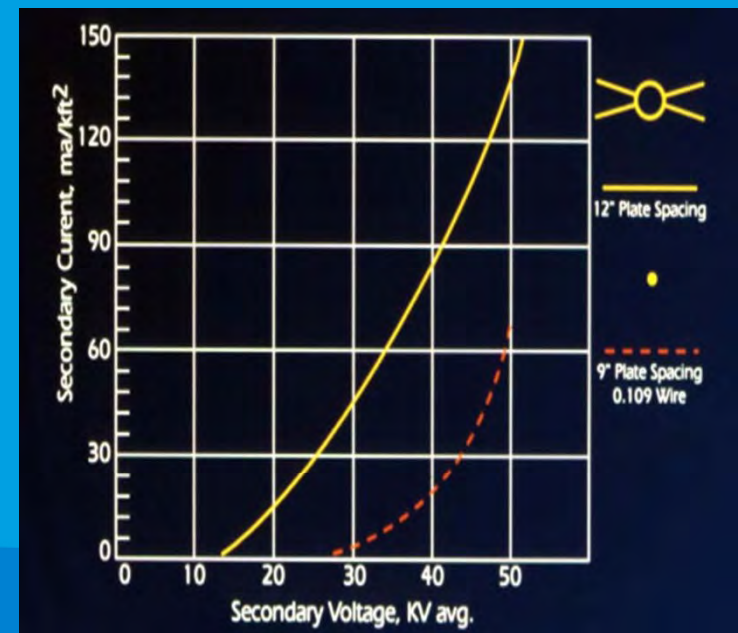


# Electrode Geometry



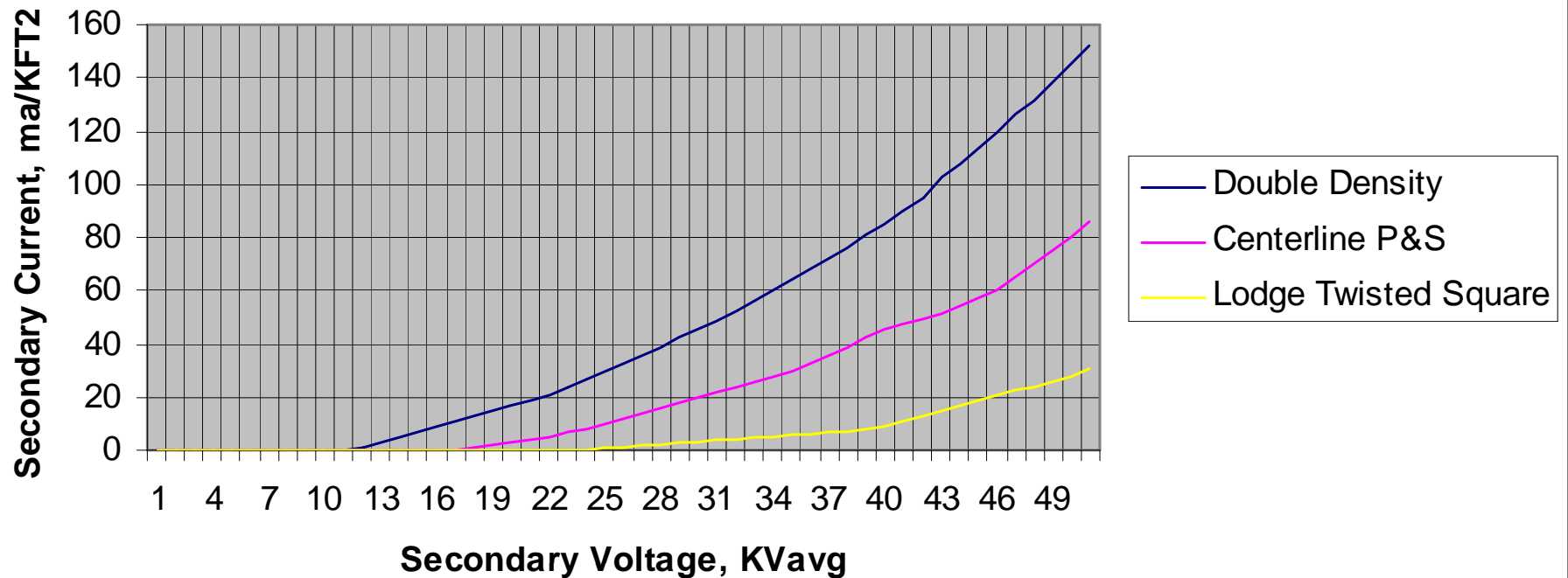
# Electrode Upgrades

- Rebuild Options
  - Rebuild Weighted Wire ESPs [9” to 12” spacing]
    - Existing T-Rs can be re-used with more aggressive electrodes
    - Lower corona onset or “starting voltage”
    - Increase power density

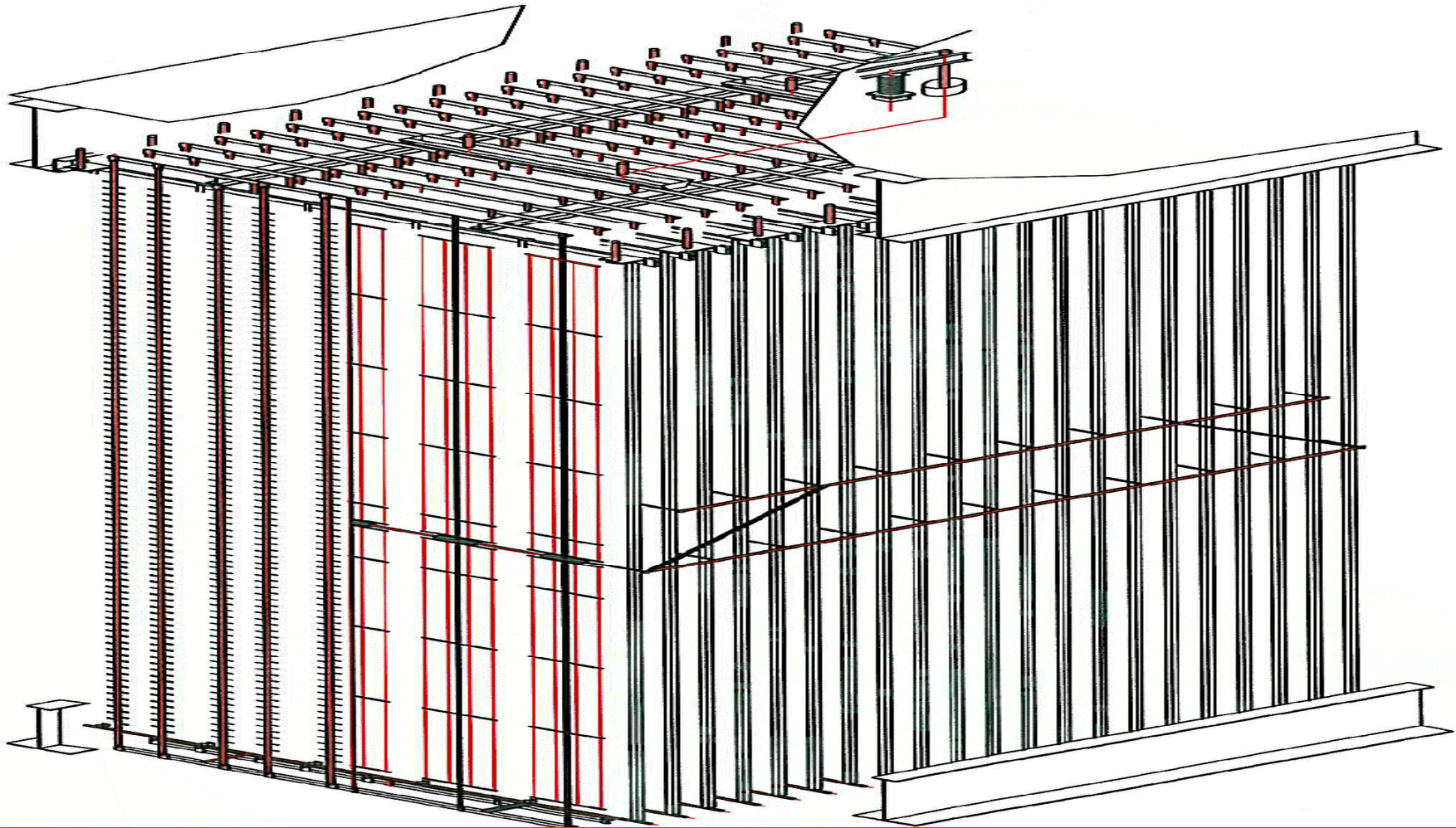


# Electrode Geometry and V/I curves

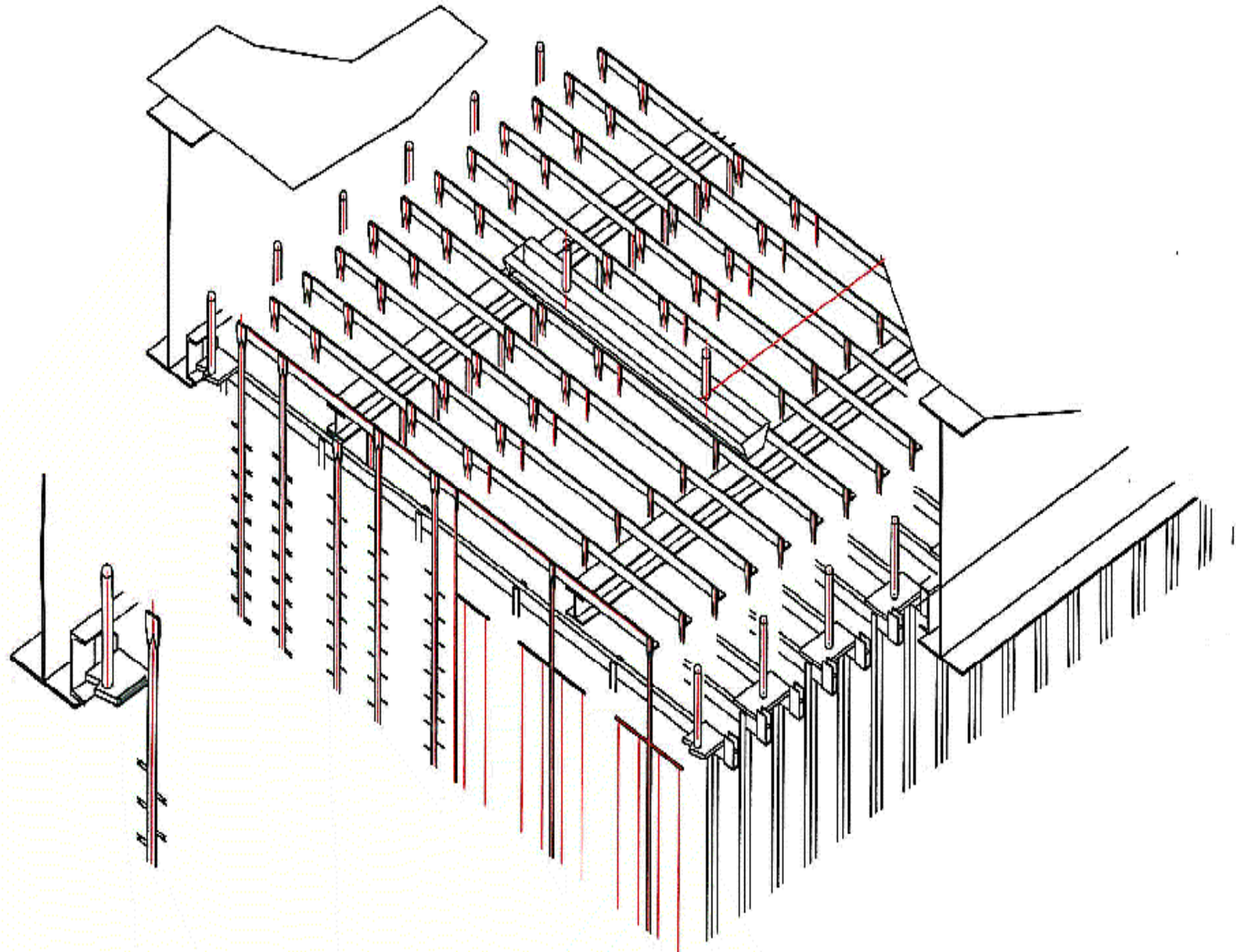
ESP Airload Data, 12" Collecting Plate Spacing



# Electrode Upgrade



# Electrode Upgrade



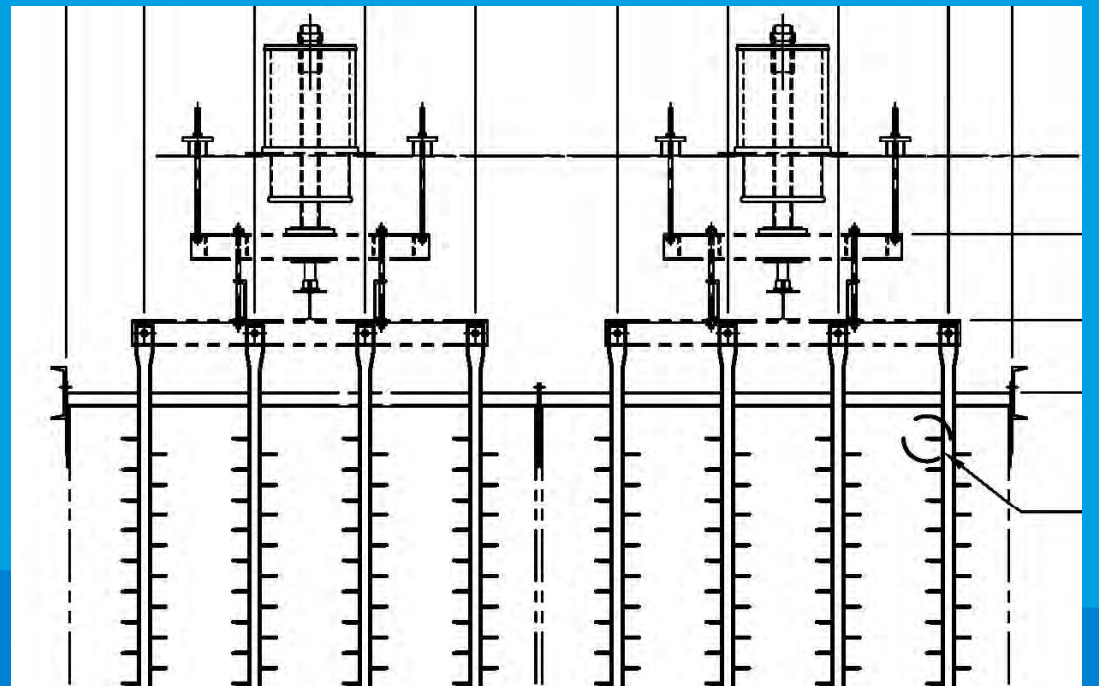
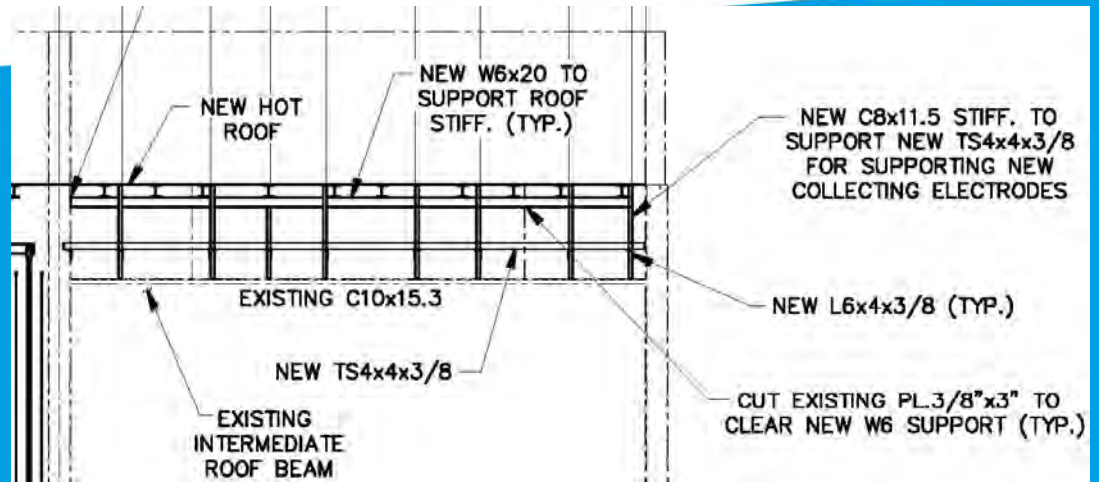
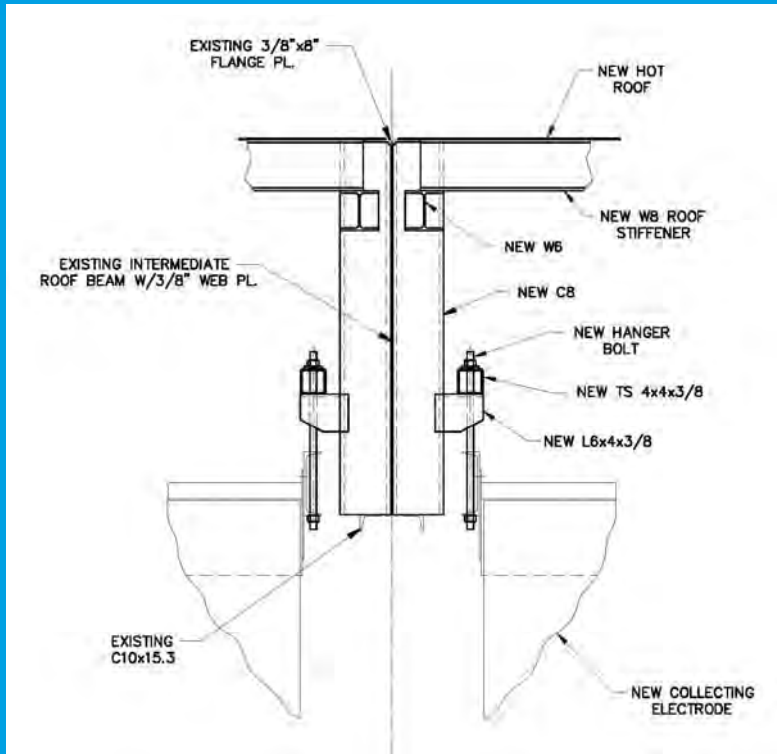
# “Gut and Stuff” Rebuilds



# “Gut and Stuff” Rebuilds

- Collecting plates & discharge electrodes are supported from above
- Determine opening between support girders or box beams
- Domestic collecting plate sizes vary between 4.5’-12’ and can be bolted together in the field up to 16’
- Plates bolted to anvil beams suspended by high strength bolts from girder supports (due to top rapping forces)
- No. of discharge electrodes is determined based on CE panel spacing

# “Gut and Stuff” Rebuilds



# Plates bolted together



# “Gut and Stuff” Rebuilds

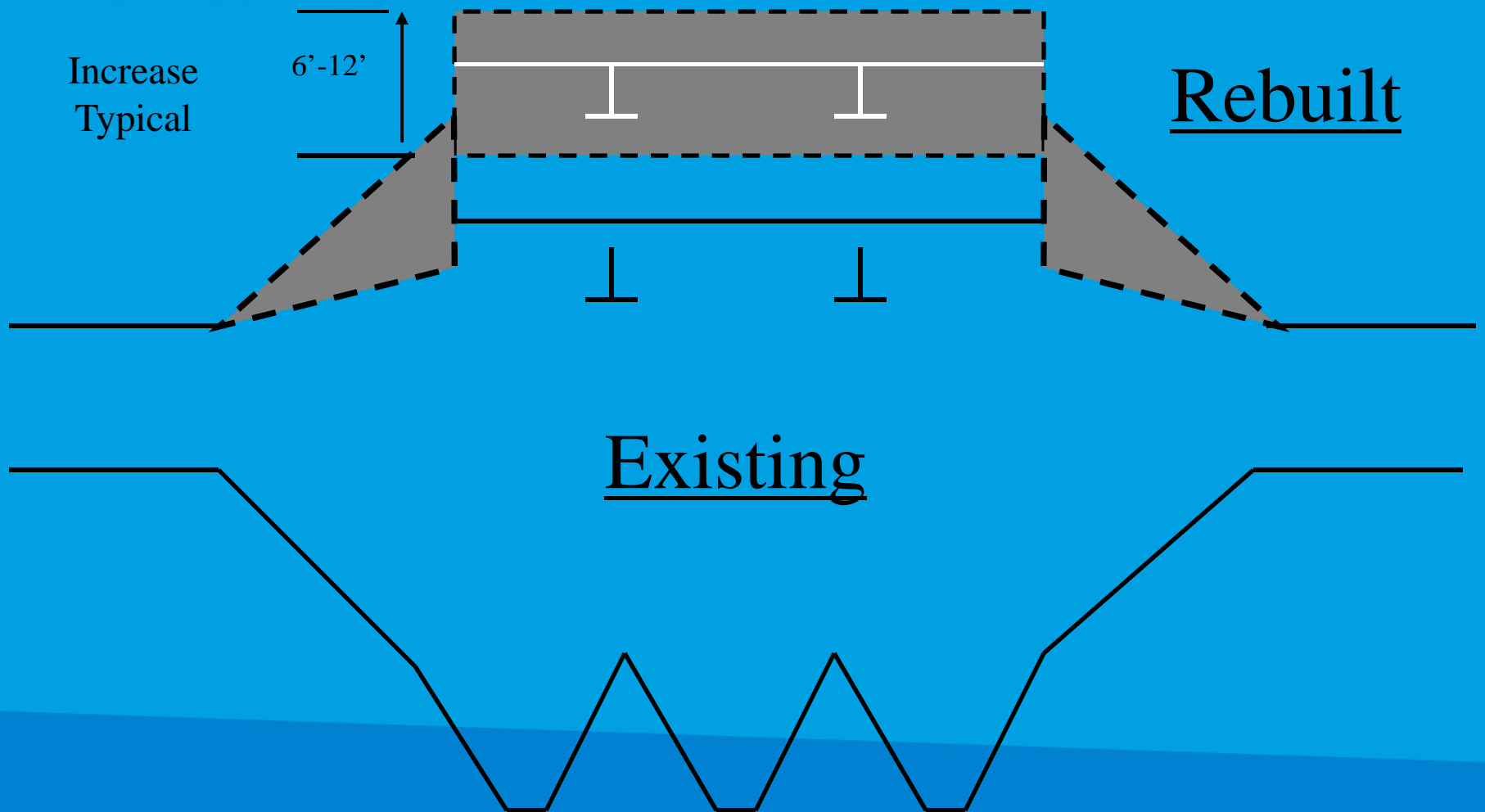
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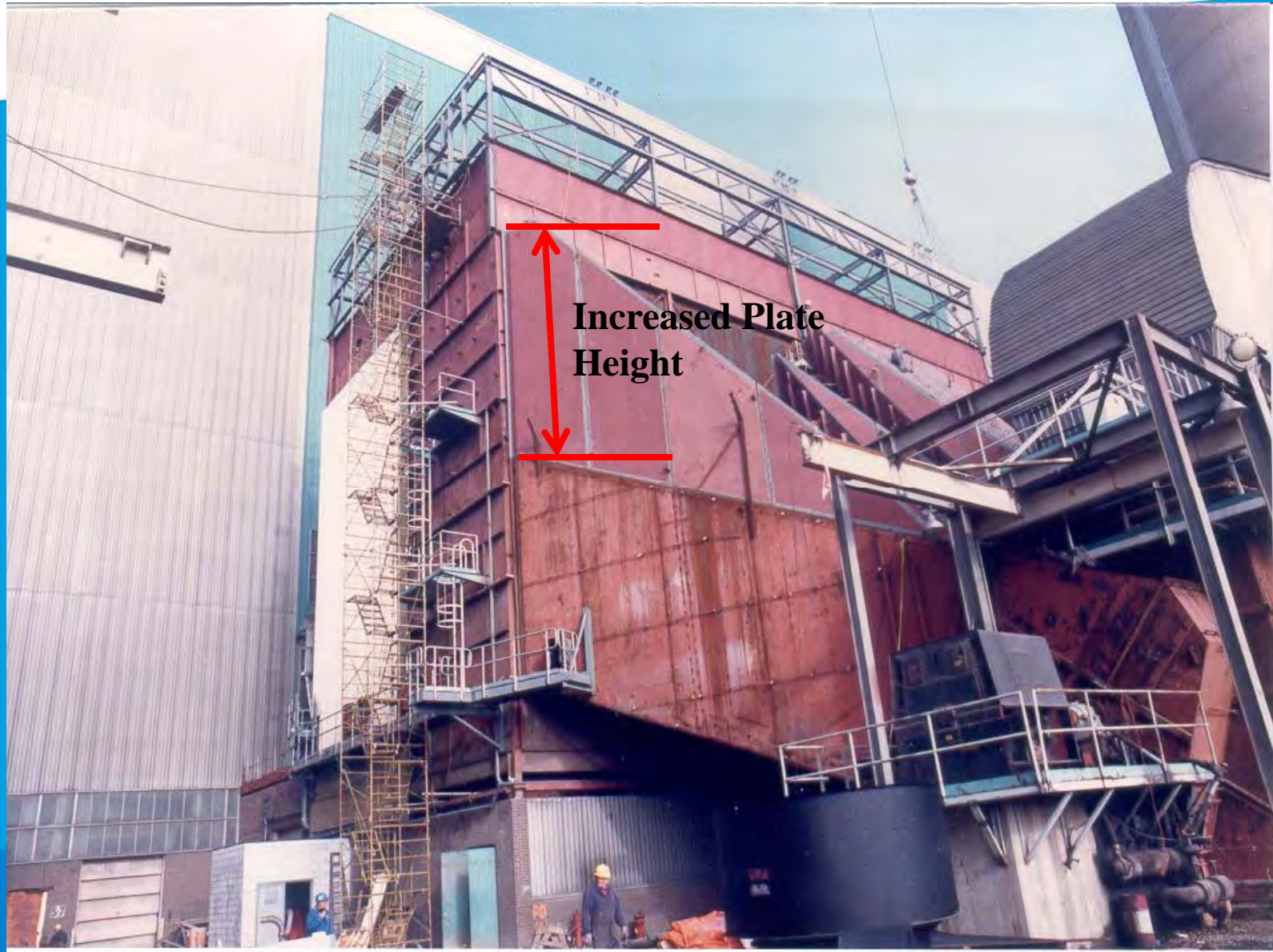
# Major Upgrades & Expansions

- Target increase in Treatment Time
  - Increase height of Collecting plates
    - Resulting in lower gas velocity at same treatment length
  - Add additional fields
    - Resulting in more treatment length at the same velocity

# Enlargement by Increased Height



# Enlargement by Increased Height



# Collecting Plate Height Trends

<u>Year</u>	<u>Collecting Plate Height, Feet</u>
• 1940's	17-20
• 1950's	17-24
• 1960's	24-30
• 1970's	24-36
• 1980's	24-48
• 1990-Present	24-50

# Height Increase with Existing Support Structure

- Increasing the height of an existing precipitator while reusing the existing support structure.
  - Gas passage spacing increase allows for weight reduction
  - Plate height determined based on dead load, wind and seismic analysis
  - Bracing must be replaced and designed for site wind conditions
  - Support structure must be checked for live and dead loads
  - Flue opening and inlet/outlet ductwork replace or modify

# Height Increase with Existing Support Structure

- Example

- Existing Precipitator 1P, 1C, 39GP@9", 30' x 36' (4x9')

- 39 gas passages @ 9" Spacing = 29'-3" =>(40 Collecting plates)

Check for spacing at 400mm (15-3/4")

- $\frac{29'-3''}{15-3/4''} = 22 \text{ GP @} 15-3/4'' \text{ Spacing} \Rightarrow (23 \text{ Collecting plates})$

Weight check (single field)

- Collecting plate 9'x30' = ~900 lbs
- 900 lbs x 40 CE's = 36,000 lbs =>36 kips
- $\frac{36,000 \text{ lbs}}{23 \text{ CE's}} = 1,547 \text{ lbs per CE}$
- This equates to a 9' x 54' collecting plate => **not practical due to**

# Height Increase with Existing Support Structure

- Example (cont'd)

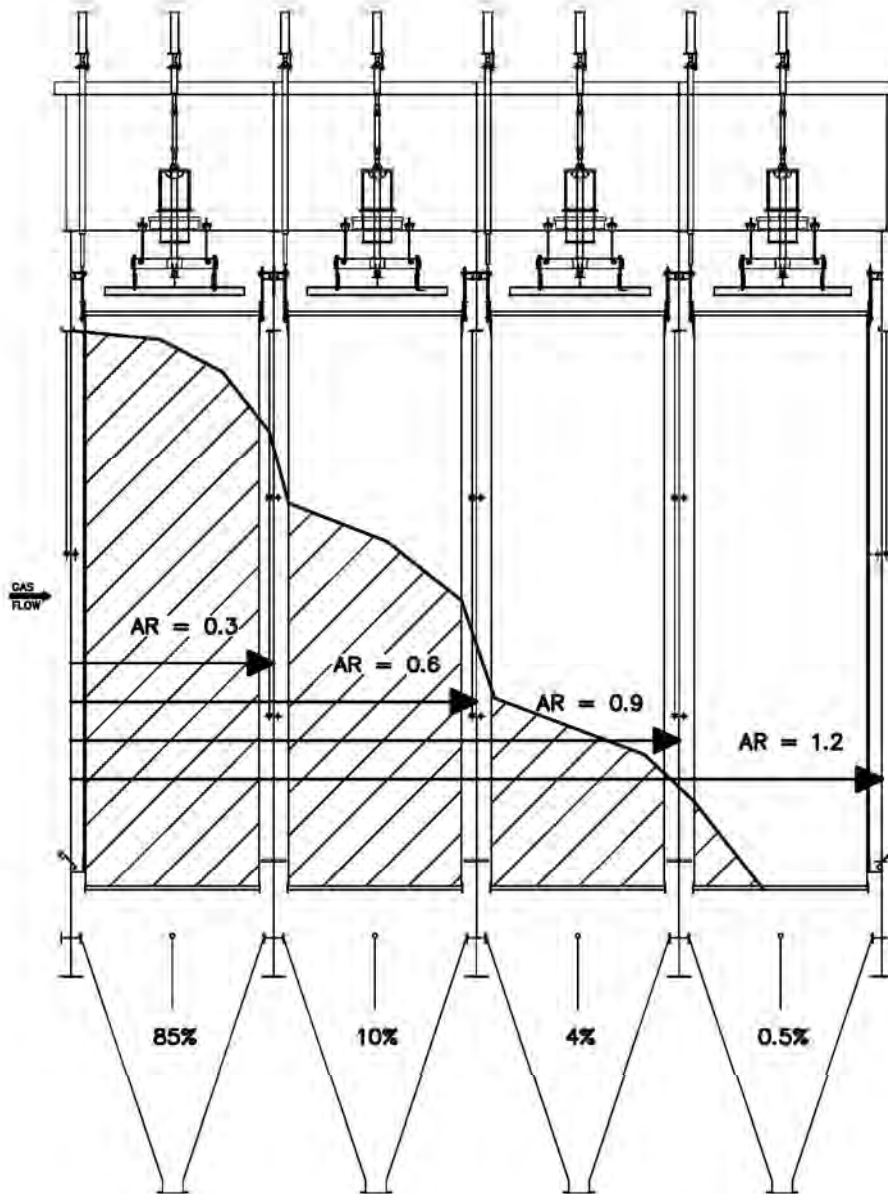
- *Aspect Ratio* =  $\frac{\text{Total Treatment Length}}{\text{C.E Plate Height}}$

- Industry standard min ~0.8 based on outlet emission rate requirement. **Why?**

- **NOT PRACTICAL**

- **GAS FLOW DISTRIBUTION**

- **FLY ASH NEEDS TO GET TO THE HOPPER !**



Basic Aspect Ratio & Fly Ash distribution with normal gas velocity

# Height Increase with Existing Support Structure

	OEM	CASE 1		CASE 2	
	39 GP @9" 30' CE	22 GP @15 3/4" <b>36' CE</b>	+/- % Change	22 GP @ 15 3/4" <b>38' CE</b>	+/-% Change
ASPECT RATIO	1.2	1.0	-16%	0.95	-20%
TREATMENT TIME	-	-	<b>+20%</b>	-	<b>+26%</b>
SINGLE CE WEIGHT (LBS)	900	1,050	+16%	1,100	+22%
TOTAL CE WEIGHT (KIPS)	<b>144</b>	<b>97</b>	-33%	<b>101</b>	-30%
TOTAL DE WEIGHT (KIPS)	<b>6</b>	<b>26</b>		<b>28</b>	
CASING EXTENSION WEIGHT (KIPS)	<b>0</b>	<b>10</b>		<b>13</b>	
<b>TOTAL WEIGHT (KIPS)</b>	<b>150</b>	<b>133</b>	-11%	<b>142</b>	-5%

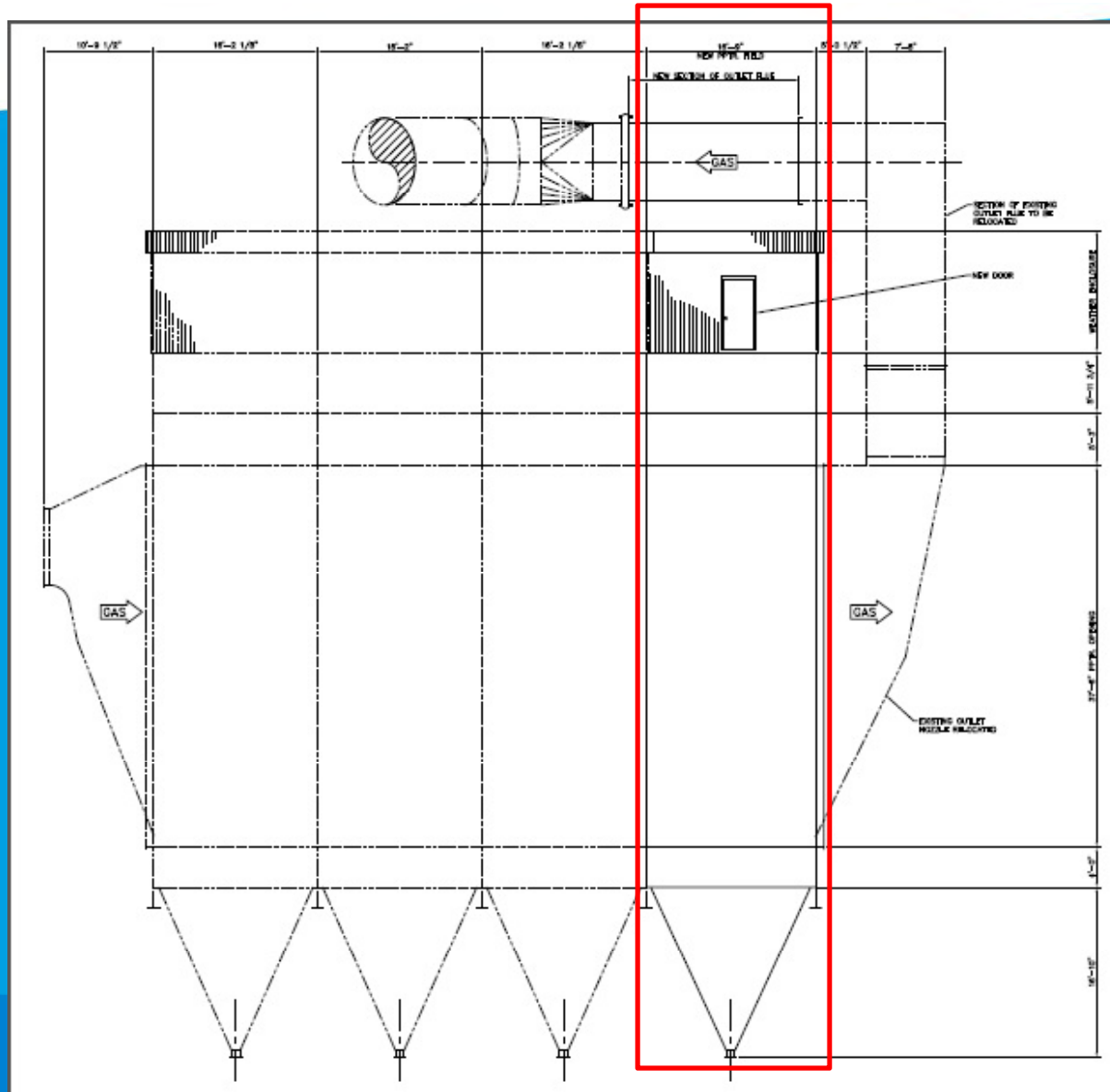
# Height Increase with Existing Support Structure

- Example (cont'd)
  - Loads do not account for weight increase on modified diffusers, gas distribution equipment. (to match larger flue opening) or any additional equipment.
  - Most critical load with taller casing is the **net increase** in uplift (due to Side Frame Height increase and possible decrease in dead load)
  - Check wind and seismic loads on below structures
  - Typical support structures and foundations designed >30% SF
  - Precipitator bracing must be replaced
  - Precipitator anchor point and hold downs

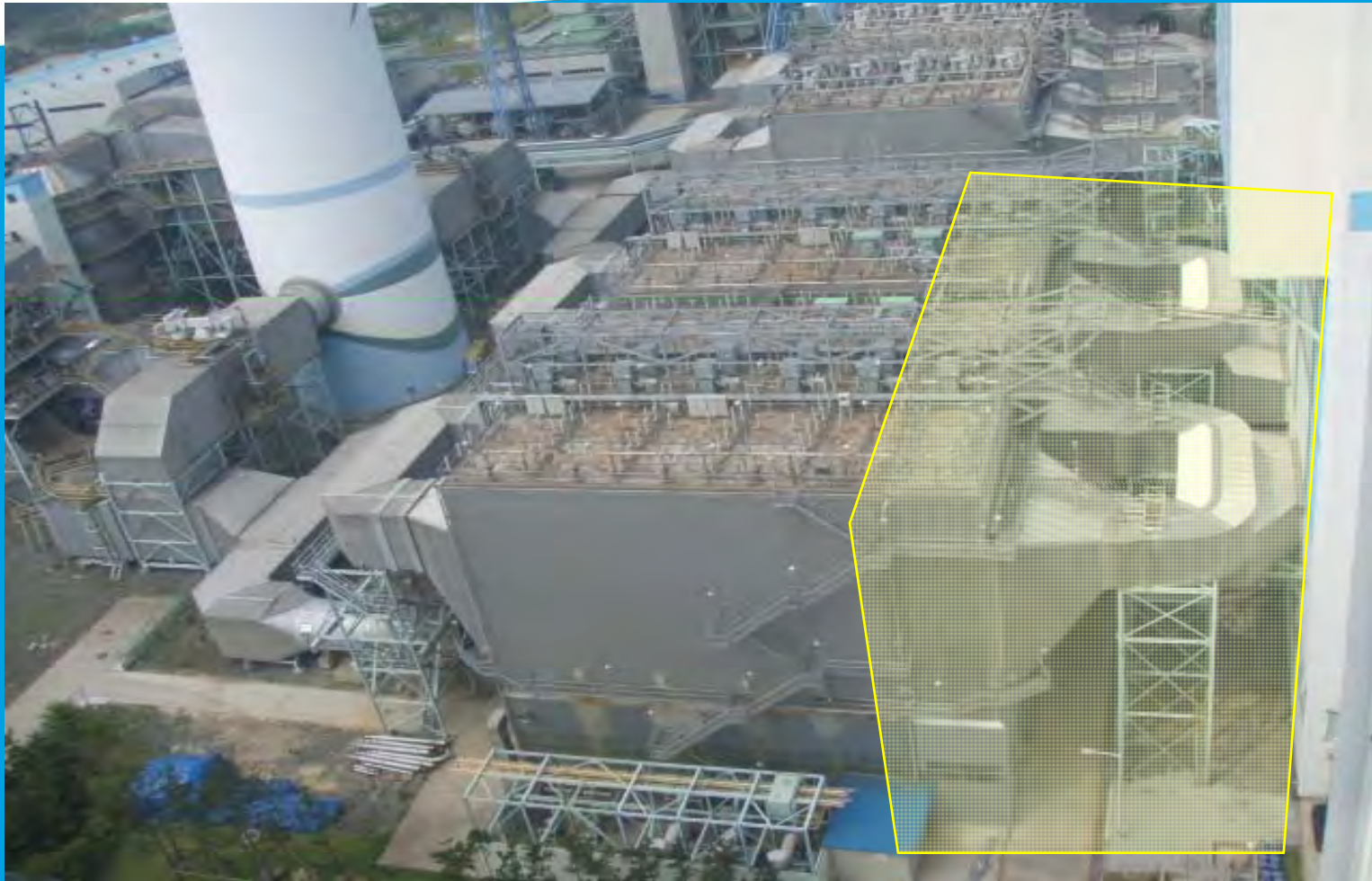
# Height Increase with Existing Support Structure

- Example (cont'd)
- Summary:
  - By increasing the GP spacing from 9” to 15-3/4”, Collecting plate height can be increased approximately 20% without significant changes to the structure below.
  - This type of rebuild is most beneficial on units with 30-36’ tall plates and 3 or 4 mechanical fields.

# Enlargement by Adding Fields



# Enlargement by Adding Fields



# Enlargement by Adding Fields

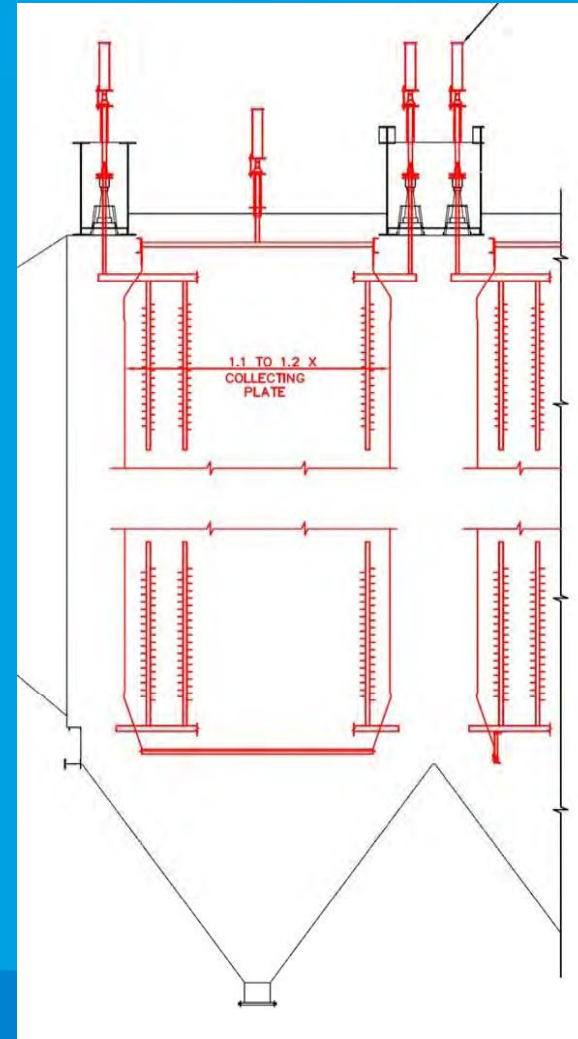
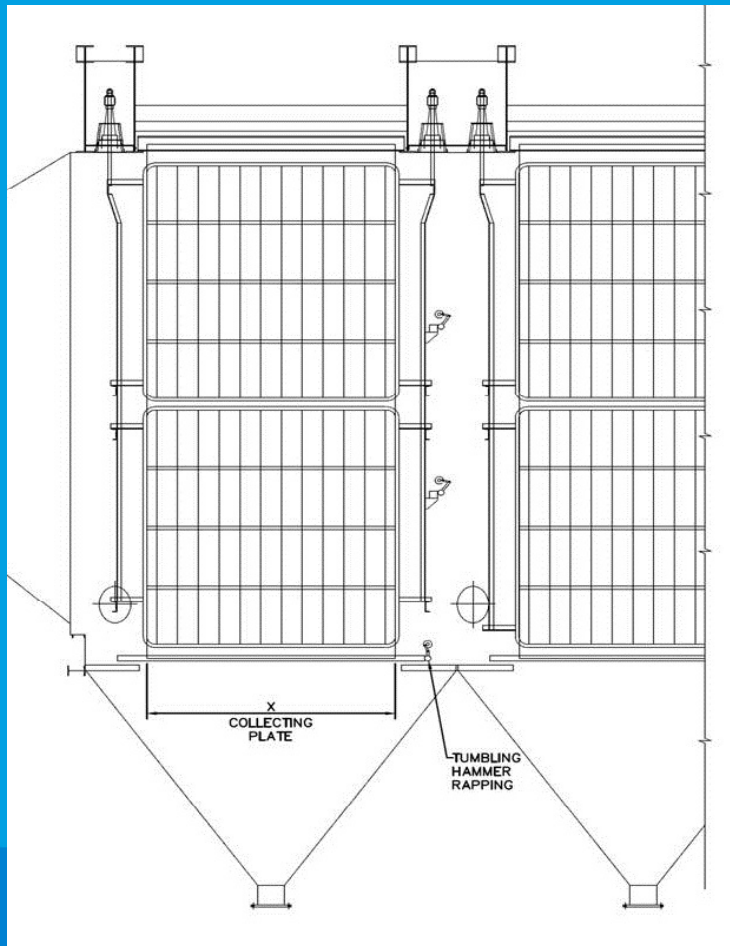
- Modify outlet flue work
- Design and supply additional support steel for extra field
- Extra treatment time has significant impact on performance
- 10% increase in volume can increase emissions 30%

- Modified Deutsch equation: 
$$E = 1 - e^{-\left(\frac{SCA \cdot Wk}{16.67}\right)^X}$$

# Rebuilding European Precipits to increase Treatment Time

- Concept has been used in the UK and USA, originally to rebuild concrete reinforced precipits
- Increase plate area by utilizing space between fields (used for tumbling hammer systems, HV truss system etc.)
- CE's expand below support girders for additional plate area
- In most cases, discharge electrodes can be added (in series) to maintain good power density and provide additional corona discharge.

# Rebuilding European Precipitators to increase Treatment Time

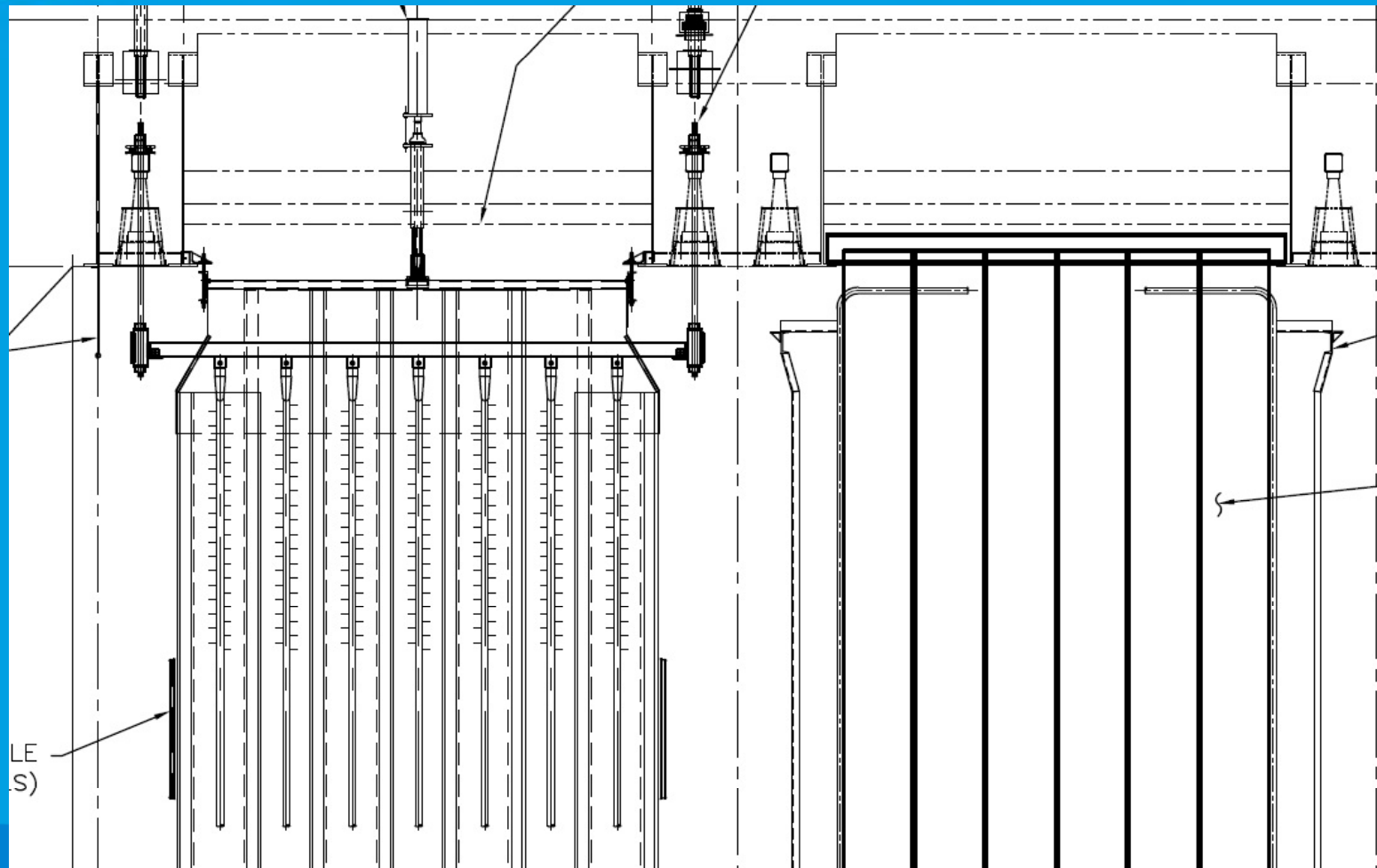


# Rebuilding European Precips to Increase Treatment Time

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# Bullnose CE, Extra DE

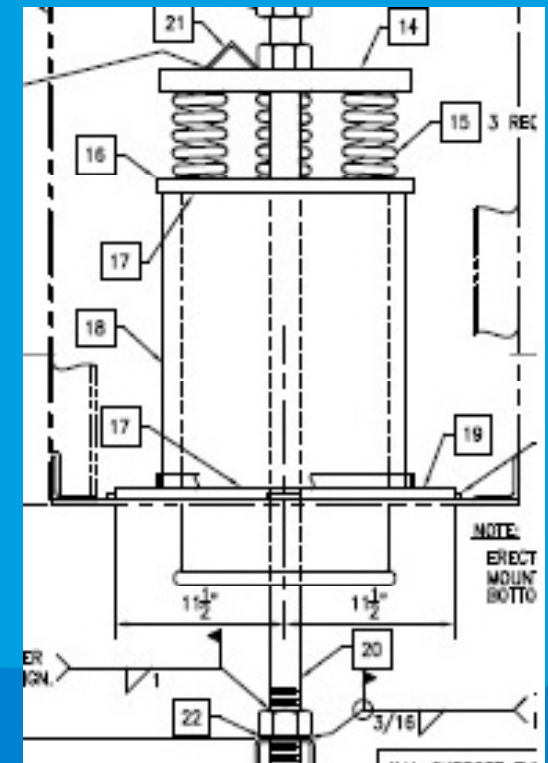


# Rebuilding European Precip to increase Treatment Time

- Determine opening between girders
- Check for obstructions between fields after rapping equipment is removed
  - ex) Flow devices, tumbling hammers, bracing
- Space between existing fields can range between 4'-8'
- New bullnose CE's can range 10-15% larger (ft<sup>2</sup>)
- Analyze CE weight increase for support system
  - Older style panel plates with channel support tend to weigh more than modern plates
- Typical weight decrease on HV support system due to removal of external framework for stabilization and tumbling hammer system

# Rebuilding European Precipits to increase Treatment Time

- Rapping system can be converted to USA style magnetic impact rapper from top
- CE and DE supports require rod suspension and/or spring support integration to prevent weld and/or HV insulator breakage. This is especially important when rapping at the support insulator locations.



# Rebuilding European Precips to increase Treatment Time

- Existing HV frame supports scan be re-used
- Due to top rapping forces, springs are used at the 4 support locations



# Existing



# New Collecting Plate

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# New CEs and DEs

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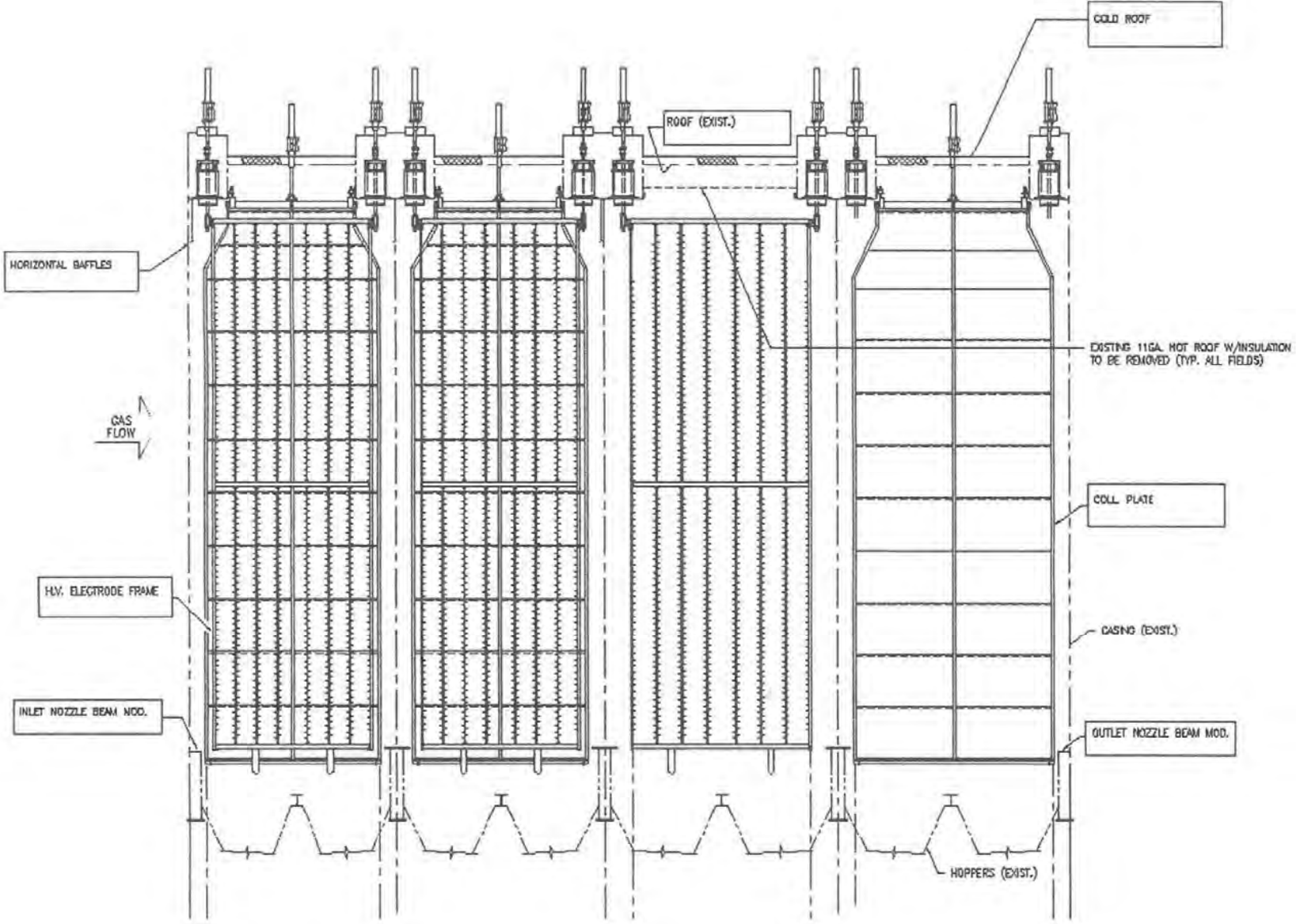


# Magnetic Impact Type Top Rapping System

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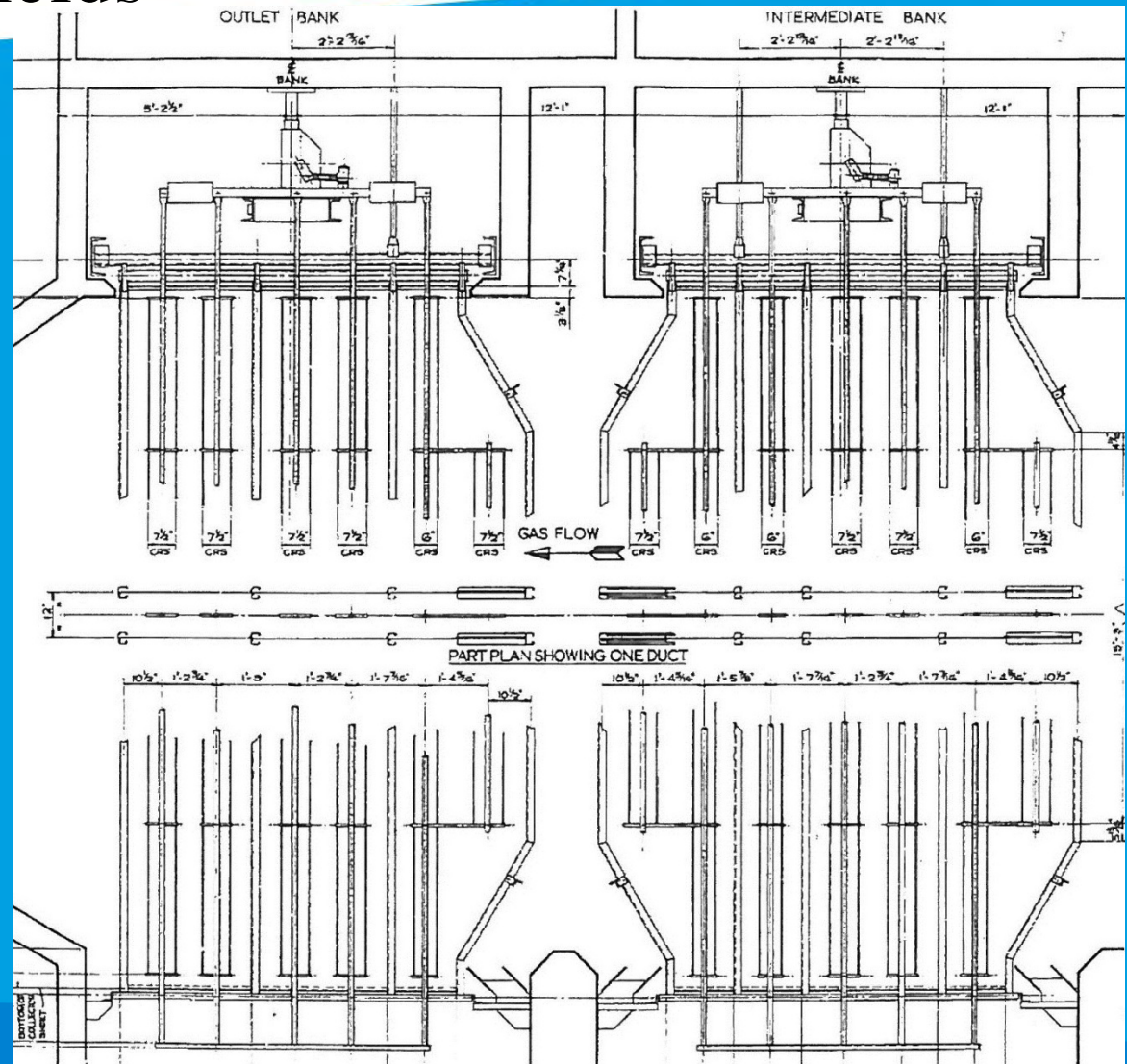


# Rebuilds Utilizing Space Between Fields



# Rebuilds Utilizing Space Between Fields

- Utilizing Winged CE & Outrigger DE





# QUESTIONS ?



# THANK YOU