# New Learnings and Strategies for Meeting Future Recovery Boiler PM Limits with Existing ESPs

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# Notes Regarding This Work

- This presentation was previously given at TAPPI PEERS Conference in November 2020
- These findings are currently pending publication in TAPPI Journal in 2021

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# Introduction

- In the USA and Canada, local point of impingement requirements, opacity requirements, or stack concentration limits generally result in emission requirements of <100 mg/Nm$^3$
- The combination of increasingly stringent emission requirements and facilities' goal of maximizing boiler throughput makes attention to ESP performance a high priority

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# ESP Theory

- ESP Efficiency Equation: $$\eta = 1 - e^{-\frac{A_p \cdot w_d}{Q}}$$
- $\eta$ = collection efficiency $= \frac{C_{in} - C_{out}}{C_{in}}$
- $w_d$ = migration velocity (speed at which particles move towards collecting plate)
- $A_p$ = collecting plate area
- $Q$ = flue gas flow rate
- Increase in gas flow, inlet dust concentration cause increased emission
- Increase in collecting area, migration velocity cause decreased emission

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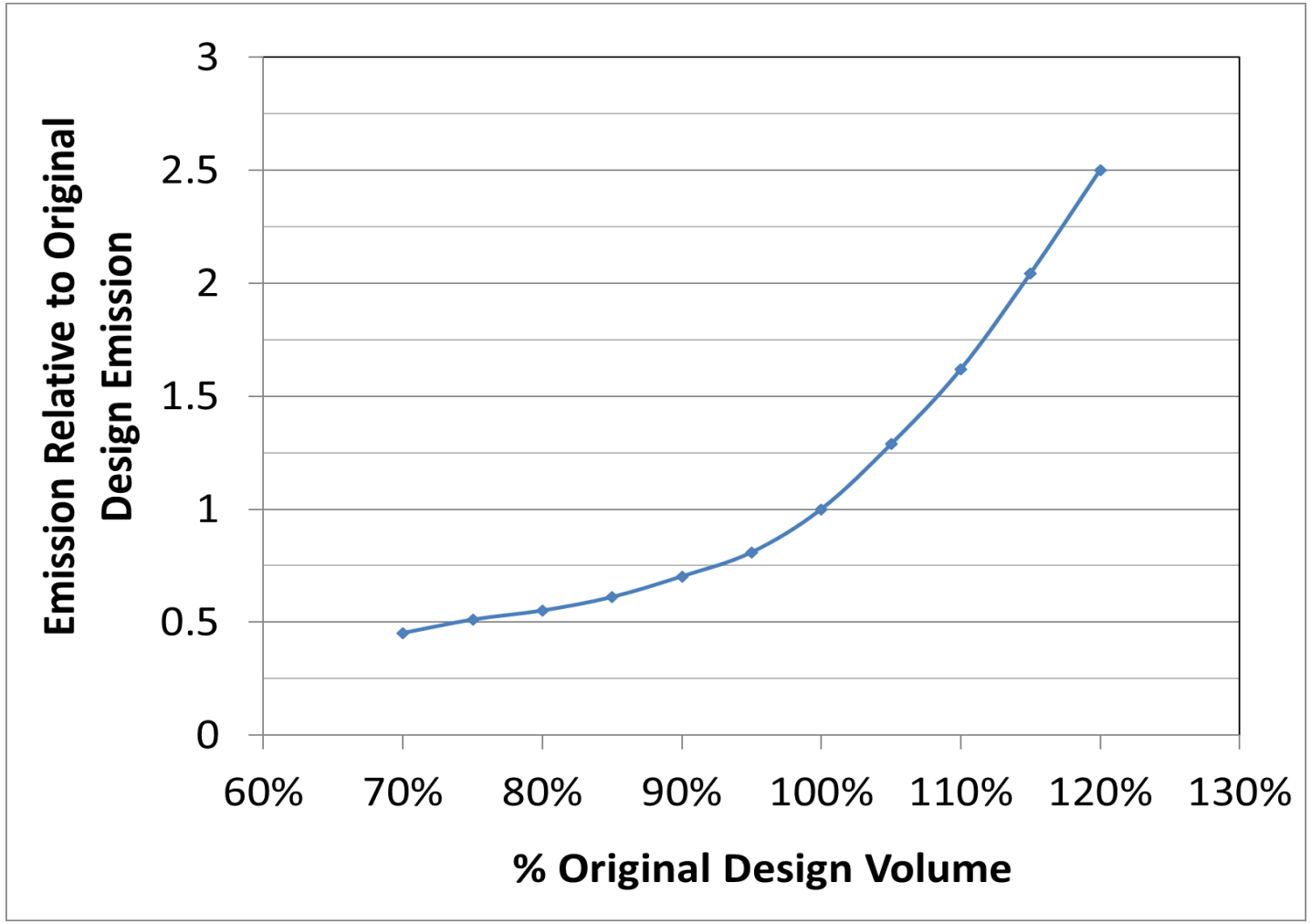
# Operating Parameters Affecting ESP Operation

| Parameter | Magnitude of Effect on ESP Operation | Type of Effect on ESP Operation |
|---|---|---|
| Flue Gas Volume | Significant | Emissions increase exponentially with increase in gas volume |
| Dust Loading | Significant | Emissions increase linearly with increase in inlet concentration |
| Moisture Content | Moderate | Migration velocity decreases with a decrease in moisture content, thus emissions increase |
| Particle Size | Minor | Migration velocity may decrease with a smaller particle size for particles > 0.5 µm in diameter, thus emissions may increase. However, below 0.5 µm, decrease in size may actually increase migration velocity. |
| Particle Composition | Minor | Migration velocity may decrease with a higher chloride content, thus emissions may increase |

# Effect of Increasing Boiler Firing Rate

- Increasing firing rate leads to increase in gas flow rate
- As previously discussed, increase in gas flow rate leads to a decrease in precipitator efficiency (for a given collecting area and migration velocity)
- However, increase in flow rate also leads to an increase in gas velocity, and a decrease in treatment time for a fixed ESP size
- This leads to a lower effective migration velocity
- Resulting effect on emissions is enormous

# Effect of Increasing Boiler Firing Rate

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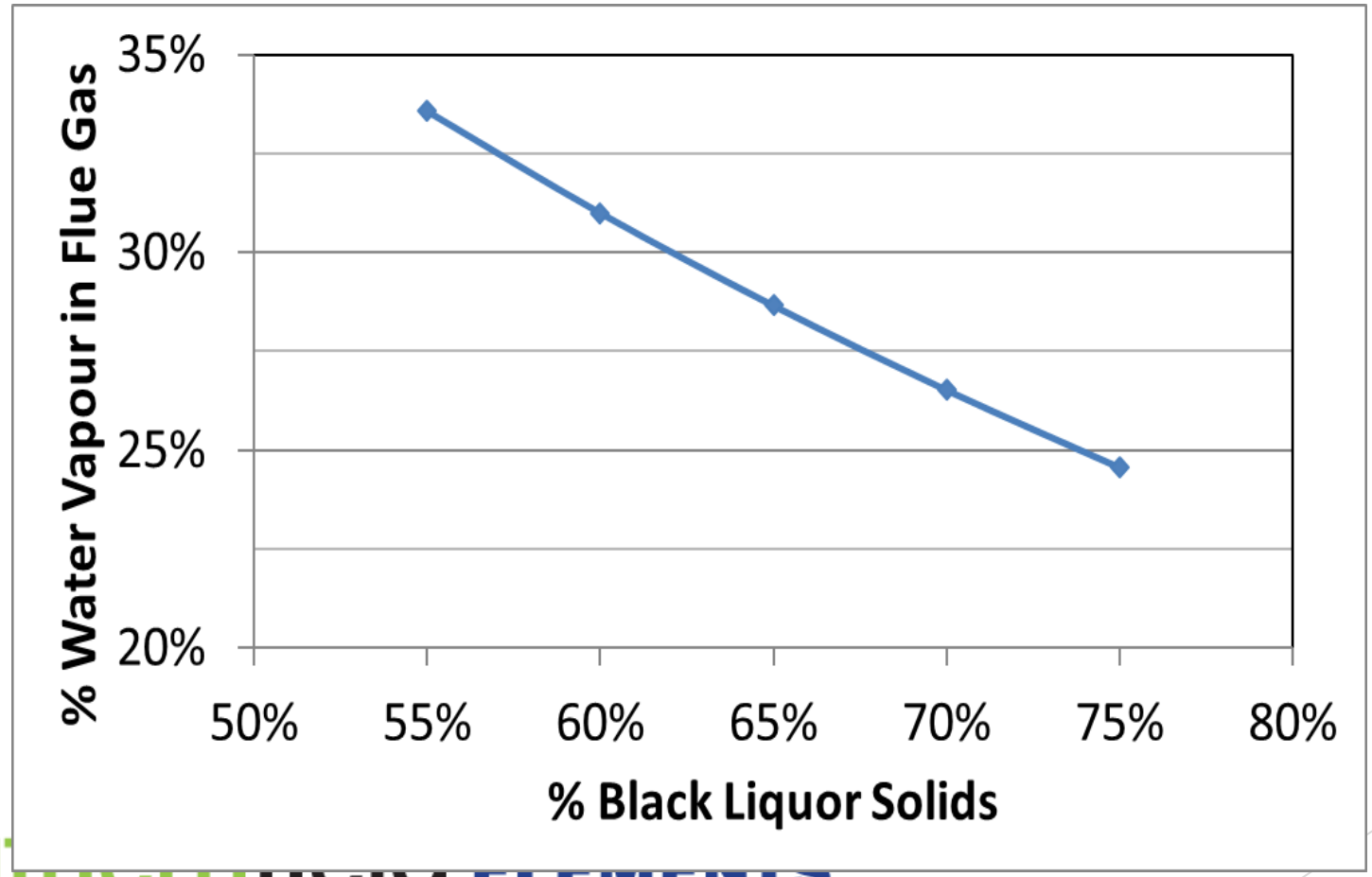
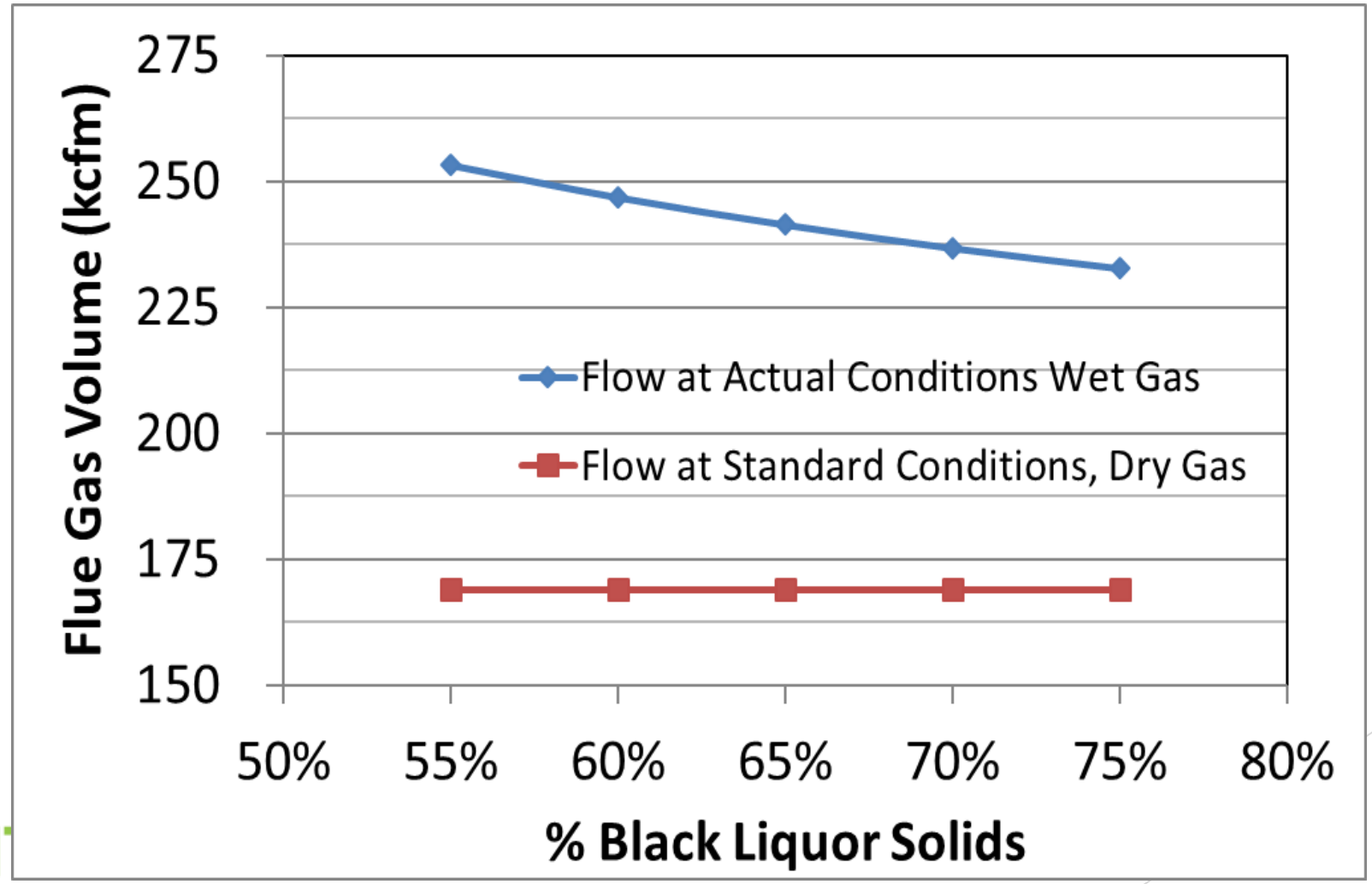
# Effect of Increasing Black Liquor Solids

- Increasing liquor solids tends to achieve better thermal efficiency and a more stable char bed
- Effect on ESP has not been extensively studied
- BLS has effect on flue gas volume, dust loading, moisture content, particle size
- BLS effect on volume and moisture is easy to calculate
- BLS increases char bed temperature, but its effect on dust loading and particle size is difficult to quantify
- Temperature at ESP inlet, hence actual flue gas volume, is also affected, but not considered in this analysis

# Effect of Increasing Black Liquor Solids on Moisture Content in Exhaust



# Effect of Increasing Black Liquor Solids on Exhaust Flow Rate

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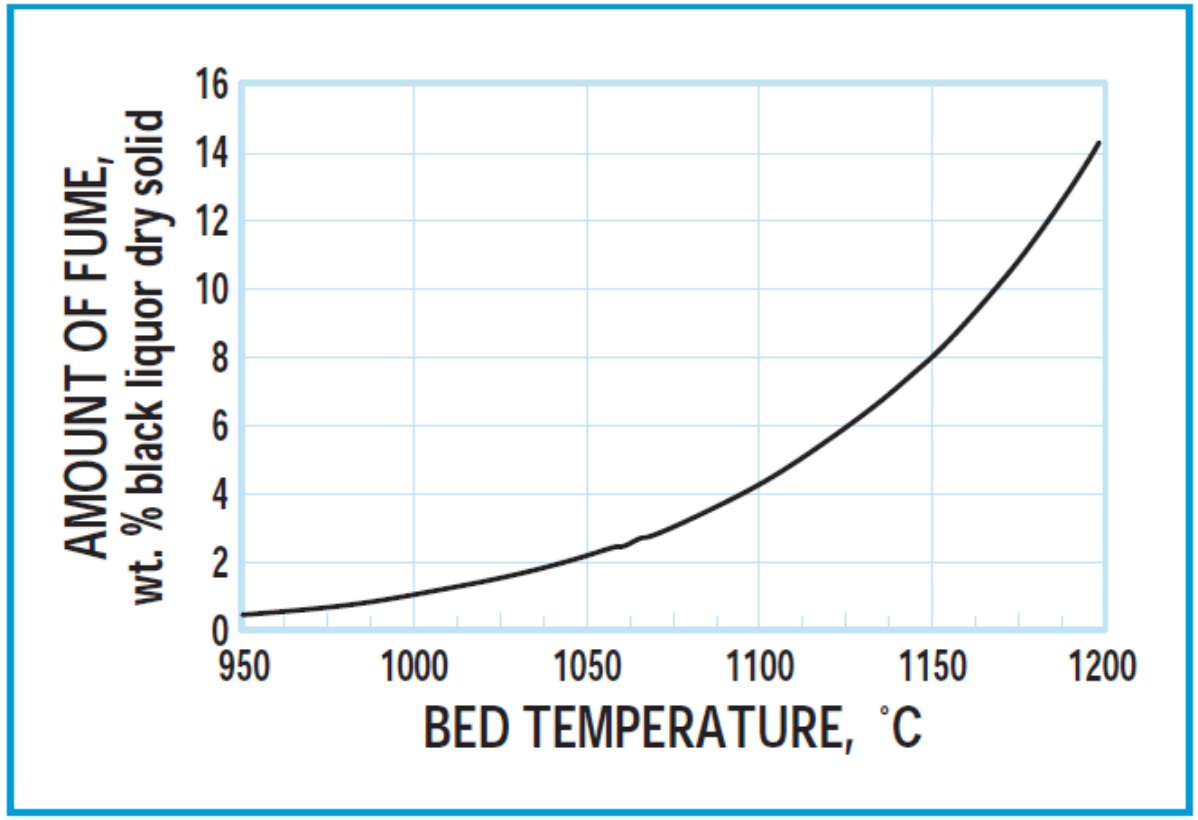
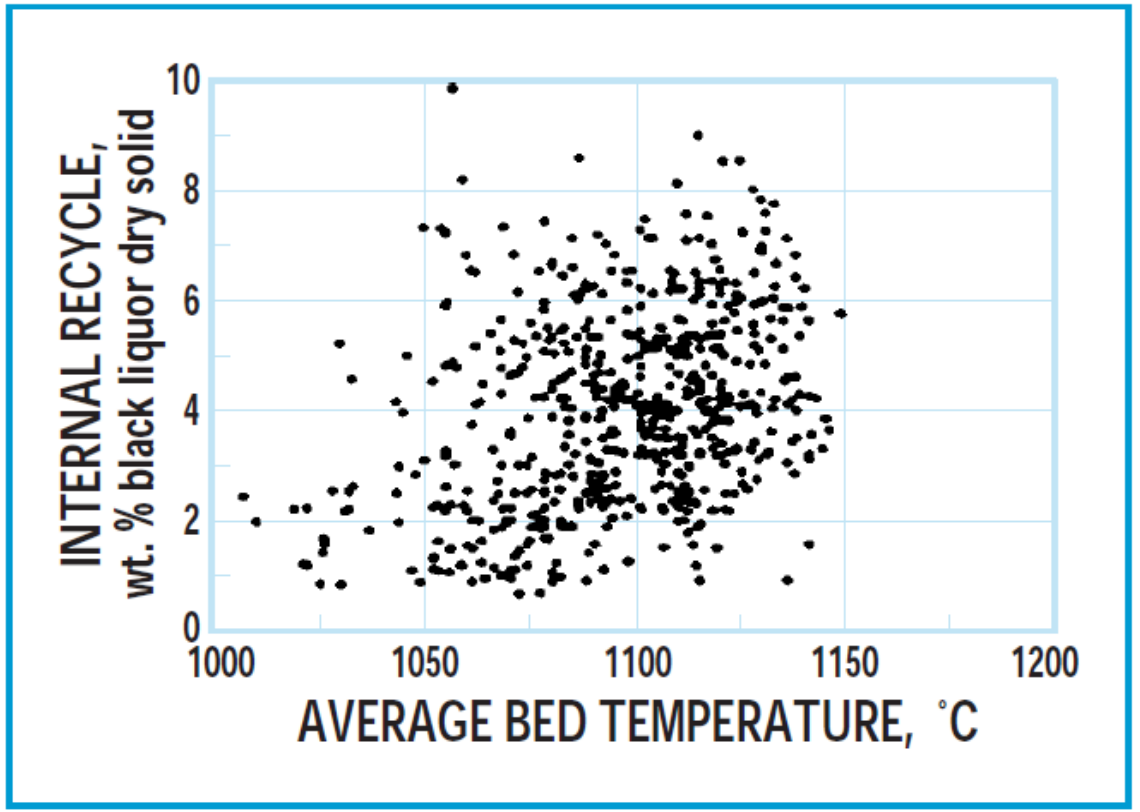
# Effect of Bed Temperature on Dust




Predicted




Measured

Courtesy of A. Tavares

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# Effects of Increasing BLS on ESP Operating Parameters and Emissions

| Parameter | Effect of Increasing BLS on Given Parameter | Most Likely Effect of Parameter Change on ESP Particulate Emissions |
|---|---|---|
| Flue Gas Volume | Decrease | Decrease |
| Dust Loading | Increase | Increase |
| Moisture Content | Decrease | Increase |
| Particle Size | Decrease | Increase |

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# Effects of Increasing BLS on ESP Operating Parameters and Emissions

- Overall effect depends on specific boiler operating conditions on a case by case basis

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# Strategies for Improving RB ESP Emissions

- Boiler Operation Optimization
- Precipitator Maintenance
- Precipitator Modifications

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# Boiler Operation Optimization

- Optimizing boiler operation can improve ESP performance:
  - Reduce gas volume by reducing excess O2 with better gas mixing (can also be achieved by minimizing air ingress through ducting, dampers, etc.
  - Optimize liquor solids content such that flue gas volume is decreased without substantial increase in particulate loading
  - Temperature also plays a role in flue gas flow rate and particle charging

# Precipitator Maintenance

- Record keeping is important (opacity and power readings vs. operating conditions)
- Inspection and maintenance log (identify recurring issues)
- Effective and optimized operation of plate/electrode cleaning mechanisms
- ESP internal alignment – most critical factor for effective ESP operation
- Gas flow distribution optimization

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# Precipitator Modifications

- Over time, ESP modifications are necessary to achieve required removal efficiencies
- These can include:
  - Power supply upgrades
  - Gas flow modifications
  - Internal modifications
  - Increasing collecting area

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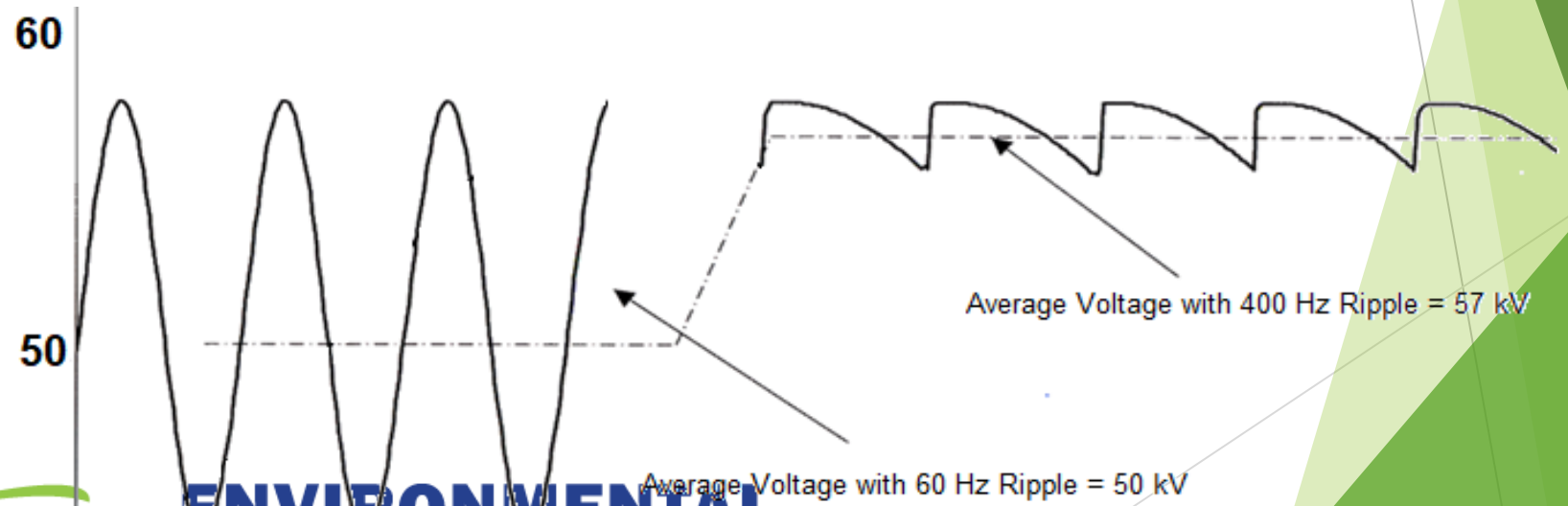
# Power Supply Upgrades

- ESP power supplies provide DC high voltage to ionize flue gas
- The higher the average voltage, the higher the migration velocity
- Power supplies regulate the DC voltage ripple in an ESP – higher frequency power supplies allow for higher average voltage

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# Gas Flow Modifications

- Poor gas flow can cause uneven gas velocities within ESP
- Best performance is achieved with uniform gas velocity throughout ESP cross section
- Accumulation of gas in certain sections of the ESP can indicate uneven gas flow distribution
- Can be rectified by CFD modelling and modification of existing gas flow distribution media

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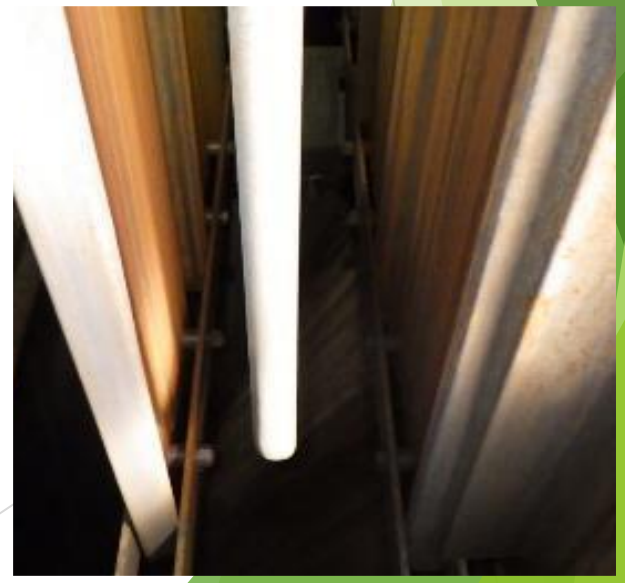
# Internal Plate/Electrode Modifications

- ESP efficiency can be improved by replacing old or worn internals
- Old/worn internals commonly lead to misalignment, points of sparking, lower power levels
- Rigid discharge electrodes provide superior reliability and electrical characteristics
- Most effective way of improving performance is by increasing total collecting area



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# Increasing Collecting Area

- When significant performance improvements are required, increasing internal collecting area may be necessary
- This can be achieved by
  - Adding fields (additional rows of collecting plates) or a secondary collector
  - Increasing number of gas passages (increasing width of existing units) or adding a new chamber in parallel
  - Increasing height of collecting plates
  - Maximizing volume of ESP internal volume (switching to external rapping for units with tumbling hammer design results in up to 25% more collecting area)

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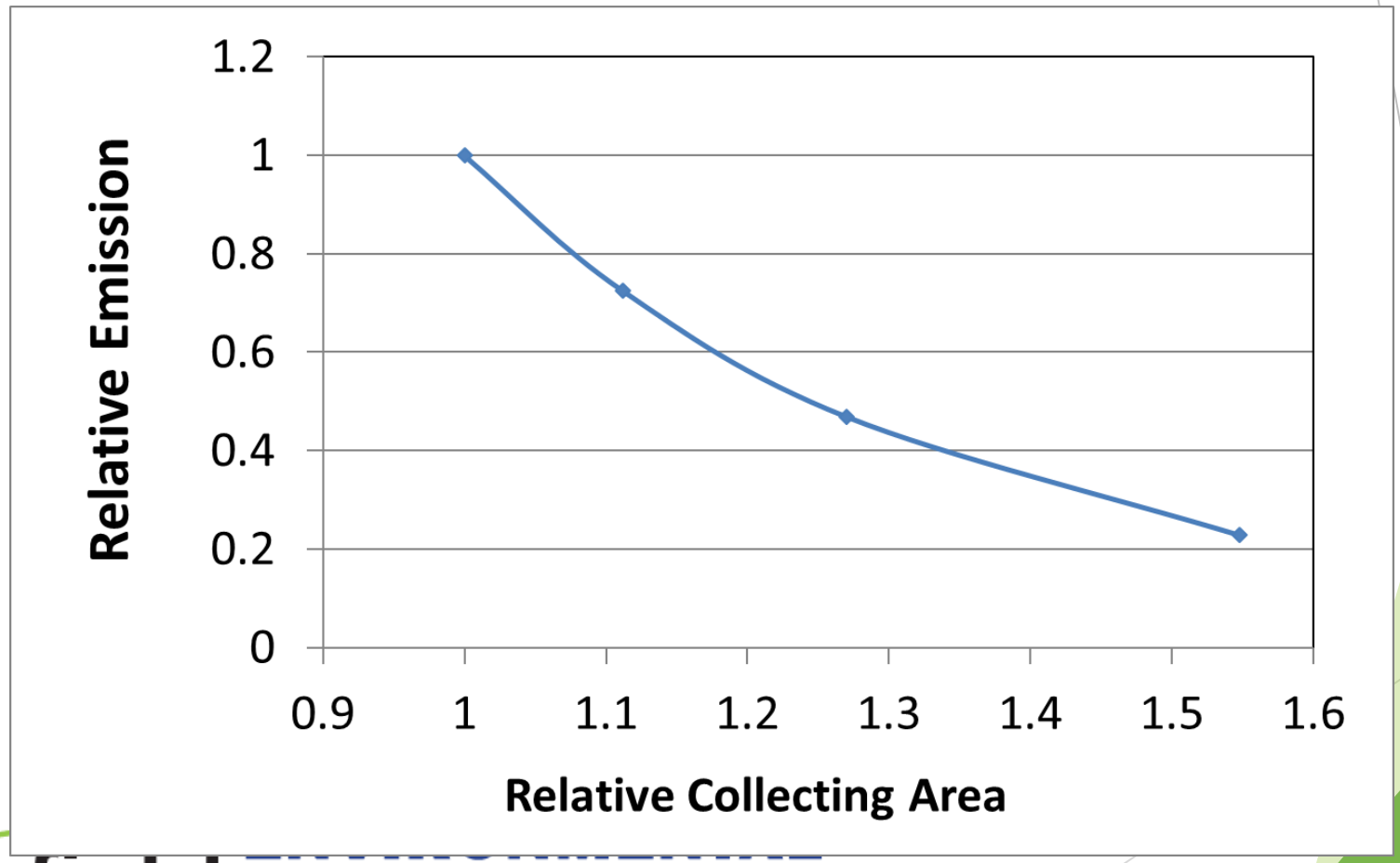
# Effect of Collecting Area on Removal Efficiency

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Thanks for your attention!

Questions?

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