REINHOLD ENVIRONMENTAL Ltd.

2013 APC Round Table & Expo Presentation

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Impact of DSI and ACI on ESPs and Fabric Filters

Advancing Cleaner Energy

Reinhold ACP/PCUG Conference
July 9, 2013
St. Louis, MS

Sorbent Injection for MATS

Mercury

- Activated Carbon – mercury control

Acid Gases

- Trona – HCl, SO_3 and SO_2 control
- Sodium bicarbonate (SBC) - HCl, SO_3 and SO_2 control
- Hydrated lime – HCl and SO_3 control

PCD’s – a.k.a. collector of dry sorbents

- Particulate control devices are now integral to mercury and acid gas removal systems
- Fabric Filter / baghouses
  - 560 installed*
- Electrostatic precipitators
  - 1,260 *

* Source – U.S. Energy information administration Form EIA-767

Fabric Filter Predictive Equation

$$\Delta P = P_R + K_2V^2Ct$$

ΔP = total pressure drop, kPa

ΔP_R = residual pressure drop, kPa

K_2 = specific resistance coefficient of freshly deposited dust, (kPa - cm sec/g)

V = Air-to-cloth ratio (cm/sec)

C = dust loading g/cm^3

t = time between bag cleaning in sec.

Collection Processes in ESP

- Ionization - Charging of particles
- Migration - Transporting the charged particles to the collecting surfaces

$$w = \frac{qE_p}{6\pi\mu r}$$ Particle migration velocity

$q =$ Charge(s) on particle

$E_p =$ Field strength, V/m

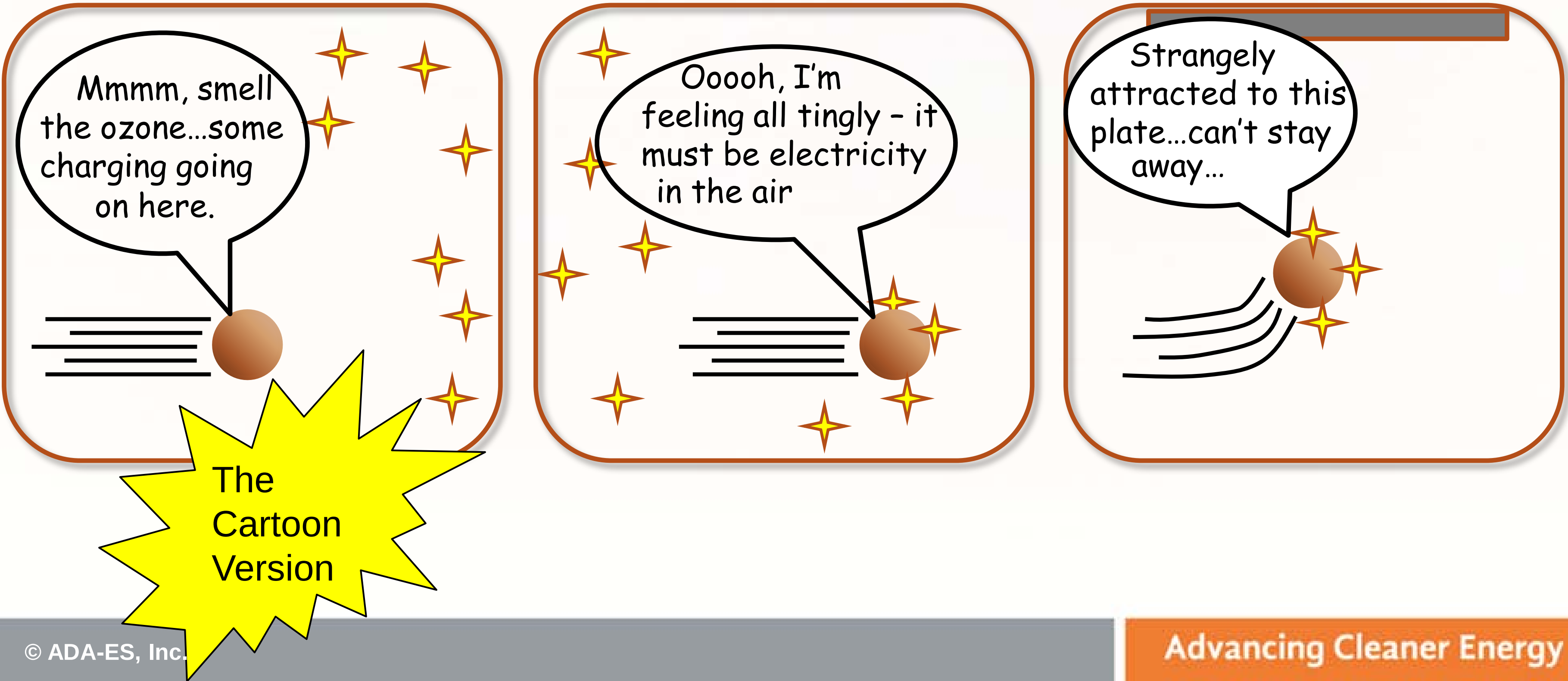
$\mu =$ Gas viscosity

$r =$ Particle radius

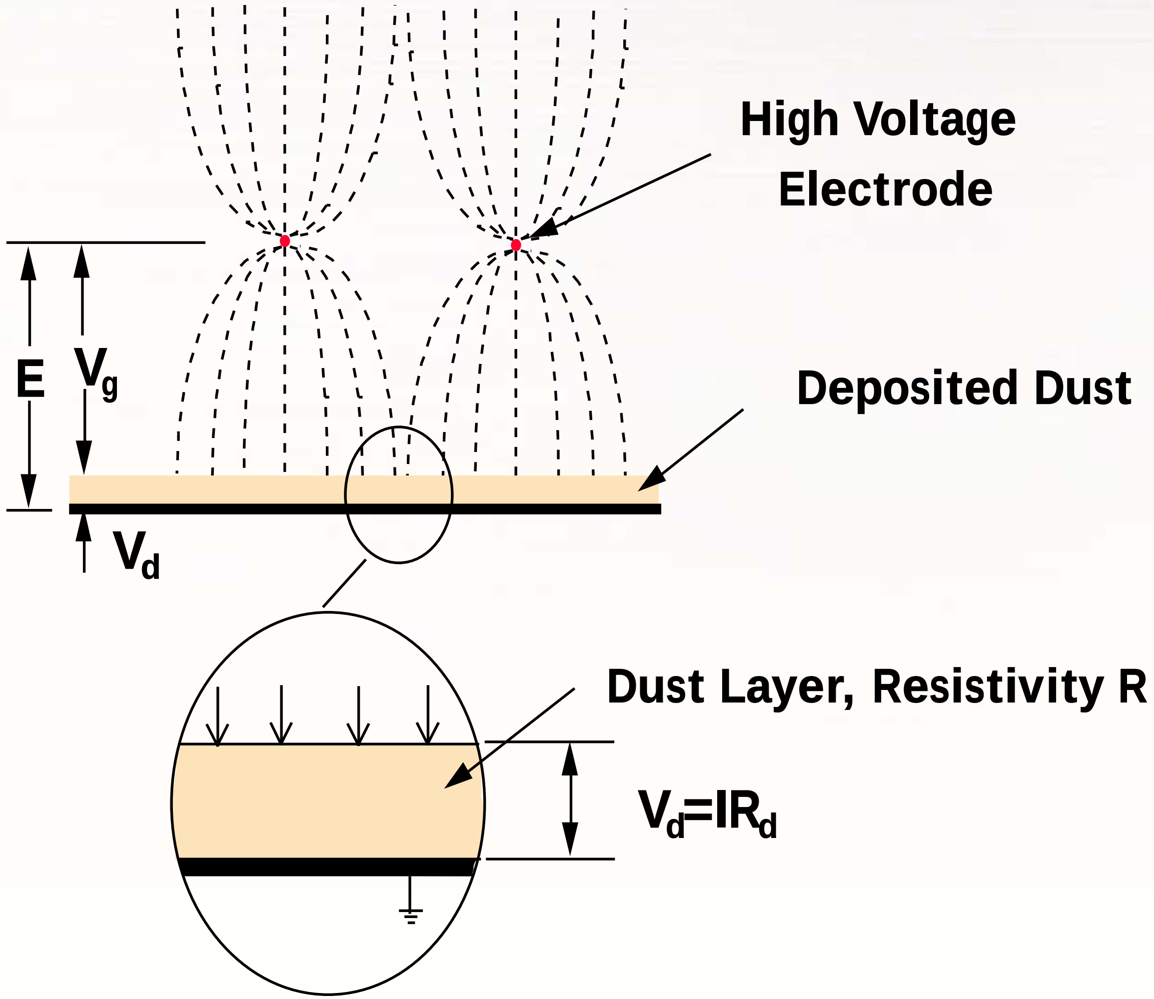
The Scientific Version

Collection Processes in ESP

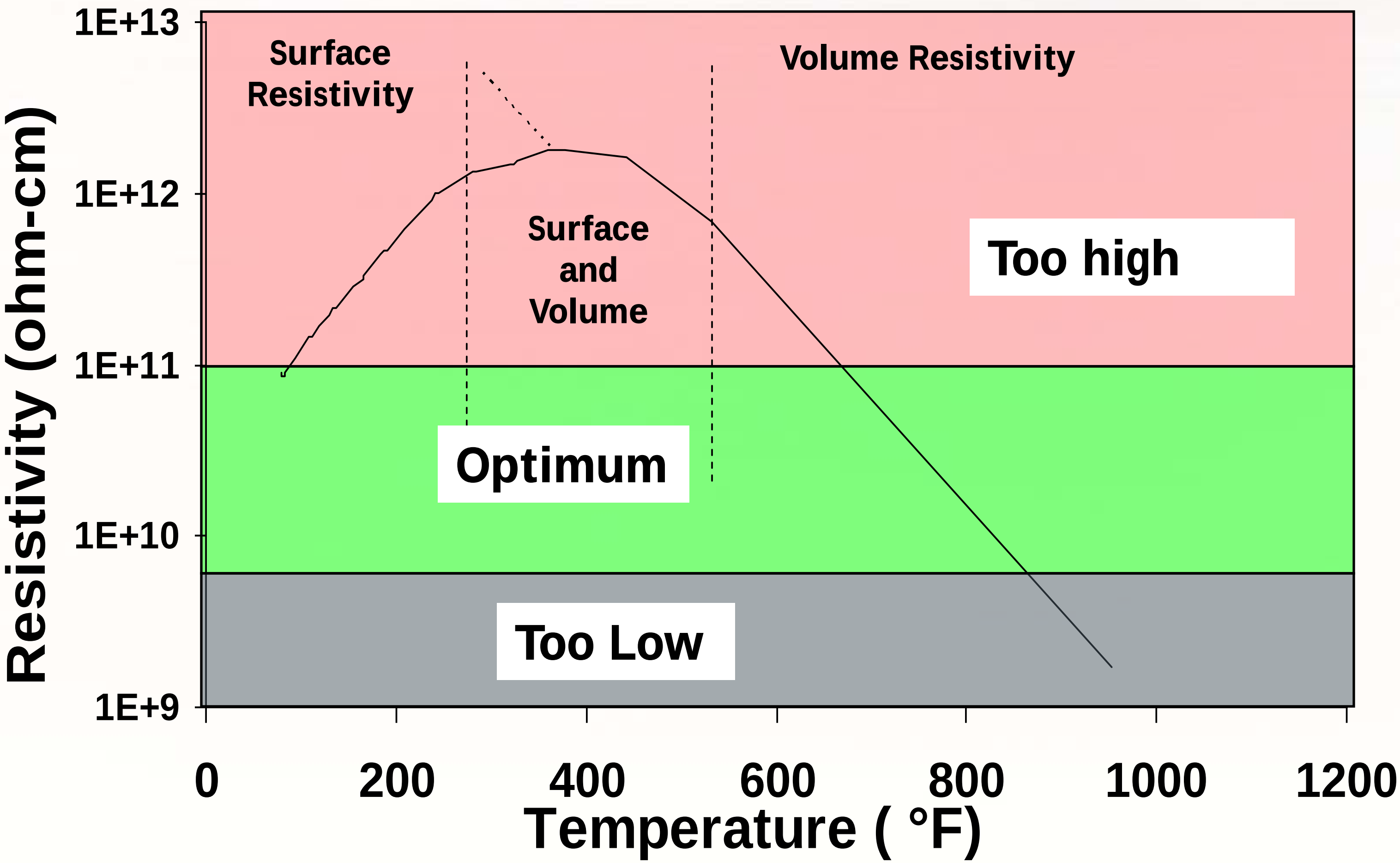
- ▸ Ionization - Charging of particles
- ▸ Migration - Transporting the charged particles to the collecting surfaces



Electric Fields in the Dust Layer



Typical Temperature Resistivity Relationship



Key BOP and variables to watch - FF

Fundamental performance variables

- Pressure drop
- Particle loading
- Cleaning frequency

Balance of Plant impacts

- Reduced bag life
- Oxidation reactions - heating
- Ash handling capacity

Key BOP and variables to watch - ESP

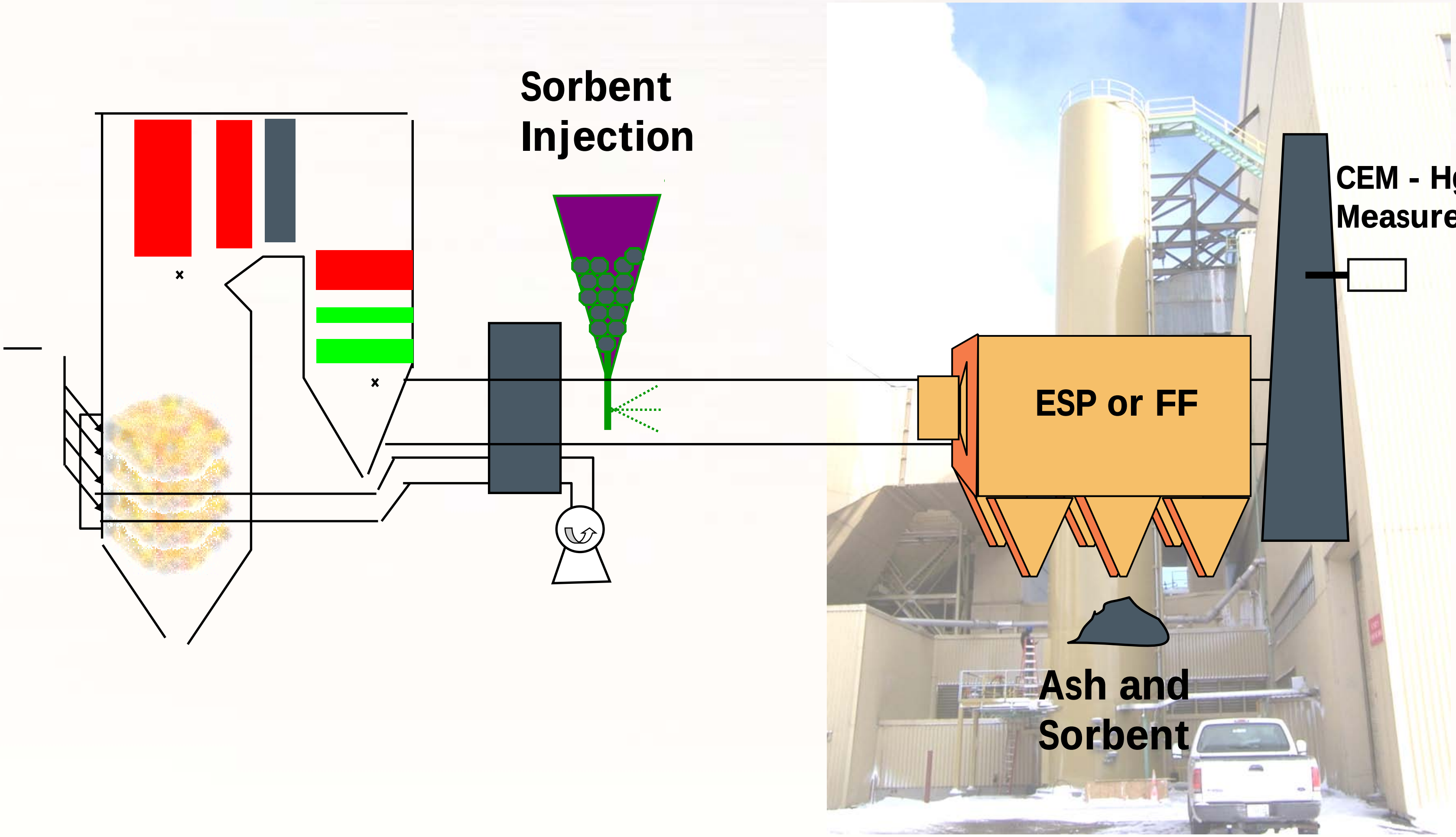
Fundamental performance variables

- Resistivity
- Particle loading
- Electric field strength (voltage and current)

Balance of Plant impacts

- Increased sparking
- Build-up on wires and plates
- Increase in opacity
- Ash handling capacity
- Oxidation reactions - heating

ACI Technology for Controlling Mercury Emissions



PAC Sorbents for Mercury Control

- PAC for Hg control mostly derived from lignite or coal
- Typical particle size is 17–20µ MMD
- Carbon has low resistivity

ACI: Technology Potential for 90% control

Coal	APCD	ACI w/ or w/o halogen	ACI + other technology
Low Rank	Dry FGD/baghouse	Viable	Viable
Low Rank	ESP	Challenges	Viable
Low Rank	SCR, dry FGD/baghouse	Viable	Viable
Low Rank	ESP plus TOXECON	Viable	Viable
LSB	SCR, ESP or baghouse	Challenges	Viable
LSB	SCR, ESP, wet FGD	Challenges	Viable
LSB	SCR, ESP plus TOXECON	Challenges	Viable
HSB	SCR, ESP, wet FGD	Difficult	Challenges
HSB	SCR, baghouse, wet FGD	Difficult	Challenges

LSB=Low-sulfur bituminous; HSB=High-sulfur bituminous

Impacts of ACI on CESPs

PM Loading: Incremental Increase 0.5 to 3%
Resistivity: PAC injection may slightly reduce Resistivity. Increased secondary currents, but PAC can selectively migrate thru ESP.
PM emissions & opacity: Little impact observed on ESPs w/SCA >250. Increased PM and possible rapping spikes on smaller ESPs operating at high (> 5 f/s) face velocities.
Insulator tracking? No major observations
Hoppers: Potential for smoldering PAC in outlet hoppers where PAC content is >40%.
Flyash Salability

Mitigation of ACI Impacts on CESPs

- Good distribution of PAC into ESP
- Review of rapper schedules/intensities to minimize spiking
- Good management of ash hoppers. Keep hoppers pulled, especially outlets. Manage hopper heaters
- Specialty PAC materials for use in concrete

PAC Impacts on Fabric Filters

- PAC may cause higher pressure drop when compared to some fly ash; COHPAC®/TOXECON™ fabric filters should be sized with PAC in mind
  - Recommended A/C ratio 5 ft/min or less
- Typical increase in grain loading by PAC injection for a baghouse application will be 0.01–0.2 gr/acf

Impacts of ACI on Conventional Baghouses

PM Loading: Incremental Increase 0.5 to 2% (0.01 – 0.2 gr/acf)
Pressure Drop: Negligible impact
PAC dwell time on bags can affect mercury removal. Change in cleaning frequency may be required, potentially impacting bag life.
Flyash Salability

Mitigation

- Good distribution of PAC into Baghouse to ensure compartment- to-compartment distribution
- Optimization of bag cleaning cycles.
- Concrete compatible PAC

Impacts of ACI on High Ratio Baghouses (COHPAC/TOXECON)

Small changes in **PM loading** can impact pressure drop & cleaning frequency. There may be limits to how much PAC can be injected.

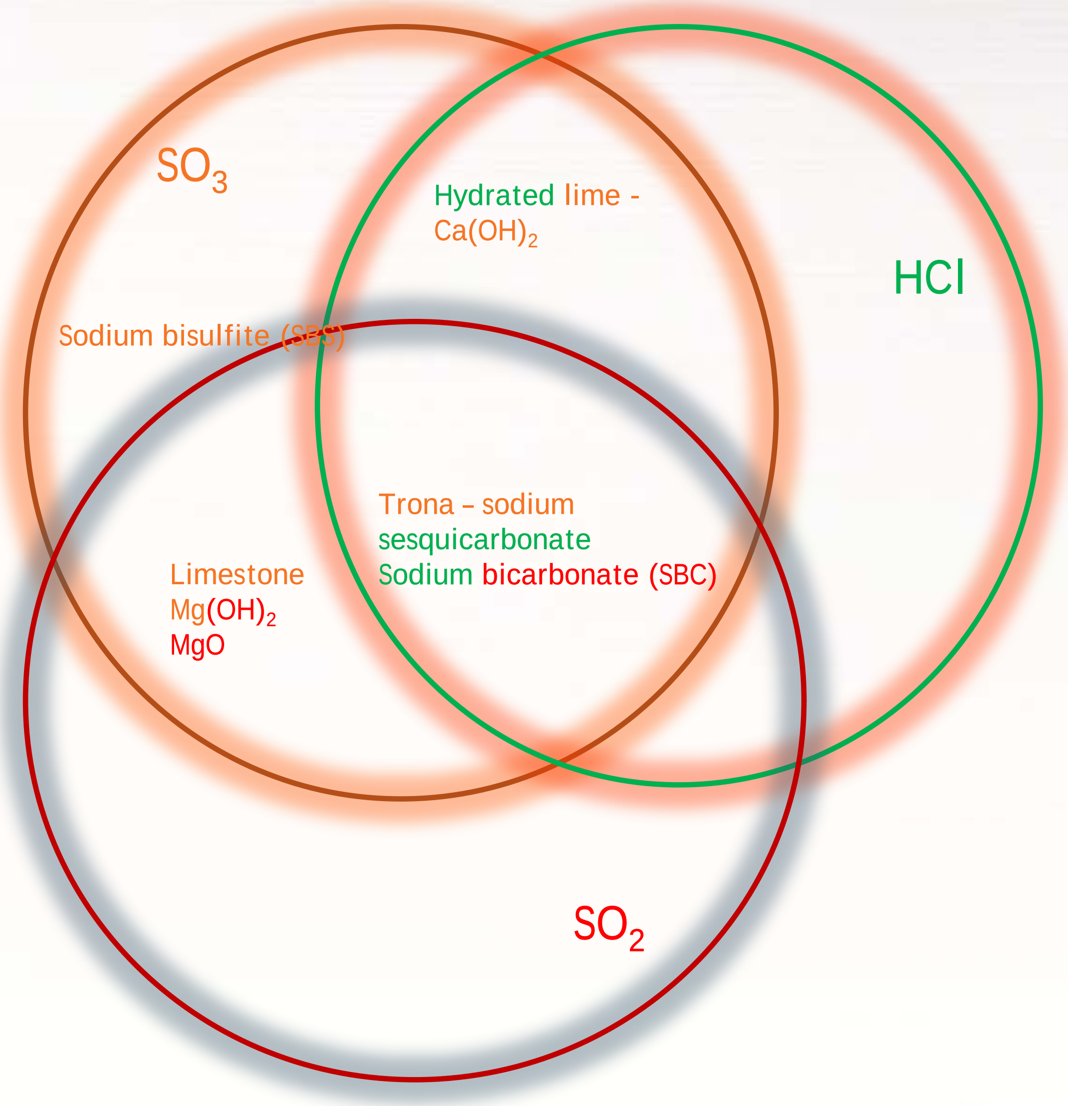
PAC dwell time on bags can affect mercury removal. Change in Cleaning frequency may be required, potentially impacting bag life.

Fabric blinding with newer fine grind PAC? Are they needed – FFs?

Smoldering PAC in hoppers

- Higher importance to keeping upstream ESP in good working order to minimize PM carryover.
- Optimization of bag cleaning cycles.
- Good management of ash hoppers. Keep hoppers pulled, minimize hopper heater set points.

Sorbents for Acid Gas Control



SO_3

Hydrated lime -
$Ca(OH)_2$

HCl

Sodium bisulfite (SBS)

Trona – sodium
sesquicarbonate
Sodium bicarbonate (SBC)

Limestone
$Mg(OH)_2$
MgO

SO_2

Acid Gas Sorbents

- Trona – HCl, SO_3 and SO_2 control
  - Contains sodium which has been used for years as additive to solve resistivity problems (provides charge carrying ions)
- Sodium bicarbonate (SBC) - HCl, SO_3 and SO_2 control
  - Contains sodium which has been used for years as additive to solve resistivity problems (provides charge carrying ions)
- Hydrated lime – HCl and SO_3 control
  - Contains calcium compounds that are highly resistive

Impacts of DSI on CESPs

Sodium Sorbents
PM Loading: Moderate to high (up to 50% and higher for SO_2 control) increase.
Resistivity: Sodium reduces bulk resistivity and can improve collection efficiency. Is this sufficient to offset loading?
PM & Opacity: Little impact on larger ESPs. Smaller units, case by case.
Ash handling system: May push system capacity. Hopper throat pluggage has been reported.
Ash disposal: Solubility and leaching potential in landfills.
Calcium Sorbents
PM Loading: Moderate (10 to 30%) increase
Resistivity: Substantial increase, reduction in secondary currents, incr sparking
PM & Opacity: Risk of increased opacity
Ash handling system: May push system capacity. Pozzalonic reactions in wet systems possible if unreacted CaO is present

Deposition on ESP inlet perf plate

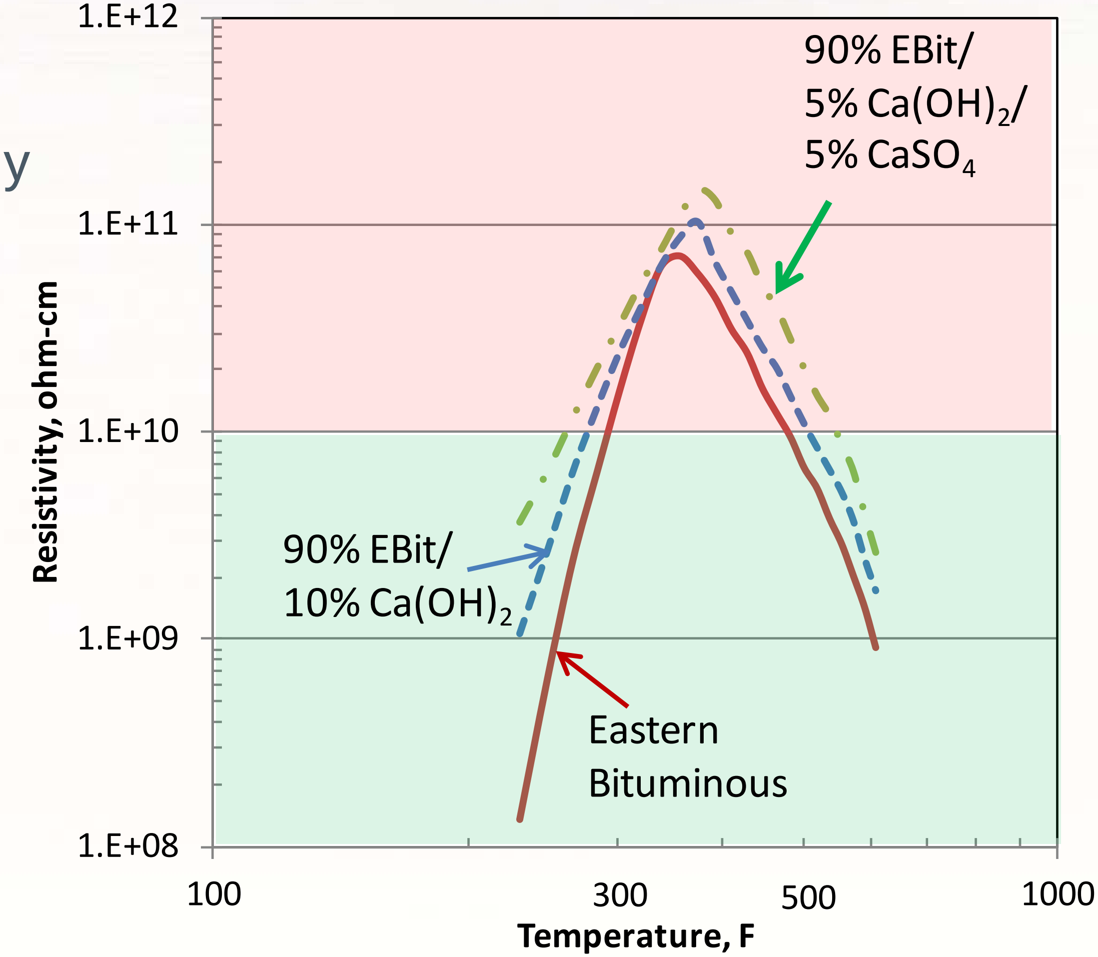
- Trona injection for SO_3 control

Gavin Precipitator
Inlet Gas Flow Distribution Perforated Plate

Source: Ritzenthaler, 2010

Impact of hydrated line on resistivity

- Laboratory measurements of resistivity show increased fly ash resistivity with hydrated lime addition (Eastern Bituminous fly ash)



Source: Mastropietro, 2010

Mitigation of DSI Impacts to CESPs

- Good distribution of sorbents into ductwork
- ESP Upgrades (the usual list!)
  - Flow distribution in and out
  - Internal baffles
  - Electrical Sectionalization
  - Rapper Sectionalization
  - Advanced HV technologies
  - Advanced controls
  - Etc
- Non SO_3 based flue gas conditioning
- Ash handling system upgrades/retrofits

Impacts of DSI on Conventional Baghouses

PM Loading: Significant Increase

Pressure Drop: Cleaning must be addressed to compensate for loading. Sodium dust cakes have shown lower drags.

Bag life – how much long term data do we have?

Ash handling system: May push system capacity. Hopper throat pluggage has been reported with sodium.

Flyash Salability with sodium

Mitigation

- Good distribution of sorbent into Baghouse to ensure compartment to compartment distribution
- Review ash handling system design

Impacts of DSI on High Ratio Baghouses (COHPAC/TOXECON)

- Baghouse must be sized with DSI in mind. Don’t undersize!

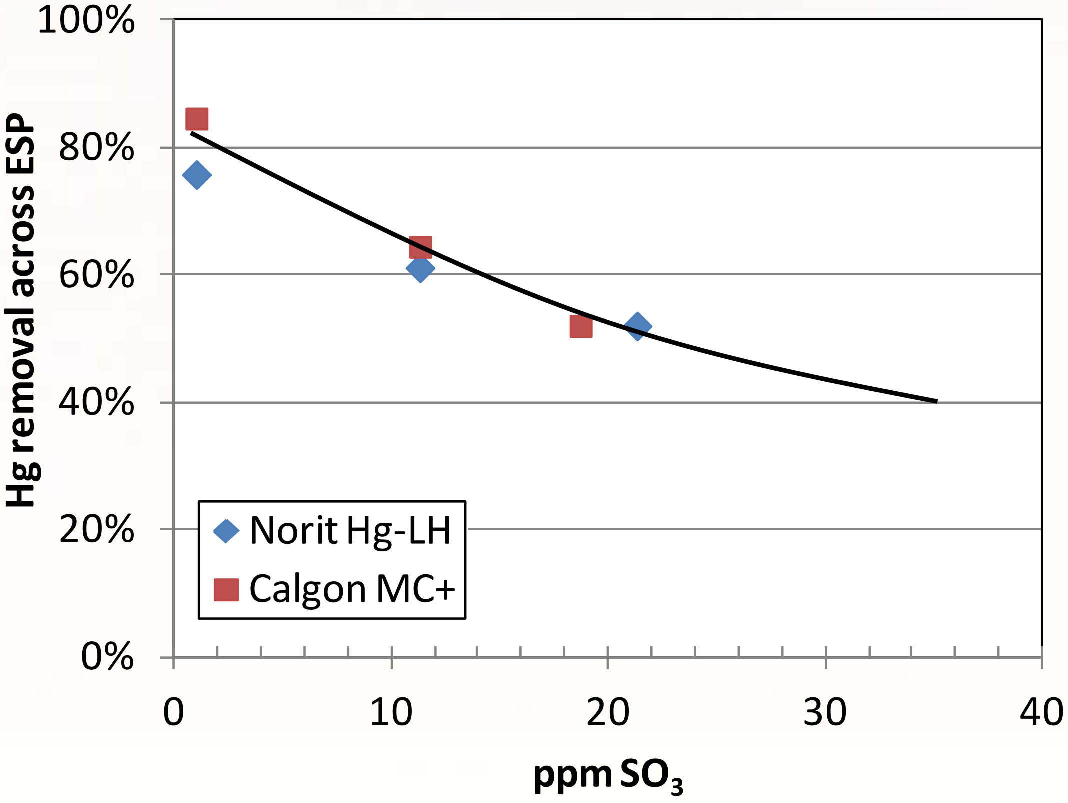
Other Major Impacts/Interactions

- Impacts of DSI on ACI
- PAC self heating

SO_3 and PAC Performance

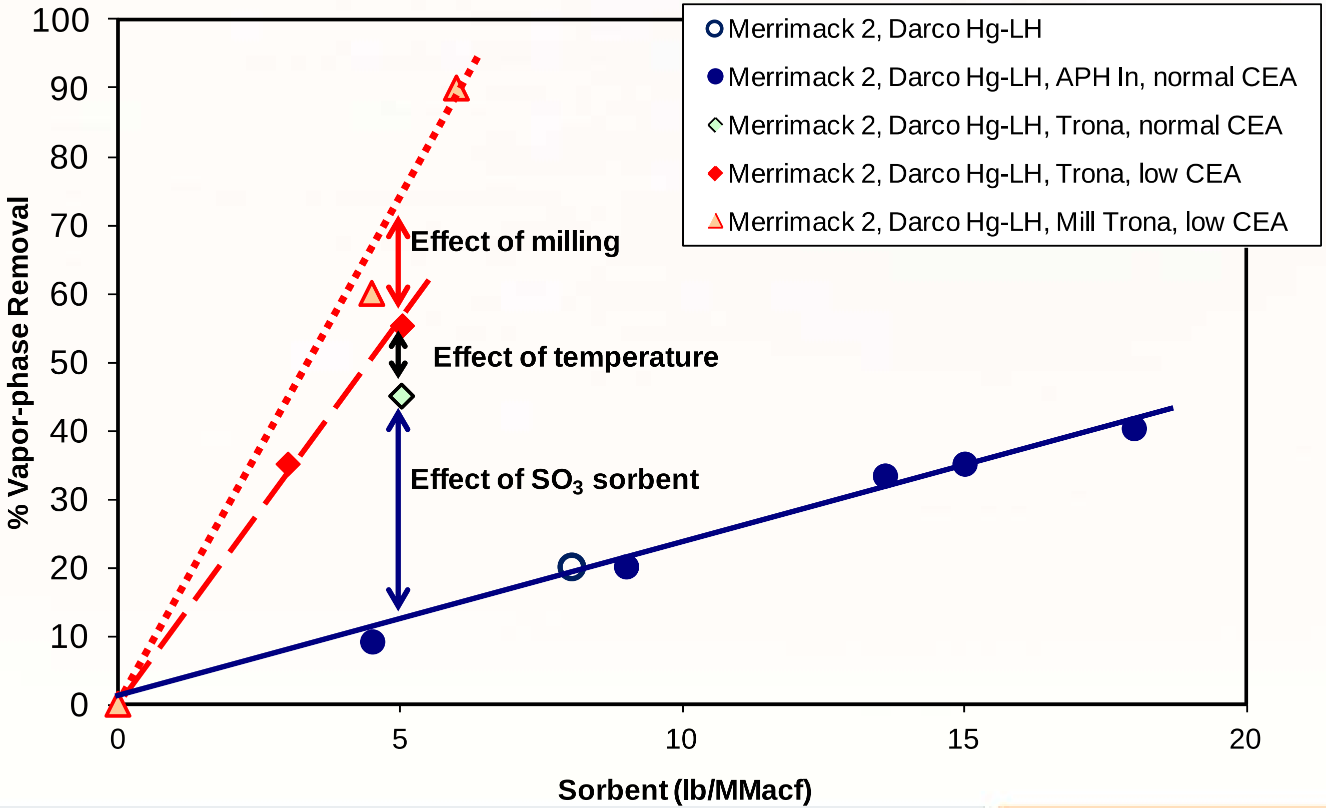
- Any SO_3 in gas phase appears to affect Hg capture
  - SO_3 is used to condition fly ash for better capture in ESPs
  - SO_3 higher in bituminous flue gas, especially after SCR

MRC Results: 10 lb/MMacf, injection upstream of APH
APH Inlet: 627 F; APH outlet: 300 F (assume 1 ppm baseline SO_3)



DSI-ACI Synergy: Example

- Low-sulfur bituminous plant with SCR
- Trona injection to reduce SO_3 => improve ACI performance for Hg control



Self-Heating

- PAC is a strong oxidant. High surface area and porosity of PAC allows oxygen to permeate these areas. Sometimes the heat of oxidation builds faster than it can be liberated. The surrounding PAC acts as an insulator.
- Several conditions can turn this into a “smoldering” event
  - Adequate bed size (sufficient amount of ash/PAC in hopper; i.e., surface-to-mass ratio)
  - External heat source (hopper heaters, high flue gas temps)
  - Concentration of PAC in the ash
  - Sufficient oxygen

Observed Smoldering

- Presque Isle TOXECON™
- Big Brown COHPAC®/TOXECON™, alkalis injected with PAC
- Dynegy Vermillion TOXECON™
- PSNH Merrimack – two ESPs in series with co-injection of trona

What do these plants have in common?

- Majority of fly ash is removed prior to PAC injection
- High concentration of PAC in affected hoppers

When am I at risk for a self-heating smoldering hopper problem?

- Approached conservatively, if PAC concentration in hopper is > 10%
- COHPAC®, TOXECON™, and Series ESPs are most at risk
- Addition of other materials that can contribute to exothermic oxidizing reactions (unreacted trona, lime, etc.)
- Conventional ACI upstream of ESPs, baghouses, and dry scrubbers should not be affected since PAC concentrations are typically < 2%

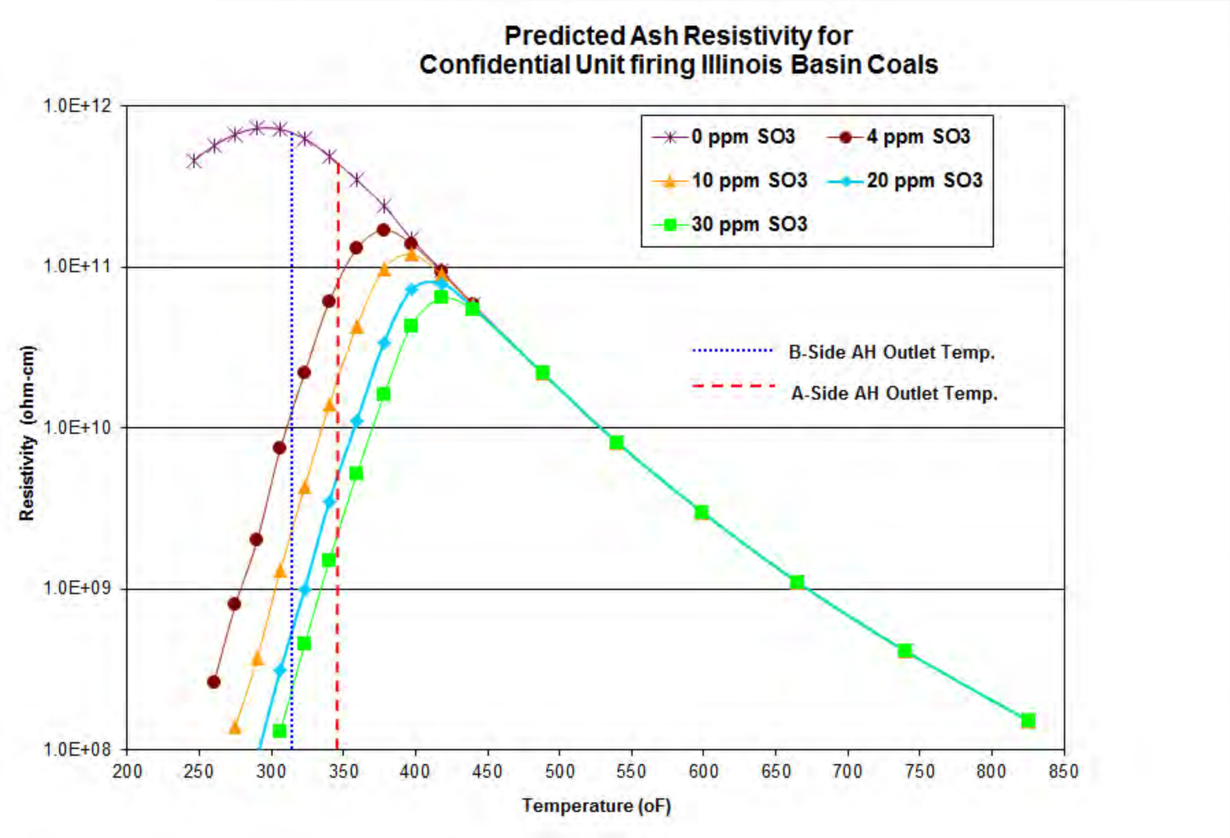
Case Example – Impact of Trona on ESP

- Unit configuration PC Boiler, APH, CESP
  - MW 430
  - Coal type 85%PRB/15% EB
  - ESP SCA: ~175
  - Test conditions PAC Injection for Hg plus Milled Trona Injection for HCL
- Observations
  - Gradual loss of secondary current over test period (wire & plate build-ups suspected). ESP ash removal problems, high hoppers and grounded sections.
- Dilemma: despite benefits from low resistivity, ESP struggled to handle high trona loading.
- Causes: Trona distribution during test was non-ideal. Sticky reaction products building up on wires & plates, high hopper levels
- Outcome: Upgrades to hopper ash removal systems planned, optimized sorbent distribution design for commercial system

Example – Impact of Hydrated lime on ESP

- **Unit configuration**
  - 425 MWg (Low NOx, FGD, ESP, SCR)
  - ESP SCA – 200ish
  - Test conditions: HL injection for SO3 & HCl mitigation
- **Observations**
  - 4 of 16 T/R sets became inoperable during HL injection upstream of the ESP due to high ash resistivity
  - SO3 mitigation and HCl control negatively impacted ESP operation at high loading rates
  - Increased sparking in outlet fields indicating elevating ash resistivity
- **Dilemma:**
  - In conjunction w/effective SO3/HCl control, degraded ESP performance and opacity increases occurred
- **Causes:**
  - Increasing ash resistivity and decreasing flue gas SO3 content lead to degraded ESP
- **Outcome :**
  - Feedback from ESP to HL injection system to limit mass loading & moderate ash resistivity
  - Maintain a SO3 floor in the range of 10-15 ppmv
  - Target ash resistivity, including the addition of HL, to between 10^10 and 10^11 ohm-cm

Resistivity Model for Previous Case

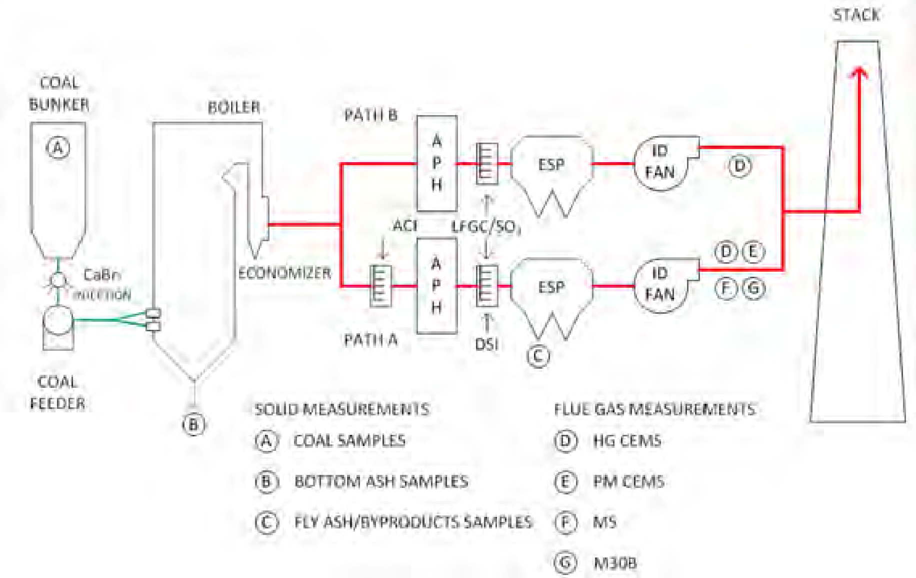


Fuel Analysis	Average (%)
Carbon (%)	60.61
Hydrogen (%)	4.25
Oxygen (%)	6.88
Nitrogen (%)	1.32
Sulfur (%)	3.18
Moisture (%)	12.81
Ash (%)	10.97
Lithium Oxide	0.01
Sodium Oxide	0.45
Potassium Oxide	2.08
Magnesium Oxide	0.9
Calcium Oxide	3.32
Iron Oxide	26.5
Aluminum Oxide	19.92
Silicon Oxide	42.68
Titanium Oxide	0.93
Phosphorous Oxide	0.29
Sulfur Trioxide	0.65

Example – Impact of Trona, ACI and FGC on ESP

- **Unit configuration**
  - 300 MWg
  - Coal type (range) - variety of coals from the Powder River Basin (PRB).
  - ESP SCA ~200 ft2/kacfm
  - Test conditions
    - Fuel Halogen Additives & ACI for Hg Control
    - Trona DSI for SO2 mitigation
    - ATI-2001™ FGC for enhanced resistivity modification
- **Observations**
  - ESP performance was progressively degraded as trona mass loading increased
- **Dilemma**
  - To increase SO2 control, higher levels of trona injection were required. Trona reacted with supplemental SO3 being used for ESP ash conditioning. ESP performance degraded signaling the need for more SO3 conditioning.
- **Causes**
  - Due to the amount of alkaline sorbent being injected for SO_2 mitigation essentially all SO_3 injected for ash conditioning would be depleted and negatively impact the ESP‟s particulate collection efficiency and opacity.
- **Outcome**
  - Trona effectively control SO2 emission
  - Trona mass rates required higher for SO2 control made the use of SO3 for ash conditioning impractical
  - ATI-2001™ , a non-sulfur flue gas conditioning chemical, does not possess the same negative interaction with alkaline sorbents and provided sufficient ash conditioning to maintain effective ESP operation.

Example – Impact of Trona, ACI and FGC on ESP



- ▸ Unit configuration
  - 385 MWg
  - Coal type - low sulfur Powder River Basin coal
  - ESP SCA 289 ft2/kacfm
  - Test conditions
    - ACI, DSI and ATI-2001™ FGC
- ▸ Observations
  - A-side performed well
  - B-side power highly suppressed
  - Variation in coal characteristic resulted in further degradation to B-Side
- ▸ Dilemma
  - Imbalance in ESP performance complicate emissions management scheme
- ▸ Causes
  - B-side power highly suppressed and appeared to be attributed to issues in the boiler that were supposed to be resolved with a SOFA damper evaluation and correction.
  - Changes in coal characteristic impact performance
- ▸ Outcome
  - Pursuing MATS strategy using ACI with options for alternate to SO_3 conditioning

Example – Impact of ACI on Baghouse

- Unit configuration PC Boiler, APH, ACI, CDS, PJFF
  - MW: 250
  - Coal type: PRB
  - PJFF Gas/Cloth: ~4:1
  - Test conditions PAC injection with CDS out of service
- Observations
  - Unable to maintain stack mercury limits, even at high PAC injection rate
- Dilemma – surprisingly baghouse and PAC were not achieving expected mercury reductions
- Causes - PAC remaining on bags well past mercury equilibrium resulting in off-gassing of Hg. With CDS out of service PM loading was low and bags did not reach DP set-point.
- Outcome: Performance restored by increasing bag cleaning frequency and taking compartments out of service until the CDS was put in service.

Example – Impact of ACI on Toxecon™ Baghouse

- Unit configuration
  - 600 MW
  - Coal type – Texas Lignite
  - TOXECON™
  - Test conditions – PAC and PAC with alkali injection
- Observations
  - Increased pressure drop
  - Continuous cleaning
  - Inspection showed moist, dense, hard to remove dust cake
- Dilemma
  - PAC needed for mercury reductions, injection upstream of baghouse caused baghouse performance issues
- Causes
  - High A/C ratio resulted in pressure drop and cleaning limiting PAC injection options
- Outcome
  - Inject PAC upstream of ESP to meet pre-MATS requirements.

Questions

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