ELECTRIC POWER RESEARCH INSTITUTE

EPRI Electrostatic Precipitator Research

Bruce Scherer
Program 76, Opacity & Particulate Control
Project Manager

2011 McIlvane Hot Topics

August 2011

EPRI Program 76 Research Proceedings

- EPRI in 2011 is engaged in precipitator research to support the upcoming regulatory requirements
  - Precipitator Optimization Study
  - Carbon Capture Study
  - High Resistivity Ash Collection - Pilot Testing
  - Power Supply Development
    - Pulsing (ROPE)
    - Polarity Reversing (EPRIswitch)
  - ESPM update
  - Wet ESP Testing & Pilot Installation
  - Dry Sorbent Injection support
  - Biomass/Coal Ash Analysis
- 2012 Research Program presently being assembled

Electrostatic Precipitator Optimization Research

- Project objective is a performance assessment that:
  - Documents upgrades realized on operating units
  - Relates improvements to emission goals
  - Provides management with confidence a selection of modifications will meet goals
- Starting point is “Advanced ESP Power Supplies Update”, #1010361 (2006)
- Basis - assessment of realized performance improvements from various upgrades
  - Smaller unit rebuilds & improvements targeted
- Builds off experience to predict upgrade abilities to meet potentially more stringent limits

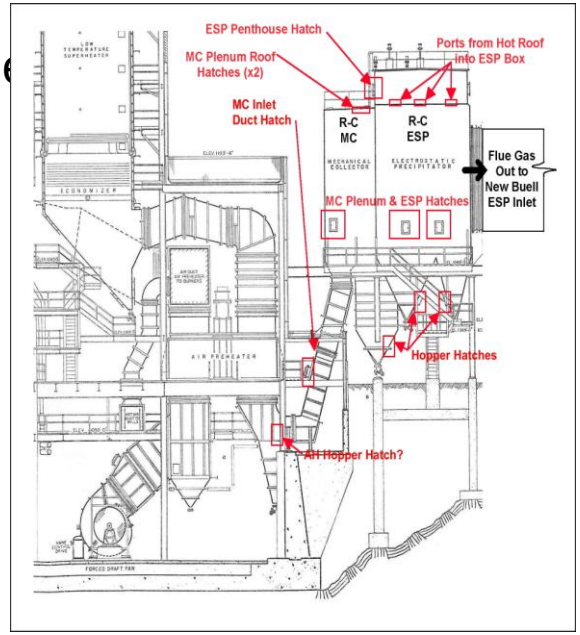
Electrostatic Precipitator Optimization Research

- Driven by the proposed EGU MACT
  - total PM limit of 0.03 lb/MBtu limit. (Total = Filterable + Condensable)
- ESP's of moderate size performing under 0.01lb/MBtu following upgrades that include:
  - Flow Modeling and remediation for inlet plane velocity, momentum, temperature & SO_3 concentration, internal flow control
  - Internal rebuild consisting of ~16" gas passes, new RDE's
  - Upgrading suspension & rapping systems
  - Increased sectionalization combating space charge effect, re-entrainment
  - Replacement of 60 Hz T/R sets with switch mode power supplies
- Research goal - establish a minimum size ESP to meet MACT
  - Produce plot of specific collection area/capture efficiency curves for existing units
  - Supplemental curves for translating ash resistivity, grain loading to collection curve
- Report data mostly collected, report in progress

Carbon Capture Project

Continued multi-year poject

- Previous 2010 study demonstrated carbon capture e
  capture
- New, small site effort in 2011 undertaken
  - Selected unit a 1959, 182 MW PC unit
  - R-C MC/ESP and Buell ESP



PM mass emission testing

- Pre-modification testing complete
  - Significant re-entrainment of carbon

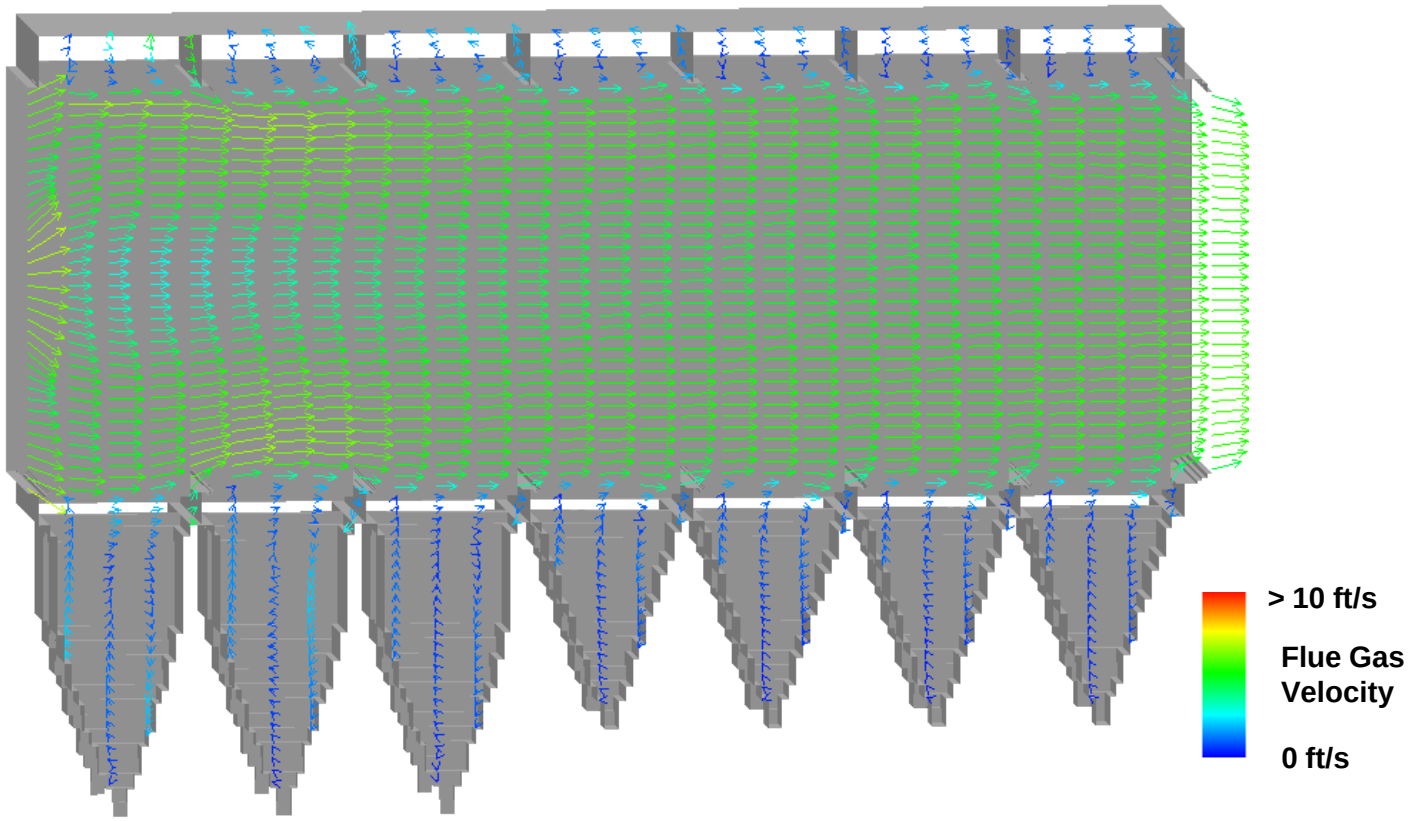
CFD model study completed

- Confirms inlet maldistribution, vertical momentum at the inlet plane
- Flow control devices designed
- Sister unit failure pushed installation into 2012

Carbon Capture Project - CFD Model Results

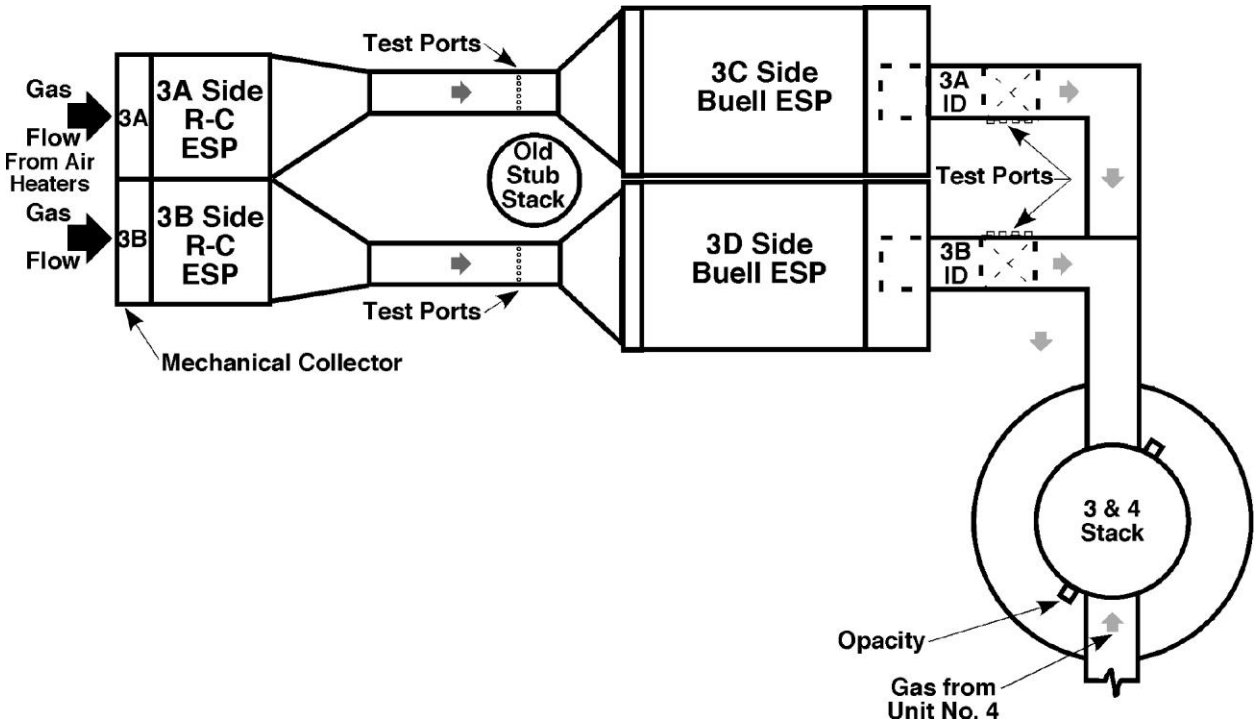
Flue Gas Velocity Vectors at Hopper Centerline

- **Near-Perfect Top-to-Bottom Flow Distribution – Minimal Hopper Flows**
- **Helps to Explain Unexpected Carbon Distribution at ESP Outlet**
- ***Mild flow corrections have little downstream "rebound"***



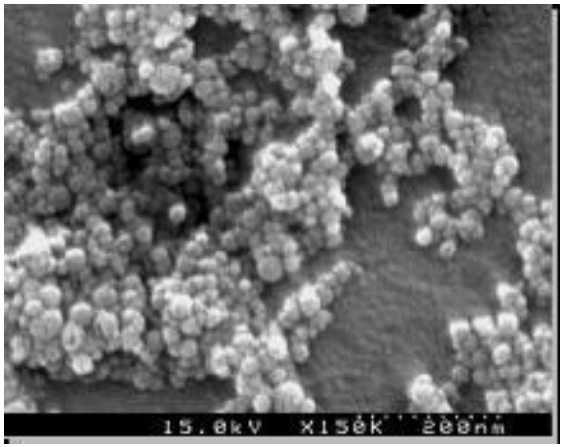
2011 Carbon Capture Project – Small Unit Flue Gas Train

- Plan view of test unit



Biomass Ash Analysis

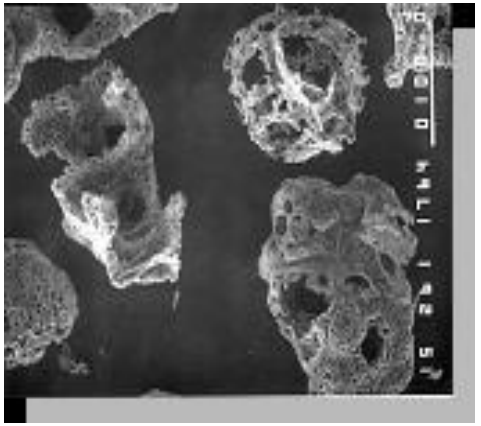
- Objective of study
  - Enhance accuracy of ESPM prediction of ash properties critical to precipitator collection efficiency as biomass introduced to fuel stream
- Original biomass ash research contained in 2002 White Paper #1004154
  - Utilized ash from pilot scale combustor
  - PSD was significantly smaller, resistivity higher than full scale ash from the same coal/biomass fuel
- Samples obtained, analyzed from 5 pulverized coal fired boilers
  - Buck Plant (Duke), Burger Plant (FE), Central Lime & Power, Greenidge (AES), and Rouge River (DTE)
  - Analysis conducted by Southern Research Inst.



Ash Micrograph

Biomass Ash Analysis

- Analysis of coal-only, various coal/biomass fuel blends for:
  - Particle size distribution (PSD)
  - Mineral ash analysis
    - 13 oxides, 5 other properties
  - Ascending and descending resistivity
  - SO_3 conditioning (resistivity) curves
- Study limitations
  - Few test burns/ash samples available in 2010
  - Some ash recovered from files of previous tests
  - Coal-only ash for old tests was not available in all cases. Greenidge did not burn coal alone.
  - Silicon from soil a significant factor in resistivity
- Final report #1023078



Acid Leached Unburned Carbon

High Resistivity Ash Collection Modifications

- Flue gas SO_3 reduction needed
  - Hg sorbent performance (under 3ppm)
  - Emission limits (various)
- Result is high resistivity ash
  - Values above $1x10^{11}$ Ohm-cm
  - Back corona and/or high spark rates
  - Severely reduced collection efficiency

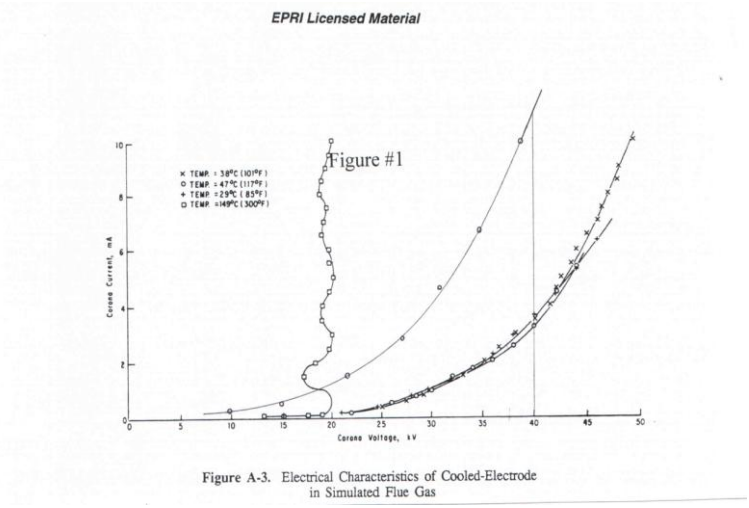


Figure A-3. Electrical Characteristics of Cooled-Electrode in Simulated Flue Gas

- Temperature control developed to reduce resistivity
  - Exploits dramatic drop in ash resistivity, below its peak ~335ºF
  - Existing power supply, rapping, hoppers, plates

Test Plan

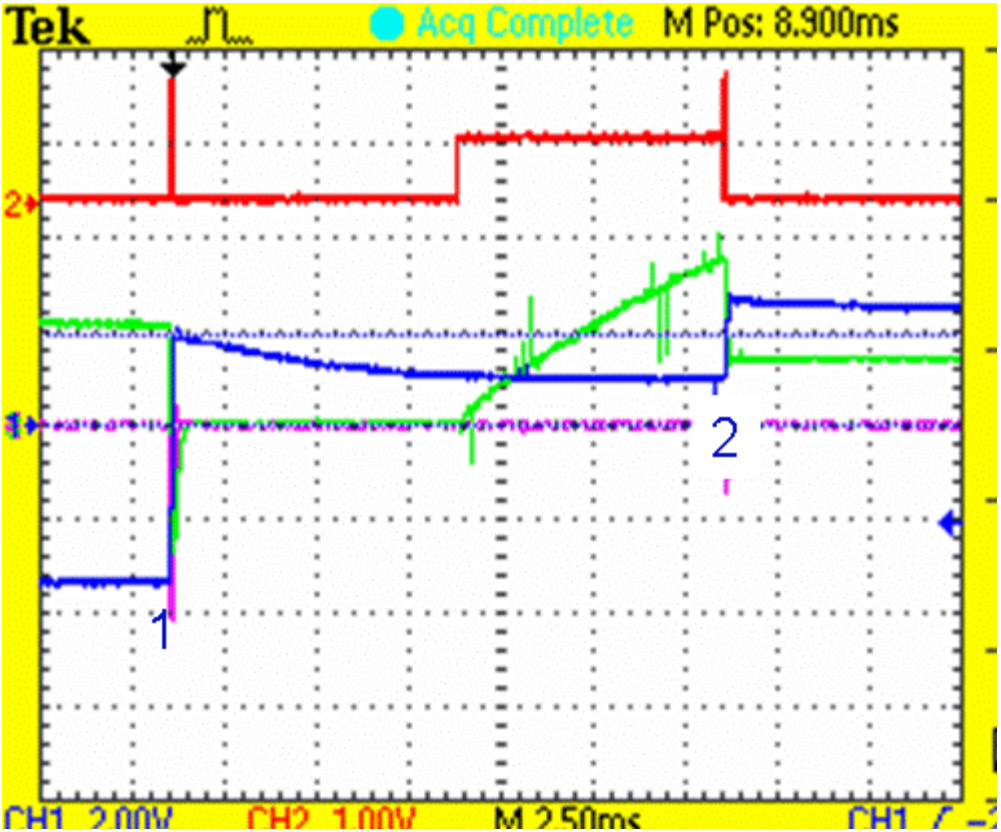
- Baseline testing
  - V/I curve without discharge electrodes in cooled area
  - Collection efficiency with native SO_3 level (Method 17)
  - Collection efficiency with all SO_3 sorbed out
- Cooled testing
  - V/I curve with discharge electrodes installed
  - Collection efficiency with native SO_3 level
  - Collection efficiency with all SO_3 sorbed out
  - Rapping effectiveness
- Other parameters of interest to be determined
  - Laboratory resistivity correlations
  - Collection efficiency change
  - Change in total power dissipation

EPRIswitch Polarity Reversal 2010 Progress

- Positive stack failure occurred (‘10), was analyzed with the ROPE failure
  - Negative stack performed properly with 4 days run time
  - Some polarity reversals were executed prior to the failure at the highest voltage
- Snubber protective circuit upgraded
  - MOV dissipation capacity upgraded
  - Increased circuit capacitance & resistance
  - Software improvements implemented
- Upgraded stacks tested in NWL lab
  - Good attenuation of switching spikes at SCRs, simultaneous SCR firing
- Testing began 1st week in February

EPRIswitch HV SCR Stack Tank
PowerPlus supply in background
Plant Barry Inlet Field

Polarity Reversal Operating Data



Blue trace = voltage applied to ESP field (scale 16.8 kV/div)

1- Switch from -30 kV to +16.8 kV in < 200 µsec, in-rush current = 41.6a!

2- Positive kV maintained through periodic re-firing of EPRIswitch during time defined by hammer interlock and DSP software.

Recent ROPE Experience

- Five-day Gadsden test 2010
  - Operated at 70 pulses/sec for 5 weeks during air-load and online operations, then failed SCR stack
  - Installation produces spark events as it charges at reduced voltages, unanticipated
- NWL field analyzed the failures
  - Software and hardware issues
  - Most significant - simultaneous magnetic switch & SCR stack turn-on during spark & arc events
- Redesign includes:
  - Modify & increase gate drive power rating
  - Controls software change in spark sensing

ESPM Improvements

- Corrections complete
  - Revised PSD; 9-10*u*m Bituminous, 8-9*u*m Subbituminous
    - Separate models for Bituminous and Subbituminous
  - Added capability specifically for alkaline flue gas and furnace injection
  - Improved flexibility in flue gas property calculation
  - Other housekeeping, calculational improvements, new chart routine

- Significant improvements in technical calculations
  - Beta testers reported good correlation with observed opacity

ESP On-Line Training Enhancements www.epri.com/esp

- Website reorganized with focus on troubleshooting for plant technicians
- Various content changes and updates
- New material
  - Troubleshooting sodium depletion issues
  - Effects of alkaline sorbent injection on ESP operation
  - Optimizing AVC setpoints
  - Current regulatory issues
- Upcoming material
  - Wet ESP operating and performance materials
    - Following operating WESP testing

Website Samples – Topics

EPRI Quick Access ESP - Windows Internet Explorer

C:\Documents and Settings\User1\My Documents\ESP Online\ESPOnline 2010\performance_troubleshoot.htm

File Edit View Favorites Tools Help

Favorites

EPRI Quick Access ESP

Page Safety Tools

Category Menu

Troubleshooting
Miscellaneous
Operation & Performance
Rapping System
Ash Handling System
Voltage System
Miscellaneous
Other Topics
ESP Design and Upgrades
Regulatory Issues

Provide Website Feedback

ESP Knowledge Base Home

Troubleshooting Topics

Introduction to Performance Troubleshooting
A discussion on how to estimate ESP performance and begin the troubleshooting process using ESP operating data.

Using ESP Modeling Software
A discussion of how ESP performance models work and how they may be used to troubleshoot ESP performance problems and evaluate upgrade options.

Troubleshooting Hot Side Sodium Depletion
A discussion on how to determine if sodium migration exists in a hot-side ESP and recommendations.

Troubleshooting Insulator Problems
A discussion on how to detect possible electrical insulator problems using visual inspection and panel meter readings.

Troubleshooting T/R-Set Grounding Problems
A discussion on how to determine if an ESP electrical bus section is grounded using panel meters.

Diagnosing Inleakage Problems
Recommendations for determining if inleakage is occurring in ESP ductwork.

Understanding Flow Distribution Problems
A discussion on how to detect and correct various flow distribution problems at the ESP inlet.

EPRI 3412 Hillview Avenue, Palo Alto, California 94304 USA
800.313.3774 or 650.855.2121
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file:///C:/Documents%20and%20Settings/User1/My%20Documents/ESP%20Online/ESPOnline%202010/inleakage.htm

My Computer 100%

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Upcoming Attractions

- Additional research & project work upcoming
  - Sectionalization performance between 60Hz & SMPS energization
  - Pilot Wet ESP testing with fabric plates at the Water Research Center
  - Full scale WESP performance characterization
  - Dry ESP startup hangover from fuel oil torches
  - Trona/fly ash mixture physical properties characterization
  - ESPM update for dry sorbent injection of sodium compounds (Trona, sodium bicarb)

Together…Shaping the Future of Electricity