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World Pollution Control Association
Ameren Seminar

Wet Electrostatic Precipitation Technology for the Utility Industry

By
James "Buzz" Reynolds
Vice-President, Wet ESPs

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Agenda

- **Opacity & Blue Plume**
- **SO3 and PM2.5**
- **New Regulations Driving Control of $PM_{2.5}$ & SO_3**
- **WESP Technology**
- **Utility Applications**
  - **After FGD in saturated flue gas**
  - **After Dry ESP in unsaturated flue gas**
- **Mercury Control**
- **Conclusion**

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Acknowledgements

- First Energy
  - Bruce Mansfield Plant WESP pilot host site
- Southern Company
  - Alabama Power Plant Miller WESP pilot host site
- DOE's NETL Office
  - Funding for Bruce Mansfield Plant pilot
- Electric Power Research Institute
  - Funding for Plant Miller pilot

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OPACITY & BLUE PLUME

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Opacity is a Function of Particle Size

0.5 micron particles are at peak of light extinction curve

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Relative Particle Sizes

LOWER LIMIT OF VISIBILITY (NAKED EYE) ..... 40 MICRONS
WHITE BLOOD CELLS ..... 25 MICRONS
RED BLOOD CELLS ..... 8 MICRONS
BACTERIA (COCCI) ..... 2 MICRONS
SULFURIC ACID MIST ..... 0.3 MICRONS

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SO_3 & $PM_{2.5}$ Determine Opacity

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SO_3 & $PM_{2.5}$

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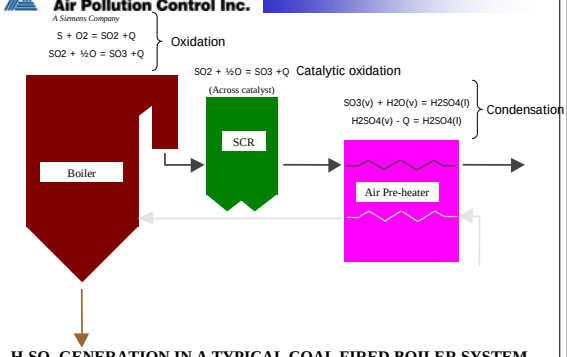

H_2SO_4 GENERATION IN A TYPICAL COAL FIRED BOILER SYSTEM

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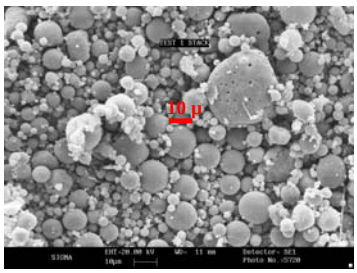
Fly Ash Particles



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$PM_{2.5}$ vs. PM_{10}

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of Particles in 1 Cubic Inch

Particle Size	Number of Particles	Compared to 10 microns	Surface Area of Particles	Compared to 10 microns
0.5	128,850,993,811,609	8000x	153,846	20x
1	16,106,374,226,451	1000x	76,923	10x
2.5	1,030,807,950,493	64x	30,769	4x
5	128,850,993,812	8x	15,385	2x
10	16,106,374,226		7,692	

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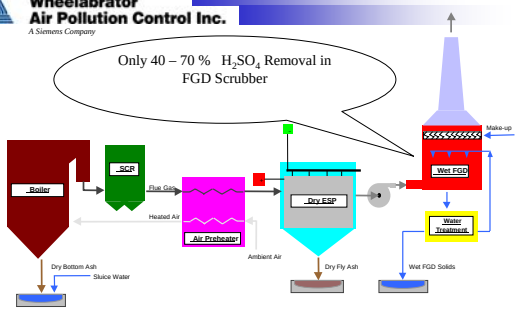

Why so little ?

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Wet FGD's typically operate at @10"-15" w.c. which translates into 50% removal efficiency in a wet scrubber

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NEW REGULATIONS

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New EPA PM Standards
The Bermuda Triangle of Regulations

New Source Performance Standards
- New Plants
- Proposed 2/9/06
- PM = 0.015 lb/MMBtu
- Measures both filterable and condensable PM

National Ambient Air Quality Standards for PM2.5
- Existing Plants
- Proposed 12/20/05
- PM= 35 µg/m3
- Measures both filterable and condensable PM

Clean Air Visibility Rule
- Existing Plants
- Proposed 6/15/05
- Plants close to National Parks
- NOx, SO2, PM levels TBD

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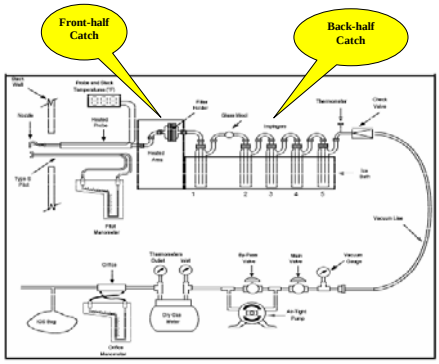
What is $PM_{2.5}$?

- ***Filterable Particulate***
  - <2.5 microns in size
  - Exists as solid particulate at temperatures of 250°F or higher
  - Collected in "front-half" filter of PM test apparatus
  - Represents @ 25% of $PM_{2.5}$ emitted by sources
- ***Condensable Particulate***
  - <2.5 microns in size
  - Vapors that condense at ambient temperatures
    - SO_3 – H_2SO_4 sulfuric acid mist
    - Toxic metals – cadmium, chromium, lead, magnesium
  - Collected in "back-half" impingers in PM test apparatus
  - Represents @ 75% of $PM_{2.5}$ emitted by sources
  - Has not been required to date to meet PM_{10} standards

EPA Method 8 Sampling Method



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New Coal-Fired Power Plant APC Configurations

Proposed Facility	Unit Size (MW)	Coal Proposed to be Fired	APC Control Technology
Elm Road	2 x 615	Pittsburgh #8	FF / WFGD / **WESP**
Thoroughbred	2 x 750	West KY Bituminous	ESP / WFGD / **WESP**
Prairie States	2 x 750	Southern IL Bituminous	ESP / WFGD / **WESP**
Longview Power	600	2.5%S WV Bituminous	DSI / FF / WFGD
Trimble County	750	Blend of Bituminous & Sub-bituminous	ESP / FF / WFGD / **WESP**
CWLP-Dallman	200	Blend of Bituminous & Sub-bituminous	FF / WFGD / **WESP**

Why a WESP?

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WESP TECHNOLOGY

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Why Wet ESP?

- **Multi-Pollutant Control**
  - **$PM_{2.5}$**
  - **SO_3**
  - **Metals**
  - **Mercury (species dependent)**
- **Opacity Reduction**
  - **<10% visible plume**
- **Operationally**
  - **Low Pressure Drop**
  - **No Moving Parts**
  - **Self-Cleaning**
  - **Small Footprint**
  - **Flexible to Upset Conditions**
  - **No impact on upstream equipment**
- **Fuel Flexibility**
  - **Switch to lower cost, higher S coal**

A Final Polishing Device

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WESP Controls SO3 + PM2.5 + Hg

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Wet Precipitation Process

1-Charging
2-Collection
3-Cleaning with water

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Wet ESP vs. Dry ESP

OPERATIONAL ISSUES	DRY ESP	WET ESP
BACK CORONA	YES	NO
RE-ENTRAINMENT	YES	NO
PM_{10} REMOVAL	YES	NO
$PM_{2.5}$ REMOVAL	Limited	YES
SO_3 REMOVAL	NO	YES
MERCURY REMOVAL	NO	YES
WASTE WATER TREATMENT	NO	YES

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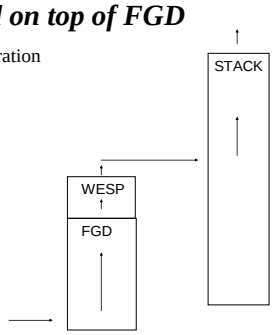
Mounted on top of FGD

- Vertical Up-Flow Configuration
- No Additional Real Estate



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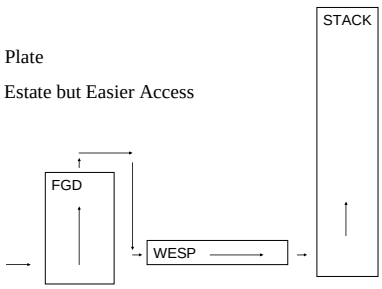
Stand Alone Configuration

- Horizontal Plate
- More Real Estate but Easier Access



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WESP History

- First ESP was wet, not dry
- Developed by Dr. Cottrell in 1907
- Used to control sulfuric acid mist
- First dry ESP was in 1922 at Detroit Edison
- Thousands of industrial applications
- Utility installations are limited
  - 3 in US
  - 2 in Canada
  - @ 25 in Japan
  - @ 12 in Europe

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Multi-pollutant Capability of a WESP

Pollutant	Units	Test Runs	MACT Limits	%
Particulate	gr/dscf, 7%O2	0.0024-0.0030	0.015	99.94
HCL/Cl2	ppmdv,	2.96-4.84	77	99.95
Chromium	ug/dscm	39.7-42.8	97	99.97
Lead	ug/dscm	3.59-3.85	240	99.95
Mercury	ug/dscm	1.82-1.98	130	79%
Dioxin/furan	ng TEQ/dscm	0.0131-0.0892	0.4	N/D

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Utility Applications

- Mid-High Sulfur Coals (bituminous)
  - FGD System installed for SO_2 control
  - Saturated Flue Gas
  - Functions as a “Wet Electrostatic Mist Eliminator”
- Low Sulfur Coals (sub-bituminous & lignite)
  - No FGD installed
  - Unsaturated flue gas
  - High LOI &/or Elemental Hg
  - Last field after a dry ESP “Hybrid dry-wet ESP”

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X-Cel Energy Sherco Plant in Becker, Minnesota
WESP Overview

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NSP Sherco Unit 1 & 2 Stack Opacity History

Opacity over time
From >40% to <10%
after all 22 modules installed

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First Energy's
Bruce Mansfield Plant

- **3 x 800 MW Units**
- **Mid-High Sulfur Coal**
- Investigated Control of:
  - PM2.5, SO3, Hg

•Current Opacity >50%
•Opacity Required <20%

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PM2.5 & SO3 Test Results

Summary of Pilot Wet ESP –PM2.5 & SO3 Test Results- Bruce Mansfield Plant –2001-2003

	PM2.5 (EPA Test Method 5)				**SO_3 Mist** (EPA Test Method 17 modified to Controlled Condensation)			
Average	URS Testing		OU Testing		URS Testing		Ohio U.	
Test Series	Sep-01	Nov-01	Nov-02	July-03	Sep-01	Nov-01	Nov-02	Oct -03
Airflow-acfm	8394	8235	N/A	8000	8394	8235	8000	8000
Velocity –ft./sec.	10	10		10	10	10	10	10
# of fields	1	2		2	1	2	2	2
Power Levels	100%	100%		100%	100%	100%	100%	100%
units	gr/dscf	gr/dscf		mg/m^3	ppm	ppm	ppm	ppm
Inlet	0.0292	0.0506		125	11.5	10.01	8.9	2.9
Outlet	0.0063	0.002		9	2.7	0.85	1.0	0.35
Removal %	**79%**	**96%**		**93%**	**76%**	**92%**	**89%**	**88%**

Note: WESP designed for 90% removal at 5,000 acfm.
Testing performed at 8,000 acfm, 60% beyond design point.

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Pilot Results
Plotted on Iso-Opacity Chart

From > 50% to < 10%

View Through Observation Tube

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Coal Fired Utility Pilot
19' Long Site Tube to
Simulate Stack Exit

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UTILITY APPLICATION

- AFTER DRY ESP
- UNSATURATED FLUE GAS
- NO FGD

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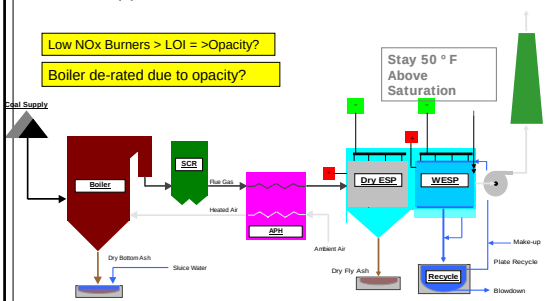
Low NOx Burners > LOI = >Opacity?

Boiler de-rated due to opacity?

Stay 50 ° F Above Saturation



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Hybrid Dry-Wet ESP Pilot

•Alabama Power
•Plant Miller
•PRB Coal
•SCR- Dry ESP
•2 MW Slip-stream

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Steps to Commercialization

- ☑ Proof of Concept:
  Single electrode
  2.5 liters/minute
  Simulated flue gas
- ☑ Bench Scale:
  Multiple electrodes
  1 scfm
  Simulated flue gas
- ☑ *Pilot Scale:*
  Full scale electrodes
  5,000 acfm
  PRB coal flue gas
- *Demonstration Scale:*
  Full scale electrodes
  50-150 MW
  PRB coal flue gas

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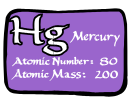
MERCURY CONTROL



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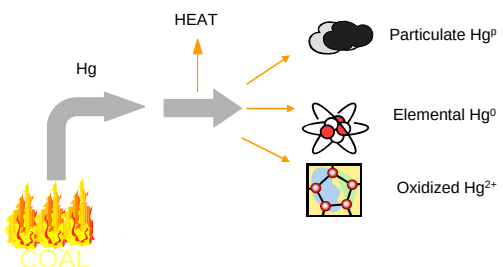
Fate of Hg from Combustion



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Bituminous Coals

- **High Sulfur / High Chlorine Content**
- **70% Hg^{2+} / 30% Hg^{O} Ratio**
- **Hg^{2+} is Water Soluble**

Incremental Hg Removal Efficiency (Ontario Hydro Test Method)

	FGD Inlet		FGD outlet		Wet ESP outlet		Total
	µg/m³	Removal %	µg/m³	FGD %	µg/m³	WESP %	FGD/WESP Removal %
Ash Hg	4.37	0%	0.85	80%	0.20	76%	95%
Hg^{2+}	6.02	0%	1.88	69%	0.26	86%	96%
Hg^{0}	2.55	0%	2.92	-15%	2.39	18%	6%
Total Hg	12.94	0%	4.88	62%	2.85	41%	78%

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Sub-bituminous Coals

- **Low Sulfur / Low chlorine content**
- **No FGD required for SO2 control**
- **70% Hg^{o} / 30% Hg^{2+} Ratio**
- **Hg^{o} is non-soluble**
- **Flue Gas is not saturated**
- **Need to Absorb or Oxidize Hg^{o}**

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Hybrid Wet ESP Pilot
Hg Test Results

Plant	Location	Flue Gas Temp.	Mercury Conc.	Out/In Ratio	Total Hg Removal
		F	$\mu g/m^3$		
Miller Unit 2	Inlet	250	5.79	0.60	
Miller Unit 2	Outlet	159	3.453		**40%**
Miller Unit 2	Inlet	257.5	5.504	0.49	
Miller Unit 2	Outlet	163	2.696		**51%**
Miller Unit 2	Inlet	257	6.334	0.66	
Miller Unit 2	Outlet	163	4.16		**34%**
Miller Unit 2	Inlet	255	5.500	0.60	
Miller Unit 2	Outlet	161	3.288		**40%**
Miller Unit 2	Inlet	253	6.317	0.61	
Miller Unit 2	Outlet	158	3.881		**39%**

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PLASMA ENHANCED ESP TECHNOLOGY
FOR
MERCURY OXIDIATION & CONTROL

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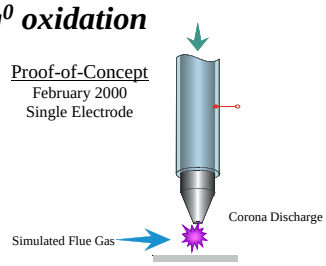
Patented PEESP™ Technology
Hg^0 oxidation

Proof-of-Concept
February 2000
Single Electrode



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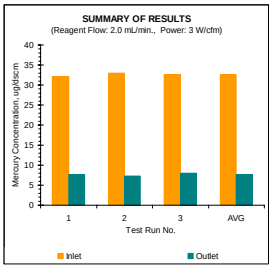
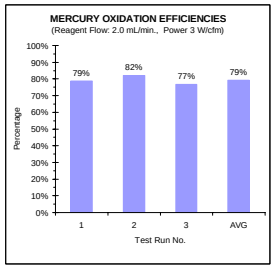
Bench Scale Test Results





79% Hg Oxidation

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Conclusions

- Opacity is a function of $PM_{2.5}$ & SO_3 Mist
- New EPA Standards will require control
  - Filterable particulate
  - Condensables including SO_3
- WESP technology
  - Captures PM2.5 & SO_3
  - Reduces Opacity to < 10%
  - Offers additional Mercury control
  - Low pressure drop, maintenance & small footprint
- Utility Applications
  - Used on mid-high sulfur coals after FGD
  - Used on low-sulfur coals after dry ESP