Worldwide Pollution Control Association

IL Regional Technical Seminar

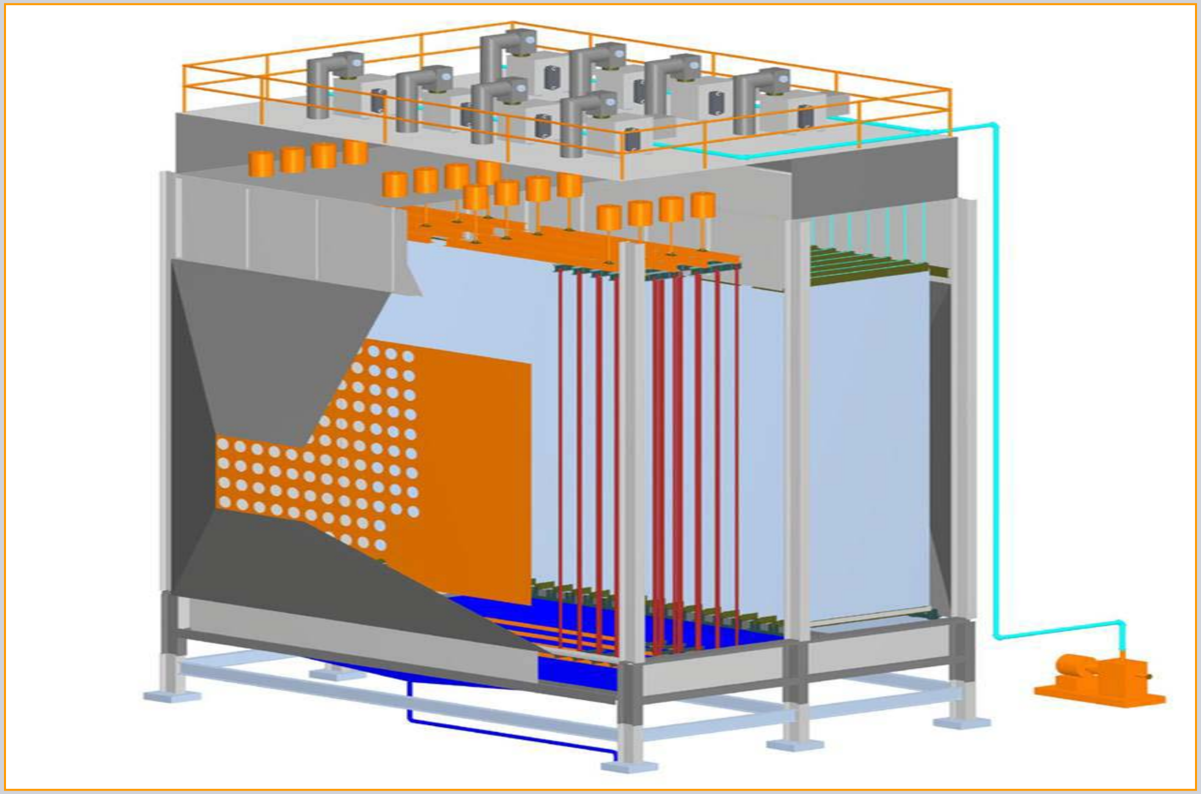
September 13-15,2011

W
P
C
A

Visit our website at www.wpca.info

Utility MACT PM Control with WESP Technology

SIEMENS



Buzz Reynolds VP Wet ESP
Siemens Environmental Systems & Services

SIEMENS

U- MACT PM Control with WESP Technology

1. Proposed Standards for New & Existing Units
2. Strategic Considerations
3. What Total PM means
4. Impact of Particle Size Distribution
5. Existing Plant Control Equipment vs Proposed Standards
6. Possible WESP Application
7. Why WESP
8. Where it is installed
9. How has it performed

11. New WESP Applications
    - Plasma ESP
    - Hybrid Dry-Wet ESP
12. Acknowledgments

Proposed Standards

Regulated Pollutant	Primary Fuel	Proposed Emission Limits for New Units	Proposed Emission Limits for Existing Units
Acid Gases	Bituminous Sub-bituminous Lignite	HCL=0.30 lb/GWh (~0.03 ppmvd @ 3%O_2) or SO_2= 0.40 lb/MWh (~0.042 lb/MMBtu)	HCL=0.0020 lb/MMBtu (~2ppmvd @ 3%O_2) or SO2= 0.20 lb/MMBtu
Non-Hg HAP Metals	Bituminous Sub-bituminous Lignite	**Total PM= 0.05 lb/MWh (~0.005 lb/MMBtu)** or Total Non-Hg HAP Metals = 0.000042 lb/MWh (~4.2 lbs/TBtu) or Individual HAP Metal Limits	**Total PM = 0.030 lb/MMBtu** or Total Non-Hg Metals = 0.000040 lb/MMBtu or Individual Non-Hg HAP Metals
Mercury	Bituminous Sub-bituminous	0.000010 lb/GWh (~0.001 lb/TBtu)	1.2 lb/TBtu* (revised)
	Lignite	0.040 lb/GWh (~4.2 lb/TBtu)	4.0 lb/TBtu

SIEMENS

EPA ICR PM Database Summary

Summary of UPLs using emission averages -- Coal-fired units/PM emissions

	Existing						New		
Pollutant	Mean (lb/MMBtu)	UPL (lb/MMBtu)	Number of units in the floor	lb/TBtu	Floor value		Mean (lb/MMBtu)	UPL (lb/MMBtu)	Number of units in the floor
PM total	0.0116	0.0264	131		0.03	lb/MMBtu	0.002821	0.01307	1
Metal total	0.0000142	0.0000376	131		0.00004	lb/MMBtu	0.0000015	0.0000021	1
Antimony (Sb)	2.0981E-07	5.4934E-07	131	0.549338529	0.6	lb/TBtu	3.1217E-09	1.6294E-08	1
Arsenic (As)	4.1029E-07	1.0816E-06	131	1.081629882	2.0	lb/TBtu	9.4542E-09	1.4847E-08	1
Beryllium (Be)	4.8952E-08	1.3337E-07	131	0.133372821	0.2	lb/TBtu	1.6477E-09	4.7302E-09	1
Cadmium (Cd)	9.8523E-08	2.1212E-07	131	0.212120593	0.3	lb/TBtu	8.1778E-09	4.0907E-08	1
Chromium (Cr)	1.2160E-06	2.8157E-06	131	2.815717862	3	lb/TBtu	1.3625E-07	6.5805E-07	1
Cobalt	2.8224E-07	7.1184E-07	131	0.711841054	0.8	lb/TBtu	1.4315E-08	7.4579E-08	1
Lead (Pb)	5.3617E-07	1.2792E-06	131	1.279165372	2	lb/TBtu	2.5577E-08	8.0335E-08	1
Manganese (Mn)	1.6846E-06	4.1963E-06	131	4.196344044	5	lb/TBtu	1.2154E-07	1.8479E-07	1
Nickel (Ni)	1.4138E-06	3.3913E-06	131	3.391265314	4	lb/TBtu	1.1961E-07	3.5102E-07	1
Selenium (Se)	1.6204E-06	5.5311E-06	131	5.531080708	6	lb/TBtu	1.3678E-08	3.1240E-08	1

Go to Database

Strategic Considerations

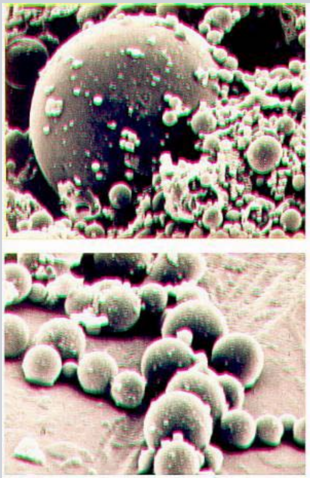
- **Utilize existing assets**
  - Look to leverage existing APC equipment (dry ESP)
  - Think of Boiler & APC equipment as an integrated system
  - How to optimize the system, not just a component

- **Think long term**
  - Limits will get more stringent as EPA collects more data
  - Design / build for worst case condition to avoid future add-ons
  - Look to limits for new coal plants–0.05 lb/MWh (0.005 lb/MMBtu)

- **Minimize risk**
  - Build in enough safety margin
  - Understand appropriate test method
  - Allow for operational flexibility
  - Belts & suspenders – complementary APC equipment

What Total PM Means

SIEMENS



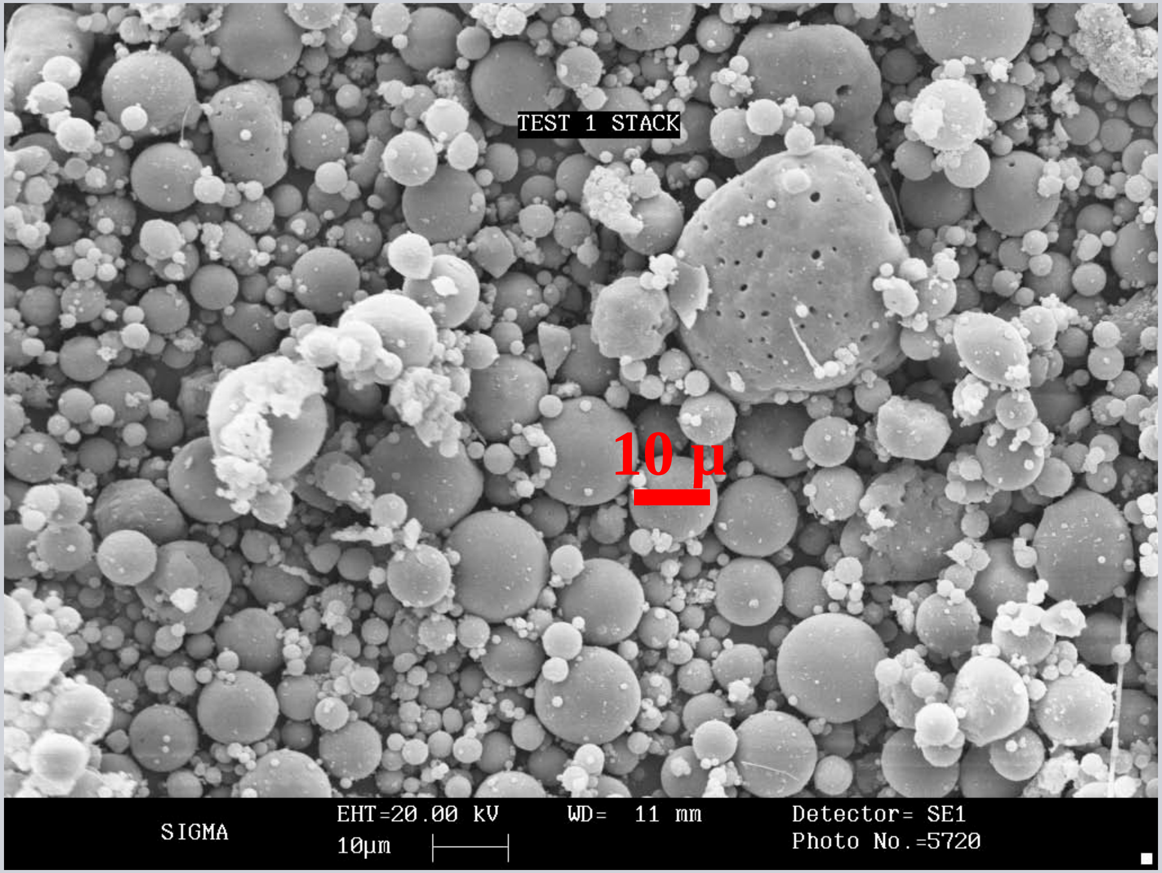
Filterable Particulate

- Exists as solid or liquid particulate
- Collected in “front-half” filter of PM test apparatus

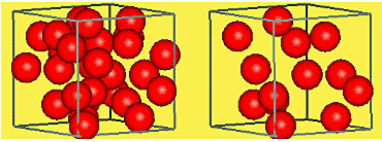
Condensable Particulate

- 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
- Has not been required to date to meet PM standards
- EPA estimates that 78% of PM 2.5 emissions are condensable

Fly Ash Particles



of Particles in 1 Cubic Inch *(1 micron = 0.000039")*

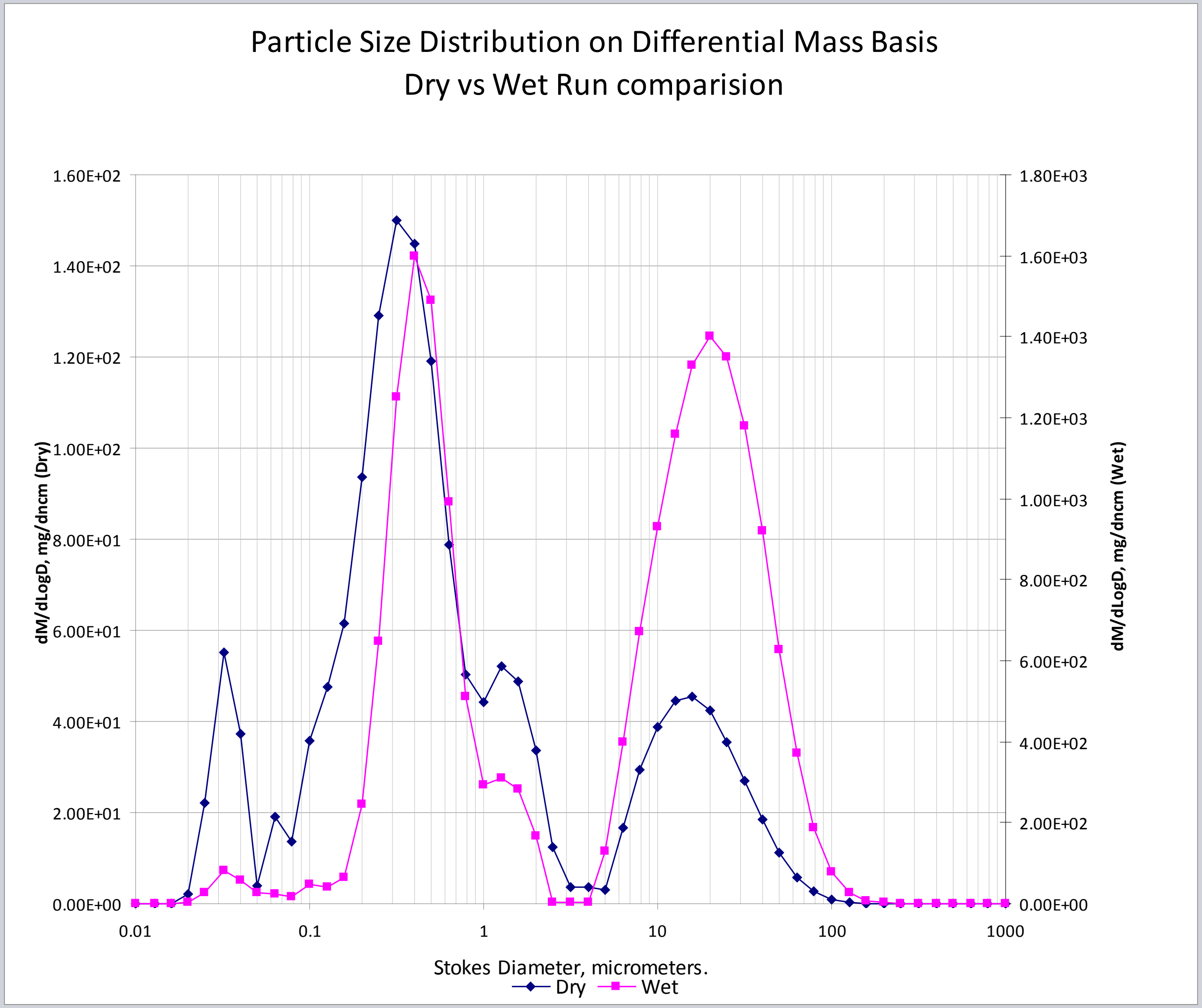


Particle Size	Number of Particles =1/(4/3πr³)	Compared to 10 microns	Surface Area of Particles = P# * 4πr²	Compared to 10 microns
0.5	128,850,993,811,609	8000x	153,846	20x
1	16,106,374,226,451	1000x	76,923	10x
2.5	1,030,807,950,493	64x	30,769	4x
5	128,850,993,812	8x	15,385	2x
10	16,106,374,226		7,692	

Particle Size Distribution from a WFGD by Mass

SIEMENS

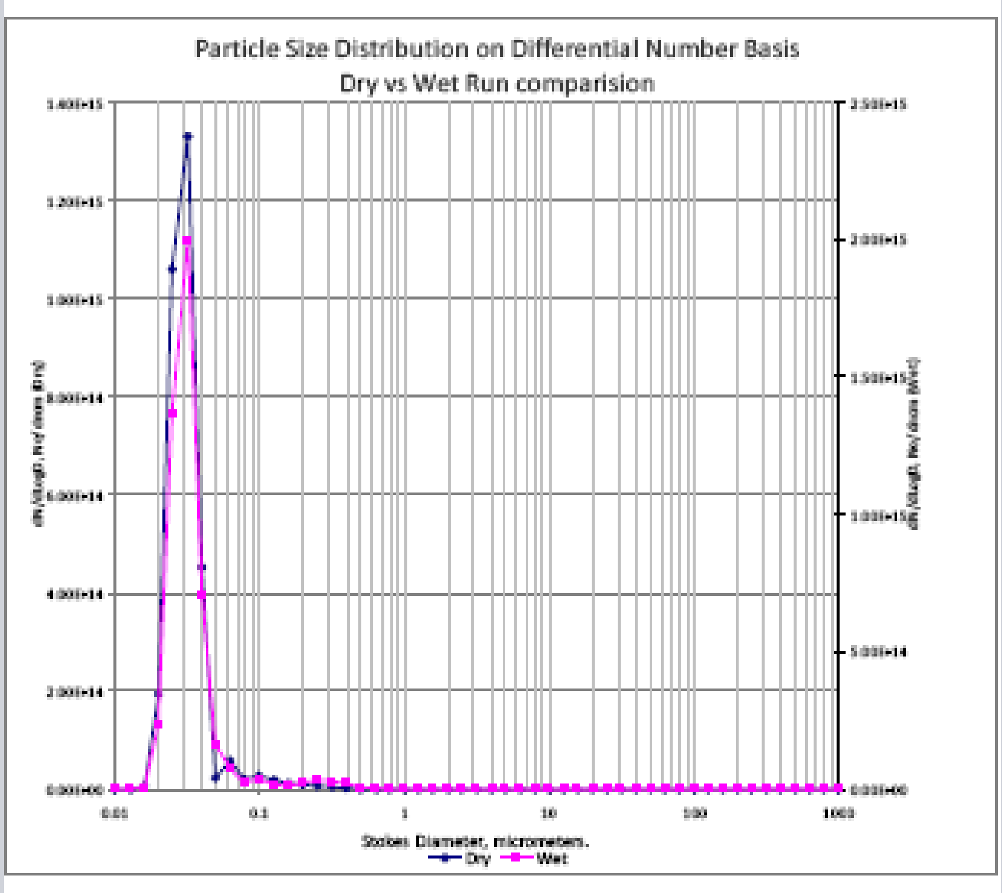
Courtesy of Clean Air Engineering



Particle Size Distribution from WFGD by Number

SIEMENS

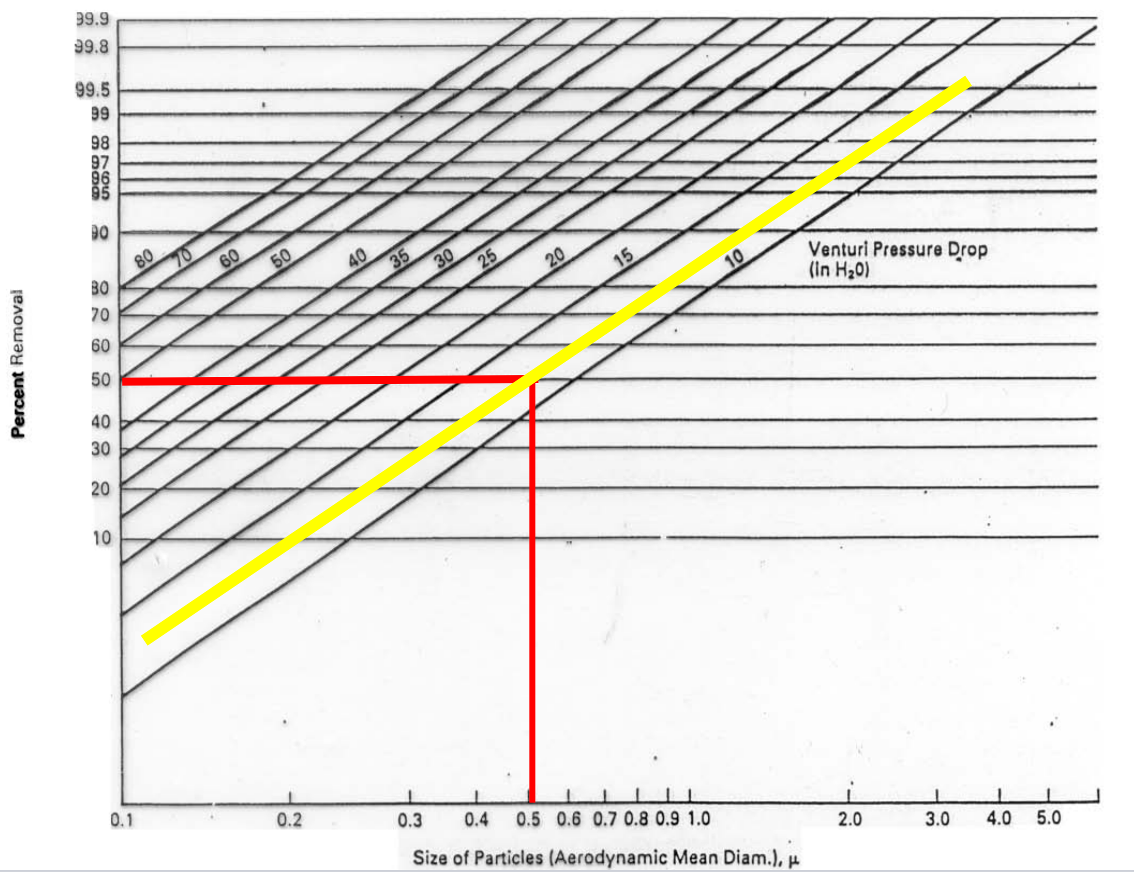
Courtesy of Clean Air Engineering



PM Removal Across Scrubber vs Pressure Drop

IEMENS

Figure 4-20. Venturi scrubber collection efficiencies.



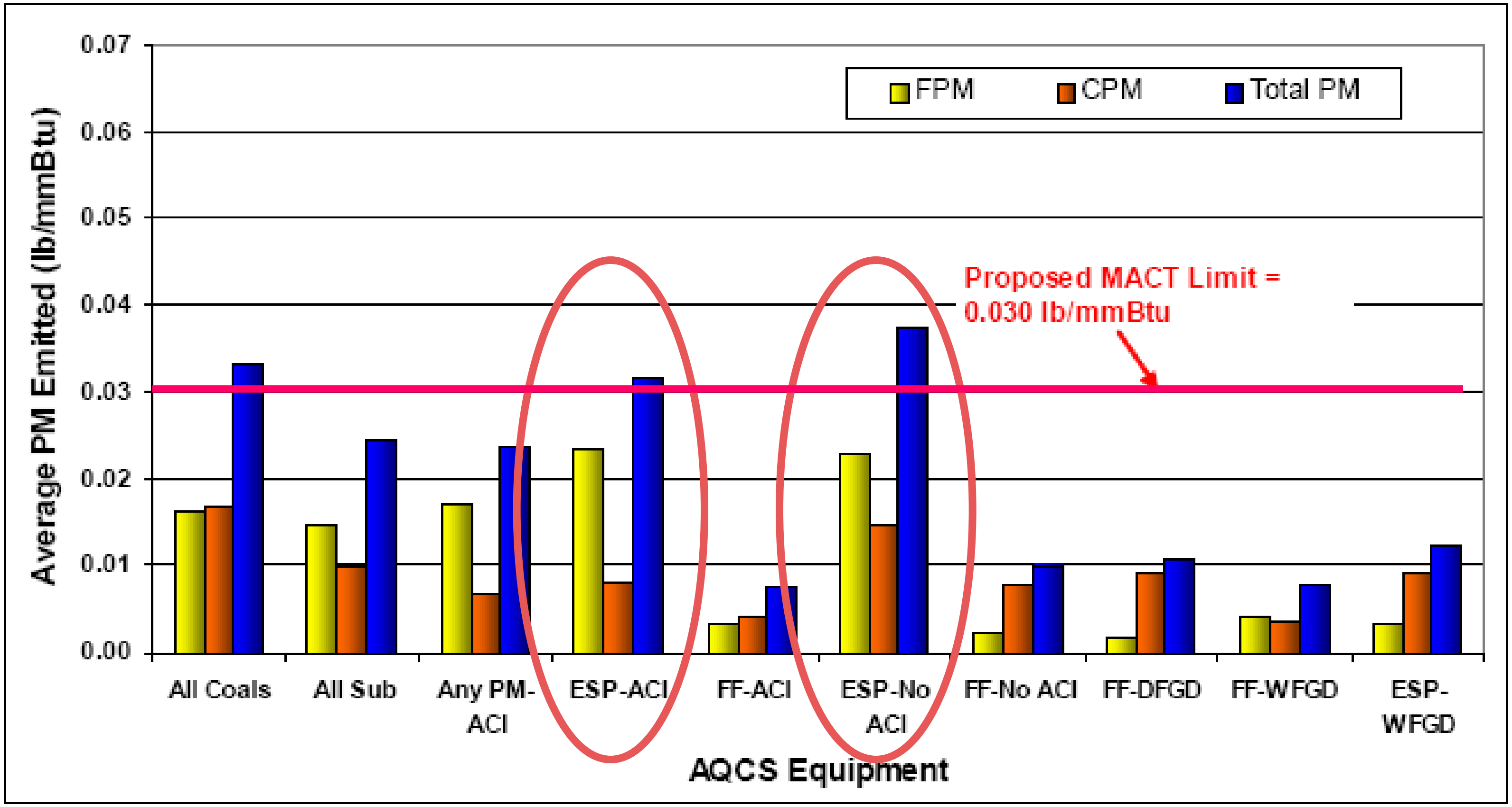
At 12" pressure drop can achieve 50% removal of 0.5 micron particles

Blue Plume” after DESP & WFGD

Sub-bituminous Coal ICR Data Control Method vs PM Standard

SIEMENS

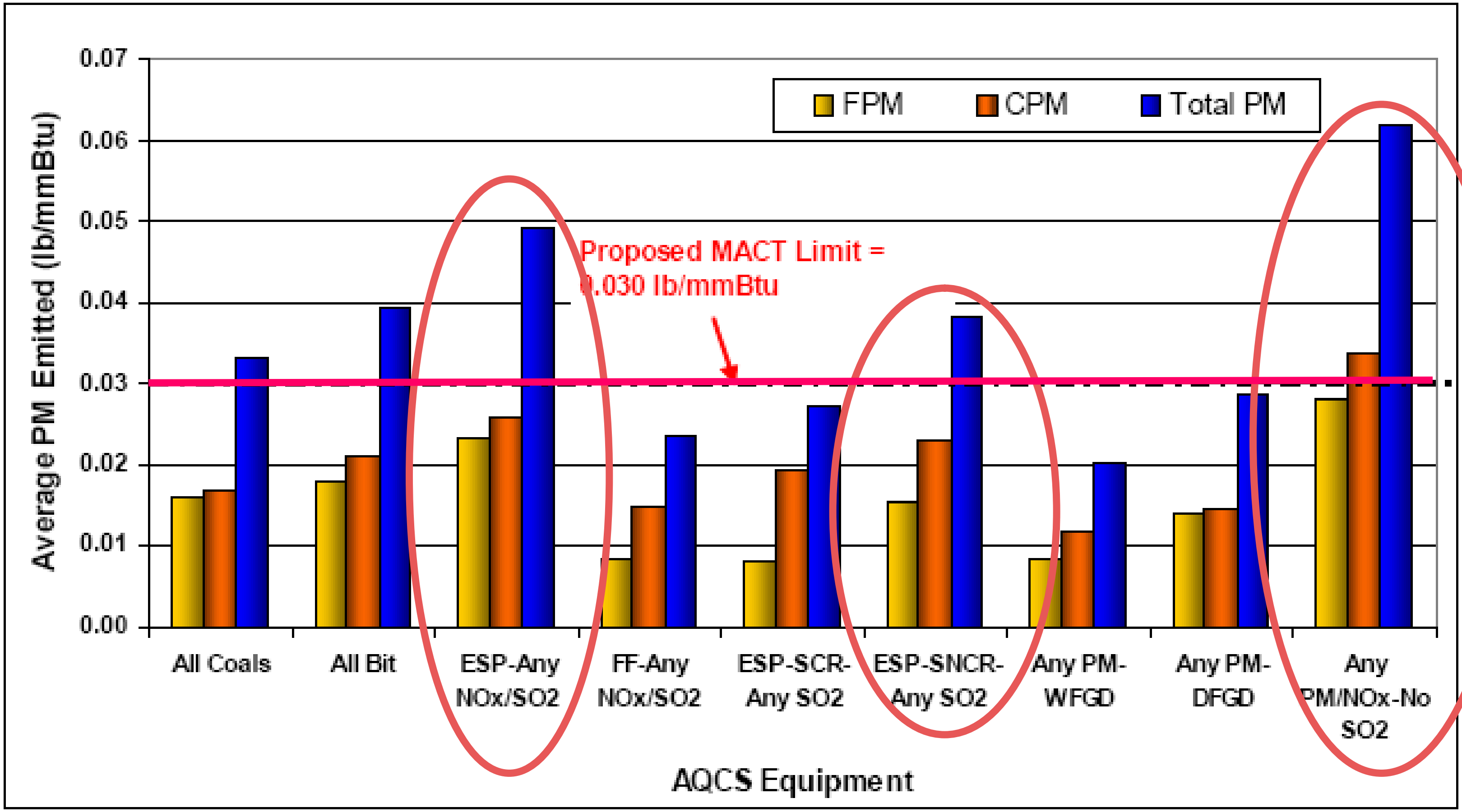
Slide created by Sargent Lundy



Bituminous Coal ICR Data
Control Method vs PM Standard

SIEMENS

Slide created by Sargent Lundy



APC Configurations NOT Meeting Proposed Total PM Standards

SIEMENS

Fuel	Existing Controls	U-MACT Suggested Equipment to Add
Bituminous Coals	Dry ESP with NOx + SO2 control	DSI/FF
	Any PM/NOx control but no SO2 control	DSI/FF/FGD (dry FGD or wet FGD)
Sub-Bituminous Coals	Dry ESPs with & w/o ACI	DSI/FF

SIEMENS

Issues with DSI / FF Controls

DSI

- Increased PM loading
  - does DESP have capacity
- Increased maintenance
  - plugging issues
- Increased operating costs
  on-going sorbent injection
- Impact on ash sales

Fabric Filter

- Increased pressure drop
  - may require new larger fans
- More real estate for FF
  - is there enough room
- On-going bag replacement
  - cost + outage time
- Increased waste by-product
  - need to landfill

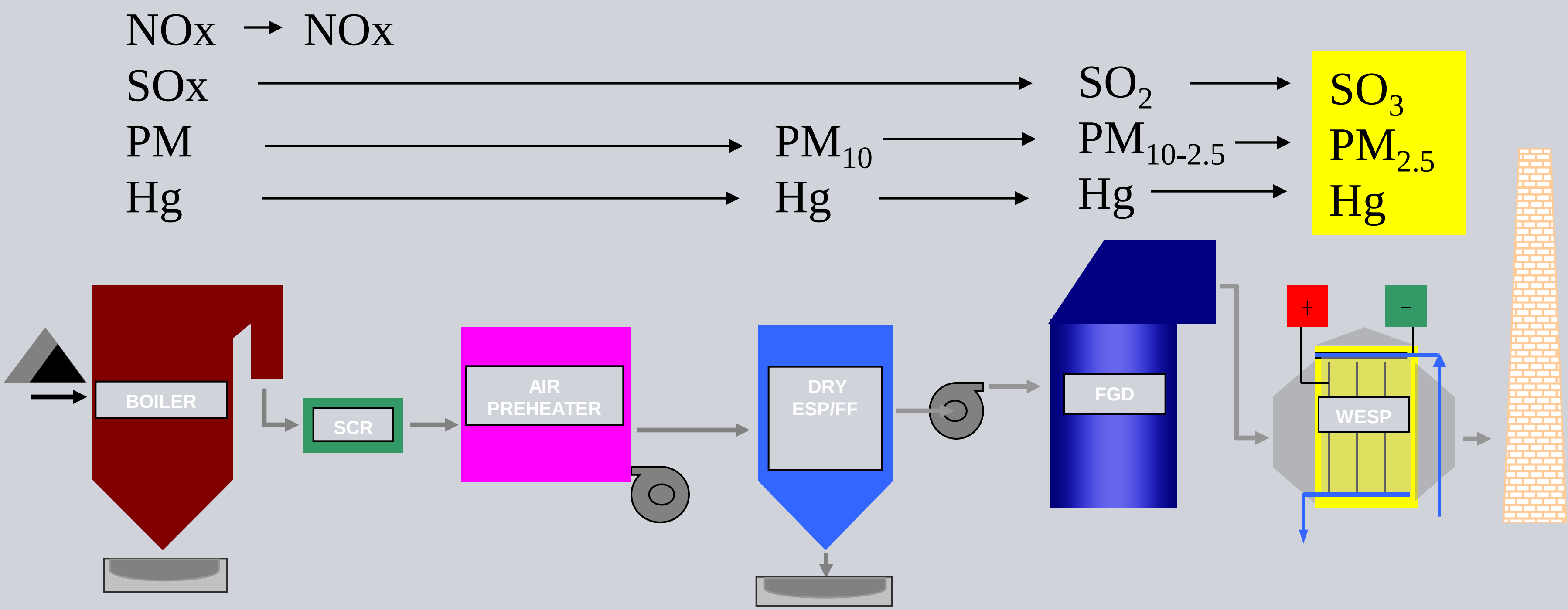
Are all costs factored into overall life cycle analysis?

An Alternative Approach for PM Control – WESP Technology

SIEMENS

Fuel	Existing Controls	U-MACT Suggested Equipment to Add	An Alternative to consider
Bituminous Coals	Dry ESP with NOx + SO2 control	DSI/FF	**WESP after a WFGD**
	Any PM/NOx control but no SO2 control	DSI/FF/FGD (dry FGD or wet FGD)	**WESP after a WFGD**
Sub-Bituminous Coals	Dry ESPs with & w/o ACI	DSI/FF	**WESP after Dry ESP In lieu of FF (piloted but not demonstrated)**

WESP Controls SO3 + PM2.5 + Hg



Why WESP Technology

SIEMENS

Multi-Pollutant Control

- $PM_{2.5}$ (filterable PM)
- SO_3 (condensable PM)
- Metals
- Mercury (limited)
- > 90% control

Opacity Reduction

- <10% visible plume

Operationally

- Low Pressure Drop (@1.0")
- No Moving Parts
- Minimal Maintenance
- Self-Cleaning with water
- Water by-product goes to WFGD
- Smaller footprint than FF
- Flexible to Upset Conditions
- No impact on upstream equipment

Fuel Flexibility

- Switch to lower cost, higher S coal

A Final Polishing Device

SIEMENS

What Utility MACT says about WESP Technology

25014 Federal Register / Vol. 76, No. 85 / Tuesday, May 3, 2011 / Proposed Rules

"A facility that wants to upgrade the PM control may choose to replace the current equipment with newer, better performing equipment. The facility may consider installation of a downstream secondary PM control device-such as a secondary FF. ***A Wet ESP can also be installed downstream of a wet FGD scrubber for control of condensable PM*****."**

25060 Federal Register / Vol. 76, No. 85 / Tuesday, May 3, 2011 / Proposed Rules

" Furthermore, an FGD designed for SO2 control has the co-benefit of reducing to some extent, condensable PM emissions. Therefore, the existing NSPS baseline for control of condensable PM is a FF in combination with an FGD. ***We have concluded that the additional use of a WESP system in combination with DSI is "Best Developed Technology" for condensable PM."***

SIEMENS

ICR DATA has 2 Plants with WESP

Microsoft Excel - Utility MACT Metals-PM database.xlsx

EA5 FF, WFGD

	A	B	C	D	E	EA	EB	EC
1	primary_fuel	ORIS code	Plant Name	physical_state	Unit Number	Control summary	control_group_1	control_type_1
2								
3	coal	7790	Bonanza Power Plant	UT	1-1	FF, WFGD	PM control	Fabric Filter, reverse air
4	coal	2554	Dunkirk Generating Plant	NY	1	SNCR, DSI, FF	NOx control	Selective Noncatalytic Reduction
5	coal	492	Martin Drake	CO	Unit 5 - Coal	FF, WFGD	PM control	Fabric Filter, reverse air
6	coal	568	Bridgeport Station	CT	BHSEMU3OS3-#2	ESP, ACI, FF	PM control	Electrostatic precipitator, cold side, w/o flue gas
7	coal	2712	Roxboro Steam Electric Plant	NC	Rox_Cfg_2c	SCR, ESP, WFGD	NOx control	Selective Catalytic Reduction
8	coal	8223	Springerville	AZ	4	SCR, DFGD, FF	NOx control	Selective Catalytic Reduction
9	coal	891	Havana	IL	Boiler 9	ESP, SCR, ACI, DFGD, FF	PM control	Electrostatic precipitator, hot side, unspecified
10	coal	2554	Dunkirk Generating Plant	NY	4	SNCR, DSI, FF	NOx control	Selective Noncatalytic Reduction
11	coal	7097	J K Spruce	TX	1	FF, WFGD	PM control	Fabric Filter, reverse air
12	coal	2324	Reid Gardner	NV	1	FF, WFGD	PM control	Fabric Filter, pulse
13	coal	2451	San Juan	NM	Unit 3	ACI, FF, WFGD	Other control	Activated carbon injection
14	coal	2712	Roxboro Steam Electric Plant	NC	Rox_Cfg_1b	SCR, ESP, WFGD	NOx control	Selective Catalytic Reduction
15	coal	963	Dallman	IL	34	SCR, FF, WFGD, WESP	NOx control	Selective Catalytic Reduction
83	coal	6041	H L Spurlock Station	KY	Unit 01	ESP, SCR, WFGD, WESP	PM control	Electrostatic precipitator, cold side, w/o flue gas
84	coal	10343	Foster Wheeler Mt Carmel Cogen	PA	SG-101	FBC, FF	PM control	Fabric Filter, reverse air
85	coal	6021	Craig	CO	C3	DFGD, FF	SO2 control	Dry FGD - Spray Dryer
86	coal	2324	Reid Gardner	NV	3	FF, WFGD	PM control	Fabric Filter, pulse
87	coal	6664	Louisa	IA	101	DFGD, FF	SO2 control	Dry FGD - Circulating Dry Scrubber
88	coal	130	Cross	SC	C1	SCR, ESP, WFGD	NOx control	Selective Catalytic Reduction
89	coal	6113	Gibson	IN	2-2007-FGDIN	SCR, ESP, WFGD	NOx control	Selective Catalytic Reduction
90	coal	52071	Sandow Station	TX	5B	FBC, SNCR, ACI, DFGD, FF	NOx control	Selective Noncatalytic Reduction
91	coal	4041	South Oak Creek	WI	OCPP-B8	ESP	PM control	Electrostatic precipitator, cold side, w/o flue gas
92	coal	2324	Reid Gardner	NV	2	FF, WFGD	PM control	Fabric Filter, pulse
93	coal	1710	Consumers Energy - J.H. Campbell	MI	JHC2-Conf	ESP	PM control	Electrostatic precipitator, cold side, w/ flue gas conditioning
94	coal	1710	Consumers Energy - J.H. Campbell	MI	JHC1-Conf	ESP	PM control	Electrostatic precipitator, cold side, w/o flue gas
95	coal	56224	TS Power Plant	NV	TSPower	SCR, ACI, DFGD, FF	NOx control	Selective Catalytic Reduction
96	coal	4042	Valley	WI	VAPP-B3	FF	PM control	Fabric Filter, pulse
97	coal	4042	Valley	WI	VAPP-B2	FF	PM control	Fabric Filter, pulse
98	coal	6170	Pleasant Prairie	WI	PPPPB2	SCR, ESP, WFGD	NOx control	Selective Catalytic Reduction
99	coal	8224	North Valmy	NV	2	DFGD, FF	SO2 control	Dry FGD - Spray Dryer
100	coal	3138	New Castle Plant	PA	NC3-2	SNCR, ESP	NOx control	Selective Noncatalytic Reduction

Summary / PM_avg_MMBtu / PM_New_MMBtu / PM_coal_MMBtu / PM_avg_MW / PM_New_MW / Total_Metal_avg_MMBtu / Total_Metal_New_MMBtu

Total PM Emissions ICR Data vs WESP Data

SIEMENS

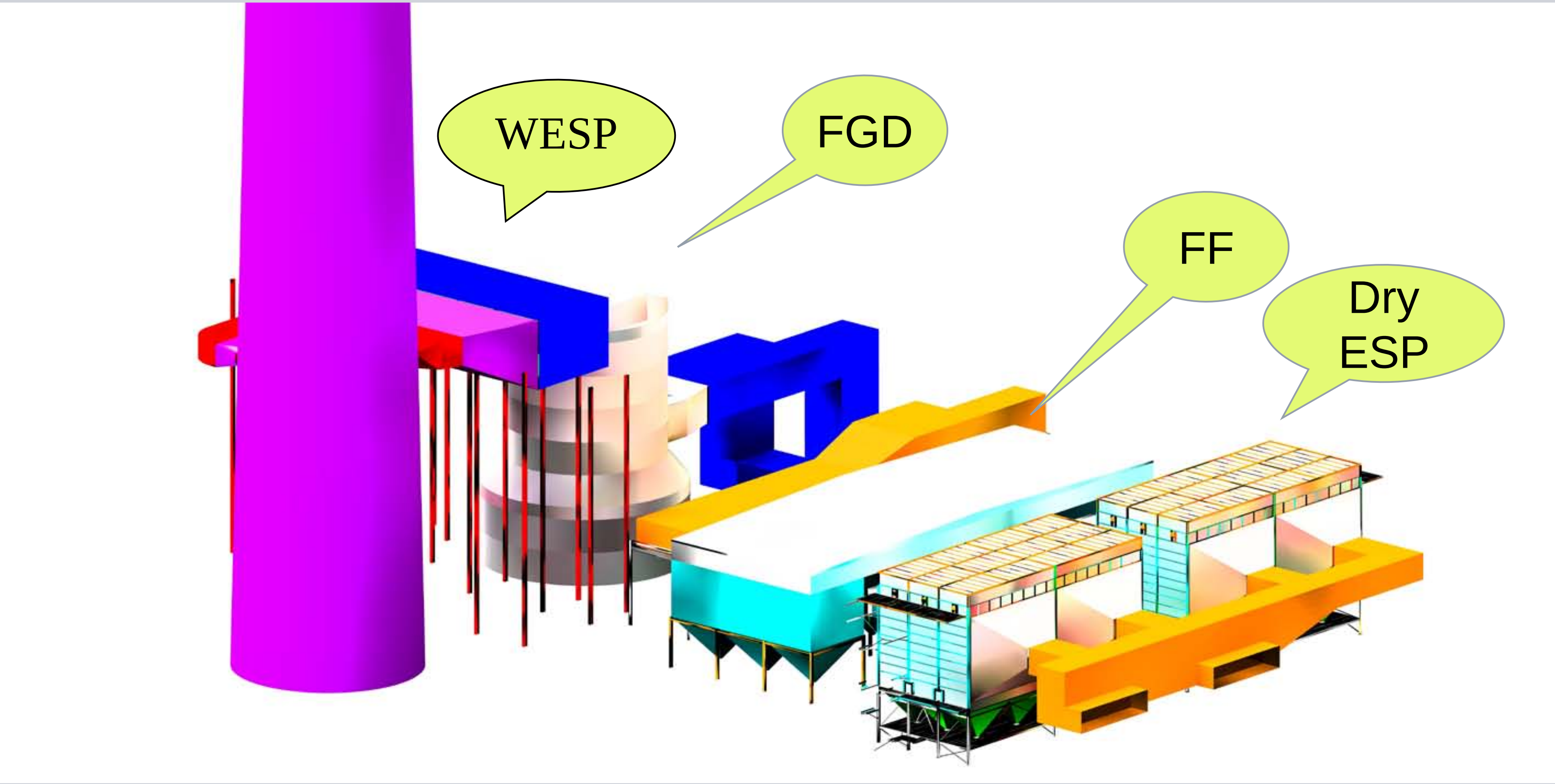
	# of Units	Range of PM	Ave PM Lb/MMBtu
PM Limit			**0.03**
All ICR Units	1091	8.60E-06 to 2.96E-01	0.0388
Top 12% mean	131	8.60E-06 2.56E-02	0.0116
Dallman Unit 3	1		0.0050
HL Spurlock Unit 1	1		0.0060

SIEMENS

New Coal Plant WESPs not in ICR Data

Facility	Unit Size (MW)	Fuel	APC Control Technology	Status
Elm Road	2 x 615	Pittsburgh #8	FF / WFGD / WESP	Online
Trimble County	750	Blend of Bituminous & Sub-bituminous	ESP / FF / WFGD / WESP	Online 2011
Prairie States	2 x 750	Southern IL Bituminous	ESP / WFGD / WESP	Fall 2011 & Spring 2012

Trimble County APC Equipment



Trimble County- 800 MW
DESP, DSI, FF, WFGD, WESP

SIEMENS

Dallman – 200 MW
DSI, FF, WFGD, WESP

SIEMENS

Prairie States – 2 x 800 MW
DSI, DESP, WFGD, WESP

SIEMENS

Older WESP Utility Installations

SIEMENS

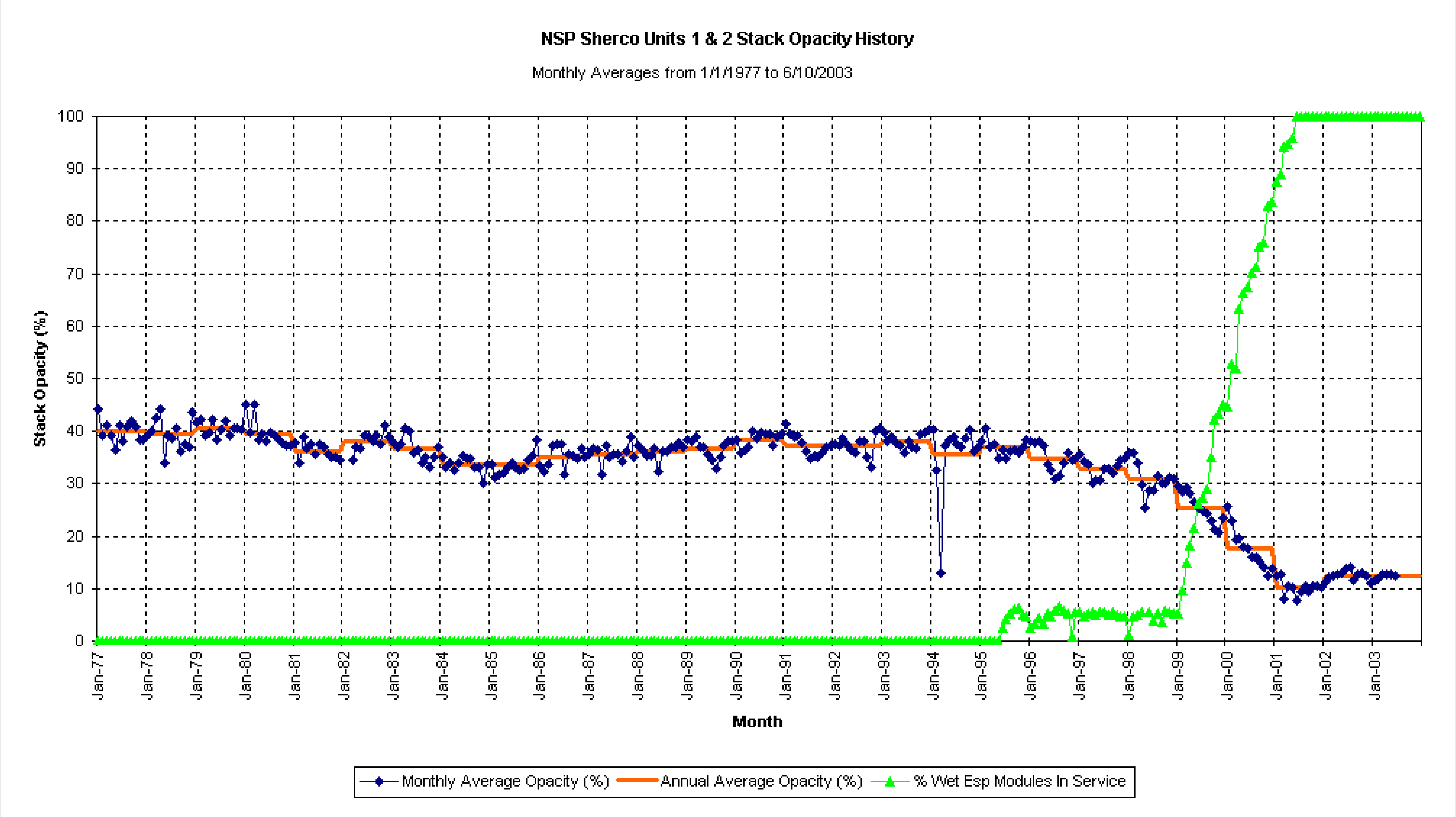
Facility	Unit Size (MW)	Fuel-Fired	Number of WESP Modules	WESP Flow Configuration
AES Deepwater USA	155	Pet Coke	12 (external to FGD)	Vertical plate 3-field
Sherco 1 & 2 USA	750 ea.	PRB Coal	12 per unit (retrofit into each existing wet scrubber absorber)	Vertical tube 2-field
Dalhousie 1 & 2 Canada	315 total	Orimulsion	1 (retrofit into existing FGD absorber tower)	Vertical tube single field
Dakota Gasification USA	420 equiv.	Waste liquids from coal gasification process	1 (external to existing FGD absorber tower)	Horizontal plate 3-field
Coleson Cove Canada	3x350	No. 6 Oil	2 (integral to each of 2 retrofit FGD absorber towers)	Vertical plate 3-field

Typical WESP Performance - Opacity

SIEMENS

Courtesy of EPRI

NSP Sherco Unit 1 & 2 Stack Opacity History (SEI, FLS, B&W)



Typical WESP Performance PM2.5 & SO3 Test Results

SIEMENS

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.

WESP Performance - Mercury

SIEMENS

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%

Limited pilot testing shows some Hg co-benefit

SIEMENS

Internal Safety Margins

PM Assumptions 1ppm = 0.003 lb/MMBtu	**Proposed Limit**	**Utility Operating Margin = 20%**	**Vendor Guarantee Margin = 20%**	**PPM**
Filterable PM (50%)	0.015 lb/MM Btu	0.012 lb/MMBtu	0.0096 lb/MMBtu	3.2 ppm
Condensable PM (50%)				
H_2SO_4 (33%)	0.010 lb/MMBtu	0.008 lb/MMBtu	0.0064 lb/MMBtu	**2.1 ppm**
Metals (17%)	0.005 lb/MMBtu	0.004 lb/MMBtu	0.0032 lb/MMBtu	1.0 ppm
Total Condensable PM	0.015 lb/MMBtu	0.012 lb/MMBtu	0.0096 lb/MMBtu	3.2 ppm
Total PM	**0.03 lb/MMBtu**	**0.024 lb/MMBtu**	**0.0192 lb/MMBtu**	**6.4 ppm**

- **Will DSI/FF get you to @ 2 ppm H_2SO_4?**
- **Even if over-control FPM to 0.0 lb/MMBtu H_2SO_4 can be no more than 5-6 ppm**
- **What happens if you have WFGD carryover?**

SIEMENS

WESP Requirements

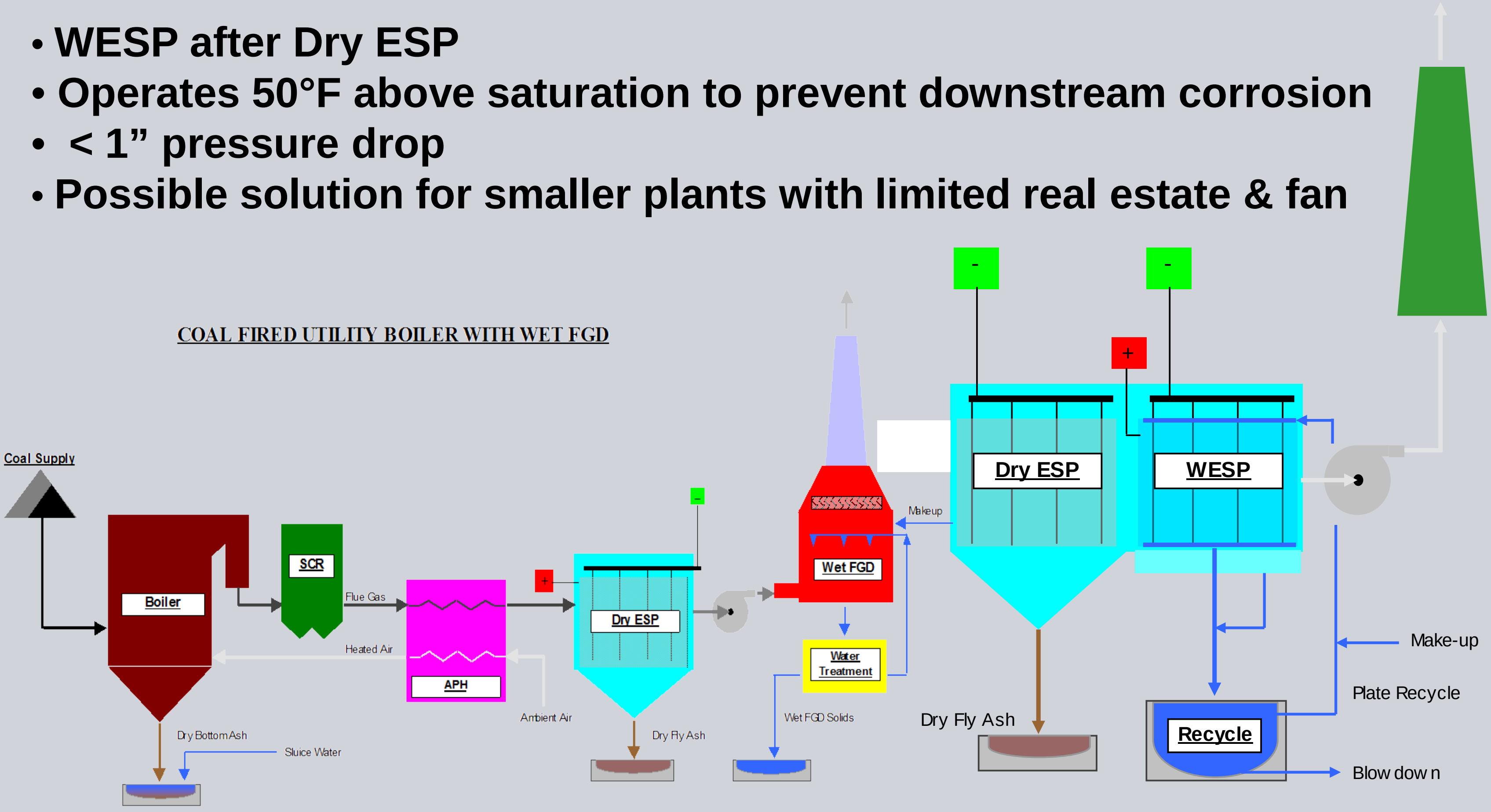
- Water
  - First use of WFGD water & give back to WFGD
  - No additional burden on plant
- Materials of Construction
  - High End Alloys – 316L, 317LMN, 2205, AL6XN, Hastelloy
  - MOC minimized by reducing size through electrical sectionalization

Other Thoughts

- To minimize risk of not meeting U-MACT standards consider using existing DESP / WFGD with WESP or DSI+WESP
- U-MACT Rule waives monthly testing if no CEMS for 3 years if emissions are 50% of standards for 3 years
- U-MACT Rule standards may become more stringent in 5 years. Will what you do today make it in the future?
- If plant is baseload unit that you plan to operate for the long term a WESP option may be more economical choice than DSI/FF
- If WFGD is creating particulate carryover no DSI/FF will help. Need a polishing WESP to remove post WFGD PM
- WESP can be ON during start-up/shutdown which is now included in emission reporting

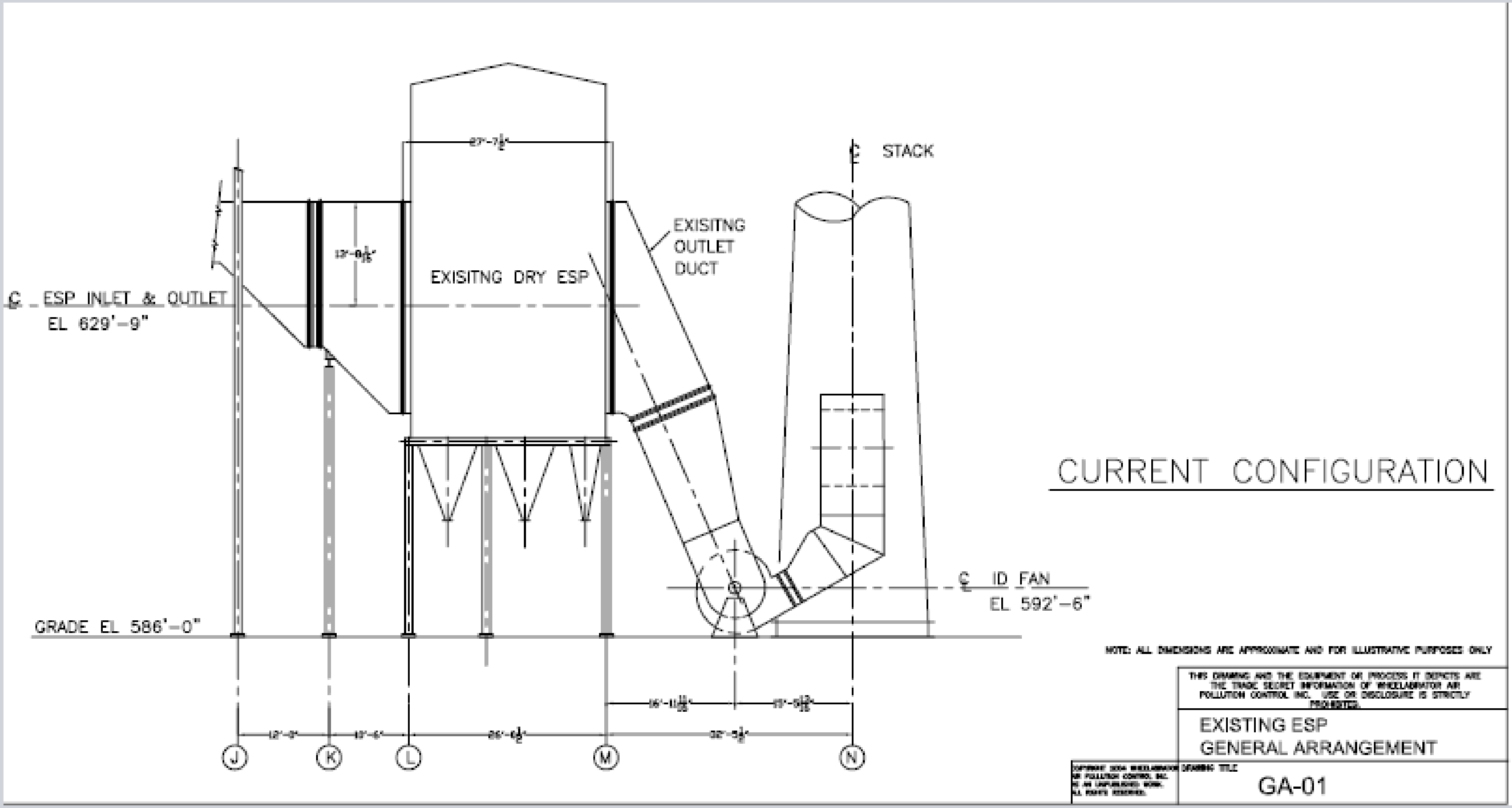
New Application: Hybrid Dry-Wet ESP

- WESP after Dry ESP
- Operates 50°F above saturation to prevent downstream corrosion
- < 1” pressure drop
- Possible solution for smaller plants with limited real estate & fan

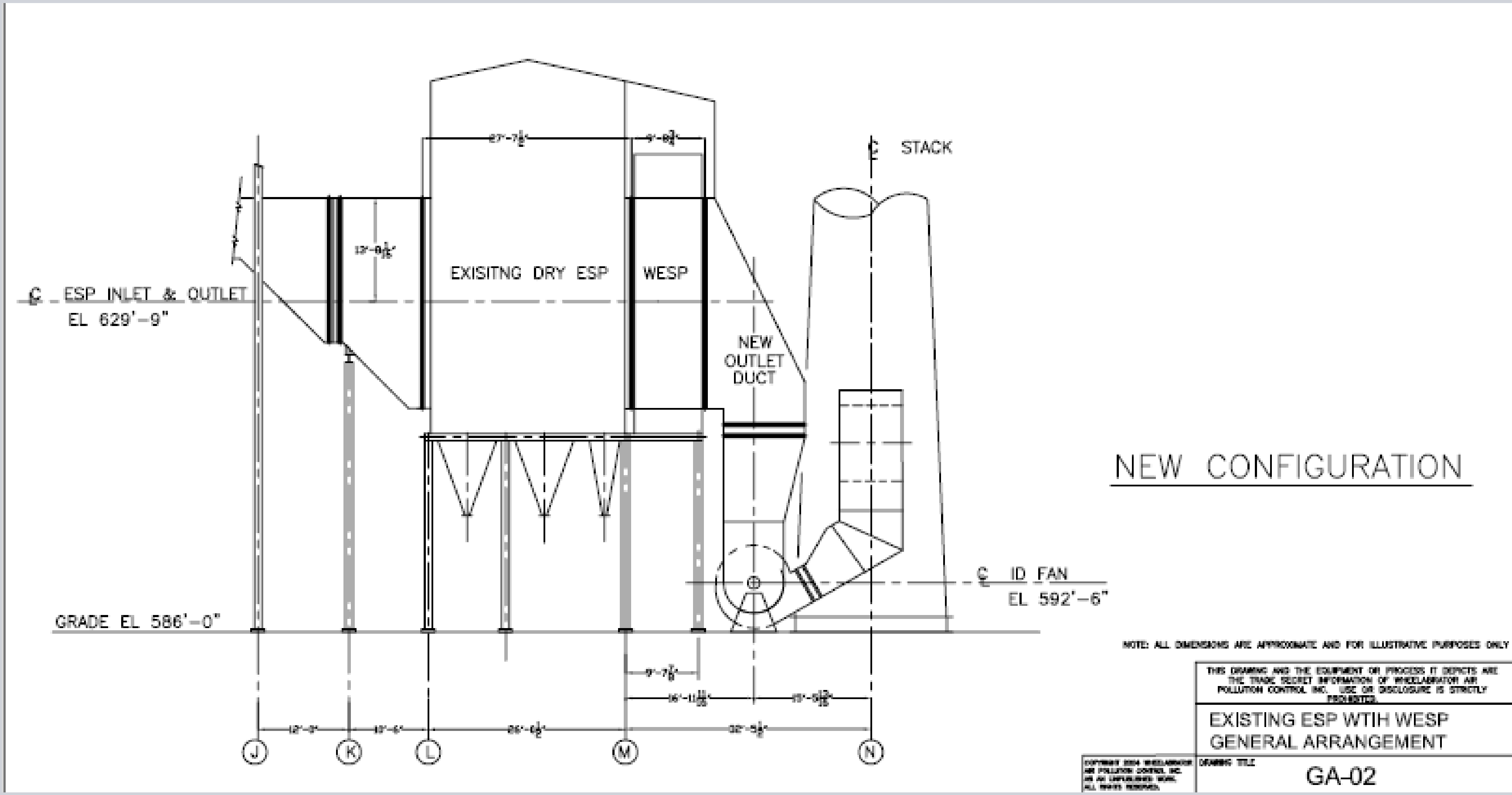


Environmental Systems & Services

SIEMENS


STACK
EXISITNG OUTLET DUCT
EXISITNG DRY ESP
ESP INLET & OUTLET
EL 629'-9"
CURRENT CONFIGURATION
ID FAN
EL 592'-6"
GRADE EL 586'-0"
J
K
L
M
N
NOTE: ALL DIMENSIONS ARE APPROXIMATE AND FOR ILLUSTRATIVE PURPOSES ONLY
EXISTING ESP
GENERAL ARRANGEMENT
GA-01

SIEMENS

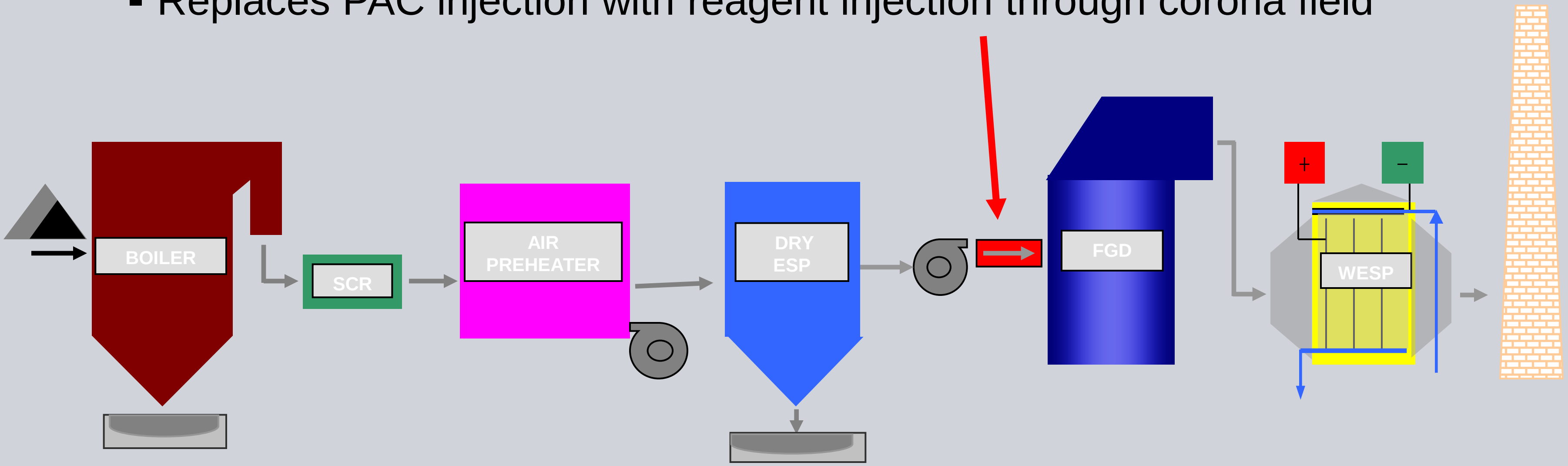


STACK
EXISITNG DRY ESP
WESP
ESP INLET & OUTLET
EL 629'–9"
NEW
OUTLET
DUCT
NEW CONFIGURATION
ID FAN
EL 592'–6"
GRADE EL 586'–0"
NOTE: ALL DIMENSIONS ARE APPROXIMATE AND FOR ILLUSTRATIVE PURPOSES ONLY
EXISTING ESP WTIH WESP
GENERAL ARRANGEMENT
GA-02
J
K
L
M
N

New Technology:
Plasma Enhanced ESP for Hg Control

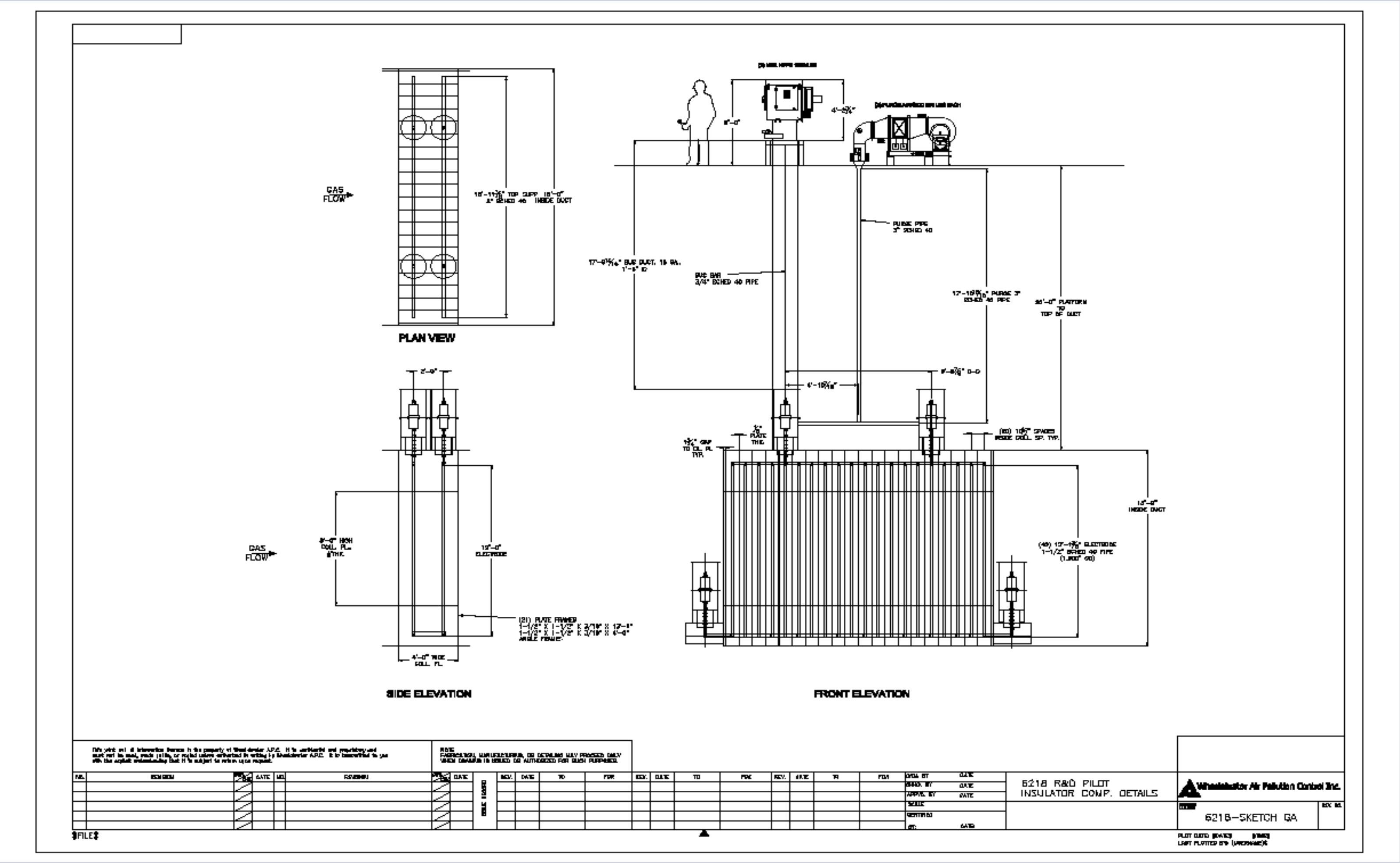
SIEMENS

- PEESP oxidizes Hg^0
- > 80% oxidation pilot unit tested
- Operates at duct velocity
- Allows WFGD to remove more total Hg
- Replaces PAC injection with reagent injection through corona field



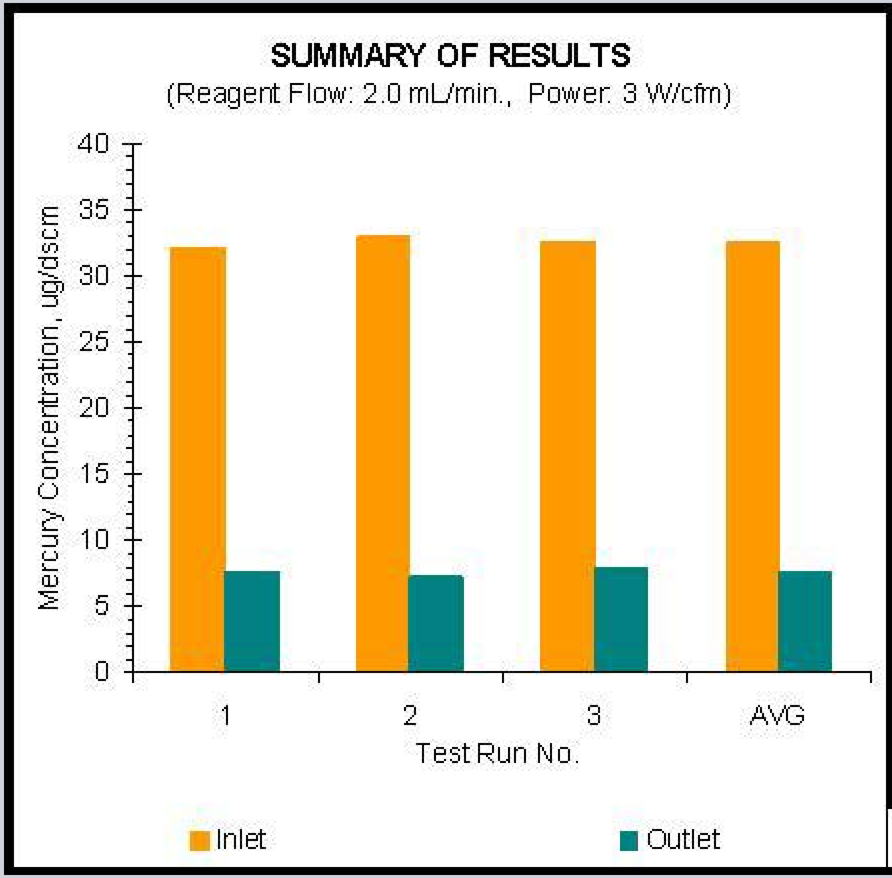
PEESP General Arrangement Concept

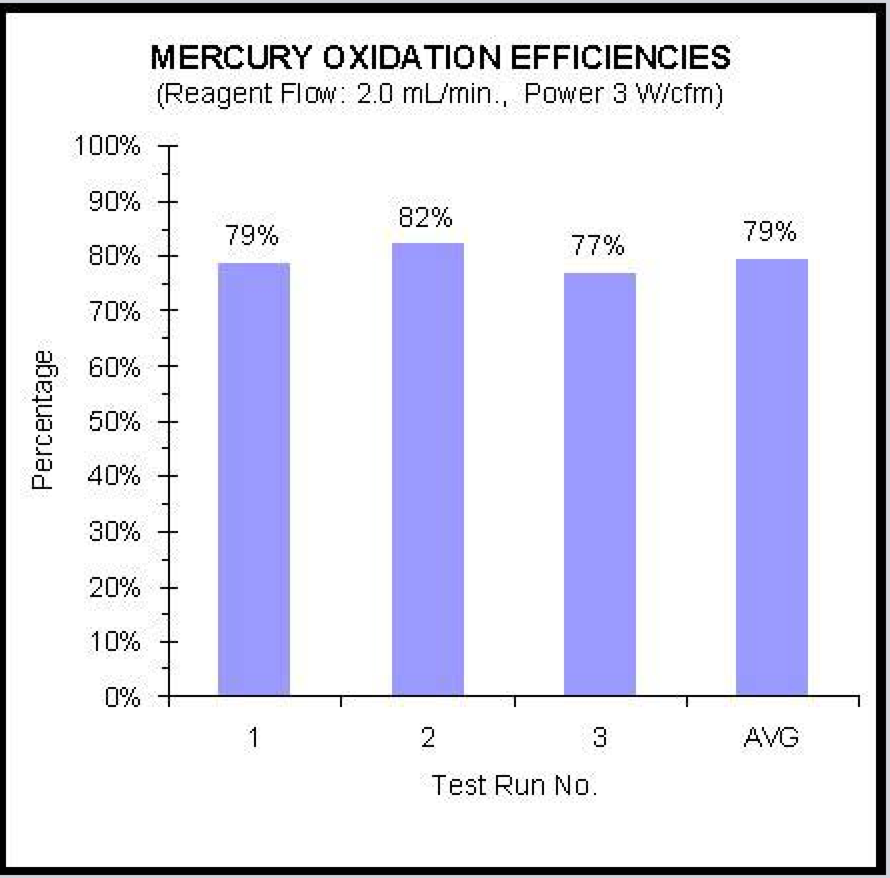
SIEMENS



SIEMENS

Summary of Results





Slip-Stream Pilot Hybrid Wet ESP with PEESP

- Alabama Power
- Plant Miller
- PRB Coal
- 2 MW Slip-stream
- WESP after DESP
- PEESP incorporated
- 90% collection Hg^p
- 92% oxidation of Hg^0
- Operates @200 F
- Next step
    - -automate reagent injection & monitor
    - -full scale demonstration

Acknowledgements

Clean Air Engineering – slides #9 & #10

Sargent Lundy – slides # 13 & 14

EPRI for slide # 26

THANK YOU

SIEMENS

Buzz Reynolds

VP – Wet ESP
Siemens Environmental Systems & Services
Siemens Energy
501 Grant Street
4th Floor
Pittsburgh, PA 15219

jamesreynolds@siemens.com
908 -522-6616