Reinhold Environmental Ltd.

2009 APC Round Table & Expo Presentation

July 12-14, 2009, in The Woodlands, TX

The Evolution of Wet Electrostatic Precipitators

2009 APC/PCUG Conference

By

Ron Triscori

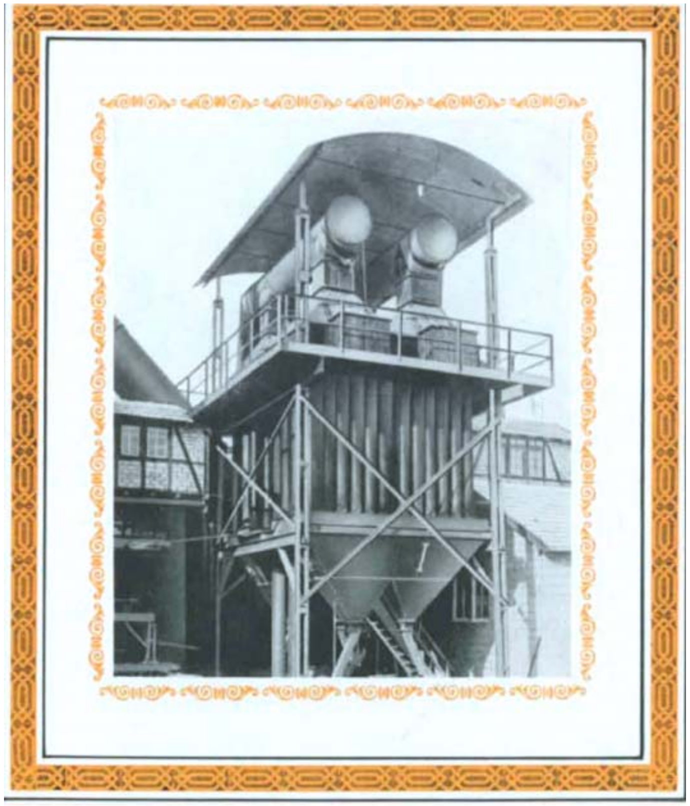
Wet ESPs Are Not New!

- First commercial ESP was a wet unit put in service in 1907 in California for collection of acid mist.
- This unit handled 5,000 cfm of process gas and collected about 2 gpm of sulfuric acid.
- This unit operated satisfactorily for many years.
- Operation was limited due to transformer voltages of 10 kv and 15 kv.

Early WESP Design

- Mild steel casing construction with strapped lead for corrosion resistance.
- Lead tubes or lead plates were common collecting electrodes.
- Vertical gas flow was most common.
- Discharge electrodes were typically mild steel core covered with lead in a star shape.

Early WESP for a Smelter Designed in the Early 20's



WESPs Utilized this Design for the Next 50+ Years.

Improvements to Lead WESP Design

- Improvements were made in manufacturing of internals.
- As operating pressures increased, a semi-sealed casing around the tube area complete with a pressurizing device was employed or lead enforcement rings were applied to tubes.
- Units were subject to leaks due to “lead creep.”

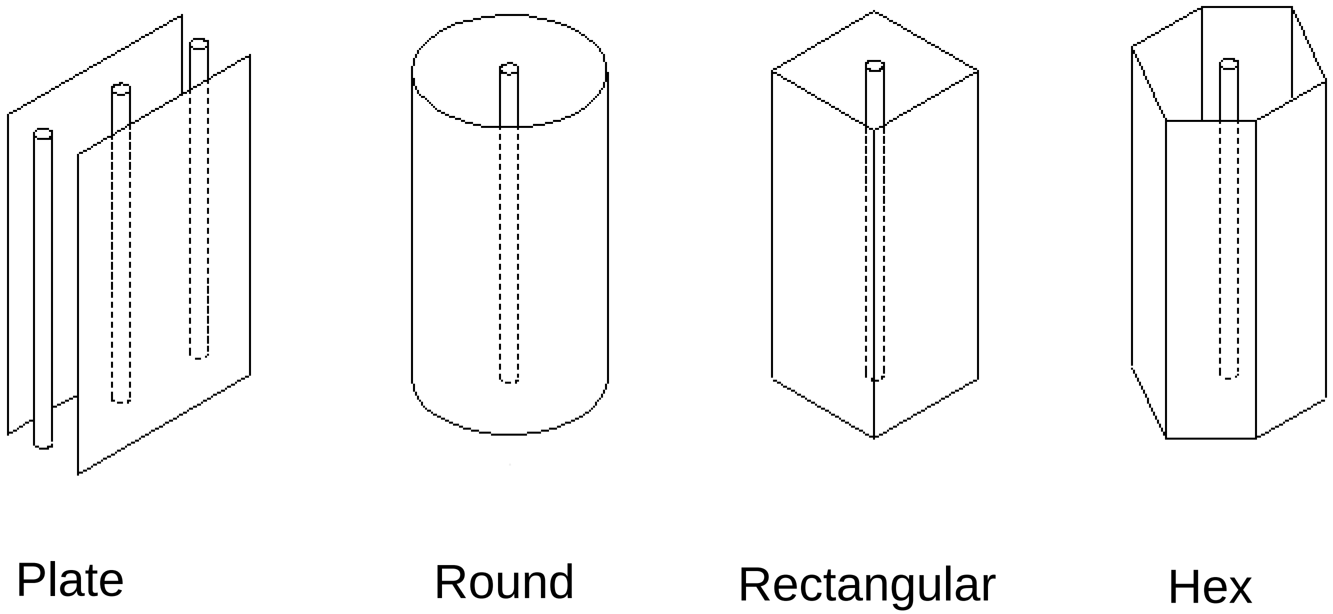
Improvements to Lead WESP Design (Continued)

- Repair/maintenance work was typically done by lead burner craftsman without OEM input.
- Design modifications were customer driven without OEM help or verification.

Innovations in materials of construction and equipment design began in the 1970's.

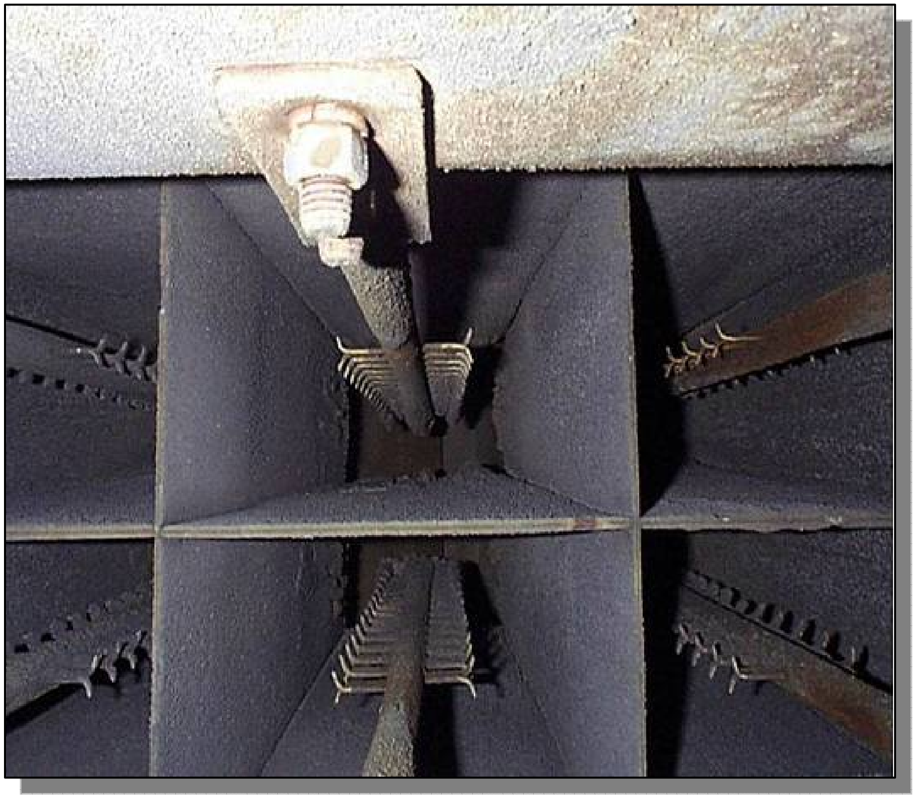
Alternate Collecting Electrode Designs Were Initiated to Reduce WESP Plan Area.

Collecting Electrode Configuration Alternatives

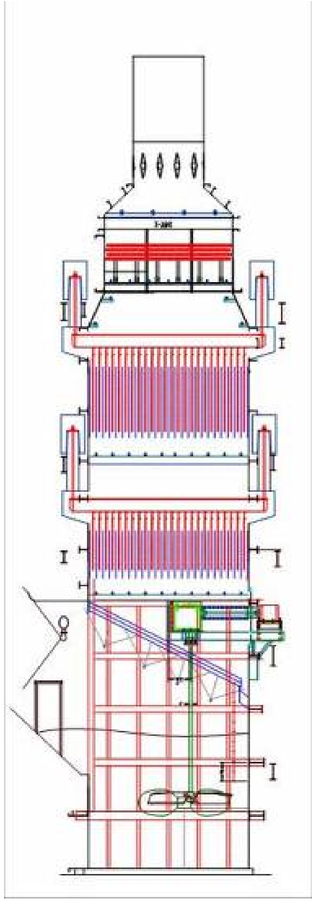


Vertical Plate WESP

Rectangular Tube WESP



Discharge Electrodes and Collecting Tubes



Innovations in Materials of Construction and Equipment Design

- Some vendors started to use plastic/FRP construction in their designs.
- These materials are corrosion resistant, however, certain limitations were noted.

Limitations

- Non-conductive plastic tubes needed special treatment to ensure proper water filming, and plate designs needed to be irrigated for conductivity.
- Some installations used FRP with carbon veil construction and carbon in the resin.
- Vendors found that not all FRP manufacturers were the same. Special care was required in vendor selection.

Limitations (Continued)

- Use of plastics carried the risk of melting, fire and/or maintenance damage.
- Some vendors used mild steel casings with linings/coatings, similar to early utility scrubbers.

Plastic WESP for Copper/Nickel Converter
Built in 1973

Hybrid FRP/Lead WESP

Polypropylene Tube WESP

As Utility Alloy Knowledge and Operational Experience in WFGD Systems Increased, Industrial WESP OEM/Users Began Considering Alloys in WESPs.

AES Wet ESP Module J Modification

Original Arrangement

Modified Arrangement

Hex Tube Design WESP

Large Hex Tube Installation

Today WESPs are Used in Many Applications

These include:

- Non Ferrous smelters
- Acid Plants
- Incinerators both municipal and hazardous waste
- Steel blast furnace applications
- Oil fired boilers
- Specialty boiler applications
- Wood and paper industry applications
- Open hearth and BOF applications
- ***Utility Boiler Applications***

The Utility WESP on Limestone Forced Oxidized Wet FGD Systems.

Process Differences –Dry ESPs vs. Wet ESPs

	Dry ESP	Wet ESP
Gas Temperature	**250 - 850F range**	**Saturation temperature (typically 130F in Wet FGD)**
Gas Humidity	**< 10% typical**	**100%**
Power Density	**Variable with coal sulfur content and ash chemistry**	**Significantly higher than Dry ESP**
Resistivity	**Critical design factor**	**Not a design factor**
Gas Velocity	**5 fps ±**	**10 fps ±**
Treatment Time	**10 seconds ± typical**	**1- 5 seconds ± typical**
Re-entrainment	**Important factor**	**Not a factor**
Corrosion	**Mild steel (typical)**	**Specialty metals and/or plastics**

Wet FGD Stack Particulate Emission

Includes:

- Flyash
- Gypsum carryover
- H_2SO_4
- Other Condensable

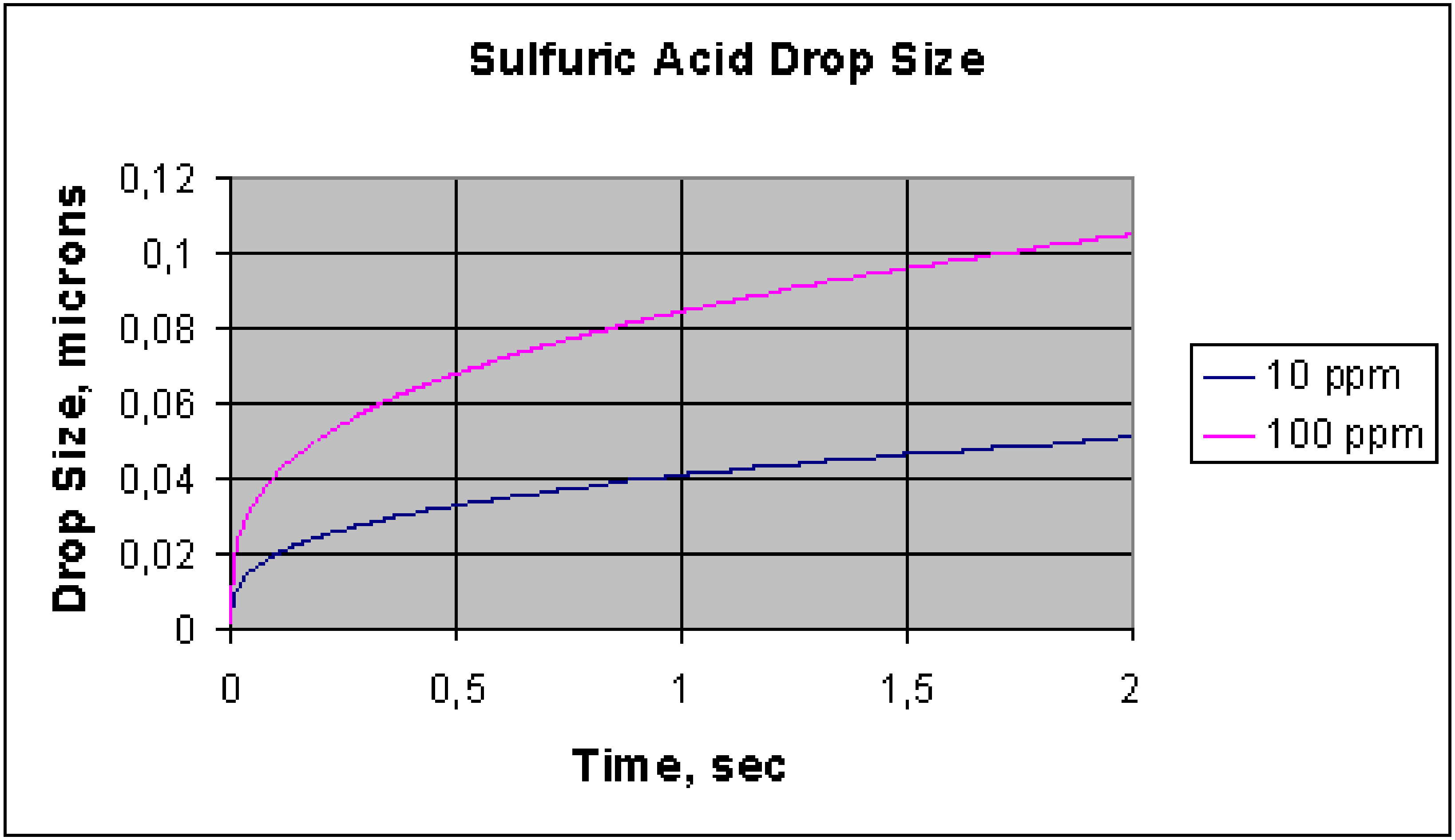
Deutsch-Andersen Equation

$$E=1-e^{-(A\omega/V)}$$

E = Collection Efficiency
V = Flue Gas Volume – ACFS
A = Total Collection Area - ft^2
ω = Migration Velocity - ft/sec

Limitations in WESP Sizing

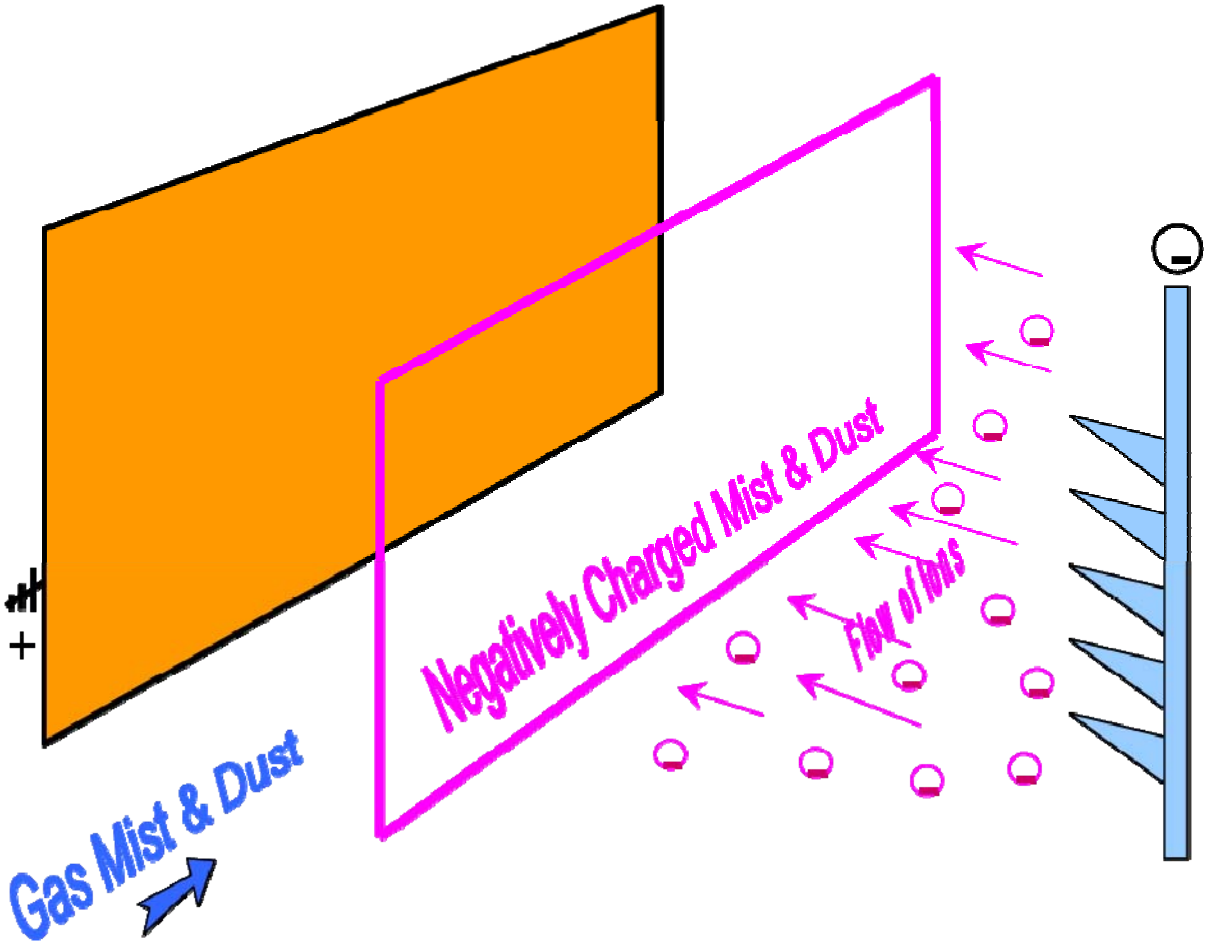
- Droplet Size


Sulfuric Acid Drop Size
Drop Size, microns
0,12
0,1
0,08
0,06
0,04
0,02
0
0
0,5
1
1,5
2
Time, sec
10 ppm
100 ppm

Limitations in WESP Sizing

- Corona Suppression/Space Charge Effect

Corona Suppression



Other Limitations in WESP Sizing

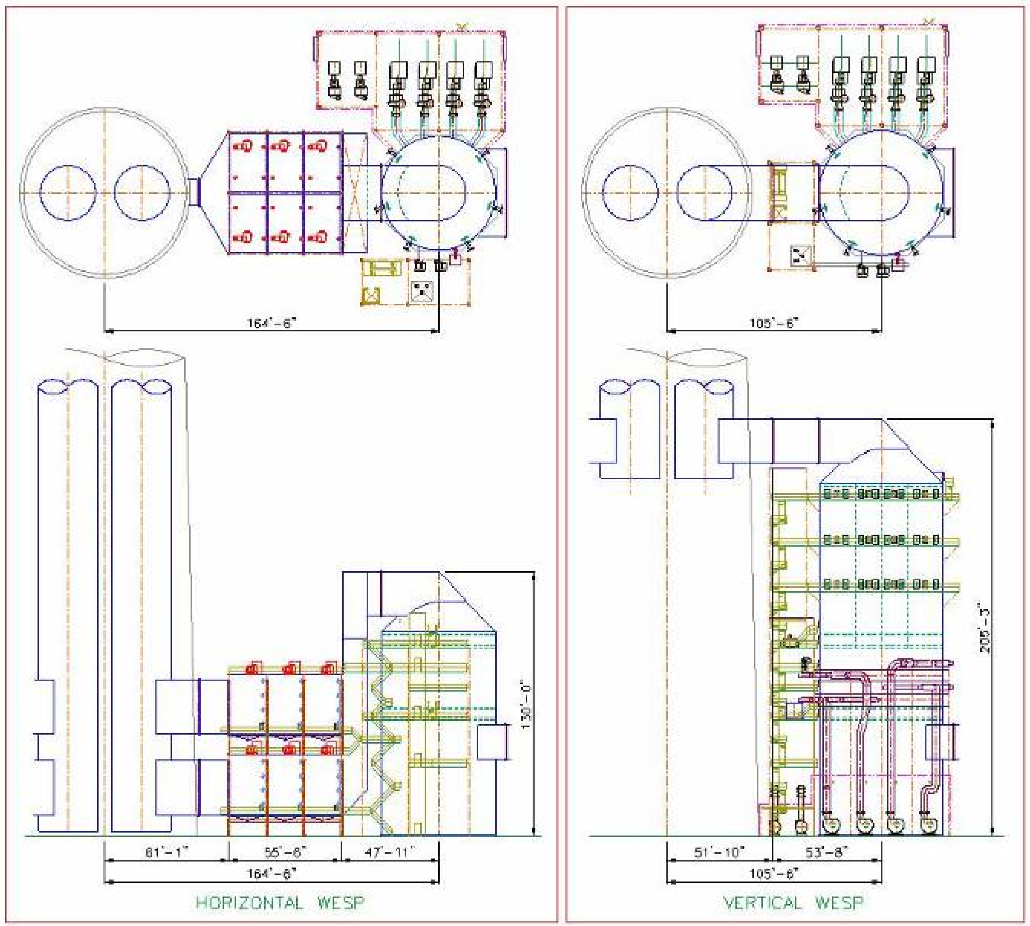
- Amount of Scrubber Carryover.
- Amount of Solid Particulate as the WESP is a Polishing Device Only.

Typical Arrangements for Utility Wet ESPs

Close-Coupled (Integrated) Wet ESP

Wet FGD with Stand-Alone Wet ESP

Horizontal (Standalone) vs Integral Wet ESP



Wet ESP Washing Methodology

1. Intermittent
   - Thorough washing with fresh water and section by section.
   - Spent water serves as necessary FGD makeup (i.e. no net system increase).
2. Continuous Irrigation
   - Typically used with non-conductive collecting electrode material.
   - Requires extra water or recycle system.
   - Requires maintenance.
3. Continuous Spray/Fogging
   - Requires extra water or recycle system.
   - Dependent on proper design/maintenance.
   - Offers use of more cost effective lower grade alloys.
4. Combination of Above

When Selecting a WESP

- The following should be considered to optimize performance and total equipment costs:

    ✓Washing Methodology

    ✓Arrangement

    ✓Material Costs (Present and Trends)

Approximate Material Costs of Alloy Plate

Alloy	June 08	May 09
304SS	$2.65/lb	$1.38/lb
316L	$5.91/lb	$4.51/lb
2205	$4.78/lb	$2.78/lb
C-276	$26.89/lb	$15.38/lb

North American Operating WESPs On Forced Oxidized Limestone Scrubbers

AES Deepwater – Pasadena, TX

AES Deepwater Unit 1 – WESP

System Size:	155 MW
Flue Gas Flow Rate	634,000 ACFM
Fuel:	Petroleum Coke (8% Sulfur)
Particulate Removal Efficiency:	99%
Acid Mist Removal Efficiency:	91%
Stack Opacity:	<10%
No. of WESP Modules:	12
No. of Fields	3
Flow Orientation	Vertical Upflow
Start Up Date:	1986

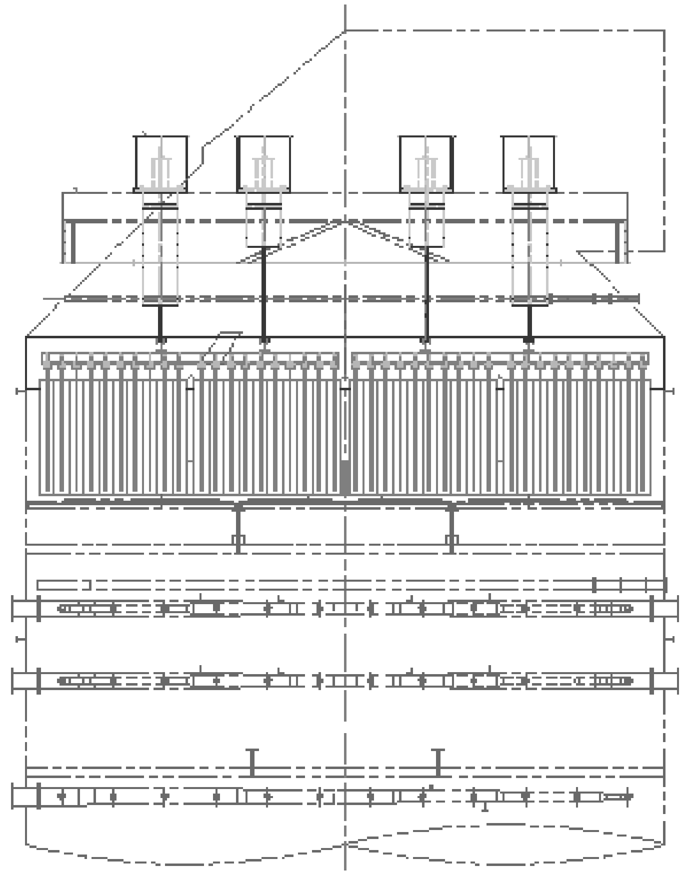
Longest Operating Utility Size WESP in North America

New Brunswick Power

Dalhousie Units 1 & 2 Wet ESP

- Single Field
- Square Tube Design

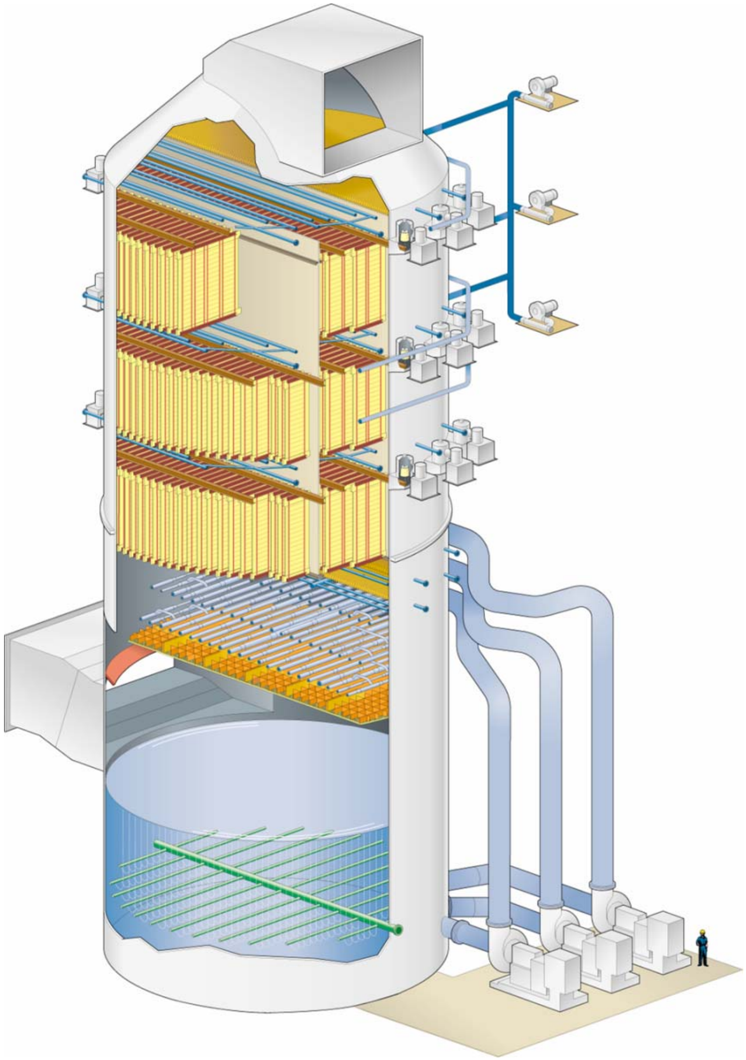
Dalhousie Units 1 & 2
- 315 MW (combined)
- 2 Boilers - 1 FGD Tower
- 1st use of Orimulsion® in North America
- Commercial 1995



New Brunswick Power

Coleson Cove Units 1 & 2

- 2 x 550 MW
- Integrated
  Wet FGD / Wet ESP



Coleson Cove Units 1 & 2

System Size:	2 x 550 MW
Flue Gas Flow Rate	1,451,528 ACFM
Fuel:	Orimulsion/Fuel Oil
Acid Mist Removal Efficiency:	90+%
No. of WESP Gas Paths:	4
No. of Fields	3
Flow Orientation	Vertical Upflow
Start Up Date:	2004

East Kentucky Power Cooperative (EKPC)

Spurlock Unit #2 Limestone WFGD followed by 3 field WESPs

Spurlock Unit #2 WESPs

Project Information:

System Size:	585 MW
Fuel:	4.2% Sulfur Bituminous Coal
WFGD Inlet Gas Flow:	2,110,000 ACFM @ 325°F
WESP Inlet Gas Flow:	1,744,000 ACFM @ 129°F
SO_2 Removal Efficiency:	98%
SO_3 Removal Efficiency:	91.2%
Stack Opacity:	<15%
No. of WESP Chambers:	2
Bus Sections Wide per Chamber:	2
Total No. of Bus Sections:	12

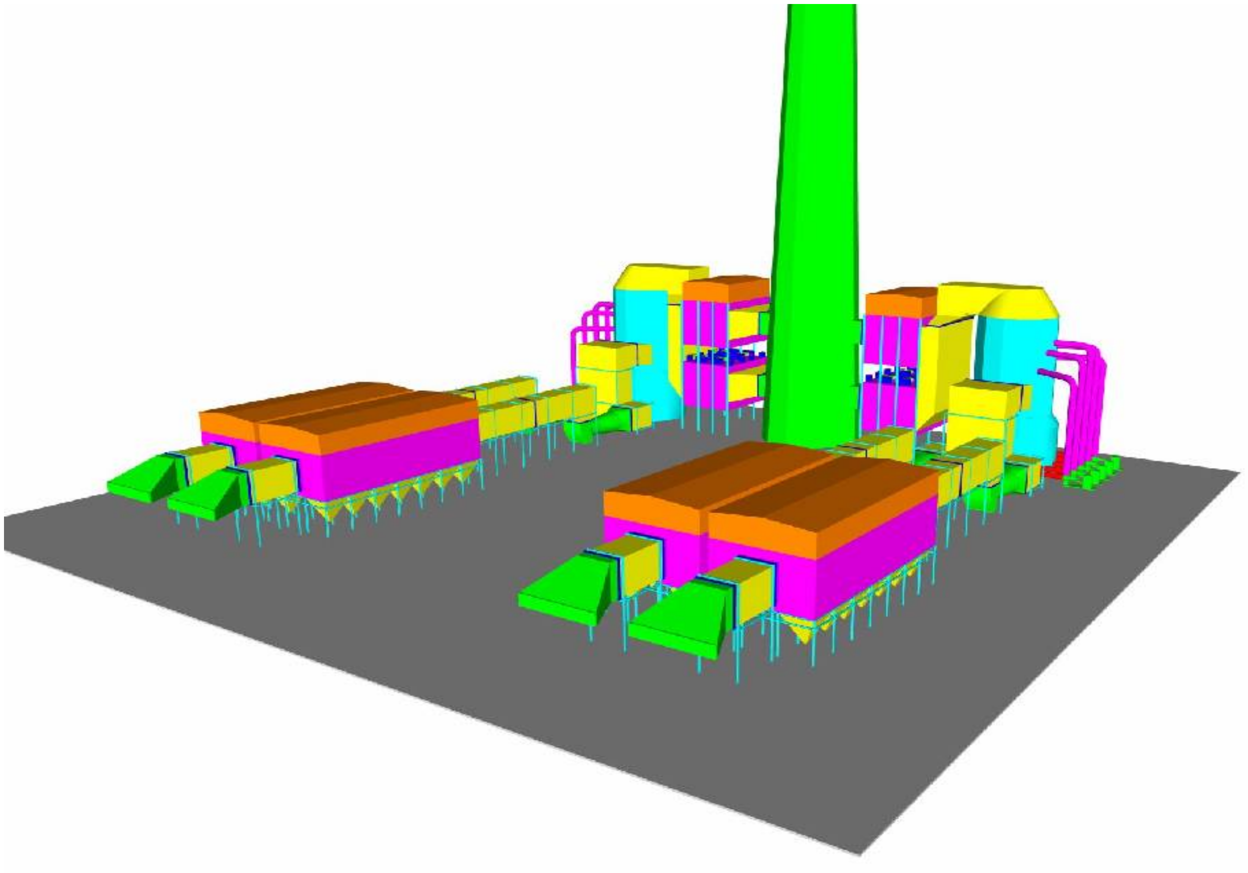
The WFGD/WESP System has met the performance requirements of the project!

Other Utility WESP Projects Awarded But Not In Operation.

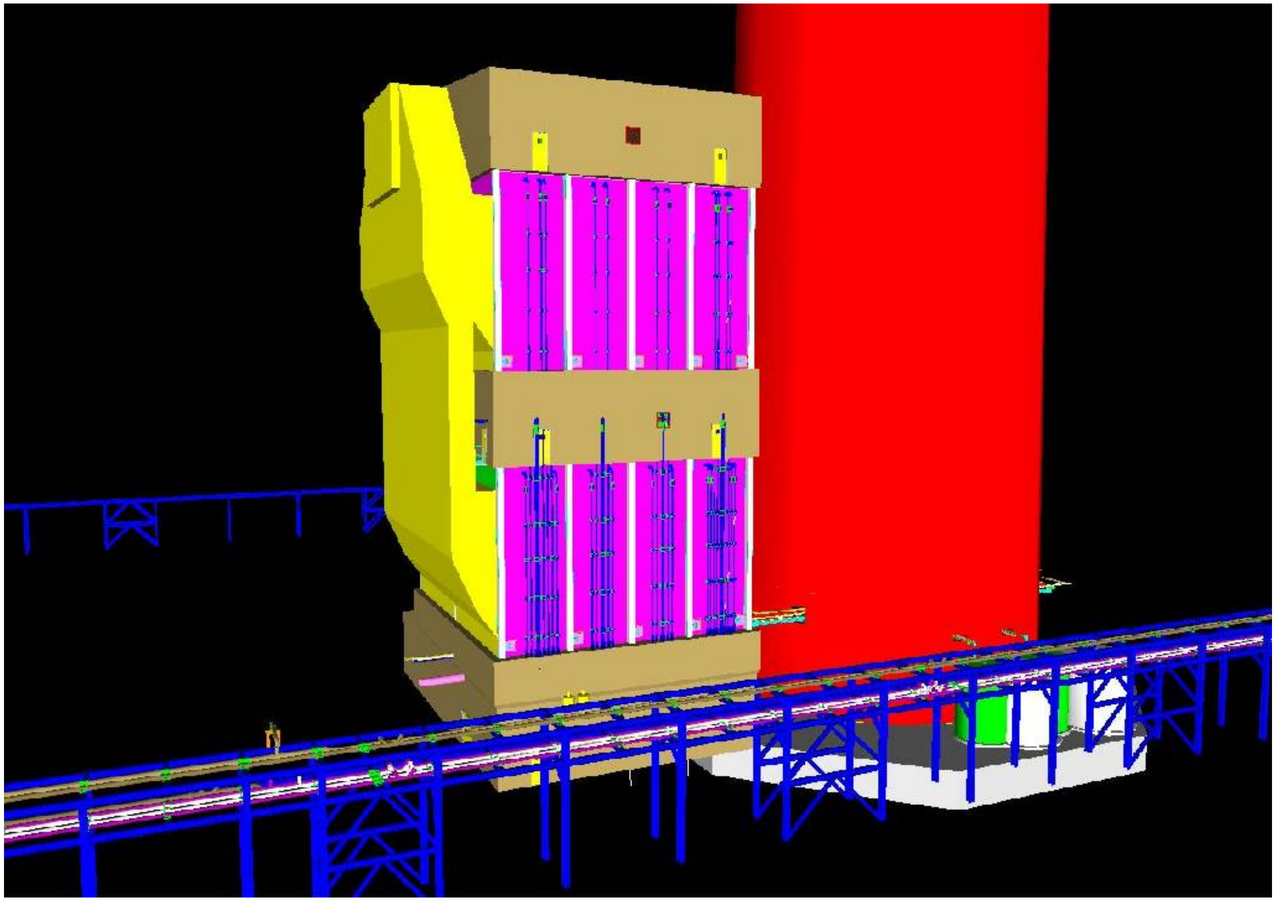
EKPC Spurlock Unit #1 WFGD – WESP

System Size:	340 MW
Fuel:	3.5% Sulfur Bituminous Coal
SO_2 Removal Efficiency:	98%
SO_3 Removal Efficiency:	90%
Stack Opacity:	<15%
No. of WESP Chambers:	2 (Stacked Arrangement)
Bus Sections Wide per Chamber:	2
No. of Fields per WESP:	3
Total No. of Bus Sections:	12
Planned Start Up Date:	June 2009

Elm Road Generating Station



Elm Road Generating Station



Wisconsin Electric Power Inc. - Elm Road WFGD – WESP

- System Size: 2 @ 615 MW(net)
- Fuel: 2.65% Sulfur Bituminous Coal
- SO_2 Removal Efficiency: 97.25%
- SO_3 Removal Efficiency: 99.1%
- Stack Opacity: <10%
- No. of WESP Chambers per Boiler: 2 (Stacked Arrangement)
- Bus Sections Wide per Chamber: 2
- No. of Fields per WESP: 4
- Total No. of Bus Sections per Boiler: 16
- Planned Start Up Date Unit 1: 4^{th} Qtr. 2009
- Planned Start Up Date Unit 2: 2^{nd} Qtr. 2010

Siemens WESP Projects

- **City of Springfield's 200 MW Dallman Plant will be operational later this year.**
- **LG&Es 750 MW Trimble County will be operational in 2010.**
- **Peabody Energy‘s 1600 MW Prairie State Campus will be operational in 2011.**

New WESP Technologies or Improvements

Operating Experience with Membrane Technology

End User	Application	Fuel	Gas Flow Rate (ACFM)	Pollutant Captured	Inlet Loading	Outlet Loading Achieved	Years of Continuous Operation
Smurfit-Stone Container Corporation (Two modules, Single field)	2- Packaged Boilers	No. 6 Oil	102000	Fine PM, SO3 mist	Unknown	0.017 gr/acf	>4 years
Knauf Insulation- System 1 (Three modules, Single field)	Fiberglass Ovens		140000	Fine PM	Unknown	0.006 gr/acf	~2 years
Knauf Insulation- System 1 (Eight Modules, Single field)	Fiberglass Ovens		625000	Fine PM, Phenol Formaldehyde Resin	Unknown	0.0032 gr/acf	~1.5 years
Smurfit-Stone Container Corporation (Two modules, Single field)	Fiberglass Ovens		310000	Fine PM, Phenol Formaldehyde Resin	Results Awaiting		~3 months
Climax Moly (Single module, Single field)	Molybdenum Roasters		35000	SO3 Mist	179ppmv, dry	34ppmv, dry	~6 months

Installing DEs in Membrane WESP

Membrane WESP for Stevenson Mill

Membrane WESP for Stevenson Mill

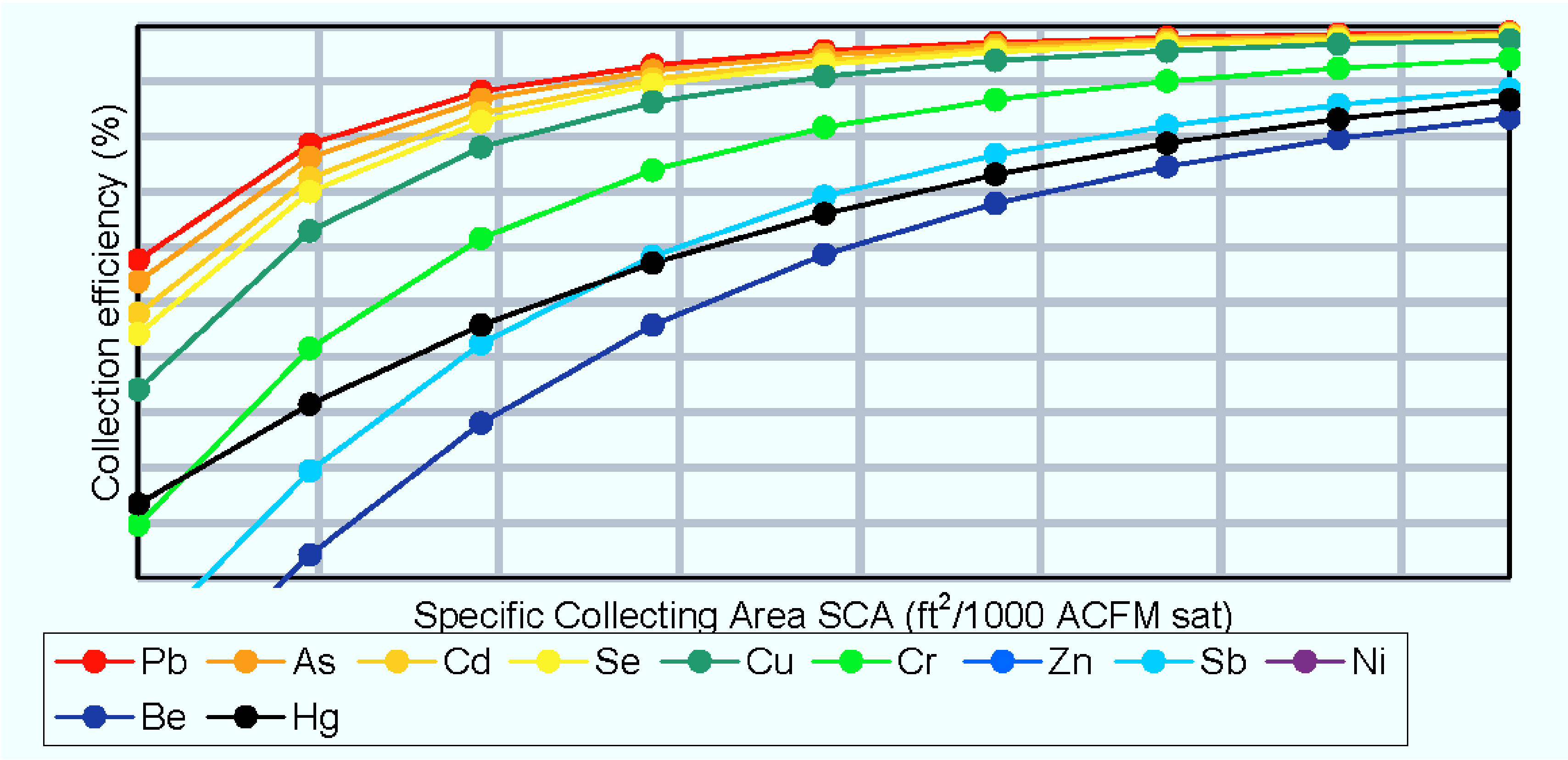
Power Supplies

- High Frequency/Switch Mode Power Supply
  - ✓Aids in Dealing with Space Charge
  - ✓Weighs Less than Conventional Power Supplies
  - ✓Aids in Plant Power Factor and Reduces WESP Power Consumption
  - ✓Extensive Experience on Industrial WESPs
  - ✓Higher Rated Power Supplies are Now Available
  - ✓Potential for reducing WESP Size

Potential Future Utility WESP Application

- Control of $PM_{2.5}$ (if Regulated)
- Control of Condensable Particulates (Post Chimney) to Meet Potential Future Regulations
- Potential Use of Ahead of CO_2 Sequestration Systems to Ensure Long Term Compressor Operation
- Collection of Heavy Metals if Regulated

WESP Fractional Efficiencies for Heavy Metals



Conclusions

- ✓ Requirements for future operating permits may address emissions of $PM_{2.5}$, SO_3 and visible plume; Wet ESP technology addresses all of these emissions.
- ✓ A Wet ESP may be required by permit for new plants. Wet ESPs have been a proven technology for the collection of sulfuric acid mist for nearly 100 years.
- ✓ The use of Wet ESPs to limit total particulates, including sulfuric acid mist, in conjunction with a Wet FGD system is becoming increasingly relevant to electric utility plants.
- ✓ A Wet ESP could address future Heavy Metal regulations.
- ✓ Wet ESP could play an important role in CO_2 capture.

Special Thanks and Acknowledgement!!

- *Steve Francis – Alstom*
- *Al Moretti – B&W*
- *Chuck Leivo – GEA Bischoff*
- *John Caine – SEI*
- *Buzz Reynolds – Seimens*
- *Bob Allan - Turbosonic*

For Further Info, please contact…

RE Consulting

3850 Bordeaux Drive
Northbrook, IL. 60062

Phone: 847-562-8556
Fax: 847-562-8894
Email: greinhold@reconsulting.info